Micriμm, Inc.

C Coding Standard

Application Note

AN-2000

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1.00 Introduction

Conventions should be established early in a project. These conventions are necessary to maintain consistency throughout the project. Adopting conventions increases productivity and simplify project maintenance.

There are many ways to code programs in C (or any other language). The style you use is just as good as any other as long as you strive to attain the following goals:

Portability
Consistency
Neatness
Easy maintenance
Easy understanding
Simplicity

Whichever style you use, I would emphasize that it should be adopted consistently throughout all your projects. I would further insist that a single style be adopted by all team members in a large project. Adopting a common coding style reduces code maintenance headaches and costs. Adopting a common style will avoid code rewrites. This application note describes the style I've been adopting for years.

2.00 Basic Principals

The fundamental purpose of these standards is to promote maintainability of the code. This means that the code must be readable, understandable, testable and portable.

Keep the *spirit* of the standards.

Where you have a coding decision to make and there is no direct standard, then you should always keep within the spirit of the standard.

All code should be written to ANSI C standards.

This means that function prototypes should be ANSI and therefore, the type definitions should be included within the parenthesis.

Keep the code simple.

Be explicit.

Avoid implicit or obscure features of the language. Say what you mean.

Be consistent.

Use the same rules as much as possible.

Avoid complicated statements.

Statements comprising many decision points are hard to follow and especially test.

Do not use GOTO.

Updating old code.

Whenever existing code is modified try to update the document to abide with the conventions outlined in this document. This will ensure that old code will be upgraded over time.

3.00 Source Files

Line width.

You should NOT limit the width of C source code to 80 characters just because yesterday's monitors only allowed you to display 80 characters wide. The width of a line could be based on how many characters can be printed on an 8.5" by 11" page using a reasonable font size. You should be able to accommodate up to 132 characters (portrait mode) and have enough room on the left of the page for holes for insertion in a three ring binder. Allowing 132 characters per line prevents having to interleave source code with comments. If more characters are needed to make the code clearer then you should not be limited to 132 characters. In fact, you could have code that contains initialized structures (placed in Read-Only-Memory, ROM) that are over 300 characters wide. Of course, you can't see (nor print) all the elements of these tables at once but at least the different fields line up neatly.

Use of TAB character.

TAB characters (ASCII character **0x09**) MUST NOT be used. Indentation MUST be done using the SPACE character only (ASCII character **0x20**).

TAB characters expand differently on different computers and printers. Avoiding them ensures that the intended spacing is maintained.

Indent level is 4 spaces.

Indentation of code will consist of 4 spaces (ASCII character **0x20**). Note that statements under a case statement is actually indented by 5 spaces (see the section on Construct). Always try to start on multiples of 4 spaces (column 1, 5, 9, 13, 17 etc.).

Include a file heading.

At the beginning of each file, include a comment block containing the company name, address, copyright notice, list of programmers, description of the file, etc. See below.

```
/*
*********************************************************************************
*                                 Company Name
*                               Company  Address
*                               City,  State ZIP
*                                   Country
*
*                (c) Copyright YYYY, Company Name, City, State
*
* All rights reserved. Company Name's source code is an unpublished work and  the
* use of a copyright notice does not imply otherwise.  This source code contains
* confidential, trade secret material of Micrium, Inc.  Any attempt or participation
* in deciphering, decoding, reverse engineering or in any way altering the source
* code is strictly prohibited, unless the prior written consent of Company Name
* is obtained.
*
* Filename     :
* Programmer(s): Joe Programmer (JP)
*                John Doe       (JD)
* Created      : YYYY/MM/DD
* Description  :
*********************************************************************************
*/
```

An implementation file is a file that contains executable statements whereas a header file does not. Both types of files are laid out in a similar fashion as shown below. A file will contain either

part or all of the these sections. Empty sections can be ommitted but, if a section is included it must take its place in the following order as shown below.

