UNISYS

BTOS
C Compiler
Programming Reference Manual

Relative to Release
Level 1.0

Priced Item

November 1987
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About This Manual

This manual contains procedures and reference information on how to install and use the BTOS C Compiler, so that a user can easily compile a C source program into object code.

It also provides all the instructions necessary to install and link the object code into an executable run file.

Who Should Use This Manual

This manual is designed for users who have a working knowledge of the C programming language; it is not intended to teach a user how to write a program in C.

The procedures are easier to perform if you are familiar with BTOS operations. However, the necessary information on how to install and operate the C Compiler, supplemented with references to your BTOS documentation, is included.

How to Use This Manual

If you are using the C Compiler for the first time, you should read section 1. It provides a brief overview of the product capabilities and features.

If you scan the contents and review the topics before you start, you may find this manual easier to use. To find definitions of unfamiliar words, use the glossary; to locate specific information, turn to the index for an alphabetic listing of topics.

How This Manual is Arranged

This manual contains seven sections, four appendixes, a glossary, and an index.

Conventions

The following conventions apply throughout this manual:

- The term BTOS refers to BTOS II in this manual.
- Information you enter at your keyboard appears in boldface.
- Executive commands appear in uppercase.
- When two keys are used together for an operation, their names are hyphenated. For example, **ACTION-GO** means you hold down **ACTION** and press **GO.**

Related Product Information

For information on the Operating System (BTOS), refer to the *BTOS II System Reference Manual.*

For more information about BTOS II system calls and structures, refer to the *BTOS II System Procedural Interface Reference Manual.*

For information on system status codes, refer to the *BTOS II System Status Codes Reference Manual.*

For information on Executive level commands, refer to the *BTOS II Standard Software Operations Guide.*

For information on the Editor, refer to the *BTOS II Editor Operations Guide.*

In addition, the following manuals are referenced in this manual:

- *BTOS II Language Development Linker and Librarian Programming Guide* (information and procedures for using the LINK, BIND, and LIBRARIAN commands)
- *BTOS II Customizer Programming Guide* (information and procedures for customizing an operating system and creating a debugger)
- *BTOS II Debugger Programming Guide* (information and procedures for debugging programs)
- *BTOS II Language Development Assembler Programming Guide* (information and procedures for Assembly 8086 modules and the Assembler)

Additional Reference Material

For additional information on C, refer to *The C Programming Language*, Kernighan and Ritchie, Prentice–Hall, 1978.

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Overview

This section gives you an overview of the Unisys BTOS C Compiler, with a look at capabilities, operations, and features.

The BTOS C Compiler is capable of generating programs with effectively unlimited amounts of instruction code and data. A compilation switch that controls the amount of code and data allowed in a program is available. The compiler allows you to compile separate source files, that you can:

- combine to produce an executable program with the BTOS Linker
- generate a file to assemble with the BTOS Assembler

C, a robust and portable programming language, was developed for a UNIX operating system in the early 1970s by Dennis Ritchie at Bell Laboratories. Its flexibility and efficient executing speed lends itself to structured programming techniques.

Using the C Compiler

The C Compiler runs on a BTOS workstation (B26, B27, B28, or B38) executing BTOS II 1.0 or higher. You can also install it on an XE520 master system and execute it on any BTOS cluster workstation.

You need to have the language development software on your operating system, specifically you must have the following:

- LINK command
- BIND command
- ASSEMBLE command (for use of the inline assembler option)
- Temporary disk storage for intermediate results during each compile

  This is twice the size of the source file you compile when you generate object files directly; three to four times its size when you generate assembly language output.

You install the software from the three installation diskettes (refer to section 2). Other files on the diskettes include the complete source code for the runtime library and the software installation submit files.

Features

The C Compiler provides you with the following features:

- Four memory models: Small, Medium, Large, and Huge

  Huge models allow applications to exceed the normal limitation of 64 Kb for data (globals, statics, and stack area).
- Mixed-model programming

  Mixed-model programming allows use of far data pointers while compiling modules in the Medium Model.
- Numerous compile-time switches

  These are provided to control compilation and code generation.
- Built-in Lint facility

  This can be used for examining a collection of source files.
- BTOS II compatibility
- 8087 support and use of a floating point coprocessor
- UNIX-like support of input/output redirection and piping

Memory Requirements

BTOS C requires a minimum of 250 Kb to compile source programs of moderate size.

BTOS C Compiler Installation

You can use the procedures in this section to install your BTOS C Compiler software. After you install the software, you enter the CCOMPILER command at the Executive level to run the compiler.

Installing C Compiler Software

You install the C Compiler software from three 5–1/4–inch software diskettes, B25CE1–1, B25CE1–2, and B25CE1–3. The diskettes are write–protected.

Note: Because C chains to other run files, all C files reside on the [Sys]<Sys> and [Sys]<BtosC> directories. No directory specification is allowed on the Software Installation command form.

To install the C Compiler software on your system, you must have BTOS II 1.0 or higher installed. To use the BTOS C Compiler, you must have approximately 2200 sectors available.

Installing C Compiler Software on a BTOS Workstation

To install the C Compiler software on a BTOS workstation, use the following procedure:

1 Disable the cluster if the system is clustered (use the Executive DISABLE CLUSTER command or power down the other cluster units).

2 Insert the software diskette into the floppy drive [f0].

3 Enter **SOFTWARE INSTALLATION** at the Executive command line.

4 Press **GO**.

5 Follow the instructions displayed.

When the system finishes software installation, the highlighted message **INSTALLATION OF BTOS C COMPILER COMPLETE** appears, followed by an Executive command prompt.

6 Remove the software diskette.

If your workstation is clustered, you can resume cluster operations using the RESUME CLUSTER command.

The CCOMPILER command is now available at the Executive level; you can use the command to compile C programs.

Installing C Compiler Software on an XE520 Master

To install the C Compiler software on an XE520 master system, use the following procedure:

1 Boot the cluster workstation you want to use for software installation on the XE520.

2 Power down all other cluster workstations.

3 Insert the diskette into the floppy drive [f0] on your workstation.

4 Enter **XESOFTWARE INSTALLATION** at the Executive command line.

5 Press **GO**.

6 Follow the instructions displayed.

Using the C Compiler

The C Compiler software package allows you to compile separate source files that can be combined to produce executable programs using the BTOS Linker. It also generates files that can be assembled using the BTOS Assembler. The compiler itself produces a standard Object file.

This section provides you with procedures and information that you need to use the C Compiler. For more information about the Linker, refer to the *BTOS II Language Development Linker and Librarian Programming Guide.*

Memory Utilization

The compiler is capable of generating programs with effectively unlimited amounts of instruction code and data. A compilation switch that controls the amount of code and data allowed in a program is available.

A total of four memory models are supported. Four sets of libraries are supplied, one set for each memory model. The memory models are:

	Maximum Code		Maximum Data
Small	64 Kb	+	64 Kb
Medium	1 Mb	+	64 Kb
Large	1 Mb	+	1 Mb(64 Kb of globals/statics and stack)
Huge	1 Mb	+	1 Mb(64 Kb of globals/statics per source file plus 64 Kb stack)

The smaller models use the workstation more efficiently, while the larger models give the programmer complete flexibility for constructing large applications.

Command Line Syntax

The CCOMPILER command invokes each pass of the compiler with appropriate options. The **[options]** line consists of a series of options (each preceded by '–'), and the Filename line specifies one source file to compile. If a filename is provided with no extension, a .C extension is supplied. If some other extension is given, the file is treated as if it had a .C extension.

To compile your C program, use the following procedure:

1 At the Executive level, enter **CCompiler**. The following form appears:

Command: CCOMPILER

[options]

Filename

2 Enter the options you need in the **Options** field.

If you supply more than one option, separate each by a space. You can place options in any order, and you can include any number of them as long as there is room in the command line.

3 Enter the name of the C source file that you want to compile in the **filename** field.

4 Press **Go**.

The system creates an output file using the same filename, and appends a **.obj** for object files or **.asm** for assembly language output files.

Frequently Used Command Line Options

The most frequently used compiler options are described in this subsection. The options are organized by topic. For a complete alphabetical list of the compiler options, refer to appendix B.

Controlling Compilation Activity Options

–S

This option is required if you have inline asm statements in your source file. When present, the named source file is compiled producing an assembly language output file, but the resulting assembly code is kept and not assembled. This option is useful when you wish to see the assembly language output for a given compilation.

Without this option, the CCOMPILER command fully compiles the named source file to an object file, ready for linking. This option requires you to use the ASSEMBLE command to produce an object file for linking.

Specifying Memory Model Options

C programs for the 8086 family of processors must be built in a memory model. The memory model determines the size of pointers in memory and as a result determines the amount of memory a program can use. A program should use the smallest memory model that the program fits in, since the smaller memory models are much more efficient than larger ones, both in execution speed and in memory requirements.

BTOS C provides four memory models to choose from: Small, Medium, Large, and Huge. All source files must be compiled with the same memory model option.

Mixed model programming allows programmers, who are not concerned with program portability, to gain finer control over the manipulation of pointers. Because they use special keywords, mixed model programs are not directly portable to other environments, so they should be used with caution. Used properly, mixed model programming can provide high performance pointer manipulation even in the larger memory models.

These compile options specify, for the Large and Huge Memory Models (and for far pointers in any memory model) which one of two forms of pointer arithmetic is to be used for the files being compiled. Files compiled with

the same memory model, but different pointer arithmetic types, can be intermixed. Refer to section 4 for more information about the runtime environment.

-mh	This option causes the compiler to produce Huge Memory Model output code. The 20-bit pointer arithmetic is performed using subroutines.
-mhf	This option causes the compiler to produce Huge Memory Model output code. The 16-bit pointer arithmetic is performed using inline instructions.
-ml	This option causes the compiler to produce Large Memory Model output code. The 20-bit pointer arithmetic is performed using subroutines.
-mlf	This option causes the compiler to produce Large Memory Model output code. The 16-bit pointer arithmetic is performed using inline instructions.
-mm	This option causes the compiler to produce Medium Memory Model output code. Far pointers use full 20-bit pointer arithmetic if they appear in the files being compiled.
-mmf	This option causes the compiler to produce Medium Memory Model output code. Far pointers use 16-bit pointer arithmetic if they appear in the files being compiled.
-ms	This option causes the compiler to produce Small Memory Model output code. Far pointers use full 20-bit pointer arithmetic if they appear in the files being compiled.
-msf	This option causes the compiler to produce Small Memory Model output code. Far pointers use 16-bit pointer arithmetic if they appear in the files being compiled.

Preprocessor Control Options

These options control two things: the specification of preprocessor #define macros and the specification of a search directory for #include files.

-Didentifier	Defines the named identifier to the string consisting of the single character '1'.
-Diden=string	Defines the named identifier iden to the string after the equal sign. The string cannot contain any spaces or tabs.
-Idirectory	The indicated directory is searched for #include files in addition to the current directory.
-Uidentifier	Undefines any previous definitions of the named identifier.

Disk Usage Options

These options change the directory used for temporary and output files.

-n1path	Places any .$CC files in the directory named by path.
-n2path	Places any other temporary files in the directory named by path.
-nopath	Places any .OBJ or .ASM files in the directory named by path.

Comment Control Option

This option controls comment usage of the compiler operation.

-C	If present, comments can be nested. Comments cannot normally be nested.

Message Control Option

This option controls messages of compiler operation.

-w	If present, no warnings messages are printed.

Advanced Options

The compiler normally generates code for an 8088 with no 8087 coprocessor. Code generated in this mode is the most portable to the full range of microprocessors. The default mode does not make maximum use of the capabilities of the more advanced processors.

8086 Support

For the 8086 family of processors, word-sized data items stored at even addresses are more efficiently fetched or stored than word-sized items at odd addresses. By default, the compiler does not align data objects. The compiler can be directed to align word-sized items on even addresses. When not aligning, some care is needed to make sure that data references do not become confused.

If a structure is used in more than one source file of a program, all source files referencing that structure should be compiled with the same alignment setting. The libraries distributed with BTOS C can be used indiscriminately with or without alignment.

Using alignment consumes slightly more storage, especially for structures containing both char and non-char members, but on microprocessors with 16-bit buses (the 8086, 80186, 80286, and 80386) the program runs faster.

-a	If present, integer size items are aligned on a workstation word boundary. Extra bytes are inserted in a structure to ensure alignment of fields. Automatic and global variables are aligned properly.

8087 Support

By default, a BTOS C compiled program uses emulation routines to perform floating point arithmetic. These routines can take advantage of an 8087 or 80287 installed

in the workstation when the program is run, even if the workstation the program was compiled on did not have an 8087.

For programs that use the math library, you must rebuild the library if you wish to use inline floating point instructions.

–f

If present, any floating point operations are generated using 8087 instructions rather than calls to runtime library routines.

The –f compile time option causes the compiler to generate 8087 instructions inline rather than call an emulation routine. When compiling files using inline 8087 instructions, all files in a program must use inline 8087 instructions. This is because the 8087 instructions use the chip itself to return floating point values from functions, rather than using 8086 registers in the default code generation.

Programs compiled with the –f switch (thus generating 8087 instructions inline) should call Check8087() and check its return value, the _8087 flag. If the flag is zero, the program should terminate. Compiling a program to use inline 8087 instructions can result in performance improvement by a factor of two over using the library routines with an 8087.

The C libraries supplied with this release have been compiled using the emulation routines. The emulation routines include the ability to exploit an 8087, 80287, or 80387 math coprocessor if one is present. Calling the library function Check8087() from your main function detects the presence or absence of a math coprocessor and sets the _8087 flag. The library floating point routines check this variable and use 8087 instructions if the chip is present. The resulting speed improvement can be a factor of five in floating point intensive applications.

Optimization Options

There are three separate optimization switches with BTOS C: -O, -G, and -Z. The first two switches, -O and -G, are always safe to apply. The -O option slows the compilation process by adding an extra pass to the compilation. This extra pass eliminates redundant jump instructions and reorganizes loop and switch statements, causing a reduction in code size from a minimum of two to a maximum of fifteen percent. The loop reorganizations can speed up tight inner loops by as much as ten percent, even though the space savings are not that great. The -G option controls the tradeoff decisions between consuming more memory with faster instructions.

The third optimization switch, the -Z option, causes the code generator to remember the contents of registers and use them if possible. If a variable A is loaded into register DX, for example, it is retained. If A is later assigned a value, the value of DX is reset to indicate that its contents are no longer current. Unfortunately, if the value of A is modified indirectly (by assigning through a pointer that points to A), the compiler does not catch this and continues to remember that DX contains the (now obsolete) value of A. Refer to the following:

```
        C Code                          Optimized Assembler

func    ()
        {
        int         A, *P, B;

        A = 4;                          mov     A,4

        ...
        B = A;                          mov     ax,A
                                        mov     B,ax
        P = &A;                         lea     bx,A
                                        mov     P,bx
        *P = B + 5;                     mov     dx,ax
                                        add     dx,5
                                        mov     [bx],dx
         printf("%d\ n", A);            push    ax
        }
```

The above artificial sequence illustrates both the benefits and the drawbacks of this optimization. Note first that on the statement *P = B + 5, the code generated uses a move from ax to dx first. Without the -Z optimization the move would be from B, generating a longer and slower instruction. Second, the assignment into *P recognizes the P is already in bx, so a move from P to bx after the add instruction has been eliminated. These improvements are harmless and generally useful. The call to printf, however, is not correct. The compiler sees that ax contains the value of A and so pushes the contents of the register rather than the contents of the memory location. The printf then displays a value of 4 rather than the correct 9. The indirect assignment through P has hidden the change to A. Note that if the prior statement had been written as A = B + 5, the compiler would recognize a change in value.

Note that the contents of registers are forgotten whenever a function call is made or when a point is reached where a jump could go (such as a label, a case statement, or the beginning or end of a loop). Because of this limit and the small number of registers in the 8086 family of processors, most programs never behave incorrectly.

-G If present, the compiler changes its code generation strategy. Normally the compiler chooses the smallest code sequence possible. With this option, the compiler chooses the fastest sequence for a given task when there is a choice.

This mostly affects the instructions used to clean up the arguments after a function call.

-O When present, a jump optimizer (CC2.run) is executed to optimize the compiled C source file given in the command.

-Z If present, the compiler performs extra optimization to suppress redundant load operations. This new optimization is optional since there are circumstances which can cause the optimized code to work incorrectly. The optimization is designed to suppress register loads when the value being loaded is already in a register. This can eliminate whole instructions and also convert instructions referring to memory locations to use registers instead.

Lint Options

Checking the declarations of functions and variables across multiple source files cannot be done by the compiler itself, so the C Compiler supplies an additional mode of operation (enabled with the -L and -Lxxx options) to perform those checks. With this extra mode, the BTOS C Compiler provides the full range of diagnostic checking found in Lint under UNIX as well as in compilers for the language Pascal.

If you had two source files (afile.c and bfile.c) that you wished to cross-check, you might use the following commands:

```
Command: CCOMPILER
  [options]   -Lafile.lnt
  Filename      afile.c

Command: CCOMPILER
  [options]   -Lbfile.lnt
  Filename      bfile.c

Command: CCOMPILER
  [options]   -L
  Filename      afile.lnt bfile.lnt [sys]<BtosC>clib.lnt
```

These commands compile both of the source files, then cross-check the call and declaration information, including any references to the Runtime Libraries, which are defined in the release file CLIB.LNT.

If you have a library of commonly used routines that are debugged, so that including them in the LINT execution would be a waste of time, you can still check any code that

calls the library. First, you need to prepare a Lint file that describes the library. Then you can use this library in subsequent LINT executions checking programs that call the library.

Lint files are created using the –L option with a filename. The name should include the .LNT extension. As each file is compiled, data about functions, calls and global variables is appended to the lint file, or replaced in the lint file if it has already been placed there. The lint files supplied with the compiler provides the definitions of the C library functions (CLIB.LNT) and the CTOS/BTOS interface procedures (CTOS.LNT). Similar lint files can be built for user constructed libraries which can then be stored for future compilations.

The following options control the level of messages issued by the compiler. The compiler provides many warnings to aid the programmer in writing and debugging code. You can disable some or all of these warnings. These flags provide control over such warnings.

–E	If present, more elastic type conversions are allowed in function arguments. Normally, types must match exactly in calls and function definitions. If this option is given, signed and unsigned integers of equal width are considered compatible, as are pointers to different types. Normally these combinations are considered as distinct types and causes error messages to be displayed.
–L	If present, the compiler performs a LINT compile for the named .LNT files. Note that this is the only time that more than one filename can be specified.

-Lfilename	If present, the compiler performs a LINT compile for the named C source file. The call, function definition and variable declaration information is written to the named filename. Only one of these options is allowed per command line. The named file should be written with the .LNT extension by convention. This output file can be included in future LINT compiles when cross-checking files. Note that multiple .LNT files can be combined into one file by using the BTOS APPEND command.
-Q	If present with a -L option, only definition information is output to the lint file for cross-checking.
-T	If present, any casts are checked for suspicious conversions. Normally casts are not checked and no warnings are printed for them. Conversions caused automatically, such as when assigning between variables of different types, are always checked for suspicious situations. It is assumed that since the programmer has specified a cast, no warning is normally needed. This flag forces warnings anyway. In particular, converting a pointer to a different kind of pointer and converting a long to an integer type produces warnings.
-b	If present, complaints about unreachable break statements are suppressed.
-d	When doing conversions from long to int, -d prevents the compiler from reporting back that you can lose some significant digits in the conversion process.
-h	If present, heuristic tests that attempt to report possible bugs, faulty style or wasteful constructs are not performed.

