Compiler Manual

E-LAB AVRco

Pascal Multi-Tasking for Single Chips

Version for

AVR

Blaise Pascal Mathematician 1623-1662

11-Mar-2019

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E-LAB
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Mikroprozessor-Technik
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Hard + Software
8-Bit • 16-Bit • 32-Bit

Important information

Everybody tries to write Software without bugs. The emphasis is on tries, because everybody knows that the more complex a Software is, the more likely it is to produce bugs.

We have the opinion, that this shouldn't have to be norm, and that we do not have to live with the problems and mistakes (although some Software giants think like that ☺).

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1 Introduction

1.1 Every Toaster its Processor!

Some comments you could interpret like that. Microprocessors are more and more used for applications, you never thought they could be used for. Some things cannot be done without them.

Partly this results from the greatly reduced price of the chips, but also because of the miniaturization of them. More and more mechanical, electromechanical problems are being solved with processors. The developer has the problem to finding solutions with little money and time.

Because of the costs, the constructor has to decide in each case, which processor to use to have the ratio between cost and performance. It is nearly impossible to use one chip (e.g. 80C535 or 68332) for all applications.

The industry for semiconductors offers controllers, which have 16 pins / 8 bits (DM3.-) to more than 84 pins with 32 bits (DM80.-). The constructor also has to decide which kind of development tool he needs. The more varied the processor that are specified, the more development tools that are needed. Altogether, at a usual price between 4000,- and 10000,- DM for each tool, you have to pay some 10,000 DM, which contradicts to cost problem, so that everything, including the development, has to get cheaper. Some customers even prefer that development costs are not calculated.

With processor size 8051, 68HC11, Z80 etc. you find many tools that differ in price and performance. Unfortunately, nearly all tools are written in “C“. Other languages are hard to find on the market. A developer who knows different kinds of languages, regards the value of the easy readability, the self-documentation and the easy maintenance of Pascal or similar languages (Modula-2, Oberon) highly.

Surely many arguments for or against a language can be relegated to philosophy, but the fact is, that in military or space projects, “C“ is prohibited, only the Pascal related language ADA is allowed. Jobs relevant for security, for example controlling railways and plane electronics are often written in Pascal not in “C“. This is surely not because of nostalgic reasons. So much to our decision to use Pascal instead of cryptic “C“.

In order to find a way out of the above problem (Costs, no or weak tools, no “C“), E-LAB Computers has developed a Pascal compiler for a series of processor families. The aim was to build a tool, which has a wide performance range, but doesn’t produce high cost internally. Because of this and also because of lack of resources on the target processors, we decided against some of the more complex functions. Further on there is now (in the profi version only) a linker and modular program/units.

In spite of this the tool is easily portable to other (small) processors. Non-Multi-Task versions are available for MicroChip’s PIC. Multi-Task versions are available for the AVR from Atmel.

The tool always includes the IDE (Editor and so on), the Compiler and the Assembler. At least the IDE is equal to the much more expensive tools of the competitors. Only the AVR version includes a simulator as a bonus.

2 Overview

2.1 AVRco Versions

All AVRco Versions support all AVR Controllers with an internal RAM (for the stack). That means in practice the whole range.

AVRco Profi Version:
The Profi Version contains all available drivers, including very complex ones like e.g. a FAT16 file system and an extensive library for graphic LCDs.
The professional program development is furthermore assisted by the full support of Units.

AVRco Standard Version:
The Standard Version omits only the most complex drivers, and does not support units.

AVRco Demo Version:
The Demo Version supports all controllers and all drivers of the Standard Version.
The **only restriction** is the limitation of the generated code to max. 4 kByte size.

2.2 Manual Versions

Chapters marked with the attribute (*P*) are only available in ***AVRco Profi Revision.***

2.3 Structure of the Documentation

..\E-Lab\DOCs\DocuCompiler.pdf:
contains the Pascal language description and the enhancements compared with Standard Pascal

..\E-Lab\DOCs\DocuStdDriver.pdf:
contains the description of the drivers contained as well in the Standard, as in the Profi Version.

..E-Lab\DOCs\DocuProfiDriver.pdf:
contains the description of the drivers contained only in the Profi Version.

..E-Lab\DOCs\DocuReference.pdf:
contains a Short Reference (the the same as the online help)

..\E-Lab\DOCs\DocuTools.pdf:
contains the description of the IDE, the simulator, a tutorial etc.

..\ E-LAB\IDE\DataSheets\Release-News.txt:
lists the enhancements in chronological order.
The enhancements are documented in the above mentioned .pdf files (DocuXXX.pdf)

..\E-Lab\AVRco\Demos\ :
contains many test and demo programs

..\E-Lab\DOCs\ :
contains the documentation and further schematics and data sheets

2.4 Known Limitations

- The function ***Integratel*** still has a problem with negative values.

- Overwriting of predefined Types, Variables, Constants, Functions and Procedures is not implemented yet.

- The order of the operators (* AND SHR etc.) is not completely implemented yet.
  So please use always **parentheses** in conjunction with expressions.

- Not implemented: "**With**" constructs with Records in Records

- Strings

  The following string **concat** result is not what you expect:

  str:= str1 + str;

  Because of the limited RAM this can not be realised.

  Possible is:

  str:= str + str1;

- Arrays

  The construction of **Array of Array** is not supported

3 Basic AVRco Language Elements

3.1 Basic Symbols

The basic vocabulary of AVRco Pascal consists of basic symbols divided into letters, digits, and special symbols:

Letters A to Z, a to z and _ (underscore). The underscore should not be used as the first letter of a symbol.

Digits 0123456789

Special symbols ***/=<>()[]{}|.,**

No distinction is made between upper and lower case letters. Certain operators and delimiters are formed using two special symbols:

Assignment operator: : **=**
Relational operators: **<>   <=   >=**
Comments: **(*** and ***)** may be used instead of { and }.
It is also possible to use C-style comments using **//**

In addition, AVRco Pascal makes use of certain constructs to allow low level access to the CPU and it's resources. There are also many language extensions to support embedded programming.

3.2 Reserved Words

Reserved words are integral parts of AVRco Pascal. They cannot be redefined and must therefore not be used as user defined identifiers.

Examples:
ABS, AND, ARRAY, ASM, BEGIN, BREAK, CASE, CONST, CONTINUE, DIV, DO, DOWNTO, ELSE, ELSIF, END, ENDFOR, ENDCASE, ENDWHILE, ENDIF, EXIT, FOR, FORWARD, FUNCTION, GOTO, IF, IN, LABEL, MOD, NOT, OF, OR, PROCEDURE, PROGRAM, RECORD, REPEAT, ROR, ROL, SHL, SHR, STRING, THEN, TO, TYPE, UNTIL, VAR, WHILE, WITH, XOR

3.3 Standard Identifier

AVRco Pascal defines a number of Standard Identifiers for predefined Types, Constants, Variables, Procedures and Functions. These can also not be redefined.

Examples:
FALSE, TRUE, NIL, CHAR, BOOLEAN, INTEGER, BYTE, INT8, LONGINT, WORD, LONGWORD, FLOAT, POINTER, SIZEOF, ADDR, @, INC, DEC, MOVE, LENGTH, COPY, INTTOSTR, BYTETOSTR, INTTOHEX, STRTOINT, LO, HI, LOWORD, HIWORD, INSERT, DELETE, UPCASE, POS

3.4 Delimiters

Language elements must be separated by at least one of the following delimiters: a blank, an end of line, or a comment. Note that comments are allowed anywhere in the source. There are some restrictions.

3.5 Program Lines

The maximum length of a program line is 250 characters.

4 Language Reference

4.1 Types

4.1.1 Standard scalar Types

A data type defines the set of values a variable may assume. Every variable in a program must be associated with one and only one data type. Although data types in the AVRco can be quite sophisticated, they are all built from simple (unstructured) types.

The basic data types of Pascal are the scalar types. Scalar types constitute a finite and linear ordered set of values.

A simple type may either be defined by the programmer (it is then called a *declared scalar* type), or be one of the *standard scalar types:* integer, int8, word, longint, longword, float, boolean, char, or byte.

Apart from the standard scalar types, Pascal supports user defined scalar types, also called declared scalar types (enumeration). The definition of a scalar type specifies, in order, all of its possible values. The values of the new type will be represented by identifiers, which will be the constants of the new type

```
type
     Operator  =  (Plus, Minus, Multi, Divide);
```

In the above example, the type Operator is nothing else but a type byte. All following values are enumerated starting from 0. Effectively Plus is a constant with the value 0, Minus a 1, Multi a 2 and so on. The use of defined scalar types is strongly recommended as it greatly improves the readability of programs.

```
type
     TDay     =  (Mon,Tue,Wed,Thur,Fri,Sat,Sun);
     TMonth   =  (Jan,Feb,Mar,Apr,May,Jun,Jul,Aug,Sep,Oct,Nov,Dec);
     TMArr    =  array[Jan..Dec] of TDay;

var
     MonArr  =  TMarr;
     ...

  MonArr[Aug]:= Sun;
  If MonArr[Jan] = Fri then ...
```

4.1.2 Type Conversion

The compiler does not perform automatic type conversion. An allocation like *byte := word* leads to a **Type Mismatch.** But it is possible to convert most types to another by using the so called typecasting. In many cases no additional machine-code will be generated
(*char := char(byte)*).
AVRco Pascal provides “Type Casting” as can be found in most Pascal compilers today. This is done by simply using the type identifier as “function” name. The single parameter in this “function call” is a variable of type A that you would like the compiler to view as a variable of type B (the type identifier used in the “function call”).

```
var    ch : char;
       b1 : byte;
       w1 : word;
       i1  : integer;
       p1 : pointer

ch:= char(b1);
b1:= byte(w1);
i1:= integer(w1);
p1:= pointer(w1);

type
  TRecordA   =      record
                      a,b,c : word;
                    end;
  TRecordB   =      record
                      X : longint;
                      Y : word;
                    end;

var
  A : TRecordA;
  B : TRecordB;
  C : char;
  D : byte;

begin
  A:= RecordA (B);
  RecordA (B):= A;
  D:= byte (C);
  C:= char (D);
end.
```

Tip:
In the Pascal world it's good practice that type declarations start with a capital "T". This is not a must but supports the readability of the program and helps to avoid programming errors.

4.1.3 Variable Overlay

Variables can be placed directly into other variables (Overlay).
But here is the problem that the second variable can be larger (memory) as the referenced variable. Because only the reference variable does a memory allocation, it is possible that a write access to the overlay destroys the subsequently placed variable at runtime.

```
var  abc             : byte;
     xyz             : byte;
     ovr1[@abc]      : byte;          // it's ok
     ovr2[@abc]      : word;          // problem
```

In this example a write access to the variable "ovr2" always overwrites also the variable "abc" as expected but also (unexpected) the variable "xyz".
The compiler checks in case of an overlay whether the overlay variable fits into the memory which was allocated by the referenced (overlaid) variable.

But to enable the construction below there is a compiler Switch {$*NOOVRCHECK*}.
So it is possible to switch off the check for a single following declaration.

```
var
v1     : byte;
v2     : byte;
v3     : byte;
v4     : byte;

{$NOOVRCHECK}
v5[@v1]  : longword;
```

Normally v5 will raise an error because a longword consumes 4 bytes but the variable v1 only offers one byte memory. By disabling the check the variable v5 occupies the memory locations of v1-v4 and overlays all four bytes, which can be legal but may not be so. The programmer is responsible for that.

Borland Pascal has another implementation for this. The AVRco also supports this type:

```
var
 abc   : byte;
 xyz   : word;
 ovr1  : byte absolute abc;            // var abc overlayed
 {$NOOVRCHECK}
 ovr2  : word absolute xyz;            // var xyz overlayed
```

"absolute" is only applicable with variables in RAM and EEprom area. “absolute” is not applicable with local variables in functions.

4.1.4 BOOLEAN

Required memory: 8bit, value: true..false
A boolean value can assume either of the logical truth values denoted by the standard identifiers *True* and *False.* These are defined such that *False = 0;* True > 0 (normally $FF). A *Boolean* variable occupies one byte in memory.

true = $FF   false = $00

```
var    flag : boolean;
```

Comment:
One boolean needs 1 byte as memory location. To economize memory location, it possibly makes sense to use a one byte-variable and divide it with the help of the BIT-definition into separate bits. So the required memory for 8 Booleans is reduced to 1 byte.

```
var    flag                    : byte;
       flag0[@flag, 0]         : bit;
       flag1[@flag, 1]         : bit;
        ...

if Bit (Flag0) then ...
Incl (Flag1);
SetBit (flag0, flag1);         {copy bit}
```

4.1.5 BIT

Required memory: 1bit, true..false, 0..1

In order to handle the necessary bits for embedded applications the ***variable bit*** was introduced. This type can be used exactly if it were a boolean. In addition *INCL(bit), EXCL(bit), TOGGLE(bit), SetBit* and "*if BIT(bit) then* .." may be used. The declaration of a bit-variable **always** consists of two grades: First the memory location or variable in which the bit resides has to be declared. This variable must be a global var. Bit definitions into Records or Arrays are not possible. First define a global variable of type byte, word or with ***REV4 also LongWord***.

```
var    Leds[$05] : byte;   or
       bits16     : word;
```

The type of the memory location (byte, word, longword) determines, too, if 8 or 16 bits are at disposal. After the declaration of a general variable the actual bit-declaration follows. The first parameter indicates a memory location and the second parameter indicates the corresponding bit of this memory location. Symbolic parameters can also be used.

```
const   LedBit2 = 3;
var     port6[6]                 : byte;
        Led2[@port6, Led2Bit]  : bit;

  if BIT (Led2) then ...
    Toggle(Led2);

SetBit (Led2, not Led2);
```

Bits can also be dynamically generated within the program.

```
Toggle (Leds, 3);              {Bit3  in 8  Bits}
Incl (bits16, 12);             {Bit12 in 16 Bits}
```

4.1.6 BITSET

8bit, 16bit or 32bit dependent of the underlying enumeration. 32bits only in REV4

Basics:
With an enumeration each of the 256 possible values each used value can/must be named. With a BitSet each used bit must be named. Because of this a byte can contain upto 8 "Names" = Bits, a word up to 16 names and a longword up to 32 names. With a BitSet each single bit can be accessed and manipulated by it's name. Also accessing in Bit-groups is then possible.

Definition:
Before a BitSet type can be defined, there must be an enumeration type which contains the Bit names.
The count of the bit names defines whether the resulting BitSet resides in a byte, word or longword.
The maximum count of names or bits is 32.

Declaration:

```
type
  TBitNames   = (one, two, three, four, five, six);      // enum
  TBitSet     = BitSet of TbitNames;                     // build a bitset type

var
  BitSet1     : TBitSet;                // build a bitset var
  BitSet2     : TBitSet;                // build a bitset var
  Bb          : byte;
```

Working with BitSets:

```
BitSet1:= BitSet2;                  // copy a set into another
bb:= byte (BitSet1);                // type convert
BitSet2:= TbitSet (bb);             // type convert
```

In order to completely fill a bitset all bits of the enum type must be entered:

```
BitSet1:= [one, two, three, four, five, six];
```

It's also possible to use the enum name:

```
BitSet1:= [tEnum];
```

BitSets can be set in conjunction with **Operators.** These are **+ - * /**

Addition:
```
BitSet1:= [one, three];
BitSet2:= [two, four, six];
BitSet1:= BitSet1 + BitSet2;          // unification – logical or
//BitSet1 contains now one, two, three, four and six.
```

Subtraction:
```
BitSet1:= [one, two, three];
BitSet2:= [two, four, three];
BitSet1:= BitSet2 - BitSet1;          // difference – logical and not
//BitSet1 contains now four.
```

Multiplication:
```
BitSet1:= [one, two, three];
BitSet2:= [two, four, five];
BitSet1:= BitSet2 * BitSet1;         // logical and
//BitSet1 contains now two.
```

Division:
```
BitSet1:= [one, two, three];
BitSet2:= [two, four, five];
BitSet1:= BitSet2 / BitSet1;          // logical xor
//BitSet1 contains now one, three, four, five.
```

BitSets can be **compared** with the use of **= <> <= >= IN**
Compared are the binary values of the corresponding bit patterns.

```
if BitSet1 = [one, two, three] then ...
if BitSet2 <= [two, four, five] then ...
if BitSet2 in BitSet1 then ...
if [two, four, five] in BitSet1 then ...
```

4.1.7 BYTE

8 bit, 0..255
Bytes are whole numbers. They are limited to a range of 0 through 255.
Bytes occupy one byte in memory.

All variable declarations can be assigned to a fixed address.

Example for a fixed address:

```
var   b[$10]  : byte;          {memory at addr. 10hex}
```

Example for a free address allocation by the compiler:

```
var    x  : byte;
```

It is also possible to specify a previous declared variable as reference. So it is possible, for example, to access the two bytes of a word variable.

```
var   w[$12]       : word;
      b1[@w]       : byte;     {b1 is at addr. 12hex – low byte}
      b2[@w + 1]   : byte;     {b2 is at addr. 13hex – high byte}
```

4.1.8 CHAR

8 bit, chr(0..255)

A Char value is one character in the ASCII character set.
Characters are ordered according to their ASCII value, for example: 'A' < 'B'. The ordinal (ASCII) values of characters range from 0 to 255. A Char variable occupies one byte in memory.

Example variable of type char:
```
var   c  : char;
```

Example constant of type char:
```
const   cd   = 'D';
        Bell = ^G;     {Control G}
        LF   = #10;    {Line Feed}
```

Character sets: see the string section below

4.1.9 STRING

0..255 bytes, variable or constant.

AVRco Pascal offers the convenience of string types for processing of character strings i.e. sequences of characters. String types are structured types and are in many ways similar to array types. In Pascal, a string is the exact equivalent of an *array of char* and such an array may be treated as a string.
AVRco Pascal uses the FIRST character in a string as a length indicator with the remainder of the string following. This is compatible with most Pascal string implementations but differs from C, which uses a zero byte as string delimiter.

In short, the Pascal string results in a better performance since the length of a string is always known without having to scan the string. The Pascal string is also a convenient dynamic storage medium for data other than characters as there is no restriction on the value of a character that can be placed inside the string. C strings on the other hand may be of indefinite length while Pascal strings are restricted to a maximum length of 255 characters.

```
type   st10  = string[10];                  {stringlength = 10}

structconst  {constant in Rom, at startup copied into Ram}
   str   : st10    = 'abcde';

const       {constant in Rom}
   st  = '1234' + 'R' + #7 + ^L;

var    st1   : string[8];

 st1:= st;
 ch:= st[2];
```

The so called Length Byte is located at first position of the string (str[0]). This byte specifies the actual occupied length of the string. It is possible, for example, to change the length dynamically by manipulating the position 0 within the declaration (str[0]:= # 5;). The better way is to use the system function **SetLength (** st : string; len : byte) ;

The length byte (= char!!) can also be read to determine the actual length. But here is the function **Length**(str) better and faster. Do string-manipulations only with Var and StructConst !

Character sets:

For Chars and Strings the AVRco uses the ANSII character set by default. Some external devices often expect the OEM character set. These two sets mainly differ in the provided special characters and the umlauts.

It is possible to globally switch to the OEM charset by the option "OEMcharSet" werden. Then the OEM charset is used for the special chars in char-types and string-types:

```
   From System Import ..., OEMcharSet;
```

The definition of a string type must specify the maximum number of characters it can contain, i.e. the maximum length of strings of that type. The definition consists of the reserved word **string** followed by the maximum length enclosed in square brackets. The length is specified by an byte constant in the range 0 through 255. Notice that strings do not have a default length; the length must always be specified.

String variables occupy the defined maximum length in memory plus one byte which contains the current length of the variable. The individual characters within a string are indexed from 1 through the length of the string.

Strings are manipulated by the use of *string expressions.* String expressions consist of string constants, string variables, function designators, and operators.
The plus-sign may be used to concatenate strings. The *Concat* function available in some Pascal implementations does the same thing but is not implemented in AVRco Pascal since the + operator is often more convenient.

The result of string expressions cannot provide a string larger than 255 characters in length, also, in string assignments, the assignment target will never receive a string larger than the size of the target permits.

```
'E-LAB ' + 'Pascal ' + 'is '+ 'fun…
' '123' + ' . + '456'
 'A ' + 'B' + ' C ' + 'D '
```

The relational operators **=** and **< >** are lower in precedence than the concatenation operator. When applied to string operands, the result is a Boolean value (*True* or *False).* When comparing two strings, single characters are compared from the left to the right according to their ASCII values.

If the strings are of different length, but equal up to and including the last character of the shortest string, then the shortest string is considered the smaller.

Strings are equal only if their lengths as well as their contents are identical.

```
'A' = 'A'                               // is true
'A' = 'a'                               // is false
'2' <> ' 12'                            // is true
'PASCAL' = 'PASCAL'                     // is true
'PASCAL' = 'pascal'                     // is false
'Pascal Compiler' <> 'Pascal compiler'  // is true
```

The assignment operator is used to assign the value of a string expression to a string variable.

```
Age := 'twenty'
Line := 'Many happy returns on your ' + Age + 'birthday'
```

If the maximum length of a string variable is exceeded (by assigning too many characters to the variable), the exceeding characters are truncated. E.g., if the variable *Age* above was declared to be of type **string[5],** then after the assignment the variable will only contain the five leftmost characters: 'twent'.

Concat restrictions

If the destination string is included in the concatenation the it **must** be the first string!
The following string concat result is not what you expect:
str:= str1 + str;

This is correct:
str:= str + str1;

4.1.10 Property

A Property can be seen as a “nearly“ normal variable. A Property can be read and written as a variable. The difference to a “normal“ variable is that a read operation does not directly access any memory location but uses a function (Getter) which returns the value. With writing to a Property a procedure (Setter) executes the writing of the passed variable in a given way.

So a Property has a name, a Type for reading and writing and the Getter and Setter functions.

```
Property
  MyWord    : word Read GetMyWord Write SetMyWord;
  MyWord    : word Read GetMyWord Write SetMyWord;       // read-write property
  MyWordWr  : word Write SetMyWordWr;                    // write only property
  MyByteRd  : byte Read GetMyByteRd;                     // read only property
```

Therefore the Setter/Getter functions must be provided before the usage of the property:

```
procedure SetMyWord(w : word); // setter
begin
  ww:= w;
end;

function GetMyWord : word;     // getter
begin
  return($5678);
end;
```

Properties can also be placed in the Definition part of an Unit and then they are valid globally.
But the setter/getter functions must be implemented before the first usage of a property!

A **sample program** “Properties“ is in the Demos directory in folder “XMega_Properties“.

4.1.11 ARRAY

An array is a structured type consisting of a fixed number of components which are all of the same type, called the *component type* or the *base type.* Each component can be explicitly accessed by indices into the array. Indices are expressions of any scalar type placed in square brackets suffixed to the *array identifier,* and their type is called the *index type.*

1..4 dimensions. One dimension can have up to 61440 ($F000) members. Total size is limited to ca. 60kbytes. Types: bytes, int8, chars, booleans, words, integers, longwords, floats, fix64, pointers, procedures.

The definition of an array consists of the reserved word **array** followed by the index type, enclosed in square brackets, followed by the reserved word **of** followed by the component type.

```
type  Day = (Mon,Tue,Wed,Thu,Fri,Sat,Sun);

var  WorkHour  : array[1..8] of Integer;
     Week      : array [ 1. . 7] of Day;

type  Players   =  (Playerl, Player2, Player3, Player4);
      Hand      =  (One, Two, Pair, TwoPair, Three, Straight, Flush, FullHouse, Four, 5traightFlush);
      Bid       =  array[Players] of byte;

var   Player    : array[Players] of Hand;
      Pot       : Bid;

Var  ArrTest : array[3] of byte; //the same as Array[0..3] of byte
```

An array component is accessed by suffixing an index enclosed in square brackets to the array variable identifier:

```
Player[Player3] := FullHouse;
Pot[Player3] := 100;
Player[Player4] := Flush;
Pot[Player4] := 50;
```

As assignment is allowed between any two variables of identical type, entire arrays can be copied with a single assignment statement.

The definition of an array constant consists of the constant identifier followed by a colon and the type identifier of a previously defined array type followed by an equal sign and the constant value expressed as a set of constants separated by commas and enclosed in parentheses.

```
type  Status : array[0..2] of string[7] ;
const Stat : Status = ('active', 'passive', 'waiting');
```

The example defines the array constant *Stat,* which may be used to convert values of the scalar type *Status* into their corresponding string representations.

The following boolean comparisons would return true:

```
Stat[0] = 'active'
Stat[1] = 'passive'
Stat[2] = 'waiting'
```

Multi-dimensional array constants are defined by enclosing the constants of each dimension in separate sets of parentheses, separated by commas. The innermost constants correspond to the rightmost dimensions.

```
type Cube = array[0..1,0..1,0..1] of integer;

const Maze : Cube = ( (  (0, 1) , (2, 3)  )  , ( (4, 5) , (6, 7)  ) ) ;

type Tars = array[0..1, 3..4] of byte;

structconst                    {constant in Rom, at startup copied into Ram}
  ars : Tars = ( (0, 1) , ($FE, $FF) ) ;

const                          {constant in Rom}
  arc : array[0..4] of word = (1, 200, 523, 1200, 9999);

var  ar1   : array[5..12] of char;
     ar2   : array [6 .. 9, 56 .. 67] of word;
     ar3   : Tars;

x:= ar[1];
ar1[8] := #7;
ars [1, 3] := $7;
ar2 [8, 60] := arc [3] ;
```

Array-manipulations only for Var and StructConst !

Special construction
Array and Record constants can be read in from a file. The programmer is responsible of the contents of the file. The file length is not important. If the file is too short, the structure is filled with zeros. If the file is too long, the read-in is aborted at the Array/Record-limits.

```
Const  Arr1 : array[0..31] of word = 'FileName.ext';
```

4.1.12 TABLE

1 dimension. Up to 255 members.
Types: bytes, Int8, chars, booleans, words, integers, longwords, floats, fix64, pointers, procedures.
TABLE is a specialized array which can contain look-up tables. The table length is limited on power of 2, to have a very fast access:
0..3, 0..7, 0..15, 0..31, ... 0..255.
The access automatically wraps, for example: an access to a table [0..7] with an index of 8 the access wraps to the table index 0. Tables have to be defined as global variables to assure a fast access. Table constants in ROM are not possible with AVR, but structured constants in ROM and EEprom are possible. Accesses to a table must be done with **GetTable** and **SetTable**.

```
structconst                   {constant in Rom, at startup copied into Ram}
  Table1 : Table[0..3]  = (0, $45, $A5, $FF);

var  tb1   : Table[0..15] of char;
     tb2   : Table[0..127] of word;

 x:= GetTable (tb1, 1);
 SetTable (tb1, x, $35);
 x:= GetTable (Table1, z);
```

4.1.13 RECORD

A record is a structure consisting of a fixed number of components, called *fields.* Fields may be of different type and each field is given a name the *field identifier,* which is used to select it.

Record Definition

The definition of a record type consists of the reserved word record succeeded by a *field list* and terminated by the reserved word **end.** The field list is a sequence of *record sections* separated by semi-colons, each consisting of one or more identifiers separated by commas, followed by a colon and either a type *identifier* or a type *descriptor.* Each record section thus specifies the identifier and type of one or more fields

```
type   tMonths = (Jan,Feb,Mar,Apr,May,Jun,July,Aug,Sep,Oct,Nov,Dec);
       Date  =    record
                      Day     :  byte;
                      Month   :  tMonths
                      Year    :  word;
                  end;
var
       Birth         : Date;
       WorkDay    : array[1..5] of date;
```

Day, Month and *Year* are field identifiers. A field identifier must be unique only within the record in which it is defined. A field is referenced by the variable identifier and the field identifier separated by a period.

```
Birth.Month := Jun;
Birth.Year := 1950;
WorkDay[Current] := WorkDay[Current-1];
```

Note that, similar to array types, assignment is allowed between entire records of identical types. As record components may be of any type, constructs like the following record of records of records are possible:

```
type   Tmonths = (Jan,Feb,Mar,Apr,May,Jun,July,Aug,Sep,Oct,Nov,Dec);
       Tname  =  record
                     FamilyName      : string[32],
                     ChristianNames : array[1..3] of string[16];
                 end;

      TRate   =    record
                     NormalRate,
                     OverTime,
                     NightTime,
                     Weekend        : Integer;
                 end;

      TDate   =    record
                     Day      : byte;
                     Month   : TMonths;
                     Year     : word;
                 end;

      TPerson =  record
                      ID      : TName;
                     Time   : TDate;
                 end;
```

```
    Twages  =  record
                    Individual   : TPerson;
                    Cost         : TRate;
                 end;

Var  Salary, Fee:  TWages;
```

Assuming these definitions, the following assignments are legal:

```
Salary:= Fee;
Salary.Cost.Overtime := 950;
Salary.Individual.Time := Fee.Individual.Time;
Salary.Individual.ID.FamilyName :=  Smith;
```

The definition of a record constant consists of the constant identifier succeeded by a colon and the type identifier of a previously defined record type followed by an equal sign and the constant value expressed as a list of field constants separated by semi-colons and enclosed in parentheses.
The constants must have the same name as in the Type-Declaration.

```
type   Point = record
                 X,Y, Z : integer;
               end;

const  APoint : Point = (X : 0; Y : 2;  Z : 4);
```

The field constants must be specified in the same order as they appear in the definition of the record type.

<u>**Special construction**</u>
Array and Record constants can be read in from a file. The programmer is responsible of the contents of the file. The file length is not important. If the file is too short, the structure is filled with zeros. If the file is too long, the read-in is aborted at the Array/Record-limits.

```
Const             Rec1 : TWages = 'FileName.ext';
```

4.1.13.1 WITH Statement for Access to Records

The use of records as described above does sometimes result in rather lengthy statements; it would often be easier if we could access individual fields in a record as if they were simple variables. This is the function of the **with** statement: it 'opens up' a record so that field identifiers may be used as variable identifiers.

A **with** statement consists of the reserved word **with** followed by a record variable followed by the reserved word **do** and finally a statement. It ends up with the **EndWith** statement.

Within a with statement, a field is designated only by its field identifier, i.e. without the record variable identifier.

```
with Salary do
  Individual := NewEmployee;
  Cost := StandardRates;
endwith;
```

4.1.14 PROCEDURE

16 bit (usually, depending on processor), parameter, word, address.
“procedure“ declares a variable, which contains the address of a procedure.

```
var   proc  : procedure;

procedure indirtest;
begin
  ...
end;

begin                      {Main Program}
  ...
  Proc:= @indirtest;       {occupy variable with address of indirtest}
  Proc;                    {call indirtest}
  ...
end.
```

4.1.15 WORD

16 bit, 2 Bytes, 0..65535

Words are whole numbers. They are limited to a range of 0 through 65535.
Words occupy two bytes in memory: low byte (lower address), high byte (higher address)

```
var    w        : word;
       w1[24]  : word;              {word at address 24}
```

4.1.16 INT8 or ShortInt

8bit, 1 Byte, -128..+127

Short integers (Int8) are whole numbers. They are limited to a range of - 128 through +127.
Short integers occupy one byte in memory.

4.1.17 INTEGER

16bit, 2 Bytes, -32768..32767

Integers are whole numbers. They are limited to a range of - 32768 through 32767.
Integers occupy two bytes in memory: low byte (lower address), high byte (higher address)

```
var   i       : integer;
     w[@i] : word;                 { word with the same address as i }
```

4.1.18 POINTER

16 bit (usually, depending on processor), 2 Bytes

Variables discussed up to now have been *static,* i.e. their form and size is pre-determined and they exist throughout the entire execution of the block in which they are declared. Programs, however, frequently need the use of a data structure which varies in form and size during execution. *Dynamic* variables serve this purpose as they are generated as the need arises and may be discarded after use.

Such dynamic variables are not declared in an explicit variable declaration like static variables, and they cannot be referenced directly by identifiers. Instead, a special variable containing the memory address of the variable is used to *point* to the variable. This special variable is called a *pointer variable.*

Sometimes it makes sense to use this type if you have not to access a variable by its name, but there is the possibility to work with the address of a variable.

An unqualified pointer always assigns to one byte, so it is “standardized“. An exception is the type conversion with p := pointer(word1);. This generated pointer is always untyped and is only qualified with an assignment to another pointer-variable. It is always better to work with qualified pointers. Therefor a private type is generated with

```
type   tpb : pointer to Byte;

var    pb : tpb;

pb:= tpb (anyPointer);
```

A value to a pointer has to be assigned with address-operator @**.** A pointer is made invalid with the assignment **p:= nil.** The pointer can itself be manipulated like every other variable. But be careful, a manipulated variable can also point to nirvana!!

A check of the validity of pointers (destination address) does not take place. The programmer should be very careful with pointers. If a pointer has possibly lost its validity, NIL should be assigned to it, to be able to test its validity when next used. But this must happen in the software, the compiler is not able to support this.
Greetings from ‘C’!

```
type  tpw : pointer to word;

var   p    : pointer to word;   {always points to a word}
      pb   : pointer;           {points to a byte}
      pw   : tpw;               {points to a word}
      b1   : byte;
      b2   : byte;
      w    : word;

Function DecWord (p : tpw) : word;
begin
  inc (p^);
  return(p^);
end;
```

```
Procedure IncByte (b : pointer to byte);
begin
  inc (b^);
  p:= pointer (b1);
end;

{Main}
...
pb:= @b1;
incByte (pb);
pb:= @b2;
incByte (pb);
p:= @w;
p^:= 1234;
p:= nil;
```

Sometimes it’s necessary to declare a pointer before the object/type to which it points to, is declared. (e.g. linked lists). Then the pointer declaration must be defined with the attribute “Forward“. The main declaration follows after the necessary type is defined:

```
type  TPtr     = pointer; forward;  // preliminary declaration
      TRec1    = record
                   ...
                   Ptr1 : TPtr;
                 end;
      TPtr     = pointer to Trec1;  // main declaration
```

Basically a pointer points into to address area of the CPU. With the AVR this is: Register-Page, IOPage, InternRam-Page and ExternRam-Page. All these areas reside in the linear address area from $0000 to $FFFF. As long as the programmer takes care of his pointer arithmetic, there are no problems (or rather: not many. Greetings from 'C'). But you cannot directly access the Eeprom or Flash with a pointer. The Compiler cannot recognize that the result of a pointer manipulation now should point into the Flash. The Compiler must be informed that the access does **not** result in the normal address area. To this end the Compiler exports some predefined pointer types which can be used for a quasi type conversion:

```
EEpromPtr (pointer)
FlashPtr (pointer)
UsrDevPtr (pointer)
BankDevPtr (bank; pointer)
```

EEpromPtr
An access by an *EEpromPtr(pointer)* is redirected into the EEprom with the address which the pointer contains. If the pointer points to $100, the access is done to the address $100 in the EEprom.

FlashPtr
An access by an *FlashPtr(pointer)* is redirected into the ROM with the address which the pointer contains. If the pointer points to $100, the access is done to the address $100 in the Flash.

UsrDevPtr
An access by an *UsrDevPtr(pointer)* is redirected into the UserDevice with the address which the pointer contains. If the pointer points to $100, the access is done to the address $100 in the UserDevice.

BankDevPtr

An access by a *BankDevPtr(bnk; pointer)* is redirected into the Banked Device with the bank that *bnk* contains and the address which the pointer contains. If the pointer points to $100, and *bnk* contains 2 the access is done to the address $100 in bank 2 of the Banked Device.

```
type    TRec1     = record
                      Rbb     : byte;
                      Rww     : word;
                    end;
        TPtr1     = pointer to TRec1;

const   FRec1     : TRec1 = (Rbb : $AA; Rww : $1234);

{$EEPROM}
var     ERec1  : TRec1;

{$UDATA}
var     URec1  : TRec1;

{$BDATA 2}
var     BRec1  : TRec1;

{$IDATA}
var     IRec1  : TRec1;
        Ptr1   : TPtr1;
        bb     : byte;
        ww     : word;
...
...

begin
  Ptr1:= @FRec1;
  bb:= FlashPtr (Ptr1)^.Rbb;
  ww:= FlashPtr (Ptr1)^.Rww;

  Ptr1:= @ERec1;
  EEpromPtr (Ptr1)^.Rbb:= $ff;

  Ptr1:= @URec1;
  UsrDevPtr (Ptr1)^.Rbb:= $ff;

  Ptr1:= @BRec1;
  BankDevPtr (2, Ptr1)^.Rbb:= $ff;

  Ptr1:= @IRec1;
  Ptr1^.Rbb:= $ff;
end.
```

4.1.18.1 Pointer AutoIncrement AutoDecrement

One of the very few advantages of C over Pascal is the AutoIncrement/AutoDecrement of Pointers. This is also possible with AVRco by writing *Pointer^++* or *Pointer^--*
The condition to use pointers with AutoIncrement is that they must be located either in the global space or local space (procedure/functions frame). You cannot manipulate pointers residing in the flash (obviously), in EEprom etc.
The pointer must be dereferenced. This means a read or write data move must be done with the pointer using the "^". An exception is *pointer++;* and *pointer--;*
Only typed pointers can be used with AutoIncrement. With **AutoDecrement** only **8bit sized** targets/sources can be used and the operation uses the **pre-decrement** feature of the AVRs.
++ means **post**-increment and **--** means **pre**-decrement.

The target/source of the pointer can be global, local, Flash or EEprom variables and constants.
But pay attention to the fact that the pointer always becomes incremented by the data size of the moved object. For a byte this is 1, with words this is 2, with arrays this is sizeOf(Array) and with records this is also sizeOf(record). With strings the increment is not length(string) but sizeOf(string).

This all is the difference to inc(pointer) where the pointer is always incremented by 1.
By the use of the AutoIncrement/AutoDecrement of pointers short and fast move loops can be build..

```
pointer^++:= variable;
pointer^++:= contant;
EEpromPtr(pointer)^++:= variable;
variable:= pointer^++;
variable:= FlashPtr(pointer)^++;
variable:= EEpromPtr(pointer)^++;
pointer1^++:= pointer2^++;

var arr : array[0..7] of byte
Pointer := @arr + sizeOf(arr) ;
pointer^--:= variable;
pointer^--:= contant;
variable:= pointer^--;
pointer1^--:= pointer2^--;
```
etc.

4.1.19 LONGWORD

32bit, 4 Bytes, 0..4294967295
Longwords are whole numbers. They are limited to a range of 0 through 4294967295.
Longwords occupy four bytes in memory.

```
var   lw  : longword;
```

4.1.20 WORD64

64bit, 8 Bytes, 0..18446744073709551615

Word64 are whole numbers. They are limited to a range of 0 through 18446744073709551615.
Word64 occupy eight bytes in memory.

```
var   w64  : word64;
```

Attention:
64 bit types like word64, int64 and Fix64 are not available by default. The corresponding type has to be explicitly imported.

```
from System Import Word64, Int64, Fix64;
```

4.1.21 LONGINT

32 bit, 4 Bytes, -2147483648..2147483647

LongInts are whole numbers. They are limited to a range of -2147483648 through 2147483647. LongInts occupy four bytes in memory.

var *li : longint;*

4.1.22 INT64

64bit, 8 Bytes, -9223372036854775808 ... 9223372036854775807

Int64 are whole numbers. They are limited to a range of -9223372036854775808 through 9223372036854775807. Int64 occupy eight bytes in memory.

var *i64 : int64;*

Attention:
64 bit types like word64 and int64 are not available by default. The corresponding type has to be explicitly imported.

from *System* ***Import*** *Int64;*

4.1.23 FLOAT

32 bit, 4 Bytes, 6..9 Digits, 10E-38..10E38

var *f : float;*

Attention:
32 bit types like longint, longword and float are not available by default. The corresponding type has to be explicitly imported.

from *System* ***Import*** *LongInt, Float;*

4.1.24 Fix64

Fixed point type. 64 bit, 8 Bytes. Limited from max 2147483647.999999999 to min -2147483648.000000000
Consists of a 32bit integer part and a 32bit fractional part.

var *f64 : fix64;*

Attention:
64 bit types like word64, int64 and fix64 are not available by default. The corresponding type has to be explicitly imported.

from *System* ***Import*** *Int64, Fix64;*

4.1.25 ENUM

8bit, 0..255 Enumeration

```
type  eKey = (Key1, Key2, Key3);    {type declaration}
var   Keys : eKey;                  {variable of type eKey}
                                    {runs from Key1..Key3}
```

```
if Key2 in Keys then ...
```

It's possible to change enumerations with the INC and DEC procedures.
The upper and lower limits are taken in account, but unlike SUCC and PRED these functions wrap around at the limits.

Enumeration can also be defined with holes or gaps:

```
type
  tEnum = (aaa, bbb, ccc=100, ddd, eee=200, fff);
                0    1    100     101    200    201   <- numerical values
```

4.1.26 SEMAPHORE

8bit, Byte   is imported by processes and tasks

```
var  sema  : Semaphore;
```

Semaphores are specialized variables and serve for the process-synchronization.
A process or a task can increment or decrement a semaphore. A value > 0 may mean for a task/process for example that a certain function/procedure is disabled.

An access can only be done with the corresponding special functions/procedures, because the access has to be secured from interrupts (task changes).

State of a Semaphore (byte)
```
Function SemaStat (sema : semaphore) : byte;
```

Incrementing of a Semaphore
```
Procedure IncSema (sema : semaphore);
```

Decrementing of a Semaphore
```
Function DecSema (sema : semaphore) : boolean;
```

Process is waiting for Semaphore > 0
```
Function WaitSema (sema : semaphore [; timeout: word]) : boolean;
```

The TimeOut parameter is optional. If omitted the process waits until the event occurs. The same is true if TimeOut is set to 0000. With a value > 0 the Wait is terminated after (TimeOut * SysTicks).
The function result becomes true if there was no Timeout.
A TimeOut in Tasks is not possible. This parameter is ignored.

4.1.27 PIPE

generic is mainly used by processes or tasks

Import:
***from** System **import** …, …, Pipes;*

4.1.27.1 Pipe for ordinal Types

A pipe is a block of memory, which is organized as a so called FIFO (First in, First Out) or queue. The pipe can be a container for all ordinal types (boolean..longint) and float. The length of the pipe or the possible number of parameters/variables is max. 255. An access to pipes can only be done with the corresp. functions/procedures, because the access has to be secured from interrupts (task changes).

Declaration:
***var** Pipe1 : Pipe[16] of byte; // int8, boolean, word, integer etc.*

State of a Pipe (byte) = number of available parameters
***Function** PipeStat (pipe1 : pipe) : byte;*
The function PipeStat is also applicable to RxBuffer, RxBuffer1, -2, -3 and TxBuffer, TxBuffer1, -2, -3 of the serial interfaces.

State of a Pipe (boolean)
***Function** PipeFull (pipe1 : pipe) : boolean;*

Add Parameter to Pipe
***Function** PipeSend (pipe1 : pipe; parm : type) : boolean;*

Fetch Parameter from Pipe
***Function** PipeRecv (pipe1 : pipe) : type;*
Waits until the pipe at least contains one parameter and then returns the oldest entry.

***Function** PipeRecv_ND (pipe1 : pipe) : type;*
This function allows the read out of a pipe without removing or changing the pipe contents "non-destructive-readout".

Empty Pipe
***Procedure** PipeFlush (pipe1 : pipe);*

Process or Task waiting for Pipe
***Function** WaitPipe (pipe1 : pipe [; timeout: word]) : boolean;*
The TimeOut parameter is optional. If omitted the process waits until the event occurs. The same is true if TimeOut is set to 0000. With a value > 0 the Wait is terminated after (TimeOut * SysTicks).
The function result becomes true if there was no Timeout.

4.1.27.2 Pipe of Bit

To save the limited resources and memory the Pipe type is able to handle bits:

*BitPipe : pipe[xx] **of** bit;*

The behavior of this Pipe is the same as with a Pipe of boolean. But only one bit is used for each entry. Because of this each 8 Bits result in a memory usage of one byte. The access follows the FIFO principle. The first bit written to the pipe is also the first bit read from the pipe.
A pipe can handle upto 248 bits which results in a maximal memory consumption of 36 Bytes.

4.1.27.3 Pipe for complex Types

It's possible to build pipes of strings, arrays and records.
To read these complex types the function *PipeRecv* is expanded:

***Function** PipeRecv (Pp : Pipe; **var** Value : PipeType{record, array, string} [, doWait : boolean]) : boolean;*
The parameter Record, Array or String must be an already defined type.
The name of the target variable must be passed as the second parameter. With the optional switch "doWait" it's possible to define whether the function returns with a FALSE, if nothing there, or waits in a loop until the pipe has any content. If the switch "doWait" is omitted the function acts like the "doWait" is defined as true and the result is always a true.

***Function** PipeRecv_ND (P : Pipe; **var** Value : PipeType{record, array, string} [, doWait : boolean]) : boolean;*
The same as the function above except that the read out of a pipe doesn't remove or change the pipe contents. "non-destructive-readout".

4.1.28 SYSTIMER

16 bit, word   is imported by SysTick
Variable is decremented by every system tick, if it is > 0.

```
var  Timer1 : SysTimer[, UpCount];          {variable of type SysTimer}

SetSysTimer (Timer1, 50000);
repeat until GetSysTimer (Timer1) = 0;
```

(better is ->)

```
repeat until isSysTimerZero (Timer1);
```

For simple time measure functions an upcounter is very useful. This timer must be started with *ResetSysTimer*. The system now increments this timer with each SysTick. An overflow/wrap is inhibited. The max value is limited to $FFFF.
The SysTimer functions "*GetSysTimer, ResetSysTimer, SetSysTimer*" are also applicable to the upcounters, but the function "*isSysTimerZero*" obviously is not.

The system supports a total count of max. 16 SysTimer (SysTimer +SysTimer8+SysTimer32).

4.1.29 SYSTIMER8

8 bit, byte   is imported by SysTick
Variable is decremented by every system tick, if it is > 0.

```
var  Timer2 : SysTimer8[, UpCount];         {variable of type SysTimer8}

SetSysTimer (Timer2, 50);
repeat until isSysTimerZero (Timer2);
```

Interrupts are not disabled during an access. So an access to this Timer type is faster and shorter as the access to a “SysTimer“.

For simple time measure functions an upcounter is very useful. This timer must be started with *ResetSysTimer*. The system now increments this timer with each SysTick. An overflow/wrap is inhibited. The max value is limited to $FF.
The SysTimer functions "*GetSysTimer, ResetSysTimer, SetSysTimer*" are also applicable to the upcounters, but the function "*isSysTimerZero*" obviously is not.

The system supports a total count of max. 16 SysTimer (SysTimer +SysTimer8+SysTimer32).

4.1.30 SYSTIMER32

32 bit, 4 bytes   is imported by SysTick
Variable is decremented by every system tick, if it is > 0.
So extreme long times/delays can be achieved. If used, LongWords must be imported.

```
from  System import longword;
var  Timer3 : SysTimer32[, UpCount];          {variable of type SysTimer32}

SetSysTimer (Timer3, 100000);
repeat until isSysTimerZero (Timer3);
```

For simple time measure functions an upcounter is very useful. This timer must be started with *ResetSysTimer*. The system now increments this timer with each SysTick. An overflow/wrap is inhibited. The max value is limited to $FFFFFFFF.
The SysTimer functions "*GetSysTimer, ResetSysTimer, SetSysTimer*" are also applicable to the upcounters, but obviously the function "*isSysTimerZero*" is not.

The system supports a total count of max. 16 SysTimer (SysTimer +SysTimer8+SysTimer32).

4.1.31 PIDCONTROL

Pseudo-Record
PID-controller, is often used in technical applications, for example temperature controlling, servos, rotation speed controller, etc.

PID-controller have two input parameters: *nominal* value = the required value and the *actual* value.
Four parameters, which are usually only adjusted once, are *pFactor*, *iFactor*, *dFactor* and *sFactor*.
The controller output, which belongs to the actuator (heating, motor etc), is calculated by the function '*execute'*.
The controller type is determined by the two initializing parameters '*iLimit'* and '*dIntVal'*.
The internal variablesw *pValue, iValue, dValue* can be read but should not be changed.

iLimit
is of type longword (0..100000) and determines the maximal size of the **I**-clipping. If iLimit = 0 the **Integral**-value will not be calculated and will be discarded (e.g. PD-controller).

dIntVal
is of type byte (0, 1, 2, 4, 8, 16, 32) and determines the degree step of calculation of the **D**-clipping (gradiation).
If dIntVal = 0 the **Differential**-value of the controller will not be calculated and will be decarded (e.g. PI-controller).
If the value = 1, the gradiation will be calculated from the last error value up to the actual error value.
In the remaining cases a corresponding array is introduced. So it is possible to calculate the gradiation with just a few values required.

The controller itself calculates with **longinteger.** In practice it is improbable to get an overflow with execute.

```
var  Pid1 : PIDcontrol[iLimit, dIntVal];

{Init}
Pid1.pFactor:= 1000;
Pid1.iFactor:= 2500;
Pid1.dFactor:= 678;
Pid1.sFactor:= 10000;

{Run}
Pid1.Actual:= 500;
Pid1.Nominal:= 550;
PWM1:= Pid1.Execute;
```

4.1.32 Alias Synonymes

With an Alias definition constants, variables, functions and procedures can be assigned to new names. The purpose of such an assignment is that on any places in a project the Alias is used und with a change (for example another UART) only the Alias must be changed and all concerned names in the whole project must not be exchanged.

Aliases should always be defined globally and always should reference global constants, vars etc. In Units in the Interface part Aliases and also the referenced types must reside in the Interface part.

```
var
  bo             : boolean;
  bb             : byte;
  ww             : word;

alias
  aBo            = bo;
  aBb            = bb;
  aWW            = ww;
  aSerOut        = SerOutC0;
  aSerInp        = SerInpC0;
  aSerStat       = SerStatC0;
  aSPI_IO        = SPIinOutD;
```

Sometimes it makes sense to define Aliases before importing any Units. Then all Units have access immediately to these Aliases.
To force this one or more Aliases must be defined in the Main after the last Define Statement and before any Unit import by the uses clause:

```
Define
  RTCsource       = SysTick;

alias
  SerOutPC       = SerOutD1;
  SerStatPC      = SerStatD1;
  SerInpPC       = SerInpD1;

uses uuuuu;

Implementation
```

A sample program is in the Demos Directory in XMega_Alias

4.1.33 Delphi – AVRco types comparison

AVRco	size	Delphi	Notes
Boolean	1 byte 8 bits	Boolean	Delphi 0 = false, <> 0 = true AVRco 0 = false, $FF = true
Byte	1 byte 8 bits	Byte	0..255
Int8	1 byte 8 bits	ShortInt	-128..+127
Char	1 byte 8 bits	AnsiChar	Delph9 and later use AnsiChar Older Delphi char can be used
Word	2 bytes 16 bits	Word	0..65536
Integer	2 bytes 16 bits	SmallInt	-32768..32767

LongWord	4 bytes 32 bits	LongWord	0..4294967295 0..2^32-1
LongInt	4 bytes 32 bits	Integer	-2^31..+2^31-1
Word64	8 bytes 64 bits	uInt64	0..2^64-1
Int64	8 bytes 64 bits	Int64	-2^63..+2^63-1
Float	4 bytes 32 bits	Single	1.5x10^-45..3.4x10^38
Fix64	8 bytes 64 bits	not applicable	-2147483648.000000000 .. 2147483647.999999999
String	1..256 bytes	ShortString	first byte in string contains length byte
Array		packed Array	
Record		packed Record	

4.2 Operators

4.2.1 NOT

*a:= **not** a;   {inverting bits of var a }*

Only the types byte, Int8, boolean, integer, word, longint, longword, word64, int64 and fix64 are permitted as operands. If the variable 'a' has the value $FF in the example above, then it has the value $00 after the operation. See also the ***Negate*** function.

