

Astrobe

ARM Cortex-M Oberon Programmers Guide

This document is generally applicable to all ARM Cortex-M editions of Astrobe. It shows Oberon programmers how the Astrobe implementation of Oberon differs from the standard Programming Language Oberon report. It also clarifies the details of some features which are intentionally left undefined by the report. Guidelines and examples of recommended Oberon coding techniques are included.

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1 Introduction

The ARM Cortex-M compilers included in Astrobe implement the Oberon language as defined in the included report titled:

The Programming Language Oberon (Revision 1.10.2013 / 3.5.2016) by Niklaus Wirth.

This document is generally applicable to all editions of Astrobe for Cortex-M. It shows Oberon programmers how the Astrobe implementation of Oberon differs from the standard Programming Language Oberon report. It also clarifies the implementation-specific details of some features which are intentionally left undefined by the report. Guidelines and examples of recommended Oberon coding techniques are included.

2 Vocabulary

2.1 Underscore Characters in Identifier Names

Underscore characters (`_`) are allowed in identifier names (i.e. constant definitions etc.). This feature is solely intended for use with *multi-word uppercase* identifiers. Normally uppercase names should only be used for Oberon's reserved words and standard procedures and *CamelCaps* should be used to distinguish separate words in your own identifier names. However a justifiable exception to this rule is the use of uppercase peripheral register names in your programs to match those used by microcontroller manufacturers in their documentation. For example:

```
MCU.PINMODEOD0
```

can be defined as:

```
MCU.PINMODE_OD0
```

3 Constants and Types

3.1 BYTE

The BYTE type is primarily intended to be used when transferring 8- and 16-bit data to and from peripheral devices. Although BYTE variables can be used wherever an INTEGER variable is allowed (except where noted here) INTEGERS should always be used unless there is a compelling reason to do otherwise.

BYTE is an unsigned integer with a minimum value of 0 and a maximum value of 255.

BYTE variables are compatible with INTEGER variables in assignments, parameter passing and as return values from procedures. No overflow checking is performed on BYTE variables at runtime. The following code could be used to trap runtime errors when assigning an integer value to a BYTE variable:

```

PROCEDURE* IntToByte(intVal: INTEGER): BYTE;
BEGIN
  ASSERT(LSR(intVal, 8) = 0);
  RETURN intVal
END IntToByte;

```

Constants in the range 0..255 can be assigned to BYTE variables, passed to BYTE parameters and returned as BYTE values from functions. Attempts to use a constant outside this range where a BYTE value is expected will result in the compile-time error: *out of range*.

When using SYSTEM.PUT to store a value at a particular absolute memory location the type of the variable passed to the *SYSTEM.PUT* function determines whether a *store register byte* (STRB) or *store register word* (STR) instruction is used to perform the transfer. Normally, if you specify a numeric constant value, SYSTEM.PUT will use a word-sized transfer as it interprets the constant as an INTEGER. If you want it to use a byte-sized transfer instead you should use a character constant or BYTE variable, whichever you prefer:

```

VAR
  addr: INTEGER;
  b: BYTE;
  ...
BEGIN
  SYSTEM.PUT(addr, 0X);
  SYSTEM.PUT(addr, CHR(0));
  b := 0;
  SYSTEM.PUT(addr, b);
  ...

```

3.2 CHAR

The characters of the Latin-1 set.

3.3 INTEGER

The range of valid INTEGERS allowed is -2^{31} to $+2^{31}-1$. In the following description these values are referred to as MinInt (-2147483648) and MaxInt (+2147483647).

A number of MinInt-related anomalies exist in the current implementation:

- The compiler does not report an error if 2147483648 (MaxInt+1) is specified as a constant. The actual value stored is MinInt.
- ABS(MinInt) = MinInt
- -MinInt = MinInt

LONGINT is an alias for INTEGER.

3.4 REAL

The range of valid REAL numbers is:

```

REAL      -3.40282E+38 .. +3.40282E+38

```

LONGREAL is an alias for REAL.

3.5 SET

The sets of integers between 0 and 31.