Implementation File Layout:

- File heading
- Revision history
- #include
- #define constants
- Macros
- Local data types
- Local variables
- Local tables
- Local function prototypes
  - Same order as they are implementated
- Global functions
  - Order functions by functionality
- Local functions
  - Order functions by functionality

Header File Layout:

- File heading
- Revision history
- #define constants
- Global macros
- Global data types
- Global variables
- Externals
- Global function prototypes
  - Same order as the implementation file
  - Separate sections for functions declared in other files.
- #error section
  - Section used for 'flagging' missing or illegal #define values.

Separate major sections.

Every section should be preceded with a comment block as shown below.

```
/*
*********************************************************************************
*                                     DATA TYPES
*********************************************************************************
*/

typedef  unsigned char  BOOLEAN;

/*
*********************************************************************************
*                                     PROTOTYPES
*********************************************************************************
*/

BOOLEAN  OSIsTaskRdy(void);
```

Header files SHOULD be guarded from duplicate inclusion by testing for the definition of a value.

Note that `!defined(X)` is preferable to `#ifndef X`.

```
#if     !defined(module_H)
#define  module_H

        Body of the header file.

#endif                                  /* End of module_H                    */
```

Use `#error` to flag missing `#define` constants or macros and, to check for invalid values.

The standard C preprocessor directive `#error` should be used to notify the programmer when `#define` constants or macros are not present and to indicate that a `#define` value is out of range. These statements are normally found in a module's `.H` file. The `#error` directive will display the message within the double quotes when the condition is not met.

```
#ifndef OS_MAX_TASKS
#error  "OS_CFG.H, Missing OS_MAX_TASKS: Max. number of tasks in your application"
#else
    #if     OS_MAX_TASKS < 2
    #error  "OS_CFG.H,         OS_MAX_TASKS must be >= 2"
    #endif
    #if     OS_MAX_TASKS > 63
    #error  "OS_CFG.H,         OS_MAX_TASKS must be <= 63"
    #endif
#endif
```

4.00 Commenting

Only use C style comments (i.e. /* and */) and not the C++ style comments (i.e. //).

Make every comment count.

Keep code and comments visually separate.

Minimize comments embedded among statements. **NEVER** start comments immediately above the code as shown below. This makes the code difficult to follow because the comments are distracting the visual scanning of the code.

```
void  ClkUpdateTime (void)
{                                       /* DO NOT comment like this!            */
    /* Update the seconds */
    if (ClkSec >= CLK_MAX_SEC) {
        ClkSec = 0;
        /* Update the minutes */
        if (ClkMin >= CLK_MAX_MIN) {
            ClkMin = 0;
            /* Update the hours */
            if (ClkHour >= CLK_MAX_HOURS) {
                ClkHour = 0;
            } else {
                ClkHour++;
            }
        } else {
            ClkMin++;
        }
    } else {
        ClkSec++;
    }
}
```

Don't use multi-line comments with a single comment terminator.

NEVER do the following:

```
/* This type of comment can lead to confusion especially when describing a function like
   ClkUpdateTime ().  The function looks like actual code! */
```

Use comment blocks to separate sections of code.

A comment block is shown below. Note that the comment block heading is centered and is written using UPPER CASE characters.

```
/*
*********************************************************************************
*                                    VARIABLES
*********************************************************************************
*/
```

Do not use 'Emotions' in comments.

For example, do NOT use comments such as "Let's make this one big happy structure!".

Use structured sentences as much as possible.

You can use UPPER CASE words to emphasize the meaning.

It's also appropriate to use acronyms, abbreviations and mnemonics as long as everybody understand the meaning of those.

Use trailing comments as much as possible.