-q	If present, warnings about undefined external symbols in executing LINT are suppressed.
-s	If present, any structure that is being passed by value (rather than passing its address) generates a warning message. This allows programmers who wish to enforce obsolete structure usage to see any instances of inadvertently passing structures by value. This can be a frustrating bug to locate if you want to pass structures by address and leaves off the & operator, there is no message and the structure is passed by value. This switch at least flags the instances where structures are passed, so any errors can be discovered without going through a full lint execution.
-x	If present, report variables declared as external, but never used.

The following options suppress all occurrences of the listed warning message.

-wamb	Ambiguous operators need parentheses.
-wamp	Superfluous & with function or array.
-wapt	Non-portable pointer assignment.
-wasm	Unknown assembler instruction.
-waus	'XXXXXXXX' is assigned a value which is never used.
-wcln	Constant is long.
-wcpt	Non-portable pointer comparison.
-wdef	Possible use of 'XXXXXXXX' before definition.
-wdgn	Degenerate constant expression.
-wdup	Duplicate definition of 'XXXXXXXX'.
-weff	Code has no effect.
-wfun	Function 'XXXXXXXX' unused.
-wign	'XXXXXXXX' return value ignored.
-wpar	Parameter 'XXXXXXXX' is never used.
-wpia	Possibly incorrect assignment.
-wrch	Unreachable code.
-wret	Both return and return of a value used.
-wrpt	Non-portable return type conversion.
-wrvl	Function should return a value.
-wsig	Conversion can lose significant digits.
-wstr	'XXXXXXXX' not part of structure.
-wstu	Undefined structure 'XXXXXXXX'.
-wstv	Structure passed by value.
-wsus	Suspicious pointer conversion.
-wuse	'XXXXXXXX' declared but never used.
-wvoi	Void functions cannot return a value.
-wzst	Zero length structure.

The -w option (without any subsequent characters) suppresses all warning messages.

Debugging Options

These options are useful in debugging programs. Stack overflow checking has space and time costs in a program, but when the stack does overflow, it can be a difficult bug to discover. Generation of a standard stack frame is useful when using a debugger to trace back through the stack of called subroutines.

-N If this option is present, stack overflow logic is generated at the entry of each function. If an overflow is detected, the program exits with an error code of 400 (insufficient memory).

-Y If this option is present, the compiler generates standard function entry and exit code. Normally, for maximum efficiency, the compiler minimizes the amount of information saved on entry to a function. This practice can prevent the BTOS debugger from displaying a complete stack trace. To consistently display the stack, the BTOS debugger requires that this flag and the -r flag be included in a compile.

-y If present, source line number debugging records are inserted in the object code output of the compiler. This does not affect the size or speed of executable code, but increases the size of an object file on disk. This option is not useful for the BTOS debugger.

Compatibility Options

These options are designed to provide facilities for moving code between BTOS C and other C environments.

-A If present, any of the BTOS extension keywords are ignored and can be used as normal identifiers. These keywords include near, far, asm, plm, interrupt, _es, _ds, _cs, _ss and _ES.

The -A option is designed to provide a maximally portable 'ANSI' environment where none of the BTOS C extensions are usable. This also means that applications programs written using the BTOS C extended keywords as normal identifiers can be compiled by using this switch.

-K

If present, this option causes the compiler to treat all char declarations as if they were unsigned char type. This allows for compatibility with other compilers that treat char declarations as unsigned.

The -K option is designed to ease conversion from C programs written for other workstations to BTOS C.

-i#

If present, this option specifies the number of significant characters in an identifier. All identifiers, whether variables, preprocessor macro names or structure member names are treated as distinct only if their first # characters are distinct. The number given can be any value from 1 to 32. The default number of characters used if this option is not given is 32.

The -i option allows you to set the number of significant characters in an identifier. BTOS C uses 32 characters per identifier. Other systems, including UNIX, ignore characters beyond the first 8. If you are porting to these other environments, you can compile your code with a smaller number of significant characters to see if there are any name conflicts in long identifiers when they are truncated to a shorter significant length.

–r	If present, this option suppresses the use of register variables. Under this option all register keywords are ignored. If you have some Assembly Language code that does not preserve the values of the SI and DI registers, the –r option allows you to call that code from BTOS C. Suppressing register variables does reduce the efficiency of generated code, in general, but can be necessary to use existing subroutines. Note that when you are using the –r option, a source file compiled with –r can call code in a source file compiled without –r, such as a routine in the Runtime Libraries. The opposite is not true, so a file compiled with –r can only be called from a file also compiled with –r.

Fast Calling Sequence Option

This option allows you to specify for a whole program that functions use the PL/M calling sequence. Functions explicitly declared to use a variable number of arguments, such as printf are clearly exempted. The advantage of this calling sequence is smaller and faster function calls.

The major disadvantage of this calling sequence is greater sensitivity to error. A function call can omit any unused trailing arguments. In the PL/M calling sequence they definitely cannot.

The 8086 family of chips works well with PL/M systems programming language. This language is similar to PL/1, Pascal and C in many ways. In one important respect, PL/M differs from C: PL/M does not allow variable length argument lists. This makes functions like printf and scanf impossible to implement with the PL/M calling sequence.

PL/M handles function arguments by pushing the arguments in the reverse order of the C argument sequence. Then, where in C the calling code pops the arguments, in PL/M the called routine uses a special return instruction that returns and pops the arguments in one stroke. If a function is called several times, this means only one set of pop code in PL/M while several such pop sequences in C.

For programs that do not involve many calls to functions like printf, a significant space savings can be gained by using the PL/M calling sequence.

There is one other disadvantage to using the PL/M calling sequence. Pointers in C are returned via the same registers as integers (or long integers depending on the memory model), while the PL/M calling sequence uses different registers. Thus the manner in which some C programs tend to move pointers to and from integers do not work in the PL/M sequence.

The BTOS C Compiler normally generates the C calling sequence. The -p flag causes the compiler to generate the PL/M calling sequence. Using this sequence, programs must be coded with greater care. LINT can help in this, since it identifies all the circumstances where the PL/M calling sequence might cause a problem. In particular, any function defined to return a pointer must be so declared everywhere it is called.

Second, all function calls must pass the exactly correct number and type of arguments (in the C calling sequence, excess arguments are ignored). This second class of error can and often does cause the offending program to crash the workstation. Function prototypes can help here as well.

Since the supplied libraries of BTOS C are built for the C calling sequence, and particularly since recompiling the libraries would not help printf and scanf, an escape is allowed. Any function defined and declared with a prototype containing an ellipsis (...) is compiled using the C calling sequence. This escape allows mixing the calling sequences in a single program.

Note that STDIO.H is written with declarations for the printf and scanf functions declared as accepting a variable number of arguments, so that including STDIO.H allows a program compiled using the PL/M calling sequence to still use printf and scanf. To build a program using this sequence, the runtime libraries must be rebuilt using the PL/M calling sequence as the default throughout.

This option differs from declaring a plm function in that register variables are not used in plm functions, but for normal functions compiled with the –p option they are used. Remember that when you call system functions they must be declared as plm functions, even if the –p option is used.

–p	If present, the compiler generates all subroutine calls and all functions using the PL/M–86 calling sequence.

Segment Naming Options

For some complex applications, the ability to place pieces of code or data into specific segments is desirable. For this reason, BTOS C provides as flexible a set of facilities as possible. Each C output file consists of three segments. The instruction code for the source file is placed in the first segment, the initialized static and global data is placed in the second segment, and the uninitialized static and global data is placed in the third. The Huge Model merges the second and third segments into a single data segment.

Groups are generated depending on the memory models and the switches present below. The code segment of a source file is not given a group association unless a –zP option is given. The data segments for all memory models are placed in the DGROUP.

-g	If present, the compiler will declare all segments as "public". This is most useful when using the huge memory model and it is desired that segments from different modules be combined and accessed with one selector.
–zAname	If present, this option changes the name of the code segment class to name. By default, the code segment is assigned to class 'CODE'.
–zBname	If present, this option changes the name of the data segments class to name. By default, the data segment is assigned to class 'STACK'.

–zCname	If present, this option changes the name of the code segment to name. By default, the code segment is named 'CODE', except for the Medium and Large Models, where the name is 'C_filename'. (Filename here is the source filename).
–zDname	If present, this option changes the name of the uninitialized data segment to name. The uninitialized data segment is named 'BSS'.
–zGname	If present, this option changes the name of the data group to name. By default, the data group is named 'DGROUP'.
–zPname	If present, this option causes any output files to be generated with a code group, for the code segment, named name.

CCompiler.CFG

As an aid to programs requiring many command line options in a single compile, a special file named CCOMPILER.CFG can be created. This file is a simple text file containing any number of compile options per line, and spread over as many lines as desired.

The CCOMPILER command first reads this file and once all of these options have been processed, the options given on the command line are processed. Any option, such as a –w or –f that has no associated string, acts as a toggle. If the option is given once, it is turned on. If the option appears more than once, it is toggled once for each appearance. Thus if an option appears in the CCOMPILER.CFG file, it can be suppressed for a compile by including it again on the command line. Define macros supplied in the CCOMPILER.CFG file can be undefined with the –U option.

Comments can be placed in the CCOMPILER.CFG file by placing a semicolon (;) on any line. Any text appearing after the semicolon up to the end of the current line is considered a comment. Completely blank lines are allowed and any amount of white space can appear before or after an option string.

The CCOMPILER.CFG file can appear in the current directory or in the [sys]<sys> directory. By appropriately creating CCOMPILER.CFG files in each directory, options specific to a particular component of a large system under development can be specified once and subsequently used without extra effort.

Examples:

```
-I [sys]<BtosC>   ;  Preprocessor options
-Y    -r          ;  Debugging options
-O                ;  Use the optimizer
-1 -a  -f         ;  80186, with 8087 instructions
```

The –I option is used to tell the compiler where the standard include files (like stdio.h) are located. The –Y and -r options cause standard function entry and exit code to be generated for debugging purposes.

The –O option invokes the optimizer on all compiles. The –1 and –a options are used for a 80186. Code executes more quickly on an 80186 if word sized variables are placed at even memory addresses (–a data alignment). This example also assumes 8087 inline floating point instructions are being generated (-f option).

Linking a Program

To produce a complete, executable program, the .OBJ files made by the compiler and assembler must be combined with the C runtime library using the BTOS Linker BIND command.

C programs are often divided into multiple source files. One source file functions refer to data and functions in another file. Dividing source code like this is particularly valuable in large programs. Even with small programs contained entirely in a single source file, that program usually refers to several functions in the C library. In fact, a C program cannot be written which does not refer to at least one library function and still accomplish any real work.

The function main is the starting point of any C program and it expects two arguments (arge, argu). A small amount of code must be executed to set up these arguments and call main. Linking is used to merge in that initialization code.

The object files C0x.OBJ contain the necessary initialization code for a C program using the appropriate memory model. It must be listed first in the object modules field entry of the BIND command. The corresponding library files must be used in the [Libraries] field entry to incorporate the library routines for the appropriate memory model (refer to table 3–1).

To link a program using the BTOS Linker, use the following command:

```
Command: BIND
  Object modules                startup_file object_files
  Run file                      exec_file
  [Map file]
  [Publics?]
  [Line Numbers?]
  [Stack size]                  stack_size (default is 8096)
  [Max array, data, code]
  [Min array, data, code]
  [Protected capability]
  [Version]
  [Libraries]                   libraries
  [DS allocation?]
  [Symbol file]
```

This command executes the linker, combines the named object files and produces as output the named exec_file.

Table 3-1 **Memory Models and Link Files**

Model	Start–up File in Object Module Field	[Libraries]
Small	C0S.OBJ	CLIBS.LIB, MATHS.LIB
Medium	C0M.OBJ	CLIBM.LIB, MATHM.LIB
Large	C0L.OBJ	CLIBL.LIB, MATHL.LIB
Huge	C0H.OBJ	CLIBH.LIB, MATHH.LIB

A stack size must be given if your program makes extensive use of the stack or the heap in the Small and Medium Memory Models. A default stack size of 8096 bytes is used if you provide no other value. In the Small and Medium models, calls to the malloc family of functions use part of the stack space for the memory heap. You should include any space needed for these calls in the stack size figure you use. For the Large and Huge Memory Models, the stack size value is used exclusively for stack space. Malloc in the Large and Huge models uses Short–Lived memory for any space it needs.

LINT Source File Comments

Command line arguments are the usual means of controlling the operation of the compiler. Certain pieces of information about the source file are not suitable for setting a single command line flag, so under UNIX the convention has been adopted of defining special comments which are interpreted by the compiler. This violates the rule that comments can have any content and do not affect the compilation. These extensions still do not affect the code produced by the compiler or the error diagnostics issued by the compiler.

The comments must be all in uppercase letters and there can be no characters between the start of the comment (/*) and the keyword of the comment. Although the forms given below do not show it, any characters can be included in the comment after the keyword as long as the keyword is separated from any more letters or digits by white space.

/*ARGSUSED*/

This comment is placed before any function definition where some of the function parameters declared are not used. This suppresses the compiler warnings about unused function parameters.

This is most often used when there are stub test routines included for unfinished parts of a program. It can be useful to force the calls to the unfinished functions to pass the correct parameters while not actually placing any code in them.

/*LINTLIBRARY*/

This comment is placed at the head of a file of declarations of library functions. LINT normally issues warnings about any functions in a program that are not called. This is because such functions are wasting space in the program. Library functions are not included by the linker, and therefore no space is wasted by unused library functions. LINT must be informed about which functions are in a library so that unnecessary warnings are suppressed.

Once a library is built, rather than compile all the functions in it and produce a large lint file with many calls that need to be checked every time LINT is called, a special file of just the function declarations (not the code in the functions) is prepared. For assembly language subroutines this is necessary, since the compiler cannot automatically figure out what the function parameters are. These source files are then compiled and compact lint files are produced with just the function interfaces included. This is precisely what has been done to create CLIB.LNT.

/*NOSTRICT*/

This comment is placed just ahead of a statement and suppresses the strict type checking for that statement alone. It has the same effect as the –h command line argument but only on one statement.

/*NOTREACHED*/

This comment is placed in a function to notify the compiler that the current point in the code is never reached in executing the function. This affects the unreachable code warning message.

This comment is usually placed after a call to a function like exit which never returns, or after a looping construct which never falls through (the compiler tries to recognize such loops but cannot recognize all of them).

The compiler claims there is a return with no value at the end of a function where the end is reachable. If the function returns a value explicitly elsewhere or is declared to return some non–integer type, a warning message is given at the end of the function. The NOTREACHED

comment is placed just ahead of the end of the function to suppress this message. The comment also serves to document functions which don't return, or unending loops.

/*VARARGSn*/

C allows functions to accept a variable number of parameter arguments. Printf and scanf are the prime examples. C formerly did not provide any formal means of notifying the compiler of this fact. The new ellipsis (...) notation is now used to declare printf and scanf, but this comment is provided for older code. The VARARGS comment notifies LINT that the following function accepts a variable number of arguments, even though it does not use the new ellipsis notation. If a number immediately follows with no intervening white space, the number gives the minimum number of fixed arguments that must be present in the call. If no number is given then zero is assumed.

Functions such as printf that accept a variable number of arguments normally have a few required arguments at the beginning of the parameter list. LINT checks the first n arguments in each call for type compatibility and ignore any excess. Without the VARARGS comment, LINT prints error diagnostics for each call which does not have the exact number and type of arguments declared in the function.

Compiler Operation

This subsection is provided for those interested in what the CCOMPILER command does, or who are curious about what temporary files the compiler uses. Normal use of the compiler should not require that you read this.

A source file is compiled by running each of the passes, CC0.RUN, CC1.RUN, CC2.RUN and CC3.RUN, in that order. The options given to each pass are the same as the options specified in the CCOMPILER command.

Executing the Individual Passes

The CC2.RUN pass can be omitted. It is the optional optimization pass invoked by the -O switch.

The CC4.RUN pass does Lint cross-checking. It is only executed when a -L option (with no trailing filename) is given on the CCOMPILER command line.

Except for CC4.RUN, each pass of the compiler can be given only one source file name, and wildcards are not allowed. The CC4.RUN pass is given as many Lint filenames as you like, and wildcards are allowed.

All passes of the compiler return zero exit codes when they complete, permitting submit files to continue processing.

Temporary Files

The individual passes produce the following temporary files:

Pass	Temporary Files
CC0.RUN	srcfil.$CC
CC1.RUN	srcfil.$CD
	srcfil.$CF
	srcfil.$CG
	srcfil.$CI
	srcfil.$CS
CC2.RUN	srcfil.$CX

These temporary files are created in the current directory, unless directed otherwise with a -n1path or -n2path option. The temporary files are normally deleted when the pass that reads them is finished with them.

Runtime Environment

Program Execution

The standard start-up code supplied with the BTOS C Compiler performs the following steps whenever a C program starts executing:

- The DS register is set to point at the Data segment.
- The SS register is set to point at the Stack segment.
- The SP register is set to point at the top of the Stack.
- The command parameters are copied into the program data. These parameters are then pointed to by the argv array.
- The files stdin, stdout and stderr are opened. Any redirection and piping options are recognized.
- The function main is called.
- After main returns, if piping was not specified, exit is called with an error code of zero. This is not in accordance with the latest draft of the ANSI C Standard, which specifies that exit should be called with the return value from main.
- If piping was specified, the next program is activated with the specified arguments.

When a C program is executed, before the function main is called, the command line used to execute the program is parsed into the form needed for argc and argv. Argv[0] is set to the command name.

By default the standard I/O files are opened so that stdin is set to the file [kbd], stdout is set to the file [vid] and stderr is also set to [vid]. If, in any of the command parameters, a parameter beginning with a left or right angle-bracket ('<' or '>') is encountered, that parameter is treated as a file redirection. The parameter is not placed in the argv array.

A redirection parameter beginning with a '<' character provides an alternate filename for the stdin file. The parameter string (excluding the leading '<' character) is treated as a filename and opened for input. A redirection parameter beginning with a '>' character provides an alternate filename for the stdout file. The parameter (excluding the leading '>' character) is treated as a

filename and opened for output. The file is created if it does not exist, and is truncated to zero length if it does exist. If the parameter begins with two '>' characters, both are ignored to find the filename, and the file is appended with the output of the program. In this second case, the file is also created if it does not exist.

For example, the command (assuming XYZ is a C program):

```
Command   XYZ
params      file1 file2
```

Main is called with a value of 3 for argc, and argv[0] is set to **XYZ**, argv[1] is **file1** and argv[2] is **file2**. If main returns, then exit is called with a zero argument.

Note that if the RUN command is used to start a C program, argv[0] is set to the **Command** entry, and the following argv[ ] entries are set to the **Parameter n** entries. The argv array does not preserve the multi-line structure of the original command entries. All subparameters are strung together as if they were all entered in one long parameter.