4 Language Extensions

4.1 ARRAY of BYTE Type Casting

If a formal parameter to a procedure is defined as ARRAY OF BYTE the actual parameter may be of any data type. The parameter can then be accessed byte-by-byte in the body of the procedure e.g.

```
VAR
  data: INTEGER;
  b1, b2, b3, b4: BYTE;

PROCEDURE WordToBytes(w: ARRAY OF BYTE; VAR b1, b2, b3, b4: BYTE);
BEGIN
  ASSERT(LEN(w) = 4, 20);
  b1 := w[0];
  b2 := w[1];
  ...
  ...

WordToBytes(data, b1, b2, b3, b4);
```

If the formal parameter is an array of bytes with a fixed size it can accept actual parameters of any type, whose size is the same number of bytes e.g.

```
TYPE
  Buffer = ARRAY 256 OF BYTE;
  IntArray = ARRAY 64 OF INTEGER;
  Data = ARRAY 12 OF INTEGER;

VAR
  ia: IntArray;
  d: Data;

PROCEDURE SendData(bytes: Buffer);
...
...
SendData(ia); (* OK *)
SendData(d); (*Error: incompatible parameters *)
```

The converse situation is also catered for i.e. a procedure with a formal parameter of any type can accept an actual parameter which is an array of bytes of the same size.

These extensions are designed to simplify and optimise the code required for tasks such as de-serialising / serialising complex data structures for Input / Output operations, writing generic debugging trace functions etc. Examples of their use can be seen in *ByteArrays.mod* in the *General* examples supplied with Astrobe.

The following compiler warnings are generated:

```
Warning: type cast to byte array
Warning: type cast from byte array
```

NOTE: You can use SYSTEM.VAL for type casting if you would prefer not to use an Oberon Language extension. Examples of its use can be seen in *VALByteArrays.mod* in the *General* examples supplied with Astrobe.

NOTE: Compiler warnings are not generated for SYSTEM.VAL as the presence of SYSTEM in the IMPORT list already warns of potentially unsafe operations.

4.2 Built-in Procedures

4.2.1 ABS

```
PROCEDURE ABS(s: SET): INTEGER;
```

An overloaded form of the standard procedure ABS takes a SET parameter and returns the number of elements in the set. For example:

```
ABS({}) = 0
ABS({0}) = 1

s := {1, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31};
ABS(s) = 11

s := {0..15};
ABS(s + {16..31}) = 32
```

4.2.2 BITS

```
PROCEDURE BITS(i: INTEGER): SET;
```

BITS takes an INTEGER parameter and returns a SET with the same bit pattern. It is a type cast function like SYSTEM.VAL rather than a type conversion function like ORD.

By definition, the following expressions, where *i* is an INTEGER and *s* is a SET, are TRUE:

```
BITS(i) = SYSTEM.VAL(SET, i)
ORD(BITS(i)) = i
BITS(ORD(s)) = s
```

BITS is convenient to use in expressions which are a mixture of INTEGERS, masks and bit fields. Note that SYSTEM.VAL can still be used if you want compatibility with other Oberon systems.

The following examples show the use of BITS with a constant value and the equivalent SET constants:

```
BITS(0) = {}
BITS(1) = {0}
BITS(3) = {0, 1}
BITS(0FFFFFFFFH) = {0..31}
```

4.2.3 BFI

```
PROCEDURE BFI*(VAR word: INTEGER; msb, lsb, bitfield: INTEGER);
```

```
PROCEDURE BFI*(VAR word: INTEGER; bitNo, bitfield: INTEGER);
```

BFI updates a bitfield, i.e. just a portion of 32-bit word, with an INTEGER value. *word* is the target variable and *bitfield* is the source data. *msb* and *lsb* are constant values. *msb* is the most-significant bit and *lsb* is the least-significant bit of the bitfield.

If *msb* = *lsb* (i.e. only a single-bit is accessed) then the two parameters can be replaced by the single *bitNo*.

Examples of its use can be seen in the realtime clock (Clock) library module e.g. the following statement updates just the *minutes* values stored in *time*; the *hours* and *seconds* values remain unchanged:

```
BFI(time, 11, 8, mm MOD 10);    (* time:11:8 := minutes units *)
BFI(time, 14, 12, mm DIV 10);    (* time:14:12 := minutes tens *)
```

4.2.4 BFX

```
PROCEDURE BFX(VAR word: INTEGER; msb, lsb): INTEGER;
PROCEDURE BFX(VAR word: INTEGER; bitNo: INTEGER): INTEGER;
```

BFX returns an unsigned *bitfield*, i.e. just a portion of 32-bit word, from an INTEGER value. *word* is the source data. *msb* and *lsb* are constant values. *msb* is the most-significant bit and *lsb* is the least-significant bit of the bitfield portion of the word.