As much as possible, always start the trailing comment on the same column. If the code goes beyond the selected column, place the comment on the line just above while still starting at the same column. As much as possible, line up the terminating comment charaters. Using trailing comments allows the code to be visually separate from the code.

```
void ClkUpdateTime (void)
{
    if (ClkSec >= CLK_MAX_SEC) {                    /* Update the seconds                */
        ClkSec = 0;
        if (ClkMin >= CLK_MAX_MIN) {                /* Update the minutes                */
            ClkMin = 0;
            if (ClkHour >= CLK_MAX_HOURS) {         /* Update the hours                  */
                ClkHour = 0;
            } else {
                ClkHour++;
            }
        } else {
            ClkMin++;
        }
    } else {
        ClkSec++;
    }
}
```

Use `#if 0` and `#endif` to comment out blocks of code.

Comments should never be nested. Instead, use `#if 0` and `#endif` to 'comment out' large portions of code.

```
#if 0                                /* Indicate the reason the code is commented out */
#define  DISP_TBL_SIZE         5      /* Size of display buffer table                  */
#define  DISP_MAX_X           80      /* Max. number of characters in X axis           */
#define  DISP_MAX_Y           25      /* Max. number of characters in Y axis           */
#define  DISP_MASK          0x5F
#endif
```

Use special comments to indicate the presense of known bugs, past and future implementations.

For example, you can use the following comments. You can then easily search through your code to find these instances.

```
/* ???? Bug or known technical issue                */

/* $$$$ Future function that needs to be implemented */

/* @@@@ Old code to leave as-is because …           */
```

5.00 Naming Convention

General conventions:

`#define` constants:

`#define` macros:

`typedefs`:

`enum` tags:

- **All upper case characters**
- **Words separated by an underscore (i.e. '_')**
- **Examples: `DISP_BUF_SIZE`, `MIN()`, `MAX()`, etc.**

Local variables (i.e. function scope):

- **All lower case**
- **Words separated by an underscore (i.e. '_')**
- **Use standard names (e.g. `i`, `j`, `k` for loop counters, `p` for pointers etc.)**

File scope variables:

- **Prefixed with the module name followed by an underscore (i.e. '_').**
- **Names separating words start with an initial capital.**
- **Declared `static`.**
- **Examples: `Disp_Buf[]`, `Comm_Ch`, etc.**

Global variables:

- **Prefixed with the module name.**
- **Names separating words start with an initial capital.**
- **Examples: `DispMapTbl[]`, `CommErrCtr`, etc.**

Local functions:

- **Prefixed with the module name followed by an underscore (i.e. '_').**
- **Names separating words start with an initial capital.**
- **Declared `static`.**
- **Example: `static void Comm_PutChar()`**

Global functions:

- **Prefixed with the module name followed by an underscore (i.e. '_').**
- **Names separating words start with an initial capital.**
- **Example: `void CommInit()`**

Name separate words with an initial capital (e.g. `DispBuf[]`).

Old code which contains only lower case characters MUST be separated by the underscore character (i.e. '_', ASCII character `0x2D`).

Use acronyms, abbreviations and mnemonics consistently.

Create a standard acronyms, abbreviation and mnemonics dictionary for all to use and adopt. Below is an example of such a list although, not complete. A reverse list sorted by the Acronym, Abbreviation, or Mnemonic field should be generated as well.

Use 'module-object-operation' format with acronyms, abbreviations and mnemonics.

When creating global constant, variable and function identifiers, specify the name of the module (or sub-system) first, followed by the object and then the operation as shown below.

```
OSSemPost()
OSSemPend()
etc.
```

Acronyms, Abbreviation and Mnemonics (AAM) Dictionary	
Description	**Acronym, Abbreviation, or Mnemonic**
Argument	Arg
Buffer	Buf
Clear	Clr
Clock	Clk
Compare	Cmp
Configuration	Cfg
Context	Ctx
Delay	Dly
Device	Dev
Display	Disp
Error	Err
Function	Fnct
Hexadecimal	Hex
High Priority Task	HPT
I/O System	IOS
Initialize	Init
Mailbox	Mbox
Manager	Mgr
Maximum	Max
Message	Msg
Minimum	Min
Operating System	OS
Overflow	Ovf
Pointer	Ptr
Previous	Prev
Priority	Prio
Read	Rd
Ready	Rdy
Schedule	Sched
Semaphore	Sem
Stack	Stk
Synchronize	Sync
Timer	Tmr
Trigger	Trig
Write	Wr

ALWAYS use the standard acronyms, abbreviations or mnemonics.