Emulation of UNIX pipes is performed by passing the stdout output of a program to the stdin input of the next program when the | symbol is processed.

For example, the command (assuming XYZ and ABC are C programs):

```
Command   XYZ
params      p1 p2 | ABC p3 p4
```

XYZ is run with parameters p1 and p2, and its stdout output is placed into [SYS]<$>pipe.file. After XYZ main returns, ABC is run with parameters p3 and p4, and its stdin comes from [SYS]<$>pipe.file. Note that ABC.run must be in the current directory or in [SYS]<SYS>, otherwise the directory must be specified in the params line (e.g. | [D1]<TEST>ABC). The space after the | is optional, but the space before it must be present to recognize piping. The number of piping specifications is limited only by the size of the Variable Length Parameter Block allocated by the Executive.

Memory Organization

Figures 4–1 through 4–4 illustrate the memory organization of the various memory models.

Figures 4–1 through 4–4 illustrate the memory layout for a BTOS C program in the various memory models. Where a segment register name is given with an arrow pointing into a figure, this represents the location where the segment registers are assigned at program start–up. Note that in the Medium, Large and Huge Models, CS changes value as functions are called in different source files. In the Huge Model, DS also changes value as functions are called in different source files.

The heap is an area of storage used to dynamically allocate memory as a program runs. The most common interface to the heap is the function malloc, together with the related free and other allocation functions. Each block of memory allocated can be a different size. There are no restrictions on the order in which objects are allocated and freed.

Figure 4-1 **Small Model Segments**

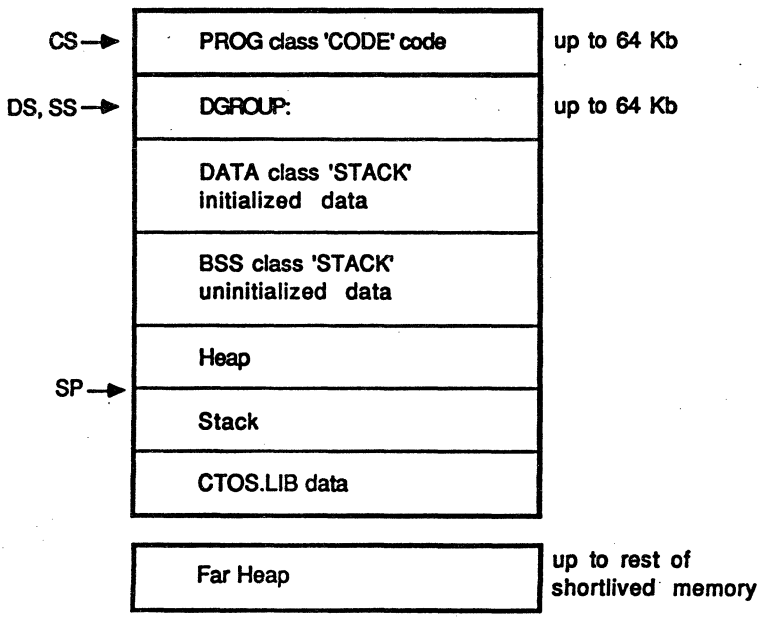
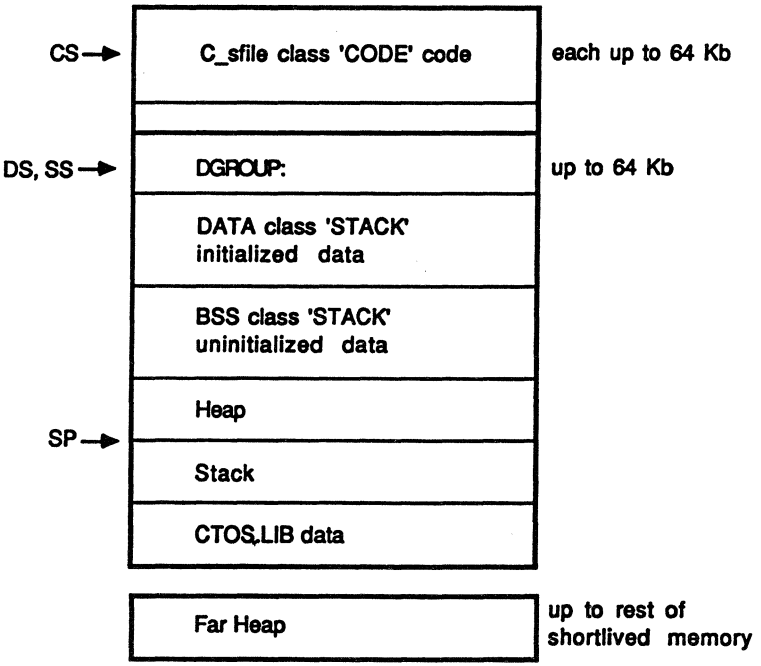


Figure 4-2 **Medium Model Segments**



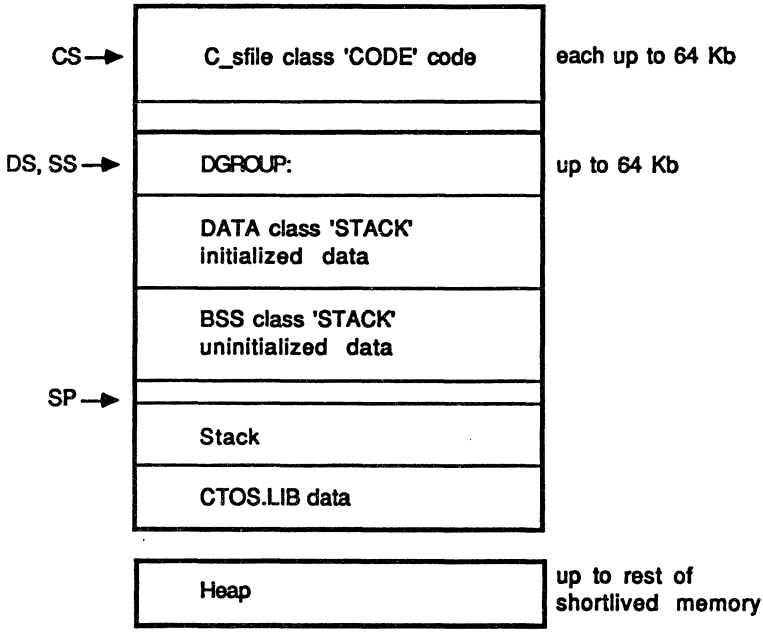
In the Small and Medium Models, the stack is located higher in memory than the heap, sharing the data segment with the static and global data. The heap grows higher in memory, while the stack grows lower.

In the Large and Huge Models, the stack is located independently of the heap, and grows downward towards the start of the data segments. Note that the first data segment still combines CTOS.LIB data with the stack. In these models the heap can extend to fill all of short-lived memory.

Pointer Arithmetic

In the Small and Medium Models, data pointers are two bytes long, and arithmetic involving them is very much like simple integer arithmetic. For the Large and Huge Memory Models and for far pointers in the other Models, there are added complexities.

Figure 4-3 **Large Model Segments**

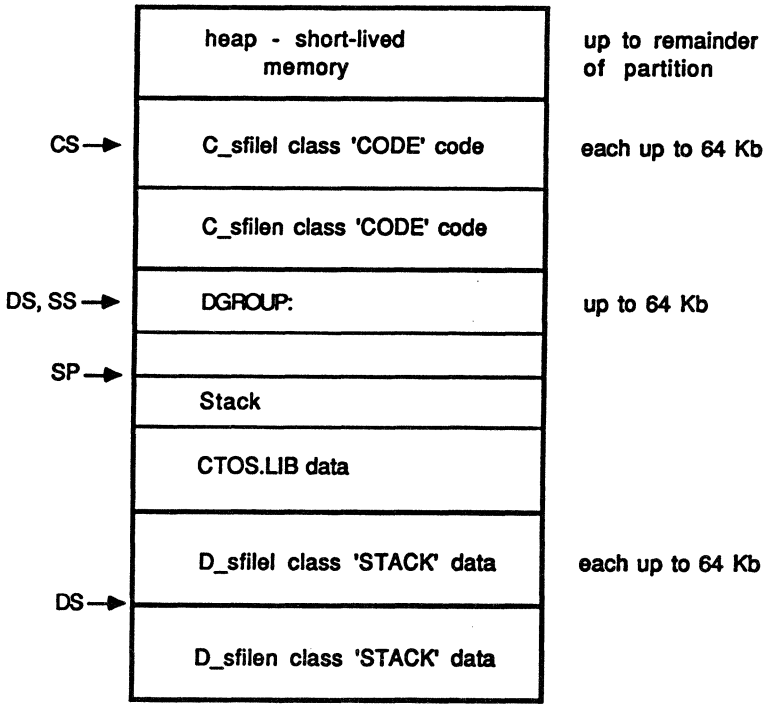


The 8086 family of microprocessors supports a Segmented Memory architecture. This means that programs may not simply treat all of the workstation memory address space as a single array of characters 1 megabyte long.

A memory address used by a program in unprotected mode is constructed as a four–byte quantity. The high–order two bytes are the segment part and the low–order two bytes are the offset part. All 32 bits of these bytes are used to find the physical memory location pointed to by the address.

The segment part is shifted by 4 bits from the offset part to produce a 20–bit result. The resulting segment and offset values are added together to compute the internal hardware location.

Figure 4-4 **Huge Model Segments**




```
Segment              [ xxxx xxxx xxxx xxxx ]
Byte of pointer            3         2
Offset          +     [ yyyy yyyy yyyy yyyy ]
Byte of pointer                1         0
                     ----------------------------------------
Physical Address     zzzz  zzzz  zzzz  zzzz  zzzz
```

There are restrictions on hardware addressing using this scheme. If an instruction uses an index register and offset to address; (for example an array element) the offset and index register value is added together. If the result exceeds 64 Kb no carry bit is retained and the actual resulting location is quite different from that intended.

The 8086 instruction set does not include suitable instructions for easily computing segment/offset combinations where the offset exceeds 64 Kb. However, any carry from the offset must be propagated, not to the low order bit of the segment, but to bit 12. In addition,

because of the wrap-around problems of referencing offsets in structures when the index register value is high, one must severely restrict such references or else generate extra code.

For these reasons, there are two pointer arithmetic options for each of the four memory models. The slow version uses subroutine calls for each pointer arithmetic operation. The routines guarantee that the resulting offset is less than 16. Also, when adding a long integer to such a pointer, the operation simulates a large linear array. Individual structures are still limited to 64 Kb because structure offsets must be supplied as part of the workstation instructions for efficiency.

Comparing two pointers in this mode always produces the true relation of the pointers in memory. The difference of two pointers is a signed long integer which reflects no difference as if the two pointers pointed into a single large array. This occurs even if the two pointers were pointing into different unrelated places.

The fast pointer arithmetic option uses inline instructions and assumes that the segment part of a pointer is never changed when adding or subtracting integers to the pointer. Also, comparing or taking the difference of two pointers assumes that the pointers have the same segment part. These limitations mean that an array must be less than 64 Kb.

In fast pointer arithmetic, two pointers can only be meaningfully compared or subtracted if they point into the same array. Equality and inequality comparisons are always valid.

The fast arithmetic option produces object files in the Large Model that are only about 20 to 25% bigger and slower than corresponding Small Model object files. Slow arithmetic is not much bigger, but is considerably slower. Pointer intensive loops can be up to five times slower and overall programs are as much as twice as slow as Small Model programs doing the same work. Modules compiled with the two different forms of arithmetic may be combined in a single program.

For programs to execute successfully in protected mode, the fast arithmetic option must be specified.

Assembly Language Interface

This section describes the workstation level interface used by C programs, as well as a number of the constructs used in the code generated by the compiler. Programmers intending to write assembly language subroutines called from C or which call C functions, as well as programmers using the inline assembly feature, may use this information to aid in writing their code.

Note that since the compiler can generate assembly output it may be desirable to hand-optimize fragments of code which are executed many times during a program. You should use the inline assembly feature to substitute assembly statements for C code wherever needed, and not actually modify the assembler output. This way subsequent changes to the source file do not require remodification of the assembly output.

External Variable Names

Global symbols, whether a function name or data name, ignore distinctions between upper- and lowercase letters. Since C global variable names may have the same spelling as an Assembler reserved word, there are some names you may not be able to use in Assembly language. One library function like this is ABS. Note that names longer than eight characters in the C source are allowed and are not truncated. If you used the compiler option to specify the length of an identifier, the name is truncated to whatever length you specified.

The C and PL/M Function Calling Sequences

The most common method of calling a function used in C programs for the 8086 is called the C calling sequence.

The most important issue in function calling is how many arguments may be supplied in a given call. PL/M, the designed systems programming language for the 8086 family, requires that all calls to a given function have the same number of parameters. C, particularly for printf and scanf, allows different calls to a function to have different numbers of parameters.

Special function return instructions are supplied to pop a number of bytes from the stack after returning from a function. This removes the function arguments and is used to implement the PL/M calling sequence. C uses the simpler return instruction that does nothing to the stack. The calling function must contain code to remove the arguments from the stack, since it is the only place where the number of arguments are known.

The BTOS C Compiler allows you to produce programs employing either calling sequence. The PL/M sequence generates smaller programs but it is more sensitive to errors in the function arguments. For example, in the C calling sequence an extra argument is completely harmless. Often, too few arguments cause erroneous behavior but the program does not crash the workstation. The PL/M calling sequence very frequently causes a system crash when an incorrect number of arguments is given. The libraries supplied with the compiler are built using the C calling sequence.

Function Arguments

Arguments are passed to a function on the stack. With the C calling sequence, the arguments are pushed onto the stack in a right to left order. For example:

```
int     i, j ;
long     k ;
.
.
.
i  = 5 ;
j  = 7 ;
k = 0x1407aa ;
funca(i, j, k)
```

would load the stack as follows at the entry point to funca using the small memory model:

SP + 08:	0014	
SP + 06:	07aa	k
SP + 04:	0007	j
SP + 02:	0005	i
SP:	return address	

For the medium, large and huge memory models, the stack appears as follows:

SP + 10:	0014	
SP + 08:	07aa	k
SP + 06:	0007	j
SP + 04:	0005	i
SP + 02:	return segment	
SP:	return address	

An assembly function cannot determine the number of arguments actually passed by the caller. The called function should not pop any arguments when returning. The calling function does that.

With the PL/M calling sequence, the arguments are pushed onto the stack in a left to right order, the reverse of the C sequence. For example:

```
int     i, j ;
long     k ;
.
.
.
i  = 5 ;
j  = 7 ;
k = 0x1407aa ;
funca(i, j, k)
```

would load the stack as follows at the entry point to funca using the small memory model:

SP + 08:	0005	i
SP + 06:	0007	j
SP + 04:	0014	
SP + 02:	07aa	k
SP:	return address	

For the medium, large and huge memory models, the stack appears as follows:

SP + 10:	0005	i
SP + 08:	0007	j
SP + 06:	0014	
SP + 04:	07aa	k
SP + 02:	return segment	
SP:	return address	

An assembly function knows the number of arguments because the number must be the same at all calls. The function uses a RET instruction with an operand of 8. The calling function needs no code to clean up the stack after the call.

Calling Functions

To call a C function from assembly language using the small memory model the following code is used:

```
EXTRN   FUNCC:NEAR
.
.
.
CALL    FUNCC
```

To call a C function using the medium, large or huge memory models, the following code is used:

```
EXTRN   FUNCC:FAR
.
.
.
CALL    FUNCC
```

Obviously, only one EXTRN statement for each function being called is needed in the assembly module. Also, the EXTRN statement must be placed outside any segments given in the file.

When calling a C function, arguments should be pushed in right to left order. After the called function returns, the caller should pop the number of words pushed. For more than one or two arguments, the best method for popping arguments is to add a constant to SP.

For example:

```
MOV     AX,10       ; push ...
PUSH    AX          ; argument 10
LEA     AX,B        ; push ...
PUSH    AX          ; argument b
LEA     AX,A        ; push ...
PUSH    AX          ; argument a
CALL    MOVMEM      ; movmem(a, b, 10)
ADD     SP,6        ; pop the arguments
```

would call the movmem function to copy 10 bytes from the global array a to the global array b. Using the PL/M calling sequence this same call becomes:

```
LEA     AX,A        ; push ...
PUSH    AX          ; argument a
LEA     AX,B        ; push
PUSH    AX          ; argument b
MOV     AX,10       ; push
PUSH    AX          ; argument 10
CALL    MOVMEM      ; movmem(a, b, 10)
```

Passing Return Values

Integer, unsigned and enumeration values are returned in AX. In the small memory model, pointers to functions are returned in AX. In the small and medium memory models, pointers to data are returned in AX.

Using the PL/M calling sequence, two–byte pointers are returned in BX. This fact forces you to be very careful when declaring C functions in the PL/M calling sequence. You must make sure that all functions returning pointers are explicitly declared as extern wherever such functions are used.

Long and long unsigned values are returned in AX and DX, with the low order bits in AX. The high order bits are in DX. In the medium memory model, pointers to functions are returned similarly. In the large and huge memory models, all pointers are returned in AX and DX.

Using the PL/M calling sequence, four–byte pointers are returned in ES:BX.

Double values are returned in AX, BX, CX and DX, where AX contains the most significant bits of the double, and DX the least significant.

Structure values are returned by placing the value in a static data location and placing the address of that location in BX. The calling function must copy that value to wherever it is needed. In the large and huge memory models, these values use ES:BX to address the static area.

Assembly Language File Structure

Assembly language modules may be included in a C program if they conform to certain conventions used by the compiler. All such assembler modules should begin with the following:

```
NAME        filename
```

An assembly language module which defines code to be used with a C program compiled for the small memory models must begin with these statements:

```
PROG        SEGMENT     BYTE PUBLIC 'CODE'
            ASSUME      CS:PROG
```

For a C program compiled for the medium, large or huge memory model, the following statements must be used:

```
C_filename                  SEGMENT BYTE 'CODE'
            ASSUME          CS:C_filename
```

Filename, by convention, is the name of the source file.

If you redefine the names of the segments generated by the compiler, you may need different values if you have set up your own segmentation scheme.

If you define data elements as follows:

```
DGROUP      GROUP       DATA
DATA        SEGMENT     WORD PUBLIC 'STACK'
```

then you must place the following statement at the beginning of the code segment:

```
ASSUME      DS:DGROUP
```

You may need to use different values if you have changed the segment, group or class names generated by the compiler.

Defining Functions

To define a function called from a C module using the small memory model, the following declarations are needed at the beginning of the function:

```
                PUBLIC          FUNCA
FUNCA           PROC            NEAR
.
.
.
FUNCA                           ENDP
```

For the medium, large or huge memory models, a slightly different sequence is used:

```
                PUBLIC          FUNCA
FUNCA           PROC            FAR
.
.
.
FUNCA                           ENDP
```

An assembly function must preserve the values of the BP, SI and DI registers. Note that when register variables have been suppressed in the program, SI and DI need not be preserved. The segment registers CS, DS and SS must always be preserved. ES may be used as a scratch register in all memory models.