If *msb* = *lsb* (i.e. only a single-bit is accessed) then the two parameters can be replaced by the single *bitNo*.

Examples of its use can be seen in the realtime clock (Clock) library module e.g. the following statement extracts just the tens and units values of minutes from *time*:

```
mm := 10 * BFX(time, 14, 12) + BFX(time, 11, 8);
```

4.2.5 CLEAR

```
PROCEDURE CLEAR(VAR v: <record or array type>);
```

CLEAR initialises every word in a record or an array variable *v* to zero. It is primarily designed to be used to simplify and optimise the code required to initialise complex data structures. An example of its use can be seen in the procedure *InitHeader* in the *HCFiler* library module *HCDir*.

4.2.6 DISPOSE

```
PROCEDURE DISPOSE(VAR ptr: <Pointer Type>);
```

DISPOSE is a built-in function which frees memory which has previously been allocated to a pointer variable with NEW. The default behaviour of DISPOSE can be changed by substituting a user-defined function for the default library function *Storage.Deallocate*.

4.2.7 LSR

```
PROCEDURE LSR(x, n: INTEGER): INTEGER;
```

LSR performs an unsigned shift right of integer x by integer expression n places, returning $x \cdot 2^{-n}$.

4.2.8 ORD

```
PROCEDURE ORD(x): INTEGER;
```

ORD returns the ordinal number of x which can be a BYTE, CHAR, BOOLEAN or SET expression.

4.3 Leaf Procedures

The code that is generated by the Oberon compiler for procedure calls is efficient for most normal purposes. On occasions where faster execution speed is required (e.g. for fast interrupts) *Leaf* procedures can be used. These are identified by an asterisk in the procedure header.

```
PROCEDURE* Speedy(n: INTEGER);
```

Features of leaf procedures that result in faster execution speed are:

Cortex-M0, M3, M4 and M7:

- Array index checks are suppressed

Cortex-M3, M4 and M7 only:

- Parameters are stored in registers
- Registers do not need to be saved or restored
- INTEGER and SET local variables are stored in registers
- Procedure overhead is as little as two instructions if no stack space is used

Limitations of leaf procedures are:

- Procedures (other than standard built-in procedures and SYSTEM procedures) cannot be called from a leaf procedure
- REAL operations are restricted for systems that do not have a hardware FPU (i.e. Cortex-M0 and M3)
- Array index out of range errors are not detected
- As there are a limited number of microcontroller registers available, there is a limit to the combined total of parameters and local variables, and the complexity of the code that can be used in a leaf procedure.

Although the standard procedures *ODD*, *CHR* etc. and SYSTEM procedures *PUT*, *GET* etc. look like normal procedures most are implemented as inline code so they can be used in leaf procedures. The exceptions are the standard procedures *FLT*, *FLOOR* and *NEW* (when used to allocate heap memory). These are implemented as procedure calls so cannot be used in leaf procedures.

The following examples illustrate the difference between an asterisk used to indicate that a procedure is a leaf procedure and an asterisk used to indicate that the procedure is exported:

```
PROCEDURE GetValue(VAR n: INTEGER);    (* Private non-leaf procedure *)
PROCEDURE GetValue*(VAR n: INTEGER);   (* Exported non-leaf procedure *)

PROCEDURE* GetValue(VAR n: INTEGER);   (* Private leaf procedure *)
PROCEDURE* GetValue*(VAR n: INTEGER);  (* Exported leaf procedure *)
```

4.4 Interrupt Handlers

An Oberon interrupt handler is a normal procedure which has an integer constant in square brackets instead of a list of parameters. The constant can be a literal or named constant e.g.

```
PROCEDURE TimerHandler[0];  
  
or  
  
CONST  
  IRQ = 0;  
  
PROCEDURE TimerHandler[IRQ];
```

The value of the constant is currently unused. Its presence is required to enable the compiler to distinguish interrupt handler procedures from normal parameterless procedures.