4.2.2 DIV

*a:= a **div** b;   {integer division}*

Only the types byte, Int8, integer, word, longint, longword, word64, int64 and fix64 are permitted as operands. If the variable 'a' has the value $10 and 'b' the value $02 in the example above, then 'a' has the value $08 after the operation.

4.2.3 MOD

a:= a **mod** *5; {Modulo of integers}*

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the variable 'a' has the value $06 in the example above, 'a' has the value $01 after the operation. With a = -6 the result is -1. Modulo is the remainder after integer division.

4.2.4 AND

*a:= a **and** $0f; {And Mask}*

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the variable 'a' has the value $13 in the example above, then 'a' has the value $03 after the operation. Thus the result of and is those bits that are set in the operand <u>and</u> in the mask.
'And' is also used with boolean functions.

***if** (a > b) **and** (a < c) **then** ... **endif**;*

4.2.5 OR

*a:= a **or** $30; {Or Mask}*

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the variable has 'a' has the value $09, then 'a' has the value $39 after the operation. 'Or' is additional setting the bits in the result, which were set in the mask.

'Or' is also used with boolean functions.

__if__ (a > b) __or__ (a < c) __then__ ... __endif__;

4.2.6 XOR

a:= a __xor__ 1;   {Xor Mask}

Only the Types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the variable has the value $01, then 'a' has the value $00 after the operation. 'Xor' is exclusive or, setting bits that are the same in the mask and in the operand to zero, and those that are different to one.

4.2.7 SHL

a:= a __shl__ 5;   {shift left}

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the variable has the value $03, then 'a' has the value $60 after the operation. 'SHL' shifts all Bits in the operand left and filling the bits from right with 0.

4.2.8 SHLA

a:= a __shla__ 5; {shift left arithmetically}

Only the Types Int8, Integer, Longint and Int64 are permitted as operands. If the variable ‘a’ has the value $03 in the example above, then ‘a’ has the value $60 after the operation. ‘SHLA’ shifts all bits within the operand to left and fills the bits from right with ’0’. In contrast to ‘SHL’ the highest value bit (sign bit) stays unchanged. So it is ensured that a negative number stays negative.

4.2.9 SHR

a:= a __shr__ 4;   {shift right}

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the Variable 'a' has the value $81, then 'a' has the value $08 after the operation. 'SHR' shifts all Bits in the operand right and fills up the bits from left with 0.

4.2.10 SHRA

a:= a __shra__ 4; { shift right arithmetically}

Only the Types Int8, Integer, Longint and Int64 are permitted as operands. If the variable ‘a’ has the value $71 in the example above, then ‘a’ has the value $07 after the operation. ‘SHRA’ shifts all bits within the operand right and fills the bits from left with ’0’. In contrast to ‘SHR’ the highest value bit stays unchanged. Thus it is ensured, that a negative number stays negative.
Attention: with negative values of ***a*** the result is rounded in positive direction!

4.2.11 ROL

*a:= a **rol** 4;   {rotate left}*

Only the Types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the Variable 'a' has the value $81, then 'a' has the value $18 after the operation. 'ROL' rotates all bits to the left. All bits are retained, but change their positions

4.2.12 ROR

*a:= a **ror** x;   {rotate right}*

Only the types Byte, Int8, Integer, word, Longint, Longword, Word64 and Int64 are permitted as operands. If the Variable 'a' has the value $01, so 'a' has the value $02 after the operation. 'ROR' rotates all bits to the right. All bits are obtained, but change their positions.

4.2.13 IN

```
if v2 in ['a'..'g'] then ...           {analyze Enum}
if Key in [Key2..Key4] then ...        {analyze Enum}
if x in[45..56] then ..
```

All ordinal types and enums are permitted as arguments Byte, Char, ... LongInt, as well as float.

4.2.14 +

```
a:= a + 5;              {add}
```

As operands only the types Byte, Int8, Integer, word, Longint, Longword, Float and Fix64 are permitted. A special case is a string-operation.

4.2.15 -

```
a:= a - b;              {subtract}
```

As operands only the types Byte, Int8, Integer, word, Longint, Longword, Floatand Fix64 are permitted. If the minus should be used as sign, this **<u>has to be</u>** enclosed by a bracket.

```
a:= a * (- b);          {multiply with negative value}
```

4.2.16 /

```
a:= a / 5.5;            {Float Division or Fix64 Division }
```

4.2.17 *

```
a:= a * %11000100;  {Multiplication, ordinals and Float, Fix64}

f:= f * 1.5;
```

4.3 Pseudo Operators

4.3.1 @

```
p:= @a;                  {memory location address}
```

Only variables, procedures and functions are permitted as operands, because only they have a physical address. After the operation ‘p’ contains the address of ‘a’. Actually '@' is not an operator, but a system function. The destination normally is a pointer.

4.3.2 ^

```
x:= p^;                  {variable from pointer}
```

Only variables of the type pointer are permitted as operands. After the operation ‘x’ contains the value, which is in the memory location ‘p’ that points to. Actually '^' is not an operator, but a system function.

Further a prefixed '^' in front of a char is the instruction for the compiler to interpret the following symbol as an ANSI control character.

A **^G ,** for example, produces the so called bell-symbol (hex 09). The compiler executes the following operation: *result: = 'G' - '@'.* ($49 - $40).

```
const Bell = ^G;         {Control G}
```

4.3.3

```
const LF  = #10;         {Line Feed}
```

The number-symbol is another way (in addition to ^), to define control symbols (non representable letters). The argument, which follows the symbol, must be a decimal number on the area of 0..255. It defines the following number as a character.

'#' is actually not an operator, but a system function.

4.3.4 $

```
const  x1 = $10;     {decimal 16}
```

The dollar symbol defines the following constant to a hexadecimal value.

4.3.5 %

```
const  b1 = %10100101;     {hex $A5, decimal 165}
```

Percent symbol defines the following constant to a binary value.

4.4 User Defined Language Elements

4.4.1 Identifier

Identifiers are used to denote labels, constants, types, variables, procedures, and functions. An identifier consists of a letter followed by any combination of letters, digits, or underscores. An identifier is limited in length to 64 characters, and all characters are significant.

```
PASCAL
square
persons_counted
BirthDate
3rdRoot                   // illegal, starts with a digit
Two Words                 // illegal, must not contain a space
```

As the AVRco does not distinguish between upper and lower case letters, the use of mixed upper and lower case as in *birthDate* has no functional meaning. It is nevertheless encouraged as it leads to more legible identifiers. *VeryLongIdentifier* is easier to read for the human reader than *VERYLONGIDENTIFIER*

4.4.2 Numbers

Numbers are constants of byte, Int8, integer type or of float type. Integer constants are whole numbers expressed in either decimal, hexadecimal or binary notation. Hexadecimal constants are identified by being preceded by a dollar sign: $1234 is a hexadecimal constant. Binary constants are preceded with a percentage sign: %1011100 is a binary constant.

The decimal longint range is -2147483648 to +2147483647, the hexadecimal integer (longint) range is $0 to $FFFFFFFF. The binary integer (longint) range is %0 to %11111111111111111111111111111111 (32 * 1).

```
12345
-1
$123
$ABC
$123G          // illegal, G is not a legal hexadecimal digit
%1011
%1003          // illegal, 3 is not a legal binary digit
1.2345         // illegal as integer, contains a decimal part
```

4.4.3 Strings

A string constant is a sequence of characters enclosed in single quotes:

```
'This is a string constant'
```

Strings containing only a single character may be of the standard type *char*. The actual type is determined by the context.

```
'PASCAL'
'You''ll see'
''
```

As shown in the examples, a single quote within a string is written as two consecutive quotes.
The quotes enclosing no characters, denoting *the empty string* - is compatible only with string types (**not** with the type *char*).

4.4.4 Control Characters

The AVRco also allows control characters to be embedded in strings.
The # symbol followed by an byte constant in the range 0..255 denotes a character of the corresponding ASCII value.

The AVRco allow the use of the ^ character followed by an alpha character to denote control characters.

```
#10         // ASCII 10 decimal (Line Feed).
#$1B        // ASCII 1B hex (Escape).
^G          // ASCII 07 hex (Bel)
```

Sequences of control characters may he concatenated into strings by writing them using a + between the individual characters:

```
#13 + #10
#27 + #20
```

Control characters may also be mixed with text strings:

```
'Waiting for input!'+#7+#7+#7+#7+'Please wake up'
```

4.4.5 Comments

A comment may be inserted anywhere in the program where a delimiter is legal. It is delimited by the curly braces { and }, which may be replaced by the symbols (* and *).
It is also possible to use the symbols // to comment the remainder of the line as can be done in the “C” language.

```
{This is a comment}
(* also a comment *)
```

Curly braces may be nested within curly braces, and (* *) may be nested within (*. *).
Curly braces may nested within (* *) and vise versa, thus allowing entire sections of source code to be commented away, even if they contain comments.

4.5 Expressions

Expressions are algorithmic constructs specifying rules for the computation of values. They consist of operands, variables, constants, and function designators combined by means of operators as defined in the following.

4.5.1 Operators

1) Operators fall into five categories, denoted by their order of precedence:
2) Unary minus (minus with one operand only)
3) Not operator.
4) Multiplying operators: *, /, div, mod, shl, shr.
5) Adding operators: +, -, or, and, xor.
6) Relational operators: =, < > , > , < , <= ,>= , in.

Sequences of operators of the same precedence are evaluated from left to right. Expressions within parentheses are evaluated first and independently of preceding or succeeding operators.
The operators must be the same type. There is no automatic type casting.

Attention
The order of the operators (* AND SHR etc.) is not completely implemented yet. So please use always parentheses in conjunction with expressions.

4.5.1.1 Unary Minus

The unary minus denotes a negation of its operand which may be of *Float*, *Longint, Int8 or Integer* types.

4.5.1.2 Not Operator

The not operator negates (inverses) the logical value of its Boolean operand:
not *True = False*
not *False* **=** *True*
In AVRco Pascal the “not” operator can be used to invert a value if the argument in of type byte, integer, longint, word or longword.

4.5.1.3 Multiplying Operators

Operator	Operation	Types
*	multiplication	Float, Fix64, Longint, Longword, Word, Integer, Int8, Byte, Bitset
/	division	Float, Fix64, Bitset
div	division	Longint, Longword, Word, Integer, Int8, Byte
mod	modulus	Longint, Longword, Word, Integer, Int8, Byte
and	arithmetic and	Longint, Longword, Word, Integer, Int8, Byte
and	logical and	Boolean
shl	shift left	Longint, Longword, Word, Integer, Int8, Byte
shr	shift right	Longint, Longword, Word, Integer, Int8, Byte
rol	rotate left	Longint, Longword, Word, Integer, Int8, Byte
ror	rotate right	Longint, Longword, Word, Integer, Int8, Byte

```
12 * 34         // = 408
123 / 4         // = 30.75
123 div 4       // = 30
12 mod 5        // = 2
True and False  // = False
12 and 22       // = 4
2 shl 7         // = 256
256 shr 7       // = 2
```

4.5.1.4 Adding Operators

Operator	Operation	Types
+	addition	Float, Fix64, Longint, Longword, Word, Integer, Int8, Byte, String, Char, Bitset
-	subtraction	Float, Fix64, Longint, Longword, Word, Integer, Int8, Byte, Bitset
or	arithm. or	Longint, Longword, Word, Integer, Int8, Byte, Bitset
or	logical or	Boolean
xor	arithm. xor	Longint, Longword, Word, Integer, Int8, Byte
xor	logical xor	Boolean

```
123+456           // = 579
456-123           // = 333
True or False     // = True
12 or 22          // = 30
True xor False    // = True
12 xor 22         // = 26
```

4.5.1.5 Relational Operators

The relational operators work on all standard scalar types: *Float, Fix64, Longword, Longint, Word, Integer, Boolean, Char, Int8,* and *Byte.* The type of the result is always Boolean, i.e. *True* or *False.*

=	equal to
<>	not equal to
>	greater than
<	less than
>=	greater than or equal to
<=	less than or equal to

```
a = b       // true if a is equal to b
a <> b      // true if a is not equal to b
a > b       // true if a is greater than b
a < b       // true if a is less than b
a >= b      // true if a is greater than or equal to b
a <= b      // true if a is less than or equal to b
```

A comparison of record and array types is also possible.
In this case the variables must consist of the same type. This means they must be predefined as types:

```
Type TRec  = record
              ...
             end;

var Rec1, Rec2 : TRec;

if Rec1 <> Rec2 then ...
bool := Rec1 = Rec2;
```

4.5.2 Function Designators

A function designator is a function identifier optionally followed by a parameter list, which is one or more variables or expressions separated by commas and enclosed in parentheses. The occurrence of a function designator causes the function with that name to be activated. If the function is not one of the pre-defined standard functions, it must be declared before activation.

```
Z:= func1(x);  // assume func1 is a declared function returning a value
F:= sqr(a);     // sqr is a builtin function returning the square of a value
```

4.6 Keywords

4.6.1 PROGRAM

Starting the program. A particular form of program framework is necessary. This starts with 'Program *name*' and ends with 'End.'

```
Program Test;
Device ...                        {hardware declaration}
Import ...                        {system Functions}
from system Import ...            {types and functions}
Define ...                        {hardware definition}
Implementation                    {program start}
const  ...                        {constant declaration}
var ..    .                       {variable declaration}

Procedure System_Init;            {private initialize}
begin
  ...
end;

Interrupt Timer1;                 {interrupt declaration}
begin
  ...
end;

Process Pxx (14,20 : iData);      {process declaration}
begin
  ...
end;

Task Txx (iData);                 {task declaration}
begin
  ...
end;

Procedure ABC (z : integer);      {procedure head}
Var xy : byte;
begin
  ...
end;

Function CDE : boolean;           {function head}
Var a, b : byte;
begin
  ...
Return(a > b);                    {result of the function}
end;

begin                             {main = main program}
  ABC (i);
  x:= CDE;
end.
```

Comment:

The ***standard version*** of the compiler has no linker. So it is not possible, to introduce units or to link extern code. At first sight this looks like a limitation. But in practice this is not really a disadvantage, because the generated code and so the program size is limited by the relative small program memory (typ. 8kB) of the destinated CPU.
Frequently recurring program parts can be included with help of the compiler switch "Include" *{$I ... }* and *{$J..}*.

Further since the often small program memory does not allow extensive stack- or frame-operations, this limits the number of local variables in procedures and functions.

In contrast to well-known programmer-systems for the PC (Turbo Pascal, Delphi etc.), in which the compiler knows exactly the hardware, a compiler for embedded systems (SingleChips) does not know the target hardware unless it is told.
Hence it is necessary for the programmer to specify the destinated hardware/CPU exactly. Because of the often limited system resources (RAM/ROM) it must further be considered which functions of the compiler (system) are really required.

To specify the available hardware and the required functions for the compiler, you need to have diverse instructions (Device, Import and Define). These three definitions are required and ***have to be specified*** in above mentioned order.

To identify the exact position of RAM and ROM and their sizes as well as the implemented hardware of the CPU (SCI, ADC etc) the compiler needs a **Description-File,** which contains this information. These are provided by E-LAB. An example be found in *P90S851 5.dsc*, for instance.

4.6.2 DEVICE

Processor and Hardware Specification.

The arguments of "Device" are totally processor specific. The processor has to be the first entry. Depending on the processor family the parameters of the compiler are evaluated in the assembler or in both program parts. In part the data is included in HexFile and is required by the programming unit. The Device parameter names correspond to the respective processor databooks where they are also specified.

The used CPU-name has to be identical with the processor-control file prefixed by a 'P'.

Example for a Device instruction of the AVR AT90S2313:

device *= 90S2313;*

The relevant control file must be named: P90S2313.dsc

4.6.3 IMPORT

Import of **Hardware dependant** system functions

As mentioned above, the sometimes modest resources of some implemented processors force us to include only the most necessary system functions. Memory or program intensive and also more exotic functions have to be imported explicitly.

Certain imports again require an additional specification, which is made by means of the *Define* section. Some functions import additional functions automatically, which possibly have to be further specified within the define section. The description of the separate import functions can be found in the ***Driver Manuals*** of the respective drivers.

Many functions assume corresponding Hardware within the CPU. Systick requires a Hardware Timer and SwitchPort a port. Further some imports require the SysTick, e.g. ADCport. So SysTick should always be imported first

```
Import SYSTICK, SWITCHPORT1;
```

4.6.4 FROM

With FROM a type, function or procedure is imported from a specific source.

```
From System Import LongInt, LongWord, Float;
```

Possible imports of **types** and system functions:

Fix64	
Float	
Int64	
LongInt	
Word64	
LongWord	
Processes	Sleep, Suspend, Resume, Priority, WaitSema ...
Tasks	Sleep, Suspend, Resume, Priority, WaitSema ...
Pipes	PipeFlush, PipeSend, PipeRecv, PipeStat, PipeFull ...
Pids	pFactor, iFactor, dFactor, sFactor, Actual, Nominal, Execute
OEMcharSet	the system uses the OEM charset for chars and strings instead of the ANSII type.

```
From System Import LongInt, LongWord, Float, Pipes;
```

4.6.5 DEFINE

Parameters for certain import functions

Certain imports require an additional specification, which is specified using *Define.* Here for example a time in msec is assigned to the system tick or a physical port address is assigned to the switch port. At the very least the processor speed **ProcClock** has to be specified.
The description of the defines can be found in the ***Driver Manuals*** of the respective drivers.

```
Define  ProcClock    = 4000000;         {4 Mhz}
        SYSTICK      = 10;              {10msec}
        StackSize    = 82, iData;       {82 Bytes in iData}
        FrameSize    = 99, xData;       {99 Bytes in xData}
        SwitchPort1  = PortA;           {Port Addr}
        SerPort      = 9600, Stop2;     {9600Bd, 2 Stopbits}
        RxBuffer     = 8, iData;        {RxBuffer 8 Chars}
        TxBuffer     = 10, iData;       {TxBuffer 10 Chars}
        PWMpresc1    = 4;               {prescaler 4}
```

Tip:
Most of the Defines, which consist of a numeric constant, can be used as a normal constant in the application.

```
Define  ProcClock  = 4000000;           {4 Mhz }
        SYSTICK  = 10;                  {every 10msec }
        ...

const   myConst = ProcClock div SysTick;
          ...
if ProcClock > 4000000 then ...
```

It's also possible to make a "Forward" reference at the point where the Define is searched by the compiler. This forward can be completely defined later in the implementation part of the program or unit.
An example how to do this can be found in the directory **..\E-Lab\AVRco\Demos\Mega161**.

4.6.6 Hardware Imports within Units

If Units are imported the definitions can also be placed into an Unit:

Main Program

```
Import SysTick, MatrixPort, SerPort;

From System Import longword, longint, float, pipes;

Define
    ProcClock    = 8000000;    {Hertz}
    SysTick      = 10;         {msec}
    StackSize    = $0020, iData;
    FrameSize    = $0040, iData;
    SerPort      = 9600;
    RxBuffer     = 16, iData;

DefineFrom unit1;    // Unit1 defines the Matrixport
```

Unit

```
Unit Unit1;

Define
    MatrixRow    = PortD, 4;   {use PortD, start with bit4}
    MatrixCol    = PinD, 0;    {use PinD, start with bit0}
    MatrixType   = 3, 4;       {3 Rows at PortD, 4 Columns at PinD}

Interface
...
```

The reserved word "*DefineFrom*" within the main "Define" block switches the scanning from main program to the given Unit name, where the scanning of the defines continues.
When the word "*Interface*" appears the scanning is switched back to the main program.

4.6.7 DEFINE_USR

With "Define_USR" it is possible to define constants which are visible and accessible from every point of the program and also from each Unit. But there can be only ordinal types.
This Define should only be used if it is absolute necessary because it's not a good programming style.
The better way is to place such globals into a Unit which resides in the last position of the Unit chain.
Then the definitions are also visible from all other parts of the application.

```
Define  SysTick = 10;
        ...
Define_USR  myConst = 1;
            myBool= true;
```

4.6.8 DEFINE_FUSES

As on option the fuse settings for the programmers can be defined in the source. The definition must be placed between the "Device" and the "Import" statement.
The fuse names correspond with the names in the datasheet of the CPU and the names found in the programmer software. Spaces in the origin names must be replaced by "_" .

The four possible fuse groups are named
"*LockBits0, FuseBits0, FuseBits1, FuseBits2*"

All fuses are low-active, this means if a fuse name is given, e.g. "CKSEL1", so this bit will be programmed to **ZERO** (low = active).
So fuses which do not appear are always programmed to "1" (high = inactive)!

For example the statement:

```
LockBits0 = [];
```

programs all Lockbits to "1" = inactive.

The statement:

```
FuseBits0 = [CKSEL1];
```

programs the fusebit CKSEL1 to "0", all other bits of this group get the value "1" = inactive.

With creating a new project these fuses are written into the ISPE-file for the programmer's purposes.
If the ISPE file already exists, it will be not changed. The optional define of "*OverRide_Fuses*" always forces an ISPE update. *OverRide_Fuses* must be placed after *Define_Fuses.*

The programmer software copies the settings in the ISPE-file to the "write boxes" of the fuses.
The general options

program Fuses
program Lockbits
program User Row (XMega)

in *Programmer Options* are not changed by that, except they are explicitely listed here.
The user selects here whether the fuses are witten which each programming cycle.

The *NoteBook* entry is used only with the professional stand alone programmers.
With an extreme large project count the selection of the desired project becomes for these programmers somewhat difficult. Because of this a tabbed notebook is implemented. It contains the pages A...N.
The above Define now selects the notebook page where the application must be stored.

ProgMode defines one of the 3 possible programming modes.

Supply instructs the programmer to provide a voltage with a current limit to the target device.

CalByte instructs the programmer to read a calibration byte out of the target and places it into a flash location. Please note that the first calbyte is automatically read by the CPU and stored into the calbyte register. So it isn't necessary to handle this by the programmer. Number = 0..3 dependent on the CPU.
Define_Fuses CalByte = CalByteNumber, Address;

Normally the SPI programming uses the "ProcClock" for speed calculation. But if a lower speed must be used for programming this can be forced with the "SPIclk" define.

AddApp instructs the programmer to load additional hexfiles build by another project:

    AddApp = 'pathname\projectname';

This provides joining a BootApplikation with the Main application in the programmer and both are programmed together in one operation. See also Demos\BootApp

```
Device = mega16, VCC = 5;

Define_Fuses
  Override_Fuses;                   // optional, always replaces fuses in ISPE
  COMport    = COM1;                // COM2..COM7, USB
  Supply      = 4.0, 200;           // programmer supplies target, 4.0Volt, 200mA
  SPIclk      = 1000000;            // optional SPI programming speed
  LockBits0   = [];
  FuseBits0   = [CKSEL1];
  FuseBits1   = [BOOTRST, BOOTSZ1, SPIEN, OCDEN];
  ProgMode  = SPI;                  // SPI, JTAG or OWD
  ProgFuses = true;                 // or false – program Fuse Bits
  ProgLock   = true;                // or false – program Lock Bits
  ProgFlash  = true;                // or false – program Flash
  ProgEEprom= true;                 // or false – program EEprom
  ProgUsrRow= true;                 // or false – program UserRow          (* XMega *)
  CalByte     = 2, $3FFF;           // read/write calibration byte
  AddApp     = 'pathname\projectname';
  AutoRelease = true;               // or false – Release Target


Import SysTick, …;

Define SysTick …
```

4.6.9 IMPLEMENTATION

Starting the program.

The compiler inserts the reset-code and the initialization at this point. The instruction must exist and has to be placed directly after the define-bloc.

Normally the global type-, constant-, and var declarations follow the implementation instruction.

4.6.10 TYPE

Starting of a type declaration

A data type in Pascal may be either directly described in the variable declaration part or referenced by a type identifier. Several standard type identifiers are provided like *boolean, byte, word, integer* etc., and the programmer may create his own types through the use of the type definition.
The reserved word **type** heads the type definition part, and it is followed by one or more type assignments separated by semicolons. Each type assignment consists of a type identifier followed by an equal sign and a type.
The definition of ones own types is a good programming practice and makes for better readability.

```
type  tpb     = pointer to byte;
      tarr    = array[2..7] of byte;
      tpa     = pointer to tarr;
      tstr    = string[8];
      tps     = pointer to tstr;
      tKey    = (Forw, Stop, BackW);

var   pb      : tpb;
      pa      : tpa;
      ps      : tps;

      str     : tstr;
      ar1     : tarr;

      keys    : tKey;

      str:= '1234';
      ar1[3]:= 56;

      pb:= tpb (pa);
      pb^:= 0;

      keys:= Stop;
```

4.6.11 CONST

Starting of a constant declaration

The constant definition part introduces identifiers as synonymous for constant values. The reserved word **const** heads the constant definition part, and is followed by a list of constant assignments separated by semicolons. Each constant assignment consists of an identifier followed by an equal sign and a constant. Constants can be of any scalar type, strings, records or arrays.

Please note that the scalar constants are **not** stored into the ROM/FLASH while constant arrays, strings and records are always stored into the Flash.

4.6.11.1 Predefined Constants

The following constants are predefined and may be referenced without previous definition:

Name:	**Type and values:**
False	Boolean (boolean value false).
True	Boolean (boolean value true).
Pi	Float pi
Nil	Zero, also zero value pointer.

The following predefined constants have a **special construction:** they dynamically generate a string which is constructed of the actual Computer Date or Time:

Date	current date as a string constant into the ROM
Time	current time as a string constant into the ROM

```
Const
    Date  = 'dd.mm.yy';      // -> '26.12.99'
    Date  = 'dd.mm.yyyy';    // -> '26.12.1999'
    Date  = 'mm/yy';         // -> '12/99'
    Time  = 'hh:mm:ss';      // -> '22:02:06'
    Time  = 'hh:mm';         // -> '22:02'
    Time  = 'hhmm';          // -> '2202'
```

Compiler Version

The compiler version and others can be found with predefined constants and can be used within the program.

```
CompilerRev      : word = rev;       // actual Compiler version
CompilerBuild_Y : byte  = yy;        // actual Compiler build, last 2 digits of current year 00..99
CompilerBuild_M : byte  = mm;        // actual Compiler build, current month     01..12
CompilerBuild_D : byte  = dd;        // actual Compiler build, last current day   01..31
CompileYear      : byte  = yy;       // last 2 digits of current year 00..99
CompileMonth     : byte  = mm;       // current month  01..12
CompileDay       : byte  = dd;       // current day      01..31
CompileHour      : byte  = hh;       // current hour    00..23
CompileMinute    : byte  = mi;       // current minute 00..59
PojectBuild      : word = pbuild;    // number, incremented with each successful project compile
OptimiserRev     : word  = rev;      // number, supplied by the optimiser
OptimiserBuild   : word  = build;    // number, supplied by the optimiser
```

4.6.11.2 Type Specification with Constant Declaration

With Borland Pascal constants have to be defined without a type declaration:
***const** abc = 1;*

The value "1" now can be used as byte, word, integer, float etc. This is similar in the AVRco Pascal.
But sometimes there are problems with such ambiguous values. Because of this the ordinal constants should be defined like this:

***const** abc : byte = 1;*

See also Compiler Switch *{$TYPEDCONST ...}*
This fixes the value of a constant to a specific type, in the example above it is an unambiguous byte.

Warning:
in Borland the meaning of this construction is always a structured constant. Do not confuse the two kinds!

4.6.11.3 Constant Load from File

Array and Record constants can be read in from a file. The programmer is responsible of the contents of the file. The file length is not important. If the file is too short, the structure is filled with zeros.
If the file is too long, the read-in is aborted at the Array/Record-limits.

```
const  name : array[a..z] of byte = 'FileName.ext';
```

This operation is also valid for records where the record must be a predefined type.
Such file constants can also be placed into the StructConst area of the EEprom.

As on option it is possible that the filesize itself defines the array size.

```
const name : array = 'FileName.ext';
```

The array now is defined as ***array****[0..filesize-1]* ***of*** *byte*.

```
const FileConst : array = 'E-LAB.pbmp';
```

It is possible to add an optional type to a constant which is loaded from a file. This type must be a simple one (Byte...Float). The Array now is implemented in this manner:

```
const array[0..(filesize div sizeOf (type))-1] of Type.
const FileConst : array of Char = 'E-LAB.txt';
```

Constant Records and Arrays can be read out of more than one file for such constants. They will be read sequentially.

```
const ArrXYZ  : tArrXYZ = 'FN1.ext', 'FN2.ext', 'FN3.ext';
```

The filenames must be separated by commas. The files are read in until the structure is full. The rest will be ignored.
If the sum of the file bytes is smaller than the structure size the rest of the structure is filled with zeros.

Example:
An Example can be found in the directory **..\E-Lab\AVRco\Demos\LCD_PCF8548**

4.6.11.4 Constant Located in Flash

Byte and Word constants can be placed into the Flash at fixed addresses:

```
{$PHASE $01EFF}
ASM;
 .WORD     0AA55h
ENDASM;
{$DEPHASE}
```

The switch $PHASE defines the absolute start address of the following statement block.
This address is a WORD address.
The address $01EFF above results in an absolute Byte-address of $03DFE.

It's possible to place ordinal, Array and Record constants into dedicated addresses in the Flash.
This is done as with variables

```
const   wwC[$1000]   : byte  = 123;
        fltC[$1010]  : float  = 0.5;
```

The address follows the name/identifier in []. A type (byte, word etc) is necessary.
With arrays and Records a previously defined type must be used. The address is only checked for Flash boandaries but not for plausibility. Use absolute addresses with care!

Further it's possible that the compiler generates the placement like it does with variables:

```
const
   Name[@FLASH] : type = value;
```

The identifier "FLASH" forces the automatic address generation and placement.

All constant definitions like:

```
const
  name    = 'x';
  name1  = 'xxx';
```

are placed into the ROM as string constants.
If character literals (immediate constants) must be possible, which are not placed into the ROM, these must be qualified like this:

```
const
  name   : char  = 'x';
  name1 : char  = #12;
```

It is possible to place constants into ROM/FLASH which contain Pointer which also point into the ROM/FLASH. You find an example in the directory **..\E-Lab\AVRco\Demos\Mega161**.
Please note that predefined/user defined arrays and records must always be used. These types must be defined in the type declaration part of the application.

With all constants in ROM/FLASH the following is always valid:
If the name of the constant never appears in the context (never referenced) the optimizer removes this constant. If only a pointer is used to reference such a constant and the pointers value is build at runtime, the constant is probably removed. If so, an assembler error is generated. To avoid this, one can make a dummy access onto this construct by its name.

Types, constants and variables should be declared completely before the first procedure or function.
Most of the calculations and operators are also permitted for constant declarations.

Complex constants (Arrays and Strings) are stored in ROM (Rom constants). It is therefore necessary for the programmer that corresponding ROM space is allocated and these values are not normally alterable (read only).

```
const  x1   = Lo (1234);
       x2   = Hi (1234);
       x3   = 24 * 2;
       x4   = x2 div 2;
       x5   = 12 mod 10;
       x6   = 1 shl 4;
       x7   = 1200 or 34;
       x8   = $FFFF and $AAAA;
       str0 = '1234' + 'R' + #7 + ^L;
       str1 = '1234';
       ch   = '9';
       TAB = ^I;
       TB   = TAB;
       bits = 3;
       st   = 'Hallo';
       x9   = %11001101;
       arr  : array[3..7] of byte = (0, 1, 7, 34, 128);
```

4.6.12 STRUCTCONST

structured Constants

```
ars      : array[3..7] of byte = (0, 1, 7, 34, 128);
px       : pointer to word = $40;
sc[$15] : word = $1234;              {fixed addr $15}
```

Structured constants behave like variables at run-time, that means they possess an address and they are readable and writeable. The value and its address, which are treated as 'constant' are stored in the program (ROM) or EEprom. After the memory initialization the stored values of the constants are loaded from ROM into RAM to the corresponding address and are now able to be handled as a variable. Because a structured constant possesses an address, a fixed address can also be optionally assigned by using the syntax xx [adr] : byte = bb; .

A destination memory area as a compiler switch should always be prefixed before a StructConst declaration, e.g. {$IDATA}.

A special case is the use of structured constants in EEprom, if EEPROM is available in the processor. The declaration of such a constant looks like this:

```
{$EEPROM}
Structconst
    ee1  : word   = $1234;
    est  : string  = 'hello';
    eflt  : float    = 1.23456;
{$IDATA}
```

All structured constant declarations following the compiler switch **EEPROM** now are going to the EEprom of the CPU (until switched back again e.g. with {$IDATA}). These constants stay in the EEprom and will not be copied into RAM. Instead the compiler generates a special Hex-File which has the ending xxx**.eep,** where these constants are held.

The programmer-tools are generally able to read a special Hex-file for the On-chip EEprom and they are able to program corresponding the CPU. The EEprom is programmed with the assigned values.

The defined constants are in the EEprom and can be read and written like normal variables with help of the CPU specific addressing algorithms, which are used automatically by the compiler.

Special construction
Array and Record constants can be read in from a file. The programmer is responsible of the contents of the file. The file length is not important. If the file is too short, the structure is filled with zeros. If the file is too long, the read-in is aborted at the Array/Record-limits.

```
Structconst  Arr1     : array[0..31] of word = 'FileName.ext';
```

4.6.13 VAR

Starting of the variable declaration

Every variable occurring in a program must be declared before use. The declaration must textually precede any use of the variable so that the variable is 'known' to the compiler when it is used.

A variable declaration consists of the reserved word **var** followed by one or more identifier(s), separated by commas, followed by a colon and a type. This creates a new variable (or variables) of the specified type and associates it with the specified identifier.

The 'scope' of this identifier is the block (function, procedure) in which it is defined, and any block within that block. This variable is said to be *local* to the block in which it is declared, and the variable access from the outer level becomes impossible. In Pascal the search for an identifier starts from the inner block and ends global. This means within a Procedure/Function/Unit the search starts with local definitions. If nothing found the search continues with global definitions, which also includes the definition part of Units.

Types, constants and variables **should be** declared **before** the first procedure or function. All variables require appropriate memory area. For the respective requirements read ***types*** above. Variables, which are not required by the program only waste the limited memory. So a careful handling with these declarations is necessary. (see also compiler switch $W)

Generally all variables have to be stored in a certain memory page of the CPU. The possible pages are : **Data, iData, iData1, pData, xData** and **EEprom, EEprom1,** depending on the type of processor used (File xxx.dsc). The actual page is selected by the according compiler switch , e.g. **{$IDATA}.** Pay attention to capitalisation! This memory page is preserved until the next re-definition.

Note that the last selected page is valid for the main program and also for some system variables. The **Default value** of the term ‘Implementation’ is, if it exists, ‘Data’, or if not ‘iData’.

XMega:
Avoid placing vars into the $DATA area. This can come to conflicts with the IO/IDATA area which is not in the linear address area like the standard AVRs. With XMegas the register area is a complete different memory compared to the AVRs.

A **global** variable can with an attached address be stored at a fixed memory location. This is necessary for memory-mapped ports and control registers. Here must be observed that the assigned address also is in the actual memory page (Data, iData, pData, xData, EEprom). Variables without addresses are stored by the compiler at the next available memory location in the currently selected memory page.

```
{$DATA}
Var    TrisA[$85]         : byte;               {var at fixed addr.}
       TrisB[$86]         : byte;               {var at fixed addr.}
       Count              : byte;               {normal declaration}
       i                  : integer;
       ix[@i]             : byte;               {Lo-byte of i}
       iy[@i + 1]         : byte;               {Hi-byte of i}
       Bit7[@TrisB, 7] : bit;                   {bit7 in TrisB Reg}
       Ar1                : array[2..9] of byte; {array}
       St1                : string[6];          {string of length 6}
```

4.6.14 LOCKED

Global ordinal variables can be extended by the attribute **locked** in order to protect them against concurrent accesses of interrupts, processes or tasks. For example if two processes have access to a global Bit-var, it's possible that a process starts a read-modify-write access with **Incl(Bit)** and after the Bit-read (byte access) is interrupted by the other process. Now this process changes this byte which the first process has read before. After passing the control back to the first process this one writes back the manipulated bit (byte-write). This write access overwrites the changes made by the second process. **Locked** prevents this by disabling a Task/Process change or interrupt during the access to such protected vars.
Read-Modify-Write statements are : INC, DEC, INCL, EXCL, SETBIT.

With 8-Bit processors also read or write accesses to global vars, which are greater than a byte, should be protected if concurrent access is possible. The **Locked** attribute should be used carefully and rare because each access generates an overhead of code and cycles. Also the interrupt is disabled during the whole access.

```
{$IDATA}
Var  i  : integer, locked;        {protected}
     Bit9[@i, 9] : bit;           {bit9 in i}
```

The integer variable **i** is locked and protected and also the Bit-variable **Bit9,** which is derived from **i**.

Attention:
Continuously polling or read of a “locked“ variable e.g. within a loop can lead to a distortion of Task/Process-changes, because interrupts are disabled nearly all of the time.

4.6.15 Align2 Align4 Align8

Sometimes it is necessary to place some variables onto even addresses. Then such a variable an attribute can be attached:

```
VAR
  st1    : string[16], Align2;
  bb     : byte, Align4;
  Arr    : tArr, Align8;
```

4.6.16 Local variables

Local variables within a procedure are stored in an area known as the frame and they are only accessible within this procedure because the frame and the variables only exist temporarily. Local variables force an indexed address calculation and a read/write access with a pointer. That leads to an increase of code and runtime.
Local variable are not initialized (default). See compiler switch *{$ZeroLocVars}*

```
Procedure LocalVars;
Var  bb : Byte;                {local variable}
begin
  bb:= not bb;
end;
```

Process and **Task** variables are programmed like normal local variables, but they always must exist.
So they are static and will be directly addressed like global variables. In spite of this they are not global but encapsulated, i.e. they are not normally accessible from outside the process in which they are defined.
However if it is necessary manipulate them from outside the process, the process name has to be prefixed before the variable,

e.g. *procName.var1:= 0;*

With concurrent accesses by other Processes or Tasks these variables must get the "locked" attribute from the user (no automatic locking).

```
{ process-vars and process-stack into xData}
Process DoTheJob (20, 10 : xData);
Var  pb : Byte;                        {local var, but static }
begin
  bb:= not bb;
end;

{$IDATA Main-stack into iData}
begin                                  {Main}
  DoTheJob.pb:= $FF;
end;
```

4.7 Procedures and Functions

A Pascal program consists of one or more *blocks,* each of which may again consist of blocks. One such block is a *procedure,* another is a *function* (commonly called *subprograms).* Thus, a procedure is a separate part of a program, and it is activated from elsewhere in the program by a *procedure statement.* A function is rather similar, but it computes and returns a value when its identifier, or *designator,* is encountered during execution.

C programmers are familiar with the type function. A procedure is a function that does not return any result. This may seem unnecessary but it actually allows the compiler to produce more compact code.

Parameters

Values may be passed to procedures and functions through *parameters.* Parameters provide a substitution mechanism which allows the logic of the subprogram to be used with different initial values, thus producing different results.

The procedure statement or function designator which invokes the subprogram may contain a list of parameters, called the *actual parameters.* These are passed to the *formal parameters* specified in the subprogram *heading.* The order of parameter passing is the order of appearance in the parameter lists. Pascal supports two different methods of parameter passing, by *value* and by *reference,* which determines the effect that changes of the formal parameters have on the actual parameters.

When parameters are passed *by value,* the formal parameter represents a local variable in the subprogram, and changes of the formal parameters have no effect on the actual parameter. The actual parameter may be any expression, including a variable, with the same type as the corresponding formal parameter. Such parameters are called a *value parameter* and are declared in the subprogram heading as in the following example. This and the following examples show procedure headings; function headings are treated later.

```
procedure Example (Num1, Num2 : Number; Str1, Str2 : Txt);
```

Number and *Txt* are previously defined types (e.g. *Integer* and *string[255]*), and *Num1, Num2, Str1,* and *Str2* are the *formal parameters* to which the value of the *actual parameters* are passed.
The types of the formal and the actual parameters must correspond.
Notice that the type of the parameters in the parameter part must be specified as a previously defined *type identifier.* Thus, the construct:

```
procedure selectIModel (array[1..5] of Integer);
```

is not allowed.
Instead, the desired type should be defined in the **type** definition of the block, and the *type identifier* should then be used in the parameter declaration.

```
type
  Range:   array[1..5] of integer;

procedure Select (Model: Range);
```

When a parameter is passed *by reference,* the formal parameter in fact represents the actual parameter throughout the execution of the sub program. Any changes made to the formal parameter are thus also made to the actual parameter, which must therefore be a *variable.* Parameters passed by reference are called a *variable parameters,* and are declared as follows:

```
procedure Example (var Num1,Num2: Number)
```

Value parameters and variable parameters may he mixed in the same procedure as in the following:

```
procedure Example (var Num1, Num2 : Number; Str1, Str2 :  Txt);
```

in which *Num1* and *Num2* are variable parameters and *Str1* and *Str2* are value parameters.

All address calculations are done at the time of the procedure call. Thus, if a variable is a component of an array, its index expression(s) are evaluated when the subprogram is called.

When a large data structure, such as an array, is to be passed to a sub program as a parameter, the use of a variable parameter will save both time and storage space, as the only information then passed on to the subprogram is the address of the actual parameter. A value parameter would require storage for an extra copy of the entire data structure, and the time involved in copying it.

Tip:

Make your job easier and improve the readability of your applications by an unambiguous use of functions:

```
Function ReturnAbyte : byte;
begin
  ...
end;
```

This function then is usually used in this manner:

```
var bb   : byte;
      ...
bb:= ReturnAbyte;
```

But looking at the statement it's not clear whether ReturnAbyte is a variable or a function.
But if you write

```
bb:= ReturnAbyte();
```

it's clear, it's a function.

With the following constructions the empty parenthesis is a must.

```
Function ReturnApointer : pointer;
begin
  …
end;
…
bb:= ReturnApointer()^;
ReturnApointer()^:= bb;
```

Here the function result (pointer) is directly used to implement a move.

4.7.1 PROCEDURE

Procedure Declaration
A procedure declaration serves to define a procedure within the current application or Unit. Procedures within procedures are not allowed. A procedure is initiated from a procedure statement, and upon completion, program execution continues with the statement immediately following the calling statement.

A procedure declaration consists of a procedure heading followed by a block which consists of a declaration part and a statement part.

The procedure heading consists of the reserved word **procedure** followed by an identifier which becomes the name of the procedure, optionally followed by a formal parameter list as described earlier.

All identifiers declared in the formal parameter list and the declaration part are local to that procedure. This is called the *scope* of an identifier, outside which they are not known. A procedure may reference any constant, type, variable, procedure, or function defined in an outer block.

The statement part specifies the action to he executed when the procedure is invoked, and it takes the form of a compound statement. If the procedure identifier is used within the statement part of the procedure itself, the procedure will execute recursively. This may be dangerous for inexperienced programmers.

Procedure are sub-routines, which can be called by name. There is a distinction between parameterless procedures and procedures with parameters.

Example for a parameterless procedure:

```
Procedure Test1;
begin
  Statement ...;
  Statement ...;
end;
```

Example for a procedure with parameters:

```
Procedure Test2 (par : byte);
begin
  if par > 0 then
    ...
  else
    ...
  endif;
end;
```

The passing parameter (argument) is, if there is no **var** prefixed, generally a invariant, i.e. it is possible to manipulate it within the procedure. It can be changed, but the original (at the calling location) is not changed, because the parameter is only a copy of the original

Often the changes made to the formal parameters in the procedure should also affect the actual parameters.
If a **var** is prefixed the original variable is used, not a copy! The parameter is treated like a pointer.

```
Procedure Test2(var par : byte);
```

Passing parameters are passed by the frame-stack and stay on the frame. That leads to a bigger code and a slower execution speed than with the global variable. If a procedure/function is time-critical, you should work without passing parameters and local variables.

Recursions (e.g. calling of `Test1` within the procedure `Test1)` are certainly allowed, but they could quickly lead to stack problems (e.g. overflow).

Local variables in functions and procedures have to be considered from the same point of view as passing parameters, namely a bigger and slower code.

```
Procedure Test3;
var loc : boolean;
begin
  if loc then
    ...
  endif;
end;
```

Every procedure **is able to** be completed (exited prematurely) with *Return*.

```
Procedure Test1;
begin
  Statement ...;
  if (a > b) then
    Return;
  endif;
  Statement ...;
end;
```

4.7.2 PROCEDURE SYSTEM_INIT

Special Procedure Declaration

System_Init is executed after the stack-initialisation. The user program is here able to execute certain hardware-initialisation, before the system is doing its own initialisation. After the procedure follows the system internal memory-, hardware,- and structured constant-initialisation etc.

```
Procedure System_Init;
begin
  Statement ...;
  Statement ...;
end;
```

Attention:

The program itself must not call the System_Init!!

4.7.3 PROCEDURE SYSTEM_MCUCR_INIT

The mega128 supports different WAIT states at some external memory areas. Furthermore parts of the address bus ports can be used as standard IOs.
In order to handle this the MCUCR register must be accessed immediately after a PowerOn or reset.

If this callback function is present in the application the system internal initialization of the MCUCR is omitted and now is completely under control of the application.
In order to do this the application must provide the following procedure:

```
Procedure SYSTEM_MCUCR_INIT;
begin
  MCUCR:= bb;
end;
```

At this time no other initialization has been done. So local vars, calling Library functions etc. are forbidden.

4.7.4 FUNCTION

Function Declaration
A function declaration consists of a function *heading* and a *block* which is a declaration part followed by a statement part. The function heading is equivalent to the procedure heading, except that the heading must define the *type* of the function result. This is done by adding a colon and a type to the heading.

The declaration part of a function is the same as that of a procedure. The statement part of a function is a compound statement as described with procedures.

A function declaration serves to define a program part which computes and returns a value. A function is activated when its designator is met as part of an expression. It is also possible to call a function like a procedure. In this case the result is discarded.

Functions are sub-routines, which are called by name. A function generally returns a result. The *Return*-statement is a **must** and has to be added with the result of the function. In general the same principles apply as with ***Procedure.*** The distinction between parameterless functions and functions with parameters are as with ***procedures***.

Example for a parameterless function:

```
Function Test1 : boolean;
begin
  Statement ...;
  Statement ...;
  Return(a > b);
end;
```

Example for a function with parameters:

```
Function Test2 (var par : byte) : byte;
begin
  if par > 0 then
    Return(0);
  else
    Return(1);
  endif;
end;
```

Example for a function with local variable:

```
Function Test3 : boolean;
var loc : boolean;
begin
  if loc then
    Return(loc);
  endif;
end;
```

With the use of the Compiler switch {$*NORETURNCHECK*} it's possible to omit the return statement in a function. This is only for special purposes.

The result of a function can also be an array or record. But the result of such a function must always be assigned to a variable of the correct type.
Other assignments or the usage of the result in an expression are not possible.

```
type tRec = record
                       abc  : byte;
                       …
                     end;

var rec  : tRec;

function GetRec : tRec;
begin
  return(rec);
end;
...
rec:= GetRec();         // legal
```

Not possible is:

```
GetRec().abc:= $12;  // illegal
xy:= GetRec().abc;    // illegal
```

4.7.5 PROCESS

Process Declaration

```
Process ProcessName (StackSize, FrameSize : word; DataPage);
```

Processes are independent programs in an application, which are able to run completely independent from other program parts (e.g. main). Processes can not be called like procedures or functions. They are instead called periodically by what is known as a scheduler, based on their priority. If processes were imported, the main program also runs as a process and has a priority, too.

If several processes exist in a program, the processing of the separate processes operate quasi-parallel, i.e. considered from outside all tasks/processes seem to work at the same time = **Multi-Tasking.** So a pseudo **parallel-processing** is achieved for events and data, although they are not really executed simultaneously.

In practice a process runs endlessly, only interrupted by interrupts and other processes and tasks. The 'begin' and 'end' limits a process with respect to its statements. Because processes cannot be called like functions they cannot have passing parameters and, may return no results.

On the first call by the scheduler it starts with the statement which comes after the ‘begin’. Now all statements will get processed until ‘end’, eventually interrupted by a **task switching** through the scheduler (switching to another process/task). If ‘end’ is reached, it is automatically continued with the first statement after ‘begin’. So a process runs continuously in a circle respective without an end. But the programmer has not to program a loop, because the jump to the begin is automatically. Here is the essential difference to a task. Tasks break up with ‘end’ and pass the control to the scheduler respective to the next process.

To declare a process, the stacksize and the framesize (10..1000 bytes), which are required by this process and the data area (iData, xData etc) has to be specified. The stacksize is depending on the depth of the sub-routines calls, the according address pushes, and the parameter pushes caused by various statements. The framesize is only depending on the frames (local and passing parameters) of the called sub-routines. The exact required amount of bytes is in practice hard to establish because all eventualities must be traced by a debugger. It is not the size (number of statements) of the processes that is relevant, but the kind of the statement (for example Floating Point or multiple nested sub-program calls). If there is enough ram available, then ‘the more the better’. An acceptable value for fairly simple processes is 32 bytes for the stack and 16 bytes for the frame.

Every process requires ca. 20 byte memory, where during an interruption by the scheduler the **pseudo-accumulators** (working registers), stack pointer and flags of the process are stored.

Local variables within processes and tasks are indeed encapsulated i.e. there is no direct access from outside, but they are located in the normal memory like global, static variables. Local variables must be available and there must always be a possibility of access. It makes no difference if the process is active, asleep or is suspended. So they reside in normal memory in ram and they have to be included in the calculation of the required memory. The access within the process or the task is made by the declared name. From outside (other processes, main etc) an access can be made by using the qualified name *‘ProcessName.VarName'*.

The above mentioned memory areas (Register-backup, stack, frame and local variable) are within the memory page, which was specified by the process declaration ($IDATA, $XDATA etc).

If processes/tasks are imported, the **main program** is treated as a process, so a compiler switch should be used to select the desired memory area immediately before the **begin**.

```
Process DoTheJob (32, 16 : iData); {Stacksize = 32 bytes, Framesize = 16 bytes}
var px : integer;
begin
  Statement ...;
  Statement ...;
end;
```

The method of working is controlled by a large number of relevant functions and procedures. An essential parameter is priority.

With **priority** a part of the available run-time is placed at disposal to a process. The higher the value of priority is, the more run-time is at disposal. At the same time priority predefines the number of system ticks, which are completely available for the process in one time slice. The proportional runtime of the total time in % is calculated by: Priority / Sum of all priorities.

Assumed there is only the process ‘DoTheJob’ and it has the priority 10 and Main Priority is 5 then % time available for the process is (estimated): run-time = 10 / (5 + 10) = 66%. The exact run-time can only be calculated if no process is suspended or locked and if no ProcessWaits etc. exist. In practice the proportional run-time can only be estimated.

A process/task is able to take over the CPU completely by **lock,** so apart from itself only interrupts are running. This state is cancelled by **unlock**.

If a process/task establishes that it has nothing to do at the moment, there should be no waste of run-time by using waitloops or delays. There are several ways to pass the control to other processes:

With **Schedule** the process/task is interrupted immediately, but is kept in the list of active processes.

With **Sleep** a process/task is able to switch itself off for a certain number of system ticks.

With **Suspend** a process/task switches off. It is not able to switch itself active again. This must be done from another process/task or by the main program using the **resume** procedure.

Because the communication between tasks/processes is made by pipes and semaphores, there is also the possibility that the task switches itself off by calling **WaitSema** or **WaitPipe.** The process/task becomes active if there is data in the specified semaphore or pipe. It is also possible for **RxBuffer** to be specified as a pipe.

The process/task is interrupted directly after an above mentioned instruction.