Defining Data Constants

Initializing data constants is done in the usual way for numeric constants. For pointers to data in the small and medium memory models, use the following method to define a word containing the address of xxx:

```
DW              DGROUP:xxx
```

To define a pointer to a function in the small memory model, use the following:

```
DW              PROG:xxx
```

To define a pointer to a function in the medium or large memory model, or any far pointer to a function, use the following:

```
DD              xxx
```

To define a pointer to data in the large or huge memory models, or any far pointer to data, use the following:

```
DD          DGROUP:xxx
```

Global Data

To define a global variable, a PUBLIC statement must be included in the DATA segment of an assembly module. For example, to define an integer variable **A** and initialize it to zero, use the following example:

```
A           PUBLIC  A
            DW      0
```

To define an external data variable, an EXTRN statement must be included in the DATA segment of an assembly module, except for the huge model where the EXTRN statement must be placed outside all segments. For example, to define an external integer variable **A**, use the following example:

```
EXTRN       A:WORD
```

To define an external character variable **B**, use the following example:

```
EXTRN       B:BYTE
```

Sample Assembly Language Modules

The following sample Assembly Language source modules implement the ABS function in the specified memory models. The medium model version is the same as the large and huge model versions because no global data or pointer references are included in the function.

Small Model Version

```
PROG    SEGMENT  BYTE PUBLIC 'CODE'
        ASSUME   CS:PROG

        PUBLIC   ABS

ABS     PROC     NEAR
        PUSH     BP
        MOV      BP,SP
        MOV      AX,[BP+4]
        OR       AX,AX          ; set condition codes
        JNL      ADONE
        NEG      AX
ADONE:
        POP      BP
        RET
ABS     ENDP
PROG    ENDS
        END
```

Medium, Large and Huge Model Version

```
C_ABS   SEGMENT  BYTE 'CODE'
        ASSUME   CS:C_ABS

        PUBLIC   ABS

ABS     PROC     FAR
        PUSH     BP
        MOV      BP,SP
        MOV      AX,[BP+6]
        OR       AX,AX          ; set condition codes
        JNL      ADONE
        NEG      AX
ADONE:
        POP      BP
        RET
ABS     ENDP
C_ABS   ENDS
        END
```

Library Reference

The C runtime library consists of a set of functions for performing input/output, numerical calculation, and file management. In addition to the functions in the library, there are a set of #include files in the package designed to be included in user source programs. These files provide definitions of many constants needed by an application program, as well as declaration of structures and functions which may also be needed.

The first part of this section gives a broad overview of each major component of the library. The second section of this reference discusses each of the #include files. The third section provides an alphabetical list of the functions in the runtime library.

Library Overview

Runtime Support

Several standard C operations, particularly the floating point arithmetic operations, are implemented as subroutines. These subroutines are included from the library as needed. The compiler generates the necessary code to call the subroutines and cause them to be linked. These functions do not obey normal C calling conventions so C code may not call them explicitly. Documentation of these functions is not included because their interface may be changed without notice and the routines are not callable from a C source program by the user.

The operators implemented as subroutines are: long shift, long multiply, long divide and remainder, double addition, subtraction, multiplication and division, conversion routines between float and double and between long and double, slow pointer arithmetic routines and structure copy and parameter passing routines.

Input/Output

The BTOS C Compiler library supports many ways of performing input and output operations. BTOS Services are callable from a C module directly, providing all of the

BTOS file access methods directly. The BTOS C Compiler also provides UNIX compatible I/O services for accessing sequential and random access files.

The method of I/O functions usable with a file are determined by which function was used to open the file. An existing file may be opened using the appropriate open operation, or a new file may be opened by using the appropriate create operation.

Only one of the methods described below should be used to access a single file at one time. Calls from one method cannot be mixed with calls from another. Files opened with BTOS I/O calls may not be used with the Standard I/O method, for example. Detailed documentation for each function mentioned below is given in the individual library entry pages. Refer to those pages for specific information.

BTOS System Services

These services are provided by means of directly calling the procedures documented in the BTOS Reference Manual. Header files (CTxxx.H) are provided for the different services. You should use these header files, since the services are accessed as external PL/M procedures and BTOS C generates an incompatible calling mechanism as a default.

UNIX Compatible I/O

An existing file is opened using **open**, and a new file is created using **creat**. Once opened, data may be read using **read** or written using **write**. Random access can be gained by using **lseek**. A file may be closed using **close**.

Disk file layouts for text files under BTOS are compatible with those used by UNIX. No special translations are needed by these routines under BTOS. For text files that must be shared with MSDOS, the user is responsible for the conversion of data formats.

Standard I/O

An existing or new file is opened using **fopen**. Fopen returns a file pointer used by the Standard I/O package to control I/O to a file.

Data may be read in Standard I/O using **getc**, **getchar**, **fgetc**, **getw**, **scanf**, **fscanf**, **fread** and others. Data may be written using **putc**, **putchar**, **fputc**, **printf**, **fprintf** and others. Random access may be gained by using **fseek** or **rewind**. A file may be closed using **fclose**.

The Standard I/O package is strongly oriented otward character streams or free format sequential streams. Buffering is used to make the operations reasonably efficient even for programs which use **getc** or **putc**. Standard I/O also is more cetain to be implemented on some non-UNIX system, making programs using only Standard I/O the most portable to a new system.

Mathematical Functions

A collection of UNIX compatible math functions are proavided for exponential, trigonometric, and hyperbolic functions. The functions are listed below:

Function	arc cosine
acos	arc sine
asin	arc tangent
atan	full circle arc tangent
atan2	ceiling
ceil	cosine
cos	hyperbolic cosine
cosh	exponential
exp	absolute value
fabs	floor
floor	remainder
fmod	return fraction and exponent
frexpa	conbine fraction and exponent
ldexp	natural logarithm
log	logarithm base 10
log10	split integer and fractional
modf	part
pow	power
sin	sine
sinh	hyperbolic sine
sqrt	square root
tan	tangent
tanh	hyperbolic tangent

Include Files

This subsection describes the include files available with the C compiler.

ASSERT.H

This header file contains the definition of the assert debugging macro.

CTxxx.H

The following files are the interface header file for CTOS/BTOS:

ctclust.h	cluster management routines
ctcomm.h	communications routines
ctcont.h	contingency routines
ctdam.h	DAM routines
ctexch.h	exchange routines
ctfile.h	file handling routines
ctinter.h	interrupt service routines
ctkeybd.h	keyboard handling routines
ctmem.h	memory management routines
ctmsg.h	message passing routines
ctos.h	all interfaces in one file
ctparm.h	parameter handling routines
ctpart.h	partition management routines
ctproc.h	process control routines
ctqueue.h	queue management routines
ctrsam.h	RSAM routines
ctserv.h	system service routines
ctspool.h	spooler management routines
ctstam.h	standard access management routines
ctstream.h	Sequential Access Method routines
cttask.h	task management routines
cttimer.h	timer management routines
ctvideo.h	video management routines
ctvirt.h	virtual code segment routines

CTYPE.H

This file is used for the character classification macros such as isalpha. These macros provide a convenient means for determining, for example, if a character is an uppercase letter.

ERRNO.H

This file defines constant mnemonics for the error codes returned by the math functions.

FLOAT.H

This file defines the characteristics of floating types and provides values that describe BTOS C's implementation of floating point arithmetic.

I8086.H

The **segread** function fills in the structure SREGS. The fields below correspond to the 8086 registers named.

```
struct      XREG        {
            short       ax;
            short       bx;
            short       cx;
            short       dx;
            short       si;
            short       di;
            } :

struct      HREG        {char       al;
            unsigned     char       ah;
            unsigned     char       bl;
            unsigned     char       bh;
            unsigned     char       cl;
            unsigned     char       ch;
            unsigned     char       dl;
            unsigned     char       dh;
            unsigned
            } :
```

```
union       REGS        {
            struct      XREG        x;
            struct      HREG        h;
            } ;
struct      SREGS       {
            short       es;
            short       cs;
            short       ss;
            short       ds;
            } ;
```

LIMITS.H

This file provides some useful information about compile time limitations of the BTOS implementation. This also contains various values for ranges of integral quantities.

MATH.H

This file declares a number of mathematical functions to return double values.

The functions perform trigonometric, hyperbolic, exponential and logarithmic calculations.

The macro HUGEVAL evaluates to an expression whose value is the maximum double precision floating point number representable on an 8087.

SETJMP.H

The functions **setjmp** and **longjmp** need this file to define a type used by the functions. The functions are useful for error handling. They allow a program to bypass the normal flow of call and return. A function nested several call-levels deep may return in a single stroke to the top level function. This is dangerous and should be avoided except in limited situations since the return does not automatically clean up open files or heap memory allocated by any intervening code.

This file defines a type **jmp_buf** as an array used by the **longjmp** and **setjmp** functions.

SIGNAL.H

This file is used by the **ssignal** and **gsignal** functions. In UNIX this file is more important, but here the file is used to define two constants, SIG_IGN and SIG_DFL needed by these two functions.

STDARG.H

This file defines the macros used to read the list of arguments in a function declared to accept a variable number of arguments.

STDDEF.H

This file defines several data types and commonly used macros.

STDLIB.H

This file defines several commonly used functions.

This file also defines a type size_t which is the type of the sizeof operator.

STDIO.H

This file defines mnemonics, types and macros needed for the standard I/O package.

This file also defines the type **FILE** used throughout the Standard I/O system and the variables **stdin, stdout** and **stderr.**

The macro NULL is defined as a suitably sized 0 for the current memory model. The macro EOF is defined to be the standard error and end of file return for Standard I/O functions (and has the value -1).

The macro SYS_OPEN is defined to be the maximum number of FILEs that can be open simultaneously.

STRING.H

This file defines the various string handling functions.

TIME.H

Time.h defines a structure filled in by the time conversion routines localtime and gmtime. UNIX provides a comprehensive set of time and date conversion routines. See the function pages ctime, time and stime for the treatment of time and date management in this library.

This file defines a type time_t which is the type of the time value used by the time and stime functions. For maximum compatibility with UNIX, this type is defined to be long int.

This file also defines the structure tm used by the various ctime functions to hold time information.

Principle C Functions

Each of the following entries are organized the same way. The name of the function is the heading of the subsection.

The format provides a C declaration of the functions or global variables described by that entry. Arguments passed to the functions must match the type declared. The information under the Include Files heading lists each of the include files which are needed if the described functions are used. Return values include the range of possible values returned by each function, in particular any values indicating error. The information under Portability gives an indication of whether the functions can be found on UNIX systems, as a guide when portable programs are desired. Functions mentioned as defined by the ANSI standard are present in the Draft ANSI standard as of June 1986 and are implemented as defined there, except where noted.

abs

int abs(int i);

Abs returns the absolute value of the integer argument **i**.

Include Files

#include <stdlib.h>

Return Value

An integer in the range of 0 to 32767 is returned except for an argument of -32768 which is returned as -32768.

Portability

Available on UNIX systems. This function is defined in the ANSI Standard.

assert

void assert(int test);

Assert is a macro that tests a condition and expands to an if statement which, if the test fails, prints a message and terminates the program.

The message is:

Assertion failed: file xxx, line nnn

The filename and line number are the source file name and line number where the assert macro appears.

If the macro NDEBUG is defined before assert.h is included, the assert macro becomes null.

Include Files

#include <assert.h>

Return Value

This function does not return a value.

Portability

This macro is available on some UNIX systems.

atof, atoi, atol, strtod, strtol

```
double  atof(char *nptr);
int     atoi(char *nptr);
long    atol(char *nptr);
long    strtol(char *nptr, char **endptr, int base);
double  strtod(char *nptr, char **endptr);
```

These functions convert an ASCII string pointed to by nptr to the specified return value type.

Atof and strtod recognize:

- an optional string of tabs and spaces
- an optional sign
- a string of digits and an optional decimal point
- an optional e or E followed by an optional signed integer

Atoi, atol and strtol recognize:

- an optional string of tabs and spaces
- an optional sign
- a string of digits

The first unrecognized character ends the conversion.

There are no provisions for overflow.

The third parameter to strtol specifies the base for the string of digits. The second parameter to strtod and strtol is a pointer to an object into which a pointer to the converted string is stored, provided the second parameter is not a null pointer.

Include Files

```
#include    <stdlib.h>
```

Return Value

Each function returns the appropriate value of the string. If there are no characters at the beginning of the string that match a number, each function returns zero.

Portability

Available on UNIX systems. All these functions are defined in the ANSI Standard.

Note: For related information, refer to the scanf function.

bsearch

```
void    *bsearch(void *key,
        void *base,
        int nelem,
        int width,
        int     (*fcmp)());
```

Bsearch is a binary search algorithm designed to search an arbitrary table of information. The address of the table to be searched is passed in base. The table has nelem entries and each entry is width bytes long. Bsearch makes repeated calls to the function whose address is passed in fcmp to do the actual comparisons.

The entries in the table must be sorted into ascending order before bsearch is called.

Fcmp is passed two arguments. The first argument is key and the second argument is the address of some entry in the table being searched. Fcmp must return an integer greater than, equal to, or less than zero according to whether the key is greater to, equal to or less than the entry in the table. Fcmp is free to interpret key and the table entries anyway it likes.

Include Files

```
#include    <stdlib.h>
```

Return Value

Bsearch returns the address of the entry in the table which matches the key. If no match is found, bsearch returns 0.

Portability

Available on UNIX systems. This function is defined in the ANSI Standard.

Note: For related information, refer to the lsearch, qsort, ssort functions.

close

int close(int handle);

Handle is a file handle obtained from a creat or open call. Close closes the file handle indicated by handle.

Close fails if handle is not a valid open file handle.

Include Files

#include <errno.h>

Return Value

Upon successful completion, close returns zero. Otherwise a value of -1 is returned.

Portability

Close is available on UNIX systems.

Note: For related information, refer to the creat and open functions.

creat

int creat(char *filename, int mode);

Creat creates a new file or prepares to rewrite an existing file named by the string pointed to by filename.

If the file exists, the length is truncated to zero and the file attributes are left unchanged.

The creat call accepts a UNIX–style access mode word, which is ignored.

Upon successful creation, the file pointer is set to the beginning of the file. The file is opened for both reading and writing.

Include Files

#include <errno.h>

Return Value

Upon successful completion, the new file handle is returned, a non–negative integer. Otherwise a -1 is returned.

Portability

Creat is available on UNIX systems.

Note: For related information, refer to the close, lseek, open, read, and write functions.

ctime, localtime, asctime, gmtime

```
char    *ctime(long *clock);
struct      tm      *localtime(long *clock);
struct      tm      *gmtime(long *clock);
char    *asctime(struct tm *tm);
```

Ctime converts a time pointed to by clock, such as that returned by the function time, into ASCII and returns a pointer to a 26–character string in the following form. All the fields have constant width.

Mon Nov 21 11:31:54 1983\n\0

Localtime returns a pointer to a structure containing the broken–down time. Localtime uses the BTOS time of day services to determine the values in the structure.

Asctime converts a broken–down time to ASCII and returns a pointer to a 26–character string.

Gmtime always returns a null pointer. It is provided for compatibility.

The structure declaration from the include file is:

```
struct  tm      {
int     tm_sec;
int     tm_min;
int     tm_hour;
int     tm_mday;
int     tm_mon;
int     tm_year;
int     tm_wday;
int     tm_yday;
int     tm_isdst;
} ;
```

These quantities give the time on a 24–hour clock, day of month (1–31), month (0–11), weekday (Sunday = 0), year –1900, day of year (0–365), and a flag that is non–zero if daylight savings time is in effect.

Include Files

#include <time.h>

Return Value

Ctime and asctime return the ASCII string date and time. Localtime returns the broken down time structure. This structure is a static which is overwritten with each call.

Portability

All functions are available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the stime and time functions.

ecvt, fcvt, gcvt

```
char    *ecvt(double value, int ndigit, int *decpt, int *sign);
char    *fcvt(double value, int ndigit, int *decpt, int *sign);
char    *gcvt(double value, int ndigit, char *buf);
```

Ecvt converts the value to a null–terminated string of ndigit ASCII digits and returns a pointer to the string. The position of the decimal point relative to the beginning of the string is stored indirectly through decpt (negative means to the left of the returned digits). If the sign of the result is negative, the word pointed to by sign is non–zero, otherwise it is zero. The low–order digit is rounded.

Fcvt is identical to ecvt, except that the correct digit has been rounded for F–format output of the number of digits specified by ndigit.

Gcvt converts the value to a null–terminated ASCII string in buf and returns a pointer to buf. It attempts to produce ndigit significant digits in F–format if possible, otherwise E–format, ready for printing. Trailing zeros may be suppressed.

Include Files

There are no include files required for this function.

Return Value

The return values point to static data whose content is overwritten by each call to ecvt or fcvt. Gcvt returns the string pointed to by buf.

Portability

These functions are available on UNIX.

Note: For related information, refer to the printf function.

exit, _exit

void exit(int status);

void _exit(int status);

Exit terminates the current program and returns control to BTOS. All files are closed and buffered output waiting to be output is written before exiting.

_exit terminates without closing any files or flushing any output.

In either case status is returned as the exit status of the program.

Include Files

#include <stdlib.h>

Return Value

Exit does not return a value.

Portability

Available on UNIX. The exit function is defined in the ANSI Standard.

exp, log, log10, pow, sqrt

double exp(double x);

double log(double x);

double log10(double x);

double pow(double x, double y);

double sqrt(double x);

Exp provides exponential, logarithm, power and square root functions.

Exp returns the exponential function e ** x.

Log returns the natural logarithm of x.

Log10 returns the base 10 logarithm of x.

Pow returns x ** y.

Sqrt returns the positive square root of x.

Include Files

#include <math.h>

Return Value

Exp and pow return a huge value when the correct value would overflow. A large argument can result in errno being set to ERANGE.

Log returns a huge negative value and sets errno to EDOM when x is less than or equal to zero.

Pow returns a huge negative value and sets errno to EDOM when x is less than zero and y is not a whole number.

Sqrt returns 0 and sets errno to EDOM when x is negative.

Portability

Available on UNIX. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the sinh and trig functions.

fclose, fflush

int fclose(FILE *stream);

int fflush(FILE *stream);

Fclose causes any buffers for the named stream to be written and the files to be closed. Buffers allocated by malloc are freed.

Fclose is performed automatically upon calling exit.

Fflush causes any buffered data being output to a named stream to be written out. The stream remains open.

Include Files

#include <stdio.h>

Return Value

These functions return 0 upon success, and EOF if any errors were detected.

Portability

Available on UNIX Systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the close, fopen, and setbuf functions.

feof, ferror, clearerr

```
int     feof(FILE *stream);
int     ferror(FILE *stream);
void    clearerr(FILE *stream);
```

Feof returns non–zero if an end–of–file was detected on the last input operation on the named stream.

Ferror performs stream status inquiries. Ferror returns non–zero if an error was detected on the named stream.

Clearerr resets the error indication on the named stream.

These are implemented as macros.

The end–of–file indicator is reset with each input operation.

Portability

Available on UNIX. These macros are defined in the ANSI Standard, although the Standard requires that they exist as functions in addition to being defined as macros.