The source code of *IRQBlinker.mod* and *IRQTimer.mod*, forming a complete working example of a timer interrupt-driven blinking LED, is included in the Astrobe examples folders.

The *IRQTimer.TimerHandler* procedure is used to handle the interrupts and *IRQTimer.Init* contains the code required to install this handler using the *Traps.Assign* procedure.

5 Clarifications and Restrictions

5.1 Constant declarations

REAL expressions are not allowed in CONST declarations.

5.2 FOR loops

The control variable in a FOR loop is a read-only variable in the body of the FOR loop. For example:

```
FOR i := 0 TO 10 DO
  i := i - 1 (* Error: read-only *)
END;
```

Note that the limit of a FOR loop is evaluated on each iteration of the loop. It is the programmer's responsibility to ensure that the limit is not modified during the execution of the loop.

If the limit is a non-trivial function then it should be assigned to a local variable first. For example:

```
strlen := Strings.Length(s);
FOR i := 0 TO strlen - 1 DO
  s[i] := CAP(s[i])
END;
```

5.3 Exports

- All parameters of exported procedures must be of exported data types.
- String constants cannot be exported. They can be assigned to exported variables which are read-only in modules that import them.
- Anonymous record and array variables can be exported.

5.4 Pointer Types

- Pointer types can only point to named record types e.g.

```
Item = POINTER TO ItemDesc;
ItemDesc = RECORD value: INTEGER; next: Item END;
```

instead of:

```
Item = POINTER TO RECORD value: INTEGER; next: Item END;
```

- Pointer types can only point to global record types.
- A warning is reported at compile-time when a pointer type, whose base type is a private record, is exported.

```
TYPE
  Item* = POINTER TO ItemDesc;
  ItemDesc = RECORD value: INTEGER; next: Item END;.
```

This is referred to as an *opaque pointer*.

- An error is reported at compile time if a type test is performed on an imported opaque pointer variable, or it is passed as parameter to the built-in function *NEW*.

5.5 Record Extensions

All identifiers declared in the extended record must be different from the identifiers declared in its base type record(s). An exception to this is that an identifier declared in the extended record may be the same as the identifier of a *private* field declared in its *imported* base type record(s).

5.6 PACK(x, e)

Prerequisite: $1.0 \leq x < 2.0$

5.7 UNPK(x, e)

Prerequisite: $x \geq 0$

6 Implementation Size Limits

Items	Maximum
Type extension levels (configurable)	8 (Default = 4)
Types exported from a module	17
Number of modules in an IMPORT list	32
Number of modules in an application	256
Number of entries in a module ¹	256
Maximum code size of a module	~100KB
Number of parameters to a procedure ²	8 (Cortex-M0) 11 (Cortex-M3, M4 and M7)
Minimum value of a CASE label	0
Maximum value of a CASE label	255
Number of labels in a CASE statement	256
Code size of a CASE statement	64KB
Step size in a FOR statement	-256 <= step < 255
Number of characters in a string constant	256 (including the terminating null)
Global variable allocation in a module	32KB

¹ Items, exported by a module (variables, procedures etc.), whose actual runtime addresses are established by the linker, are included in a section of the object module known as *entries*.

Note, for example, that only 1 entry is needed for the following declaration as only one absolute address is involved:

```
Ptr* = POINTER TO PtrDesc;  
Ptr1* = POINTER TO PtrDesc;  
PtrDesc* = RECORD i1*: INTEGER END;
```

The number of entries is reported in the compilation summary to warn if the limit is close and there may be a need to refactor the module.

If the limit is exceeded the compilation terminates with the error message *too many entries*.

² Records / arrays count as two parameters.

7 CASE Statements

7.1 Numeric CASE Statements

In the ARM Oberon compiler, the numeric CASE statement has been implemented in a way that provides maximum speed and predictability of code-generation at the expense of memory consumption. The maximum size of the code that can be contained in a single CASE statement is 64KB.

For best results, restrict the use of numeric CASE statements to situations where:

- The case labels are naturally bytes, integers or characters
- The case labels are relatively contiguous
- There are a large number of cases (i.e. more than half-a-dozen)
- All cases have similar probabilities of occurrence

Otherwise consider using an IF-ELSIF...ELSIF-ELSE series of statements instead.