4.7.5.1 Define Options

It is possible to optionally define a Process's priority and/or initially suspend or resume it:

```
Process Name (StackSize, FrameSize : MemoryArea[; Priority, RunMode]);

Process Proc1 (32, 32 : iData);               // default prio=3, autostart
Process Proc1 (32, 32 : iData; 5);            // priority 5
Process Proc1 (32, 32 : iData; resumed);      // default prio=3, automatic start
Process Proc1 (32, 32 : iData; 5, suspended); // prio= 5, no automatic start
```

4.7.6 TASK

Task Declaration

```
Task TaskName (DataPage);
```

Tasks are independent programs within an application, which are able to run absolutely independently from other program parts (e.g. main), i.e. tasks cannot be called like functions or procedures. Instead they are called periodically by the scheduler. If tasks have been imported, the main program runs as a process, and also has a priority. Tasks are **extremely specialized processes** and they only should be used for certain jobs, for example PID-controller.

If there are several processes/tasks within a program, the tasks are done quasi-parallel, i.e. it seems like all processes are done at the same time = **Multi-Tasking.** So an apparent **parallel-processing** for example of events or data is achieved, although they do not actually run simultaneously.

In practice a task runs perpetually, only interrupted by interrupts and other processes and tasks. The ‘begin’ and ‘end’ limits a task with respect to its statements. Because tasks can not be called like functions, they do not have any passing parameters or results.

With **every** call of a task by the scheduler, it is started with the statement which immediately follows the 'begin' statement. Following statements are all processed until the 'end' statement is reached. If the 'end' is not reached within a system tick, the task is **interrupted** by a **task change** by the scheduler (Switch over to another process/task). So the task never reaches the 'end', if its required run-time from 'begin' to 'end' is longer than a system tick. The run-time must **never** be longer than a system tick. Similar conditions are also valid for interrupts. A timer-interrupt-service-routine for example, should never take more time than the period between two interrupts.

If the 'end' is reached, the control is automatically passed to the scheduler, which now activates the next process or task. In contrast to a process a task runs from 'begin' to 'end' and then aborts itself.

If tasks have been imported, a **TaskStack** and a **TaskFrame** have to be defined. All tasks within the system use the same stack and frame, i.e. only one task stack and frame exists, because tasks are normally not interrupted by the scheduler and always resume at the same point (statement). The required **stack size** is determined by the demand of the largest task (7..255 bytes). The stack size depends on the depth of the calls of sub-programs and the resulting address push's as well as on parameter pushes, caused by various statements. In practice the exact number of required bytes can not be established, because all eventualities have to be traced.

As with all other stack definitions it has to be estimated with common sense and experience. It is not the size (number statements) of the task is important, but the kind of statement (for example Floating Point or multiple nested sub-program calls). If there is enough ram available, the best policy is 'the more the better'. An acceptable value for a simple task is 32 bytes.

Every task requires ca. 20 byte memory, where during an interruption by the scheduler the **pseudo-accumulators** (working registers), stack pointer and flags of the process are saved. This memory is also the same for all tasks and exists only once.

Local variables within processes and tasks are encapsulated, i.e. there is no direct access from outside, but they are held in normal memory like global and static variables. Local variables must be available and there must always be a possibility of access. It makes no difference if the task is active, asleep or is suspended. They are usually use memory in ram and they have to be included in the calculation of the required memory. Access within the process or the task is made by the declared name. From outside (other processes, main etc) an access can be made by 'Task*Name.VarName*'.

The above mentioned memory areas (register-backup, frame and stack) are within the memory page specified by Define TaskStack = size, RAMpage (iData, xData etc) and Define TaskFrame = size.
The 'local' variables of a task also reside in this memory page.

```
Task RunPid (xData);
var tx : integer;
begin
  Statement ...;
  Statement ...;
end;
```

The method of working of a task is controlled by a large number of relevant functions and procedures. An essential parameter is priority.

As opposed to a process, the calling interval of the **task** is predefined by **priority.** The lower the value of priority is, the more often the task is called. Assumed the task 'RunPid' has the priority 10, then it is called every 10 Systicks.
Thus the period between two calls is always 10 ticks.

Note:
If there are several **tasks,** and if it is possible, that several of them are active, pay absolutely attention that all priorities have a **common denominator.**
I.e. all priorities must be a multiple of 2, for example. If this condition is not met, then there are irregular call intervals, i.e. the period between two calls is not constant any more. Further the lowest priority has to be higher than the sum of all tasks.

If a task establishes that it has nothing to do at the moment, there should be no waste of run-time by waitloops or delays. There are several possibilities to pass the control to other processes:

With ***schedule*** the task is interrupted immediately, but is enqeued again into the waiting loop.

With ***sleep*** a task is able to switch itself off for a certain number of system ticks.

With **suspend** a task switches off. It is not able to switch itself active again. This must be done by a task from outside or by the main program with ***resume***.

The task is directly suspended after any instruction mentioned above.

A task is able to take over the CPU completely by ***lock*****,** so that except itself only interrupts are running. This state is abolished by ***unlock*****.**

Because the communication between tasks/processes can be with pipes or semaphores, there is the possibility that the task switches off by calling **WaitSema** or **WaitPipe.** The task gets active again if there is data in the specified semaphore or pipe. **RxBuffer** can also be specified as a pipe.

4.7.6.1 Define Options

It is possible to optionally define a Task's priority and/or initially suspend or resume it:

```
Task Name (MemoryArea[; Priority, RunMode]);

Task Task1 (iData);                // default prio=5, autostart
Task Task1 (iData, 8);             // priority 8
Task Task1 (iData, resumed);       // default prio=5, automatic start
Task Task1 (iData, 8, suspended);  // prio= 8, no automatic start
```

4.7.7 FORWARD

Forward declarations of pointers, functions, procedures and processes

A forward reference is properly not possible in Pascal as well as in other programming languages and some assemblers. I.e. all statement referenced elements (types, variables, constants, procedures, functions) have to be declared before they could be used.

Sometimes it is absolutely necessary that a procedure/function/process is referenced before it has been declared. Therefore a *Forward* declaration is possible. The procedure/function/process head is written again after the variable/constant declaration and before the first function/procedure declaration with the addition 'forward'. The proper declaration can happen at any later position. Here *forward* must not be used again!

```
Program Abc;
...
var   ...;
const ...;

Procedure Test1; Forward;
Process   Proc1(32); Forward;
Function  Test2(par : byte) : byte; Forward;
...
...
Process Proc1(32);
begin
  ...
end;

Procedure Test1;
begin
  Statement ...;
  if (a > b) then
    Return;
  endif;
  Statement ...;
end;

Function Test2 (par : byte) : byte;
begin
  if par > 0 then
    Return(0);
  else
    Return(1);
  endif;
end;
```

Forward also can be used for type declarations, particularly for pointers.

```
  Type TRec1      = record; forward;     // preliminary declaration
       TPtr       = pointer to Rec1;
       TRec1      = record
                       Ptr1 : TPtr;
                     end;
```

4.7.8 BEGIN

Starting procedure-, function-, process- or task body

Every procedure, function, process, task as well as the main program has to begin with a ***begin*** and to end with an ***end*;** as you see also in above mentioned examples. Pascal programmers will surely have already recognized that after a *then* and *else* generally no begin and no end statement follows.

The designer of Pascal, N.Wirth, has not been consistent by this and the result is that begin/end is either a *must* or a *can.* A concrete example is the exception with the *Case..Else* statement. Every programmer must often consider, how did it come about? In the successor of Pascal, *Modula-2,* Wirth clarified it, and he abolished the begin/end in these constructs. This made the relevant compiler construction easier and safer at this point.

This feature (as well as others) has been introduced in the existing compiler. The protest: This is not now Pascal-compatible, can be ignored in a system, which knows as many hardware dependences as an 'embedded' development system. To make development easy there have to be many language extensions introduced.

Anyone who knows Borland-Pascal or Delphi, also knows that about half of the construction is not standard Pascal compatible either.

Statements

The statement part is the last part of a block. It specifies the actions to be executed by the program.
The statement part takes the form of a compound statement followed by a period or a semicolon.
A compound statement consists of the reserved word ***begin*,** followed by a list of statements separated by semicolons, terminated by the reserved word ***end.***

The final ***end*** in a program is followed by a "**.**" (dot) in traditional Pascal.

4.7.9 RETURN

Abort and exit within a procedure/function

The *Return* statement allows for the abort (return) of a procedure or a function at any point. Return is a **must** for all functions. (With the use of the Compiler switch {$*NORETURNCHECK*} it's possible to omit the return statement in a function, but this is only for special purposes.)
Every procedure **can be** terminated with the *Return* statement. The Return statement is parameterless.

```
Procedure Test1;
begin
  Statement ...;
  if (a > b) then
    Return;
  endif;
  Statement ...;
end;
```

Every function **has to be** terminated by the *Return*-statement.. Return **has to have** a parameter. The type of this parameter has to be declared in the function header. Permissible types are 8, 16, 32 and 64bit values.

```
Function Test2 : boolean;
begin
  Statement ...;
  Return(a > b);
  Statement ...;
end;
```

4.7.10 END

End of a procedure-, function-, task- or process-body

Every procedure, function, task and process **has to** begin with a ***begin*** and end with an ***end;*** see also examples above. The end-statement has to be followed by a semicolon. See also description of *Begin.* The *End*-statement is in contrast to standard Pascal only permitted for the end of functions procedures and the main program. IF, WHILE, REPEAT etc. have their own qualified abort, i.e. ENDIF etc. This is for a better readability of the source.

For a better readability it is optionally possible to insert the name of the procedure/function in front of the semicolon (***end*** *Test2;*)

4.7.11 ASM:

Start of a single Assembler statement in a Pascal source.

```
ASM:  PUSH _ACCA;
```

4.7.12 ASM;

Start of an assembler text block

A program for Embedded Control often does not work without assembler code, because either the compiler generated code is too slow for some operations, or certain assembler commands have to be done, which are not known or not used by the compiler.
Assembler source can be inserted directly at every position of the Pascal source. This source is passed untested and unprocessed by the compiler to the assembler. Because the compiler also generates assembler code, the assembler text is seamlessly inserted.
Asm-syntax errors are only recognized by the assembler, not by the compiler.
Access to all declared variables is possible in the assembler text.

Attention:
Labels in an assembler-block have to start at the beginning of a line and terminated with a '**:**'. This line may not contain any further instructions, e.g. code.
The analysis of the compiler generated assembler-files 'xxx.ASM' may help:

```
ASM;
  LDI     _ACCA, 040h
  ANDI    _ACCA, myProg.a;          {a = Pascal var in myProg }
ENDASM;
```

4.7.13 ENDASM

End of an assembler text

ASM and ENDASM are Pascal statements and have to end with a semicolon **;**

4.8 INTERRUPTs, TRAPs and EXCEPTIONs

4.8.1 INTERRUPT

Declaration of an Interrupt Procedure.

Possible interrupt sources totally depend on the processor. Within a CPU-family there are considerable differences. Interrupt sources are defined declared in the processor description file (xxx.dsc).

This procedure sets only an entry in the interrupt-vector-table and creates a program frame for the selected register savings (see below).

In addition the I/O control registers of the CPU for the specific interrupt handling must be initialized by the application itself (see the descriptions in the controller manual) !

Example (AVR Mega103):

TIMER0	timer0 overflow interrupt
TIMER0COMP	compare match interrupt timer0
TIMER1	timer1 overflow interrupt
TIMER1COMP	compare match interrupt timer 1
TIMER1COMPA	compare match "a" interrupt timer 1
TIMER1COMPB	compare match "b" interrupt timer 1
TIMER1CAPT	capture event timer 1
TIMER2	timer2 overflow interrupt
TIMER2COMP	compare match interrupt timer2
EERDY	eeprom ready
ACOMP	analog comparator
SPIRDY	SPI serial transfer complete
ADCRDY	ADC conversion complete
INT0	External Interrupt 0
INT1	External Interrupt 1
INT2	External Interrupt 2
INT3	External Interrupt 3
INT4	External Interrupt 4
INT5	External Interrupt 5
INT6	External Interrupt 6
INT7	External Interrupt 7
RXRDY	uart1 rx complete
UDRE	uart1 data register empty
TXRDY	uart1 tx complete
RXRDY2	uart2 rx complete
UDRE2	uart2 data register empty
TXRDY2	uart2 tx complete

The declaration of an interrupt generates automatically corresponding entries in the interrupt vector table, and also as a special code-frame for the interrupt procedure.
Here are at default all registers saved -> **complete register saving**.
This can be controlled by the compiler switches *{$NOSAVE}*, *{$NOREGSAVE}* and *{$NOSHADOW}.*

The global-interrupt-enable-flag, which is reset automatically by the CPU, is not changed, i.e. the interrupts stay disabled in runtime. If the ‘end’- statement is reached, a RETI (return from interrupt) will be done, which enables the interrupt.

That means, that an interrupt procedure should be **as short as possible,** so the other interrupts are not disabled too long.

A **complete register saving** needs about 20 Bytes in RAM, statically, not on Stack or Frame. Because of this a stacked interrupt is impossible. That means within an interrupt procedure the interrupt never should be enabled again. The CPU itself does this enabling with the *RETI* instruction

Because with the **XMega** the global interrupt is not disabled on entry into a service routine, this is done by the system itself, also the enable. So it is possible that higher prioritised interrupts can get control. But therefore the globale interrupt must be enabled. This can be forced by

```
    Define Interruptible_Ints = true;
```

in the Define section. So higher prioritised interrupts can get control within the actual interrupt. System-internal interrupts basically run with a priority of 2.

If an interrupt nesting is undispensable, the compiler switch *{$NOSAVE}* must be used. So only the flags and the main work registers are saved. The procedures *PushAllRegs* and *PopAllRegs* can be used to save the remaining registers via the stack if necessary.

Interrupt nesting is very dangerous and ends frequently in a system crash. It should be avoided whenever possible. At least a very careful planning an absolute necessity.

Attention:
the correct initialization of interrupts needs usually settings in different control and mask registers.
With the contained drivers that are running in interrupt mode this a done by the corresponding drivers.
If the application defines the interrupts, the compiler can not be of any assistance.

In these cases it is the duty of the application to do the necessary initializations !!

If the system reaction is too time-critical and more statements need to be executed, the following procedure is recommended:
the interrupt increments a semaphore and returns. A process is always waiting for this semaphore and will get the control briefly.

```
Interrupt Int0;
begin
  IncSema (sema0);
end;

Process ProcessInt0 (32, 16 : iData);
begin
  WaitSema (sema0);          {wait for sema0 > 0 }
  ...
end;
```

Interrupt Service Routines can have own local variables. Because there is no Frame here, these vars are static/nonvolatile which means they are placed into the iData (SRAM) area and they are always accessible (static) and their content is always valid (nonvolatile).
Inside of the Interrupt procedure they can be accessed and used like any other var. Because of their static nature they can also be used by other parts of the application. But they are a property of a procedure so an access must be qualified:

```
Interrupt Timer1;
var abc : byte;
begin
  abc:= 123;                 // no qualification
  ...
end;
...
Interrupt_Timer1.abc:= $67;  // qualify with "Interrupt_name"
```

Please note that "Interrupt_" must always precede the qualifier.

Basically all Interrupts which are not supported by an interrupt Handler are handled by a default/dummy interrupt service routine with a simple "RETI". For debug and test purposes this interrupt error can be supported by the application. Normally such a condition should never occur so this routine should never be called by any interrupts. The implementation must be done in the application:

```
Interrupt IntErrorHandler;
begin
  ...
end;
```

4.8.1.1 Push, Pop

```
Procedure Push (regnum : byte  |  regname : internal);       //e.g. Push (24);
Procedure Pop (regnum : byte  |  regname : internal);        //e.g. Pop (_ACCFLO);
```

For a better readability. Creates the same code as
ASM: PUSH ... ;   or
ASM: POP … ;

4.8.1.2 PushRegs, PopRegs

```
Procedure PushRegs;         // working registers to stack
Procedure PopRegs;          // working registers from stack
```

These procedures are simplified versions of PushAllRegs and PopAllRegs and can always be used as pairs in Interrupts if there are only the 4 important registers (ACCA, ACCB etc) are saved.

4.8.1.3 PushAllRegs, PopAllRegs

Sometimes, but only sometimes, it makes sense to re-enable globals interrupts in an interrupt procedure for example a Timer Interrupt. This avoids too long interrupt disable times. In this case, if registers must be saved, this can not be done by the common automatic register save (Switch $NOSHADOW inactive).
This register save does not support "nested interrupts".

In order to save all registers in such a function where the global interrupt must be re-enabled, the register save must be done in a special way:

```
{$NoSave}
Interrupt TIMER1COMPA; // TickTimer
begin
  PushAllRegs;
  EnableInts;
  ...
  ...
  PopAllRegs;
end;
```

The switch {$NoSave} is mandatory here.
This method should only be used if the global interrupts must be enabled in an interrupt service routine. The user should exactly know why and what he is doing here :-)

4.8.2 External Interrupts

The AVR family provides two external Interrupt types which can by controlled by port pins.

The first group contains these Pins/Interrupts where every pin can fire an own vector interrupt (unique vector). These are the interrupts INT0..INT7 and the associated port pins.

The second group contains the so called **P**in**C**hange**I**nterrupts PCINT0..PCINTxx. Here always upto 8 pins of a port are joined together and firing one common interrupt vevtor.

4.8.2.1 Interrupt Pins INT0..INTx

These standard external interrupts are supported by the AVRco system in a way that if a concerned interrupt procedure is defined in the application, for example ***Interrupt INT0***, the system enters the address of this procedure into the interrupt vector table. If this interrupt is raised the selected register saving is executed an this procedure is called. The initialisation of this interrupt in the associated Enable and Mask registers must be done by the application.

4.8.2.2 PinChangeInterrupts PCINT0..PCINT3

Most of the newer AVR CPUs provide this interrupt mechanism. Upto 4 Ports (PCINT0..3) or 32 interrupt pins are supported. This looks very powerful but it must be used with some restrictions. So there is only one vector for one port and eache state change at every pin fires an interrupt. Means the Low/High edge fires and also the High/Low edge.

With many applications this is still sufficient. But sometimes it is necessary to identify the pin source of the interrupt. A separate vector or service routine per pin is necessary. So each PinChange should end in a specific service routine. The AVRco system supports this with a special interrupt handler ***PCintServer*** for the PCINT Interrupts.

Here the previous PIN state is compared with the actual one in order to find out which port pin was the reason for this interrupt. If then the application provides a special interrupt service routine so this one will be called and the register R16 (_ACCB) contains a true or false ($00/$FF) dependend which edge of the pin change was the source of this interrupt. The associated iinterrupt procedurs must follow this naming conventions: PCINT00 upto PCINT31.
The Interrupt Handler *PCintServer* for the PCINT Interrupts must be imported.

```
From System Import PCINTserv0, PCINTserv1, …;
```

In order to use the individual Pin Change Interrupts the necessary Interrupt procedures must be defined.

```
Interrupt PCint00;   // PinB.0 mega168
begin
  if _ACCB <> 0 then
    …
  else
   …
  endif;
end;
```

PCINTxx is also supported by the Application Wizard and the Simulator.
An example program can be found in the Demos Directory in PCintServ.

4.8.3 External Interrupts XMega

The XMega family provides an interrupt with each IO-Port pin. But because each port provides only two Interrupt vectors it makes sense to operate with two modes. If more than one interrupt pro port is needed then a Dispatcher must be implemented which informs the application which port pin raised the interrupt. If only one interrupt pro port is used then this Dispatcher is not necessary.

With only one interrupt pro port then one vector is occupied which raises an interrupt, PortIntX. Vector1 is used.

With more than one interrupt pro port the Dispatcher must be used which identifies which one of the upto 8 pins was the source, because there are only two vectors pro port. This method then is called PinChangeInterrupt PCintX. Vector0 is used.

Both interrupt types can coexist on the same port.

4.8.3.1 Interrupt Pins PortIntA .. PortIntR

The PortInts must not be imported but only be defined:

```
Define   PortIntD  = 0, PullUp, bothedges;     // pin0 used, Pullup on, both edge
```

PortInt**X** defines the IO-Port where X stands for the port, PortA…PortR
0..7 defines the port pin
PullUp, PullDown, None defines the internal connection, resistor about 20kOhm
LowLevel, BothEdges, Rising, Falling defines the port state which raises the interrupt. LowLevel must only be used with special cases because as long the pin is low this interrupt will fire.

Each PortIntX must have a corresponding CallBack procedure which then is called by the interrupt.
For PortIntD :

```
Procedure PortIntD;           // Interrupt CallBack
begin
end;
```

Attention: these procedures are Interrupt Procedures! So large or complex operations must be avoided here, because this can disable all other Interrupts in an unexpected long time. Furthermore one must know that here only the registers R16/R17 (_ACCA/_ACCB) and R30/R31 (_ACCCLO/_ACCCHI) were saved. If additional register are in use wthin this procedure then these must be saved here with Push und Pop. Example: Push(R18) and Pop(R18) or PushAllRegs and PopAllRegs.

A sample program is in the Demos Directory in XMega_PortInt

4.8.3.2 PinChangeInterrupts PCintA .. PCintR

PCints must be imported and defined:
For each port which shall have one or more PCints a PCint must be imported. PortA .. PortR

```
Import   …, PCintD, PCintE;
```

Each PCint must be defined, the PortPins used and their Pin states.

```
Define  PCintDmask    = $FF;             // all pins used
        PCintDedge    = $00;             // all falling edges
        PCintEmask    = %00100001;       // only Pin0 and Pin5 used
        PCintEedge    = $FF;             // all rising edges
```

PcintXmask **X** defines the Port (A..R). Each 1-Bit in th mask enables the corresponding pin interrupt for this port.
PcintXedge **X** defines the Port (A..R). A 0-Bit in Edge defines a falling, a 1-Bit defines the rising edge as the interrupt source for the corresponding Port-Bit.

Each enabled PCintX-bit must have an associated CallBack procedure which then is called by this interrupt.
For PCintD :

```
Procedure PCintD0;           // Interrupt CallBack PinD.0
begin
end;

Procedure PcintD1;           // Interrupt CallBack PinD.1
```

Attention: these procedures are Interrupt Procedures! So large or complex operations must be avoided here, because this can disable all other Interrupts in an unexpected long time. Furthermore one must know that here only the registers R16/R17 (_ACCA/_ACCB) and R30/R31 (_ACCCLO/_ACCCHI) were saved. If additional register are in use wthin this procedure then these must be saved here with Push und Pop. Example: Push(R18) and Pop(R18) or PushAllRegs and PopAllRegs.

A sample program is in the Demos Directory in XMega_PCint

4.8.4 TRAPS and Software Interrupts (SWI)

Using Software-Interrupts (SWI), also called Traps, is usually the only way with larger processors to switch from the application layer to the system layer (application level - system level). Many important operations are only enabled on the system level, e.g. IO-accesses, memory accesses into protected areas etc.

An additional reason for having SWI or Traps is the communication between one program part and another where neither part knows the structure, functions and addresses of the other part. Such types are Debug-Monitors for example.

Privileged layers don't exist with the AVR. Because of this there are no SWI or Traps. But in some cases it could be an advantage if they were available. It is possible to use hardware interrupt for these purposes, as Atmel suggests. But most of the interrupts of the AVR can't be used because a peripheral part or a pin interrupt must be wasted. Most of the mega CPUs provide a SPMRDY interrupt which is used very rarely, doesn't use any additional resources and is very simple to use.

The AVRco supports Traps through the SPMRDY. Not as elegant as native Traps or SWIs, but practical.

Why Traps with AVR?
With the almost all AVR applications using Traps/SWI is definitely not necessary. There are only a very few special cases where they make sense. When a program is patched or parts of it do not “know“ each other there can be the problem of communication between them. It is impossible to call any function of the other. And also the data transfer between them is very difficult.

A typical application is for example a Debug Monitor. Without Traps/SWI it must have its entry at a fixed known address. This is a necessity for the application to contact this monitor.

How does it work?
The system provides the procedure ***Trap (t : byte*)** which can be called at anytime. The parameter “t“ can be any byte which is passed to the receiving function. Assuming that the global interrupt is enabled the procedure “Trap“ triggers a SPMRDY interrupt.

Either this interrupt then is processed by the interrupt procedure ***Interrupt SPMRDY*** or by a TrapHandler, which the application must then provide ***TrapHandler (t : byte)***.

All this happens in the completely in the application. But how can the external part be involved? In the first case with “Interrupt SPMRDY“ an entry address can be passed with the definition of the Trap mode which then will be called instead of the interrupt procedure in the application itself. So the app-internal interrupt procedure can be omitted. The same is true for the TrapHandler procedure.

In both cases if an external part is involved and Traps are used for communication this external entry address must be defined. This external address must be the absolute address of the external interrupt procedure or TrapHandler. This is similar as with most of the bigger architectures (16/32bit).
This address is a **Byte**-address and must have an even value.

The parameter “t“ is passed to the interrupt procedure “SPMRDY“ in _ACCA = R17.

A special case are traps in the boot area. Here are interrupts not the right way. They can be used with another implementation that has nothing in common with this one.
For more details see the chapter ***BootTraps***.

4.8.4.1 Implementation of the Traps

Defines

The definition of the TrapHandler controls how the Traps are handled by the system.

```
Define  ProcClock     = 8000000;          {Hertz}
        SysTick       = 10;               {msec}
        StackSize     = $0030, iData;
        FrameSize     = $0030, iData;
        TrapHandler   = false, 0;         {Intproc only, no ext address}
```

With the define of the TrapHandler the first parameter (true/false) defines whether an interrupt or TrapHandler procedure is expected.
The second parameter DestAddr (longword) defines whether this procedure is a part of the application (0) or of the external part (> 0).

TrapHandler = false
The *Trap(nn)* call triggers a SPMRDY interrupt. This interrupt then is executed either

- application-internaly (DestAddr = 0)   or
- externally (DestAddr > 0).

The Interrupt procedure must be defined and handled in the same way as all other Interrupt procedures. The same restrictions are true like: short processing time, possible register save etc. The global Interrupt is still **disabled** at the entry time.

```
Interrupt SPMRDY;
begin
  // _ACCA/R17 contains the parameter "t"
end;
```

TrapHandler = true
The *Trap(nn)* call triggers a SPMRDY interrupt. The TrapHandler then is executed either

- application-internaly (DestAddr = 0)   or
- externally (DestAddr > 0).

The interrupt itself is completely handled by the system and calls the internal/external Handler procedure. At the entry time into the Handler the global interrupt is already **enabled**. So the Handler is a procedure without any restrictions.

```
Procedure TrapHandler(t : byte);
begin
  ...
end;
```

DestAddr
As described above this address is the entry address of the external Interrupt procedure or TrapHandler and must be an even byte address. So the Flash-end of the mega128 has the address $1FFFE.

Note:
If the DestAddr = 0 then the corresponding procedure (Interrupt or TrapHandler) must be defined in the application.
If the DestAddr > 0 then the corresponding procedure (Interrupt or TrapHandler) must be present externally. Declarations in the application itself are ignored by the system.

4.8.5 EXCEPTIONS

With complex applications with many sub-routines and drives often there is a circumstance that in a deep level in a basic function (e.g. In/Out) there is an error or a time-out. Now this function can return a FALSE to the calling function, this function again returns also a false etc. until the call returns to this location where this action was initiated. Here the result (FALSE) can or must be interpreted which had its reasons “very deep down“. This can work only when each concerned function returns a boolean and the calling function interprets this

```
if not funcx then
  Return(false);
else ...
```

in a proper way.

The whole operation can be difficulty and erroneous. For this purpose Borland introduced some years ago the elegant and powerful ***Exceptions*** in Delphi. Exceptions are error handlers. This means, if such an exception occurs the program immediately returns to this location where the exception handler was implemented. The difficult stepping up through all the functions used is discarded.

Exceptions always consist of an implementation part, limited by ***Try*** and ***EndTry*** and one or more ***RaiseException*** statements. Between *Try* and *EndTry* there can be an optional ***Except*** statement

```
Try
  StatementE..
  StatementE..
  StatementE..
EndTry;
```

or

```
Try
  StatementE..
  StatementE..
  StatementE..
except
  StatementN..
  StatementN..
EndTry;
```

If the execution of a *Statement* meets the statement

```
RaiseException (num);
```

all further operations are discarded and the application returns to the initiating Try/EndTry block. In the first example the execution continues with the statement after the line “EndTry”. In the second example the next executed statement is this one which follows the line “except”. With the function

```
GetExceptResult
```

the parameter “num”, which was passed with the function *RaiseException* can be read.

If there was no exception then with the first example all statements are executed. In the second example only the statements between *Try* and *Except* are executed and the execution jumps to the line after the *EndTry* statement.

The better way is always example two where the application always gets notified that an execution happened (raised) because the block between *Except* and *EndTry* is executed.

Attention
An exception can only be raised (by *RaiseException(num))* if it happens between the execution of *Try* and *EndTry* or *Except*. Otherwise it will be ignored. A *Try/EndTry* block always must be placed into a block. This is illegal:

```
if a > b then
  Try
else
 Endtry;
endif;
```

Restriction
With MultiTasking there a some restrictions at this time. *Try/EndTry* must only be placed in the *MAIN*. So the *RaiseException* function is only valid if at this time the *MAIN* process is controlling the system. Otherwise it is ignored.

4.8.5.1 Implementation

Imports
The exception support must be imported.

```
Import SysTick, TickTimer, ..;
From System Import Exceptions, ...;
```

Defines
The Exceptions can be nested indirectly. The max. nesting must be defined

```
Define Exceptions = 2[, Boot[, iData1]];        // 1..15 levels, Boot and iData1 are optional
```

Exceptions must not be directly nested, but it is possible while a *Try/EndTry* is active additional ones can be placed into function statements. The count of the nested levels is limited by the above define. Each level needs a set of parameters which is placed into the RAM in a stacked order. If all *Try/EndTry* levels are occupied at runtime additional ones are ignored. The structure is build at runtime and released with an *EndTry*. So this can be called an Exception Stack.

If the Option *Boot* is selected then the Exception Handler is placed into the Boot area. Because this handler builds and uses some system variables the addresses of these vars must never be changed after a Flash download. Because this can not always be ensured by the application it makes sense that these vars will be placed into the already defined Idata1 area (must be separately defined) where they are always be placed into the very first locations.

4.8.5.2 Functions

With the import of Exceptions two support functions also become imported:

```
Procedure RaiseException (num : byte);
```

This procedure raises the exception. Then the program immediately returns to the location which is on the first place (Top Level) of the exception stack. The parameter num is stored and can later be read back with the function described below. Please note that the global interrupt stays disabled from here on.

If the exception stack is empty, meaning there is no responsible *Try/EndTry* active at this time the RaiseException procedure will be ignored.

```
Function GetExceptResult : byte;
```

The parameter *num* passed by the function *RaiseException* can be read back by this function. The parameter can be used for several informations, e.g. It shows which Exceptions was the initiator or what kind of problem occurred.

Example Program:
An example can be found in the directory **..\E-Lab\AVRco\Demos\Exceptions**

4.9 Statements

The statement part defines the action to be carried out by the program (or subprogram) as a sequence of *statements;* each specifying one part of the action. In this sense Pascal is a sequential programming language: statements are normally executed sequentially in time, not simultaneously. The statement part is enclosed by the reserved words **begin** and **end** and within it, statements are separated by semi-colons. Statements may be either *simple* or *structured.*

4.9.1 Simple Statements

Simple statements are statements which contain no other statements. These are the assignment statement, procedure statement, goto statement, and empty statement.

4.9.2 Assignment Statement

The most fundamental of all statements is the assignment statement. It is used to specify that a certain value is to be assigned to a certain variable. An assignment consists of a variable identifier followed by the assignment operator **:=** followed by an expression.

Assignment is possible to variables of any type as long as the variable (or the function) and the expression are of the same type or assignment compatible.

```
Angle:= Angle * 3;
AccessOK:= False;
AccessOK:= Answer = PassWord;
Result:= (Entry * 13) shl 8;
```

4.9.3 Procedure Statement

A procedure statement serves to activate a previously defined user defined procedure or a pre-defined standard procedure. The statement consists of a procedure identifier, optionally followed by a parameter list, which is a list of variables or expressions separated by commas and enclosed in parentheses. When the procedure statement is encountered during program execution, control is transferred to the named procedure, and the value (or the address) of possible parameters are also transferred to the procedure. When the procedure finishes, program execution continues from the statement following the procedure statement.

```
Find (Name,Address);
Sort (Address);
Uppercase (Text);
```

4.9.4 Empty Statement

An 'empty' statement is a statement which consists of no symbols, and which has no effect. It may occur whenever the syntax of Pascal requires a statement but no action is to take place

```
repeat until KeyPressed;     {wait for any key to be hit}
```

4.9.5 Structured Statement

Structured statements are constructs composed of other statements which are to be executed in sequence (compound statements), conditionally (conditional statements), or repeatedly (repetitive statements).

4.9.6 Compound Statement

A compound statement is used if more than one statement is to be executed in a situation where the Pascal syntax allows only one statement to be specified. It consists of any number of statements separated by semicolons. The block starts with a preliminary statement (e.g. *if .. then*) and ends with an associated reserved word (e.g. *endif*).

```
if Small > Big then
  Tmp := Small;
  Small := Big;
  Big := Tmp;
endif;
```

4.9.7 NOP Statement

The Pascal Statement "NOP" is implemented. It produces an Assembler "NOP"

```
Incl (bit);
NOP;
Excl (bit);
```

4.9.8 Conditional Statements

A conditional statement selects for execution a single one of its component statements.

In most cases decisions and branches are build with "*if..then..else*". This is a common and always usable way, but sometimes it is inefficient and code and time consuming.
If constants are used with decisions it is better to use this: " ***if*** *x* ***in****[a, b, m..p]* ".
Another way is to use "case" constructs.

But in many cases there are no constants but variables and so "*case*" is unusable. But also here using powerful system functions like *IncToLim, DecToLim, IncToLimWrap, DecToLimWrap, ValueTrimLimit, ValueInTolerance, Lower, Higher* etc. can reduce code size in IF-constructs and also in general.

4.9.8.1 IF Statement

IF
The IF statement requires at least THEN and ENDIF

THEN
```
iF a > b then a:= b; endIf;
```

ELSE
```
iF a > b then a:= b; else b:= a; endIf;
```

ELSIF
```
iF a > b then ..; elsif b = a then ..; endIf;
```

ENDIF End of an IF Statements

IF is the leading statement of a branch. After *IF* **has to** be an operation with a boolean result (*true*/*false*). This can be a compare (a > b) or abstractly a boolean (*bit* or *var*).

After the operation there **has to** be a *then.* The *begin,* which is normal in Pascal, is not permitted in this case (see also description of *begin).* After *then* there has to be at least 1 executable statement. Then optional an *else* or *elsif* can follow, whereby *begin* is not permitted, too, and there has to be at least one executable statement.

In contrast to Standard-Pascal *IF* has always to be terminated with *ENDIF*.
In certain cases it makes sense to work with GoTo instead of If, but this should be an exception.

Attention:
Nested IF's are permitted, but they have to be programmed very carefully, because provisional results are generally stored on the stack. In case of doubt (Stack-Overflow) the corresponding program code has to be tested with help of a debugger/simulator. Sometimes using **elsif** is better than a nested if.

```
if a > b then
  ...
elsif a = b then
  ...
else            {a is less than b}
  ...
endif;
```

4.9.8.2 GOTO Statement

GOTO is an absolute branch statement, which leads to any location (forwards and backwards) in a **block** (block definition see below), and that is the danger. The branch destination always is a label, which has to be declared beforehand. Within a block only **one label definition** and so only **one branch destination** is permitted. But **Several GOTOs** can point to one destination.

A goto statement consists of the reserved word **goto** followed by a label identifier. It serves to transfer further processing to that point in the program text which is marked by the label.
The following rules should be observed when using goto statements:

1) Before use, labels must be declared. The declaration takes place in a label declaration in the declaration part of the block in which the label is used.
2) The scope of a label is the block in which it is declared. It is thus not possible to jump into or out of procedures and functions.

```
Procedure GotoSample;
begin
  Label: lab1;          {Definition of a Labels}
  ...
  Goto Lab1;
   ...
  Lab1:                 {Branch destination, no Semicolon!!}
   ...
  IF a > b then
    Label: Lab2;
    Lab2:               {Branch destination, no Semicolon!!}
    ...
    goto Lab2;
    ...
  endif;
    ...
  goto Lab1;
end;
```

Block Definition
In Pascal blocks are determined by certain block limits. A typical block limit is for example the BEGIN and END of a procedure or function. Loop blocks are limited by LOOP..ENDLOOP, REPEAT..UNTIL, WHILE..ENDWHILE, FOR..ENDFOR. The statements between IF..ENDIF, IF.. ELSE, IF..ELSIF, ELSIF..ELSIF, ELSIF..ELSE, ELSE..END also form **respectively one block**.

All three statements (label, Goto and the destination) of a Goto have to be within such a block. But it is irrelevant if the block is split in sub-blocks (see *Begin IF..ENDIF END*). In above mentioned example LAB2 is only recognized within IF..ENDIF, while Lab1 is known in the whole procedure, however not in the subblock IF..ENDIF.

Comment:
in C block limits are determined with **{** and **}** and so very clear :-)

GOTO
The Goto statement requires a definition of the label and use of this label in the same block.

LABEL
The label defines the destination address of the Goto statement.
The programmer always should take care to produce a readable and hence easily maintainable code. But this described GoTo-statement generally contradicts this aim. Sometimes, and only sometimes, a GoTo helps to get a better view over the program. Because of that GoTo should only be used in emergency, because in most cases an If- or loop-statement is much more elegant and safe.

4.9.8.3 CASE Statement

The case statement consists of an expression (the selector) and a list of statements, each preceded by a case label of the same type as the selector. It specifies that the one statement be executed whose case label is equal to the current value of the selector. If none of the case labels contain the value of the selector, then either no statement is executed, or, optionally, the statements following the reserved word **else** are executed. The else clause is an expansion of standard Pascal.

A case label consists of one to many constants or subranges separated by commas followed by a colon. A subrange is written as two constants separated by the subrange delimiter '..'. The type of the constants must be the same as the type of the selector. The statements following the case label are executed if the value of the selector equals one of the constants or if it lies within one of the subranges.

The case label may be any 8 bit data type such as *byte*, *Int8, enum* or *char* and also *word* or *integer* (16 bit).

Case is the leading statement of a branch block. After case an 8bit variable **has to** follow (byte, char or enum) and then the word “of“ (case v1 of ..). Within this block there are instructions what to do, if a variable is identical with a constant or a constant area (7 :... or 8..12 :...).

This area-declaration has to be terminated with a colon. The following area-block must contain at least one statement. Every single statement **has to** be terminated with a ‘**;**’. This sub-block is to abort with a separator-symbol (**|**).

After one or several area-blocks there can be an optional **Else** with further statements. The EndCase-statement generally forms the termination. Case is actually a specialized If-statement.

```
const   c1 = 83;
        c2 = 105;

Case x of
  0           : inc(a);
              |
  1, 7        : a:= 4;
              |
  2..6        : x:= x + a;
                dec(x);
              |
  8..9, 12 :   PWMport1 (45);
              |
  14..23,
  27..67      : a:= a * a;
              |
  c1..c2      : a:= c1;
              |
else
  x:= 0;
EndCase;
```

CASE

Begin of a Case Block.

Case *x* ***of*** *…*

ENDCASE

End of a Case Block.

4.9.8.4 FOR Statement

For is the leading statement of a program-loop. After For, an 8 or 16bit runtime-variable (control variable) has to follow. A start value has to be assigned to this variable by **:= .** Then follows the operator **TO** or **DownTo,** which specifies whether the runtime-variable should be incremented or decremented within every pass. The optional argument **BY** determines the increment or the decrement-value (1..255). Then follows the termination-value and the instruction **DO.** The start-value and the termination value may be 8 or 16bit variable or constants.

After the head-declaration (For x:= 0 to v1 do) follows a block with instructions, which is to be executed on each pass. This block can be empty.

The number of passes is depending on the difference between termination- and start-value.

With ***for*** *i:= 2* ***to*** *1* the loop is not executed since **i** initially has the value **2**
With ***for*** *i:= 2* ***to*** *2* the loop is executed once and **i** then has the value **3**
With ***for*** *i:= 2* ***to*** *7* the loop is executed six times and **i** then has the value **8**

In contrast to Standard-Pascal *FOR* has to be terminated with *ENDFOR.*

```
const   a  = 0;
var  v1  : byte;
      x    : byte;

for x:= a to v1 do              {ramp up}
  PWMport1:= x;
endfor;

for x:= x downto 0 do           {ramp down}
  PWMport1:= x;
endfor;
```

A FOR-loop can be terminated with a break-statement:

```
for x:= 1 to 9 by 2 do
  ...
  if a:= 0 then Break;
  ...
endfor;
```

See also **Continue!**

FOR
Begin of a For loop

```
for a:= 0 to 45 do inc (x); endfor;
```

ENDFOR
End of a For loop

4.9.8.5 WHILE Statement

While is the leading statement of a program-loop. After While an operation with a boolean result (true/false) **must** follow. This can be a compare (a > b) or a boolean (bit or var). The expression controlling the repetition must be of type Boolean. The statements contained in the loop are repeatedly executed as long as *expression* is *True.* If its value is *false* at the beginning, the statement is not executed at all. The loop is repeated as long as the controlling expression returns *true*.

The statement **must** be terminated with a ***do.*** The *begin,* which is usual in Pascal, is not permitted in this case (see also description of *begin).* After *do* there should be at least one executable statement. Leaving the while-loop is possible with a **BREAK**. See also **Continue**!

In contrast to standard-Pascal *WHILE* always has to be terminated with *ENDWHILE*.

```
while x < 100 do
  inc (x);
endwhile;
```

WHILE
Begin of a While loop

```
while a < b do inc (a); endwhile;
```

ENDWHILE
End of a While loop

4.9.8.6 REPEAT Statement

REPEAT is the leading statement of a program-loop. After REPEAT there **can** be one or several executable statements. The *begin,* which is usual in Pascal, is not permitted in this case (see also description of *begin)*.

The statement UNTIL forms the termination of the loop. After that there has to follow an operation with a boolean result (true/false). This can be a compare (a > b) or a boolean (bit or var). The loop is executed as long as the operation returns false. So in contrast to *WHILE* it is executed at least once.
Leaving the loop is possible with **BREAK .** See also **Continue**!

```
x:= 0;
repeat
  inc(TCC);
until TCC > 20;
```

REPEAT
Begin of a Repeat loop

UNTIL
End of a Repeat loop

4.9.8.7 CONTINUE

The Continue statement interrupts the normal flow of program execution of a **for-, while**- or **repeat**-loop and transfers execution to the beginning of the loop. The following statements until EndFor, EndWhile or Until are ignored.

4.9.8.8 LOOP Statement

Within a Controller-application the program normally never terminates, i.e. the program runs in an endless-loop. In this case Pascal only offers the construction: *Repeat ... until false = true;*
This is formally o.k., but is nonsense.

Modula-2 allows the endless-loop *LOOP* and this is implemented, too.
All statements within *Loop ... Endloop;* are repeatedly processed.

Loop .. Endloop; is also permitted within a procedure or even within a loop.
The statement *ExitLoop* is necessary to exit.
ExitLoop exits the loop and continues with the next statement after *EndLoop*.

```
begin
  loop
    ...
  endloop;
end.
```

LOOP
Begin of an endless-loop

ENDLOOP
End of an endless-loop

EXITLOOP
Termination of an endless loop

```
loop
  ...
  ...
if a > b then
  exitloop;
endif;
  ...
endloop;
```

4.10 System Library - Standard

4.10.1 TRUE

Pre-defined constant = $FF

4.10.2 FALSE

Pre-defined constant = $00

4.10.3 PI

Pre-defined constant = 3.141592654 (float)

4.10.4 NIL

Pre-defined constant of type pointer = $0000

p:= nil;

4.10.5 Type Conversion

4.10.5.1 BOOLEAN

Converts the argument into a boolean

***Function** Boolean (a : type) : boolean;*

bo:= boolean (x);

4.10.5.2 BYTE

Converts the argument into a byte

***Function** Byte (a : type) : byte;*

b:= byte (x);

4.10.5.3 Int8

Converts the argument into a Int8

***Function** In8(a : type) : int8;*

i:= Int8 (x);

4.10.5.4 CHAR

Converts the argument into a char

***Function** Char (a : type) : char;*

ch:= char (x);

4.10.5.5 WORD

Converts the argument into a word

***Function** Word (a : type) : word;*

w:= word (x);

4.10.5.6 INTEGER

Converts the argument into an integer

***Function** Integer (a : type) : integer;*

i:= Integer (x);

4.10.5.7 LONGWORD

Converts the argument into a LongWord

***Function** LongWord (a : type) : longword;*

ww:=longword (x);

4.10.5.8 LONGINT

Converts the argument into LongInt

***Function** LongInt (a : type) : longint;*

Li:= LongInt (x);

4.10.5.9 FLOAT

Converts the argument into a float

***Function** Float (a : type) : float;*

f:= Float (x);

4.10.5.10 FLOATASLONG

Converts the argument into a LongWord. But there is no converting or processing at all.

***Function** FloatAsLong (f : float) : longword;*

```
structconst
  lws : longword = FloatAsLong (1.234);

const
  lwc : longword = FloatAsLong (1.234);

// var
  lw:= FloatAsLong (fc);
  lw:= FloatAsLong (fs);
```

4.10.5.11 LONGASFLOAT

Converts the argument into a Float. But there is no converting or processing at all.

```
Function LongAsFloat (L : LongWord) : float;

strutconst
  fs  : Float    = LongAsFloat ($12345678);

const
  fc  : Float    = LongAsFloat ($12345678);

// var
  f:= LongAsFloat (lws);
  f:= LongAsFloat (lwc);
```

4.10.5.12 POINTER

Converts the argument into a pointer

```
Function Pointer (a : type) : pointer;

p:= Pointer (x);
```

4.10.6 Character and String Functions

4.10.6.1 ORD

Ordinal number of a symbol/character.

```
Function Ord (ch : char) : byte;

b:= ord (‘a’);              { $61 }
```

4.10.6.2 UPCASE

Converts char into capitals.

```
Function Upcase (ch : char) : char;

ch:= UpCase (ch);
```

4.10.6.3 LOWCASE

Converts char into lowercase letters.

```
Function LowCase (ch : char) : char;

ch:= LowCase (ch);
```

4.10.6.4 UPPERCASE

Converts String into capitals.

```
Function Uppercase (st : string) : string;

st:= UpperCase (st);
```

4.10.6.5 LOWERCASE

Converts String into lowercase letters.

Function *LowerCase (st : string) : string;*

st:= LowerCase (st);

4.10.6.6 COPY

Returns a string which is a substring from the source, beginning at “pos“ and has the length “count“. The destination must be a string var. Can be used in conjunction with concatenate.

Function *Copy (st : string; pos, count : byte) : string;*

st:= Copy (st, 2, 3);

4.10.6.7 STRREPLACE

The string/char src overwrites the destination string dest at position pos.
The length of the destination string remains as previous.

Procedure *StrReplace (src : string[char];* ***var*** *dest : string; pos : byte);*

4.10.6.8 TRIM

Removes leading and trailing spaces from the string.

Function *Trim (**const** st : string) : string;*

4.10.6.9 TRIMLEFT

Removes leading spaces from the string.

Function *TrimLeft (**const** st : string) : string;*

4.10.6.10 TRIMRIGHT

Removes trailing spaces from the string.

Function *TrimRight (**const** st : string) : string;*

4.10.6.11 PADLEFT

Inserts leading spaces (or the optional Pad Char) into the string. The string becomes extended so that the new length is now ***len***. If the origin length >= len then nothing changes.

Function *PadLeft (**const** st : string; len : byte [;pad : char]) : string;*

4.10.6.12 PADRIGHT

Appends spaces (or the optional Pad Char) to the string. The string becomes extended so that the new length is now ***len***. If the origin length >= len then nothing changes.

Function *PadRight (**const** st : string; len : byte [;pad : char]) : string;*

4.10.6.13 LENGTH

Function returns the actual length of a string.

***Function** Length (s : string) : byte;*

x:= length (st1);

4.10.6.14 SETLENGTH

This procedure changes the length of a string to the desired length, in the limits of the underlying string type.

***Procedure** SetLength (st : string; len : byte);*

SetLength (st, 6);

4.10.6.15 POS

Function returns the position of a character within a string.

***Function** Pos (a : char; s : string) : byte;*

x:= Pos (ch1, st1);

4.10.6.16 POSN

Function returns the position of a character within a string. Search starts at a given position.

***Function** PosN (a : char; s : string; start : byte) : byte;*

This is a non-standard Pascal function. It is functionally similar to the “POS” function in that it can be used to find a char in a string. POS searches for the char starting at the beginning of the string to search. It can find only one occurrence of the char. POSN on the other hand allows you to start the search from any position inside the string, thus POSN can be used to find multiple occurrences of the char.

POSN returns the position of “char” in “string”. The first possible position in string is “1”. The result is of type byte. If “char” cannot be found, the function returns a “0”. “position” may be any number from 1 to 255 subject to the actual string length. A search past the end of the string will return a “0” result.
POSN(char, string, 1) is the equivalent of POS(char, string).
“string” must refer to an existing string variable. It may not be a string expression.

```
var
   S : string[30];
   N : byte;
begin
  S:= ’Hello World Hello World’;
  N:= PosN (‘W’, s, 10);                //N will be set to 19
end;
```

4.10.6.17 APPEND

Procedure, appends the string/char "src" to the end of the string "dst" (concat).

***Procedure** Append (src : string[char]; **var** dst : string);*

The maximum length of "dst" will be not exceeded..

4.10.6.18 INSERT

Procedure, inserts a string/char into a string.

***Procedure** Insert (src : string[char]; **var** dst : string; p : byte);*

Insert (‘abc’, st1, 4);

4.10.6.19 DELETE

Procedure, deletes a number of characters within a string.

***Procedure** Delete (**var** s : string; pos, count : byte);*

Delete (st1, 3, 2);

4.10.6.20 STRCLEAN

Function, removes/replaces control characters from a string.

***Function** StrClean (**const** st : string; gt127 : boolean; subst : char) : string;*

The string "st" is scanned for chars < $20 (space) and if the boolean "gt127" is true,
also chars > $7F (> #127) are scanned for. If such a char id found it will be replaced by the char "subst" in case subst is > #0. If subst = #0 then char found will be deleted and not replaced.

4.10.6.21 STRTOINT

Function, converts a string to a Byte, Word, Int8, Integer, LongWord, LongInt, Word64 or Int64 depending on the destination variable. The function accepts variables in RAM or EEPROM. Strings in flash are not supported.

***Function** StrToInt (st : string) : byte; {integer ..}*

w:= StrToInt (st);

<u>string formats:</u>

decimal string:	"1234"
hexadecimal string:	"$ABCD"

4.10.6.22 StrToFix64

Function, converts a string to a Fix64. The function accepts variables in RAM or EEPROM. Strings in flash are not supported.

***Function** StrToFix64 (st : string) : Fix64;*

f:= StrToFix64 (st);

4.10.6.23 HEXTOINT

With *StrToInt* the hexadecimal string has to begin with a dollar sign "$".
But there are already fixed strings, for example out of a communication, which receive without a "$".
So it makes sense to convert these strings without the insertion of a "$" at string[1]. It expects a hex-string but without a leading "$"

***Function** HexToInt (st : string) : integer [byte, int8, word, longint, longword];*

4.10.6.24 STRTOFLOAT

Converting of a string into a float value. The decimal point is defined by the global constant "*DecimalSep*" default "**.**", which can be redefined

***Function** StrToFloat (st : string) : float;*

f:= StrToFloat (st);

4.10.6.25 STRTOARR

Generation of Null-terminated strings (C Strings).