Note: For related information, refer to the open and fopen functions.

floor, ceil, fmod, fabs

```
double  floor(double x);
double  ceil(double x);
double  fmod(double x, double y);
double  fabs(double x);
```

Floor returns the largest integer (as a double) not greater than x.

Ceil returns the smallest integer (as a double) not less than x.

Fmod returns the number f such that x = iy + f, for some integer i, and 0 <= f < y.

Fabs returns the absolute value of x.

Include Files

```
#include    <math.h>
```

Portability

Available on UNIX Systems. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the abs function.

fopen, freopen

FILE *fopen(char *filename, char *type);

FILE *freopen(char *filename,char*type, FILE*stream);

Fopen opens the file named by filename and associates a stream with it. Fopen returns a pointer to be used to identify the stream in subsequent operations.

Freopen substitutes the named file in place of the open stream. The original stream is closed, regardless of whether the open succeeds.

Freopen is useful for changing the file attached to stdin, stdout or stderr.

The type string used in each of these calls is one of the following values:

"r"	open for reading only
"w"	create for writing
"a"	append; open for writing at end of file, or create for writing if the file does not exist
"r+"	open an existing file for update (reading and writing)
"w+"	create a new file for update
"a+"	open for append; open (or create if the file does not exist) for update at the end of the file

When a file is opened for update, both input and output may be done on the resulting stream. However, output may not be directly followed by input without an intervening fseek or rewind, and input may not be directly followed by output without an intervening fseek, rewind, or an input which encounters end of file.

Include Files

#include <stdio.h>

Return Value

On successful completion, each function returns the newly open stream. Freopen returns the argument stream. In the event of error each function returns NULL.

Portability

These functions are available on UNIX Systems and are also defined in the ANSI Standard.

Note: For related information, refer to the open and fclose functions.

fread, fwrite

int fread(void *ptr, int size, int nitems, FILE *stream);

int fwrite(void *ptr, int size, int nitems, FILE *stream);

Fread reads, into a block pointed to by ptr, nitems of data of the type ptr pointed to from the named input stream.

Fwrite appends nitems of the type pointed to by ptr beginning at ptr to the named output stream.

Ptr in the declarations is a pointer to any object. Size is the size of the object ptr points to. The expression sizeof *ptr produces the proper value.

Include Files

#include <stdio.h>

Return Value

On successful completion, each function returns the number of items (not bytes) actually read or written. Fread returns a short count (possibly zero) on end–of–file or error. Fwrite returns a short count on error.

Portability

These functions are available on all UNIX systems. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the read, write, fopen, getc, putc, gets, puts, printf, and scanf functions.

frexp, ldexp, modf

```
double  frexp(double value, int *eptr);

double  ldexp(double value, int exp);

double  modf(double value, double *iptr);
```

Frexp returns the mantissa of a double value as a double quantity, x, of magnitude less than 1 and stores an integer n such that value = x * 2 ** n. The number n is stored in the integer pointed to by eptr.

Ldexp returns the quantity value * 2 ** exp.

Modf returns the fractional part of value and stores the integer part in the double pointed to by iptr.

Include Files

```
#include        <math.h>
```

Portability

These functions are available on all UNIX systems. These functions are also defined in the ANSI Standard.

fseek, ftell, rewind

int fseek(FILE *stream, long offset, int whence);

long ftell(FILE *stream);

int rewind(FILE *stream);

Fseek sets the file pointer for the next input or output operation on the stream. The new position is at the

- signed distance offset bytes from the beginning
- current position
- end of the file

respectively, as whence has the value 0, 1, or 2.

Fseek discards any character pushed back using ungetc.

After fseek or rewind, the next operation on an update file may be either input or output.

Ftell returns the current file pointer. The offset is measured in bytes from the beginning of the file.

Rewind(stream) is equivalent to fseek(stream, 0L, 0).

Include Files

#include <stdio.h>

Return Value

Fseek and rewind return non–zero for improper seeks, otherwise zero. Ftell returns the current file position, or EOF on an error.

Portability

These functions are available on all UNIX systems. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the lseek and fopen functions.

getc, getchar, fgetc, getw

```
int     getc(FILE *stream);
int     getchar(void);
int     fgetc(FILE *stream);
int     getw(FILE *stream);
```

Getc returns the next character on the named input stream.

Getchar() is a macro defined to be getc(stdin).

Fgetc behaves exactly like getc, except that it is a true function while getc is a macro.

Getw returns the next integer in the named input stream. Getw assumes no special alignment in the file.

Include Files

```
#include    <stdio.h>
```

Return Value

Getc, getchar and fgetc return the next input character upon success. On end–of–file or error, they return EOF. Getw returns the next integer on the input stream. On end–of–file or error, getw returns EOF. Because EOF is a legitimate value for getw to return, feof or ferror should be used to detect end–of–file or error.

Portability

All functions are available on UNIX systems. These macros and functions are also defined in the ANSI Standard.

Note: For related information, refer to the ferror, fopen, fread, gets, putc, and scanf functions.

gets, fgets

```
char    *gets(char *s);

char    *fgets(char *s, int n, FILE *stream);
```

Gets reads a string into s from the standard input stream stdin. The string is terminated by a newline character, which is replaced in s by a null character.

Fgets reads n–1 characters, or up to a newline character (which is retained), whichever comes first, from the stream into the string s. The last character read into s is followed by a null character. Fgets returns its first argument.

Include Files

```
#include    <stdio.h>
```

Return Value

Each function, on success, returns the string argument s.

Each returns NULL on end–of–file or error.

Portability

Available on UNIX systems. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the ferror, fopen, fread, getc, puts, and scanf functions.

index, rindex

```
int     index(char *s, char *t);
int     rindex(char *s, char *t);
```

Index returns the index of the leftmost occurrence of the string t in s (not counting the terminating null character). The first character of s is numbered 0, so that subscripting produces the correct result.

For example, a call of:

index("four score and seven", " s");

returns 4.

Rindex returns the index of the rightmost occurance of t in s.

Include Files

There are no Include Files required for this function.

Return Value

Both functions return a non–negative index if a character was found, and -1 of no character was found.

Portability

These functions are not available under UNIX System III or V.

Note: For related information, refer to the string function.

inport, inportb

int inport(int port);

int inportb(int port);

Inport reads the value of a word port and returns the value read.

Inportb read the value of a byte port and returns the value read.

Include Files

#include <i8086.h>

Portability

These functions are unique to the 8086 family of microprocessors.

isalpha, isupper, islower, isdigit, isxdigit, isalnum, isspace, ispunct, isprint, isgraph, iscntrl, isascii

```
int     isalpha(int c);
int     isupper(int c);
int     islower(int c);
int     isdigit(int c);
int     isxdigit(int c);
int     isalnum(int c);
int     isspace(int c);
int     ispunct(int c);
int     isprint(int c);
int     isgraph(int c);
int     iscntrl(int c);
int     isascii(int c);
```

These macros classify ASCII-coded integer values by table lookup. Each is a predicate returning nonzero for true and zero for false. Isascii is defined on all integer values; the rest are defined only where isascii is true and on the single non-ASCII value EOF.

Include Files

```
#include    <ctype.h>
```

Return Value

isalpha	Non-zero if c is a letter.
isupper	Non-zero if c is an uppercase letter.
islower	Non-zero if c is a lowercase letter.

isdigit	Non–zero if c is a digit.
isxdigit	Non–zero if c is a hexadecimal digit [0–9], [A–F] or [a–f].
isalnum	Non–zero if c is an alphanumeric.
isspace	Non–zero if c is a space, tab, carriage–return, newline, vertical tab, or form–feed.
ispunct	Non–zero if c is a punctuation character (neither control nor alphanumeric).
isprint	Non–zero if c is a printing character, code 0x20 (space) through 0x76 (tilde).
isgraph	Non–zero if c is a printing, like isprint, except that space is excluded.
iscntrl	Non–zero if c is a delete character (0x7f) or ordinary control character (0x00 to 0x3f).
isascii	Non–zero if c is an ASCII character, code in the range from 0x00 to 0x7f.

Portability

All these macros are available on UNIX workstations. These macros are defined in the ANSI Standard, although the Standard requires that these be available as functions as well as macros.

lsearch

```
char    *lsearch(void *key,void *base,int nelemp,int
        width,int (*fcmp)());
```

Lsearch is a linear search algorithm that searches a table for a specific key, and if not found inserts it at the end of the table. The address of the table is given in base. Nelemp points to a word containing the number of entries in the table. Width contains the number of bytes in each entry. Key points to the item to be searched for. Lsearch calls the function pointed to by fcmp repeatedly until the item is found or the end of the table is reached.

Fcmp is called with two arguments. The first is key, the address of the item being searched for. The second is the address of an entry in the table. Fcmp must return zero if the two items are equal, and non–zero if they are not equal.

If the search item is not found in the table, it is copied into the end of the table and the word pointed to by nelemp is incremented. The table must have enough room to add any new entries. If there is not enough room, unpredictable results may happen.

Include Files

There are no Include Files required for this function.

Return Value

Lsearch returns the address of the entry matching the search key. If the item was not in the table, then lsearch returns the address of the new entry.

Portability

This function is available on UNIX systems.

lseek

long lseek(int handle, long offset, int whence);

Handle is a file handle obtained from a creat or open call. Lseek sets the file pointer associated with handle as follows:

If whence is 0, the pointer is set to offset bytes.

If whence is 1, the pointer is set to its current location plus offset.

If whence is 2, the pointer is set to the size of the file plus offset.

Return Value

Upon successful completion, a non–negative integer indicating the file pointer value is returned. Otherwise, a value of -1 is returned.

Portability

Available on UNIX systems.

Note: For related information, refer to the creat and open functions.

malloc, calloc, free, cfree, realloc

```
void    *malloc(unsigned size);
void    *calloc(unsigned nelem, unsigned elsize);
void    free(void *ptr);
void    cfree(void *ptr);
void    *realloc(void *ptr, unsigned size)
```

These functions provide access to the C memory heap. The heap is available for use for creating variable sized blocks of memory. Many data structures such as trees and lists naturally employ heap memory allocation.

Malloc returns a pointer to a memory block of length size. If not enough memory is available to allocate the block, malloc returns NULL (0). The contents of the block are left unchanged.

Calloc allocates a block like malloc, except the block is of size nelem times elsize. The block is cleared to zero.

Free deallocates a previously allocated block. Ptr must contain the address of the first byte of the block.

Cfree is an alternative name for free. They each perform the same work and may be used interchangeably.

Realloc changes the size of a block previously allocated. Ptr is the address of the block. Size is the new size in bytes.

Blocks may be allocated and freed in any order.

Include Files

```
#include    <stdlib.h>
```

Return Value

Malloc, realloc, and calloc return a null pointer (0) if there is not enough space available to allocate the needed block. When realloc returns 0, the block pointed to by ptr is preserved.

Portability

Calloc, malloc, realloc and free are available on UNIX systems. Calloc, malloc, realloc and free are also defined in the ANSI Standard.

memcpy, memset, memcmp, memchr

```
void    *memcpy(void *dst, void *src, unsigned n);
void    *memset(void *s, char c, unsigned n);
int      memcmp(void *s1, void *s2, unsigned n);
void    *memchr(void *s, char c, unsigned n);
```

These functions are portable memory functions.

Memcpy copies n bytes from the src to the dst array.

Memset sets all of the bytes of s to the char c. The size of the s array is given by n.

Memcmp compares two strings, given by s1 and s2 for a length of n bytes.

Memchr searches the first n bytes of array s for c.

In all of these functions arrays are n bytes in length, even if they contain null bytes.

Include Files

```
#include    <string.h>
```

Return Value

Memcpy returns the value of dst.

Memset returns the value of s. Memcmp returns -1, 0 or 1 depending on whether the s1 string is less than, equal to or greater than the s2 string. Exactly n bytes are compared. Memchr returns a pointer to the first occurrence of c in s, or 0 if c does not occur in the s array.

Portability

Available on UNIX System V systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to movmem and setmem.

movmem

void movmem(void *src, void *dest, unsigned len);

Movmem moves a block of len bytes from src to dest using the 8086 string move instruction. If the source and destination strings overlap, the copy direction is chosen so that the data is always copied correctly.

Include Files

#include <i8086.h>

Portability

These functions are unique to the 8086 family.

Note: For related information, refer to the memcpy and string functions.

open

int open(char *filename, int oflag);

This function opens a file for reading or writing.

Filename points to a string naming a file. The function opens a handle for the named file according to the value of oflag.

For open, the oflag values may be:

0	Read access only
1	Write access only
2	Both read and write access

Upon successful completion a non–negative integer, the file handle, is returned.

The file pointer used to mark the current position in the file is set to the beginning of the file.

The maximum number of simultaneously open files is 20.

Return Value

On successful completion, this function returns a non–negative integer.

On error, open returns -1.

Portability

Open is available on UNIX systems.

Note: For related information, refer to the close, creat, lseek, read, and write functions.

outport, outportb

void outport(int port, int value);

void outportb(int port, char value);

Outport writes value to the word port.

Outportb writes value to the byte port.

Include Files

#include <i8086.h>

Portability

These functions are unique to the 8086 family.

peek, peekb

```
int     peek(int segment, int offset);

char    peekb(int segment, int offset);
```

Peek returns the integer stored at the memory location addressed by segment and offset. Segment is treated as a paragraph address, while offset is a byte offset from the segment.

Peekb returns the byte stored at the memory location addressed by segment and offset.

Include Files

```
#include    <i8086.h>
```

Portability

These functions are unique to the 8086 family.

Note: For related information, refer to poke.

poke, pokeb

void poke(int segment, int offset, int value);

void pokeb(int segment, int offset, char value);

Poke deposits the integer value at the memory location addressed by segment and offset. Segment is a paragraph address, while offset is a byte offset from that address.

Pokeb is the same as poke, except that a byte is deposited instead of an integer.

Include Files

#include <i8086.h>

Portability

These functions are unique to the 8086 family.

Note: For related information, refer to the peek function.

printf, fprintf, sprintf

int printf(char *format, ...);

int fprintf(FILE *stream, char *format, ...);

int sprintf(char *s, char *format, ...);

These functions format output.

Printf places its output on the standard output stream stdout. Fprintf places its output on the named stream. Sprintf places output, followed by the null character (\0), in consecutive bytes starting at the address s. With sprintf it is the user's responsibility to ensure there is enough space in s to hold the formatted output.

Each of these functions converts, formats and prints its args under control of the format string. The format is a character string containing two types of objects: plain characters, which are simply copied to the output stream, and conversion specifications, each of which results in fetching zero or more arg's. The results are unpredictable if there are insufficient args for the format. If the format is exhausted while args remain, the excess args are ignored.

Each conversion specification is begun by the character %. After the %, the following options appear in sequence.

1 An optional list of flag characters appears, in any order:

-

Forces the result of the conversion to left–justified within the field.

+

The result of a signed conversion always begins with a sign (+ or -).

blank

If the first character of a signed conversion is positive, a space is used instead, negative signs still show as a -.

Note: + takes precedence over blank if both flags are present.

#

This flag specifies that the arg is to be converted using an alternate form. For c, d, s, or u conversions, the flag has no effect. For o conversion, it increases the precision to force the first digit of the result to be zero. For x (X) conversion, a non–zero arg has 0x (0X) preceding it. For e, E, f, g, and G conversions, the result always contains a decimal point, even if no digits follow the point (normally, a decimal point appears in the result of these conversions only if a digit follows it). For g and G conversions, trailing zeroes are not removed from the result (as they are normally).

2 An optional width specifier, width is given either by a decimal digit string or by the character asterisk (*). An asterisk indicates that the width should be obtained by using the next arg in the call (treating it as an integer).

3 An optional precision specifier. The precision, if present, is preceded by a decimal point to separate it from any preceding width specifier. The precision specifier is either a decimal digit string or an asterisk. The asterisk, as in the width specifier, indicates that the precision should be gotten by using the next arg in the call (treating it as an integer).

Note: If asterisks are used for width or precision specifiers, the width arg must appear first, then the precision arg if any, and finally the arg for the data to be converted.

4 An optional character **l** follows specifying that a following d, o, u, x, or X conversion applies to a long integer arg instead of an integer.

5 The conversion character itself then appears. The conversion characters and their meanings are:

d,o,u, x,X

The integer (or long integer if l preceded the conversion character) arg is converted to signed decimal, unsigned octal, unsigned decimal, or hexadecimal (x or X), respectively. For hexadecimal conversions the letters abcdef are used if the conversion character was lowercase x, and ABCDEF if the conversion was uppercase X. The precision specifies the minimum number of digits to appear; if the value being converted

needs fewer digits, the output is padded with leading zeroes. The default precision is 1. The result of converting a zero value with a precision of zero is a null string (unless the conversion is o, x, or X AND the # flag is present).

A leading zero given with the width of the format spec (for example a "%04d" format spec) forces printf to display the number with zero fill instead of blank fill.

f

The float or double arg is converted to decimal notation in the style "[–]ddd.ddd", where the number of digits after the decimal point is equal to the precision specification. If the precision is missing, 6 digits are output; if the precision is explicitly 0, no decimal point appears.

e,E

The float or double arg is converted in the style "[–]d.ddde{+-} ddd", where there is one digit before the decimal point and the number of digits after it is equal to the precision; when the precision is missing, 6 digits are produced; if the precision is zero, no decimal point appears. The E format code produces a number with E instead of e introducing the exponent. The exponent always contains exactly three digits.

g,G

The float or double arg is printed in style f or e (or in style E in the case of a G format code), with the precision specifying the number of significant digits. The style used depends on the value converted: style e is used only if the exponent resulting from the conversion is less than -4 or greater than the precision. Trailing zeroes are removed from the result; a decimal point appears only if it is followed by a digit.

c

The character arg is printed.

s

The arg is taken to be a string (character pointer) and characters from the string are printed until a null character (\0) is encountered or the number of characters indicated by the precision is reached. If the precision is missing, it is taken to be infinite, so all characters up to the first null character are printed.

%

Print a %; no argument is converted.

In no case does a non–existent or small field width cause truncation of a field; if the result of a conversion is wider than the field width, the field is simply expanded to contain the conversion result. Characters generated by printf and fprintf are printed as if putc had been called.

Include Files

#include <stdio.h>

Return Value

Each function returns the number of bytes output. Sprintf does not include the null byte in the count.

In the event of error, these functions return EOF.

Portability

These functions are available on UNIX systems. The ANSI Standard provides a definition for these functions, but with slightly greater functionality.

Note: For related information, refer to the ecvt, putc, and scanf functions.

putc, putchar, fputc, putw

```
int     putc(char c, FILE *stream);
int     putchar(char c);
int     fputc(char c, FILE *stream);
int     putw(int w, FILE *stream);
```

Putc and fputc append the character c to the named output stream. Putc is a macro, while fputc is a true function.

Putchar(c) is a macro defined to be putc (c, stdout).

Putw appends the integer w to the output stream. Putw neither expects nor causes special alignment in the file.

The streams stdout and stderr are unbuffered, while all other output files are by default buffered. Setbuf may be used to change the buffering style being used. Unbuffered means that characters written to a stream are immediately output to the file or device, while buffered means that the characters are accumulated and written as a block.