In some cases a hybrid combination of CASE and IF statements can result in a good compromise between readability, efficiency and memory usage.

Consider the following example which could be used to map a set of strings to a corresponding integer code:

```
PROCEDURE FindKeyword*(id: ARRAY OF CHAR; VAR sym: INTEGER);
BEGIN
  sym := ident;
  IF id = "ARRAY" THEN sym := array
  ELSIF id = "BEGIN" THEN sym := begin
  ELSIF id = "BY" THEN sym := by
  ELSIF id = "CASE" THEN sym := case
  ELSIF id = "CONST" THEN sym := const
  ELSIF id = "DIV" THEN sym := div
  ...
  ...
```

You can write this more efficiently with a hybrid combination of CASE and IF-THEN as follows:

```
PROCEDURE FindKeyword*(id: ARRAY OF CHAR; VAR sym: INTEGER);
BEGIN
  sym := ident;
  CASE id[0] OF
    "A":
      IF id = "ARRAY" THEN sym := array
      END |
    "B":
      IF id = "BEGIN" THEN sym := begin
      ELSIF id = "BY" THEN sym := by
      END |
    "C":
      IF id = "CASE" THEN sym := case
      ELSIF id = "CONST" THEN sym := const
      END |
    "D":
      IF id = "DIV" THEN sym := div
      ELSIF id = "DO" THEN sym := do
      END |
    ...
    ...
```

Timing tests using an example with ~30 cases, assuming each word occurs with the same

frequency, indicates that the CASE solution is approximately 4 times faster than the IF-THEN ladder solution. However, the CASE approach generates approximately 8% (6% for M0) more code.

If you do use the IF-THEN ladder it will be more efficient if the expressions that are tested first have a greater probability of being TRUE.

7.2 Numeric CASE Error Reporting

The following CASE statement errors are trapped and reported:

- Duplicate CASE labels are reported as compile-time errors.
- A reference to a missing label results in a runtime error and program termination.
- The type of the selector must be BYTE, INTEGER or CHAR
- The type of each label must be type-compatible with the selector.

You should design your programs so that any conditions not satisfied by the CASE statement are handled separately, as illustrated in the following example:

```
PROCEDURE ToUpperCase(VAR ch: CHAR);
BEGIN
  IF (ch >= "a") & (ch <= "z") THEN
    ch := CHR(ORD(ch) - ORD("a") + ORD("A"))
  END
END ToUpperCase;

PROCEDURE SoundexCode(ch: CHAR): INTEGER;
VAR
  value: INTEGER;
BEGIN
  ToUpperCase(ch);
  IF (ch < "A") OR (ch > "Z") THEN
    value := 0
  ELSE
    CASE ch OF
      "A", "E", "H", "I", "O", "U", "W", "Y":
        value := 0 |
      "B", "F", "P", "V":
        value := 1 |
      "C", "G", "J", "K", "Q", "S", "X", "Z":
        value := 2 |
      "D", "T":
        value := 3 |
      "L":
        value := 4 |
      "M", "N":
        value := 5 |
      "R":
        value := 6
    END
  END;
  RETURN value
END SoundexCode;
```


7.3 Type Extension CASE Statements

Note that the syntax definition for the type test form of the CASE statement is:

```
CaseStatement = CASE qualident OF case {"|" case} END.  
case = [qualident ":" StatementSequence]
```

This differs from both the numeric form of the CASE statement:

```
CaseStatement = CASE expression OF case {"|" case} END.  
case = [CaseLabelList ":" StatementSequence].  
CaseLabelList = LabelRange {"|" LabelRange}.  
LabelRange = label [".." label].  
label = integer | string | qualident.  
WhileStatement = WHILE expression DO
```

and the IS form of type test:

```
expression = SimpleExpression [relation SimpleExpression].  
relation = "=" | "<" | "<=" | ">" | ">=" | IN | IS.
```

which allow the type of an *expression* rather than a *qualified identifier* to be tested.