***Function** StrToArr (**var** st : string) : **array of** char*

copies characters out of the string into the array until either the strings end is reached or the array is full. In both cases the last transferred character is always a null. This function is only applicable in an assignment. The string as the source must reside either in RAM, Flash or EEprom. Functions as a source are not allowed.

array:= StrToArr (st);

4.10.6.26 ARRTOSTR

Processing of Null-terminated Strings (C Strings).

***Function** ArrToStr (arr : **array of** char) : string;*

copies characters out of the array into the string until either a null is found or the end of the array is reached or the string is full. The null is not transferred. This function is only valid in an assignment statement. The string as the source must reside either in RAM, Flash or EEprom. Functions as a source are not allowed.

string:= ArrToStr (ar);

4.10.6.27 StrCompareN

This function compares two strings but ignores lower/upper case chars. Both strings must reside in RAM.

***Function** StrCompareN(var st1, st2 : string) : boolean;*

4.10.6.28 StrCompareW

This function compares two strings where the second one "pattern" can contain wild cards "?" und "* "
If "caseSens" is set then lower/upper case chars are taken in account. Both strings must reside in RAM.

***Function** StrCompareW(var inpStr, pattern : string; caseSens : boolean) : boolean;*

4.10.6.29 EXTRACTFILEPATH

returns the path-part of a FileName if present.
"A:FName.ext" -> "A:" "ppp\nnnn" -> "ppp\"

***Function** ExtractFilePath (FName : string) : string;*

4.10.6.30 EXTRACTFILENAME

returns the name-part of a FileName
"A:FName.ext" -> "FName" "ppp\nnnn" -> "nnnn"

***Function** ExtractFileName (FName : string) : string;*

4.10.6.31 EXTRACTFILEEXT

returns the extension-part of a FileName if present.
"A:FName.ext" -> "ext" "nnnn.ee" -> "ee"

***Function** ExtractFileExt (FName : string) : string;*

4.10.7 Access to Parts of Variable / Constants

4.10.7.1 SWAP

Swaps LoByte with a HiByte of Word or Integer or the LoNibble with the HiNibble of a Byte respective a Char. For 32bit types the low-word is swapped with the high-word.

***Function** Swap (x : type) : type;*

X:= Swap (i);

4.10.7.2 SWAPLONG

Sometimes it is necessary to make a mirrored value of a 32bit value.
The first and the last byte exchange their position. The same is true for the two middle bytes.

***Function** SwapLong (**const** x : LongWord|LongInt) : LongWord|LongInt;*

longVal:= SwapLong (longVal);

If the variable "longVal" had the value $12345678 before the operation, so after the function call it contains the value $78563412.

Attention: don't confuse with *Swap (longVal)* !!

4.10.7.1 EXCHANGEV

Exchanges the two arguments. Only simple variables supported.

***Procedure** ExchangeV(var v1, v2 : var);*

4.10.7.2 MIRROR8

Mirrors the argument. Exchange bit7 <-> bit0, bit6 <-> bit1, ...

***Function** Mirror8 (b : byte|int8|char) : byte|int8|char;*

4.10.7.3 MIRROR16

Mirrors the argument. Exchange bit15 <-> bit0, bit14 <-> bit1, ...

***Function** Mirror16(w : word|integer) : word|integer;*

4.10.7.4 MIRROR32

Mirrors the argument. Exchange bit31 <-> bit0, bit30 <-> bit1, ...

***Function** Mirror32(Lw : longword|longint) : longword|longint;*

4.10.7.5 LONIBBLE

returns the Low-nibble of a byte (lower 4bits)

***Function** LoNibble (b : byte|Int8) : byte|int8;*

4.10.7.6 LO (Function)

returns least significant byte of a 16bit value

***Function** Lo (w : word) : byte;*
***Function** Lo (i : integer) : byte;*

a:= lo (i);

4.10.7.7 LO (Assignment)

assignment to the Low byte of a word

LO (word):= byte;

4.10.7.8 LOWORD (Function)

returns the Low word of a 32bit value (LongInt or LongWord)

***Function** LoWord (ww : Longword) : word [integer];*
***Function** LoWord (ii : LongInt) : integer [word];*

a:= loWord (i);

4.10.7.9 LOWORD (Assignment)

assignment to the Low Word of a LongWord

LOWORD (long):= word;

4.10.7.10 HINIBBLE

returns the High-nibble of a byte (higher 4bits)

***Function** HiNibble (b : byte|int8) : byte|int8;*

4.10.7.11 HI (Function)

returns most significant byte of a 16bit value

***Function** Hi (w : word) : byte;*
***Function** Hi (i : integer) : byte;*

a:= hi (i);

4.10.7.12 HI (Assignment)

assignment to the High byte of a word

HI (word):= byte;

4.10.7.13 HIWORD (Function)

returns the High word of a 32bit value (LongInt or LongWord)

Function *HiWord (ww : Longword) : word [integer];*
Function *HiWord (ii : LongInt) : integer [word];*

a:= hiWord (i);

4.10.7.14 HIWORD (Assignment)

assignment to the High Word of a LongWord

HIWORD (long):= word;

4.10.8 ABS

Calculates the absolute value of an Int8, Integer, Longint, Int64, Fix64 or Float value

Function *Abs (i : integer) : integer;*
Function *Abs (f : float|fix64) : float|fix64;*

a:= abs (a);

4.10.9 Diff8, Diff16, Diff32, Diff64

Calculates the absolute difference of two whole positive numbers.

Function *Diff8(b1, b2 : byte) : byte;*
Function *Diff16(w1, w2 : word) : word;*
Function *Diff32(lw1, lw2 : longword) : longword;*
Function *Diff64(lww1, lww2 : word64) : word64;*

4.10.10 Negate

The negative value (Two’s Complement) of a Byte, Int8..Longword, LongInt, Int64, Fix64 or Float value

Function *Negate (v : type) : type;*

a:= Negate (a);

4.10.11 INC

Variables only increment for byte, int8, word, integer, longword and longint. Argument is wrapped if the limits are exceeded.

Procedure *Inc (var v [, step] : type);*

inc (a);

4.10.12 INCTOLIM

***Function** IncToLim (**var** v : ordinal [, limit : ordinal[; val : ordinal]]) : boolean;*

The argument "v" is incremented, provided that "v" has not reached it's natural limit.
If the optional parameter "limit" is given, then this serves as the limit. If the function was successful, this means there was an increment, and the function returns true. Otherwise it returns false.
The optional parameter "*val*" specifies the increment value.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint
The function is extremely fast and short. It is very well suited for loop implementations.

```
var i : integer;
repeat
 ...
until not IncToLim (i, 1000);
```

The loop will be repeated until "i" becomes the value 1000.

4.10.13 INCTOLIMWRAP

***Function** IncToLimWrap (**var** value, lim, pres : type) : boolean;*

Increments the variable "value" by 1. If this exceeds the value of "lim" the variable "value" is reset to the content of "pres" and the result returns true. Otherwise the result is false.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint

4.10.14 DEC

Variables only decrement for byte, Int8, word, integer, longword and longint. Argument is wrapped if the limits are exceeded.

***Procedure** Dec (**var** v [, step] : type);*

dec (b);

4.10.15 DECTOLIM

***Function** DecToLim (**var** v : ordinal [, limit : ordinal[; val : ordinal]]) : boolean;*

The argument "v" is decremented, provided that "v" has not reached it's natural limit.
If the optional parameter "limit" is given, then this serves as the limit. If the function was successful, this means there was a decrement, and the function returns true. Otherwise the function returns false.
The optional parameter "*val*" specifies the decrement value.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint
The functions is extremely fast and short. It is very well suited for loop implementations.

```
var i : integer;

while DecToLim (i) do
  ...
endwhile;
```

The loop will be repeated until "i" becomes the value -32768.

4.10.16 DECTOLIMWRAP

***Function** DecToLimWrap (**var** value, lim, pres : type) : boolean;*

decrements the variable "value" by 1. If this exceeds the value of "lim" the variable "value" is reset to the content of "pres" and the result becomes true, otherwise false.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint

4.10.17 VALUETRIMLIMIT

***Function** ValueTrimLimit (value, vmin, vmax : type) : type;*

compares the content of "value" to the two limits "vmin" and "vmax", where vmin must always be smaller than vmax. If one of the two limits is exceeded the result becomes the content of this limit, otherwise the origin content of value is returned.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint, Word64, Int64, Fix64, Float

4.10.18 VALUEINTOLERANCE

***Function** ValueInTolerance (value, ref, tol : type) : boolean;*

compares the content of "value" to the limit "vmin" which is build from (ref - tol) and "vmax", build from (ref + tol). If one of the two limits is exceeded the result returns false. Otherwise it returns true.
Type = Byte, Int8, Word, Integer, Longword, Longint, Float

4.10.19 VALUEINTOLERANCEP

***Function** ValueInToleranceP (value, ref : type; tol : byte) : boolean;*

compares the content of "value" with the limit "vmin" which is build from (ref - (ref div 100) * tol) and "vmax", build from (ref + (ref div 100) * tol). If one of the two limits is exceeded the result is false. Otherwise it is a true.
The value "tol" must be in the range of 0..100 because it is used as "percent". This function is the same as the function "*ValueInTolerance*" except that here the tolerance is not absolute but relative in percent.
Type = Byte, Int8, Word, Integer, Longword, Longint, Float

4.10.20 VALUEINRANGE

***Function** ValueInRange (value, vmin, vmax : type) : boolean;*

compares the variable "value" with the two limits "vmin" and "vmax" where vmin must be smaller than vmax. If value exceeds one of two limits the function returns False. Otherwise it returns true.
Type = Enum, Byte, Int8, Char, Word, Integer, Longword, Longint, Word64, Int64, Fix64, Float

4.10.21 MULDIVBYTE

With division of bytes the result is imprecise in many cases. Only with the help of a trick it's possible to multiply a byte by a non-integer value. The following is not possible, normally:

*b:= b * 0.2;*

But one can replace the above by:

*b:= (b * 10) **div** 50;*

This works in many cases, but fails if the result of the multiplication is greater as the bounds of a byte (0..255).

*b:= (100 * 100)* ***div*** *250;*

The multiplication results in an byte-overflow and the total result is completely wrong. To avoid this problem, one can do the whole operation in word. But this means that the values used must be converted to word, which results in a larger and slower program.

Function *MulDivByte (a1, a2, d : byte) : byte;*

The function calculates the 16bit result of the multiplication and divides this result by the 8bit divisor. This assures that an overflow error is impossible. The result of this function must fit into a byte.

```
bb:= 100;                          // byte
bb:= MulDivByte (ww, 99, 100);     // -> bb:= bb * 0.99
```

4.10.22 MULDIVINT8

Similar function as MulDivByte or MulDivInt but for ShortInt = Int8.

Function *MulDivInt8 (a1, a2, d : Int8) : Int8;*

4.10.23 MULDIVINT

With division of integers the result is imprecise in many cases. Only with the help of a trick it's possible to multiply an integer or Word by a non-integer value.
The following is not possible, normally:

*i:= i * 0.27;*

But one can replace the above by:

*i:= (i * 100)* ***div*** *370;*

This works in many cases, but fails if the result of the multiplication is greater as the bounds of and integer (+/- 32767).

*i:= (1000 * 100)* ***div*** *370;*

The multiplication results in an integer-overflow and the total result is absolutely wrong. To avoid this problem, one can do the whole operation in LongInt. But this means that longints must be imported, which results in a larger and slower program.

Function *MulDivInt (a1, a2, d : integer) : integer;*
Function *MulDivInt (a1, a2, d : word) : word;*

The function calculates the 32bit result of the multiplication and divides this result by the 16bit divisor. This assures that an overflow error is impossible. The result of this function must fit into an integer or Word. The first parameter defines the principal operation. If it is an integer, a signed calculation is executed, otherwise it is an unsigned one.

```
ww:= 1000;                     // word
ww:= MulDivInt (ww, 2, 3);     // -> ww:= ww * 0.666

ii:= -1000;                    // integer
ii:= MulDivInt (ii, 100, 125); // -> ii:= ii * 0.8
```

4.10.24 MulDivLong

This ffunction is the same as MulDivInt above, except that the parameters are LongInt or LongWord.

function MulDivLong(a1, a2, d : longint|longword) : longint|longword;

4.10.25 SQUAREDIVBYTE

Function *SquareDivByte (val, divfact : byte) : byte;*

Calculate the square of a value and divide the result by another value. The advantages of these functions are that an overflow of the square result does not matter

4.10.26 SQUAREDIVINT8

Function *SquareDivInt8 (val, divfact : int8) : int8;*

Calculate the square of a value and divide the result by another value. The advantages of these functions are that an overflow of the square result does not matter

4.10.27 SQUAREDIVINT

Function *SquareDivInt (val, divfact : word|integer) : word|integer;*

Calculate the square of a value and divide the result by another value. The advantages of these functions are that an overflow of the square result does not matter

4.10.28 INTEGRATEB

Function *IntegrateB (oldVal, newVal, fact : byte) : byte;*

Integrate a new value with an existing.
Calculation: *result:= ((oldVal * fact) + newVal)* ***div*** *(fact + 1);*
An overflow in the multiplication cannot happen because the internal maths is done with the next bigger type.

4.10.29 INTEGRATEI8

Function *IntegrateI8 (oldVal, newVal : int8; fact : byte) : int8;*

Integrate a new value with an existing.
Calculation: *result:= ((oldVal * fact) + newVal)* ***div*** *(fact + 1);*
An overflow in the multiplication cannot happen because the internal maths is done with the next bigger type.

4.10.30 INTEGRATEI

Function *IntegrateI (oldVal, newVal : integer; fact : byte) : integer;*

Integrate a new value with an existing.
Calculation: *result:= ((oldVal * fact) + newVal)* ***div*** *(fact + 1);*
An overflow in the multiplication cannot happen because the internal maths is done with the next bigger type.

4.10.31 INTEGRATEW

***Function** IntegrateW (oldVal, newVal : word; fact : byte) : word;*

Integrate a new value with an existing.
Calculation: *result:= ((oldVal * fact) + newVal) **div** (fact + 1);*
An overflow in the multiplication cannot happen because the internal maths is done with the next bigger type.

4.10.32 Even

Tests the value for even. Function returns True if the argument is even.
Only for byte, int8, word, integer, longword, longint, word64, int64

***Function** Even(x : type) : boolean;*

***If** Even(V1) **then** ..*

4.10.33 ODD

Tests the value for odd. Function returns True if the argument is odd.
Only for byte, int8, word, integer, longword, longint, word64, int64

***Function** Odd (x : type) : boolean;*

***If** Odd (V1) **then** ..*

4.10.34 PARITY

Function returns the parity, even/odd of a byte or char. True, if parity is odd

***Function** Parity (**const** b : byte|char) : boolean;*

Bool:= Parity (bb);

4.10.35 ISPOWOFTWO

Function checks the number "n" whether is a power of 2. Valid parameters are Byte..LongInt.

***Function** IsPowOfTwo (n : type) : boolean;*

4.10.36 SIGN

Function returns the sign of a number as a boolean:

***Function** Sign (**const** num : integer[int8, longint, word64, int64, fix64, float]) : boolean;*

If the argument is positive the function returns a true otherwise a false.

4.10.37 SGN

Function, returns the sign of a number. The resulting type is of the same type as the number

***Function** Sgn (**const** num : integer, int8, longin, word64, int64, fix64t, float) : type;*

If the argument is > 0 the function returns a '1'. If the argument is zero the function returns a zero otherwise a '-1'.

4.10.38 PRED

Function, returns the next-lower value of a variable. The type has to be ordinal, for example byte, word, integer. The limits of the type given are not exceeded. There is no “wrap“. The predesessor of Byte 0 is always 0.

***Function** Pred (x : type) : type;*

x:= Pred (y);

4.10.39 SUCC

Function returns the next-higher value of a variable. The type has to be ordinal, for example byte, word, integer. The limits of the type given are not exceeded. There is no “wrap“. The successor of Byte 255 is always 255.

***Function** Succ (x : type) : type;*

x:= Succ (y);

4.10.40 MIN

Returns the lowest possible value of the type.

***Function** Min (x: type) : type;*

x:= min (a);

4.10.41 MAX

Returns the highest possible value of the type.

***Function** Max (x: type) : type;*

x:= max (a);

4.10.42 SIZEOF

Function returns the required memory of an object in bytes.

***Function** SizeOf (x : type) : word;*

```
x:= SizeOf (a);
x:= SizeOf (st1);        {whole memory area of a string}
```

4.10.43 BitCountOf

Function returns the count of bits of an ordinal which have the value of “1”.

***Function** BitCountOf (x : ordinal) : byte;*

n:= BitCountOf (a);

4.10.44 ADDR

```
p:= Addr (a);            {Address of the memory location}
```

Valid operands are only variables, procedures and functions because only these have a physical address.
The result is a **typed** pointer. After the operation 'p' contains the address of 'a'.
The target is usually a pointer.

4.11 System Library - Fix64 (*P*)

Created with the great support from user Avra.

Fix64 type must be imported:
from system **import** ..., Fix64;

Note:
Execution times for some operations (@16MHz):

F1 + F2	speed : 7usec		
F1 - F2	speed : 8usec		
F1 * F2	speed : 250usec		
F1 / F2	speed : 500usec		
Sqr	speed : 250usec		
Sqrt	speed : 0.5msec	result : 5 frac digits	
Fix64Sqrt	speed : 2.2msec	result : 9 frac digits	
Delphi Sin(3.0)	result : 0.14112000806		
AVRco Sin(3.0)	result : 0.141120008		5..8msec

Attention: the function Fix64Sqrt and all trigonometric functions use upto 60 bytes on the Frame!

4.11.1 FIX64 Unit

Compiler switch for Fix64 Library: ***{$Define FIX64_USE_PRECISE_SQRT}***.
If this switch is active then all Fix64 functions which internally have to use SQRT (trigonometric functions) now use the high precise but slow internal SQRT function. Without this switch the much faster but less precise SQRT function is used.
Precise SQRT   9 fractional digits 81435 cycles
Standard SQRT 5 fractional digits   9333 cycles

The following complex Fix64 functions are contained in an unit that must also be imported if needed:
uses uFix64;

Less complex functions (like standard maths) are part of the compiler itself and already available in the *Standard Version* of the AVRco.
(see specified types in chapters “Operators” and “System Library – Standard”).

For those who don’t want to use this unit here is a function which converts a FIX64 to a Float and vice versa:

```
type
  TFix64Overlay = record
                    fix         : fix64;
                    i   [@fix+4]: longint;
                    f   [@fix]  : longword;
                  end;

function FloatToFix64(a : float) : fix64;
var
  Tmp : TFix64Overlay;
begin
  Tmp.i:= Trunc(a);
  if (a <= -2.3283064365386962890625E-10) and (Frac(a) <> 0) then
    Dec(Tmp.i);
  endif;
  Tmp.f:= Trunc(Frac(a) * (float($FFFFFFFF) + 1));
  return(Tmp.fix);
end;
```

```
function Fix64ToFloat(a : fix64) : float;
var
  Tmp[@a] : TFix64Overlay;
begin
  return(float(Tmp.i) + float(Tmp.f) / (float($FFFFFFFF) + float(1)));
end;
```

4.11.2 FIX64 und Delphi

The following functions are for a conversion of Fix64 types in Delphi:

```
const
  FIX_ONE = $100000000; // 1.0 is neutral in multiplication and division of fixed
                        // point numbers
type
  fix64 = int64;

function ExtendedToFix64(const a: extended): fix64;
begin
  result := Round(a * FIX_ONE);
end;

function Fix64ToExtended(const a: fix64): extended;
begin
  result := a;
  result := result / FIX_ONE;
end;
```

4.11.3 Math

***Function** Fix64MulLong (const a: fix64; const b: longint): fix64;*
returns the product of a fix64 and a long integer.

***Function** Fix64MulInt (const a: fix64; const b: integer): fix64;*
returns the product of a fix64 and an integer.

***Function** Fix64DivLong (const a: fix64; const b: longint): fix64;*
returns the quotient of a fix64 diveded by a long integer.

***Function** Fix64DivInt (const a: fix64; const b: integer): fix64;*
returns the quotient of a fix64 diveded by an integer.

***Function** Fix64Mod (const a, modulus: fix64): fix64;*
returns “a mod *modulus*“. Both arguments are fix64.

***Function** Fix64ModInt (const a: fix64; modulus: integer): fix64;*
returns “a mod *modulus*“. *modulus* is here an integer.

***Function** Fix64Odd (const a: fix64): boolean;*
returns *true* if the argument *a* is odd.

***Function** Fix64Even (const a: fix64): boolean;*
returns *true* if the argument *a* is even.

***Function** Fix64Sqrt(const a: fix64): fix64;*
Returns the square root of the argument. **Fast**, but less precise

***Function** Fix64SqrtEx(const a: fix64): fix64;*
Returns the square root of the argument. Slow, but very **precise**

***Function** Fix64Integrate (const aold, anew: fix64; const factor: byte): fix64;*

Integrate a new value with an existing.
Calculation: *result:= ((aold * factor) + anew)* ***div*** *(fact + 1);*
An overflow in the multiplication can happen so be careful with big numbers!

4.11.4 Conversion

Function *Fix64ToLongInt (const a: fix64): longint;*
type cast: converts a fix64 to a long integer.

Function *IntToFix64 (const a: longint): fix64;*
This function converts an ordinal value (Byte…LongInt) into a Fix64.

Function *Fix64ToInt (const a: fix64): integer;*
type cast: converts a fix64 to an integer.

Function *FloatToFix64 (const a: float): fix64;*
type cast: converts a float to a fix64.

Function *Fix64ToFloat (const a: fix64): float;*
type cast: converts a fix64 to a float.

4.11.5 Compare

Function *Fix64ValueInTolerance (const a, aref, atol: fix64): boolean;*
compares the content of "a" to the limit "vmin" which is build from (aref - atol) and "vmax", build from (aref + atol). If one of the two limits is exceeded the result returns false. Otherwise it returns true.

Function *Fix64ValueInToleranceP (const a, aref, atol: fix64): boolean;*
compares the content of "a" with the limit "vmin" which is build from (aref - (aref div 100) * atol) and "vmax", build from (aref + (aref div 100) * tol). If one of the two limits is exceeded the result is false.
Otherwise it is a true.
The value "atol" must be in the range of 0..100 because it is used as "percentage". This function is the same as the function "*Fix64ValueInTolerance*" except that here the tolerance is not absolute but relative in percent.

4.11.6 Logarithm, etc.

Function *Fix64IsPowOfTwo (const a: fix64): boolean;*
returns *true* if “a” is a power of 2.

Function *Fix64Exp (const a: fix64): fix64;*
returns “e” raised to the “a” power, “*e”* is the base of the natural logarithm (2.71828...).

Function *Fix64Ln (const a: fix64): fix64;*
Function *Fix64LogN (const a: fix64): fix64;*
both functions return the base e logarithm of a, “*e”* is the base of the natural logarithm ((2.71828...).

Function *Fix64Log10 (const a: fix64): fix64;*
returns the base 10 logarithm of a.

Function *Fix64Log (const a, base: fix64): fix64;*
returns the base *“base”* logarithm of a.

Function *Fix64Power (const base, exponent: fix64): fix64;*
returns the power *base* ^ *exponent*. “*base*” and “*exponent*” are fix64 types.

Function *Fix64PowerInt (const base: fix64; const exponent: integer): fix64;*
returns the power *base* ^ *exponent*. “*base*” is a fix64 type, “*exponent*” is an integer type.

4.11.7 Trigonometry

Function *Fix64Sin (const radians: fix64): fix64;*
returns the sine of the argument (argument=angle in radians).

Function *Fix64SinD (const degrees: fix64): fix64;*
returns the sine of the argument (argument=angle in degrees).

Function *Fix64Cos (const radians: fix64): fix64;*
returns the cosine of the argument (argument=angle in radians).

Function *Fix64CosD (const degrees: fix64): fix64;*
returns the cosine of the argument (argument=angle in degrees).

Function *Fix64Tan (const radians: fix64): fix64;*
returns the tangent of the argument (argument=angle in radians).

Function *Fix64TanD (const degrees: fix64): fix64;*
returns the tangent of the argument (argument=angle in degrees).

Function *Fix64Cot (const radians: fix64): fix64;*
returns the cotangent of the argument (argument=angle in radians).

Function *Fix64CotD (const degrees: fix64): fix64;*
returns the cotangent of the argument (argument=angle in degrees).

Function *Fix64Sec (const radians: fix64): fix64;*
returns the secant of the argument (argument=angle in radians).

Function *Fix64SecD (const degrees: fix64): fix64;*
returns the secant of the argument (argument=angle in degrees).

Function *Fix64Csc (const radians: fix64): fix64;*
returns the cosecant of the argument (argument=angle in radians).

Function *Fix64CscD (const degrees: fix64): fix64;*
returns the cosecant of the argument (argument=angle in degrees).

Function *Fix64Sinh (const a: fix64): fix64;*
returns the hyperbolic sine of a.

Function *Fix64Cosh (const a: fix64): fix64;*
returns the hyperbolic cosine of a.

Function *Fix64Tanh (const a: fix64): fix64;*
returns the hyperbolic tangent of a.

Function *Fix64ArcSin (const sine: fix64): fix64;*
returns the angle in radians for given sine of that angle.

Function *Fix64ArcSinD (const sine: fix64): fix64;*
returns the angle in degrees for given sine of that angle.

Function *Fix64ArcCos (const cosine: fix64): fix64;*
returns the angle in radians for given cosine of that angle.

Function *Fix64ArcCosD (const cosine: fix64): fix64;*
returns the angle in degrees for given cosine of that angle.

Function *Fix64ArcTan (const tangent: fix64): fix64;*
returns the angle in radians for given tangent of that angle.

Function *Fix64ArcTanD (const tangent: fix64): fix64;*
returns the angle in degrees for given tangent of that angle.

Function *Fix64ArcTan2 (const y, x: fix64): fix64;*
variation of the arctangent function. For any real arguments x and y not both equal to zero, arctan2(x,y) is the angle in radians between the positive x-axis of a plane and the point given by the coordinates (x,y) on it.

Function *Fix64ArcTan2D (const y, x: fix64): fix64;*
variation of the arctangent function. For any real arguments x and y not both equal to zero, arctan2(x,y) is the angle in degrees between the positive x-axis of a plane and the point given by the coordinates (x,y) on it.
Function *Fix64ArcCot (const cotangent: fix64): fix64;*
returns the angle in radians for given cotangent of that angle.

Function *Fix64ArcCotD (const cotangent: fix64): fix64;*
returns the angle in degrees for given cotangent of that angle.

Function *Fix64ArcSec (const secant: fix64): fix64;*
returns the angle in radians of a given secant of that angle.

Function *Fix64ArcSecD (const secant: fix64): fix64;*
returns the angle in degrees of a given secant of that angle.

Function *Fix64ArcCsc (const cosecant: fix64): fix64;*
returns the angle in radians of a given cosecant of that angle.

Function *Fix64ArcCscD (const cosecant: fix64): fix64;*
returns the angle in degrees of a given cosecant of that angle.

Function *Fix64ArcSinh (const a: fix64): fix64;*
returns the angle in radians of a given hyperbolic sine of that angle.

Function *Fix64ArcCosh (const a: fix64): fix64;*
returns the angle in radians of a given hyperbolic cosine of that angle.

Function *Fix64ArcTanh (const a: fix64): fix64;*
returns the angle in radians of a given hyperbolic tangent of that angle.

Function *Fix64RadToDeg (const radians: fix64): fix64;*
returns the degrees value of the argument (argument in radians).

Function *Fix64DegToRad (const degrees: fix64): fix64;*
returns the randians value of the argument (argument in degrees).

Function *Fix64Quadrant (const radians: fix64): byte;*
returns the quadrant (1..4) of an angle in radians.

Note
The unit uFix64 contains many powerful functions which also produce much code. So it is recommended that the **Merlin Optimiser** should be used here.

Examples
A sample program for the Math functions is in the directory **..\E-Lab\AVRco\Demos\Fix64**
A sample program for the Trigonometry functions is in the directory **..\E-Lab\AVRco\Demos\Fix64**

4.12 System Library - Bit Processing

Bit processing is an essential part of controller applications. Pascal only knows the bit-mask,
e.g. ***if** (x **and** 1) > 0 **then** ..*

The remedy is the well-known bit processing of Modula-2 *incl(bit), excl(bit)* and *bit(bit).* For simplification the *TYPE BIT* was introduced (see also the description of *type bit* above). This type can be used for all 5 Bit-functions (Incl, Excl, Toggle, SetBit, Bit).

The declaration of a bit-variable **always** consists of two levels: first the memory location of the variable, in which the bit is located, has to be defined. This happens with a normal VAR-statement:

```
var    Leds[$05] : byte;        or
        bits16      : word;
```

The **type of the memory location** (byte, word) determines if 8 or 16 bits are at the disposal of the programmer. After the declaration of the common variable follows the actual bit-declaration. Thereby the first parameter indicates a memory location, the second parameter indicates the corresponding bit at this location.

```
Const  LedBit2 = 3;
var    port6[6] : byte;
       Led2[@port6, Led2Bit] : bit;

if BIT(Led2) then ...
Toggle(Led2);
```

Bits also can be dynamically generated within the program.

```
Toggle (Leds, 3);              {Bit3  in 8  Bits}
Incl (bits16, 12);             {Bit12 in 16 Bits}
```

Further bits can be accessed as usual with 8051 tools in the way "variable.bit".

```
PortB.0:= true;
bool:= PortA.5;
Toggle(PortC.2);
```

"BIT" must be a constant in the range of 0..7.
This works also with local variables in procedures/functions.

With all bit-write-operations it is also possible to use a number "0" or "1" instead of "False" or "True".

```
PortB.0:= 0;
BitX:= 1;
```

4.12.1 INCL

Set Bit

```
Incl (port6, 3);               {This instruction is identical with}
Incl (Led2);                   {this instructions provided above definition}
```

Under certain conditions using the procedure **SetBit** is preferred.

INCL with BitSets:

Procedure *Incl (SrcDest : BitSet; op : BitSet);*
Where "SrcDest" is the BitSet to change and "op" contains the bits which must be changed.
"op" can be either a BitSet variable of the same type or a BitSet constant "[aa, bb, cc, ...]" of the same type.

XMega and atomic Port manipulation
With the XMegas the port corresponding OUTSET and DIRSET register can be used to set specific bits in the port. The compiler must know this using the statement “PortX.outset:= byte“ or “PortX.dirset:= byte“ :

PortA.outset:= $13;
PortB.dirset:= bb;

4.12.2 EXCL

Reset Bit

```
Excl (Leds, a);          {Leds is a byte-variable}
Excl (b);                {Symbol b is a Bit declaration}
```

Under certain circumstances using the procedure **SetBit** is preferred.

EXCL with BitSets:

Procedure *Excl (SrcDest : BitSet; op : BitSet);*
Where "SrcDest" is the BitSet to change and "op" contains the bits which must be changed.
"op" can be either a BitSet variable of the same type or a BitSet constant "[aa, bb, cc, ...]" of the same type.

XMega and atomic Port manipulation
With the XMegas the port corresponding OUTCLR or DIRCLR register can be used to clear specific bits in the port. The compiler must know this using the statement “PortX.outclr:= byte“ or “PortX.dirclr:= byte“:

PortA.outclr:= $13;
PortB.dirclr:= bb;

4.12.3 TOGGLE

Invert Bit, as Bit, in a BitSet, complete Byte or Boolean

```
Toggle (Leds, 3);  //bit
Toggle (Led2);     // bit
Toggle(byte);
Toggle(Boolean);
```

TOGGLE with BitSets:

Procedure *Toggle (SrcDest : BitSet; op : BitSet);*
Where "SrcDest" is the BitSet to change and "op" contains the bits which must be changed.
"op" can be either a BitSet variable of the same type or a BitSet constant "[aa, bb, cc, ...]" of the same type.

XMega and atomic Port manipulation
With the XMegas the port corresponding OUTTGL register can be used to toggle specific bits in the port. The compiler must know this using the statement “PortX.toggle:= byte“ :

PortA.toggle:= $13;
PortB.toggle:= bb;

4.12.4 SETBIT

Set/Reset Bit

SetBit (BitType, boolean);
SetBit sets, depending on the parameter boolean, the bit, which is described in the first parameter, to 1 or 0.
There is an access to 8 or 16 bits, depending on the used variable.
To find the definition of the type BIT see also *type bit*.

SetBit is a combination of *Incl(bit)* and *Excl(bit)*. So it is **slower** and essential **bigger** (with the number of assembler commands) as a singular *Incl(bit)*, for example. SetBit should only be used, if speed and/or program size are necessary, to replace the following construction:

```
if boolean then
  Incl (bit);
else
  Excl (bit);
endif;
```

Here it is better faster and shorter:

```
SetBit (bit, boolean);
```

but instead of the following construction:

```
SetBit (bit, true);
```

it is better to use this construction:

```
Incl (bit);
```

```
const    a   =  7;
         c   =  5;

var      v1     =  byte;
         Led1   =  [@V1, a];

Function TestB : boolean;
begin
  ...
  return(x);
end;

SetBit (v1, c, TestB);
SetBit (Led1, TestB);
```

SETBIT with BitSets:

__Procedure__ SetBit (SrcDest : BitSet; op : BitSet|Enum; bool : boolean);
Where "SrcDest" is the BitSet to change and "op" contains the bits which must be changed.
"op" can be either a BitSet variable of the same type or a BitSet constant "[aa, bb, cc, ...]" of the same type.
Also the basic underlying enumeration can be used.

```
SetBit (myBitSet, [a, b, c], true);
SetBit (myBitSet, myBitSet1, true);
SetBit (myBitSet, a, false);
```

4.12.5 BIT

Test Bit

```
if Bit (a, 0) then ... ; endif;
if Bit (b) then ... ; endif;
```

4.13 System Library - Diverse System Functions

4.13.1 SYSTEM_RESET

Resets and restarts the whole system. The effect is almost the same as a Hardware Reset, but here some bits within control registers assume a certain value, this is not the case within a system reset. Here interrupts are disabled, followed by a jump to the beginning of the program.
Xmega
A real hardware reset is executed.

If the special function **System_Init** has been defined, it is naturally executed, too.

System_Reset;

4.13.2 DELAY

4.13.2.1 mDelay

Software Delay in msec. The procedure returns after a delay of x msec. The passed parameter has to be between 1 and 65000 (word). Depending on the system the accuracy is about +/-20%. To get an accurate timing **SysTimer** or **SysTimer8** should be used.
Sleep should be used in MultiTasking systems, so there is no wastage of runtime.

***Procedure** mDelay (d : word);*

```
mDelay (100);                {wait for 100 msec}
```

4.13.2.2 uDelay

Software Delay in microseconds x 10. The procedure returns after a passing of n x 10 microseconds. The passed parameter has to be between 1 and 255 (byte). Depending on the system the accuracy is about +/-20%. With CPU-Clocks lower than 2MHz the accuracy is extremely poor.
To get an accurate timing the type **SysTimer** or **SysTimer8** should be used.

***Procedure** uDelay(d : byte);*

```
uDelay(10);                  {waiting for100 usec}
```

4.13.2.3 uDelay_1

Software Delay in 1 usec. "uDelay_1" works precisely only if the CPU Clock is >= 8MHz. If interrupts occur while the Delay is running, the resulting time is stretched, possibly dramatically

***Procedure** uDelay_1 (d : byte);*

4.13.2.4 sDelay

Software Delay in CPU cycles. The procedure returns after a passing of n CPU cycles. The passed parameter has to be between 1 and 255 (byte). An accuracy can not be defined. Useable for very short delays in the micro second range.

***Procedure** sDelay (d : byte);*

```
sDelay (10);                 {wait for about 10 cycles}
```

4.13.3 SYSTIMER

4.13.3.1 SetSysTimer

This procedure loads a **SysTimer** with the passed value. Therefore the interrupt must be disabled and then enabled again. Because of this a continuous writing to a Systimer should be avoided.

```
var  Timer1 : SysTimer8;              {variable of type SysTimer 8bit}

SetSysTimer (Timer1, 50);
```

Also for SysTimer in UpCount mode.

4.13.3.2 SetSysTimerM

```
Procedure SetSysTimerM (tm : SysTimer; time : byte|word);
```

Define the timeout in milli second values. The internal resolution is still in SysTick values.
This means that with a SysTick of 10msec a parameter value of 27 results in a timer value of 30msec.
(TimerValue:= time div SysTickTime).
With a SysTimer8 also floating point SysTick values are allowed, for example 2.5.
The result of the function (in SysTicks) must not exceed 255 ticks.
With the SysTimer (16bit) floating point SysTick times are rounded

4.13.3.3 GetSysTimer

This function reads out a **SysTimer** and returns it's actual value. Therefore the interrupt must be disabled and then enabled again. Because of this a continuous writing to a Systimer should be avoided.

```
var  Timer1 : SysTimer;               {variable of type SysTimer 16bit}

Ww:= GetSysTimer (Timer1);
```

Also for SysTimer in UpCount mode.

4.13.3.4 ResetSysTimer

This procedure resets a **SysTimer** to a zero value. Therefore the interrupt must be disabled and then enabled again. Because of this a continuous writing to a Systimer should be avoided.

```
var  Timer1 : SysTimer8;              {variable of type SysTimer 8bit}

ResetSysTimer (Timer1);
```

Also for SysTimer in UpCount mode.

4.13.3.5 IsSysTimerZero

If SystemTick is imported and a **SysTimer** is defined, then a timer can be polled for zero. Because with each normal access to a timer the interrupt must be disabled and enabled again, which leads to a waste of CPU power and slows down the interrupt system, a better way is to poll the state of such a timer with the function “IsSysTimerZero“. This is much faster and interrupts aren’t disabled. If the timer = 0 the function returns a true, otherwise a false.

```
var  Timer1 : SysTimer;                  {variable of type SysTimer 16bit}

SetSysTimer (Timer1, 50000);

repeat until isSysTimerZero (Timer1);
```

Not for SysTimer in UpCount mode.

4.13.4 LOWER

The function returns the lower of two values. The types of both arguments have to be identical, for example Byte, Int8, word, integer, Longint, Longword, Int64, Word64, Fix64, float.

```
Function Lower (x, y : type) : type;

x:= lower (y, z);
```

4.13.5 HIGHER

The function returns the higher of two values. The types of both arguments have to be identical, for example Byte, word, Int8, integer, Longint, Longword, Int64, Word64, Fix64, float.

```
Function Higher (x, y : type) : type;

x:= higher (y, z);
```

4.13.6 WITHIN

Function, checks against bounds:
The function checks a number against two bounds. The first value is the lower limit, the second value is the value, which has to be checked, and the third is the higher limit. If the second value is within these limits, so it is the result. If it is too low, the result is the lower limit, otherwise it is the higher limit. All types have to be identical, for example Byte, Int8, word, integer, Longint, Longword, Int64, Word64, Fix64, float.

```
Function WithIn (lo, x, hi : type) : type;

x:= WithIn (low, a, high);
```

4.13.7 VAL

In standard Pascal the procedure *Val* converts a string-value into its numeric statement.
This general procedure is very complex and would need much code space in flash.
For that reason *val* is in AVRco Pascal **not** implemented but was replaced by several shorter procedures.
See chapter "System Library –Standard, Character and String Functions".

4.13.8 Block Functions

4.13.8.1 FILLBLOCK

Fills a memory area with a byte or char. **P** can be any pointer. A check of the area for validity does not take place. **Fill** can be a byte or a char.

Procedure *FillBlock p : pointer; cnt : word; fill : byte);*

```
FillBlock (@Start, len, fill);
FillBlock (@array1, SizeOf (array1), 0);
FillBlock (@w1, 2, '1');
```

4.13.8.2 FILLRANDOM

Fills a memory area with a random value. **P** can be any pointer. A check of the area for validity does not take place. The Random function must be imported from the system.

Procedure *FillRandom (p : pointer; cnt : word);*

```
FillRandom (@Start, lenl);
FillRandom (@array1, SizeOf (array1));
FillRandom (@w1, 2);
```

4.13.8.3 COPYBLOCK

Copies a memory area to another. The blocks should not overlap. A check of the area for validity does not take place. Source and dest can be any pointer.

Procedure *CopyBlock(Source, Dest : pointer; len : word);*

```
CopyBlock (@array1, @array2, SizeOf (array1));
CopyBlock (@w1, @w2, 2);
```

4.13.8.4 COPYBLOCKREVERSE

Copies a memory area to another. The blocks should not overlap. A check of the area for validity does not take place. Source and dest must be pointers to the ***iData*** area. The order of the bytes are exchanged, the last one becomes the first, the first one becomes the last etc.

Procedure *CopyBlockReverse(Source, Dest : pointer; len : word);*

```
CopyBlockReverse(@array1, @array2, SizeOf (array1));
CopyBlockReverse(@w1, @w2, 2);
```

4.13.8.5 COMPAREBLOCK

Two memory areas can be compared for equal/same content. If the content is the same a true is returned, otherwise a false.

Function *CompareBlock (**const** addr1, addr2 : pointer; **const** len : word) : boolean;*

<u>Mögliche Bereiche:</u>

RAM	<-->	RAM
EEprom	<-->	EEprom
ROM	<-->	RAM
ROM	<-->	EEprom
RAM	<-->	Eeprom

4.13.9 Pointer Access Outside the Linear Adress Range

Pointers are always 16 bit und there is no information about the memory area where they should point to.
So a pointer implies always an access into the linear CPU address range $0000..$FFFF.
To access the Flash, the EEProm or a Banked Device with a pointer the following functions must be used:

4.13.9.1 FlashPtr

Redirects the access to the Flash

***Function** FlashPtr (p:pointer): pointer;*

```
Ptr1 := @FlashByte;
bb := FlashPtr (Ptr1)^;
```

4.13.9.2 EEPromPtr

Redirects the access to the EEProm

***Function** EEPromPtr (p:pointer): pointer;*

```
Ptr1 := @EEPromByte;
bb := EEPromPtr (Ptr1)^;
```

4.13.9.3 UsrDevPtr

Redirects the access to the User Device

***Function** UsrDevPtr (p:pointer): pointer;*

```
Ptr1 := @UsrDevByte;
bb := UsrDevPtr (Ptr1)^;
```

4.13.9.4 BankDevPtr

Redirects the access to the Banked Device

***Function** BankDevPtr (b:byte; p:pointer): pointer;*

```
Ptr1 := @BankDevByte;
bb := BankDevPtr (2, Ptr1)^;           //bank #2
```

4.13.10 FLUSHBUFFER

Deletes the content of the buffer of a serial interface. As argument *RxBuffer, TxBuffer, RxBuffer1, TxBuffer1, RxBuffer2, TxBuffer2, RxBuffer3, TxBuffer3* are possible.

***Procedure** FlushBuffer (Buffer : tBuffer);*

```
FlushBuffer (RxBuffer);
```

4.13.11 CRC Checksum

4.13.11.1 CRC CHECK

A block of data with the appended CRC-word results in a zero, if this block is again checked by this CRC-function

***Function** CRCcheck (p : pointer; count : word) : word;*

Notes:
This conform to the CCITT Standard: CrcCCITT = x^16+x^12+x^5+1 with a seed value of $0810.
The programmer can build CRC from RAM, EEPROM and FLASH. It is required that the passed pointer to the memory is defined with the address-of-operator @:

xx:= CRCcheck (@EEprom, sizeOf (EEprom));

4.13.11.2 CRC STREAM

A CRC stream can be used to repeatedly add bytes/chars of an Input/Output stream into a CRC sum and finally get a 16bit CRC sum calculated over the whole stream.
For XMegas see also the Standard Driver Manual

Implementation
The driver must be imported:

***Import** SysTick, CRCstream, ...*

Procedures and Functions
The driver provides three functions:

***Procedure** CRCstreamInit (seed : word);*

This function clears the CRC start value to 0 and "seed" is the initial operating value, in most cases it should be $0810.
After the call of this init function the byte/char stream can be continuously added to the checksum with

***Function** CRCstreamAdd (value : byte) : word;*

This function adds the byte always returns the current CRC checksum.

***Function** CRCstreamAddP (ptr : pointer; count : word) : word;*

This function adds a memory block (RAM) always returns the current CRC checksum.

4.13.11.3 FLASH CHECKSUM

The Compiler offers two 16bit checksum calculations at compile-time which can be checked at runtime.
The destination address of the checksum must be defined:

```
Define FlashChkSum = $1ffe;        // Byte address
or
Define FlashChkSum = ProgEnd;      // Program end
```

The checksum will be placed into the absolute address location or at the end of the program. The area of the check starts at address $0000 and continues up to either the program end or up to the destination address. The DEFINE must be used to set the upper checklimit. Please note that the boot area if present can not be checked for several reasons so the check must end below this area. The number counts in bytes.

The function

***Function** CalcFlashCheck : boolean;*

generates at runtime checksum and compares it with the value stored in the Flash.
The result of this compare is returned as ok/true or failed/false.

Note:
This function is not applicable with devices > 128kB Flash. Furthermore the interrupts are disabled while this function runs.

In order to support also devices with more than 128kB and also to limit the time the interrupts are disabled the following function should be used:

```
Function CalcFlashCheck_S(count : word) : byte;
```

This is a so called sequential or partial flash check. It must be called repeatedly until the result is non zero. So the check can be splitted into any partitions and the interrupts are only disabled for a short time.
The driver must be imported with:

```
From System Import FlashCheck_S;
```

The function parameter defines the amount of bytes to be checked.

The function returns a zero if the end is not reached yet. If finished a non-zero result is returned:
1 = check finished and ok
2 = check finished but failed.

After a non zero value is returned the check parameters are setup to default values so that a check can be restarted.

Example:

```
  repeat
    bb:= CalcFlashCheck_S($1000);
  until bb <> 0;
```

If a **BootBlock** is defined a separate boot checksum can be imported:

```
From System Import FlashCheck_B;
```

Then it is possible to execute an extra Flash check over the entire boot area:

```
Function CalcFlashCheck_B: boolean;
```

It is also possible to check the application checksum out of the boot area. Then these Imports and Defines must be present:

```
From System Import …, FlashCheck_A, FlashCheck_S, …;
```

FlashCheck_S imports the checksum generation for the applications area.
FlashCheck_A imports the checksum test in the boot over the application area.

```
Define
         …
         FlashChkSum    = (2 * BOOTRST) -2;  // byte addr of checksum placement
                                             // at app area end, required for FlashCheck_A
```

If the FlashCheck in the Boot over the application is imported with FlashCheck_A so the system must be informed to place the generated checksum into the uppermost/last 2 bytes of the application. Optional other addresses are also possible.This can be done with an absolute byte address ($xxxxx) or symbolic like shown above.

This address must also be introduced to the BootApplication with:

```
Define FlashChkSum    = aaaa;     // Byte address
```

Now the application checksum can be tested out of the boot area:

***Function** CalcFlashCheck_A (count : word) : byte;*

The function parameter defines the amount of bytes to be checked.

The function returns a zero if the end is not reached yet. If finished a non-zero result is returned:
1 = check finished and ok
2 = check finished but failed.

After a non zero value is returned the check parameters are setup to default values so that a check can be restarted.

Example:

```
repeat
  bb:= CalcFlashCheck_A ($1000);
until bb <> 0;
```

A sample program can be found in the Demos directory in “BootCheckSum“.

4.13.11.4 EEPROM CHECKSUM

Calculates the sum of all bytes in the passed area and returns the negated result.

***Function** calcCheckSum (**const** start, end : pointer) : word;*

```
{$EEPROM}
structconst
  eInt     : word   = 1;
  eStr     : string = 'eeprom';
  eWord    : word   = $1234;
  eByte    : byte   = $AA;
  ...
check:= CalcCheckSum (@eStr, @eByte);
```

The address of "eByte" is used as the end-pointer but the value of "eByte" itself is not included into the calculation.

It's also possible to build an EEprom checksum at compile-time and store it into the EEprom as a structured const:

```
{$EEPROM}
structconst
  eInt      : word   = 1;
  eStr      : string = 'eeprom';
  eWord     : word   = $1234;
  eByte     : byte   = $AA;
  eCheck    : word   = CalcCheckSum (@eStr, @eByte);
```

The memory location "eCheck" now contains the checksum of all EEprom bytes from "eStr" (inclusive) to "eByte" (exclusive). A special construction allows to use the destination of the function result as the end pointer with using the "$" sign:

eCheck : word = CalcCheckSum (@eStr, $);

Both operations are only valid if placed in the "StructConst" area of the EEprom.

4.13.12 RANDOM

Function, returns a random number of the type Word. Random must be imported.

From *System* ***import*** *Random…*
Function *Random : word;*

W:= Random;

4.13.13 RANDOMRANGE

Function, returns a random number of the type Word. The value is limited by min and max. Random must be imported.

From *System* ***import*** *Random…*
Function *RandomRange(min, max : word) : word;*

W:= RandomRange(100, 500);

4.13.14 RANDOMSEED

Defines the Seed/startvalue of type word. Must not be 0! Random must be imported.

Procedure *RandomSeed(seed : word);*

RandomSeed($1234);

4.13.15 SQR

Functions, return the square of an ordinal/float/fix64 argument

Function *Sqr (f : float) : float;*
Function *Sqr (f : fix64) : fix64;*

f:= Sqr (f);

4.13.16 SQRT

Functions, return the square root of an ordinal/float/fix64 argument.

Function *Sqrt (i : LongInt) : LongInt;*
Function *Sqrt (ii : Int64) : Int64;*
Function *Sqrt (f : float) : float;*
Function *Sqrt (f : fix64) : fix64;*   *// precision 5 frac digits, 600usec@16MHz*

f:= Sqrt (f);

4.13.17 POW

Function, returns the result of x power of y. The base (x) must always be positive!

Function *Pow (x, y : float) : float;*

f:= Pow (x, y);

4.13.18 POW10

Function, returns the result of 10 power of x

Function *Pow10 (f : float) : float;*

f:= Pow10 (x);

4.13.19 EXP

The functions Exp returns the power of X (float).
The return value is e power of X, and e is the base of the natural logarithm.

Function *Exp (f : float) : float;*

f:= Exp (x);

4.13.20 LogN

The functions LogN and LogN_D return as result the nature logarithm of X.
The log naturalis is based on the Euler number e = 2.71…

Function *LogN(f : float) : float;*

f:= LogN(x);

4.13.21 Log10

The functions Log10 and Log10_D return as result the logarithm to base 10 of X.

Function *Log10 (f : float) : float;*

f:= Log10 (x);

4.13.22 Trigonometrical Functions

4.13.22.1 TAN

The functions return as result the tangent of an angle w (in radians).

Function *Tan (w : float) : float;*

t:= Tan (w);

4.13.22.2 TAND

The functions return as result the tangent of the angle w (in degrees).

Function *TanD (w : float) : float;*

t:= TanD (w);

4.13.22.3 ARCTAN

The functions return the arctangent in radians.

Function *ArcTan (w : float) : float;*

a:= ArcTan (w);

4.13.22.4 SIN

The functions return the sine of the argument.
w is a term of the type float. Return the sine of the angle w in radians.

Function *Sin (w : float) : float;*

s:= Sin (w);

4.13.22.5 SININT

The function returns the Sine of the angle multiplied by the Integer argument.
Very fast and short!!

Function *SinInt (angle, v : integer) : integer;*

4.13.22.6 SININT16

This function calculates the sine of an angle, multiplies the result by 10000 and returns the result as an integer value. The angle must be passed in tenths of a degree (2.5deg -> 25).
The result for the angle 90deg (parameter angle = 900) is then 10000.

Function *SinInt16 (angle : integer) : integer;   // angle in 0.1deg*
*// result:= round (Sin (angle / 10) * 10000);*

Provides much more precise results without needing much more runtime.
Disadvantage of this version:
there must be a sine table in ROM/Flash of about 2kByte size.

4.13.22.7 SIND

The functions return the sine of the argument.
w is a term of the type float. Return the sine of the angle w in degrees.