Always use the acronym, abbreviation or mnemonic even though you can write the full word. For example, ALWAYS use **`Init`** instead of **`Initialize`**!

6.00 Data Types

All data types MUST be declared using upper case characters.

Words are separated by the underscore character (i.e. '_', ASCII character **0x2D**).

Use the following portable data types.

All standard C data types MUST be avoided because their size is not portable. Instead, the following data types (**INT??** and **FP??**) should be declared based on the target processor and compiler used.

```
typedef  unsigned  char   BOOLEAN;       /* Logical data type (TRUE or FALSE)   */
typedef  unsigned  char   CHAR;          /* Unsigned  8 bit character           */
typedef  unsigned  char   INT08U;        /* Unsigned  8 bit value               */
typedef  signed    char   INT08S;        /* Signed    8 bit value               */
typedef  unsigned  short  INT16U;        /* Unsigned 16 bit value               */
typedef  signed    short  INT16S;        /* Signed   16 bit value               */
typedef  signed    short  INT32U;        /* Unsigned 32 bit value               */
typedef  signed    short  INT32S;        /* Signed   32 bit value               */
typedef  signed    short  INT64U;        /* Unsigned 64 bit value (if available)*/
typedef  signed    short  INT64S;        /* Signed   64 bit value (if available)*/
typedef  float            FP32;          /* 32 bit, single prec. floating-point */
typedef  double           FP64;          /* 64 bit, double prec. floating-point */
```

2 spaces

Structures and Unions MUST be typed.

All structures and unions MUST be typed as shown below. Also, the data type MUST be written using ALL upper case characters. Context will make it obvious that all upper case characters in front of a variable or function must mean that it's a data type as opposed to a constant or macro.

```
typedef struct {
    char    RxBuf[COMM_RX_SIZE];     /* Storage of characters received      */
    char   *RxInPtr;                 /* Pointer to next free loc. in buffer */
    char   *RxOutPtr;                /* Pointer to next char. to extract    */
    INT16U  RxCtr;                   /* Number of characters in Rx buffer   */
    char    TxBuf[COMM_TX_SIZE];     /* Storage for characters to send      */
    char   *TxInPtr;                 /* Pointer to next free loc. in Tx Buf */
    char   *TxOutPtr;                /* Pointer to next char to send        */
    INT16U  TxCtr;                   /* Number of characters left to send   */
} COMM_BUF;
```

Structure alignment.

The data types of each member are indented 4 spaces and the structure member names are also ligned up with respect to each other. Notice also that the comments are lined up starting at the same column (possibly starting on the previous line if the structure member ends up going beyond this column).

Data type scope.

If a data type is only to be used in the implementation file then, it MUST be declared in the implementation file. If the data type is global, it MUST be placed in the module's header file.

7.00 Layout

Only have one action per line of code:

Example #1:

```
DispSegTblIx =    0;
DispDigMsk   = 0x80;
```

l Instead of:

```
DispSegTblIx = 0; DispDigMsk = 0x80;
```

Example #2:

```
ptcb++;
*ptcb = (OS_TCB *)0;
```

Instead of:

```
*++ptcb = (OS_TCB *)0;
```

Separate code chuncks with blank lines or comments.