Include Files

```
#include    <stdio.h>
```

Return Value

Putc, fputc and putchar return the character c on success. Putw returns the integer w. On error all the functions return EOF. Since EOF is a legitimate integer, ferror should be used to detect errors with putw.

Portability

All functions are available on UNIX systems. All these functions, except putw is defined in the ANSI Standard.

Note: For related information, refer to the ferror, fopen, fwrite, getc, printf and puts functions.

puts, fputs

int puts(char *s);

int fputs(char *s, FILE *stream);

Puts copies the null–terminated string s to the standard output stream stdout and appends a newline character.

Fputs copies the null–terminated string s to the named output stream, and does not append a newline character.

Include Files

#include <stdio.h>

Return Value

Upon successful completion, each function returns 0. Otherwise a value of EOF is returned in the event of an error.

Portability

Both functions are available on UNIX systems. These functions are also defined in the ANSI Standard.

Note: For related information, refer to the ferror, fopen, fwrite, gets, printf, and putc functions.

qsort, ssort

```
void    qsort(void *base,
              int nelem,
              int width,
              int (*fcmp)());

void    ssort(void *base,
              int nelem,
              int width,
              int (*fcmp)());
```

Qsort is an implementation of the quicker–sort algorithm. Ssort is an implementation of the shell–sort algorithm. Base is a pointer to the table to be sorted. Nelem is the number of entries in the table. Width is the size of each entry in the table in bytes. Qsort and ssort sort the entries into order by repeatedly calling the function pointed to by fcmp.

Fcmp accepts two arguments, each the address of an entry in the table. Fcmp returns a number greater than zero if the first argument should appear after the second in the final sequence. Fcmp returns a number less than zero if the first argument should appear before then second in the final sequence. Fcmp returns zero if the two arguments are equal. If the table entries are already sorted, qsort requires approximately (20*numberofentries) bytes of stack space. Ssort always uses only 20 bytes of stack.

Include Files

```
#include    <stdlib.h>
```

Return Value

These functions do not return a value.

Portability

Qsort is available on UNIX systems and is defined in the ANSI Standard. Ssort is not portable.

Note: For related information, refer to the bsearch and lsearch functions.

rand, srand

```
void    srand(unsigned seed);

int     rand(void);
```

Rand uses a multiplicative congruential random number generator with period 2**32 to return successive pseudo–random numbers in the range from 0 to 2**15 -1.

The generator is reinitialized by calling srand with an argument value of 1. It can be set to a random starting point by calling srand with whatever you like as argument.

Include Files

```
#include    <stdlib.h>
```

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

read

int read(int handle, void *buf, int nbyte);

Read attempts to read nbyte bytes from the file associated with handle into the buffer pointed to by buf.

Handle is a file handle obtained from a creat or open call.

On disk files, the read begins at the current file pointer. On completion of the read, the file pointer is incremented by the number of bytes read.

On devices the bytes are read directly from the device.

Upon successful completion, the functions return the number of bytes read and placed in the buffer.

A value of zero is returned when an end–of–file has been reached.

Include Files

#include <errno.h>

Return Value

Upon successful completion a positive integer is returned indicating the number of bytes placed in the buffer.

On end of file, read returns zero.

On error, read returns -1.

Portability

Read is available on UNIX systems.

Note: For related information, refer to the creat and open functions.

scanf, fscanf, sscanf

```
int     scanf(char *format, ...);

int     fscanf(FILE *stream, char *format, ...);

int     sscanf(char *s, char *format, ...);
```

Scanf reads from the standard input stream stdin.

Fscanf reads from the named input stream.

Sscanf reads from the character string s.

Each function reads characters, interprets them according to a format, and stores the results in its arguments. Each expects as arguments a control string format, described below, and a set of pointer arguments indicating where the converted input should be stored.

The control string usually contains conversion specifications, which are used to direct interpretation of input sequences. The control string may contain:

Blanks, tabs, or newlines, which cause input to be read up to the next non–white–space character.

An ordinary character (not %), which must match the next character of the input stream.

Conversion specifications, consisting of the character %, an optional assignment suppressing character *, an optional numerical maximum field width, and a conversion character.

A conversion specification directs the conversion of the next input field; the result is placed in the variable pointed to by the corresponding argument, unless argument suppression was indicated by *. An input field is defined as a string of non–space characters; it extends to the next inappropriate character or until the field width, if specified, is exhausted.

The conversion character indicates the interpretation of the input field; the corresponding pointer argument must usually be of a restricted type. The following conversion characters are legal:

%

A single % is expected in the input. No assignment is done.

d

A decimal integer is expected. The corresponding argument should be a pointer to an integer.

o

An octal integer is expected. The corresponding argument should be an integer pointer.

x

A hexadecimal integer is expected. The corresponding argument should be an integer pointer.

i

An integer is expected. If it begins with 0x or 0X it is assumed to be hexadecimal. If it begins with 0 it is assumed to be octal. Otherwise it is assumed to be decimal. The corresponding argument should be a pointer to an integer.

s

A character string is expected. The corresponding argument should be a character pointer pointing to an array of characters large enough to accept the string and a terminating \0, which is added automatically. The input field is terminated by a space or a newline.

c

A character is expected. The corresponding argument should be a character pointer. The normal skip over space characters is suppressed in this case. To read the next non–space character, use %1s. If a field width is given, the corresponding argument should refer to a character array, the indicated number of characters is read.

e,f

A floating point number is expected. The corresponding argument should be a pointer to a float. The input format for floating point numbers is an optionally signed string of digits, possibly containing a decimal point, followed by an optional exponent field consisting of an E or an e, followed by an optionally signed integer.

[

Indicates a string that is not to be delimited by space characters. The left bracket is followed by a set of characters and a right bracket. The characters between the brackets define a set of possible characters making up the string. If the first character is a circumflex (^), then the search set of characters is inverted to include all ascii characters EXCEPT those between the circumflex and the right bracket. The input is scanned until a character not in the search set is found. The corresponding argument should point to a character array.

The conversion characters d, o, x and i may be capitalized and/or preceded by the letter l or L to indicate that a pointer to long rather than to int is in the argument list. Similarly, the conversion characters e and f may be capitalized and/or preceded by the letter l or L to indicate a pointer to double rather than to float is in the argument list.

Scanf conversion terminates at EOF, at the end of the control string, or when an input character conflicts with the control string. In the latter case, the offending character is left unread in the input stream.

Trailing white space is left unread (including a newline) unless explicitly matched in the control string.

A pointer to unsigned character, integer or long can be used in any conversion where a pointer to a character, integer or long is allowed.

The success of literal matches and suppressed assignments is not directly determinable.

Sscanf does not change the source string s.

Include Files

#include <stdio.h>

Return Value

Upon successful completion these functions return the number of successfully matched and assigned input items. In the event of a conflict between the format string and the input, a lesser count is returned, which may be zero if the conflict occurs early enough. If the input ends before the first conflict or conversion, EOF is returned.

Portability

These functions, except for the i (general integer) conversion, are available on UNIX systems. These functions, with slightly greater functionality, are defined in the ANSI Standard.

Note: For related information, refer to the atof, getc, and printf functions.

segread

void segread(struct SREGS *segtbl);

This function reads segment registers and places the current values into the segtbl structure. For the small memory model, the value of the CS register does not change during execution. For the medium, large, and huge memory models, the CS register varies from one function to another. Each source file is given a different CS register value.

DS, ES and SS are the same and remain unchanged for the duration of the execution of a program.

Include Files

#include <i8086.h>

Portability

This function is unique to BTOS C.

setbuf, setvbuf

void setbuf(FILE *stream, char *buf);

int setvbuf(FILE *stream, char *buf, int type, unsigned size);

Setbuf and setvbuf are used after a stream is opened but before any reading or writing is done on the stream. They cause the buffer buf to be used instead of an automatically allocated buffer.

In setvbuf, the type parameter is one of the following:

_IOFBF The file is fully buffered. When a buffer is empty, the next input operation attempts to fill the entire buffer. On output the buffer is completely filled before any data is written to the file.

_IOLBF The file is line buffered. When a buffer is empty, the next input operation still attempts to fill the entire buffer. On output, however, the buffer is flushed whenever a newline character is written to the file.

_IONBF The file is unbuffered. The buf and size parameters are ignored. Each input operation reads directly from the file and each output operation immediately writes the data to the file.

In setbuf, if buf is the constant pointer NULL, i/o is unbuffered, otherwise it is fully buffered. In setvbuf, if buf is the constant pointer NULL a buffer is allocated using malloc using the size parameter as the amount allocated.In setbuf the buffer must be BUFSIZ (specified in stdio.h) bytes long. In setvbuf, the size parameter specifies the buffer size, and must be greater than zero.

A common cause for error is to allocate the buffer as an automatic variable and then failing to close the file before returning from the function where the buffer was declared.

Setbuf produces unpredictable results if it is called for a stream except immediately after opening the stream or any call to fseek. Calling setbuf after a stream has been unbuffered is legal and does not cause problems.

Include Files

#include <stdio.h>

Return Value

The setvbuf function returns non–zero if an invalid value is given for type or size, or when buf is NULL if there is not enough space to allocate a buffer.

Portability

Setbuf is available on UNIX systems. Both functions are defined in the ANSI Standard.

Note: For related information, refer to the fopen, fseek, and malloc functions.

setjmp, longjmp

int setjmp(jmp_buf env);

void longjmp(jmp_buf env, int val);

These routines are useful for dealing with errors and interrupts encountered in a low-level subroutine of a program.

Setjmp saves the current stack environment in env for later use by longjmp. It preserves the current stack pointer, register variable and automatic variable frame pointer as well as the return instruction pointer. It returns zero when it is initially called.

Longjmp restores the environment in env and then returns in such a way that it appears that setjmp returned with the value val. Longjmp cannot return the value 0; if passed 0 in val, longjmp returns 1.

The routine that called setjmp, and set up env, cannot have returned in the interim before calling longjmp. If this happens the results are unpredictable.

Automatic variables and function arguments have values as of the time longjmp was called. Any register variable is restored to the value at the time of the call to setjmp.

Include Files

#include <setjmp.h>

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the ssignal function.

setmem

void setmem(void *addr, int len, char value);

Setmem assigns the byte value to each character in the string pointed to by addr. Len gives the number of characters to assign. This function uses the 8086 stosb instruction and is extremely fast.

Include Files

#include <i8086.h>

Portability

This function is unique to the 8086 family.

Note: For related information, refer to the movmem and string functions.

sinh, cosh, tanh

double sinh(double x);

double cosh(double x);

double tanh(double x);

These functions compute the designated hyperbolic functions for real arguments.

Include Files

#include <math.h>

Return Value

Sinh and cosh return a huge value of appropriate sign when the correct value would overflow.

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

ssignal, gsignal

```
int     (*ssignal(int sig, int (*action)()))();

int     gsignal(int sig);
```

Ssignal and gsignal implement a software signalling facility. Ssignal is used to establish an action routine for servicing a signal. Gsignal is used to raise the signal and execute the action routine.

Software signals are associated with integers in the range from 1 to 15.

The first argument to ssignal is a number identifying the type of signal for which an action is established. The second argument defines the action; it is either the name of a (user defined) action function or one of the manifest constants SIG_DFL (default) or SIG_IGN (ignore). Ssignal returns the action previously established or if the signal number is illegal, ssignal returns SIG_DFL.

Gsignal raises the signal identified by its argument, sig:

If an action function has been established for sig, then that action is reset to SIG_DFL and the action function is entered with argument sig. Gsignal returns the value returned to it by the action function.

If the action for sig is SIG_IGN, gsignal returns the value 1 and takes no other action.

If the action for sig is SIG_DFL, gsignal returns the value 0 and takes no other action.

If sig has an illegal value or no action was ever specified for sig, gsignal returns the value 0 and takes no other action.

Include Files

```
#include     <signal.h>
```

Portability

These functions are available on UNIX systems.

stime

int stime(time_t *tp);

Stime sets the system time and date. Tp points to the value of time as measured in BTOS SimpleDate format.

Include Files

#include <time.h>

Return Value

A value of 0 is returned.

Portability

These functions are available on UNIX systems.

Note: For related information, refer to the time function.

strcat, strncat

```
char    *strcat(char *dest, char *src);

char    *strncat(char *dest, char *src, int maxlen);
```

Strcat appends a copy of src to the end of dest. The length of the resulting string is strlen(dest) + strlen(src).

Strncat copies at most maxlen characters of src to the end of dest, and then appends a null–byte terminator. The maximum length of the resulting string is strlen(dest) + maxlen.

Include Files

```
#include    <string.h>
```

Return Value

Both functions return the first argument.

Portability

This function is available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strchr, strcmp, strcpy, strlen, strspn, and strtok functions.

strchr, strrchr, strpbrk

```
char    *strchr(char *s, char c);

char    *strrchr(char *s, char c);

char    *strpbrk(char *s1, char *s2);
```

Strchr and strrchr scan a string for a specific character. The null character terminating a string is considered to be part of the string, so that for example:

strchr(s, 0)

returns a pointer to the terminating null byte of the string.

Strpbrk scans a string for one of several different characters.

Include Files

```
#include    <string.h>
```

Return Value

Strchr returns a pointer to the first occurrence of the character c, or NULL if c does not occur in s. Strrchr returns a pointer to the last occurrence of the character c, or NULL if c does not occur in s. Strpbrk returns a pointer to the first occurrence of any of the characters in s2, or NULL if none of the s2 characters occurs in s1.

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strcat, strcmp, strcpy, strlen, strspn, and strtok functions.

strcmp, strncmp

int strcmp(char *s1, char *s2);

int strncmp(char *s1, char *s2, int maxlen);

Strcmp lexicographically compares its arguments up to the terminating null–bytes.

Strncmp makes the same comparison but looks at no more than maxlen characters.

Include Files

#include <string.h>

Return Value

These functions return -1 if s1 is less than s2, 0 if s1 equals s2, and 1 if s1 is greater than s2.

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to memcpy, movmem, setmem, strcat, strchr, strcpy, strlen, strspn, strtok.

strcpy, strncpy

char *strcpy(char *dest, char *src);

char *strncpy(char *dest, char *src, int maxlen);

Strcpy copies string src to dest, stopping after the null character has been moved.

Strncpy copies exactly maxlen characters, truncating or null-padding dest; the target may not be null-terminated if the length of src is maxlen or more.

Include Files

#include <string.h>

Return Value

Both functions return dest.

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strcat, strchr, strcmp, strlen, strspn, and strtok functions.

strlen

int strlen(char *s);

Strlen returns the number of non–null characters in s.

Include Files

#include <string.h>

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strcat, strchr, strcmp, strcpy, strspn, and strtok functions.

strspn, strcspn

int strspn(char *s1, char *s2);

int strcspn(char *s1, char *s2);

Strspn returns the length of the initial segment of string s1 which consists entirely of characters from string s2.

Strcspn returns the length of the initial segment of string s1 which consists entirely of characters not from string s2.

Include Files

#include <string.h>

Portability

Available on UNIX systems. These functions are defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strcat, strchr, strcmp, strcpy, strlen, and strtok functions.

strtok

char *strtok(char *s1, char *s2);

Strtok considers the string s1 to consist of a sequence of zero or more text tokens separated by spans of one or more characters from the separator string s2.

The first call (with pointer s1 specified) returns a pointer to the first character of the first token, and writes a NULL character into s1 immediately following the returned token.

Subsequent calls with zero for the first argument works through the string s1 in this way until no tokens remain. The separator string s2 may be different from call to call. When no tokens remain in s1 a NULL is returned.

Include Files

#include <string.h>

Portability

This function is available on UNIX systems. This function is defined in the ANSI Standard.

Note: For related information, refer to the memcpy, movmem, setmem, strcat, strchr, strcmp, strcpy, strlen, and strspn functions.

swab

void swab(char *from, char *to, int nbytes);

Swab copies bytes from the from string to the to string for nbytes length. Adjacent even and odd byte positions are swapped. This is useful for carrying data from one workstation to another. Nbytes should be even.

Include Files

There are no include files required with this function.

Portability

This function is available on UNIX systems.

time

time_t time(time_t *tloc);

Time returns the value of time in BTOS SimpleDate format.

If tloc is non–zero, the return value is also stored in the location to which tloc points.

Include Files

#include <time.h>

Portability

Available on UNIX systems. This function is defined in the ANSI Standard.

Note: For related information, refer to the stime function.

toupper, tolower, _toupper, _tolower, toascii

```
int     toupper(int c);
int     tolower(int c);
int     _toupper(int c);
int     _tolower(int c);
int     toascii(int c);
```

Toupper and tolower convert integers in the range EOF to 255. Toupper leaves the character unchanged, except for lowercase letters which are converted to uppercase. Tolower similarly converts uppercase letters to lower and leaves all others unchanged.

_toupper and _tolower do the corresponding conversions, except that _toupper only works for lowercase letters and _tolower only works for uppercase letters. These are implemented as macros and are therefore much faster than the functions tolower and toupper.

Toascii yields its argument with all bits cleared except the lower seven bits, giving a value in the range of 0 to 127. It is intended for compatibility with other systems.

Include Files

```
#include    <ctype.h>
```

Portability

All functions are available on UNIX systems. These functions, except for toascii are defined in the ANSI Standard.

Note: For related information, refer to isalpha.

sin, cos, tan, asin, acos, atan, atan2

```
double  sin(double x);
double  cos(double x);
double  tan(double x);
double  asin(double x);
double  acos(double x);
double  atan(double x);
double  atan2(double y, double x);
```

These calls perform trigonometric functions.

Sin, cos and tan return the corresponding trigonometric functions. Angles are specified in radians.

Asin, acos and atan return the arc sine, arc cosine and arc tangent respectively of the input value. Arguments to asin and acos must be in the range -1 to 1. Arguments outside that range causes asin or acos to return zero and set errno to EDOM.

Atan2 returns the arc tangent of y/x and produces correct results even when the resulting angle is near pi/2 or -pi/2 (x near zero).

Include Files

```
#include        <math.h>
```

Return Value

Sin and cos return a value in the range –1 to 1. Tangent returns any value for valid angles. For angles close to pi/2 or -pi/2, tangent returns zero and sets errno to ERANGE.

Asin returns a value in the range -pi/2 to pi/2.

Acos returns a value in the range 0 to pi.

Atan returns a value in the range -pi/2 to pi/2.

Atan2 returns a value in the range -pi to pi.

Portability

These functions are available on UNIX systems. These functions are defined in the ANSI Standard.

ungetc

int ungetc(char c, FILE *stream);

Ungetc pushes the character c back onto the named input stream. This character returns on the next call to getc or fread for that stream. Ungetc returns c.

One character may be pushed back in all situations. A second call to ungetc without a call to getc forces the previous character to be forgotten.

Fseek erases all memory of a pushed back character.

Include Files

#include <stdio.h>

Return Value

Ungetc always returns the character pushed back.

Portability

This function is available on UNIX systems. This function is defined in the ANSI Standard.

Note: For related information, refer to the fseek and getc functions.

unlink

int unlink(char *filename);

Unlink deletes a file specified by the filename. Any BTOS drive, directory and filename may be used as a filename.

Return Value

On successful completion, a zero is returned. On error a -1 is returned.