Function *SinD (w : float) : float;*

s:= SinD (w);

4.13.22.8 COS

The functions return the cosine of the argument.
w is a term of the type float. Return the cosine of the angle w in radians.

Function *Cos (w : float) : float;*

c:= Cos (w);

4.13.22.9 COSINT

The function returns the Cosine of the angle multiplied by the Integer argument.
Very fast and short!!

Function *CosInt (angle, v : integer) : integer;*

4.13.22.10 COSINT16

This function calculates the cosine of an angle, multiply the result by 10000 and return the result as an integer value. The angle must be passed in tenths of a degree (2.5deg -> 25).
The result of the angle 45deg (parameter angle = 450) for the cosine then is 7071.

Function *CosInt16 (angle : integer) : integer;*   *// angle in 0.1deg*
*// result:= round (Cos (angle / 10) * 10000);*

Provides much more precise results without needing much more runtime.
Disadvantage of this version:
there must be a sine table in ROM/Flash of about 2kByte size.

4.13.22.11 COSD

The functions return the cosine of the argument.
w is a term of the type float. Return the cosine of the angle w in degrees.

Function *CosD (w : float) : float;*

c:= CosD (w);

4.13.22.12 DEGTORAD

The functions turn an angular value, which is in degrees, into radians.
360 degrees corresponds to 2 Pi radians.
{ rad := degree * Pi / 180 }

***Function** DegToRad (w : float) : float;*

r:= DegToRad (w);

4.13.22.13 RADTODEG

The functions turn an angular value in radians into degrees.
{ degree := rad * 180 / Pi }

***Function** RadToDeg (w : float) : float;*

w:= RadToDeg (r);

4.13.22.14 ROTATEPNTi

The point(XPo, YPo) is rotated by angle (degrees). The result is returned in XPd, YPd.

***Procedure** RotatePnti (angle, XPo, YPo : integer; **var** XPd, YPd : integer);*

4.13.23 TRUNC, (*P*): TRUNC_D

The functions truncate a value of the type Float/Fix64 to an Integer value.
f is a term of the type Float/Fix64. Trunc returns the type (integer or longint) corresponding to the destination.

***Function** Trunc (f : float|fix64) : integer; {LongInt}*

i:= Trunc (f);

4.13.24 ROUND

The functions round a value of the type Float/Fix64 to a value of the type integer (Byte, Word, Longint, Longword).
f is a term of the type float/fix64. Return an int-value, which describes the value of *f* rounded to the next integer number. If *f* is exactly in the middle of two integer numbers, in the result the number with the highest absolute value is returned.

***Function** Round (f : float|fix64) : integer; {Byte,Word,LongInt,LongWord}*

i:= Round (f);

4.13.25 FRAC

The functions return the fractional part of the argument of x. X is a term of the type float/fix64. The result is the fraction part of x; i.e. Frac(x) = x - Int(x).

Function *Frac (f : float|fix64) : float|fix64;*

f:= Frac (x);

4.13.26 INT

The functions return the integer part of the argument. X is a term of the type Float/Fix64. The result is the integer part of X; i.e., X is rounded to 0.

Function *Int (f : float|fix64) : float|fix64;*

f:= Int (x);

4.13.27 IntToFix64

This function converts an ordinal value (Byte…LongInt) into a Fix64.

Function *IntToFix64(i : ordinal) : fix64;*

F64:= IntToFix64 (x);

4.13.28 GETTABLE

The function GetTable returns a member of a LookUp-Table.

Function *GetTable (t : Table; index : byte) : type;*

x:= GetTable (Table1, b);

4.13.29 SETTABLE

The procedure SetTable changes a member in a LookUp-Table.

Procedure *SetTable (t : Table; index : byte; new : type);*

SetTable (Table1, b, x);

4.13.30 Conversion to Strings

With all this kinds of conversion do not underestimate the frame usage.
This is also true for Processes and Tasks where these functions are used.

e.g.:

ByteToStr	> 12 bytes
IntToStr	> 17 bytes
LongToStr	> 37 bytes !
Int64ToStr	> 70 bytes !!!

4.13.30.1 BYTETOSTR

Converts a numeric 8bit value into a string. The parameter can be an ordinal numeric constant (byte, Int8, Enum) or a variable of this type.

```
Function ByteToStr (b : byte[Int8, Enum]) : string;

const  st  = '1234' + 'R' + #7 + ^L;
var  st1   : string[9];
     bb    : byte;

write (LCDout, ByteToStr (100));
write (SERout, ByteToStr (100:6));   {-> '   100'}
bb:= 10;
st1:= ByteToStr (bb);                { -> '10'}
st1:= ByteToStr (bb:6);              { -> '    10'}
st1:= ByteToStr (bb:6:1);            { -> '   1.0'}
st1:= ByteToStr (bb:6:1:'_');        { -> '___1.0'}
st1:= ByteToStr (bb:6:'_');          { -> '____10'}
```

4.13.30.2 INTTOSTR

Converts a numeric 16bit value into a string. The parameter can be an ordinal numeric constant (integer, word) or a variable of this type.

```
Function IntToStr (i : word) : string;

write (LCDout, IntToStr (100));
write (SERout, IntToStr (i:6:2));    {-> '  1.00'}
st1:= IntToStr (123:4);              {-> ' 123'}
ii:= -1;
st1:= IntToStr (ii);                 {-> '-1'}
st1:= IntToStr (ii:10);              {-> '        -1'}
st1:= IntToStr (ii:10:2);            {-> '     -0.01'}
st1:= IntToStr (ii:10:2:'x');        {-> 'xxxxx-0.01'}
st1:= IntToStr (ii:10:'x');          {-> 'xxxxxxxx-1'}
```

4.13.30.3 LONGTOSTR

Converts a numeric 32bit value into a string. The parameter can be an ordinal numeric constant (Longint, Longword) or a variable of this type.

```
Function LongToStr (ii : longword) : string;

write (LCDout, LongToStr (100000));
write (SERout, LongToStr (ii:6:2));  {-> '  1.00'}
st1:= LongToStr (123456:8);          {-> '  123456'}
Li:= 100;
st1:= IntToStr (Li);                 {-> '100'}
st1:= IntToStr (Li:10);              {-> '       100'}
st1:= IntToStr (Li:10:2);            {-> '      1.00'}
st1:= IntToStr (Li:10:2:'x');        {-> 'xxxxxx1.00'}
st1:= IntToStr (Li:10:'x');          {-> 'xxxxxxx100'}
```

4.13.30.4 FLOATTOSTR

Converts a Floating Point value into a string. The parameter can be a float constant or a variable of this type.

```
Function FloatToStr (f : float) : string;

write (LCDout, FloatToStr (1000.00));
write (SERout, FloatToStr (f:6:2));     {-> '  1.00'}
st1:= FloatToStr (123.456:8);           {-> '     123'}
f:= -100.1;
st:= FloatToStr (f);                    {-> '-100.1'}
st1:= FloatToStr (f:11);                {-> '        -100'}
st:= FloatToStr (f:11:0);               {-> '        -100'}
st:= FloatToStr (f:11:2);               {-> '     -100.10'}
st:= FloatToStr (f:11:2:'=');           {-> '====-100.10'}
st1:= FloatToStr (f:11:'=');            {-> '=======-100'}
st1:= FloatToStr (f:'E');               {-> '-1.001E2'}
st1:= FloatToStr (f:'E':11);            {-> '   -1.001E2'}
st1:= FloatToStr (f:'E':11:'=');        {-> '===-1.001E2'}
```

If no formatting is given "FloatToStr(f)" then the resulting string contains all digits.

If there is one parameter given "FloatToStr(f:n)" then the length of the string is at least "n" characters, if necessary with leading spaces. Digits after the decimal point are discarded. It is the same as with "FloatToStr(f:n:0)"

If two parameters are given the second one can either be numeric or a character.
If numeric it defines the count of the digits after the decimal point.
If it is a character it defines the fill character and there are no digits and no decimal point.
a. FloatToStr(f:n:3) returns a string with the total length of "n" with 3 digits after the decimal point. Leading digits are filled with spaces.
b. FloatToStr(f:n:'x') returns astring with the total length of "n" where leading spaces are replaced by an "x". No decimal digits.

If 3 parameters are given "FloatToStr(f:n:k:'x')" a string with the total length of "n" with "k" decimals is returned. Leading spaces are replaced by 'x'

Attention:
This system function requires additional 20 bytes on the frame.

Note:
The functions *ByteToStr*, *IntToStr*, *LongToStr* and *FloatToStr* accept also byte variables for the digits and decimal parameter.
But please note that range checking by the compiler of these parameters not possible. The programmer himself is responsible for valid values. With illegal parameter unexpected results can occur. Even a system crash is possible

Example for variable parameters:

```
var  digs,
     dec : byte
     ii    : integer;
   ...
st:= IntToStr (ii:digs:dec);
```

4.13.30.5 LONG64TOSTR

Converts a numeric 64bit value into a string. The parameter can be an ordinal numeric constant (Int64, Word64).

***Function** Long64ToStr (**const** ii : Int64|Word64[: **const** len : byte[: **const** space : char]]) : string;*

4.13.30.6 Fix64toSTR

Converts a Fix64 value into a string. The optional parameters int, frac and space format the string.

***Function** Fix64ToStr(f : Fix64[:int : byte[:frac : char] [:space : char]]) : string;*

```
f:= -100.1;
st:= Fix64ToStr (f);             {-> '-100.100000000'}
st:= Fix64ToStr (f:6);           {-> '      -100'}
st:= Fix64ToStr (f:6:0);         {-> '      -100'}
st:= Fix64ToStr (f:6:2);         {-> '    -100.10'}
st:= Fix64ToStr (f:6:2:'=');     {-> '====-100.10'}
st:= Fix64ToStr (f:6:'_');       {-> '_______-100'}
```

If no formatting is given "Fix64ToStr(f)" then the resulting string contains all digits and the fractional part is 9 digits long.

If there is one parameter given "Fix64ToStr(f:n)" then the length of the string is
at least "n" (int digits) characters, if necessary with leading spaces. Digits after the decimal
point are discarded. It is the same as with "Fix64ToStr(f:n:0)"

If two parameters are given the second one can either be numeric or a character. If numeric it defines the count of the digits after the decimal point (fractional part). If it is a character it defines the fill character and there are no frac digits and no decimal point.
a. Fix64ToStr(f:n:3) returns a string with the total length of "n" int digits with 3 fractional digits after the decimal point. Leading digits are filled with spaces.
b. Fix64ToStr(f:n:'x') returns a string with the total length of "n" int digits where leading spaces are replaced by an "x". No decimal digits.

If 3 parameters are given "Fix64ToStr(f:n:k:'x')" a string with the total length of "n" int digits and with "k" decimals (fract part) is returned. Leading spaces are replaced by 'x'

Attention:
This system function requires additional 20 bytes on the frame.

Note:
This function accepts also byte variables for the digits and decimal parameter.
But please note that range checking by the compiler of these parameters not possible. The programmer himself is responsible for valid values. With illegal parameter unexpected results can occur. Even a system crash is possible

4.13.30.7 BOOLTOSTR

Converts a boolean value to it's corresponding string value.
Two functions are implemented. The first converts the boolean argument into the string *'true'* or *'false'*.
The second function returns either the TrueStr or FalseStr, dependant of the value of the boolean argument.

***Function** BoolToStr (bool : boolean) : string;*
***Function** BoolToStr (bool : boolean; TrueStr, FalseStr : string) : string;*

4.13.30.8 BYTETOHEX

Converts a numeric 8bit value into a hex-string. The parameter can be an ordinal numeric constant (byte, Int8, Enum) or a variable of this type.

***Function** ByteToHex (b : byte[Int8, Enum]) : string;*

```
x:= 48;
st1:= ByteToHex (x) + 'h';          {st1 contains '30h'}
```

4.13.30.9 INTTOHEX

Converts a numeric 16bit value into a hex-string. The parameter can be an ordinal numeric constant (integer, word) or a variable of this type.

***Function** IntToHex (i : integer) : string;*

```
st1:= IntToHex (123);               {st1 contains '7B'}
```

4.13.30.10 LONGTOHEX

Converts a numeric 32bit value into a hex-string. The parameter can be an ordinal numeric constant (Longint, Longword) or a variable of this type.

***Function** LongToHex (w : longword) : string;*

```
st1:= LongToHex (123456);           {st1 contains '1E240'}
```

4.13.30.11 LONG64TOHEX

Converts a numeric 64bit value into a hex-string. The parameter can be an ordinal numeric constant (Int64, Word64).

***Function** Long64ToHex (**const** ii : Int64|Word64) : string;*

4.13.30.12 Fix64ToHEX

Converts a Fix64 value into a hex-string.

***Function** Fix64ToHex (**const** f : Fix64) : string;*

4.13.30.13 BYTETOBIN

***Function** ByteToBin (value : byte[Int8}) : string;*

The result of the functions is the representation of the bits of the arguments by '0' or '1' in the resulting string. A byte with the value 5 then results in '00000101'.

4.13.30.14 INTTOBIN

***Function** IntToBin (value : word|integer) : string;*

The result of the functions is the representation of the bits of the arguments by '0' or '1' in the resulting string. A word with the value 257 then results in '0000000100000001'.

4.13.31 BYTETOBCD

***Function** ByteToBCD (b : byte) : byte;*

Real Time Clocks frequently use what is known as *Packed BCD* values:
BCD numbers represented in the highest 4bits are the tens digits and in the lowest 4 bits ones digits.
Each digit can only represent a number of 0..9.
This function converts a byte value into the BCD format. Please note that max. number that can be passed to this function is 99. A value of $10 (16dec) is returned as $16.

4.13.32 WORDTOBCD

***Function** WordToBCD (w : word) : word;*

This function converts a word value into the BCD format. Please note that max. number that can be passed to this function is 9999. A value of $270F (9999dec) is returned as $9999.
In the highest 4bits are the thousands digits, in the next 4bits the handreds digits, then the tens digits and in the lowest 4 bits the ones digits. Each digit can only represent a number of 0..9.

4.13.33 BCDTOBYTE

***Function** BCDtoByte (b : byte) : byte;*

Real Time Clocks frequently use what is known as *Packed BCD* values:
BCD numbers represented in the highest 4bits are the tens digits and in the lowest 4 bits ones digits.
Each digit can only represent a number of 0..9.
This format will be read out.
The function expects a packed BCD value and converts it to a decimal Byte $16 -> $10 (=16dec).

4.13.34 PCU SI-Conversion (*P*)

by Tassilo Heinrich

4.13.34.1 Utility Functions

Function *CountsToVolts (Counts:Word; VRef:Float; Res:word; Gain:Float):Float;*
Converts AD-Counts to Volts.
Volt := CountsToVolts (512, 5.0, 1024,1.0): Float; //= 2.5Volt

Function *MX_B (m:Float; x:Float; b:Float): Float;*
Y = mX+t

Function *ByteToBcd (byteVal : Byte) : Byte;*
Converts Byte to BCD.

Function *BcdToByte (bcdVal : Byte) : Byte;*
Converts BCD to Byte.

4.13.34.2 Temperature

Function *F_CelsiusToKelvin (Cel:Float): Float;*
Converts °C to Kelvin.

Function *F_KelvinToCelsius (Kelvin:Float): Float;*
Converts Kelvin to °C.

Function *F_FahrenheitToCelsius (Fahrenheit:Float): Float;*
Converts Fahrenheit to °C.

Function *F_CelsiusToFahrenheit (Celsius:Float): Float;*
Converts °C to Fahrenheit.

4.13.34.3 Volume

Function *F_LiterToGal (Liter:Float): Float;*
Converts Litres to US Galons.

Function *F_GalToLiter (Gal:Float): Float;*
Converts US Galons to Litres.

Function *F_LiterToCuFt (Liter:Float): Float;*
Converts Litres to Feet^3 .

Function *F_CuFtToLiter (CuFt:Float): Float;*
Converts Feet^3 to Litres.

Function *F_CuFtToCuIn (CuFt:Float): Float;*
Converts Feet^3 to Inches^3.

Cunctios*CuInToCuFt (CuIn:Float): Float;*
Converts Inches^3 to Feet^3.

4.13.34.4 Pressure

***Function** F_PSITomBar (PSI:Float): Float;*
Converts PSI to Bar.

***Function** F_mBarToPSI (mBar:Float): Float;*
Converts Bar to PSI.

***Function** F_mmHgTomBar (mmHg:Float): Float;*
Converts mmHg to Bar.

***Function** F_mBarTommHg (mBar:Float): Float;*
Converts Bar to mmHg.

***Function** F_cmH2OtomBar (cmH2O:Float): Float;*
Converts cmH_2O to Bar.

***Function** F_mBarTocmH2O (mBar:Float): Float;*
Converts Bar to cmH_2O.

4.13.34.5 Length

***Function** F_MeterToFeet (Meter:Float): Float;*
Converts Meter to Feet.

***Function** F_FeetToMeter (Feet:Float): Float;*
Converts Feet to Meter

***Function** F_InTocMeter (Inch:Float): Float;*
Converts Inches to Meter.

***Function** F_cMeterToIn (cMeter:Float): Float;*
Converts Meter to Inches.

***Function** F _ydToMeter (yd:Float): Float;*
Converts Yards to Meter.

***Function** F_MeterToyd (Meter:Float): Float;*
Converts Meter to Yards.

***Function** F_miTokMeter (mi:float): Float;*
Converts Miles to Kilometer.

***Function** F_kMeterTomi (kMeter:Float): Float;*
Converts Kilometer to Miles.

***Function** F_nmiTokMeter (nmi:float): Float;*
Converts Nautical Miles to Kilometer.

***Function** F_kMeterTonmi (kMeter:Float): Float;*
Converts Kilometer to Nautical Miles.

4.13.34.6 Area

***Function** F_SqrMeterToSqrFeet (Meter:Float): Float;*

Converts Meter^2 to Feet^2.

***Function** F_SqrFeetToSqrMeter (Feet:Float): Float;*
Converts Feet^2 to Meter^2.

***Function** F_SqrInToSqrcMeter (Inch:Float): Float;*
Converts Inches^2 to Centimeter^2

***Function** F_SqrcMeterToSqrIn (cMeter:Float): Float;*
Converts Centimeter^2 to Inches^2

***Function** F_SqrydToSqrMeter (yd:Float): Float;*
Converts Yards^2 to Meter^2

***Function** F_SqrMeterToSqryd (Meter:Float): Float;*
Converts Meter^2 to Yards^2

***Function** F_SqrmiToSqrkMeter (mi:float): Float;*
Converts Miles^2 to Kilometer^2

***Function** F_SqrkMeterToSqrmi (kMeter:Float): Float;*
Converts Kilometer^2 to Miles^2

4.13.34.7 Weight

***Function** F_KaratToGramm (Karat:Float): Float;*
Converts Carat to Gram

***Function** F_GrammToKarat (Gramm:Float): Float;*
Converts Gram to Carat

***Function** F_GrainsToGramm (Grains:Float): Float;*
Converts Grains to Gram

***Function** F_GrammToOunces (Gramm:Float): Float;*
Converts Gram to Ounces.

***Function** F_OuncesToGramm (Ounces:Float): Float;*
Converts Ounces to Gram

***Function** F_GrammToOuncesTroy (Gramm:Float): Float;*
Converts Gram to Ounces troy.

***Function** F_OuncesTroyToGramm (OuncesTroy:Float): Float;*
Converts Ounces troy to Gram.

***Function** F_kGrammToStones (kGramm:Float): Float;*
Converts Kilograms to Stones.

***Function** F_StonesTokGramm (Stones:Float): Float;*
Converts Stones to Kilogram.

***Function** F_kGrammToPounds (kGramm:Float): Float;*
Converts Kilogram to Pound.

***Function** F_PoundsTokGramm (Pounds:Float): Float;*
Converts Pounds to Kilograms.

4.13.34.8 Energy

***Function** F_kWToPS (kW:Float): Float;*
Converts Kilowatts to PS.

***Function** F_PSTokW (PS:Float): Float;*
Converts PS to Kilowatts.

***Function** F_CalToJ (Cal:Float): Float;*
Converts Calories to Joule.

***Function** F_JtoCal (J:Float): Float;*
Converts Joule to Calories.

4.13.34.9 Integer Functions

***Function** I_CelsiusToKelvin (Cel:Integer): Integer;*

***Function** I_KelvinToCelsius (Kel:Integer): Integer;*

***Function** I_FahrenheitToCelsius (Fahrenheit:Integer): Integer;*

***Function** I_CelsiusToFahrenheit (Celsius:Integer): Integer;*

4.13.34.10 Constants

ZeroPoint : Float = -273.16;

MSL_Pressure_PSI : float = 14.697;

MSL_Pressure_InHg : float = 29.92;

MSL_Pressure_mBar : float = 1013.25;

Euler : Float = 2.7182818284;

4.13.35 Interpolation

Many sensors and other functions show a nonlinear curve. This means that the relation between an input value and the corresponding output value is not linear.
Examples: PT100, PTC, NTC, light-detectors, and also diodes.
This is only a very small count of nonlinear sensors. Normally the measured result has a fixed relation to the external events, but in many cases this relationship is not linear, but logarithmic, cubic etc. A PT100 shows a resistance of 100 Ohms at 0degC, at 50degC 124Ohms and at 100degC 143Ohms. The relation between temperature and the resistance value is nonlinear.

There are two ways to calculate the temperature from the resistance:
1. With a proper formula, which is usually a complex thing, one can calculate the temperature which corresponds with the resistance.
2. Build a so called LookUp-Table. Insert in steps resistance values and the related temperature values. Access the table with the resistance value as an index. The result is the temperature. If the input value ranges from 100 to 200 there must be 100 value pairs in the table. More difficult is a large span of the input values (0 to 1023). Then the table must have 1024 entries

The following implementation is table based, with paired values (search/result).
The LookUp algorithm searches with a known value in the table until either this value is found or this argument fits between two values.
The search is done with a binary search function for best speed results.

If a proper value(s) is found it will be linearly interpolated. This method allows short tables, dependent of the required accuracy. If the count of the value pairs is relative high, the linear interpolation results in an acceptable accuracy.

4.13.35.1 InterPolX, InterPolY

Function *InterPolX (**const** LookUp : pointer; x: integer; **var** y: integer) : boolean;*
Function *InterPolX (**const** LookUp : pointer; x: longint; **var** y: longint) : boolean;*
Function *InterPolX (**const** LookUp : pointer; x : float; **var** y : float) : boolean;*

Function *InterPolY (**const** LookUp : pointer; y: integer; **var** x: integer) : boolean;*
Function *InterPolY (**const** LookUp : pointer; y: longint; **var** x: longint) : boolean;*
Function *InterPolY (**const** LookUp : pointer; y : float; **var** x : float) : boolean;*

The pointer must point into a table in the ***ROM*** or ***EEprom***. The first argument is the search value. The result is placed into the location of the second argument, if the function was successful.

As a support tool for the creation of the lookup table a Table Generator "CurveGen" is included. With it's help one can interactive and graphically create a curve and then store it into a binary file which can be imported into the application.

Example Program:

An example program can be found in the directory **..\E-Lab\AVRco\Demos\Interpol**.
Here an optical distance/proximity sensor (Sharp) is sampled by the ADC and then linearised.

A Datasheet can be found in **..\E-Lab\DOCs\Sharp.pdf**
A detailed description of the above functions and also of the support tool "CurveGen" is in the *Tools Manual*.
An schematic example can be found in **..\E-Lab\DOCs\NonLinSensSch.pdf**

4.13.36 Moving Average Filter

Build an average for example over the last 16 measure results.
The results are stable values which nevertheless are changing too fast to follow changing input values.
The filter is constructed like an array of Byte/Word/Integer etc. If a new value is inserted, this value replaces the oldest value in the array. By adding all values and then dividing the sum by the value count the resulting average is built.

The filter (Array) must be declared as a variable in standard RAM. Banks, EEprom, procedure-local variables or records etc. are not allowed.
The filter can consist of Bytes, Words, Integer, LongWords, LongInts or Float. The size/count runs from 0 to x - 1, where x is always a power of 2 in the range 4..256. With the declaration the upper limit must be one less than the sample count.

***var** Filter : AVfilter[0..15] **of** integer;*

4.13.36.1 PresetAVfilter

***Procedure** PresetAVfilter (**var** Filter : AVfilter; val : type);*
Populates the entire filter with "val".

4.13.36.2 SetAVfilter

***Function** SetAVfilter (**var** Filter : AVfilter; val : type) : type;*
Replaces the oldest entry with "val" and returns with the new build average value.

4.13.36.3 AddAVfilter

***Procedure** AddAVfilter (**var** Filter : AVfilter; val : type);*
Sometimes it is not necessary that a new average must be build when a new value is inserted.
This function works in the same way as "SetAVfilter" except that no new average value is calculated and returned.

4.13.36.4 GetAVfilter

***Function** GetAVfilter (**var** Filter : AVfilter) : type;*
Computes the current averages without changing the content of the filter.

4.13.36.5 DeclAVfilter

***Function** DeclAVfilter (**var** Filter : AVfilter) : type;*
Calculates the gradient between the oldest and the youngest entry.
The result is always signed. This means that with a Byte, Integer or Word filter the result is always an integer. With a LongWord or LongInt filter the result is always an LongInt

Example Program:

An Example can be found in the directory **..\E-Lab\AVRco\Demos\AVfilter**.

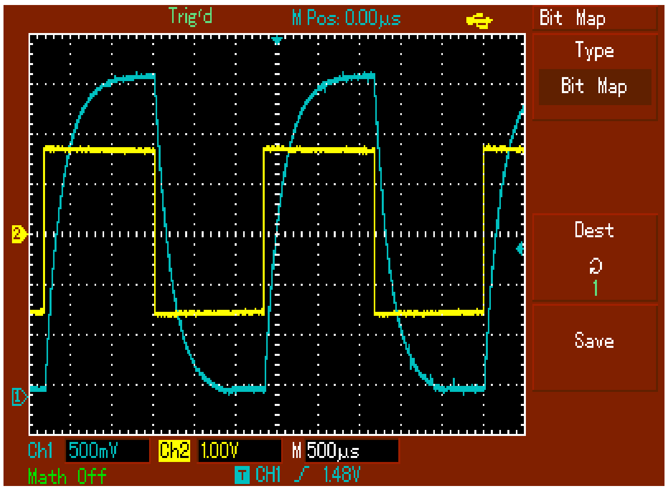
4.13.37 Filter Low and High Pass

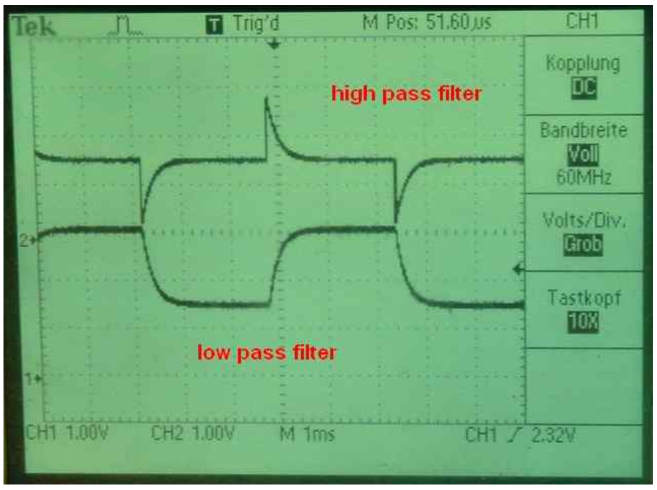
Filters must be imported. The driver exports the following types and functions

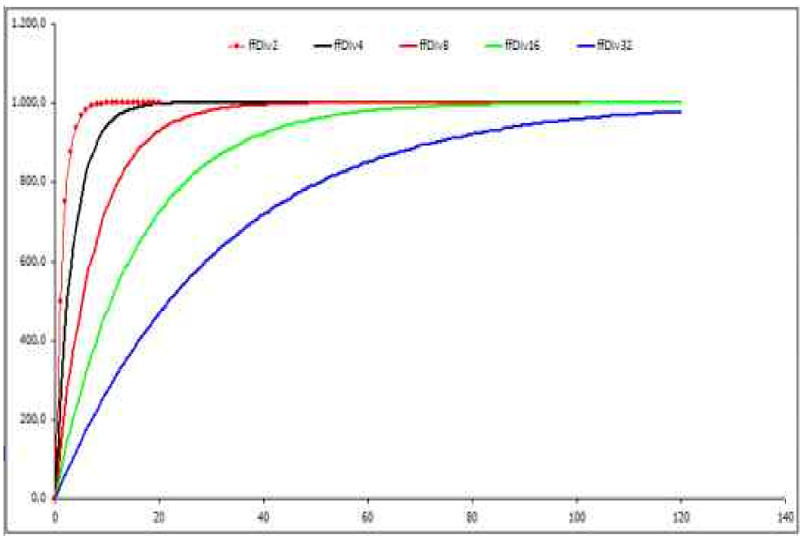
```
type
TFilterFreq = (ffdiv2, ffdiv4, ffdiv8, ffdiv16, ffdiv32, ffdiv64, ffdiv128, ffdiv256);

TFiltData = record
  value    : word;
  Err      : byte;
  HPbias : word;    // optional high pass filter bias
end;

function LowPassFW(var FiltData : TFiltData; NewVal : word; FilterFreq : TFilterFreq) : word;
function HighPassFW(var FiltData : TFiltData; NewVal : word; FilterFreq : TFilterFreq) : word;
```







These filters provide changing filter values, with using resistance as TFilterFreq parameter. Higher parameter value gives higher resistance to changing filter value. Left picture explains everything. Using shifting bits in a word for fast division, and takes just between 354 cycles (ffDiv2) and 423 cycles (ffDiv256) to provide a result quickly.

For example, if we start with FiltData.Value = 0 and want to apply NewValue = 1000 once using ffDiv2, then after first LowPassFW call FiltData.Value will have half of a difference between FiltData.Value and NewValue which is (1000-0)/2=500. Then in next call to LowPassFW difference between FiltData.Value and NewValue is (1000-500)/2=250 and FiltData.Value will be 500+250=750. After next call FiltData.Value will be 750+125 =875, next 875+62=937, and so on and so on (if NewValue is still 1000, of course). So, ffDiv2 will adjust on each call for half of a difference, ffDiv4 will adjust for one fourth of a difference, ffDiv8 one eight of a difference, etc. Therefore ffDiv2 allows filter value to change with much higher frequency then with ffDiv256, which is much, much slower. So, choosing higher TFilterFreq allows us to filter more peaks in analog signal data acquisition and smoother trending data without instant jumps.

Examples can be found in the directory **..\E-Lab\AVRco\Demos\XMega_Filters**.

4.13.38 Network Functions

4.13.38.1 Predefined Types

***type** TIPAddr = **array**[0..3] **of** Byte;*
***type** TMACAddr = **array**[0..5] **of** Byte;*

4.13.38.2 Converting Functions

***Procedure** STRtoIP (IPstr : String[15]; **var** Result : TIPAddr);*
Converts an IP-address string "aaa:bbb:ccc:ddd" to a byte array

***Procedure** STRtoMAC (MACstr : String[17]; **var** Result : TMACAddr);*
Converts a MAC-address string "aa:bb:cc:dd:ee:ff" to a byte array

***Function** IPtoSTR (IP : TIPAddr) : String[15];*
Converts an IP-address array to a string "aaa:bbb:ccc:ddd"

***Function** MACtoSTR (MAC : TMACAddr) : String[17];*
Converts a MAC-address array to a string "aa:bb:cc:dd:ee:ff"

4.13.38.3 Compare Functions

***Function** CompareNet (a1, a2, mask : TIPAddr) : boolean;*
Compares the network part of two IP-address arrays

***Function** CompareIP (ip1, ip2 : TIPAddr) : boolean;*
Compares two IP-address arrays

***Function** CompareMAC (mac1, mac2 : TMACAddr) : boolean;*
Compares two MAC-address arrays

4.13.38.4 Miscellaneous Functions

***Procedure** SwapIPaddr (**var** ip : TIPAddr);*
Mirrors an IP-address. Converts A3-A2-A1-A0 to A0-A1-A2-A3.

***Procedure** SwapMACaddr (**var** mac : TMACAddr);*
Mirrors a MAC-address. Converts A5-A4-A3-A2-A1-A0 to A0-A1-A2-A3-A4-A5.

4.14 System Library - String Formatting

The destination of a string conversion can be a string variable or the procedure WRITE as shown in the description of *ByteToStr* and *IntToStr* above.

A conversion of values (variables) within strings as well as the formatting the output is necessary to handle, for example, an LCD-display.

The conversion routines in co-operation with WRITE solve this need.

The **Formatting** is almost the same as in Turbo Pascal. The parameter after the **first** colon specifies the required overall length. Be careful, as the string can get longer, but not shorter than the format specified. For example "100:0" results in the string "100", so the length is three not zero.

The parameter after the **second** colon is not identical with TurboPascal within *ByteToStr* and *IntToStr.* This parameter specifies the **number of** the post decimal positions. But integers do not possess any decimal positions! That is true, but often integers with a fixed point are used and then there is the problem to get the correct representation.
Take care, the decimal point is counted, too! Thus "100:6:2" results " 1.00" with two leading spaces, so altogether the length is 6.
Leading spaces can be replaced by another character, which must be defined after the last colon.

4.14.1 Decimal Separator

Some of the string conversions above work with a decimal point. This character is by default a "." This constant can be redefined e.g. to a "," to fit for some requirements. For this the following statement must be inserted into the Define Block:

```
Define  DecimalSep = ',';
```

4.14.2 WRITE

String or number output by a procedure with conversion. The first parameter of Write must be a procedure.

The first parameter is called as a procedure (Device) once for every character in the second parameter, passing each character in urn as a parameter to the first procedure. The procedure **must** have the following form:

```
proc (b : byte);
```

A simple output to external devices is possible, because the procedure can access any hardware.

```
const  st  = '1234' + 'R' + #7 + ^L;
var  st1 : string[5];

Write (proc, 'x');                        {'x' is returned }
Write (proc, st1);                        {st1 is returned }
Write (LCDout, ByteToStr (100));
Write (LCDout, st[0]);                    {Length byte}
Write (SerOut, st);                       {Output of compl. string}
Write (LCDout, st[1]);                    {1. char in st}
Write (LCDout, '1234');
Write (SERout, ByteToStr (100:6));        {-> '   100'}
Write (SERout, ByteToStr (100:6:2));      {-> '  1.00'}
Write (SERout, IntToStr (i:6:1));         {-> '  10.0'}
Write (DispOut, #13 + 'Hallo');
```

Write is able to access user-defined device-drivers. Pay attention to some special requirements:

This procedure must have a passing parameter of the type byte or Char, it may not have a local variable and hence no frame. Further only the pseudo-accumulators "_ACCA, _ACCB, _ACCCHI and _ACCCLO = Z" may be used within the procedure. That excludes a calling of other procedures and functions as well as the system functions.

If additional ACCUs for intermediate memory are used anyhow, they have to be saved with help of Push/Pop. These restrictions mean that in practice this procedure must be written completely in assembler. The passing parameter is via _ACCA. The compiler switch {*$NOFRAME*} **or** *{$DEVICE}* is essential

```
{$NOFRAME}
Procedure TestDriver (const b : byte);
begin
  ASM;
    OUT   SPDR, _ACCA;       { SPI Data reg }
  ENDASM;
end;
```

4.14.3 WRITELN

WriteLn appends a CarriageReturn/LineFeed $0D+$0A to the output line.

```
Procedure WriteLn (DeviceFunc : function; var str : string);

WriteLn (SerOut, 'Test');
WriteLn (SerOut);                 // write an empty line
```

4.14.4 READ

Reading of a character or string is similar to write. The first parameter is a function, which returns a character as result. The second parameter is a string variable and the optional third is the number of the bytes, which have to be read, or a delimiter character.

The function Read has three modes of operation:

1. read a string completely. The string gets filled completely
2. read a certain number of characters. The 3rd parameter must be of the type **byte**.
3. read bytes/chars until a limiter char appears that must be specified as 3rd parameter.
   The received delimiter char is appended to the string, but the string length is not incremented, so the delimiter disappears, but is still present (invisible). The 3rd parameter must be of the type char.

I If the string is shorter then the byte number specified, the string gets filled to the whole length. The additional bytes are read, but they are not stored. The length byte of the string is set to the number of the read bytes, but limited to the sizeOf(str).

Function *Read (p : Function;* ***var*** *st : string);*
Function *Read (p : Function;* ***var*** *st : string; count : byte);*
Function *Read (p : Function;* ***var*** *st : string; limiter : char);*

```
Read (func(2), st1, 4);        {st1 is filled}
Read (func, st2, 20};          {st2 is filled with 20 chars}
Read (func, st2, #0};          {st2 is filled until a #0 appears}
```

The function, which is called, **may** have a parameter. In this case it has to be a constant.

4.14.5 READLN

ReadLn reads from a Device until either a CarriageReturn/LineFeed $0D+$0A (#13+#10) is found or the supplied string is full..

Procedure *ReadLn (DeviceFunc : function;* ***var*** *str : string);*

ReadLn (SerInp, st);

4.15 Error Handling

4.15.1 RUNERR

Function. Reading resets the error flag. Many operations set the variable RunErr depending on their result. A RunErr is not absolutely critical, so the program continues run. An error can be an integer-overflow after a multiplication, for example. All operations, which may cause a RunTimeError, set the Flag if necessary. As opposed to the procedure RunTimeError the RunErr can not be switched off and is always active.

The following operations are able to set the flag RunErr:

Division
With a zero-division. In this case the highest possible value is returned.
With a Float the highest possible value is returned.
With a Float underflow zero is returned.

Multiplication
With an Overflow. Result for example of byte $64 x $64 = $10
With a Float Overflow the highest possible value is returned.
With Float underflow zero is returned.

Addition
With an Overflow. Result for example of byte $84 + $84 = $08
With a Float Overflow the highest possible value is returned.

SQR
With a Float Overflow the highest possible value is returned.

SQRT
With Float underflow zero is returned. For a negative argument.

Type Conversion
With overflow. Float to Word, to Int, to LongWord, to LongInt

StrToInt
With a faulty string or Overflow.

StrToFloat
With a faulty string.

Indexed String and Array Manipulation
With a wrong index

4.15.2 RUNTIMEERR

Declaration of the RunTimeError function.

If the switch ***RangeCheck*** is “on“ and the system procedure “RunTimeErr“ is imported, so it is checked after every index access (string/array) and its calculation, if the index is valid. If the index is invalid, the procedure is called and the error code 1 is passed within the working register (_ACCB). The error code 2 specifies an illegal string length-operation.

The size and the runtime speed can be optimized by a considered use of compiler switches (+/-). If a compiler switch is still active at the end of the program (end.), then it is also used for the system library.

If the procedure “RunTimeErr“ is not imported, the two compiler switches have no meaning and they are ignored. Stringcopy statements (e.g. str: = ‘abcd’;) are always processed without overrun. Here an additional watch is not necessary.

Please also pay attention to **StackSize** and **Compiler Switches**.

```
Define  StackSize  = 32, iData;  {32 bytes in iData}


procedure RunTimeErr;
begin
  DisableInts;
  {WatchDog ??}
  {_ACCB contains runtime error number}
  {0 -> software stack or Frame overflow}
  {1 -> string or array index error}
  {2 -> string length error}
  {3 -> reserved}
  {4 -> convert error float -> ordinal}
  {5 -> float overflow}
  {6 -> float underflow}
  ASM;
    ; store error
    MOV    errnum, _ACCB;
    ; do not use high level instr if Stack overflow is possible
    TST    _ACCB;
    ; if _ACCB = zero then stack error
    BRNE   NOTSTACK;
    ; do something with stack error
    NOP
    NOP
    NOTSTACK:
  ENDASM;
end;
```

Attention:
RunTimeErr must not be called from the program itself !!

4.15.3 CLEARRUNERR

Resets a RunTimeError

```
Procedure ClearRunErr;
```

4.16 Multi-Task Functions

The AVRco contains a multitasking-system, which is supported by many functions and procedures.
Upto 15 processes and tasks can be defined. These are called periodically by the scheduler, depending on their priority and their state.

Assignments can be done in the background without co-operation with the main program. The processes and the main program are able to communicate with pipes and semaphores.

Tasks are specialized processes, which are called cyclically by the scheduler, whereby the time interval is constant. So tasks can do jobs that have to run in a fixed time grid, for example the PID-controller.

Nearly all of the following functions that expect a process/task name accept also the identifier "SELF".
So it is possible forl the calling process/task to control itself.

```
Sleep (self, 10);        //suspends the actual process for 10 ticks
```

Further most functions can use the process/task ID in place of the name.

*Sleep (**const** ProzessID, Ticks: word);*

ProcessID must be a numerical constant (see below).

Attention!
All suspend and wait functions can only be used if the Idle-process is imported or the application takes care that never all processes inuding the Main are sleeping, suspended or waiting at the same time.

4.16.1 SLEEP

Process Sleep in ticks. The process or task stays inactive for n ticks and is then “woken up“ by the scheduler.

***Procedure** Sleep (p : process; t : word);*

Sleep (process1, 50);

4.16.2 SUSPEND

The process/task is stopped and stays inactive until there is a “resume“. Because of that a resume has to be executed from outside the procedure or task.

***Procedure** Suspend (p : process);*

Suspend (process1);

4.16.3 SUSPEND ALL

```
SuspendAll (Processes, Tasks);      // disable processes + tasks
SuspendAll (Processes);             // disable processes only
SuspendAll (Tasks);                 // disable tasks only
```

Subsequently the *Idle Process* (if defined) runs. Without *Idle Process* the control switches to the *Main Process*.

4.16.4 RESUME

A process/task, which is de-activated by “Suspend“ or “Sleep“ gets activated.

***Procedure** Resume (p : process);*

Resume (process1);

4.16.5 RESUMEALL

```
ResumeAll (Processes, Tasks);     // resume processes + tasks
ResumeAll (Processes);            // resume processes only
ResumeAll (Tasks);                // resume tasks only
```

4.16.6 PRIORITY

The importance of the run-time part of a process is specified by the priority. The process processes number of system ticks, which is given by the priority without an interruption. The interval of task calls is specified by the priority in case of tasks. A task runs a maximum of one SysTick without an interruption.
See also chapter *Mutitasking Programming – Priority!*

Process	min/max Priority = 1..15	Default=3
Task	min/max Priority = 1..255	Default=5

Attention:
A Task priority of 1 is only for special purposes because this task then is called every SysTick by the Scheduler. Hence no other task must be active at the same time.

***Procedure** Priority (p : process; prio : byte);*

Priority (process1, 12);
Priority (task1, 5);

4.16.6.1 GetPriority

returns the actual priority of a process/task

***Function** GetPriority (prcs : process|task) : byte;*

4.16.7 MAIN_PROC

If MultiTasking is imported, the Main Program also runs as a process and it’s parameters and functions, like processes, can be manipulated (*lock*, *unlock*, *priority*).
To identify the main use the fixed name **Main_Proc**

```
Priority (Main_Proc, 5);          //Default=5

Lock (Main_Proc);
```

4.16.8 IDLE PROCESS

If all processes including the MAIN_PROC are stopped by SLEEP, SUSPEND or WAIT there is no process which consumes the CPU time.
There is optional IDLE process implemented and so this problem doesn't exist anymore. All processes can be stopped without making the system unstable. Without the IDLE process at least MAIN must always run and take the role of the Idle process.
Because this IDLE process also must be able to handle interrupts it needs an environment with stack and frame. Furthermore the code/Flash consumption will be increased somewhat and the Scheduler (process handler) is also minimally increased and slowed down a few usec.
The import is done by an enhanced Scheduler Define.

The standard Define (without IDLE process) is:
***Define** Scheduler = DataArea;*

To import the Idle process the IDLE stack and frame size must be added:
***Define** Scheduler = IdleStack, IdleFrame, DataArea;*   *//use optional idle process*

The minimum stack and frame size is 10 Bytes.

4.16.8.1 On Idle Process

Callback procedure. The Idle process must be defined (with the Scheduler define):

***Procedure** OnIdleProcess;*

If the application implements the procedure

```
Procedure OnIdleProcess;
begin
  ...
end;
```

then "OnIdleProcess" is called with each restart of the Idle process.

Attention:
The Idle process always "lives" only one SysTick (like a Task). So this procedure must not last longer as a SysTick otherwise it will be canceled by the Scheduler.

4.16.9 SCHEDULE

The process/task is suspended here and the control is passed to the scheduler. The scheduler now looks for the next process with the highest priority, and this process gets activated.
***Procedure** Schedule;*

4.16.10 SCHEDULER ON/OFF

The Process-scheduler can be stopped with "SchedulerOff" and continued with "SchedulerOn".
If the Scheduler is stopped, only the current process runs. The Scheduler will be skipped completely.
***Procedure** SchedulerOff;*
***Procedure** SchedulerOn;*

4.16.11 GetSchedulerState

This function returns the current state of the Scheduler, a TRUE if it is running.
***Function** GetSchedulerState : Boolean;*

4.16.12 LOCK

The whole run-time is placed at disposal of a process. Interrupts also get processed. Also applies to the Main_Proc.

Procedure *Lock (p : process);*

Lock (process1);
Lock (Main_Proc);

A *Lock(Process)* disables the scheduling of this process, the scheduler doesn't pass the control to another process but Tasks are not affected. Tasks are treated like interrupts

4.16.13 UNLOCK

A locked process is released, enabling the scheduler again.

Procedure *UnLock (p : process);*

UnLock (process1);
UnLock (Main_Proc);

4.16.14 RESET PROCESS

This function re-initializes a process completely and suspends it.
It can not be applied to the currently running process so at first this process must be supended.

Procedure *ResetProcess (P : Name* | *i : ID);*

4.16.15 SEMAPHORE

4.16.15.1 WAITSEMA

A process/task becomes itself inactive until a special semaphore is > 0. When this happens the scheduler makes the task active again. The semaphore is automatically decremented by one.

Function *WaitSema (s : semaphore [; timeout: word]) : boolean;*

WaitSema (sema1);

Only within a process or task.
TimeOut is optional. If omitted, the process waits until the semaphore is > 0.
The same is true if the TimeOut is set to 0000.
If the value is > 0 the wait functions returns after (TimeOut * SysTicks). The result of the function is true if there was no timeout.
With tasks TimeOut is not possible and is ignored.

WaitSema can only be used if the Idle-process is imported or the application takes care that never all processes inuding the Main are sleeping, suspended or waiting at the same time.

4.16.15.2 ProcWaitFlag

The proper use of WaitSema can save a lot of MultiTasking process time. But this function expects a special variable of type Semaphore which then is decremented by one if it is > 0.

If the semaphore must not be changed by the Scheduler or if a variable of any kind must be watched by the Scheduler (var <> 0) a more general function must be used:

Function *ProcWaitFlag (Flag : var[; timeout : word]) : boolean;*

Here the variable Flag can be of any type. Unlike WaitSema, this variable will not be changed by the function. The other rules are the same as with WaitSema.

4.16.15.3 SETSEMA

The content of the semaphore is set to the required value.

Procedure *SetSema (sema : semaphore; v : byte);*

4.16.15.4 INCSEMA

A semaphore is incremented by one.

Procedure *IncSema (s : semaphore);*

IncSema (sema1);

4.16.15.5 DECSEMA

A semaphore is decremented by one. If the decrement was successful (Sema was > 0) a true is returned, otherwise a false.

Function *DecSema (s : semaphore) : boolean;*

DecSema (sema1);

4.16.15.6 SEMASTAT

Returns the content of a semaphore.

Function *SemaStat (s : semaphore) : byte;*

b:= SemaStat (sema1);

4.16.16 PIPES

4.16.16.1 WaitPipe

A process/task makes itself inactive until a special pipe has data. When this happens the scheduler makes the task/process active again.

***Function** WaitPipe (p : pipe [; timeout: word]) : boolean; {also RxBuffer and RxBuffer1, -2, -3}*

WaitPipe (pipe1);
WaitPipe (RxBuffer);

Only within a process or task.
TimeOut is optional. If omitted, the process waits until the semaphore is > 0.
The same is true if the TimeOut is set to 0.
If the value is > 0 the wait functions returns after (TimeOut * SysTicks). The result of the function is true if there was no timeout. With tasks the TimeOut is not possible and is ignored.

WaitPipe can only be used if the Idle-process is imported or the application takes care that never all processes inuding the Main are sleeping, suspended or waiting at the same time.

4.16.16.2 PipeFlush

Empties a pipe completely.

***Procedure** PipeFlush (p : pipe); {also RxBuffer and RxBuffer1, -2,- 3}*

PipeFlush (pipe1);
PipeFlush (RxBuffer);

4.16.16.3 PipeSend

Inserts an argument into a pipe. The result shows whether the operation was successful. If the pipe is full, a false will be returned.

***Function** PipeSend (p : pipe; v : type) : boolean;*

bo:= PipeSend (pipe1, value);

4.16.16.4 PipeRecv

Fetches an argument from a pipe. The function only returns if the operation was successful. In order to waste no run-time, processes should use “PipeStat“ or better still "WaitPipe".

***Function** PipeRecv (p : pipe) : type;*

val:= PipeRecv (pipe1);

4.16.16.5 PipeStat

The count of the number of parameters is interrogated.

***Function** PipeStat (p : pipe) : byte;*

b:= PipeStat (pipe1);

The function PipeStat can also be used with RxBuffer, RxBuffer1, -2, -3 and TxBuffer, TxBuffer1, -2, -3 of the serial interfaces.

4.16.16.6 PipeFull

The full-status of a pipe is interrogated.

Function *PipeFull (p : pipe) : boolean;*

bo:= PipeFull (pipe1);

4.16.17 PROCESS ID

Some functions or procedures which are used by several processes or tasks have to behave differently, depending on the calling process of task. Such a procedure must be able to establish which process/ task is calling it. To this end following three functions are used.

The main program (Main_PROC) always has the process-ID 0 and has the process name 'Main_Proc'.

4.16.17.1 ISCURPROCESS

Function. Interrogation if the actual process has the ID x. or the Name ‚abc'.

Function *isCurProcess (ID : byte[; Name : ProcName]) : boolean;*

```
bo:= isCurProcess (0);                  { 0 = Main }
bo:= isCurProcess (Main_Proc);
```

4.16.17.2 GETCURPROCESS

The process ID of the actual process/task is interrogated.

Function *GetCurProcess : byte;*

Id:= GetCurProcess;

4.16.17.3 GETPROCESSID

The process ID of a process is interrogated.

Function *GetProcessID (ProcName) : byte;*

Id:= GetProcessID (Main_Proc);

4.16.18 PROCESS STATE

The state of a process or task can be found.
To this end the system exports the enumeration:

tProcessState = (eProcStop, eProcRun, eProcIdle, eProcWait, eProcSleep, eProcLock);

and the function:

Function *GetProcessState (name : process|task) : tProcessState;*

```
if GetProcessState (ProcessA) = eProcSleep then
  ...
endif;

case GetProcessState (Main_Proc) of
  eProcStop :
              inc(bb); |
  eProcRun  :
              inc(bb); |
  eProcIdle :
              inc(bb); |
  eProcWait :
              inc(bb); |
  eProcSleep:
              inc(bb); |
  eProcLock :
              inc(bb); |
endcase;
```

4.16.19 DEVICE LOCK

When using device drivers in a MultiTasking environment sometimes it is necessary to lock these drivers against other processes/tasks. To this end the type "*DeviceLock*" was implemented (only for global Vars and not for Arrays or Records).
Processes which access the Device should use this mechanism to signal other processes that this driver is in use momentarily.

4.16.19.1 SetDeviceLock

Function *SetDeviceLock (d : DeviceLock) : boolean;*

Returns with a true if the Device is free and changes the value into locked.
If the Device is in use the function returns a false.
With a true the process now can use the Device driver. When the job is done it should free the Device with the function *ClearDeviceLock*.