Parentheses after function names have no space(s) before them when calling functions:

```
DispInit();
```

At least one space is needed after each comma to separate function arguments:

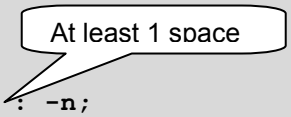
```
DispStr(x, y, s);
```

The unary operators are written with no space between them and their operand:

```
!value
~bits
++i
j--
(INT32U)x
*ptr
&x
sizeof(x)
```

The binary operators (and the ternary operator) are written with at least one space between them and their operand:

```
c1 = c2;
x + y
i += 2;
n > 0 ? n : -n;
a < b
c >= 2
```



At least one space is needed after each semicolon:

```
for (i = 0; i < 10; i++)
```

The keywords `if`, `else`, `while`, `for`, `switch` and `return` are followed by one space.

```
if (a > b)

while (x > 0)

for (i = 0; i < 10; i++)

} else {

switch (x)

return (y);
```

For assignments, the equal signs (i.e. '='), and numbers should be vertically aligned to keep layout tidy.

Note also that the least significant portion of integers and floating-point numbers are lined up.

```
DispSegTblIx =    0;
DispDigMsk   = 0x80;
DispScale    =    1.25;
```

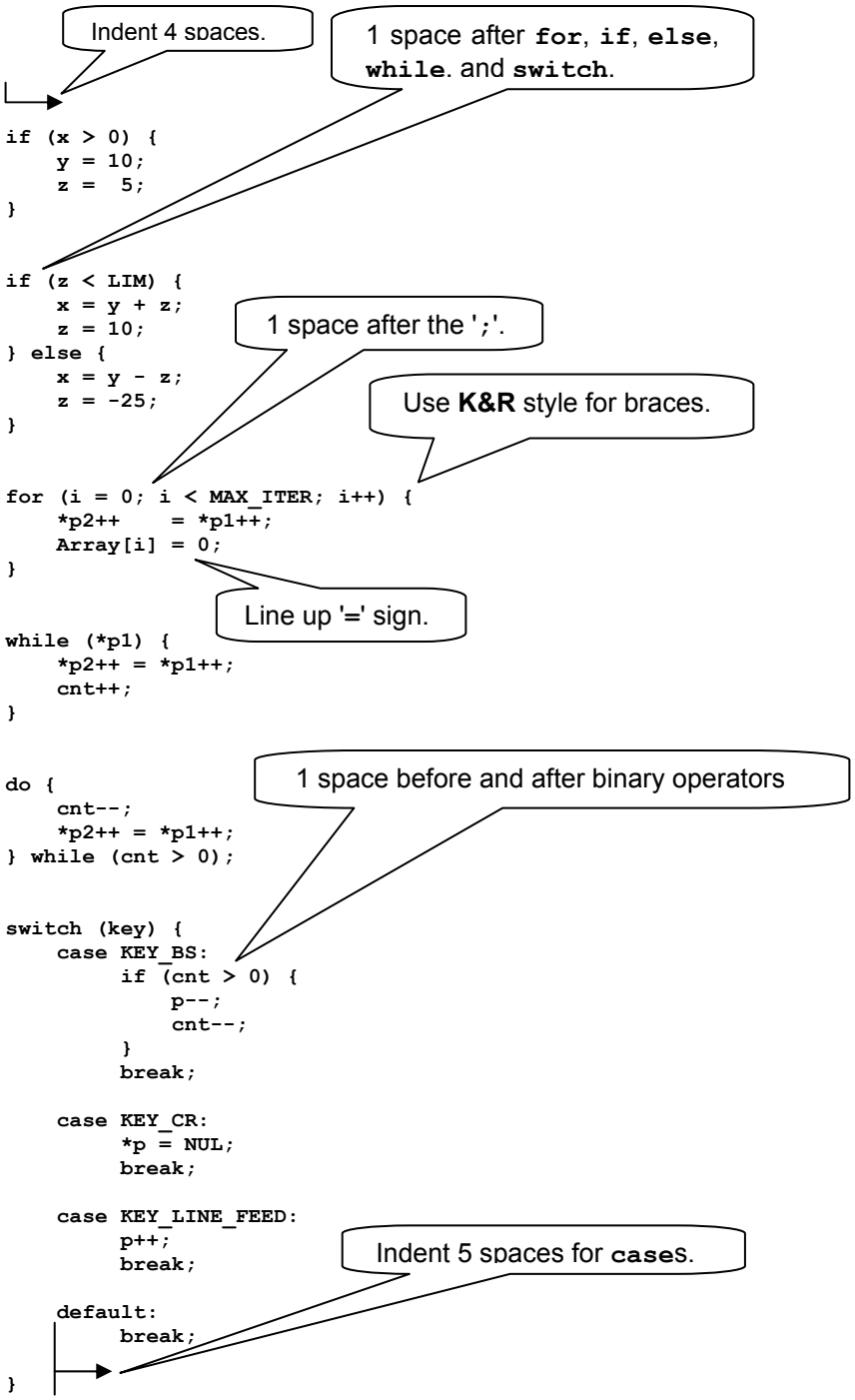
Expressions within parentheses are written with no space after the opening parenthesis and no space before the closing parenthesis:

```
x = (a + b) * c;
```