Portability

This function is available on UNIX systems.

vprintf, vfprintf, vsprintf

int vprintf(char *format, va_list argp);

int vfprintf(FILE *stream, char *format, va_list argp);

int vsprintf(char *s, char *format, va_list argp);

These functions are alternate entry points for the printf functions. They behave exactly like the corresponding printf functions, except that instead of providing the arguments to be formatted explicitly in the command line, they are supplied in an array pointed to by argp.

The argp parameter is the vaelist array filled in by a call to va_start.

Include Files

include <stdio.h>

include <stdarg.h>

Return Value

The return value is the same as for the corresponding *printf function.

Portability

These functions are available on UNIX. These functions are defined in the ANSI Standard.

vscanf, vfscanf, vsscanf

```
int     vscanf(char *format, va_list ap);

int     vfscanf(FILE *stream, char *format, va_list ap);

int     vsscanf(char *s, char *format, va_list ap);
```

These functions are alternate entry points for the scanf functions. They differ from the normal scanf functions in that instead of supplying the list of arguments explicitly in the call, a pointer to an array of arguments is supplied.

The ap parameter is actually the array set up by a call to va_start. The ap parameter then points to an array of scanf parameter pointers. The pointers in this array must correspond to the format specifiers in the format string.

Include Files

```
#include    <stdio.h>
#include    <stdarg.h>
```

Return Value

The return value is the same as for the corresponding *scanf function.

Portability

These functions are available on UNIX.

write

int write(int handle, void *buf, int nbyte);

This function writes a buffer of data to the file or device named by the given handle.

Handle is a file handle obtained from a creat or open call.

This function attempts to write nbyte bytes from the buffer pointed to by buf to the file associated with handle. If the number of bytes actually written is less than that requested, the condition should be considered an error and probably indicates a full disk.

For disk or diskette files, writing always proceeds from the current file pointer (see lseek). For devices, bytes are directly sent to the device.

Include Files

There are no include files required for this function.

Return Value

The number of bytes written are returned by write. In case of error write returns -1.

Portability

Write is available on UNIX systems.

Note: For related information, refer to the creat, lseek, and open functions.

Using the C Programming Language

This section gives you reference information on the C programming language. It contains a brief history and description of C with emphasis on the language capabilities and advantages.

Language History and Features

The C programming language was developed for a UNIX operating system in the early 1970s by Dennis Ritchie at Bell Laboratories. (For more information, refer to *The C Programming Language*, Kernighan and Ritchie, Prentice–Hall, 1978. On the BTOS C Compiler you can run the sample program given in book.)

The American National Standards Institute (ANSI) is currently working on a C Language Standard. The standard is sufficiently stable to safely implement features of it. A summary of the major features that are not found in the proposed ANSI standard are as follows:

- Comments can optionally be nested.
- The keywords interrupt, plm, _cs, _ds, _es, _ES, _ss, near, and far have been added for special hardware support.
- Inline assembly language code, using the keyword asm, can be included in C source modules.

For users of BTOS C version 1.0, a list of features in the language follows. The 8086 extensions are included in this list for completeness.

- The preprocessor supports #pragma, #error, and # directives.
- The preprocessor supports the __DATE__ and __TIME__ macros.
- The preprocessor no longer expands macro arguments inside strings and character constants.
- The preprocessor uses the # symbol in front of the argument name in a macro expansion to support 'string–izing' macro arguments.

- The preprocessor uses the ## symbol between two other tokens to support token–concatenating in macro expansion.
- Comments are replaced with a single space character after macro expansion.
- Nested macros mentioned in a macro definition string are expanded only when the macro itself is expanded. This mostly affects the interaction of #undef with nested macros.
- The #include and #line directives can have macros on them. If a macro is mentioned on the directive line it is expanded before the directive is performed. This allows using macros to define source file names.
- A progression of signed and unsigned types that an integer constant could be, depending on the value and radix of the constant.
- Floating point constants can contain F or L suffixes to specify float or long double constants.
- A keyword, signed, implies the integer object is signed. This is important for char objects. A compile time switch (-K) does not affect char objects explicitly declared as signed char.
- There is a new floating type, long double. This type is treated exactly like double.
- A type modifier, const, declares constant data objects. You can use this to define ROMable data objects.
- A type modifier, volatile, declares objects that can be modified in unseen ways. These objects include those that can be modified by an interrupt processing routine, and which may not be overly optimized.
- A function prototype is a function declarator that, unlike the normal empty pair of parentheses, contains a list of function parameter types. These types are used in two ways. First, to check the validity of the parameters actually given in a call. Second, to adjust the type of function arguments to match the parameter types in the prototype.
- Extern declarations given inside a function obey proper block scope. The declarations are not recognized beyond the scope of the block in which they are defined.

- The default conversion rules for mixed type expressions have been modified slightly. This affects the type conversions whenever unsigned char is present, or when unsigned int is combined with signed long.
- A series of addressing type modifiers, near, far, _cs, _ds, _es and _ss can be given with pointer declarations. These modifiers declare the specific addressing the pointer uses in the 8086 architecture.
- Definitions have been added for the following pseudo–variables:

_AX	_BX	_CX	_DX
_SI	_DI	_BP	_SP
_AL	_AH	_BL	_BH
_CL	_CH	_DL	_DH
_CS	_DS	_ES	_SS

  You can use these as unsigned int (or unsigned char for the byte registers) variables. You should be careful when you use these names, since most of these registers are not saved across function calls. If a function uses the _ES variable, the ES register is saved before each function call and restored on return. Also, except for _SI, _DI, _BP, _SP, _CS, _DS, and _SS, the registers are treated as available scratch registers even in the same expression where they are used. You should make sure that you use them in simple statements as much as possible. If you have any doubts about how an expression is generated, have the compiler produce an assembly listing produced by a given expression. That should reveal any problems.

  In general, these pseudo–variables are most useful for setting register parameters to non–C routines, like assembly code routines.
- A function type modifier allows interrupt functions that return a value. This change makes the syntax for specifying non–standard functions a little more uniform.
- A series of function modifiers, near, far, plm, and interrupt give greater flexibility in creating functions in mixed model and mixed language environments.
- The Huge memory model has been implemented.
- All passes of the BTOS C Compiler run in protected mode under BTOS II on a B28 or B38.
- Emulation of UNIX pipes has been implemented.

Translation Phases and Limits

Preprocessor Translations

This pass reads a source file, processing each source line independently. Preprocessor statements are acted upon as they are encountered. Include files are expanded inline. The only factor limiting the nesting level of include files is the maximum number of files which can be open simultaneously. Since this number is 20, the maximum include file nesting depth is 14.

Define macros can be expanded to up to 4096 bytes in length, and there is no particular limit on the number of macro arguments.

Conditional compilation skips lines by replacing the input line by a line containing nothing but white space. All conditional compilation statements must be complete in the source or include file in which they are begun.

Comments are removed.

The output file is a text string fully readable by any text editor. Lines are placed in the output beginning with a '# ' character to indicate the correct line number and source filename.

Parser Translations

The parser (CC1.Run) performs all of the C syntax checking of the compiler. Declarations are recorded and subsequently written to an intermediate file. A minimum of memory allocation is performed at this stage. Automatic storage and function arguments are deferred so that intelligent allocation of register variables can be made.

Executable code is written as a series of expression trees, punctuated by jump and label statements. All iteration and conditional statements are transformed into simple tests and jumps.

Constant subexpressions are evaluated and replaced by a single constant. Both integer and floating point values are calculated. Floating point values are computed using some 8087 emulating arithmetic, so that even with cross-compilers on other hardware, the constant values are computed in exactly the same manner.

A few limited special cases in expressions are reduced in complexity (such as adding or subtracting a constant zero). Conditional statements with a constant test are reduced to either a no–op or an explicit jump.

Optimizer Translations

The optimizer (CC2.Run) makes a few simple reductions in the code. Jumps to jumps are removed. Unreachable code is eliminated. The condition and increment parts of a for loop are moved to the bottom of the loop. The switch case table is moved from the bottom of the switch to the top (eliminating a jump). Two or more identical code sequences are reduced to a single copy.

These optimizations are guaranteed to preserve the exact execution sequence of the program, with the exception that execution is somewhat faster and the code is almost always smaller.

Code Generator Translations

The parser and/or optimizer output a series of expressions. The Code Generator (CC3.Run) reads these expressions and generates a code, a single expression at a time. Before code is actually written to the output, enough code is held in order to generate the shortest size jump instructions for the given output file. As much as possible, the assembly language output is designed to match the object code output.

Compiler Limits

Other than the following limits, the compiler makes use of all available memory to hold intermediate tables.

The maximum number of nested include files is 14.

The maximum size of a single macro definition is 4096 characters.

The maximum size of a single expression is limited to 1000 expression tree nodes. Each identifier and operator consumes a single node. In addition, each function call argument consumes one extra node. Implicit or explicit

conversions consume one node each. Structure member references consume two extra nodes for arrow (->) and three for dot (.).

The maximum number of cases in a switch is 256.

Preprocessing

The preprocessor (CC0.Run) scans the source text character by character. Lines with an initial '# ' character are directives to be processed as encountered. White space can appear before or after the '# ' character.

Preprocessor directives normally are limited to a single line. Directives can be continued onto multiple lines by ending all but the last line of a continuation with a backslash (\) character. In general, any source line of a C program can be continued in this way. Thus string literals can use this technique to continue the literal onto multiple source lines. The backslash and the following newline are removed, effectively splicing the adjacent lines together into a single long source line.

Source File Inclusion

The complete contents of a text file can be included in a source file for compilation by means of the #include preprocessor directive. The compiler treats the named file as if it appeared in its entirety in place of the #include directive. This directive is of the form:

```
#include    "filename"
```

or

```
#include    <filename>
```

In general, the quoted form is used to indicate application specific include files, while the angle bracket form is reserved for system supplied include files. This convention is suggested, but not enforced.

The filename given does not have to be a complete pathname. If one is given, regardless of the filename delimiter used in the directive, the exact pathname is used. If the file is not found, an error message is displayed.

If no pathname is given, or an incomplete one is given, the file is searched for in a number of different directories. For either delimiter form, the first location checked is the current default directory. Then, each of the directories given on the command line with the -I option are searched. If the named directories do not exist, no error is reported. If the include file cannot be found anywhere in the list of directories searched, an error is displayed.

The pathname, including the delimiters, can be constructed using macro-expansions. However, if a string is enclosed in quotes it is not examined for embedded macros. Also, token and string concatenation cannot be used in macros within an include directive.

Trigraphs are replaced inside the pathname, but escape characters are not translated (you can use "\" characters in a pathname; they are not replaced).

Define Macros

The define macros are as follows:

#define identifier token-string newline

or

#define identifier (argument-list) token-string newline

#undef identifier

The identifier named in a #define directive is defined as either a define string or a macro. If the character immediately following the identifier is a left parenthesis (no white space is allowed) the definition is of a macro. Otherwise, the definition is of a simple define string macro. The definition applies from the line after the directive to the end of the source file even across include files, or until an #undef directive is encountered.

The following identifiers may not appear in a #define or #undef directive: defined, __FILE__, __LINE__, __DATE__, or __TIME__. These are names possessing special significance to the preprocessor.

The #undef directive causes the current definition, if any, of the identifier to be forgotten. In the case of a define string, the identifier is replaced in all subsequent lines by the token and the string given in the directive.

In the case of a macro, the argument-string is a list of identifiers separated by commas. When the macro is actually used, each of the arguments is substituted within the macro. A macro invocation supplies a list of token and strings, separated by commas and enclosed in parentheses. The entire sequence from the macro identifier to the closing parenthesis is replaced with the token and the string in the macro definition.

Exactly the correct number of macro arguments must be given. Commas can be given in a macro invocation argument only if they are enclosed in parentheses, double quotes, or single quotes.

When the #define directive is processed no macros and define strings are expanded. Then, when the macro or define string is activated, a scan is performed on the token and the string, recursively expanding any more defined names as they are encountered. The following example should clarify this:

```
#define iszero(a)          ((a) == '0')
#define isalnum(a)         (iszero(a) || islower(a))
#define islower(c)         ((c) >= 'a' && (c) <= 'z')

isalnum(*p)
```

expands to:

```
(((*p) == '0') || ((*p) >= 'a' && (*p) <= 'z'))
```

if then we have the following:

```
#undef   islower

isalnum(*p)
```

expands to:

```
(((*p) == '0') || islower(*p))
```

if then we have the following:

```
#undef   iszero

isalnum(*p)
```

would expand to:

```
(iszero(*p) || islower(*p))
```

Identifiers inside comments, strings, or character constants are never expanded, even if they are the same as defined macros.

Identifiers inside strings or character constants never expand during preprocessing. Since a common feature programmers need is the ability to enclose a macro argument inside quotes and display the string at runtime, a macro argument identifier preceded by a # is converted to a string by the preprocessor.

Thus, the following macro definition can be used:

```
#define     DEBUG(a)          printf(#a " = %d\n", a)
            DEBUG(x + y);
                    would expand to:
            printf("x + y" " = %d\n", x + y);
```

Note that the argument is replaced with the overt spelling of the argument, before any macros in the argument are expanded. Strings of white space are replaced with a single space character, including comments.

Two tokens can be concatenated together in a macro definition. Two tokens are separated by a ## plus optional white space. The preprocessor removes the white space and the ##, effectively combining the separate tokens. Typically, this is used to construct identifiers. It is notguaranteed to be portable to concatenate two things that do not result in a single token distinguishable from any adjacent tokens. For example:

```
#define     VAR(i, j)       (i ## j)
            VAR(x, 6);
                    would expand to:
            x6;             /* Guaranteed ok */
            VAR(x +, 6);
                    would expand to:
            x +6;           /* Not portable */
```

The second example does not port to other systems because the sequence in which a compiler is required to process input allows compilers to verify tokens in their input at an early stage, and do the concatenating process later on as a special case. If the two concatenated tokens do not form a single simple token, the compiler may not produce the same results as the C implementation.

The definition of a replacement string is trimmed of all leading and trailing spaces, so care must be taken when using macros beginning or ending with operators. The compiler can get confused if the macro identifier is used with more operators immediately around it. In general, enclosing the macro expansion string in parentheses eliminates any problems.

__FILE__

This macro is automatically defined to be the current source file being processed. This macro is changed whenever a new #include directive is processed, when the include file is completed, or a #line directive is processed.

This macro appears as a string in the processed text. Backslashes expand to double backslashes, preventing characters in a string from being improperly interpreted.

__LINE__

This macro is automatically defined to be the number of the current source file line being processed. The first line of a source file is defined to be 1.

__DATE__

This macro is automatically defined to be the date the preprocessor began processing the current compiled source file. Thus, each inclusion of the macro in a source file is guaranteed to contain the same value, even near midnight.

The date appears as "Mmm dd yyyy", where Mmm is the month (from Jan to Dec), and dd is the day (from 01 to 31) including a leading zero for days less than ten, and yyyy is the year.

__TIME__

This macro is automatically defined to be the time the preprocessor began processing the current compiled source file. Thus, each inclusion of the macro in a source file is guaranteed to contain the same value.

The format of the replacement string of this macro is "hh:mm:ss", where hh is the hour (from 00 to 23) using a twenty-four hour clock, mm is the minutes (from 00 to 59) and ss is the seconds (from 00 to 59).

__SMALL__

This macro is defined by the Small Memory Model selection options. The value is 1.

__MEDIUM__

This macro is defined by the Medium Memory Model selection options. The value is 1.

__LARGE__

This macro is defined by the Large Memory Model selection options. The value is 1.

__HUGE__

This macro is defined by the Huge Memory Model selection options. The value is 1.

Conditional Compilation

Six directives are defined that can be used to provide conditional compilation of source text. One or more blocks of text lines are delimited by these directives, an #ifdef, #ifndef or #if directive to begin the sequence, then a series of text lines to be compiled if the initial condition is true. Next optionally appears a #elif or #else statement. If the first condition is false, a subsequent #elif condition is tested and if true, the following set of text lines compiled. If a #else directive is encountered and all previous condition directives in the sequence were false, then the set of text lines following the #else are compiled. The entire sequence is terminated by an #endif statement.

Other preprocessor directives can be nested within a conditional compilation, including more conditional compilation directives. The #else, #elif and #endif directives associated with a leading #ifdef, #ifndef or #if directive must appear in the same text file. They cannot be spread across several include files.

When skipping text in a conditional sequence, the lines are examined only to keep track of nesting of conditional compilation directives and filename and line number information.

Constant Expressions

In the following conditional directives the term "constant expression" applies to any expression involving only integer constants and excluding the sizeof operator and any operators which involve side effects, such as increment, decrement or the assignment operators. Macros and define strings are expanded by the preprocessor. Any undefined identifiers in the expression after expansion is complete are replaced with a constant 0.

Only constant expressions in the preprocessor can incorporate the following subexpression:

defined (identifier)

or

defined identifier

This operation has the value 1 if the identifier is a defined macro or string, 0 otherwise. Thus the following pairs of directives are equivalent:

#if defined (XYZ)

and

ifdef XYZ

#if !defined (XYZ)

and

#ifndef XYZ

#ifdef Directive

ifdef identifier

This directive causes the following text lines to be compiled if the identifier is a defined string or macro. This is considered a true condition. Otherwise the following text lines are skipped.

#ifndef Directive

ifndef identifier

This directive causes the following text lines to be compiled if the identifier is not a defined string or macro. This is considered a true condition. Otherwise the following text lines are skipped.

#if directive

if constant expression

This directive causes the following text lines to be compiled if the constant expression evaluates to non–zero, or true. Otherwise the following text lines are skipped.

#elif Directive

elif constant expression

If all of the preceding conditional directives of a sequence are false, the constant expression is evaluated. If non–zero, the following text lines are compiled, otherwise they are skipped. A non–zero value is considered a true value.

#else Directive

else

If any of the preceding conditional directives in a sequence are true, the text after the #else directive is skipped. Otherwise, the following text is compiled. The #else directive must be the last directive in a conditional sequence to appear before the #endif directive.

#endif Directive

endif

An #endif directive completes a conditional compilation sequence.

Line Number Control

line constant "filename"

line constant

This directive causes its warning messages, the line number and source file name to be displayed on error. The filename continues until the next #line directive, or the end of the current include file. The line number of the next source line is taken to be the constant, and subsequent lines have progressively higher line numbers until a new #line statement is encountered or the end of the current include file is reached.

This directive is most useful when the compiler is used in conjunction with a front–end language that translates to C.

Macros are expanded in this directive.

#pragma Directives

pragma x_char_sequence new_line

This directive is intended to supply implementation specific extensions. The C Compiler recognizes such directives, but does not process them. A comment which begins on this directive can be continued onto another line, but any other text must be continued using the backslash (\), newline convention.

#error Directives

error x_char_sequence new_line

This directive causes the preprocessor to terminate immediately. A fatal diagnostic is issued, formatted as follows:

Fatal: filename line–no: Error directive: x_char_sequence

The text on the directive is scanned to remove comments, but any remaining text is displayed. The text is not examined for embedded macros.

Null Directive

new_line

This directive has no effect when processed. No other text can appear between the # and the new_line, except white space and comments.