4.16.19.2 ClearDeviceLock

Function *ClearDeviceLock (d : DeviceLock) : boolean;*

Free the Device. If the Device was already released the function returns a "*false*", otherwise it returns a "*true*".

4.16.19.3 TestDeviceLock

The function checks a device lock state without changing it. It returns a "*true*" if the Device is free. Otherwise it returns a "*false*".

Function *TestDeviceLock (d : DeviceLock) : boolean;*

4.16.19.4 WaitDeviceFree

***Function** WaitDeviceFree (s : DeviceLock [; timeout: word]) : boolean;*

With this function the process will be suspended until the Device is released.

TimeOut is optional. If omitted, the process waits until the device is free.
The same is true if the TimeOut is set to 0000.
If the value is > 0 the wait functions returns after (TimeOut * SysTicks). The result of the function is true if there was no timeout. If a timeout occurred the "DeviceLock" is automatically set to *locked*.
With tasks the TimeOut is not possible and is ignored.

WaitDeviceFree can only be used if the Idle-process is imported or the application takes care that never all processes inuding the Main are sleeping, suspended or waiting at the same time.

```
var DevSema : DeviceLock;

Procedure Init;
begin
  ClearDeviceLock(DevSema);                    // first free of the device
  ...
end;

Process CheckDevice(32,64 : idata);
begin
  WaitDeviceFree(DevSema);
  // enter the device driver
  ....
  // free the device driver
  ClearDeviceLock(DevSema);
  ...
end;
```

4.16.20 Stack and Frame Usage

4.16.20.1 GETSTACKFREE

Get the Stack usage of processes at runtime.
The function returns a word with the minimum count of unused bytes in the Stack so far.

***Function** GetStackFree (p : Process)   : word;*

```
ww:= GetStackFree (Main_Proc);
ww:= GetStackFree (Proc1);
```

4.16.20.2 GETTASKSTACKFREE

Get the Stack usage of tasks at runtime.
The function returns a word with the minimum count of unused bytes in the Task Stack so far.

***Function** GetTaskStackFree : word;*

```
ww:= GetTaskStackFree;
```

4.16.20.3 GETFRAMEFREE

Get the Frame usage of processes at runtime.
The function returns a word with the minimum count of unused bytes in the Frame so far.

Function *GetFrameFree (p : Process)   : word;*

ww:= GetFrameFree (Main_Proc);
ww:= GetFrameFree (Proc1);

4.16.20.4 GETTASKFRAMEFREE

Get the Frame usage of tasks at runtime.
The function returns a word with the minimum count of unused bytes in the Task Frame so far.

Function *GetTaskFrameFree : word;*

ww:= GetTaskFrameFree;

4.16.20.5 CHECKSTACKVALID

Checks a stack overflow. When an overflow happend the result is $FFFF.
Without an overflow the result is the free stack size.

Function *CheckStackValid (p : Process|Task) : integer;*

4.16.20.6 CHECKFRAMEVALID

Checks a frame overflow. When an overflow happend the result is $FFFF.
Without an overflow the result is the free frame size.

Function *CheckFrameValid (p : Process|Task) : integer;*

Both functions need the System Import *StackChecks*
If MultiTasking is not implemented so no argument (Process/Task) must be supplied, otherwise with the main program part the argument *Main_Proc* must be used.

4.16.21 SCHEDULER CALL BACK

For debugging it is sometimes necessary to know when the Scheduler needs to switch from one process/task to another.
Because this time depends heavily on the program implementation (count of processes/tasks, priorities etc.) this can only be evaluated at runtime. To help with this there are two predefined procedures:

Procedure *OnSchedulerEntry;*
Procedure *OnSchedulerExit;*

If the application implements these procedures:

```
Procedure OnSchedulerEntry;
begin
  ...
end;

Procedure OnSchedulerExit;
begin
  ...
end;
```

"OnSchedulerEntry" is called every time at the entry into the Scheduler and "OnSchedulerExit" is called every time on exit of the Scheduler.
For example with the simulator it's possible the find out the time the Scheduler used. To do this a breakpoint must be placed on each of these 2 procedures. The heavily varying results depend on the current job the scheduler is doing, e.g. task/process-switch yes/no etc. The resulting time cycle count also represents the total time of the disabled global interrupt whilst scheduling.

<u>Important:</u>

1. There must be no local parameters.
2. If Pascal statements or registers are used, the related registers must be saved before their usage and restored afterwards.
3. Operations which change the CPU flags can only be executed after the status register of the CPU has been saved.

4.17 PID-Controller

Pseudo-Record
A PID-controller is often used in technical applications, for example temperature regulation, servos, rpm-controllers etc.

A PID-controller has to have entry-parameters: the nominal value = '*Required'* and the *actual* value. Four parameters, which are normally only adjusted once, are *pFactor*, *iFactor*, *dFactor* and *sFactor*. The controller-output, which goes to the actuator (heating, motor etc.) is calculated by the function '*Execute'*

The controller type is determined by the two initializing parameters '*iLimit'* and '*dIntVal'*.

iLimit
is of the type LongWord (0..100000) and determines the max. size of the **I**-part (clipping). If iLimit = 0, the **Integral**-value of the controller is not calculated and is omitted (e.g. PD-controller).

dIntVal
is of the type Byte (0, 1, 2, 4, 8, 16, 32) and determines the degree step of the calculation of the **D**-part (gradient). If dIntVal = 0, the **Differential**-value of the controller is not calculated and so is omitted (e.g. PI-controller). If the value = 1, the gradient from the last nominal value to the actual nominal value is calculated. In the remaining cases a corresponding array is framed, which absorbs the history of the last n nominal values. So the gradient can be calculated over a large number of nominal values.

The controller calculates internally with **LongInteger.** So overflows within Execute are not expected.

Imports

As always with AVRco the driver must be imported.

```
Import SysTick, Pids, ..;

Var  Pid1 : PIDcontrol[iLimit, dIntVal];

{Init}
Pid1.pFactor:= 1000;
Pid1.iFactor:= 2500;
Pid1.dFactor:= 678;
Pid1.sFactor:= 10000;

{Run}
Pid1.Actual:= 500;
Pid1.Nominal:= 550;
PWM1:= Pid1.Execute;
```

4.17.1 pFACTOR

PIDname.pFactor:= p;

Charging-factor of the P-value. The Pvalue is the difference between *nominal* and *actual* value, also known as error. The execute operation calculates the internal pValue. *PIDname.pValue*

4.17.2 iFACTOR

PIDname.iFactor:= i;

Charging-factor of the I-value. The I-value is the sum of the differences between *nominal* and *actual* value. In general: integral- value of the errors. The execute operation calculates the internal iValue.*PIDname.iValue*

4.17.3 dFACTOR

PIDname.dFactor:= d;

Charging-factor of the D-value. The D-value is the gradient of the differences between the *nominal* and *actual* value. In general: error gradient.
The execute operation calculates the internal dValue. *PIDname.dValue*

4.17.4 sFACTOR

PIDname.sFactor:= s;

Charging-factor of the output-value (result). The output-value is the sum of P, I and D.
In general: ((P x pFactor) + (I x iFactor) + (D x dFactor)) div sFactor.

4.17.5 NOMINAL

PIDname.Nominal:= i;

Nominal value. Calculates, together with the *actual*, the deviation, which is incorporated in the P, I and D values.

4.17.6 ACTUAL

PIDname.Actual:= i;

Actual-value. Returns, together with the *nominal*, the deviations, which is incorporated in the P, I and D values.

4.17.7 EXECUTE

i:= PIDname.Execute;

Function, which is calculating the output value by using the given values (nominal, actual and factors). The result is an integer value.

4.18 Functions depending on HardWare

4.18.1 ProcClock

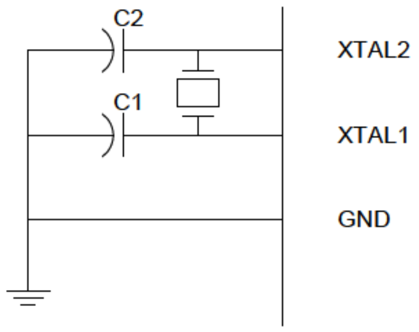
Processor Clock in Hertz. Is needed for Software Delays, for example *Mdelay* and *uDelay,* as well as for the calculation of the SysTick. It **has to be** defined, but not with Xmegas.

Define *ProcClock = 4000000;* *{4Mhz clock}*

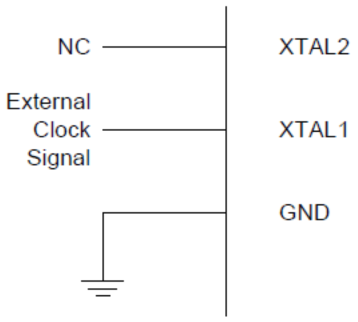
4.18.1.1 Xmega ProcClock

The XMegas don't provide any Oscillator fuses. The Define of ProcClock is not applicable here. So the application must setup the desired values.
Possible OSC types: extXTAL, extClock, ext32kHz, int32Khz, int2MHz, int32MHz
The intXXXhz select an internal oscillator, the extXXX an external type.

extXTAL ext32kHz
min 440kHz max 16MHz



extClock
min 440kHz max 32MHz



Possible additional, mostly optional parameters then define the effective processor and peripheral clock: PLLmul, prescA, prescB, prescC, CLK256, CLK1K, CLK16K, LPM, FailDet, Lock, DFLLint, DFLLext.

With the clock type ***extXTAL*** a start-up time can be given:
CLK256, CLK1K or CLK16K corresponds to 256, 1024 or 16000 clock cycles.

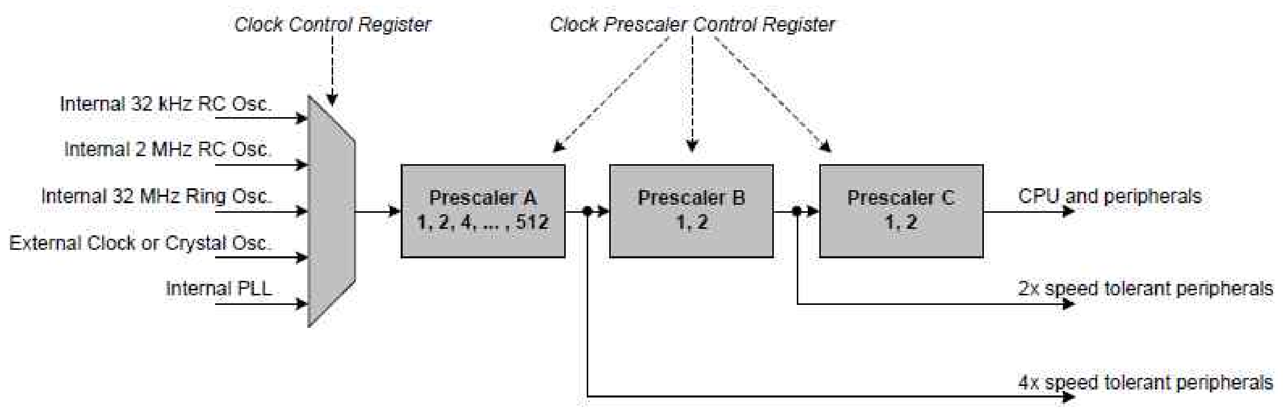
If working with an external clock crystal (32kHz) the oscillator type ***ext32kHz*** must be choosen. This oscillator type provides the option ***LPM***. If given, this oscillator runs in a very low power mode. But then a precision RTC crystal must be used.

With extXTAL and extClock the optional parameter ***FailDet*** can be used. If such an oscillator fails or is not present then the clock system automatically switches to the int2MHz. If this option is active and the clock fails then always a non-maskable Interrupt (NMI) *OSCF_INT* is executed!

With all oscillator types the option ***Lock*** kann be used. This means that after a *RESET* the clock settings are not reset to default values.

The internal oscillatoren can be calibrated automatically and continously. To forces this there are two DFLLs. If the internal 32kHz oscillator should be used for this so the option ***DFLLint*** must be used. If the oscillator type ext32kHz is active then the alternate option ***DFLLext*** can be used.

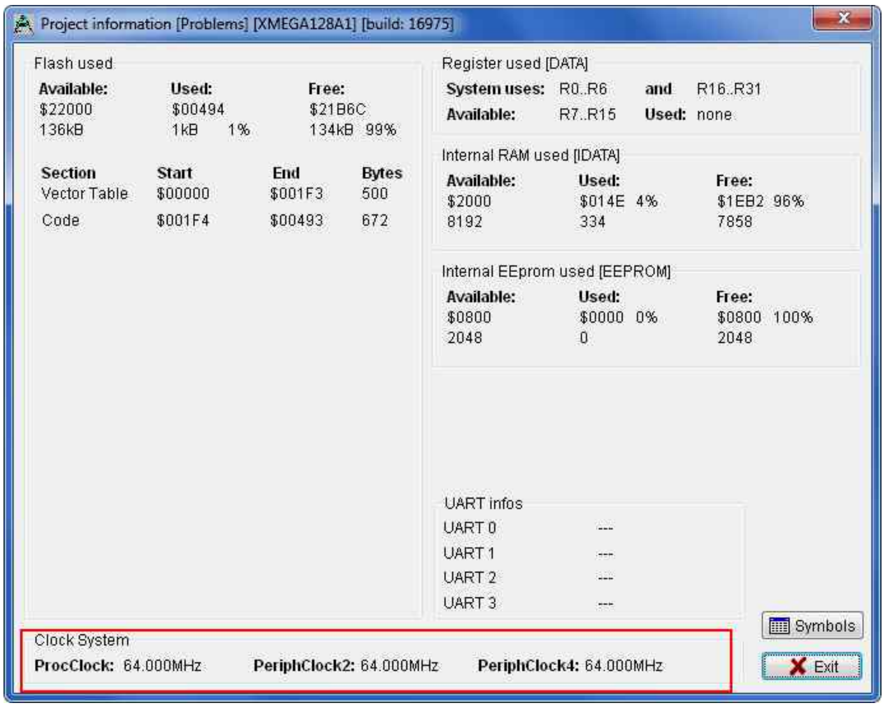
The Xmegas provide an internal PLL (phase locked loop). If the optional parameter ***PLLmul*** is given the output of the PLL is connected to the prescaler A. The PLL multiplies its input clock in the range of 1..31. But be sure that the result of the PLL does not exceed 200MHz. Possible PLL sources are: int2MHz, int32MHz, extClock > 440kHz, extXTAL > 440kHz.
With the int32MHz type this clock is always devided by 4. This means the PLL will be clocked with 8MHz !


Clock Control Register
Clock Prescaler Control Register
Internal 32 kHz RC Osc.
Internal 2 MHz RC Osc.
Internal 32 MHz Ring Osc.
External Clock or Crystal Osc.
Internal PLL
Prescaler A 1, 2, 4, ... , 512
Prescaler B 1, 2
Prescaler C 1, 2
CPU and peripherals
2x speed tolerant peripherals
4x speed tolerant peripherals

All clock types are always connected to the Prescaler A. This one divides the clock by 1 or by 2's potences. Example: prescA = 32. The output is always connected to the HiRes module (extension of waveform generator) = PeriphClock4. The output of the Prescaler B is always connected to the EBI (External bus interface) = PeriphClock2. The output of the Prescaler C controls the rest, CPU and peripherals.

With a combination of the prescalers the system can be tuned optimal. If for example the PLL output is 128MHz and prescA=1, prescB=2 and prescC=2 then the CPU and peripherals run with 32MHz, the EBI with 64MHz and HiRes with 128MHz. If the define of a prescalers is omitted in the Define this prescaler is assigned to the value 1. Examples of OSCtype Defines:

```
 //>> CPU=32MHz, PeripherX4=32MHz, PeripherX2=32MHz
 OSCtype       = int32MHz, PLLmul=4, prescB=1, prescC=1;
```
is the same as:
```
 OSCtype       = int32MHz, PLLmul=4;
 //>> CPU=32MHz, PeripherX4=128MHz, PeripherX2=64MHz
 OSCtype       = int32MHz, PLLmul=16, prescB=2, prescC=2;
 //>> CPU=16MHz, PeripherX4=16MHz, PeripherX2=16MHz
 OSCtype       = int2MHz, PLLmul=8;
 //>> CPU=10MHz, PeripherX4=20MHz, PeripherX2=20MHz
 OSCtype       = extClock=5000000, PLLmul=8, prescA=2, prescB=1, prescC=2, FailDet;
```


Project information [Problems] [XMEGA128A1] [build: 16975]

Flash used

Available:	Used:	Free:
$22000	$00494	$21B6C
136kB	1kB 1%	134kB 99%

Section	Start	End	Bytes
Vector Table	$00000	$001F3	500
Code	$001F4	$00493	672

Register used [DATA]

System uses:	R0..R6	and	R16..R31
Available:	R7..R15	Used:	none

Internal RAM used [IDATA]

Available:	Used:	Free:
$2000	$014E 4%	$1EB2 96%
8192	334	7858

Internal EEprom used [EEPROM]

Available:	Used:	Free:
$0800	$0000 0%	$0800 100%
2048	0	2048

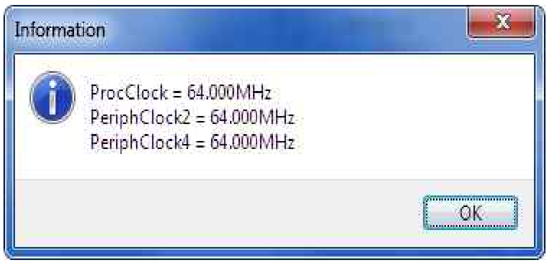
UART infos

UART 0	---
UART 1	---
UART 2	---
UART 3	---

Clock System

ProcClock: 64.000MHz PeriphClock2: 64.000MHz PeriphClock4: 64.000MHz

For checking the clock results after a successful compile the IDE PED32 provides these results. Either in the dialog Project Informations or via a mouse click. To do this the cursor must be placed onto the word *OSCtype* and the CTRL key must be pressed.


Information

ProcClock = 64.000MHz
PeriphClock2 = 64.000MHz
PeriphClock4 = 64.000MHz

If the parameters are set in a way that a clock > 32MHz is reached, then an error message is raised. If such an "over clocking" is desired this error message can be suppressed with the option "**overdrive**".

```
 OSCtype       = int32MHz, PLLmul=8, prescB=1, prescC=1, overdrive;   // 64MHz
```

4.18.2 STACKSIZE, RAMpage

The required stack size (Software Stack) **has to be** defined. It is needed for the allocation and testing of stack- and program inter-variables. Because the stack grows and shrinks, from “above“ to “below“ during the program execution and the used variables are established from “below“ to “above“ by the programmer, the compiler is able to give a warning, if the stack could “grow into“ the variables.

A stack size has to be defined to help the compiler, because the actual size of the stack can only be established during the run-time. With an overlap of program variables and stack (+StackSize) the compiler gives a warning.

The lowest StackSize is 16. The required Ram-area of the stack also has to be specified (iData, xData).

```
Define  StackSize  = 32, iData;        {32 bytes in iData}
```

4.18.3 FRAMESIZE, RAMpage

The required FrameSize (passing parameter and local variable) **has to be** defined. It is needed for allocation and testing of passing parameters (procedures, functions) and local variables.
Because the frame grows and shrinks, from “above“ to “below“ during the program execution and the used variables are established from “below“ to “above“ by the programmer, the compiler is able to give a warning, if the frame could “grow into“ the variables.

A frame size has to be defined to help the compiler, because the actual size of the stack can only be established during the run-time. With an overlap of program variables and frame (+FrameSize) the compiler gives a warning.

The lowest FrameSize is 8. The required Ram-area for the frame also has to be specified (iData, xData).

```
Define  FrameSize = 32, iData;         {32 Bytes in iData}
```

4.18.4 TASKSTACK, RAMpage

The required stack size (all tasks have the same stack-area) **has to be** defined, if tasks have been imported. Is needed for the allocation of the memory.
The lowest value of TaskStack is 8. The required Ram-area of the stack also has to be specified (iData, xData).

```
Define  TaskStack = 32, iData;        {32 bytes in iData}
```

4.18.5 TASKFRAME

The required frame size (all tasks have the same stack-area) **has to be** defined, if tasks have been imported. Is needed for the allocation of the memory.
The lowest value of TaskFrame is 8. The required Ram-area of the frame also has to be specified (iData, xData).

```
Define  TaskFrame = 16;               {16 Byte}
```

4.18.6 SCHEDULER

The required memory page (iData, xData) for the process- and task administration **has to be** defined, if processes or tasks have been imported.

The scheduler does the task- and process administration and switches them over. The scheduler is called by the timer0 action of the Systick. Because it is an interrupt, the global interrupt stays blocked until the scheduler has done its job. This time can be, depending on the jobs of the SysTick, number of processes etc., upto 500usec. If there is the danger that, for example, fast interrupts can not be interrogated, because the global interrupt is still blocked, the global interrupt within the timer0 can be immediately set free by using the additional instruction “interruptible“.

```
Define  Scheduler = iData;                  {Scheduler in iData}
Define  Scheduler = iData, interruptible;   {Scheduler in iData, not with XMegas}
```

4.18.7 SYSTICK

Timer-controlled interrupt for time functions. If SysTick has been imported by the *IMPORT* clause, the required tick time has to be specified. The value can be in the range of 0.1..100 (msec). This value can be expressed in floating point, which allows a precise adjustment for the needs of the application. SysTick is implemented as a hardware interrupt of a timer. Within the AVR normally this is the timer0 (8bit timer). If the selected CPU has the Timer2 (also an 8bit timer) it also can be used for the SysTick. The used timer is at then not useful for the program itself. Manipulations on the timer hardware or register can lead to a crash of the program.

A good value for the tick is 10 (msec). So the interrupt does not make the system *dense* and the jobs of the ticks, for example debouncing of the *SwitchPort* can be settled well. With the AVR *SysTick Timer0 (or Timer2)* is the only interrupt, which is directly used and evaluated by the system. The programmer has to initialize hardware interrupts himself from with the program. These interrupts have to be completely processed in the pre-defined procedure *Interrupt xxx;*.

The Timer is loaded from the variable "*SysTickTime*". The application is able to manipulate the SysTick time within certain limits at runtime by changing this variable.

SysTick is absolutely necessary for many Drivers, so normally **SysTick** always **has to be imported and defined**.

```
Import    SysTick;
Define    ProcClock  = 4000000;        {4Mhz clock }
          SysTick    = 10;             {10msec Tick}
or
          SysTick    = 5.5;            {5.5msec Tick}
or
          SysTick    = 8.0, Timer2;    {8msec Tick}
```

4.18.7.1 XMega SYSTICK

With the XMega types there are some differences concerning the Definition because of the different Timers. Here the SysTick can not be implemented with Timer0 or Timer2 but only with the internal 16bit 32kHz RTC Timer. Its Interrupt can only be defined in 1msec steps, 1, 2, 3, 4 …

The internal resolution of the RTC32K is exactly 1.024msec and very stable. So it is impossible to have exact 1msec steps, but with most cases this is not necessary. An adjust is not possible.

```
          SysTick    = 10;             {10msec Tick, 1..20msec}
```

A fine-tuning by the variable *SysTickTime* is not possible here.
Caused by the internal logic of this timer a SysTick of 1msec has a big error. Here the result is about 1.7msec. Do not use a tick below 5msec

4.18.7.2 XMega SYSTICK without RTC Timer

Some XMegas, such as XMega256A3B, don't provide the 16bit RTC Timer. In ordert o use the SysTick here it is possible to use any oft he standard 16bit timer. This must then be selected with the SysTick define:

```
Define  SysTick      = 10, User;    // 10msec, user = use any regular 16bit Timer
```

Now the SysTick job must be connected to a timer. This can be done by an user implementation of a timer interrupt, where the initialization of the interrupt must be done by the application. In the interrupt service function of this timer interrupt then the SysTick Jobmust be called:

```
{$NoSave}               // standard register save is sufficient
Interrupt TCD0_INTOVF;
begin
  ASM: CALL System.$INTERRUPT_SYSTICK_USER;
end;
```

A **smarter** way is to import a TickTimer and then use its interrupt callback:

```
Import SysTick, …, TickTimer;
…
Define  TickTimer    = Timer_C0;    // use Timer_C0 and no PortPin
…
Procedure onTickTimer;              // onTickTimer(SaveAllRegs); SaveAllRegs not necessary here
begin
  ASM: CALL System.$INTERRUPT_SYSTICK_USER;
end;
…
begin
  EnableInts($87);
  TickTimerTime(10000);     // 10000usec = 10msec
  TickTimerStart;
```

4.18.7.3 OnSysTick

For timing jobs which must be executed through SysTick the procedure "*OnSysTick*" is implemented. Because this is a call-back out of a Timer interrupt the global interrupt is disabled here. Be carefull and don't overload this function in order to avoid long interrupt disable time. "OnSysTick" is called with each SysTick (Timer Interrupt).

```
Procedure OnSysTick;
Procedure OnSysTick (SaveAllRegs);
```

Implementation in the application:

```
Procedure OnSysTick;
begin
  ...
end;
```

or

```
procedure OnSysTick (SaveAllRegs);   // SaveAllRegs is not possible if MultiTasking is used!
begin
  ...
end;
```

Attention:
With MultiTasking import the "*SaveAllRegs*" option must not be used. It's not applicable here and only the standard registers ACCA, ACCB, ACCLO, ACCHI are preserved. If the global switch *{$NOSHADOW}* is used then with non-multitasking all registers are saved in the SysTick.
With non-MultiTasking and the option "*SaveAllRegs*" there are no limits, but remember that saving and restoring all regs takes time

With MultiTasking or non-MultiTasking without the option "*SaveAllRegs*" the following is true:
1. Local parameters are prohibited.
2. The register SREG, _ACCA/R17, _ACCB/R16, _ACCCLO/R30 and _ACCCHI/R31 are saved always. If Pascal statements or other additional registers are used, then these register must be saved manually before their usage and restored afterwards.

If it is impossible to use *SaveAllRegs* then the following procedures can be inserted within onSysTick and all other Callbacks as an alternative:

```
Procedure PushRegs;   // push regs _ACCALO.._ACCFHI
Procedure PopRegs;    // pop  regs _ACCALO.._ACCFHI
```

4.18.7.4 SysTickStop

For special purposes procedure for SysTick manipulation

```
Procedure SysTickStop;              // Disable Timer Interrupt, STOP Timer
```

This function must always be used in conjunction with *SysTickStart.*

4.18.7.5 SysTickStart

For special purposes procedure for SysTick manipulation

```
Procedure SysTickStart;             // Start Timer Interrupt, preset TCNT, Start Timer
```

This function must always be used in conjunction with *SysTickStop*.

4.18.7.6 SysTickRestart

Re-initializes the hardware timer which triggers the SysTick.

4.18.7.7 SysTickDisable

For special purposes procedure for SysTick manipulation

```
Procedure SysTickDisable;           // disable only Timer Interrupt, Timer keeps running
```

This function must always be used in conjunction with *SysTickEnable*.

4.18.7.8 SysTickEnable

For special purposes procedure for SysTick manipulation

```
Procedure SysTickEnable;            // enable only Timer
```

This function must always be used in conjunction with *SysTickDisable*.

4.18.7.9 SystemTime

Sometimes it is necessary to have a system time. This is not a clock but the count of SysTicks elapsed since Startup/Reset. For this the the SysTick must be imported and also an import of the SystemTime:

```
From SysTick Import SystemTime16;   // 16bit word system time
or
From SysTick Import SystemTime32;   // 32bit longword system time
```

This import defines and exports a variable, either as a WORD or LONGWORD. This variable becomes incremented with every SysTick and can be read or written by the application. Because of the activated attribute ***locked*** each acces by the application is executed with disabled interrupts!

```
Var SystemTime16 : word; locked;       // 16bit word system time
or
Var SystemTime32: longword; locked;   // 32bit longword system time
```

4.18.8 ENABLEINTS

Enables the global interrupt. Often it is necessary, that the main program is able to do various initializations (ports etc) before the system tick starts to run. So the global interrupt is not enabled within the system itself , even if interrupts have been imported/defined (SysTick, Serial etc). The application program can and **has to** call the system procedure "*EnableInts*" once so that interrupts are possible.

```
{Program Body = Main}
begin
  ...
  EnableInts;
  Loop
    ...
  EndLoop;
End.
```

Xmega
With the XMegas this function is extended with a parameter which defines the enabled/disabled Interrupt Levels. This value then is written into the PMIC Control register. The standard value is $87 = all levels are enabled.

```
  Procedure EnableInts(level : byte);
```

If subsequent EnableInts must be placed anywhere then the

```
 Procedure EnableIntsX;
```

can be used which avoid further manipulating of the interrupt levels.

4.18.9 START_PROCESSES

Starts processes and tasks. Resets the timer (SysTick) and sets the global interrupt free.
This procedure **replaces** the procedure **EnableInts** if processes or tasks are imported.

It is often necessary for the main program to make several initializations (ports etc.) before the system tick/processes/tasks start. Therefore the system itself does not enable the global interrupt. Even when processes are imported/defined (SysTick, Serial etc.). The application **has to call** the system-procedure "*Start_Processes*" once to enable Interrupts.

```
{Program Body = Main}
begin
  ...
  Start_Processes;
  Loop
    ...
  EndLoop;
End.
```

Xmega
With the XMegas this function is extended with a parameter which defines the enabled/disabled Interrupt Levels. This value then is written into the PMIC Control register. The standard value is $87 = all levels are enabled.

```
  Procedure Start_Processes(level : byte);
```

If further changes of the levels must be done then an *EnableInts(x)* is sufficient.

If subsequent EnableInts must be placed anywhere then the

```
  Procedure EnableIntsX;
```

can be used which avoid further manipulating of the interrupt levels.

4.18.10 DISABLEINTS

Disables the global interrupt. Now interrupts are no longer accepted. Interrupts should not be disabled for too long. Enable the interrupts by EnableInts.

```
Procedure DisableInts;
```

4.18.11 NOINTS, RESTOREINTS

EnableInts and DisableInts have an additional function, they set/reset a system flag, so that the system always knows which interrupt state the application has. If the system must disable the interrupt it can only re-enable it if the interrupt was enabled before the system had disabled it. Similar is true for parts of the application where the actual interrupt state is unknown.

This handling is supported by NoInts and RestoreInts. NoInts disables the interrupt regardless of its actual state but does not change the system flag. RestoreInts then re-enables the interrupt only if the system flag is set. This means that the interrupt was enabled before NoInts was called.
Use these functions very carefully!!

4.18.12 CPUSLEEP

The CPU goes to sleep, i.e. the program is stopped and internal activities of the CPU are switched off. The CPU awakes only with an external interrupt or a reset. The parameter is written into the corresp. Register of the CPU (mcucr) and defines the kind of the sleep mode.

```
Procedure CpuSleep (sleepcmd : byte);

CPUsleep (MCUCR or $30);             // absolute powerdown
```

Sample Program:

A sample program can be found in the directory **..\E-Lab\AVRco\Demos\Sleep**
It has three separate programs that demonstrate the Sleep Modes of the AVR in a simple way.

XMega
With the XMegas the specific control register ***SLEEPCTRL*** is used. Here many different Sleep or PowerDown modes can be selected. Disabling of whole IO-areas, clocks, interrupts etc. are passible. The parameter sleepcmd is written into this register.

4.18.13 HardwareReset XMega only

The CPU executes a real hardware reset, the same as pulling the external Reset pin low.

***Procedure** HardwareReset;*

4.18.14 POWERSAVE

The CPU sleeps n SysTicks. SysTick must be imported. The parameter “mode“ is stored into the control register of the CPU (see also CPUsleep), the parameter “ticks“ defines the time of the PowerDown, counted in SysTick cycles. The parameter “mode“ must provide that at least the timer which is used by SysTick runs and can generate interrupts.
The SysTick Timer wakes the CPU with each tick. The parameter “Ticks“ is decreased by one and if not zero, the CPU again falls into the PowerDown Mode.

***Procedure** PowerSave (**const** mode : byte; **const** ticks : word);*

XMega
With the XMegas the specific control register ***SLEEPCTRL*** is used. Here many different Sleep or PowerDown modes can be selected. Disabling of whole IO-areas, clocks, interrupts etc. are passible. The parameter sleepcmd is written into this register. But note that the SysTick must be disabled.

4.18.15 WATCHDOG

Imports with an “Import“ the WatchDog. With “Define“ the prescaler of the timer is adjusted, if it is available.

```
Import SysTick, WatchDog;

Define  SysTick  = 4000000;        { 4MHz }
        WatchDog = 7;              { WatchDog Prescaler}
```

Possible is also a better readable definition:

```
Define WatchDog = msec16;          // msec32, msec64, msec125, msec250, msec1000, msec2000
```

With the **XMegas** only this Define is applicable:

```
Define WatchDog = msec16;          // msec8, msec16, msec32, msec64, msec125, msec250,
                                   // msec1000, msec2000, msec4000, msec8000
```

4.18.16 WATCHDOGSTART

Initializing and start of the WatchDog, if it is available .
***Procedure** WatchDogStart;*

4.18.17 WATCHDOGSTOP

Stops the WatchDog, if it is available.
***Procedure** WatchDogStop;*

4.18.18 WATCHDOGTRIG

Triggers the Hardware WatchDog of the CPU. The general enabling of the Watchdog depends on the CPU and has to be adjusted with device or import/define if necessary.
***Procedure** WatchDogTrig;*

4.18.19 GETWATCHDOGFLAG

Function. Returns a byte which is the copy of the "MCUSR" register content after the last reset or PowerOn. So the application can determine what causes the last RESET by examining this byte result.
The content and it's bits can have different meaning with different CPUs

Function *GetWatchDogFlag : byte;*

Note: The previous function "*WatchDogFlag*" is replaced by the new "*GetWatchDogFlag*".

4.18.20 {$NOWATCHDOGAUTO}

Compiler switch. Only for special purpose. If active no automatic watchdog retriggers are done in the delays like mDelay etc. and in system caused delays.

4.18.21 ENABLE_JTAGPORT

In order to use JTAG port of a AVR at runtime as a standard IO-port the application must be able to disable and enable the JTAG Port

If JTAG is (via Fuse Bit) enabled the application can control the actual use of these pins at runtime
This function switches the corresponding pins to **JTAG** mode..

Procedure *Enable_JTAGport;*

4.18.22 DISABLE_JTAGPORT

In order to use JTAG port of a AVR at runtime as a standard IO-port the application must be able to disable and enable the JTAG Port.

If JTAG is (via Fuse Bit) enabled the application can control the actual use of these pins at runtime
This function switches the corresponding pins to **"alternate functions"** mode, eg ADC.

Procedure *Disable_JTAGport;*

Attention:
If system drivers (like SysLedBlink) also use these pins occupied from JTAG and have been initialised at Startup, then this setup now gets lost! The application then after executing Disable_JTAGport must re-init the corresponding DDR and Port register!

4.18.23 Debugger Breakpoints

AVR devices with JTAG and XMegas provide a powerful on-chip debug support. Because there are only a very few breakpoints supported at runtime debugging, it is possible to set an unlimited breakPoint count at compile time by inserting breakpoint opcodes into the source. This forces to stop the CPU at this opcode location and then wait for the in-circuit debugger access. Please don’t forget to remove this instruction from the source after the debugging session.

If a CPU is not in Debug mode, then such a breakpoint is treated as a NOP by the CPU.
So a breakpoit can also stay in the source. Such not necessary breakpoints can be switched inactive or active with these two compiler switches:

```
{$Disable_DEBUG_BREAK}
  …
{$Enable_DEBUG_BREAK}
```

Procedure *Debug_Break;*

4.19 XMega Support Functions

The XMega family provides several extensions like Read Fuses, Read/Write LockBits, Read Serial Number, Read User Signature Row. The AVRco system supports these useful functions.

Attention: While executing these functions the Interrupt can be disabled for a short time. Furthermore there can be big change in the System Clock while executing so the UARTs can be influenced in this time when sending or receiving is in progress!

Import
Import *SysTick, … XMegaSupport;*

Function *ReadDeviceID : longword;*
Returns the DeviceID of the controller. XMega128A1 = $001E974C

Function *ReadDeviceRev : char;*
Returns the Device Revision of the controller. Example “G“

Function *ReadFuseByte0 : byte;*
Function *ReadFuseByte1 : byte;*
Function *ReadFuseByte2 : byte;*
Function *ReadFuseByte3 : byte;*
Function *ReadFuseByte4 : byte;*
Function *ReadFuseByte5 : byte;*
Returns the content of a Fuse byte.

Function *ReadLockByte : byte;*
Returns the content of the Lock byte.

Procedure *WriteLockByte(lb : byte);*
Changes the Lock byte. But note that bits can only be changed to 0. 1-bits are ignored!
The LockByte can be only reset by an exteral ChipErase command ($FF).

Function *ReadDevSerNum: word64;*
Computes an 8 byte serial number using the internal Lotnumbers, Wafernumber and Coordinates.

Basic functions for a read out of the ***ProductionRow*** and the ***UserRow***:
Function *ReadProductionRow(loc : word) : byte;*
Function *ReadUserRow(loc : word) : byte;*
Procedure *WriteUserRow(loc : word; b : byte);*

An example program is in the Demos Directory in “XMEGA_Support“.

4.20 XMega UserSignatureRow

In addition to the registers, SRAM, IO-area, Flash and EEprom the XMega family provides another memory type, the UserSignatureRow. This is a separate Flash memory with the size of one Flash Page.
With the smaller types (<128kB) the size is 256 bytes, with the larger (>=128kB) the size is 512 Bytes.

Like the Flash this area is readonly but accesible from the application. It is a not in the Flash area but separate like the EEprom. A chip Erase byt the programmer doesn't erase this memory but it must be extra deleted and rewritten by the programmer. The advantage is that once stored data can not be erased or rewritten by a standard re-programming, provided that the programmer is not instructed to do this:
(checkbox program UserRow).

This property makes this memory perfect suited for serial numbers, calibation data etc. And also data which should never be changed.

Because these data must be available for the programming device it makes sense that the AVRco system can build a corresponding Hex-File. To support this the system must provide (like EEprom) an additional switch in the constant area *{$UserRow}*. Constants placed into this area then can be accessed by the application as constants out of the EEprom, for example.

The AVRco system then generates a Hex-File ***name*.USR** which can be processed by the programmer.
Example:

```
{--------------------------------------------------------------}
{ Type Declarations }
type

{--------------------------------------------------------------}
{ Const Declarations }
const
{$UserRow}
  uSerNum[$1f8]  : word64    = $1234567890ABCDEF;
  urB            : byte      = $AA;
  urW            : word      = $1234;
  urI            : integer   = 1234;
  urLW           : longword  = $12345678;
  urLI           : longint   = -12345678;
  urW64          : word64    = $1234567890AABBCC;
  urI64          : int64     = -123456789054321;
  urSt           : string    = 'abcdefg';
{--------------------------------------------------------------}
{$IDATA}
...
  st:= urSt;
  bb:= urB;
  ww:= urW;
  ii:= urI;
  Lw:= urLW;
  Li:= urLi;
  i64:= urI64;
  w64:= urW64;
  w64:= uSerNum;
```

Attention:
Only numbers and strings are supported in this area, no arrays or records possible.
At the end of such a constant list there must be a memory type change *{$IDATA}*, so that possibly following "normal" constants are not placed into the UserRow.

An example program is in the Demos Directory in "XMEGA_Support".

4.21 EEPROM

Some of the older single chips types have an internal EEprom memory. Most of the newer versions generally have an EEprom.

The problem is that usually access is done with an index- or address-register and additional control registers. This contrasts to the normal addressing within a compiler. At the very least the writing of the EEprom needs additional outlay. An access-implementation in a direct high-level-language by the application program is possible, but it makes no sense, because the generated code would increase. An Inline-Assembler solution is imaginable, but it is not everyone’s taste and also often faulty.

If the chosen processor has an EEprom and is this EEprom registered in the Description-File (xxx.dsc), the the AVRco offers three possibilities for EEprom-access:

4.21.1 Structured Constant

With the compiler switch {$EEPROM} and the instruction **StructConst** the following constants are defined as positioned within the EEprom. An access to the variables into the EEprom then succeeds automatically.

An indirect addressing by a pointer is possible with *EEpromPtr()*.

This method is efficient and very clear and readable, because it can be inserted into the source without any problems. The disadvantage is, that every single byte, which should be accessed, also has to be defined as a constant.

A separate hex-file is generated, which contains the defined constant, and which can be programmed into the CPU by a programmer. See also **StructConst.**

Important:
After the definition of the EEprom StructConst switch back to normal memory with {$DATA} or {$IDATA}.

4.21.2 Variable

With the compiler switch {$EEPROM} and the instruction **VAR** the following variables are defined as located within the EEprom. An access to the variables into the EEprom then succeeds automatically.

An indirect addressing by a pointer is possible with *EEpromPtr()*.

This method is efficient and very clear and readable, because it can be inserted into the source without any problems. The disadvantage that every single byte which should be accessed also has to be defined as a variable.

Important:
After the definition of the EEprom vars switch back to normal memory with {$DATA} or {$*i*Data}.

4.21.3 Memory Block

The EEprom is treated as an one-dimensional array of byte. For this an **EEprom** is pre-defined within the system. With this array there is an access by indexes. But array copy is not possible.

Because the index is a constant or a variable, it is comfortably worked with it. The size of the EEprom array can be established during the run-time by SizeOF(EEprom).

The disadvantage of this method is, that an index is not that meaningful as a name, and it has to be administrated.

Basic EEprom Limitations:
Some Read-Modify-Write operations are not possible.

4.21.4 EEprom Access

All three methods have their own advantages for using the EEprom. A combination of the methods offers a optimal usage. With StartUp for example, the application reads data out of the array into available RAM-variables by a pointer within a loop and among other things they maybe written back later. Within the "normal execution" the EEprom-variable may be used. Look out for unwanted overlapping!

All CPU’s, which have an internal EEprom, assume that during a writing-access to the EEprom the interrupts are blocked. The compiler addresses this issue.
While the internal byte-programming-logic is active there can be no further access to the EEprom. Before there is an access to the EEprom, the state is interrogated, so it is secured. The writing- and reading-routine waits at the beginning for the release of the EEprom.

```
{$DATA}
var
   b1   : byte;
   w1   : word;
   i1   : integer;

{$EEPROM}
var
   be           : byte;
   we           : word;
   ie           : integer;
   el[@we]      : byte;         // low byte
   eh[@we+1]    : byte;         // high byte

{$IDATA}
var
   b2   : byte;
   w2   : word;
   i2   : integer;

b2:= be;               {copy out of eeprom to b2}
W2:= we;               {copy out of eeprom we to w2}
I2:= ie;               {copy out of eeprom ie to i2}
```

4.22 HEAP (*P*)

With the standard version of AVRco and also with many other compilers for embedded applications the memory usage/management is limited to global variables, stack and frame. This means that the memory partitioning is already known at compile-time and not dynamically changeable. This is not a problem in most cases.

In AVRco the memory is allocated from address 0 (register) over the I/O-area upto the iData (or xData) area upward. At the end of the used area there are the stacks and frames. The following memory, if any, is normally not accessible for the program. If there is a need for additional memory at runtime, e.g. for linked lists etc., there is no possibility to provide and use this memory.

With larger systems, e.g. on the PC, the free unused memory can be required and allocated through the heap management. The Profi-version of AVRco there is such a heap management implemented. Dependent on which memory area is defined as the heap (iData, xData), the unused free memory in this area is completely administrated by the heap system.

A special requirement of the heap is that accesses must be done with pointers. Therefore free memory must be requested by the program. The address of the assigned block is returned in a pointer from the heap manager. After the use by the program the memory should be deallocated respectively passed back to the heap manager. Otherwise the memory stays allocated and can't be used from other parts of the program.

It's very important that the address (pointer) at deallocation is the same as with the allocation. Otherwise the deallocation fails and the heap will eventually become is completely allocated and each memory request will fail.

4.22.1 Implementation

Imports
The driver must be imported as usual with AVRco.

```
Import SysTick, Heap, ..;
```

Defines
The memory area which should be used by the heap manager:

```
Define  ProcClock   = 8000000;       {Hertz}
        SysTick     = 10;            {msec}
        StackSize   = $0030, iData;
        FrameSize   = $0030, iData;
        Heap        = iData;
```

4.22.1.1 Functions

Memory allocation and deallocation through the heap management functions:

***Function** GetMem (**var** ptr : pointer [; **const** size : word]) : boolean;*
Requests memory from heap with the optional value "size". If size is not passed, there will be a block of memory allocated which the structure needs, where the "ptr" points to. If ptr is a pointer to string[10], so 11 Bytes are allocated. The variable "ptr" can be a pointer of any type.

The function returns a true, if there was sufficient memory for the requested block. The variable ptr returns the address of this memory block. If the function fails, a false is returned and the variable ptr returns the value NIL.

Attention:
The optional parameter “size” should only be used with care and is only intended for special cases.

***Function** FreeMem (**var** ptr : pointer) : boolean;*
Deallocates used memory. The size block of memory deallocated is as large as the structure needs, where the “ptr“ points to. If ptr is a pointer to string[10], so 11 Bytes are deallocated. The variable ptr should be the same which was used when this block was requested by GetMem.

If the memory could be deallocated, this means the above conditions are fulfilled, a true is returned, otherwise a false. A false should **never** occur with correct programming. The variable ptr is always returned with NIL.

***Function** GetMemAvail: word;*
Returns the total amount of free memory. With repeatedly allocation and deallocation it’s possible the free memory is partitioned in several blocks.
The returned value doesn’t say anything about whether it’s available in one piece or not.

***Function** GetLargestBlock: word;*
Returns the value of the largest one-piece unfragmented memory block.

Remarks:
Pointers in general and with the heap in particular are dangerous (Hello C). But if one keeps in mind a few rules there can be new and streamlined programming possibilities (linked list for example).

1. **Always** use **typed** pointers for GetMem and FreeMem.
2. **Always** use the **same** pointer variable for GetMem and the corresponding FreeMem.
3. **Avoid** the usage of the parameter **size**. It’s unnecessary with typed pointers.
4. **Avoid manipulating** the pointer itself.
5. Unused memory should be **deallocated** at **soon** as possible, so it can be used again.
6. **Observe** the boolean **result** of GetMem. If **false** there is simply no more memory.
7. If there is a **false** result with FreeMem, you have programmed a big **bug**.
8. Note that with each allocation additional 4 bytes are required for administration purpose.
   So a request for one byte (with Pointer to Byte) a total of 5 bytes are used.
9. Always use the **Simulator** to test and debug your program.
10. If you think it’s necessary to use the parameter **size**, define the amount of used bytes of a type or structure with the system function **sizeOf()**

In general, be careful with pointers ☺

4.22.1.2 Example

```
Program AVR_Heap;

Device = 90S8515, VCC=5;

Import SysTick, Heap;

From System Import ;

Define
       ProcClock    = 6000000;       {Hertz}
       SysTick      = 10;            {msec}
       Heap         = iData;
       StackSize    = $0020, iData;
       FrameSize    = $0010, iData;

Implementation

{$IDATA}
{--------------------------------------------------------------}
{ Type Declarations }
type
  tStr10    = string[10];
  tArr      = array[0..23] of byte;
  tRec      = record
                rb   : byte;
                rw   : word;
              end;

  tpStr     = pointer to tStr10;
  tpArr     = pointer to tArr;
  tpRec     = pointer to tRec;


{--------------------------------------------------------------}
{ var Declarations }
{$IDATA}
var
   ww          : word;
   ptr, ptr1   : pointer;
   pStr        : tpStr;
   pArr        : tpArr;
   pRec        : tpRec;
   bool        : boolean;
```

```
{--------------------------------------------------------------}
{ Main Program }
{$IDATA}

begin
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= GetMem (ptr, 1);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= GetMem (pStr);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= GetMem (pArr);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= GetMem (pRec);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;

  bool:= FreeMem (ptr);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= FreeMem (pStr);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= FreeMem (pArr);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;
  bool:= FreeMem (pRec);
  ww:= GetMemAvail;
  ww:= GetLargestBlock;

  EnableInts;
  loop
    Nop;
  endloop;
end AVR_Heap.
```

Sample Program:

A complete example can be found in the directory **..\E-Lab\AVRco\Demos\Heap**

4.23 BOOT VECTORS

The majority of the mega-AVRs support a second vector table in the Boot area. With this it is possible to use interrupts also while running updates with the FlashLoader. The UART is an example.

The problem with the Self-Update of an AVRs through the Boot Loader is that at least the original Interrupt Vector Table must also be rewritten. So it is erased first before being rewritten. Then at least for a short period of time no interrupts can be executed. Consequently interrupt driven boot loaders cannot be used.

In some cases it makes sense or it is necessary to work with interrupts in the loader. Most of the Mega AVRs support this by a remapping of the vector table into the start of the boot area. This must be done by the application by manipulating the IVSEL bit in the MCUCR or GICR register.

Interrupts vector read accesses then go either into the vector table at address 0 (IVSEL =0) or into the second vector table at the beginning of the boot area (IVSEL = 1).

The AVRco system supports this, and there is another advantage that the interrupt service routines which reside in the boot area can also be used by the application. In this case the concerning interrupt (vector) is placed into both tables. The related interrupt service routine then must always be implemented in the Boot area.

There are three types of interrupts:

1. The service routine is implemented outside of the boot area. This is the standard case and there is no influence on the boot area and its vector table.
2. The service routine resides in the boot area and has a standard name. Both vector tables have an entry (vector) of this routine. So both the application and the boot loader can use this interrupt.
3. The service routine is implemented in the boot area and has a name extension ***_BOOT***, *INT0_BOOT* for example. Then this routine is only useable by the loader and also only this table contains a corresponding entry. The application then can define its own *INT0* interrupt.

Important
The BootBlock must start always with this statement:

{$PHASE BootBlock nnnnn}

Then a procedure must follow which serves as the entry point (quasi Main) for the BootBlock. Then Interrupt procedures or other functions/procedures can follow. The last line must always be:

{$DEPHASE BootBlock}

Limitation
If the system uses an interrupt exclusively, as SerPort does with RxBuffer, then the RxRDY interrupt is not shareable. Each table must have its own entry.

4.23.1 Implementation

Imports
The boot interrupt support must be imported.

Import *SysTick, TickTimer, ..;*

From *System* ***Import*** *BootVectors, ...;*

4.23.2 Functions

Procedure *SetVectTabBoot (boot : boolean);*
This procedure should be used for the time critical switch of the vector tables (IVSEL, MCUCR/GICR).

Procedure *Boot_Init;*
Provides the stack and frame as defined and initializes the frame and stack pointer and also the XRAM access, if present.
If structured constants are placed into the BootBlock they also become initialised. Please note that with *BootVectors* import this function is always executed and **must not be called**.

Procedure *BootRestart;*
Also the application can execute a boot operation by calling this procedure. But this entry is only available if *BootVectors* are imported !

4.23.3 Constants

In conjunction with complex Boot drivers sometimes it is necessary to have “nonvolatile“ constants and structured constants in the BootBlock which can be accessed at any time by the Boot driver.

These constants then must be defined in the BootBlock. They don’t reside in the common Flash constant pool but in the BootBlock. If *BootVectors* are imported then the structured constants will be automatically copied to their correct place in the RAM. Without the BootVectors import the function *Boot_Init* must provide this.

All constants are also accessible by the application.
Absolute Constants in the BootBlock are allowed.