Consequently, valid examples of type tests, using the type definitions in the *ExtensionsCase.mod* example supplied with Astrobe, are:

```
Shape: Shape;  
shapes: ARRAY 4 OF Shape;  
  
shape := shapes[1];  
CASE shape OF  
  Rectangle: shape.width := w;  
  ...  
  ...  
  
IF shape[1] IS Rectangle THEN  
  shape[1](Rectangle).width := w;
```

and an invalid example of a type test is:

```
CASE shape[1] OF  
  Rectangle: shape[1].width := w;  
  ...  
  ...
```

8 Programming Conventions and Guidelines

This chapter describes the programming guidelines and source code formatting conventions which have been used in software developed using Astrobe.

Some programming guidelines are more important than others. In the first section, the more important ones are described. The remaining sections contain more cosmetic rules which describe the look-and-feel of Oberon programs published by CFB Software. If you like them, feel free to use them for your programs as well. It may make your programs easier to understand for someone who is used to the design, documentation, and coding patterns used in applications developed using Astrobe.

8.1 Essentials

The most important programming conventions all centre around the aspect of evolvability. It should be made as easy as possible to change existing programs in a reliable way, even if the program has been written a long time ago or by someone else. Evolvability can often be improved by increasing the locality of program pieces: if a piece of program may only have an effect on a clearly locatable stretch of program text, it is easier to know where a program modification may necessitate further changes. Basically, it's all a matter of keeping "ripple effects" under control.

8.1.1 Precondition Checks

Preconditions are one of the most useful tools to detect unaccounted ripple effects. Precondition checks allow to pinpoint semantic errors as early as possible, i.e. as closely to their true source as possible. After larger design changes, properly used assertions can help to dramatically reduce debugging time.

Whenever possible, use static means to express what you know about a program's design. In particular, use the type and module systems of Oberon for this purpose; so the compiler can help you to find inconsistencies, and thus can become an effective refactoring tool.

Precondition assertions should be used consistently. Don't allow client code to "enter" your module if it doesn't fulfil the preconditions of your module's procedures. In this way, you avoid propagation of foreign errors into your own code.

```
PROCEDURE Ten*(e: INTEGER): REAL;  
BEGIN  
  ASSERT((e >= 0) & (e <= 38), 21)  
  ...  
END
```

Assertion codes should be in the range 100 to 255 to avoid being confused with those used in the Astrobe runtime system and libraries.

8.1.2 Global Variables

There should be as few global variables as possible. Global variables can be accessed from many places in a program, at different times. This makes it difficult to keep track of all possible interactions ("side effects") with such variables. This in turn increases the likelihood of introducing errors when changing the use of them.

8.1.3 Function Procedures

Procedures which return a result should not modify global variables or VAR parameters as side effects. It is easier to deal with function procedures if they are true functions in the mathematical sense, i.e., if they don't have side effects. Returning function results is ok.

Procedures should be kept as small as is practicable. It is preferable if the whole function is visible on the screen without having to scroll.

8.2 Indentation

A new indentation level is realised by pressing the tab key. The number of spaces inserted depends on the editor option *Indent width*.

A monotype font (e.g. Times New Roman, Consolas) should be used to assist consistent indentation.

Do not use more than three levels of nesting (IF, WHILE etc.). Aim to limit the scope of each block statement so that it is completely visible on one screen.

Combine nested IFs into single boolean expressions where appropriate:

```
IF (p # NIL) THEN  
  IF (p.val # 0) THEN
```

should be written as:

```
IF (p # NIL) & (p.val # 0) THEN
```

Oberon uses short-circuit evaluation of such expressions, i.e. if the first expression is FALSE, the second expression is not evaluated.

8.3 Semicolons

Semicolons are used to separate statements, not to terminate statements. This means that there should be no superfluous semicolons.

Good

```
IF done THEN  
  Print(result)  
END
```

Bad

```
IF done THEN  
  Print(result);  
END
```

8.4 Loop Statements

Oberon has three different types of loop statements: FOR, WHILE and REPEAT.

- If the loop is repeated a *predetermined number* of times use a FOR loop.
- If the loop is repeated *zero or more* times and a test can be performed at the beginning of the loop use a WHILE loop.
- If the loop is repeated *one or more* times and a test can be performed at the end of the loop use a REPEAT loop.
- If the loop is repeated without ever terminating use:

```
WHILE TRUE DO
...
END
```

or:

```
REPEAT
...
UNTIL FALSE
```

8.5 Dereferencing

The optional dereferencing operator ^ should be left out wherever possible.