8.00 Constructs

The following construct style should be use.

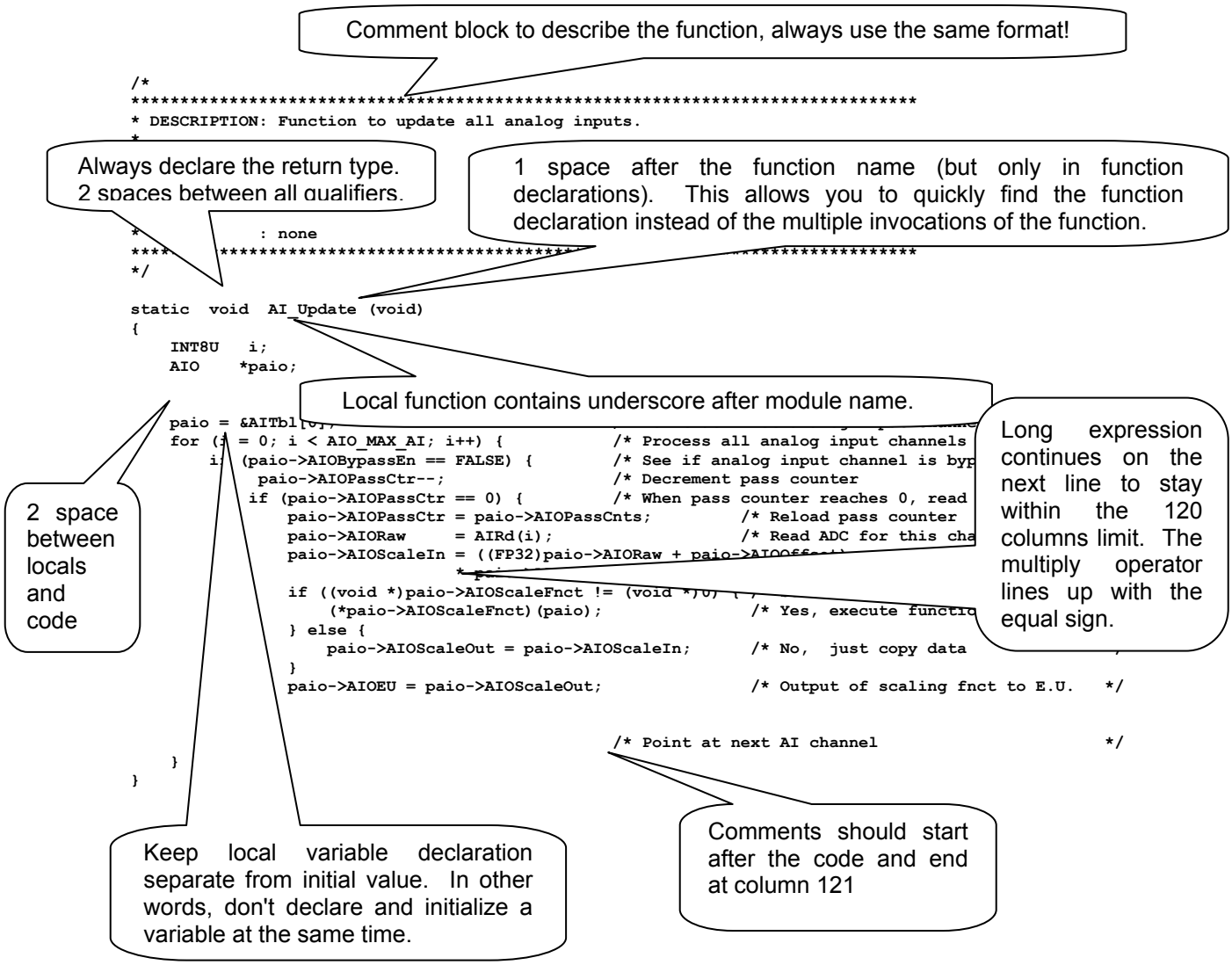
Indentation is 4 spaces.
TABs MUST not be used.
Always use braces, even for null statements.
Use K&R style for braces.




```
if (x > 0) {
    y = 10;
    z =  5;
}


if (z < LIM) {
    x = y + z;
    z = 10;
} else {
    x = y - z;
    z = -25;
}


for (i = 0; i < MAX_ITER; i++) {
    *p2++    = *p1++;
    Array[i] = 0;
}


while (*p1) {
    *p2++ = *p1++;
    cnt++;
}


do {
    cnt--;
    *p2++ = *p1++;
} while (cnt > 0);


switch (key) {
    case KEY_BS:
         if (cnt > 0) {
             p--;
             cnt--;
         }
         break;

    case KEY_CR:
         *p = NUL;
         break;

    case KEY_LINE_FEED:
         p++;
         break;

    default:
         break;
}
```