Important
Working with these constants in the BootBlock can be dangerous. Because the Flash becomes erased or rewritten at this time in most cases system functions are invalid or have changed their absolute address. So many operations with constants may be impossible in the BootBlock. An exact analysis of the involved system calls (CALL or RCALL) then is necessary. The same is true with the handling of variables

```
type
  tTestrec  = record
                   b1 : byte;
                   b2 : byte;
                 end;

{$PHASE BootBlock $0F000}
structconst
  abcde        : array[0..3] of byte = ($12, $34, $56, $78);
  TestrecS     : tTestrec = (b1 : $12; b2 : $34);
  vStr         : string = 'abcdef';

const
  xyz        : array[0..3] of byte = ($12, $34, $56, $78);
  cStr       : string = '12345';
  TestrecC : tTestrec = (b1 : $12; b2 : $34);

Procedure BootTest;
begin
  if abcde[0] <> xyz[0] then ...
  endif;
  if TestrecS.b1 <> TestRecC.b2 then ...
  endif;
  if cStr[1] <> 'a' then ...
  endif;
  if vStr[1] <> cStr[1] then ...
  endif;
```

4.23.4 Example Program

The following shows a small example how to use boot vector switching and the interrupt routines.
Then the resulting vector tables are listed.

```
program AVR_BootVectors;

{$BootRst $0F000}        {reset jumps to here}
{$NOSHADOW}

Device = mega128, VCC=5;

Import SysTick;

From System Import BootVectors;

Define
      ProcClock   = 8000000;      {Hertz}
      SysTick     = 10;           {msec}
      StackSize   = $0020, iData;
      FrameSize   = $0040, iData;
```

```
Implementation

{$IDATA}
{--------------------------------------------------------------}
{ Var Declarations }
var
  iii  : byte;

{--------------------------------------------------------------}
{ functions }

{$PHASE BootBlock $0F000}        // start of boot area
Procedure BootTest;              // this is the first code building
begin                            // part of the boot block
                                 // this is the absolute reset entry
  SetVectTabBoot(true);          // vector table in Boot area
  iii:= 0;
  EnableInts;
  repeat                         // wait for pin interrupts
  until iii > 3;                 // which increments iii
  DisableInts;                   // start over to the MAIN
                                 // enable vector relocation
  SetVectTabBoot(false);         // vector table on address 0
  ASM: JMP    SYSTEM.VectTab;    // absolute address $0000 = RESET vector
end;

Interrupt INT0_BOOT;             // only for the Boot vector table
begin                            // forced by the extension "_boot"
  inc(iii);
end;

Interrupt INT1;                  // for both vector tables
begin                            // because there is no extension
  inc(iii);                      // but it is still located in the boot area
end;
{$DEPHASE BootBlock}             // end of boot area

Interrupt INT0;                  // only for the basic vector table
begin                            // because it is outside of the boot block
  inc(iii);
end;

{--------------------------------------------------------------}
{ Main Program }
begin
  EnableInts;
  loop
    nop;
  endloop;
end AVR_BootVectors.
```

BOOT Area

```
F000                                     .PHASE     01E000h BOOT
F046                                     .ORG       01E08Ch, BOOT
F046             SYSTEM.$BOOT_ENTRY:
F046
F046                                     .FUNC     BootTest, 42, 00020h
F046             AVR_BootVectors.BootTest:
F046                                     .BLOCK    45
F046                                     .LINE     45
F046       EF1F                          LDI       _ACCA, 0FFh
F047       2311                          TST       _ACCA
F048       F009                          BREQ      AVR_BootVectors.L0000
F049       E012                          LDI       _ACCA, 2
F04A             AVR_BootVectors.L0000:
F04A   91000055                          LDS       _ACCB, MCUCR
F04C       7F0D                          CBR       _ACCB, 02h
F04D       6001                          SBR       _ACCB, 01h
F04E   93000055                          STS       MCUCR, _ACCB
F050       7F0E                          CBR       _ACCB, 01h
F051       2B01                          OR        _ACCB, _ACCA
F052   93000055                          STS       MCUCR, _ACCB
F054                                     .LINE     47
F054       E010                          LDI       _ACCA, 000h
F055   93100101                          STS       AVR_BOOTVECTORS.III, _ACCA
F057                                     .LINE     48
F057       E810                          LDI       _ACCA, 1 SHLB IntFlag
F058       2A21                          OR        Flags, _ACCA
F059       9478                          SEI
F05A             AVR_BootVectors.L0001:
F05A                                     .BLOCK    50
F05A                                     .ENDBLOCK 50
F05A                                     .LINE     50
F05A             AVR_BootVectors.L0002:
F05A   91100101                          LDS       _ACCA, AVR_BootVectors.iii
F05C       3013                          CPI       _ACCA, 003h
F05D       E010                          LDI       _ACCA, 0h
F05E       F011                          BREQ      AVR_BootVectors.L0004
F05F       F008                          BRLO      AVR_BootVectors.L0004
F060       EF1F                          SER       _ACCA
F061             AVR_BootVectors.L0004:
F061       2311                          TST       _ACCA
F065                                     .BRANCH   4,AVR_BootVectors.L0005
F062       F411                          BRNE      AVR_BootVectors.L0005
F05A                                     .BRANCH   20,AVR_BootVectors.L0001
F063   940CF05A                          JMP       AVR_BootVectors.L0001
F065             AVR_BootVectors.L0005:
F065             AVR_BootVectors.L0003:
F065                                     .LINE     52
F065       94F8                          CLI
F066       E71F                          LDI       _ACCA, 0FEH ROLB IntFlag
F067       2221                          AND       Flags, _ACCA
F068                                     .LINE     54
F068       E010                          LDI       _ACCA, 000h
F069       2311                          TST       _ACCA
F06A       F009                          BREQ      AVR_BootVectors.L0006
F06B       E012                          LDI       _ACCA, 2
F06C             AVR_BootVectors.L0006:
F06C   91000055                          LDS       _ACCB, MCUCR
F06E       7F0D                          CBR       _ACCB, 02h
F06F       6001                          SBR       _ACCB, 01h
F070   93000055                          STS       MCUCR, _ACCB
F072       7F0E                          CBR       _ACCB, 01h
F073       2B01                          OR        _ACCB, _ACCA
F074   93000055                          STS       MCUCR, _ACCB
F076                                     .LINE     55
F076   940C0000                          JMP    SYSTEM.VectTab;     // absolute address $0000
                                                                    // = RESET vector
F078                                     .ENDBLOCK 56
F078             AVR_BootVectors.BootTest_X:
F078                                     .LINE     56
0000                                     .BRANCH   19
F078       9508                          RET
F079                                     .ENDFUNC  56
F079
```

```
0315  F079                                  .FUNC     INTERRUPT_INT0_BOOT, 58, 00020h
0316  F079              AVR_BootVectors.INTERRUPT_INT0_BOOT:
0317  F079        94E8                      CLT
0318  F07A        F827                      BLD       Flags, IntFlag
0319  F07B                                  .BLOCK    60
0320  F07B                                  .LINE     60
0321  F07B    91100101                      LDS       _ACCA, AVR_BootVectors.iii
0322  F07D        9513                      INC       _ACCA
0323  F07E    93100101                      STS       AVR_BootVectors.iii, _ACCA
0324  F080                                  .ENDBLOCK 61
0325  F080              AVR_BootVectors.INTERRUPT_INT0_BOOT_X:
0326  F080                                  .LINE     61
0327  F080        9468                      SET
0328  F081        F827                      BLD       Flags, IntFlag
0329  0000                                  .BRANCH   19
0330  F082        9508                      RET
0331  F083                                  .ENDFUNC  61
0332  F083
0333  F083                                  .FUNC     INTERRUPT_INT1, 63, 00020h
0334  F083              AVR_BootVectors.INTERRUPT_INT1:
0335  F083        94E8                      CLT
0336  F084        F827                      BLD       Flags, IntFlag
0337  F085                                  .BLOCK    65
0338  F085                                  .LINE     65
0339  F085    91100101                      LDS       _ACCA, AVR_BootVectors.iii
0340  F087        9513                      INC       _ACCA
0341  F088    93100101                      STS       AVR_BootVectors.iii, _ACCA
0342  F08A                                  .ENDBLOCK 66
0343  F08A              AVR_BootVectors.INTERRUPT_INT1_X:
0344  F08A                                  .LINE     66
0345  F08A        9468                      SET
0346  F08B        F827                      BLD       Flags, IntFlag
0347  0000                                  .BRANCH   19
0348  F08C        9508                      RET
0349  F08D                                  .ENDFUNC  66
0350  F08D
0351  F08D                                  ; ============ String-constant tables ============
0352  F08D
0353  F08D              SYSTEM.BootIntErr:
0354  F08D        9518                      RETI
0355  F08E
0356  F08E              SYSTEM._Boot_Init:
0357  F08E        E011                      LDI       _ACCA, 01h
0358  F08F        BF1B                      OUT       RAMPZ, _ACCA
0359  F090
0360  F090        E110                      LDI       _ACCA, 010FFh SHRB 8
0361  F091        EF0F                      LDI       _ACCB, 010FFh AND 0FFh
0362  F092        BF1E                      OUT       sph, _ACCA
0363  F093        BF0D                      OUT       spl, _ACCB
0364  F094        E1D0                      LDI       _FPTRHI, 010BFh SHRB 8
0365  F095        EBCF                      LDI       _FRAMEPTR, 010BFh AND 0FFh
0366  F096
0367  F096              ; no Peripheral sram-waits
0368  F096        B715                      IN        _ACCA, mcucr
0369  F097        7B1F                      CBR       _ACCA, 040h
0370  F098        BF15                      OUT       mcucr, _ACCA
0371  F046
0372  F046                                  .BRANCH   20,AVR_BootVectors.BootTest
0373  F099        CFAC                      RJMP      AVR_BootVectors.BootTest
0374  F09A
0375  F09A              SYSTEM.$INTERRUPT_INT0_BOOT:
0376  F09A        93EF                      PUSH      _ACCCLO
0377  F09B        93FF                      PUSH      _ACCCHI
0378  F09C        930F                      PUSH      _ACCB
0379  F09D        931F                      PUSH      _ACCA
0380  F09E        B71F                      IN        _ACCA, SREG
0381  F09F        931F                      PUSH      _ACCA
0382  F079                                  .BRANCH   17,AVR_BootVectors.INTERRUPT_INT0_BOOT
0383  F0A0    940EF079                      CALL      AVR_BootVectors.INTERRUPT_INT0_BOOT
0384  F0A2        911F                      POP       _ACCA
0385  F0A3        BF1F                      OUT       SREG, _ACCA
0386  F0A4        911F                      POP       _ACCA
0387  F0A5        910F                      POP       _ACCB
0388  F0A6        91FF                      POP       _ACCCHI
0389  F0A7        91EF                      POP       _ACCCLO
0390  F0A8        9518                      RETI
0391  F0A9
```

```
0392  F0A9                SYSTEM.$INTERRUPT_INT1:
0393  F0A9        93EF                                PUSH      _ACCCLO
0394  F0AA        93FF                                PUSH      _ACCCHI
0395  F0AB        930F                                PUSH      _ACCB
0396  F0AC        931F                                PUSH      _ACCA
0397  F0AD        B71F                                IN        _ACCA, SREG
0398  F0AE        931F                                PUSH      _ACCA
0399  F083                                            .BRANCH   17,AVR_BootVectors.INTERRUPT_INT1
0400  F0AF    940EF083                                CALL      AVR_BootVectors.INTERRUPT_INT1
0401  F0B1        911F                                POP       _ACCA
0402  F0B2        BF1F                                OUT       SREG, _ACCA
0403  F0B3        911F                                POP       _ACCA
0404  F0B4        910F                                POP       _ACCB
0405  F0B5        91FF                                POP       _ACCCHI
0406  F0B6        91EF                                POP       _ACCCLO
0407  F0B7        9518                                RETI
0408  F000
0409  F000                                            .ORG       01E000h, VECTTABB
0410  F000                                            .VECTTAB_B
0411  F000                SYSTEM.VectTab_B:
0412  F000    940CF08E                                JMP       SYSTEM._Boot_Init
0413  F002    940CF09A                                JMP       SYSTEM.$INTERRUPT_INT0_BOOT
0414  F004    940CF0A9                                JMP       SYSTEM.$INTERRUPT_INT1
0415  F006    940CF08D                                JMP       SYSTEM.BootIntErr
0416  F008    940CF08D                                JMP       SYSTEM.BootIntErr
0417  F00A    940CF08D                                JMP       SYSTEM.BootIntErr
0418  F00C    940CF08D                                JMP       SYSTEM.BootIntErr
0419  F00E    940CF08D                                JMP       SYSTEM.BootIntErr
0420  F010    940CF08D                                JMP       SYSTEM.BootIntErr
0421  F012    940CF08D                                JMP       SYSTEM.BootIntErr
0422  F014    940CF08D                                JMP       SYSTEM.BootIntErr
0423  F016    940CF08D                                JMP       SYSTEM.BootIntErr
0424  F018    940CF08D                                JMP       SYSTEM.BootIntErr
0425  F01A    940CF08D                                JMP       SYSTEM.BootIntErr
0426  F01C    940CF08D                                JMP       SYSTEM.BootIntErr
0427  F01E    940CF08D                                JMP       SYSTEM.BootIntErr
0428  F020    940CF08D                                JMP       SYSTEM.BootIntErr
0429  F022    940CF08D                                JMP       SYSTEM.BootIntErr
0430  F024    940CF08D                                JMP       SYSTEM.BootIntErr
0431  F026    940CF08D                                JMP       SYSTEM.BootIntErr
0432  F028    940CF08D                                JMP       SYSTEM.BootIntErr
0433  F02A    940CF08D                                JMP       SYSTEM.BootIntErr
0434  F02C    940CF08D                                JMP       SYSTEM.BootIntErr
0435  F02E    940CF08D                                JMP       SYSTEM.BootIntErr
0436  F030    940CF08D                                JMP       SYSTEM.BootIntErr
0437  F032    940CF08D                                JMP       SYSTEM.BootIntErr
0438  F034    940CF08D                                JMP       SYSTEM.BootIntErr
0439  F036    940CF08D                                JMP       SYSTEM.BootIntErr
0440  F038    940CF08D                                JMP       SYSTEM.BootIntErr
0441  F03A    940CF08D                                JMP       SYSTEM.BootIntErr
0442  F03C    940CF08D                                JMP       SYSTEM.BootIntErr
0443  F03E    940CF08D                                JMP       SYSTEM.BootIntErr
0444  F040    940CF08D                                JMP       SYSTEM.BootIntErr
0445  F042    940CF08D                                JMP       SYSTEM.BootIntErr
0446  F044    940CF08D                                JMP       SYSTEM.BootIntErr
0447  F046
0448  F046                                            .VECTTABE_B
0449  0046                                            .DEPHASE
```

Application Area

```
0749  8004                                        .ENDCODE
0750  0000                                        .ORG       0, VECTTAB
0751  0000                                        .VECTTAB
0752  0000            SYSTEM.VectTab:
0753  0000   940C0065                             JMP       SYSTEM.RESET
0754  0002   940C00A9                             JMP       SYSTEM.$INTERRUPT_INT0
0755  0004   940CF0A9                             JMP       SYSTEM.$INTERRUPT_INT1
0756  0006   940C00FB                             JMP       SYSTEM.DefIntErr
0757  0008   940C00FB                             JMP       SYSTEM.DefIntErr
0758  000A   940C00FB                             JMP       SYSTEM.DefIntErr
0759  000C   940C00FB                             JMP       SYSTEM.DefIntErr
0760  000E   940C00FB                             JMP       SYSTEM.DefIntErr
0761  0010   940C00FB                             JMP       SYSTEM.DefIntErr
0762  0012   940C00FB                             JMP       SYSTEM.DefIntErr
0763  0014   940C00FB                             JMP       SYSTEM.DefIntErr
0764  0016   940C00FB                             JMP       SYSTEM.DefIntErr
0765  0018   940C00FB                             JMP       SYSTEM.DefIntErr
0766  001A   940C00FB                             JMP       SYSTEM.DefIntErr
0767  001C   940C00FB                             JMP       SYSTEM.DefIntErr
0768  001E   940C00FB                             JMP       SYSTEM.DefIntErr
0769  0020   940C0093                             JMP       SYSTEM.$INTERRUPT_TIMER0
0770  0022   940C00FB                             JMP       SYSTEM.DefIntErr
0771  0024   940C00FB                             JMP       SYSTEM.DefIntErr
0772  0026   940C00FB                             JMP       SYSTEM.DefIntErr
0773  0028   940C00FB                             JMP       SYSTEM.DefIntErr
0774  002A   940C00FB                             JMP       SYSTEM.DefIntErr
0775  002C   940C00FB                             JMP       SYSTEM.DefIntErr
0776  002E   940C00FB                             JMP       SYSTEM.DefIntErr
0777  0030   940C00FB                             JMP       SYSTEM.DefIntErr
0778  0032   940C00FB                             JMP       SYSTEM.DefIntErr
0779  0034   940C00FB                             JMP       SYSTEM.DefIntErr
0780  0036   940C00FB                             JMP       SYSTEM.DefIntErr
0781  0038   940C00FB                             JMP       SYSTEM.DefIntErr
0782  003A   940C00FB                             JMP       SYSTEM.DefIntErr
0783  003C   940C00FB                             JMP       SYSTEM.DefIntErr
0784  003E   940C00FB                             JMP       SYSTEM.DefIntErr
0785  0040   940C00FB                             JMP       SYSTEM.DefIntErr
0786  0042   940C00FB                             JMP       SYSTEM.DefIntErr
0787  0044   940C00FB                             JMP       SYSTEM.DefIntErr
0788  0046
0789  0046                                        .VECTTABE
0790  0046            SYSTEM.ENDPROG:
```

Sample Program

An example can be found in the directory **..\E-Lab\AVRco\Demos\BootVectors**

4.24 BOOT TRAPS (BootTraps)

If essential parts of the system are placed into the Boot section and these functions must also be accessible from the application section then there is the problem that with a download of a new application part through the Boot Loader the new application can use new but illegal physical addresses in the boot section.

A simple call of functions or procedures out of the application can point to wrong or illegal addresses in the code or the boot block with catastrophic results. In order to avoid this there must be a special interface which was introduced many years ago by CP/M and DOS for entering the BIOS.

Here a function is never called directly but indirectly through a jump table which is placed at the beginning of this area on a well known and fixed address. By this theoretically both parts can be changed without leading to dramatic results. However our table is unchangeable at runtime as is the whole boot area.

How does it work?
The system builds a jump table with 16 entries after the Boot Vector Table. If no Boot Vectors are used this table is directly placed at the Boot entry address. Each function or procedure in the Boot area which has the "***TRAP***" attribute is entered into this table by its address.

A call of such a function or procedure from the application section then is not built as usual with a "CALL Procedure" but the address of this function is read out of this table and used for an ICALL operation. However a call of such a Trap function from within the Boot area is handled as usual with a standard CALL.

4.24.1 Implementation of the Boot Traps

Imports
The Boot Trap Handler must be imported.

```
From System Import Traps {,BootVectors};
```

Defines
There is no special Boot Trap Handler define. Normally a Trap table for 16 entries is reserved. To save flash space this table can be tailored fort he exact size:

```
Define  MaxTraps      = 4;   // 2..16

{$PHASE BootBlock $0F000}
…

Procedure TestTrapP(b : byte; w : word); Trap;
begin
  ww:= w;
end;

Procedure TestTrap; Trap;
begin
  TestTrapP (12, 1234);            // procedure is called as usual
end;

{$DEPHASE BootBlock}

// MAIN
begin                              // functions are called through the jump table
  TestTrap;
  bo:= TestTrapF (12, 1234);
  TestTrapP (12, 1234);
  ...
```

4.25 Inheritance

The basis for objects is what is known as inheritance. A new object takes on all the properties of an existing object and extends the new one with additional properties. Objects are special records. If it is possible to import an existing record into a new one simple objects can be constructed.

The import respectively the inheritance of an existing record into a new one must be done with the use of

```
inherit RecordName;
```

```
type
    tFirstRec  =     record
                       bb    : byte;
                       ww    : word;
                       pp    : pointer;
                     end;

    tObjRec  =       record
                       inherit firstRec;  // import of firstRec
                       ii      : integer;
                       pro   : procedure;
                     end;
```

"ObjRec" inherits the properties of "firstRec". Please note that the inherit instruction must always be the **first** declaration of the new record.
Internally the new records is constructed in this way:

```
    tObjRec  =       record
                       bb    : byte;       // inherited
                       ww    : word;       // inherited
                       pp    : pointer;    // inherited
                       ii      : integer;
                       pro   : procedure;
                     end;
```

It must be clear that no identifier can be used twice, all must be unique.
A simple application of such a construct is the hiding of the inherited part:

```
type
  tpFirstRec  = pointer to tFirstRec;
  tpObjRec    = pointer to tObjRec;

var
    ObjRec      : tObjRec;
    pFirstRec   : tpFirstRec;
    pObjRec     : tpObjRec;
    ...
pFirstRec:=  tpFirstRec (@ObjRec);  // only FirstRec is visible
pObjRec:= @ObjRec;                  // all is visible
```

5 Multi-Tasking Programming

5.1 Introduction

With an Embedded Application (Single-Chip application) often there is the problem, that several jobs should be done at the same time. For example the characters of a serial interface should be fetched, checked and perhaps they should be converted from hex into an integer. At the same time ports should be watched by limit-switches or a LED should flash. Additional a measurement value should be gathered by a pot and this value should be passed as a control output to an external controller. And the controller should calculate an output value in a fixed time grid.

So the programmer has the problem with all these targets to do all things concurrently. The programmer is in the difficult situation to watch several processes at the same time, whereby he must take care that all functions run **concurrently and independently.**

With simple time-loops etc. this problem cannot be solved except maybe with tricks, which make the program inflexible and bovine.

So a solution is needed, which makes it possible to distribute the jobs, that they frequently get a chance to work, but do not block other jobs. Such a system is called **Multi-Tasking,** whereby a task is a job/assignment.

The terms **tasks** or **processes** are often treated as synonyms in literature, but within the AVRco they are distinguished. Details see below.

In connection with Multi-Tasking there is always associated the term **Real-Time.** Strictly speaking real-time has nothing to do with multi-tasking. Real-time means to responding to external events as quickly as possible. In general this is achieved via interrupts. But the reaction-time is not predefined anywhere. Depending on the requirement this can mean the system has to react within microseconds or sometimes milliseconds. The application basically determines what is real-time and what is too slow.

5.2 Principle of Operation

Multi-Tasking or Multi-Processing is defined as the ability to process several jobs/tasks quasi-parallel, it seems as if they run at the same time. Because it is not possible for a processor to read and process several machine commands at the same time, this must be done sequentially, i.e. one after another.

This sequential processing of jobs (calling of jobs, handout of run-time, switch over to the next job) is done by what is known as the **scheduler.** The scheduler is processed in a timer-interrupt (SysTick). It checks if the running process/task has consumed it's temporary run-time. If it is consumed, the working-register, stackpointer, flags etc. are saved in a memory area, which is assigned to this process, and the next process or task is called.

This method is also called **Round-Robin,** because the processes are done essentially in a circle. Other possible methods are not considered, because the administrative outlay is too big.

The scheduler observes the state of the separate tasks. This is the *priority*, which defines the time-slice, and waiting flags (pipe, semaphore, sleep), which switch off a process temporarily. *Suspend* switches a process completely off and *lock* ties the CPU completely to this process.

5.2.1 Processes and Tasks

Processes and tasks are essentially independent programs within an application, which are able to run independently from other program parts (e.g. main). Processes can not be called like functions or procedures. Instead of this they are called periodically by the scheduler. If processes have been imported, the main program runs as a process, too, and also has a priority, name(Main_Proc) and process-ID(0).

If there are several processes/tasks within a program, the processes are done quasi-parallel, i.e. it seems as if all processes are done at the same time = **Multi-Tasking.** So an apparently **parallel processing** for example of events or data is achieved, although they are always processed sequentially, i.e. one after another.

A process practically runs for ever, only interrupted by interrupts and other processes and tasks. The ‘begin’ and ‘end’ limits a process and its statements. Because processes cannot be called like functions, they do not have any passing parameters or results.

With the first call of a process by the scheduler, it is started with the statement which follows directly after the ‘begin’ statement. Then all statements are processed until ‘end’ is reached, perhaps interrupted by a **task change** by the scheduler (Switch over to another process/task). If the ‘end’ is reached, it is automatically continued with the first statement after ‘begin’. So a process runs continuously in a ‘circle’ without ending. The programmer does not need program a loop, because the jump back to the beginning (begin) happens automatically.

This is the essential difference to a task. With **every** call of a task by the scheduler it is started with the statement which follows immediately after the ‘begin’ statement. Then all statements are processed until ‘end’ statement. If the ‘end’ is not reached within a system tick, the task is **interrupted** by a **task change** by the scheduler (Switch over to another process/task). So the task never reaches the ‘end’, if it’s required run-time from ‘begin’ to ‘end’ is longer than a system tick. The run-time may **never** be longer than a system tick. Similar conditions are also valid for interrupts. A timer-interrupt-service-routine for example, should never take more time than the period between two interrupts.

If the ‘end’ is reached, the control is automatically passed to the scheduler, which now activates the next process or task. In contrast to a process a task runs from ‘begin’ until ‘end’ with every call through the scheduler and then aborts.

5.2.2 Priority

The behavior of a process/task is controlled by a number of corresp. functions and procedures.
An essential parameter is priority.

With **priority** a part of the globally available run-time is placed at disposal to a process. The higher the value of priority is, the more run-time is at disposal. At the same time priority predefines the number of system ticks, which are completely available for the process in a piece. The proportional run-time of the total time in % is calculated by: Priority / Sum of all priorities.

Assumed there is only the process ‘DoTheJob’ and it has the priority 10 and Main Priority is 5 then is valid: run-time = 10 / (5 + 10) = 66%. But the exact run-time can only be predefined if no process is suspended or locked and if no ProcessWaits etc. exist. In practice the proportional run-time can only be estimated.

In contrast to a process the calling interval of the **task** is predefined by **priority.** The lower the value of priority is, the more often is the calling of the task. Assumed the task ‘RunPid’ has the priority 10, so it is called every 10. Systick. So it is established, that the period between two callings is always 10 ticks.

Note:

If there are several **tasks,** and if it is possible, that several of them are active, pay absolutely attention that all priorities have a **common denominator.**
I.e. all priorities must be a multiple of 2, for example. If this condition is not met, so there are irregular calling intervals, i.e. the period between two callings is not constant any longer. Further the lowest priority should be higher than (count of all tasks + count of all processes) but at least higher than the task count.

A process/task is able to take over the CPU completely by **lock,** so apart from itself only interrupts are running. This state is terminated by **unlock.**

If a process/task finds out, that it has nothing to do at the moment, there should be no waste of run-time by waitloops or delays. There are several possibilities to pass the control to other processes:

With **Schedule** the process/task is interrupted immediately, but is enqeued again into the waiting loop. With **Sleep** a process/task is able to switch itself off for a certain number of system ticks.

With **Suspend** a process/task switches off. It is not able to switch itself active again. This must be done by another process/task or by the main program with **resume.**

Because the communication between tasks/processes is made by pipes and semaphores, the task may suspend itself by calling **WaitSema** or **WaitPipe.** The process/task then becomes active if there is data in the specified semaphore or pipe. It is also possible that **RxBuffer** (RxBuffer1, -2, -3) is specified as a pipe.

The process/task is interrupted directly after an above mentioned instruction.

5.2.2.1 Default Priorities

without explicit priority setting the priorities are

Main:	Priority 5
Prozess:	Priority 3
Task:	Priority 5

5.3 Optimal Multi-Tasking

With a multitasking application accurate planning is necessary.

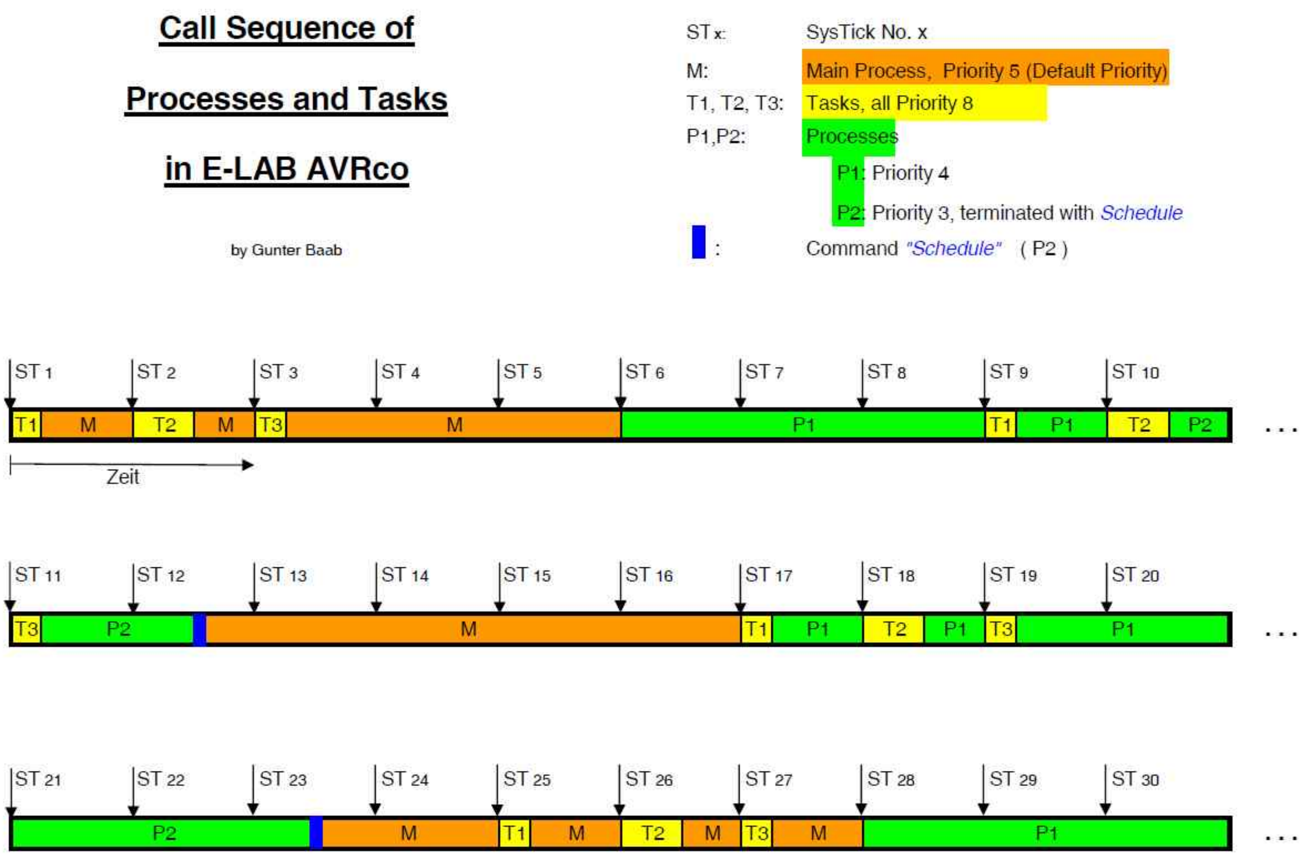
1. With the right strategy and a good partitioning of the jobs into separate tasks and processes fast program processing is achieved.

2. In spite of the overhead (ca. 330 cycles), which is caused by the scheduler, a multitask program runs much faster than a normal programmed program, if there is suitable use of schedule, sleep, WaitSema, WaitPipe and suspend.

3. The right distribution of the priorities decides the reaction-time of the separate processes and hence the real-time capability. If the priorities are dynamic, i.e. they are changed for the needs of the application during the program run, an additional improvement of the system is achieved.

5.4 MultiTasking Diagram

The diagram below shows the operating principle of the MultiTasking system and how the internal Scheduler at every SysTick checks whether a new Task must be started or the control must be passed from an expired Process to another Process.



6 Optimisation

6.1 Library

The compiler optimizes the library calls completely, i.e. only those library functions, which are used, are imported and occupy code space and possible RAM space (variable). So there is no waste of resources.

6.1.1 Variable

The Pascal compiler has no variable optimization at the moment. That means that a variable, which has been declared, also physically occupies space. If this variable is not used within the program, so the space is wasted. It is planned about to introduce a variable optimization later, which eliminates the unused variable.

The programmer must take care to delete the unused variables and to treat the resources with care. The compiler switch *{W+}* helps.

6.1.2 Constant

A constant declaration like **"*Const*** *x = 123;*" occupies no resources within the CPU, whether this constant is used or not.
Constant expressions for example "*a:= (5 * 10) + (24* ***div*** *2);*" are parsed by the compiler, if possible. This is called constant folding. The result of the above expression is "62". The compiler then uses the constant result and passes it to the assembler like: *LDI _ACCA, 62*

6.1.3 Runtime

The generated program within many compilers is what is known as stack machine. All passing parameters and provisional results within terms are stored in stacks and frames. Often there are unnecessary PUSH and POP operations connected with it. Also variables are often loaded into the working register, although this variable is already in this register. This is caused by the formalism, which exists in every compiler.

A run-time optimization realizes those unnecessary operations and eliminates them. This is built into this compiler. There are many further possibilities for optimization, which will be reserved for future releases.

6.2 Highly Optimising?

Many compilers attire themselves (sometimes even with justification) with the attribute "highly optimising". A very hard optimisation often has two sides. If, for example, all actual variables are within the register set and are processed there, there is no possibility for an interrupt-routine or a multitask to get an access to these actual values! Further this routine cannot be recursive, but at least it must try to save the registers. Highly optimised code is generally not reentrant also (abort of a routine by an interrupt or multitasking and a calling of it within the interrupt task).

Because of that it is necessary within certain compilers that certain procedures or functions require a compiler switch to switch off the optimisation.
Beginners as well as experienced users often forget it, and so sometimes there is a crash that cannot be reproduced. Such a system is not easy to clean. For beginners it is only possible if essential optimisations are switched off.

The AVRco generally works with stack frames, it is slower, but extremely secure. All system- and user-functions/procedures are generally reentrant as well as recursive. The recursion depth is only limited by the Ram and the stack/frame size.

Within the AVRco the floating point library is reentrant, i.e. it could be used within interrupts and recursions, this is not the case with all compilers. (With interrupts save all registers!).

Although the speed and a compact code are necessary targets of a compiler, within the AVRco the most necessary thing is the reliability requirement and the optimisation was secondarily, but this does not mean that optimisation is no theme. As mentioned above in future there will be better optimising versions, too.

The most compact and fastest code
is reached within every system by the system library. The more functions are within the system, the less has the programmer to formulate in a high-level language. System functions are completely written in assembler, so they are highly efficient, i.e. fast and short. The “Librarian“, which is contained in some compilers, generates out of the high-level language a linkable library. The generated code is exactly the same as the code, which is made out of the statements by the compiler, if they are directly included in the program. So there is no profit that way.

An I^{2}C-Bus has to be formulated in a high-level language by the programmer within most of the systems. This code is many times bigger and slower than the corresponding system functions. By the import of several system functions, and there are many of them in the AVRco, the moderate optimisation of the AVRco is made much better.

The best optimiser is the programmer himself. There can be an optimal code, if multitasking is used and local variables are used sparingly.

The generated code of the AVRco (also in connection with Multi-Tasking) can also feel free with the compare to more complex applications.

A “foolproof“ program is the target of the AVRco. A highest optimised program can only be reached with a careful using of the compiler switches, and so there can be many mistakes/errors!

As a matter of fact a little bit bigger processor with larger ram/rom gives a better improvement than an optimisation, and often it costs just a little bit more than a weaker version, even the increase of efficient periphery (ports, timer, interfaces) is better.

6.3 The "Merlin Optimiser"

The Merlin Optimiser is a Plug-In for the Standard and Profi Version of the AVRco System.
It reduces the code size between 5..30%.
The Optimiser is called from inside the IDE with HotKey or SpeedButton.
The complete sequence "compile "" – "optimise" – "assemble" needs also only a single mouse click.

{$OPTIMISE}
This switch forces a compilation with the use of the Merlin Optimiser. This switch **must** be located in the first line of the main program!

From Version 4 of the AVRco (Standard and Profi) the Merlin Optimiser is included.

6.3.1 Getting the best out of the Merlin Optimiser

6.3.1.1 Introduction

The aim of any optimiser is primarily to improve (optimise) code so that it runs faster and in a smaller space. Sometimes these two requirements (size and speed) conflict and many optimisers allow you to choose the balance between the two. Being an optimiser for microcontrollers, the Merlin Optimiser only ever optimises for size, although speed is usually improved as a consequence.
In fact there are very few flags to control the optimiser, and these are summarised at the end of the chapter. Like compiler directives, these are embedded in comments starting with the $ symbol.
This chapter will discuss how some of the optimisations work, and how you can organise your code to get the best out of the optimiser.

6.3.1.2 What levels of optimisation can I expect?

It depends on what sort of programs you write. If you use a lot of the built in drivers (most of which are already highly optimised) and small programs, don't expect a great deal – maybe 5%. For large programs with lots of your own code it can be as much as 30%, and this could mean not having to migrate to a larger processor.
If you want to see what levels of optimisation you are getting look at the bottom of the assembly (.asm) file, where the details are given.

6.3.1.3 What is optimised

Only code is optimised. No attempt is made to optimise data of any form
(although loop optimisation can optimise the frame a little).

6.3.1.4 Beta code

The optimiser, like the compiler, is continually being improved. With so many ways to write programs, it is impossible to 100% test new features. If you find any bugs, please contact Merlin via the forum. He will endeavour to fix your problem as quickly as possible.

New optimisations are always conditioned on the flag {$OPTI_BETA_OFF}, so you may be able to carry on working by using this flag while the bug is fixed. But if you have to use this flag, please tell Merlin, and give samples of your problem (i.e. send the .dsm and .asm files showing your problem). Otherwise the bug may never be fixed. Some bugs are so obscure that they only affect one person's program.

Don't depend on this flag. Eventually the optimisation will no longer be governed by this flag,
and you may get upset when your program suddenly stops working!

6.3.1.5 Volatility

Consider the following code:

```
x:= 3;
x:= 4;
```

Is the first statement redundant? Well, it depends. For example if x is actually a set of I2C clock lines, it isn't. On the other hand if it is just a normal memory block, the first statement is not needed. In the first case (the I2C clock) x is said to be *volatile*. In the second case it is said to be *non volatile*. The optimiser has different defaults for different spaces.

$DATA, $IDATA and $EEPROM are assumed to be non volatile (with a few exceptions). $PDATA, $XDATA and $UDATA are assumed to be volatile. With volatile both of the statements above are executed, with non-volatile only the last one. Mainly, volatile switches are only necessary in XData.

These defaults can be over-ridden by {$OPTI VOLATILE_xxx} statements. These are arranged in blocks that must end with {$OPTI VOLATILE_DFT}. So, for example:

```
{$XDATA}
var
{$OPTI VOLATILE_OFF}
lastChangedData : tDate;
{$OPTI VOLATILE_ON}
I2ClinesA : byte; // clock, data etc
I2ClinesB : byte; // clock, data etc
{$OPTI VOLATILE_DFT}
...
```

{$OPTI VOLATILE_ON} means following data is treated as volatile, no optimization here
{$OPTI VOLATILE_OFF} means that following data is treated as non-volatile, optimisation
{$OPTI VOLATILE_DFT} means following statements are treated according to default rules as described above.

Attention:
The XDATA area is volatile by default!

6.3.1.6 Loop optimisation

The AVRCo implementation of for-loops is extremely powerful, compared to, say Delphi.
Delphi requires that the loop variable be local, and that all evaluations be done at the outset.

Also in Delphi something like the following

```
var
  i : byte;

begin
  for i := 0 to 255 do
...
```

would produce an infinite loop because i can never exceed 255 (it wraps round).
AVRCo is not fooled by such things and works fine.

AVRCo allows any variable to be the control variable, local, global, even record elements.
The down side to this power is that AVRCo loops are relatively slow and need a lot of code.

Common loop constructs, like the one above can be made much simpler and quicker, and the optimiser does this simplification where it can, but only for local control variables. To see the impact optimising has, see the sample source ..\E-LAB\AVRco\Optimiser\Demos\ForLoopTest.pas.

To make best use of the optimiser, always use local variables for loops.

Now consider the following:

```
var
  i, iMax : byte;
begin
  iMax := 255;
  for i := 0 to iMax do
  ...
```

and the equivalent

```
const
  iMax : byte = 255;
var
  i : byte;
begin
  for i := 0 to iMax do
  ...
```

There might be reasons why you would want to do this – perhaps to use iMax elsewhere, and make maintenance easier. The optimiser produces much better optimisation in loops where the bounds are constants than where they are variables, and so the second form is to be preferred.

To make best use of the optimiser, use constants for loop bounds wherever possible.

6.3.1.7 Common sub-expression Exit points

This sounds quite complicated but it is quite simple really. It is best explained with an example. Consider the following code fragment

```
Procedure Setup (var a : byte; var b: byte; var c: byte; var Mode : byte);
begin
  Case Mode of
    0:   a := 1;  b := 5;  c := 1;  |
    1:   b := 1;  c := 5;  a := 1;  |
    2:   c := 1;  a := 5;  b := 1;  |
    3:   a := 1;  b := 1;  c := 1;  |
  End_case;
```

The optimiser will do a reasonable, but not great job of optimising this. On the other hand, if we rearrange things a little, it can make a dramatic difference.

```
Procedure Setup (var a : byte; var b: byte; var c: byte; var Mode : byte);
begin
  Case Mode of
    0:   a := 1;  b:= 5;   c := 1;  |
    1 :  a := 1;  b:= 1;   c := 5;  |
    2:   a := 5;  b :=1;   c := 1;  |
    3:   a := 1;  b :=1;   c := 1;  |
  End_case;
```

Here the optimiser can see that there are 3 places where we assign 1 to c and then jump to the end of the loop, and in two of these places we also assign 1 to b before jumping to the end of the loop. The optimiser is able to merge these. (If you are interested in how, look at the file for CSE_Test.asm generated after compiling and optimising ..\E-LAB\AVRco\Optimiser\Demos\CSE_Test.pas in the optimiser samples directory).

However, this is a bit of a double edged sword. If you wanted to step through the code in the simulator, or indeed JTAG, which line would the 'c:=1' be on? The simulator simply can't know after optimisation because several lines of code have been merged into one. So, if you need to disable this optimisation for debugging, there is a flag you can use {$OPTI NO_CSE_OPT}.
This will stop this optimisation occurring throughout the program. This flag is global and can be placed anywhere in the program, but it is an important optimisation, so don't forget to take it out after debugging!

When assigning the same value to the same variables in several places that have a common exit point, keep assignments in the same order.

6.3.1.8 Hand Crafted Assembly Code

It is sometimes necessary to 'hand craft' assembly code. For most optimisations this is not a problem, but for one in particular it can be an issue.
The compiler gives a directive to the optimiser at the start of most function that tells the optimiser what register is should preserve on return. (For those interested, this is the *RETURNS* directive). However, with hand crafted code, the compiler doesn't know, and this can cause problems. Here is an example to illustrate the point.

```
UserDevice KeyBoard8IOS : byte;
begin
  ASM;
    PUSH   _ACCCLO
    LDI    _ACCCLO, x AND 0FFh
    LDI    _ACCCHI, x SHRB 8
    LD     _ACCA, Z
    COM    _ACCA
    POP    _ACCCLO
  ENDASM;
end;
```

The compiler will tell the optimiser that _ACCA is required by the calling program, but not that _ACCCLO is needed. To overcome this, two flags are provided that tell the optimiser that all registers are needed:

```
{$OPTI   NO_CHECK_RETURN_REGS}
UserDevice KeyBoard8IOS : byte;
begin
  ASM;
    PUSH   _ACCCLO
    LDI    _ACCCLO, x AND 0FFh
    LDI    _ACCCHI, x SHRB 8
    LD     _ACCA, Z
    COM    _ACCA
    POP    _ACCCLO
  ENDASM;
end;
{$OPTI   CHECK_RETURN_REGS}
```

An example ..\E-LAB\AVRco\Optimiser\Demos\No_Return_Check.pas is provided in the Optimiser samples directory.

6.3.1.9 Setters and Getters

Often (particularly OO) programmers want to make a variable read only from outside a unit.
The obvious way to do this is to create what is known as a **getter** function, which just looks like this

```
Function GetVar_a : byte
begin
  return (Var_a);
end;
```

and to make the function visible (by putting its declaration in the interface part) and the variable local (by putting it in the implementation part).

This form (just one simple return line) is a “simple” form of getter.

The advantage is to do with maintenance. We prevent uncontrolled access to the variable, which can cause problems later. It also makes it easy to add secondary actions (side effects) later, e.g.

```
Function GetVar_a : byte
begin
  inc (Var_a_AccessCount);           // secondary action – count the accesses
  return (Var_a);
end;
```

This form (e.g. with side effects) is a “complex form”

The other side of this is a setter.

```
Procedure SetVar_a (Value : byte);
begin
  Var_a := Value;
end;
```

The advantage of this is similarly that if later we need to do some error checking or secondary action we don’t need to hunt through loads of units to find everywhere we set the value of the variable, like this.
Again, the form shown above (a simple assignment) is the “simple” form. One like the example below (with side effects) is the “complex” form.

```
Procedure SetVar_a (Value : byte);
begin
  Var_a := Value;
  if Var_a > VarAMax then            // secondary action – what was the max value of Var a?
    VarAMax := Value;
  end_if;
end;
```

The problem with this idea is, of course, the overheads of getters and setters when they are in their simple form. In their complex form they need to be functions and procedures anyway.
The optimiser specifically looks for the simple forms of setters, getters, and other simple functions and replaces the call with simple assignments. This is known as making the code ‘Inline’, which is to say although the source looks like a function or procedure, the final assembly code does not.
If later the function becomes more complicated, the optimiser will no longer make it inline. So you get the best of both worlds.
(Note – the optimiser will make any function that is just one assembly line long ‘inline’, not just setters and getters.)
Again, like other options mentioned in this document, it is possible that, if you don’t understand what is happening, tracing with JTag or the simulator could be difficult, so this can be turned off and on using the {$OPTI ALLOW_INLINE} and {$OPTI NO_ALLOW_INLINE} options, e.g.

```
{$OPTI   NO_ALLOW_INLINE}
x1 := x2Getter;
{$OPTI ALLOW_INLINE}
```

Putting {$OPTI NO_ALLOW_INLINE} solely at the top of the main unit disables inline action throughout the whole program.
Note also that in the above code the inline function is disabled for this call only. The inline actions will still occur in the rest of the program, even for the same function.
Surrounding a setter or getter with these parameters will have no effect, so

// WRONG – this will NOT work:

```
{$OPTI   NO_ALLOW_INLINE}
Function MyGetter : byte;
begin
  Return (My);
end;
{$OPTI ALLOW_INLINE}
```

would not prevent inline substitution of this function.

Samples ..\E-LAB\AVRco\Optimiser\Demos\ SetGetMain.pas etc. are provided in the Optimiser samples directory.

6.3.2 Summary of Optimiser Directives

{$OPTI_BETA_OFF}
Disables latest optimisations. Don't use this unless you have to, and then please let Merlin know of any problems via pm. In the directory with your .pas file will be a .asm and .dsm file with the same name as the .pas file. Please attach these with your comments. If you can generate a simple example showing the problem this will be better than a full application.

{$OPTI   NO_CSE_OPT}
Disables Common sub-expression Exit points optimisation. This is a global flag that can be anywhere in the code. Just use for debugging if necessary.

{$OPTI   ALLOW_INLINE}** and **{$OPTI NO_ALLOW_INLINE}
Allows or disallows simple functions and procedures (such as simple setters and getters) to be placed inline. Use for debugging if necessary, but once you are used to what is going on, it should not be necessary even for debugging.

{$OPTI   NO_CHECK_RETURN_REGS}** and **{$OPTI CHECK_RETURN_REGS}
Particularly intended for use with assembler code these control whether the optimiser uses the .RETURNS directive to determine whether a register is needed by the calling function.
The first should be placed before a function or procedure containing assembly lines where a register is required by the calling procedure, and the second should be placed after the 'end' statement of that procedure.

{$OPTI_QUICK}
The optimiser runs through the assembly code several times, but the bulk of the optimisation is done in the first cycle. The {$OPTI_QUICK} directive tells the optimiser to do only one iteration. This is mainly for backwards compatibility. Version 2 of the optimiser was much slower than version 3, and in version 2 this could be an important flag, but in version 3 very little time is saved.

{$OPTI SMARTLINK_ONLY}
The Merlin Optimiser now completely replaces the AVRco SmartLinker. If only the origin SmartLinker functionality is needed, this can be passed to the Merlin Optimiser with this switch:
The Merlin then only removes unused functions/procedures (dead code). All other Optimiser functions then are disabled. This switch works global, also for Units and Includes.

7 Compiler Switches

Compiler Switches are serving to control the behavior of the compiler. These switches are components of the source.

A switch is started with a **{** and a following **$** without a space. Immediately after the $ the switch name has to follow. Instruction for further parameters has to be done like the usual conventions.
The switches should start in the first column of a line. The same line may not contain any statements.

Syntax: **{$SWITCH [arg] }**

Each Import and each Device Define is added to the compiler switch list. This means that:

Import *LCDport, ...*

is treated like: {$DEFINE LCDPORT} and

Define *ProcClock = 8000000;*

is treated like: {$DEFINE PROCCLOCK}

7.1 Memory Administration

{$DATA} {$IDATA} {$IDATA1} {$PDATA} {$XDATA} {$XDATA1}..{$XDATA4} {$EEPROM} {$UDATA}
Selects the memory page of the CPU. Most of the small processors are only able to reach a small memory range if there is a direct address. Possible additional existing memory needs extra processing. This is specially valid for the external memory, if it existing. The switch assigns the appropriate area to the following variables.

{$DATA}
$DATA assigns the area, which is found in the processor control file (xxx.dsc) within DATA, to all following variable declarations (also **structconst).** With the AVR this area is from $04 upto $1F. The defined variables now are progressed placed from $04. If another switch of this type occurs later, the following variables are processed analogously. Variables in the area $DATA are always reachable with very short and fast machine commands.
XMega
Here the use of $DATA should be avoided because the registers start here with addr 0 and also the IO area starts with addr 0 which can produce some difficulties here.

{$PDATA}
$PDATA assigns the area, which is found in the processor control file (xxx.dsc) within PDATA, to all following variable declarations. With the AVR 8515 this area is from $20 upto $5F. The defined variables now are progressed placed from $20. PDATA is reserved for an IO-area, if existing.

$PDATA mostly is accessed with special machine commands. Within the definition of variables in this area, the compiler should not allocate the address, but the programmer must/should specify the required address of every variable:

Var *Port1[$35] : byte;*

{$IDATA}
$IDATA assigns the area, which is found in the processor control file (xxx.dsc) within IDATA, to all following variable declarations (also **structconst).** With the AVR 8515 this area is from $60 upto $25F. The defined variables now are progressively placed from $60. If another switch of this type is found, with the following variables are proceeded analogously. Variables in the area $IDATA are always accessible with longer and slower machine commands.

The iData normally includes the whole internal SRAM of the CPU. If necessary this area can be divided into two parts. This is supported with a Define. With iDATA1 the internal RAM is divided into two parts. The necessary parameter then defines the end of the first (lower) part and on the other hand the start address of the second part. (* REV4 *)

```
    Define iData1     = $800;
```

Variables now can be placed into the iData or Idata1 area.
Example:

```
    {$IDATA1}
    Var
      Test1     : word;

    {$IDATA}
    Var
      Test     : word;
```

{$XDATA} {$XDATA1} {$XDATA2} {$XDATA3} {$XDATA4}
$XDATA assigns the area, which is **Defined** with XDATA, to all following variable declarations (also **structconst).** XDATA is external memory, which is only available within the bigger types. If another switch of this type is found, with the following variables are proceeded analogously. Variables in the area $XDATA are always accessible with longer and slower machine commands. Often the CPU uses additional Wait states.

```
Define xDataWaits  = nn;      // 0..3
```
Select the xData Waits for e.g. mega8515, mega162, mega64 and mega128.

```
Define  XDATA1 = $8000, $80FF, NoInit;
```
Each XDATA can be assigned to **NoInit** within the XDATA definition.