Good

```
h.next := p.prev.next
```

Bad

```
h^.next := p^.prev^.next
```

8.6 Letter case

In general, each identifier starts with a small letter, except:

- A module name always starts with a capital letter
- A type name always starts with a capital letter
- A procedure always starts with a capital letter, this is true for procedure constants, types, variables, parameters, and record fields.

Good

```
null = 0X;
DrawDot = PROCEDURE (x, y: INTEGER);
PROCEDURE Proc (i, j: INTEGER; Draw: DrawDot);
```

Bad

```
NULL = 0X;
PROCEDURE isEmpty (q: Queue): BOOLEAN;
R = RECORD
  draw: DrawDot
END;
```

Don't capitalise identifiers with more than one character. They should be reserved for the language. An exception is when you use peripheral register names in your programs that are consistent with those used in the MCU manufacturers' documentation e.g. *MCU.PINSEL1*

8.7 Names

- A proper procedure has a verb as name, e.g. *DrawDot*
- A function procedure has a noun or a predicate as name, e.g. *Exponent(r)*, *IsEmpty(q)*
- Procedure names which start with the prefix *Init* are snappy, i.e., they have an effect only when called for the first time. If called a second time, a snappy procedure either does nothing, or it halts. In contrast, a procedure which sets some state and may be called several times starts with the prefix *Set*.
- *CamelCaps* should be used to identify each word in an identifier, e.g. *startAddress* not *startaddress*
- Underscores should only be used in multi-word uppercase names where CamelCaps cannot be used e.g. *MCU.PINMODE_OD0* not *MCU.PINMODEOD0*
- Names should not be unnecessarily long nor unnecessarily abbreviated, e.g. *maxStep* not *maximumForLoopStep*, *nextPage* not *nxtpg* etc.

8.8 White space

A single space should be inserted between lists of symbols, between actual parameters, and between operators:

Good

```
VAR a, b, c: INTEGER;
DrawRect(1, t, r, b);
a := i * 8 + j - m[i, j];
```

Bad

```
VAR a,b,c: INTEGER;
DrawRect(1,t,r,b);
a:=b;
a := i*8 + j - m[i,j];
```

8.9 Alignment

- Opening and closing keywords are either aligned or on the same line
- IMPORT, CONST, TYPE, VAR, PROCEDURE sections are one level further indented than the outer level.
- PROCEDURE X and END X are always aligned
- If the whole construct does not fit on one line, there is never a statement or a type declaration after a keyword
- The contents of IF, WHILE, REPEAT, FOR, CASE constructs are one level further indented if they do not fit on one line.

Good

```
IF expr THEN S0 ELSE S1 END;

REPEAT S0 UNTIL expr;

WHILE expr DO S0 END;

IF expr THEN
  S0
ELSE
  S1
END;
```

```

REPEAT
  S0
UNTIL expr;

i := 0; WHILE i # 15 DO DrawDot(a, i); INC(i) END;

TYPE Square = POINTER TO RECORD(Rectangle) END;

IMPORT Lists, Out,
  Reals, Main;

VAR
  proc: Lists.Proc;

```

Bad

```

IF expr THEN S0
ELSE S1 END;

PROCEDURE P;
BEGIN ... END P;

BEGIN i := 0;
  j := a + 2;
  ...

REPEAT i := 0;
  j := a + 2;

```

8.10 Boolean Expressions

Boolean expressions are often misused. Complex logical expressions can often be reduced to a simpler form. Use truth tables to confirm that the simpler form is equivalent.

```
IF (~summary) OR (summary & ~printing)
```

can be simplified to:

```
IF ~(summary & printing)
```

Some transformations reveal that two booleans are essentially equivalent and one can be removed altogether.

```
IF continue THEN finished := FALSE ELSE finished := TRUE END;
```

should just be:

```
finished := ~continue;
```

NOTE: DO NOT be tempted to make the same transformation to the statement:

```
IF continue THEN finished := FALSE END;
```

Finally,

```
IF continue = TRUE THEN
```

should just be:

```
IF continue THEN
```

8.11 Acknowledgements

The guidelines in this chapter have been adapted from the original *BlackBox Component Builder Programming Conventions* with the kind permission of Oberon microsystems AG.
(www.oberon.ch)