9.00 Functions

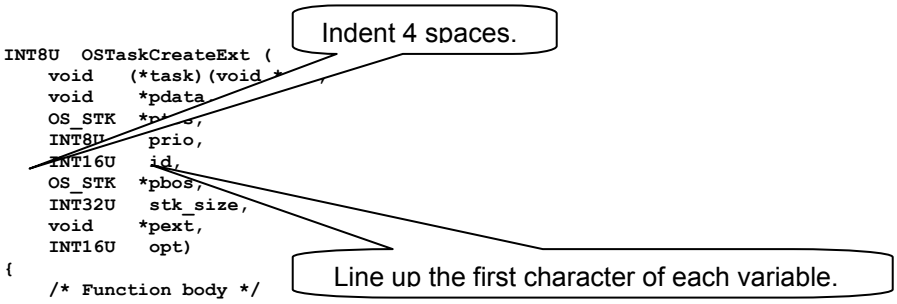
The format of a function should be as shown below.




```
/*
*********************************************************************************
* DESCRIPTION: Function to update all analog inputs.
*
*
*  ARGUMENTS  : none
*********************************************************************************
*/

static  void  AI_Update (void)
{
    INT8U   i;
    AIO    *paio;


    paio = &AITbl[0];
    for (i = 0; i < AIO_MAX_AI; i++) {           /* Process all analog input channels */
        if (paio->AIOBypassEn == FALSE) {        /* See if analog input channel is byp
          paio->AIOPassCtr--;                    /* Decrement pass counter
          if (paio->AIOPassCtr == 0) {           /* When pass counter reaches 0, read
              paio->AIOPassCtr = paio->AIOPassCnts;        /* Reload pass counter
              paio->AIORaw     = AIRd(i);                  /* Read ADC for this cha
              paio->AIOScaleIn = ((FP32)paio->AIORaw + paio->AIOOffset)
                               * paio->AIOGain;
              if ((void *)paio->AIOScaleFnct != (void *)0) {
                  (*paio->AIOScaleFnct)(paio);             /* Yes, execute functio
              } else {
                  paio->AIOScaleOut = paio->AIOScaleIn;    /* No,  just copy data
              }
              paio->AIOEU = paio->AIOScaleOut;             /* Output of scaling fnct to E.U.   */


                                                  /* Point at next AI channel                  */
    }
}
```

Functions with many arguments.