{$EEPROM}
$EEPROM assigns the area, which is found in the processor control file (xxx.dsc) within EEprom, to all following variable declarations (also **structconst).** EEprom only can be a chip intern memory.

The EEPROM normally includes the whole internal EEPROM of the CPU. If necessary this area can be divided into two parts. This is supported with a Define. With EEPROM1 the internal EEPROM is divided into two parts. The necessary parameter then defines the end of the first (lower) part and on the other hand the start address of the second part. (* REV4 *)

```
    Define EEprom1     = $800;
```

Variables now can be placed into the EEPROM or EEPROM1 area.
Example:

```
    {$EEPROM1}
    Var
      Test1     : word;

    {$EEPROM}
    Var
      Test     : word;
```

{$UDATA}
$UDATA assigns the area, which is **Defined** in the definitions section with UserData (UserDevice), to all following variable declarations. This data area resides in an external device which is not accessible through the normal CPU-addressings, e.g. a serial EEprom. The programmer must supply a device driver. See also paragraph **Device Driver** in the *Standard Driver Manual*.

The variables always build up from the lower to the higher address. If the memory areas are changed by a new switch, so it is continued with the actual memory at **last specified address**.

Memory Initialization

The memory areas $DATA, $IDATA and the $XDATA section basically are initialized to $00. This initialization can be disabled for the $XDATA areas at the definition time by the attribute **NOINIT.** This is valid for the entire area. The following compiler switch can be used for the $DATA and $IDATA sections:

{$NOINIT}
Switch for the $DATA and $IDATA area. The following variables of this section upto it's end are not initialized, i.e. they are not filled with zeros.
But you should note that the standard initialization is done in a very fast loop over a single block.
If you insert NoInit variables in between this process may take much more time.
You should group these var definitions to avoid extensive fragmentation.

Because $NOINIT stays valid until a recall the NoInit maybe cleared with
{$NOINIT OFF}

Variables outside any area

If variable has to be located outside any defined area, the compiler generates an error. The error can be suppressed with the following Compiler switch:

{$NORAMCHECK}
The following variable is not checked for a valid RAM area.

```
{$IDATA}
{$NORAMCHECK}
var
  Extreme[@$FFFF]  : byte;
```

{$PHASE} {$DEPHASE}
Switches to a fixed **WORD**-Address in Flash and back to the standard code page.

{$PHASE $1E00};	places the following code at addr $1E00 and up.
{$DEPHASE} ;	switches the address generation back to the default page.

{$ALIGN2}, {$ALIGN4}, {$ALIGN8}
Places the following variable to an address which is aligned accordingly.

7.1.1 Considerations about Memory Usage

The main difference between the separate memory areas is obviously the required time and the program space consumption, caused by the according addressing types of the CPU. Within time critical applications the programmer should assign his variables corresponding to the number of accesses to the variables.

Default: {$DATA}

```
var
        b1      : byte;         {$06}
        ch1     : char;         {$07}
        w1      : word;         {$08}
        bool1   : boolean;      {$0A}

{$IDATA}
var
        b2      : byte;         {$60}
        ch2     : char;         {$61}
        w2      : word;         {$62}
        bool2   : boolean;      {$64}

{$PDATA}
var
        Port1[$25]    : byte;   {$25}
        Timer4[$34]   : char;   {$34}
        Per2[$28]     : word;   {$28}

{$DATA}
var
        x       : byte;         {$0B}
        y       : char;         {$0C}

{$EEPROM}
var
        ex      : byte;         {$0}
        ey      : char;         {$1}
```

7.2 XData External Memory

If external memory exists and in use then this memory must be declared and defined by the compiler switches {$XDATA} {$XDATA1} {$XDATA2} {$XDATA3} and {$XDATA4} .

The definition of a XDATA area enables the use of the defined external memory area. The possibility to split the external memory into max. 5 parts supports the implementation of external peripherals and also battery buffered RAM.
Normally the compiler initializes the entire memory with “0“. In the case of peripherals and buffered RAM this is not desirable. Therefore it is possible to append the attribute **NoInit** to the definition. Then the initialization of this area is disabled.

```
Define  Xdata =  StartAddr, EndAddr [, NoInit];
…
var
{$XDATA}
        abc             : integer;
        fix[$3000]      : byte;
{$XDATA1}
        port1[$8000]  : byte;
        port2[$8001]  : byte;
{$IDATA}
```

If external memory is in use and defined, at first the area **XDATA** must be **defined.** Following further external areas can be defined with **XDATA1** etc. The definition includes the start- and end address of the memory block, followed by the optional **NoInit**.

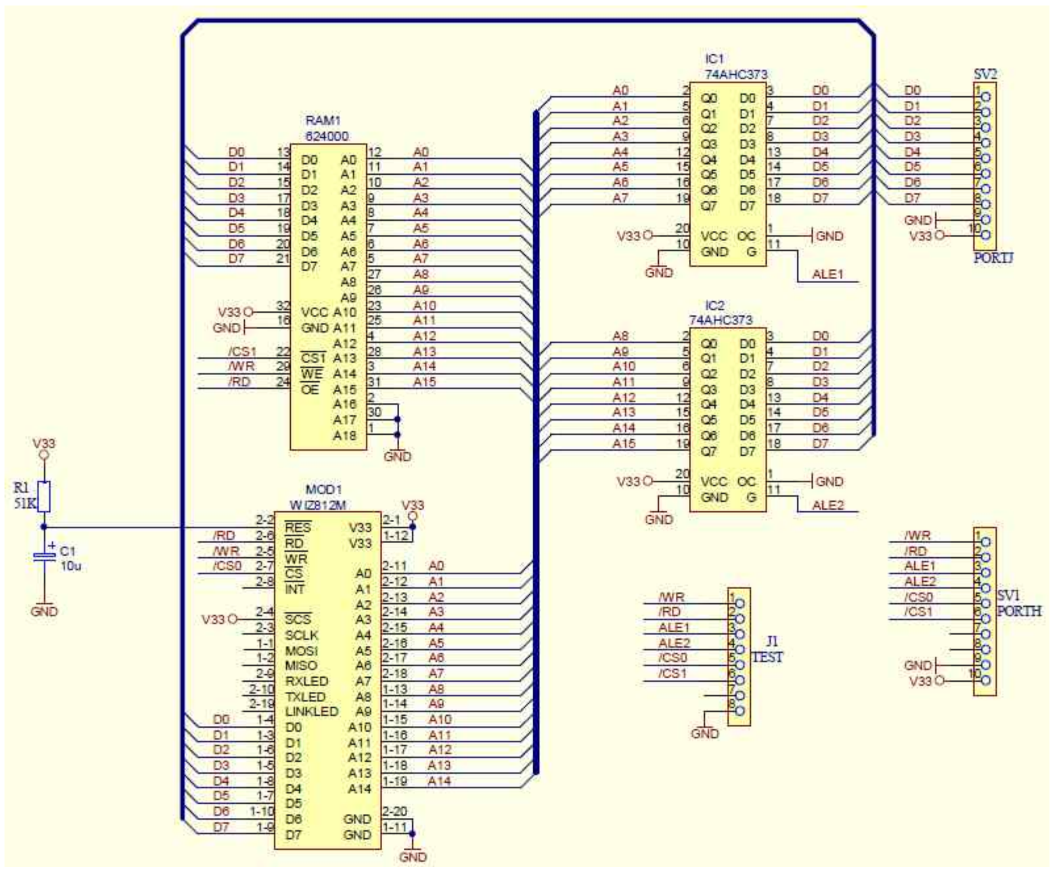
{$XIO +} {$XIO -}
Can be used in the XDATA area. It can tell the Optimiser about a memory mapped IO-area in XDATA. The memory area between these two switches then is treated in a different way by the optimiser. For example redundant accesses are not removed.

XMega
With the XMega a $XDATA0 can also be used for a $XDATA. Furthermore there are only upto 4 areas possible: XDATA0, XDATA1, XDATA2, XDATA3. Only 64kB are supported with SRAM and Memory Mapped IO. The 2 Port Interface is used in LPC mode.

Because of the internal logic of the XMegas there are some important facts which must be known. The minimum blocksize for an XData (= /CS) is 4kByte. The physical blocksize is defined by the given logical blocksize. For example if XDATA0 = $5000, $7FFF then the log block = $3000 but the phys block = $4000. So this block must start at $4000 because an address block must always start at a block boundary.

Example:
Log blocksize $1000 -> blocksize = $1000. Blockstart = $0000, $1000, $2000, $4000 etc.
If such a log. 1kByte block starts at address $5000 and ends at $5FFF then it must physically start at $4000 and end at $5FFF. New we have phys. Blocksize of $2000.
The AVRco supports the necessary calculations and rises an error message if bounds are incorrect.

An additional feature of the XMega is the so called overlapping. Here a block/CS with higher priority can override a block/CS which has a lower priority. The highest priority has the internal RAM/iDATA followed by XDATA0/CS0, XDATA1/CS1 etc. In order to avoid splitting of memory areas the smallest block should be placed on the highest address (end of 64k) and should be XDATA0/CS0. The next smaller block then is placed at a lower address (XDATA1/CS1). This logic may be somewhat disturbing so a deep look into the XMegaA1 datasheet may help.



A sample program is in the demo directory in ...\Demos\XMega_XDATA

7.3 Include Files

{$I Filename.ext}
Reads an include-file, whereby "filename" also can contain a path. If there is no path it is searched within the working directory of the application. So sources, which are used again and again, can be included. The include-file can contain assembler or Pascal-source as well as both together. The usual conventions are further valid.

{$J Filename.ext}
Reads an include-file, whereby "filename" may not contain a path. The "Home-Directory“ of the compiler is generally prefixed as path. This is very advantageous in case of procedures etc., which return again and again and it replaces almost a linker in the unit-concept.

7.3.1 Search Path for Include Files

Include files are searched in the following order:
1. actual working/project directory
2. in directories defined in Project Admin (IDE)
3. in directories defined in System Admin (IDE)
4. in the AVRco directory
5. in the "System" directory below the AVRco directory

7.4 Runtime Checks

If there is enough memory, “StackSize“ can be enlarged. If the compiler now reports a stack overflow only the elimination of variables can help. This may be possible by removing unused variables. If there are no unused variables, it must be solved by a double-assignment of variables. But the programmer has to be extremely careful, to avoid a time based conflict of the assignment.

```
Var   ch1         : byte;
      ch2[@ch1]   : byte;     {ch1 and ch2 same Address}
```

Please pay attention to chapter **RunTimeErr**.

{$ShowError err: string}
raises an error message

{$ShowError 'Error with ...'}	raises an error message at assembly time

{$ShowWarning err: string}
raises a warning

{$ShowWarning 'Attention: ...'}	raises a warning at assembly time

7.5 Variable, Constant and Procedure Check

{$WG}
Globaly enables the check of variables and procedures. With obviously unused variables, ROM-constants or procedures the compiler produces a warning, which is evaluated by the IDE. This switch is off by default and can only be set to on.

{$W+} {$W-}
Switches the check of variables and procedures on for the actual module (Main/Unit). With obviously unused variables, ROM-constants or procedures the compiler produces a warning, which is evaluated by the IDE. (see also optimisation)
Default: {$W-}

{$NORETURNCHECK}
Only valid in conjunction with functions. With the following function there is no error message if there is no Return statement.

{$NOOVRCHECK}
Disables the Check for the following Variable Overlay Declaration.

{$OverLay @VarName[, NoOvrCheck]} {$OverLay 0}
To avoid the separate overlay of each variable with: *yyy[@xxx] : byte;*
To place more than one variable into the referenced var, e.g. an existing Array or buffer.

"VarName" is must be existing variable (@VarName)in the RAM area.
The optional parameter "*NoOvrCheck*" defines that no overflow checks must take place. If this switch has a zero parameter "0" then this is the end of this overlay area.

All variables which are defined between these two switches now get upcounting addresses starting with the address of "VarName". This means they are placed "over" the basic variable.

Basically this variable at least should occupy the same or more memory as the sum of all overlaying ones. If an overflow is created it is displayed with the trailing switch. But this overflow is ignored with if the option "*NoOvrCheck*" is set with the leading switch.

Instead of a variable as the reference also an absolute address can be defined by
{$OverLay $nnnn, NoOvrCheck}
Then the option "*NoOvrCheck*" is mandatory.

{$Q-}
disables the need to qualify identifiers within assembler coding.
Only for already existing older programs.

{$TYPEDCONST OFF} {$TYPEDCONST ON}
For a better readability of programs and to avoid compiler errors.
With "ON" the compiler expects with each constant declaration also a proper type declaration. Because of this a "0" for example becomes unambiguous a byte, word, integer or a float. The “OFF” switch should not Be used anymore!

```
const bb : byte = 0;
```

The switch is default "ON".
If existing programs should not be changed and to avoid error messages the typed const feature must be disabled in the main file like this:

```
{$TYPEDCONST OFF}
program ProgName;
```

{$VALIDATE name}
Constants and variables of the system and also of the application in most cases will be removed by the compiler/optimiser if they don't appear in the context. This means they must be included at least once in a statement.

This can lead to problems with inline assembler code in the Pascal sources.
The assembler shows an error because the called procedure etc. is not present in the asm source.
The switch {$VALIDATE name} forces the compiler to import or implement the construct "name" and the optimiser is disabled for this item. The switch can only be used after the declaration of “name”.
ATTENTION:
this option (is the only one that) is not working with the *"Merlin Optimiser"*

{$VALIDATE $}
Functions and procedures can be excluded from any optimiser remove with this switch. It must be placed before a function/procedure declaration.

{$VALIDATE_ALL}
It tells the compiler to place obviously not used constants of type String, Array and Record into the program code. The optimisation for these type of constants is then disabled completely.

{$VALIDATE_ON} {$VALIDATE_OFF}
To set variable blocks as "used" so the message "possibly unused variable" becomes suppressed for this area.

{$ZeroLocVars +}
If active all local variables in functions and procedures are cleared to zero if a function or procedure is entered.

{$NOADDRCHECK}
For Mega128..256: Placing of constants always use the highest Flash Page as the destination. Basically other pages are not usable for this by the system. With this compiler switch the address or page check is disabled for the following constant definition. This constant can also be an external binary file which should be placed here. If the address given is not inside the uppermost flashpage (standard constant page), so an access to this constant by the application with its standard addressing mechanism is impossible. Then the application must provide very special own access methods.

```
const
{$NOADDRCHECK}
   LookUpTab[$20000] : array[1..256] of byte = 'Name.ext';  //mega2561
```

{$REUTILIZE }

XMega

serves to reuse Timer, SPI and TWI for different drivers.
For example if the driver A uses the SPI_C and the driver B must also use the SPI_C then an error is raised.
To avoid this and be able to use the SPI_C for both drivers then before the second define of the SPI_C this compiler switch must be used:

```
Define
   DriverA   = SPI_C;
 {$REUTILIZE SPI_C}
   DriverB   = SPI_C;
```

Valid arguments are TIMER_C0..TIMER_F1, SPI_C..SPI_F, TWI_C..TWI_F

7.6 System Controlling

{$NOSAVE}
Is only valid in connection with application interrupt procedures. With the following interrupt procedure the system does not save the working register automatically (except the status register and 4 main working registers). The programmer has to do it himself. It only makes sense for fast service - routines, written in assembler.

{$NOREGSAVE}
is only valid in connection with application interrupt procedures. With the following interrupt procedure the system does not save any the working registers. The programmer has to do it himself. It only makes sense for service routines written in assembler.

{$NOSHADOW}
The definition must be, if necessary, before the device declaration. With non-multitask applications only those working registers are saved, which are used by the interrupts within all interrupts. This saves essentially ram, rom, and run-time. This switch is overwritten by the import of tasks and processes.

{$NOFRAME}
Is only valid in connection with device driver procedures, which are called by the procedures **Write** or **Read.** With the following device procedure, which may only have one 8-bit passing parameter, this parameter is passed within a register. A parameter frame is not made. So local variables are not possible. This only makes sense for fast driver routines, written in assembler.

{$DEBDELAY}
For the simulator. Shortens the mDelays in the Simulators by 90%.
This switch does not have any meanings for the generated Hexfile, i.e. it's not necessary to remove it.

{$D+} {$D-}
Debug informations on or off. If off, the following statements are not stepped by the simulator.
This switch does not have any meanings for the generated Hexfile, i.e. it's not necessary to remove it.

{$X-} {$X+}
Disables the execution of a source code area in the Simulator. Useful if the program polls or waits for an external hardware.
This switch does not have any meanings for the generated Hexfile, i.e. it's not necessary to remove it.

{$DEVICE}
This is only valid in connection with Device driver procedures, which are called by the procedures **Write** or **Read.** In the following Device procedure, which may only have an 8bit parameter; this parameter is passed in a register. A parameter frame is not built, so local variables are not possible. It only makes sense for fast driver routines written in assembler. Identical with the $NOFRAME switch.

{$LCDNOWAIT}
Disables the Busy-Polling of the display driver. Only for debug purpose!

{$LCDNOINIT}
The LCD controller is not initialized at Reset time. The application must do it with a invocation of the system procedure “*LCDsetup*“.

{$ENUMTOASM}
Enumerations normally are not exported into the assembler file to save computing time with the compiler and assembler and to have a good overlook over these files.
If the enum values are needed for inline assembly it is possible to force the export of the values of each enumeration into the asm-file as constants with this compiler switch.

{$SL+} {$SL-} (*P*) temporarily disabled ! Please use Merlin Optimiser instead !
Enabled or disables the Smart-Linker. Using this switch removing dead code can be enabled (+) or disabled (-). These switches can be placed anywhere and without limitation Please note that this switch is always set to "off" at the entry point of an unit. The same is true for the main program file.

{$SL ON} (*P*) temporarily disabled ! Please use Merlin Optimiser instead !
Switches the default mode of the linker at program start to active.
If the switch state is "on" (remove), it can be temporarily set "off" for a specific function or procedure by using the switch *{$VALIDATE ProcedureName}.*
But this switch is only valid at locations where the concerned function is already known (defined) by the system. For validating before a function/procedure declaration use *{$VALIDATE $}.*

Instead of the obsolete $SL switches the Merlin Optimser should be used. If only the $SL functuality of the Merlin will be used the Optimiser directive
{$OPTI SMARTLINK_ONLY}
should be used.

{$OPTIMISE}
This switch forces a compilation with the use of the Merlin Optimiser. This switch **must** be located in the first line of the main program!

{$PCU} (*P*)
The switch located in the IDE "Project/Project Options" controls all Units of the current project. If activated all Units of the project are processed by the precompiler and PCU files are build, dependant of the other "PCU copy" switches.
By the usage of this compiler switch in the source area of an Unit the rebuild of a PCU out of this Unit is forced, regardless of the meaning of the global switch in the IDE. But the "copy PCU" switches of the IDE are still valid and control the destination of this PCU.

{$VectTab $nnnn}
{$CodeStart $nnnn}
With standard AVR applications the Interrupt Vector Table always resides on address $0000 in the code area (Flash). The same also is true with the Codestart. This means that also the generated code starts with address $0000, but more exactly immediately behind the vector table. With these two switches the system can be forced to start the address generation with other addresses as the default ones.
The address parameter for these switches are always word addresses!

{$BootApplication $nnnn}
This switch is a combination the above two but in addition enables this application to use the Flash Downloader. So now it is possible to build an application which completely runs in the boot sections of the controller and still has access to all of the system resources and drivers because they are also placed into the boot section. The address parameter of this switche is always a word address and must be placed below the Device declaration!

A sample application can be found in the Demos Directory in “BootApp“.

7.7 Optimiser Directives

see chapter “The Merlin Optimiser”

7.8 Conditional Compile

Sometimes it is necessary to generate different, for example hardware dependant versions of an application. The respective behavior can be controlled with the help of the compiler switch for depended compilation (Conditional Compile). The used ***“Label“*** only has a symbolic character. If the result of a switch is “false“, so the here beginning source-code is treated as a comment as it does not exist until the switch is “true“. All switches of this group can appear at any position within the source. An “IFxx“-introduction must be finished with an “ENDIF“. There can be an “ELSE“ in between. Nested IF’s are permitted!

It is also possible to pass one or several DEFINES from the IDE PED32 to the compiler by using the menu item ***Project/Project Options*** and define a Label (without $, parenthesis and DEFINE). The parameters and labels must be separated with a semicolon. These parameters are then treated by the compiler as if they are in the first source line and have the outline *{$DEFINE Label}*.

{$DEFINE label}	sets “label” to true
{$UNDEF label}	sets “label” to false
{$IFDEF label}	If “label“ is true, the following source is compiled upto “ELSE“ or “ENDIF“. If “label“ is false, it is processed reverse.
{$ELSIFDEF label}	If “label“ is true, the following source is compiled.
{$IFNDEF label}	If “label“ is false, the following source is compiled upto “ELSE“ or “ENDIF“. If “label“ is true, it is processed reverse.
{$ELSE }	Reverses the actual state. If, for example the preceding source was compiled, so the following source is treated as a comment upto “ENDIF“.
{$ENDIF}	Closes an conditional block.

It's also possible to use a boolean expression consisting of DEFINEs. Only the operators "AND" and "OR" are implemented and as arguments only previously introduced with {$DEFINE ..} can be used.

```
{$IFDEF ABC AND XYZ}
...
{$ELSIFDEF HIJK OR OPQ}
...
{$ENDIF}
```

Also parenthesis can be used:

```
{$IFNDEF ABC and (UVW or XYZ)}
...
{$ENDIF}
```

Further it is possible to check with IFDEF etc whether a Unit is present or not.
Unit names and Unit filenames are included in the Define pool.

If the Unit-fileName is "ABC.pas" and the internal Unit name is "U245" then the following is possible:

{$IFDEF FILE_ABC}	is true because the Unit filename is "ABC".
{$IFDEF U245}	is true because the internal Unit name is "U245".

```
Program Test;
{$DEFINE pp}
{$IFDEF pp}
Procedure ABC;      {Procedure head}
begin               {will be compiled and executed}
  ...
end;

{$ELSE}
Procedure ABC;      {Procedure head}
begin               {will be treated as comment}
  ...
end;
{$ENDIF}
```

{$IF equation = true} {$ELSIF equation = true}
In place of values defined by $DEFINE it's possible to use constants defined by the system or in the program source:

```
const
    x   : 25;
    y   : 1;

{$IF x > y}
...
{$ELSIF x = y}
...
{$ENDIF}

{$IF PROCCLOCK = 8000000}
```

Examples of System defined constants for the Compiler Switches (and also for Statements):

```
_iDataStart
_iDataEnd
_EEpromStart
_EEpromEnd
_FlashStart
_FlashEnd
```

{$IFDEF CPUname}
This switch makes it possible to build CPU type dependent code.

{$HEXPATH 'pathname'}
If "conditional compile" switches generate different firmware out of the same source, it makes sense to place the generated hex-files also into different directories. This compiler switch serves this purpose.
All involved tools which are called from the IDE like Editor, Compiler, Assembler, Programmer recognize this switch.
The argument 'pathname' must be delimited like any string in the system.
If the path or directory doesn't exist they will be created by the system.

{$HEXNAME 'filename'}
If "conditional compile" switches generate different firmware out of the same source, it makes sense to save the generated hex-files also with different file names. This compiler switch serves this purpose.
All involved tools which are called from the IDE like Editor, Compiler, Assembler, Programmer recognize this switch.
The argument 'filename' must be delimited like any string in the system.
Both switches can also be combined.

Note:

A copy of the Flash and EEprom hex files is also stored in the current project directory with their origin names so that the incircuit programmer at this point does not handle different locations for the same project. On the other hand the programmer's project administration must be extended with the different possible projects.

8 Program Structure

8.1 Program Frame

Because of syntax requirements a certain program frame is necessary. This starts with 'Program *name'* and ends with 'End.' As mentioned above in different chapters, diverse devices, system functions etc. have to be **imported** to be **defined.**

The programmer should take the example below as model for his own program structure. If there is a new project, there is automatically a main-file with the corresponding entries created by the IDE PED32. But the passumtion is, that a template-file (*.tmpl) exists and the entry of this file in the according “Control“ of PED32.

Within some versions there is a so called **Application Wizard.** This is helpful to interactively create the source of a new application.

Of course the compiler creates a syntax error if there are false or missing imports or defines.

Unnecessary imports or variable declarations should be avoided. Think about the small resources (ram) of most processors. At least with the overwrite of variables and stacks the compiler gives a warning.

Nested procedures, long arithmetic statements with many brackets or procedure calls within Interrupts leads to run-time problems with the **stack-overflow** (parameter stack).

8.1.1 Order

The order of the declarations of *program* up to *implementation* **must be** followed. *Const* and *Var* declarations can be mixed after that. **After the first** *procedure* or *function* declaration it is best to avoid to use global *Var* or *Const* declarations **as far as possible.**

Local variables or constants within a procedure or function mean a bigger code and a longer run-time. With procedures or functions, where as short process time as possible is required, it only should be coded with global variables. That is also true for passing parameters.

With **String** and **Array** variables you should be thrifty. The memory consumed can exhaust the system sources very fast. It is the same with the string conversions.

8.2 Initializing

After a reset or a program start the complete memory (variables) is set to zero (var:= 0;). So global variables need not be preinitialized by the program in general.
The initializing is directly after the introduction *implementation* or after calling the procedure **System_Init,** if it exists.

Under some circumstances it could be necessary that some memory location are not initialized or erased. This can be achieved by the compiler switch **{$NOINIT}.** But it must be clear that no more initialization is done after this switch. This means that all memory locations residing before this switch, are erased and all defined after this switch are unchanged.

The compiler and its system library only does such hardware initialization that is necessary for the function of the imported functions. If, for example **SwitchPort1** is imported, the defined port is switched to input. The import **ADCport** initializes all hardware, which is necessary for the execution of the converter. Separate bits (for example bit7 of LCDport) are not initialized and changed.

So the programmer **himself** has to initialize the hardware which he requires and which was **not imported.** The IO-Ports, which are in the CPU, are defined by the processor description-file *xxx.dsc* and imported by the compiler. So a new definition of the port by the programmer is not necessary. Example for PortB input/output mixed:

```
var
  DDRB[@PortB -1] : byte;   { Data Direction reg PortB}
  Led1[@PortB, 0]   : bit;
  Rel1[@PortB, 1]   : bit;

begin                 {Main}
 DDRB:= $0F;          {upper 4 bits Input, lower 4 bits output}
 EnableInts;          {Interrupt enable if necessary}
 Incl (Led1);         {Led1 On}
 Loop
   Toggle (Rel1);     {switch Relais1}
   mDelay(1000);      {1sec delay}
 endLoop;
end.
```

Example of a Program Scheme:

```
Program Test;

Device ...                        {Hardware declaration}

Import ...                        {System functions/HardWare}

From System Import ..             {System types/Software}

Define ...                        {Hardware Definition}

Implementation ...                {Program start}

Type ...                          {Type declaration}

Const  ...                        {Constant declaration}

Var    ...                        {Variable declaration}


Procedure System_Init;            {optional}
begin
 ...
end;


Procedure ABC;                    {Procedure head}
begin
 ...
end;


Function CDE : boolean;           {Function head}
begin
 ...
 Return(a > b);                   {Result of the function}
end;


Process PPP (20, 10 : iData);     {Process head}
begin
 ...
end;

Task TTTT (iData);                {Task head}
begin
 ...
end;

begin                             {Main program start}
 ...
 EnableInts;
 {Start_Processes;}               {if processes imported}
 Loop
  ...
  ABC;
  x:= CDE;
 EndLoop;
end.
```

9 Compiler Errors

9.1 Error File

If the compiler notices any errors it generates an error-file with the File Extension ‘xxx.err’. This file is used by the IDE PED32 to locate errors and their display.

9.1.1 Type Mismatch

Programming beginners will often stumble over the error **Type Mismatch.** The experienced programmer would be also astonished by the same fact, because maybe he knows and uses the automatic type conversion from Turbo Pascal, Delphi or C.

The automatic type-conversion, which is almost not existent within the compiler, gives the above mentioned error message.

There are several reasons, why this type of conversion does not exist in this compiler:

1. It is difficult and complex to realize a faultless automatic conversion within a compiler.

2. Every Turbo-programmer can sing a song about how to search for the cause of a wrong calculation result, to recognize finally, after many inspections of nested statements, that the type-conversion was the reason. To save the honor of Turbo it must be said that the formal compiler always behaves correctly, but the programmer often thinks in a different way about it. Often there is missing just a bracket pair.

3. With certain security relevant applications this kind of automatic convertion is not desirable.

3. It is the better and safer programming style if the programmer is forced to explain the compiler, what he wants. Or better: the programmer knows best, what should happen and how it should happen.

5. Type Casting (type conversion) is clearer and more readable *word := word (byte);*

A little problem should not kept secret at this point. It might appear that with constants < 256 and with certain operations, that the compiler does not know if it should treat the constant as an 8-bit or a 16-bit value. This might lead to a Type Mismatch.

```
var   b    : boolean;
      i    : integer;

      b:= 5 > i;
```

When the compiler reaches the position ‘5’ it only knows, that a boolean is expected and ‘5’ can be a byte. So the ‘5’ is treated as a byte and leads with the following integer ‘i’ to a Type Mismatch.

Remedy:

```
      b:= integer(5) > i;
```
or
```
      b:= i < 5;
```

10 Units (*P*)

10.1 Declaration and Construction of a Unit

A Unit consists of types, constants, variables and routines (procedures and functions). Each Unit has to be defined in a separate Unit-file (.PAS).
A Unit-file begins with the Unit-header and contains the sections **interface, implementation** (and optional **initialization).** The structure of a Unit-file looks like this:

```
unit Unit1;

interface

uses  { List of additional Units }

        { interface-section }

implementation

        { implementation-section }

initialization

        { initialization-section }

finalization

        { finalization-section }

end.
```

A Unit must conclude with the word **end** followed by a period.

10.1.1 Unit-Header

The Unit-header defines the name of the Unit. It consists of the reserved word **unit,** a valid identifier and a semicolon. The identifier must be the same name as the Unit-filename.

```
unit Hello;
```

This Unit-header can be used in a source file named Hello.PAS. The file with the compiled Unit then has the name Hello.PCU.

Unit-names must be unique in a project. Also when the Unit-files reside in different directories it's not possible to use multiple Units with identical names in a project.

10.1.2 Interface-Section

The interface-section of a Unit begins with the reserved word **interface.** It ends with the begin of an implementation-section. The interface-section declares constants, types, variables, procedures and functions which are accessible for Clients. Clients are other Units or the project itself, which import this Unit by a uses-clause. Such identifiers are called public because the Client can access them as they were declared in the Client itself.

The interface-declaration of a procedure or a function only contains the header of the routine. The block of the procedure or function must be declared in the implementation-section only. Procedure- and function declarations in the interface-section conform to the normal forward-declarations, but the forward directive must not be written.
The interface-section also can have an uses-clause, which directly must be placed after the interface statement.

10.1.3 Implementation-Section

The implementation-section of an Unit begins with the reserved word **implementation** and ends with the begin of the optional initialization-section or – if there is no initialization-section – with the finalization section or the end of the Unit. The implementation-section defines procedures and functions, which were defined in the interface-section. Within the implementation-section order of definitions or call of these procedures and functions is arbitrary. The parameter lists of functions and procedures must be the same as in the declarations in the interface section.

Except of the definitions of the published procedures and functions the implementation –section can have additional declarations of constants, types, variables, procedures and functions, which are private (local) for the Unit. Clients don’t see this objects and can’t access them.

With *Define_USR* it is possible to define constants which are visible and accessible from every point of the program and also from each Unit.
This Define should only be used if it is absolute necessary because it's not a good programming style.
The better way is to place such globals into an Unit which resides in the last position of the Unit chain.
Then the definitions are also visible from all other parts of the application

10.1.4 Initialization-Section

The initialization-section is optional. It begins with the reserved word **initialization** and ends with the finalization section or the end of the Unit. The initialization-section contains statements, which are processed at program start in the given order. If you have to initialize hardware or variables concerning the Unit, it can be done here before the main program is invoked.

The initialization-sections of Units, which are imported by Clients, are processed in a hierarchical order. This means: the last Unit, which resides at the end of the chain is the first which is initialized.

10.1.5 Finalization-Section

The Finalization-Section is optional. It begins with the reserved word **finalization** and ends with the end of the Unit.
The statements in this block are processed when the application calls the system procedure "*System_ShutDown*". The calling order of the finalizations is exactly opposite to the calling order of the initializations. The procedure "*System_ShutDown*" simply calls the Finalization Statements and nothing else.
The "Finalization" is useful for a dedicated run down of the system before a switch off or a start of the sleep mode

10.1.6 Uses-Clause

The uses-clause of the main-program defines all Units, which are imported into the program. These Units themselves also can have own uses-clauses. A uses-clause in a program or a Unit defines the Units which are used by this module. A uses-clause can be used in the source of the following files:

Mainfile of a program
Interface-section of a Unit

The Unit **System** is automatically imported by an application and must not be imported in a uses-clause. (The Unit System implements routines for hardware and software drivers, string conversion, Floating point etc.).

A uses-clause always consists of the reserved word **uses,** one or several unit names, separated by commas. It concludes with semicolon.

```
uses Hello, MyMath;
```

In the uses-clause of a program it’s possible that each Unit name can be extended by the reserved word **in** followed by the path and name of the source file. The name is written with or without the path in quotes. The path can be absolute or relative.

```
uses Hello, MyMath in 'C:\MyProg\MyMath', InitUnit;
```

Use **in ...** after the unit name, if you must define the filename of a Unit source. The reserved word **in** is only necessary if the location of the source is ambiguous for the following reason:

the Unit-source file is in a different location than the project itself, and this directory is not in the search path of the compiler nor in the home path of the compiler.

10.1.6.1 Search Path for Units

Units are searched in the following order:

1. actual working/project directory
2. in directories defined in Project Admin (IDE)
3. in directories defined in System Admin (IDE)
4. in the AVRco directory
5. in the "System" directory below the AVRco directory
   Precompiled Units (PCUs) initially included in the AVRco system are placed here

10.1.7 Info Part of a Unit

The Info part of an Unit consists of any lines at any positions in this Unit.
An Info line must start with

```
|||  and here the info
```

The three pipe chars must not contain spaces. The system treats an Info line like a comment.

In the IDE (Editor) there is a menu item "Project/Unit infos". All Units which are declared in the SourceCodeControlSystem (SCCS) are listed here.
A mouseclick onto an Unit name opens a window which shows the Info part of this Unit

10.1.8 Hardware Imports within Units

If Units are imported the definitions can also be placed into an Unit:

Main Program

```
Import SysTick, MatrixPort, SerPort;

From System Import longword, longint, float, pipes;

Define
    ProcClock    = 8000000;    {Hertz}
    SysTick      = 10;         {msec}
    StackSize    = $0020, iData;
    FrameSize    = $0040, iData;
    SerPort      = 9600;
    RxBuffer     = 16, iData;

DefineFrom unit1;    // Unit1 defines the Matrixport
```

Unit

```
Unit Unit1;

Define
    MatrixRow    = PortD, 4;   {use PortD, start with bit4}
    MatrixCol    = PinD, 0;    {use PinD, start with bit0}
    MatrixType   = 3, 4;       {3 Rows at PortD, 4 Columns at PinD}

Interface
...
```

The reserved word "*DefineFrom*" within the main "Define" block switches the scanning from main program to the given Unit name, where the scanning of the defines continues.
When the word "*Interface*" appears the scanning is switched back to the main program.

10.2 PreCompiled Units

The Profi-version allows to build precompiled units and also include files.
This works similar like a linker, but isn't really exact the same.

The units will be precompiled and therefore are not readable for others. But in the compiled project one can see the generated asm sources of these units. Normally this isn't a problem at all, because the generated asm is also visible in the asm window of all debuggers and simulators.

In the IDE PED32 in the menu "Project/Project options" there is a checkbox "Precompile Units".
If this box is checked, all units and includes are precompiled into files with the extension "filename.PCU".

These files can be passed to others without their accompanying sources.

11 Assembler

11.1 Overview

The AVRco System includes an Assembler, which can be used as a stand-alone program. Please note that all processor mnemonics can be used, but no macros and similar function are possible like complex assembler have.

Basically the assembler is used for assembly of the asm sources generated by the compiler and also for asm statements defined with the "ASM"- definitions in the Pascal-Source.

The construction and meanings of the mnemonics can be found in the processor manuals. With some processors it's possible that some mnemonics, e.g. register names, can collide with variable names of the application. Then other names are used for that definition.

ASM: *mnemonic* ;Definition of a single assembler statement.

11.1.1 ASM;

Start of an assembler text block

A program for Embedded Control does not often work without an assembler code, because either the compiler generated code is too slow for some operations, or certain assembler commands have to be done, which are not known or not used by the compiler.

It is possible to include the assembler source directly at every position of the Pascal source. This source is passed non-tested and unmodified by the compiler to the assembler. Because the compiler also generates assembler code, the assembler text is seamless inserted.

Asm-syntax errors are only recognized by the assembler, not by the compiler. All declared variables are accessible in the assembler text.

Warning:
Labels in a assembler-block have to start at the beginning of a line and limited with a '**:**'.
This line may not contain any further instructions, e.g. code. The analysis of the compiler generated assembler files 'xxx.ASM' may help.

```
ASM;
 LDI          _ACCA, 67;
 STS          a, _ACCA;            {a = Pascal var }
ENDASM;
```

11.1.2 ENDASM;

End of an assembler text

ASM and ENDASM are Pascal statements and must end with a semicolon **;**
Exception: single assembler statement with ***ASM:***

11.2 Assembler - Keywords

11.2.1 Register

With the AVR the register names ‘R0’.. ‘R31’ in the mnemonics are changed to _ACCA, _ACCB etc. in order to avoid naming conflicts with possible Pascal vars or constants.

Relations between register numbering and pseudo ACCUs:

R0	=	_ACCGLO	Arithmetic reg and Flash access
R1	=	_ACCGHI	only with Imports of 32bit Types and Floats
R2	=	_ACCHLO	only with Imports of 32bit Types and Floats
R3	=	_ACCHHI	only with Imports of 32bit Types and Floats
R4, R5	=	$_CURPROCESS	no User Access if defined by the system
R6, R7	=	$_CURTASK	no User Access if defined by the system
R8, R9	=	$_SAVERET	no User Access if defined by the system
R10	=	FLAGS	
R11	=	FLAGS2	
R12	=	_SYSTFLAGS	no User Access if defined by the system
R13	=		not used and not defined
R14	=		not used and not defined
R15	=		not used and not defined
R16	=	_ACCB	main working register low byte (16bit and 32 bit types)
R17	=	_ACCA	main working register 8bit types hi byte (16bit types) hi byte of low word (32bit and floats)
R18	=	_ACCALO	main working register Lo byte of hi word (32bit and float)
R19	=	_ACCAHI	main working register Hi byte of hi word (32bit and float)
R20	=	_ACCDLO	Arithmetic reg
R21	=	_ACCDHI	Arithmetic reg
R22	=	_ACCELO	Arithmetic reg
R23	=	_ACCEHI	Arithmetic reg
R24	=	_ACCFLO	Arithmetic reg
R25	=	_ACCFHI	Arithmetic reg
R26	=	_ACCBLO	Arithmetic reg
R27	=	_ACCBHI	Arithmetic reg
R26, R27	=	X-register	second pointer reg
R28, R29	=	_FRAMEPTR	
R30	=	_ACCCLO	Arithmetic reg
R31	=	_ACCCHI	Arithmetic reg
R30, R31	=	Z-register	main pointer reg

All the above registers _ACCxx, excluding those, which are only present with 32bit types, can be used freely within the assembler part of the source. Those registers which are named and imported with 32bit imports (_ACCGHI, _ACCHHI, _ACCHLO) can only be used if a 32bit type is imported by an Import definition (LongInt, LongWord or Float).

All other registers which are named by the Compiler ($_CURPROCESS, FRAMEPTR etc) should only be read, but never written or altered in any way, otherwise a system crash at runtime is certain.

An exception are the 3 register pairs X, Y and Z. These mnemonics respective register names must be used in conjunction with pointer operations.

```
LDI   _ACCCLO, 00h;
LDI   _ACCCHI, 10h;        load _ACCCLO/HI = Z-reg with 1000h
LD    _ACCA, Z+;           load _ACCA with contents of RAM loc 1000h
```

For better readability the registers R28..R30 have additional names:

```
R26 -> XL   LDI  XL, 45h
R27 -> XH
R28 -> YL
R29 -> YH
R30 -> ZL
R31 -> ZH   LDI  ZH, 01
```

Labels
Within an assembler block labels must start immediately at the **line's start** and must end with a colon **:** . Appended directives or mnemonics after the colon lead to an assembler error. All other lines, except comments and definitions, must have at least one leading space.

Definitions
must also start immediately at the **line's start** and must end with a assembler directive. No colon is used. The corresponding assembler directive must be on the same line.

11.2.2 Assembler Directives

.ORG addr
changes the internal program-counter of the assembler to the address “addr‘. Should not be used by the programmer, it's reserved for the Compiler

name .EQU nn
Constant definition. Can be used. The better way is to define constants in the Pascal Code. Then they are accessible in assembler and also in Pascal.

.BYTE .WORD .ASCII
Constant placed into the Flash. Should not be used. With the mega it's forbidden, because here the constants are always placed into the second 64k-Page.

.END
End of the assembler text. Is defined by the Compiler.

ADDI ADCI
The AVR doesn't know the opcodes "ADDI" and "ADCI".
These can be easily implemented wit SUBI/SBCI and a negated argument. But the carry-flag can't be used as previously. ADDI and ADCI now are implemented as pseudo-ops in the Assembler.

```
ADDI  R16, nn
ADCI  R16, nn
```

ADIW SBIW

The mnemonics "ADIW" and "SBIW" in the origin Atmel way of writing are related to R26/X R28/Y and R30/Z. To improve the readability the Assembler is extended to accept the following mnemonics:

```
ADIW  X, nn
ADIW  Y, nn
ADIW  Z, nn
SBIW  X, nn
SBIW  Y, nn
SBIW  Z, nn
```

SYSTEM.VectTab

For JUMPs and CALLs to the absolute program start (ResetVector 0) it is possible to use Assembler statements like

```
JMP  $0000
CALL $0000
```

This absolute addressing mode is only possible with assembler and restricted to mega16/32/,...
Smaller CPUs don't support absolute CALL/JMPs.
To use it also with these types and also in Pascal there is the call/jump target label "SYSTEM.VectTab"

```
RJMP  SYSTEM.VectTab
RCALL SYSTEM.VectTab
JMP   SYSTEM.VectTab
CALL  SYSTEM.VectTab
```

11.2.3 Operators for Constant Manipulation

NOT Inverts the following argument.

```
LDI _ACCA,  NOT  0FFh;          load _ACCA with 00h
```

AND logical AND of two parameters.

```
LDI _ACCA,  0FFh AND 0F0h;      load _ACCA with 0F0h
```

SHRB Shift operation with a byte result.

```
LDI _ACCA,  0FF00h  SHRB 8;     load _ACCA with 0FFh
```

SHLB Shift operation with a byte result.

```
LDI _ACCA,  0FFh  SHLB 4;       load _ACCA with 0F0h
```

RORB Rotate with a byte result.

```
LDI _ACCA,  0A5h  RORB 4;       load _ACCA with 05Ah
```

ROLB Rotate with a byte result.

```
LDI _ACCA,  081h  ROLB 1;       load _ACCA with 03h
```

The Assembler accept character constants, too.

```
LDI    _ACCA, 'z';
```

11.2.4 Access to Pascal Constants and Variables

As stated above an assembler statement can access constants and vars which are declared in the Pascal source. Please note that a var normally must be qualified by it's ***Modulename*.** With accesses to words and longs bear in mind that the AVR uses the "Liitle Endian" principle. This means that the loByte of a word is determined by the lower order of the address, the hiByte by the higher order.

```
var
        bb   : byte;
        ww   : word;

begin
    ASM;
         LDS              _ACCA, module.bb      ; load byte bb to _ACCA
         ; load address of var ww to pointer reg Z
         LDI              _ACCCLO, module.ww AND 0FFh;
         LDI              _ACCCHI, module.ww SHRB 8;
         ;
         ; the Z-reg contains now the adr of var ww
         ; store a 0FFh to loByte of ww
         LDI              _ACCA, 0FFh;
         ST               Z, _ACCA;
         ;
         ; store a 00h to hiByte of ww
         LDI              _ACCA, 00h;
         STD              Z+1, _ACCA;
         ;
         ; move hiByte of ww to bb
         LDS              _ACCA, module.ww + 1;
         STS              module.bb, _ACCA;
    ENDASM;
End;
```

The basically necessary ***Modulname*** can be replaced by a **%**.
Example:

```
       Unit ABC;

       var xyz : byte;
       ...
       ASM
         LDS   _ACCA, ABC.xyz;
         ; or
         LDS   _ACCA, %.xyz
;
```

11.3 Assembler Routines

11.3.1 Local Variables and Assembler Access

Local variables in procedures and functions, as well as the passed parameters, are stored temporarily in the Frame. The addressing of the Frames is via the FramePointer (Y-register). It's impossible to access these vars and parameters by their names, because these types are always located relative to the FramePointer and not absolute.

The FramePointer always points to the last defined variable/parameter. The offset of the previous respective the above parameters must be calculated by the assembler programmer himself. Here he must take in account the order of the definitions and also the memory representation in bytes of the used types.

An erroneous offset calculation can lead to a system crash at runtime, at least with a write access.

```
Procedure LocTest (var x : byte; bb : byte; ww : word; pt : pointer);
var
   Lbb    : byte;
   Lww    : word;
   Lpt    : pointer;

begin
   ASM;
      ; Access to local pointer Lpt
      ; copy Lpt to Z-reg
      LD     _ACCCLO, Y              ; lo byte of Lpt
      LDD    _ACCCHI, Y+1            ; Y-reg offset 1
      ;
      ; Access to local word Lww
      ; copy ww to _ACCA, _ACCB
      LDD    _ACCB, Y+2              ; lo byte of Lww
      LDD    _ACCA, Y+3              ; hi byte of Lww
      ;
      ; Access to local byte Lbb
      ; copy lobyte of Lww to Lbb
      LDD    _ACCA, Y+2              ; lo byte of Lww
      STD    Y+4, _ACCA              ; byte Lbb
      ;
      ; Access to parameter pointer pt
      ; copy pt to Z-reg
      LDD    _ACCCLO, Y+5                    ; lo byte of pt
      LDD    _ACCCHI, Y+6            ; hi byte of pt
      ;
      ; Access to parameter word ww
      ; copy ww to _ACCA, _ACCB
      LDD    _ACCB, Y+7              ; lo byte of ww
      LDD    _ACCA, Y+8              ; hi byte of ww
      ;
      ; Access to parameter byte bb
      ; copy lobyte of ww to bb
      LDD    _ACCA, Y+7              ; lo byte of ww
      STD    Y+9, _ACCA              ; byte bb
      ;
      ; Access to parameter byte x
      ; mov a 00h to x
      ; remember that a var parameter is passed by it's address
      ; and not by it's value. So this param is always a pointer !!!
      LDD    _ACCCLO, Y+10           ; lo byte of adr of x
      LDD    _ACCCHI, Y+11           ; hi byte of adr of x
      LDI    _ACCA, 00h              ; load a zero
      ST     Z, _ACCA                ; store it with Z-Pointer reg to x
      ;
    ENDASM;
end;
```

Please note, that addressing with the use of the pointer registers of the AVR, in this case the Y-register (FramePointer) is only possible with an offset within 0..+63. If the Frame incl. Parameters is larger than 63 bytes, and the offset of the desired parameters/var is larger than 63, so the FramePointer Y must be copied into another pointer register (eg X or Z) and the offset must be added to this register pair as a constant. Never manipulate the Y-register !!

11.3.2 Procedure Calls and System Functions

Inside an assembler block it’s possible to call user defined Pascal procedures/functions and also system functions. Please note that the required Jump and Call labels must be qualified. With system functions (ser. interface etc.) the qualifier “SYSTEM“ must be used. With user functions in the main program the program name (not the filename) and with functions in Units the Unit name (not the filename) must be used

```
Program CallTest;
...

Procedure isCalled;

begin
  ...
end;

ASM;
  LDI         _ACCA, 2Ah;          ” * ”
  RCALL       SYSTEM.SEROUT;
  RCALL       CallTest.isCalled;
ENDASM;
```

11.3.3 Function Results and Assembler

The results of a function are always passed in registers to the calling location.

8bit Results (Byte, Char, Boolean etc)
Register _ACCA

16bit Results (Word, Integer, Pointer etc)
Register _ACCA (hiByte) _ACCB (loByte)

32bit Results (LongWord, LongInt, Float etc)
Register _ACCA (hiByte, loWord) _ACCB (loByte, loWord)
Register _ACCAHI (hiByte, hiWord) _ACCALO (loByte, hiWord)

11.3.4 Function/Procedure Exit

The Compiler often generates, depending on the construction of the procedure or function, exit code at the place of the Pascal End-Statement. Because of this there should be no *RET* or *RETI* statement programmed. The result can be a strange behavior of the procedure or system.
The better way is to place an *ASM-Label* before the End-Statement and then place a *RJMP* into the code to get to the exit code of the compiler.

11.3.5 Interrupt Procedures with Assembler

The Compiler saves at Interrupts always the registers *_ACCA, _ACCB, _ACCCLO* and *_ACCCHI*.
If processes or Tasks are imported, before calling the interrupt procedure all registers are saved. This can be disabled by the compiler switch {$*NOSAVE*} direct before the interrupt procedure. An other switch is {$*NOREGSAVE*} which disables any register saving. For special purposes, (very dangerous).

If no processes or Tasks are imported, the global compiler switch {$*NOSHADOW*} disables the complete saving of the registers. Alternatively one can disable the complete saving with {$*NOSAVE*} and only the 4 Accus are saved.

With complete saving of the registers each ACCU can be used within the assembler code. Otherwise only the ACCUs *_ACCA*, *_ACCB*, *_ACCCLO* and *_ACCCHI* can be used. If there is a need for more ACCUs, these must be saved by a *PUSH* and restored by a *POP*.

A complete register saving needs about 20 Bytes in RAM, statically, not on Stack or Frame. Because of this a stacked interrupt is impossible. That means within an interrupt procedure the interrupt never should be enabled again. The CPU itself does this enabling with the *RETI* instruction.

With the minimal saving of the 4 ACCUS (pushed onto the Stack) an Enable Interrupt is possible, but is strongly discouraged. The results can be catastrophic, depending of the operations within the procedure.

11.3.6 Constants and Optimisation

Constants, variables and system functions which are only accessed within an assembler block are normally removed by the optimiser. Because the Compiler doesn't analyze the assembler code it doesn't have any access to these parts. Therefore there can be errors while assembling the project, because the referenced labels don't exist.

In order to avoid optimisation removing such constructs (e.g. constants) it is necessary to make at least one access in HLL (Pascal) of these constants etc.

11.4 Assembler Switches

The assembler knows several command-line switches, which can be specified with the name of the source-file by a calling within the Batch-Mode by PED32. Because this tool needs many additional infos from the system it is impossible to run the assembler outside of the IDE PED32.

-R	Assembler runs without showing itself in the background	
-H	Hexfile output with the FileExtension	'xxx.hex'
-L	Listfile output on. FileExtension	'xxx.lst'

11.5 Assembler Errors

If the assembler recognizes any errors then it generates an error-file with the FileExtension 'xxx.err'.
This file is used by the IDE PED32 to locate and display the error.

Assembler errors should generally not appear, unless assembler statements are used.

Notes

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