When a function has many arguments, it doesn't make sense to list them all on the same line. Instead, declare the function as shown below.




```
INT8U  OSTaskCreateExt (
    void   (*task)(void *
    void    *pdata
    OS_STK  *p
    INT8U    prio,
    INT16U   id,
    OS_STK  *pbos,
    INT32U   stk_size,
    void    *pext,
    INT16U   opt)
{
    /* Function body */
```

One function per page.

As much as possible, there will be one function declared per page.

More than one very small functions can be declared on a single page. However, they must all contain the comment block describing the function. The beginning of a function must start between two and three lines after the end of the previous function.

Functions should be made to fit on one page. There are few instances where it makes sense to have functions spanning pages and pages. In those rare instances that this is absolutely necessary, page breaks should occur in logical positions within the function.

More than one small function could share a page by separating the function declarations by at least 2 spaces. Functions must also start on page boundaries.

Functions that are only used within the file should be declared **`static`** to hide them from other functions in different files.

10.00 Initialized Tables

Line up similar fields in a table.

Very often, it's useful to create tables that are based on data structures as shown in the example below. You should note that the initialized fields are neatly organized in columns. This makes the code quite easy to read. You should also not limit yourself to a column width for such a situation since it doesn't make sense to wrap table entries at the beginning of the next line.

```
typedef struct {
    INT16U  ParamNbr;
    void   *ParamAddr;
    void   *ParamMin;
    void   *ParamMax;
    void   *ParamDflt;
    void   *ParamInc;
} PARAM;



const  PARAM  RPM_ParamTbl[] = {
/*-- ParamNbr ----- *ParamAddr ------------- *ParamMin ---- *ParamMax ---- *ParamDflt ----- *ParamInc
*/
    { 2981,   (void *)&RPM,            (void *)&FP0,  (void *)&FP0,  (void *)&FP0,    (void *)&FP0},
    { 2982,   (void *)&RPMAvg,         (void *)&FP0,  (void *)&FP0,  (void *)&FP0,    (void *)&FP0, },
    {  2984,     (void  *)&RPMFilterConst,  (void  *)&FP0,    (void  *)&FP1,    (void  *)&FP0Pt1,  (void
*)&FP0Pt01},
    { 2985,   (void *)&RPMTeeth,       (void *)&W4,   (void *)&W500, (void *)&W60,    (void *)&W1},
};


const  UWORD  RPM_ParamTblSize = sizeof(RPM_ParamTbl) / sizeof(PARAM);
```

11.00 Global Variables

Only place global variable declarations in the .H file.

As you know, a global variable needs to be allocated storage space in RAM and must be referenced by other modules using the C keyword `extern`. Declarations must thus be placed in both the `.C` and the `.H` files. This duplication of declarations, however, can lead to mistakes. The technique described below only requires that the declaration be done in one place, the `.H` file.

In all `.H` files that define global variables, you will need to add the following code:

```
#ifdef   xxx_GLOBALS
#define  xxx_EXT
#else
#define  xxx_EXT  extern
#endif
```

Each variable that needs to be declared global will be prefixed with `xxx_EXT` in the `.H` file as shown below. '`xxx`' represents a prefix identifying the module name.

```
xxx_EXT   INT16U    ParamVars;
xxx_EXT   FP32      ParamMaxVal;
```

The module's `.C` file will contain the following declaration:

```
#define   xxx_GLOBALS
#include  "INCLUDES.H"
```

The module for which the global variables belongs to will 'allocate' storage for the variables while all the other modules that simply includes the `.H` file will see `extern` statements in front of those variables.

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