Comments

Comments can be inserted between any adjacent tokens, and have no effect on the compilation of a C program, except for LINT comments that only affect diagnostic messages displayed.

Comments are begun with the characters /* and continue across text lines if necessary until a */ character sequence is encountered. Comments are allowed in preprocessor directives, and if a comment begins on the same line as a directive, the comment can continue across multiple lines.

Comments cannot be nested in the standard definition of C and this is the default. A compile time option for the preprocessor is provided which allows nested comments, though it is not recommended where portability is a concern.

Lexical Conventions

Source Text Conventions

A C program is specified as a sequence of ASCII text lines, such as any text file produced by the BTOS editor and not produced by the word processor. In this documentation we use the term "newline" as if it were a single character separating adjacent text lines. In UNIX and other systems this is true, but under CP/M and MSDOS text lines are separated by Carriage–return / line–feed pairs. BTOS C ignores all carriage–return characters in the source program and treats the line–feed characters as newlines.

There are no constraints on where items must appear on a source line. C statements can be spread over as many source lines as desired for readability. The only restriction imposed is that keywords and other identifiers cannot be split across source lines.

White space (spaces, tabs, formfeeds and newlines) can be ignored and left out in most circumstances. In strings or character constants spaces are significant. Also, spaces must be used to separate adjacent identifiers, such as in the expression 'sizeof x' or 'int i'. White space also cannot be inserted in the middle of an identifier or operator.

Newlines can be placed anywhere between tokens. A newline character by itself cannot be placed inside a character constant or string unit. If you wish to include a newline character in a program data, such as in a string or character constant, you must use the escape sequence \ n. If you wish to break up a long string across multiple source lines, you must use multiple string units, or you must precede any newlines inside the string with backslashes (\). A backslash – newline sequence does not appear at all in a string.

Identifiers

An identifier is a sequence of upper– and lowercase letters, digits and the underbar (_) character. An identifier must begin with a letter or the underbar. Identifiers can be of any length, but only the first 32 characters are significant. Identifiers which differ only beyond the first 32 characters are considered identical.

An identifier can name a global variable, a function, a function argument, an automatic (local) variable, a structure or union member, an enumeration constant, a preprocessor macro or define string, a typedef, a structure or union tag or a goto label. An identifier can be used only within its scope. There are three kinds of scope defined in BTOS C: file, function and block scope.

Identifiers declared in an external declaration have file scope. An identifier with file scope can be used from the point of the declaration to the end of the file being compiled. These identifiers include global variables, functions, structures and members, typedefs and enumerations.

Be careful when you see the term external declaration. In C there is a confusion in terminology. An external declaration is simply a declaration that occurs outside any function. Such a declaration can define an object, can declare a typedef or can declare an external object. The keyword extern is normally used to declare an external object. An external object is one defined in a different source file (and defined there in an external declaration). The extern keyword can be used in two other special circumstances: inside a function to declare an object that is defined in an external declaration in the same source file, or to declare an object that is defined later in the file in an external declaration. In each of these last two cases, the definition can be either global or static.

Identifiers declared as goto labels are the only identifiers with file scope. These identifiers can be used anywhere in the same function in which the label is located.

Identifiers with block scope include the same array of objects and entities as in file scope. Block scope identifiers are declared at the beginning of a block compound statement. These identifiers can be used from the point of declaration to the end of the block in which they are

defined. In addition, the arguments to a function have block scope extending to the end of the main block of the function. Upper– and lowercase letters are distinct for all local variables, structure field names and preprocessor define names. Thus two structure members, 'abc' and 'AbC' are distinct.

The compiler itself treats upper– and lowercase letters as distinct in global variables, but the BTOS linker does not distinguish the two cases. Any symbol passed to the linker is converted to uppercase. The linker indicates multiply defined symbols if two identifiers differ only in the case of the letters. Thus, the symbols 'strcpy' and 'Strcpy' are the same to the linker.

Keywords

The following list of identifiers are the keywords of C. These identifiers cannot be used to name any variable.

In theory you can use a keyword to define a macro or define string, but this practice is extremely dangerous and should be avoided.

asm	auto	break
case	char	const
continue	default	do
double	else	enum
extern	far	float
for	fortran	goto
if	int	interrupt
long	near	plm
register	return	short
signed	sizeof	static
struct	switch	typedef
union	unsigned	void
volatile	while	_cs
_ds	_es	_ss

Numerical Constants

C allows several different kinds of constants in a source program.

Integer Constants

Integer constants can be specified in decimal, octal or hexadecimal. Normally, integer constants have type int, but large valued integers, or constants with a trailing letter L have type long.

Integer constants can be any length, but if the constant overflows the size of a long integer there is no warning given. Negative integer constants cannot be directly specified. A source file containing, for example, a -34 is actually specifying a positive constant of 34 which is then negated with the standard negation operator. Such a construction is treated as a constant expression evaluated at compile time.

Any integer constant can be followed by an upper– or lowercase letter L, and/or an upper– or lowercase letter U. The L suffix forces the constant to have long type, regardless of the magnitude of the constant. The U suffix forces the constant to have unsigned type, regardless of the magnitude of the constant.

A decimal integer constant is any string of digit characters beginning with a non–zero digit. An unsuffixed decimal constant that is greater than 32767 is treated as long, greater than 2147483647 is treated as unsigned long, and greater than 4294967295 overflows without warning and the resulting constant is the low–order bits of the actual value.

An octal integer constant is a string of octal digits (0 through 7) beginning with a zero. An unsuffixed octal constant that is greater than 077777 is treated as unsigned, greater than 0177777 is treated as long, greater than 017777777777 is treated as unsigned long, and greater than 037777777777 overflows without warning and the resulting constant is the low–order bits of the actual value.

A hexadecimal constant begins with a 0x or 0X and contains a string of digits plus the upper– and lowercase letters A through F. An unsuffixed hex constant that is greater than 0x7FFF is treated as unsigned int, greater than 0xFFFF is treated as long, greater than 0x7FFFFFFF is treated as unsigned long, and greater than 0xFFFFFFFF overflows without warning and the resulting constant is the low–order bits of the actual value.

A constant suffixed with a U is treated as unsigned or unsigned long. If the constant is greater than 65535 the constant is treated as unsigned long, regardless of the radix of the constant.

Character Constants

A character constant is a mechanism for specifying integer values that correspond to ASCII characters. A character constant is a string of ASCII characters enclosed in single quotes, such as 'x' or 'gh'. A character constant is always an int quantity and is exactly equivalent to an integer constant with the same value. Character constants cannot contain newline characters. A double quote can be included in a character constant, but a single quote must be given as an escape sequence.

A character constant can be one or two characters long in this implementation. Character constants longer than one character are not portable and should be avoided. In BTOS C the first character is placed in the low order byte of the resulting integer, and the second character in the high order byte. If only one character is given, then the high order byte is zero.

Escape Sequences

In order to specify non–printable characters, escape sequences are provided. All escape sequences begin with a backslash character (\). The simplest escape sequences consist of a backslash followed by a single letter. The following table identifies each escape sequence and the resulting character in hex and its ASCII abbreviation.

Sequence	Value	Character	Name
\a	0x07	BEL	Audible bell
\b	0x08	BS	Backspace
\f	0x0C	FF	Force
\n	0x0A	LF	Newline
\r	0x0D	CR	Carriage return
\t	0x09	HT	Horizontal tab
\v	0x0B	VT	Vertical tab
\\	0x5C	\	Backslash
\'	0x2C	'	Single quote
\"	0x22	"	Double quote
\?	0x3F	?	Question mark

In addition, octal escape sequences can be given by following the backslash with from one to three octal characters. A hexadecimal escape sequence can be given by specifying a backslash, letter x (or X) followed by one to three hex digits. Any 8-bit ASCII character value from 0 to 255 can be specified.

Valid escape sequences include \n, \v, \004, \x0A. A character constant of '\058' would be treated as two characters: an octal 05 and an ASCII '8', since 8 is not a legal octal digit.

Floating Constants

A floating point constant is given as a mantissa followed by an optional exponent and optionally terminated with a type suffix. The mantissa consists of a string of digits with a single decimal point. Legitimate mantissas can have the decimal at the start or end of the digit string, or embedded in the middle of digits. The exponent begins with an upper- or lowercase letter E, followed by an optional sign (plus or minus) and then a string of digits. The type suffix can be an F or f, indicating float type, or an L or l, indicating long double type.

Floating point constants can contain up to 15 significant decimal digits in the mantissa and can have an exponent in the range plus or minus 306. Exponents beyond the range given cause overflow but no error message are displayed.

Strings

A string consists of one or more string units. Each string unit is a sequence of ASCII characters and/or escape sequences enclosed in double quotes. A newline cannot occur in the middle of a string unit. A string unit can be any length.

Multiple string units can be given, possibly on several source lines. The units are concatenated together.

Note that Kernighan and Ritchie in a *C Programming Language* allow only a single string unit in a string. The addition of multiple units was designed to allow splitting long strings among several source lines and still keep flexible formatting of the strings on the page. For example, the following string can be coded in BTOS C as:

```
"hello world, this is an example of "
"a long string\n"
"spread across source lines\n";
```

In C in the *C Programming Language*, this must be written as:

```
"hello world, this is an example of \
a long string\n\
spread across source lines\n";
```

Operators

An operator specifies an operation to be done that produces a value. The operators of C are built for the most part out of punctuation and other special ASCII characters. Sizeof is the only C operator that is a keyword. Operators consisting of more than one character must not be divided by white space. If more than one operator is given with no intervening spaces, the compiler chooses the longest operator to fit the initial sequence of characters. For example, y---z is interpreted as y -- - z.

The C operators are:

[	]	(	)	.	->
++	--	&	!	%	^
*	-	+	=	==	!=
>	<	>=	<=	<<	>>
%=	^=	&=	*=	-=	+=
<<=	>>=	?	:	,	/
/=	sizeof				

Note that [ ], ( ), and ? : are only found in matching pairs, possibly enclosing expressions.

Punctuation

Punctuation is used to delimit or separate components of a C declaration or statement without causing any actual operations to be performed. The punctuation marks of C are:

[	]	(	)	{	}
*	,	:	=	;	

Note that [ ], ( ), and { } occur only in matched pairs, possibly enclosing other constructs.

Trigraphs

To support portability to workstations without certain ASCII characters in their native character set, these trigraphs were added to the language. They should be thought of as substitutes for standard characters. Each trigraph begins with a ?? pair, since this sequence is not used in normal C programming. If a sequence of three characters beginning with ?? is encountered that is not in the following list, no translation is done on the characters.

The legal trigraphs, with the standard ASCII equivalents are:

??=	#
??(	[
??/	\
??)	]
??'	^
??<	{
??!	|
??>	}
??-	~

These trigraphs are recognized, but we do not recommend using them unless the corresponding C character is not available on your workstation.

Types

Every data object in C has a type. In addition, operations in expressions produce a value which also has a type. The type of an object or expression determines the operations allowed on it. For a data object the type also determines how much memory the object takes up.

Basic Types

The following basic types are supported by this compiler:

char	unsigned char
short	unsigned short
int	unsigned int
long	unsigned long
float	double
long double	enum
void	

Integral Types

The basic types correspond closely to the kinds of data manipulated by the 8086 hardware. Char, short, int and long types, plus the corresponding unsigned types, and enum (enumerations) are called the integral data types. Char, short, int and long are considered distinct types as

far as the abstract definition of C is concerned, but on most workstations int type objects are the same as either short or long objects. In this implementation int and short objects are the same.

Characters and Integers

Character data in the BTOS C Compiler implementation is treated as signed by default, in the range -128 to 127. Unsigned character data falls in the range 0 to 255. A character constant specified with an octal or hex escape sign extends (unless the –K compile option is given), so the value '\377' given in their book is represented as an integer with the value of -1.

Unsigned

Unsigned quantities can be 8, 16, or 32 bits wide, just as signed integral values are. All of the bits of the object are magnitude bits. All unsigned values are numerically non–negative and span a range of positive integers twice that of signed integers occupying the same number of bytes.

Floating

Float, double and long double types implement the IEEE floating point standard data format used by the 8087 math coprocessor. Float objects occupy 4 bytes, double and long double objects occupy 8 bytes. Long double and double types are treated identically.

Void

Void type only occurs in limited situations and is used to signify that the operation produces no value at all. This most commonly occurs when calling a certain function which returns nothing. No actual objects are of void type.

Void functions are provided as a means for explicitly documenting a certain function which does not return a value. Under Kernighan and Ritchie C there is no mechanism for describing this fact.

As a special construct, to explicitly indicate that the return value of a function is being ignored, an expression can be cast to void type. If the expression is a function call to a function that returns a type, LINT processing reports that the return value is being ignored unless such a void cast is present.

Enumerated

Enumerated type data is used to describe a discrete set of alternative values. In this implementation of C enumerated type data can be used as if it were an integer without restriction. The compiler does not even check whether an enumeration constant is being assigned to a correct enumerated variable.

Composite Types

In addition to the basic types, the following composite types are supported:

pointer to data	pointer to a function
function	array
structure	union

Pointers

In the original Kernighan and Ritchie definition of C, there was no distinction between pointers to different kinds of objects, the assumption being that all pointers work more or less alike. This assumption is not correct on BTOS workstations. The two most basic classes of pointers are pointers to data or pointers to functions.

Pointers to data are treated exactly as described by Kernighan and Ritchie. The full range of pointer arithmetic operators are available to these pointers. Pointers to functions are restricted in their use. Function pointers can only be copied or used to call the function pointed to. Function pointers cannot be assigned to data pointers and vice versa, though they can be cast appropriately.

Part of the reason for strongly distinguishing these varieties of pointers is that, depending on the memory model used in compiling a program, pointers are of

different sizes, and data pointers and function pointers cannot be the same size as each other. Note that addressing modifiers override the size of a pointer given by the Memory Model in effect.

A pointer type must be declared to point to some other specific type. A pointer can point to any other type. This implementation allows you to mix pointers to different kinds of data objects to be compared or assigned to one another, but you are warned when this happens.

A special pointer declaration, a pointer to void, is allowed. This does not mean a pointer to nothing. A pointer to void is a mechanism adopted to avoid defining a new language keyword. It means a pointer to any kind of data object, the type of which is not necessarily known. You can assign any pointer to a void pointer and vice versa without a cast. You cannot use the indirection operator with a void pointer.

Functions

Functions are declared to return a specific type when called. Functions can return any type except arrays, or other functions (although returning a pointer to a function is allowed).

As an extension introduced by BTOS C, a function declaration can include a language specifier following the function name. The allowed language specifiers are:

- **interrupt** for interfacing with workstation interrupts.
- **plm** for interfacing with PL/M modules.
- **near** for functions using near returns and calls.
- **far** for functions using far returns and calls.

Only one language modifier can be given for each function declarator, except that near or far can be combined with plm. The altered calling conventions have different effects on a program (refer to Function Calls). Function calls must match the language given with the function definition.

Interrupt functions are designed to be used with the 8086 interrupt vectors. An interrupt function saves all registers on entry and restores them on return. A far pointer to an interrupt function can be stored directly into an 8086 hardware interrupt vector, although under BTOS the SetIntHandler procedure should be used instead (refer to your BTOS documentation).

Arrays

Arrays are declared to be a collection of objects of a single type. Arrays must be declared to be a fixed size at compile time. An array occupies exactly the size of each object in the array times the number of objects. No extra information is maintained to check the bounds of the array at runtime. Arrays can be constructed from any type except void or a function type (but again pointers to functions are allowed). C declares multi–dimensional arrays by constructing an array of arrays as needed.

Structures and Unions

Structures and unions are similar to each other. A structure allows the definition of a set of named members, each with their own type. A structure takes up as much memory as the sum of the sizes of the members. If the structure is compiled with alignment selected (option –a), padding bytes are added as needed to ensure that any non–char members are an even offset from the beginning of the structure, and a pad byte can be added to ensure that the structure itself is an even number of bytes long.

Unions differ from structures in that the value of a union is only one of the individual members at a time. The members of a union are stored on top of one another so that all members have an offset of zero. The size of a union is the size of the largest member. If alignment is selected, a union is padded to make an even size in bytes. Assigning a value to one member of a union and then extracting the value of a different member can produce unpredictable and certainly non–portable results.

Bitfields

Structures, but not unions, can contain bitfields. Bitfields normally allow packing of several objects into a single workstation word. A bitfield can be either a signed or unsigned int type, and can occupy from 1 to 16 bits. Objects in the BTOS C implementation occupy a whole number of bytes. Other implementations can have different rules for allowed bitfield types and sizes.

Type Modifiers

The type modifiers are const and volatile. Any object can be declared with these modifiers. The effect of the const modifier is to prevent any assignments to the object, or other side effects such as increment or decrement. A const object can be initialized, even an auto const object.

Volatile objects have a less obvious effect. Volatile objects can be modified in some invisible way, such as by an interrupt routine, so the compiler is directed that these objects cannot be specially optimized. These declarations only affect a program if it is compiled using the –Z optimization option. Volatile objects are always treated as if no –Z optimization were in effect.

Pointers to const or volatile objects can be declared. Without a cast a pointer to a non–const object can be assigned to a pointer to a const object, but not the other way around. Similarly, a pointer to a non–volatile object can be assigned to a pointer to a volatile object, but not the reverse. Any pointer can always be explicitly cast to any other pointer type.

The pointer type modifiers are const, volatile, and the addressing modifiers.

The const modifier states that the pointer itself cannot be modified, though the object pointed to can be.

The volatile modifier states that the pointer itself is volatile.

Addressing modifiers have been introduced by BTOS C implementations as an extension to support the complex addressing capabilities of the 8086 family of microprocessors. The addressing type modifiers are:

- Default Memory Model addressing (no modifier)
- near pointer
- far pointer
- _ds pointer (same as near)
- _es pointer
- _ss pointer
- _cs pointer

Note that _ds is fully equivalent to near for data pointers in the Small and Medium Memory Models. Similarly _cs is fully equivalent to near for function pointers in the Small

Memory Model. Data pointers in the Large and Huge Memory Models are equivalent to far pointers. Function pointers in the Medium, Large and Huge Memory Models are equivalent to far pointers.

Only one addressing qualifier can be present in a single pointer. (Obviously, if a declaration contains more than one pointer declarator, each can have its own addressing modifier). Use addressing modifiers sparingly, since understanding how they interact can be obscure at times.

Declarations

All declarations, whether of global variables, functions, structure members or local variables use the same general syntax. The purpose of a declaration is to do one of the following:

- define a structure, union or enumeration
- define an alias for some type (A typedef)
- define a data object
- define a function
- describe a global data object or function defined in some other source file

In addition to the components of a declaration itself, the context of the declaration is important in determining the exact nature of the objects being declared. There are six contexts in which a declaration can occur:

- external context (outside of any function, structure, or union definition)
- structure context (inside a structure)
- union context (inside a union)
- formal parameter context (after the function declarator and before the function code block)
- block context (at the beginning of any block)
- function prototype context (inside a function declarator)

You begin with a storage–class. Then you can follow that with a declarator and possibly an initializer. A declaration can be as simple as a type by itself. The allowed combinations of storage–class specifiers, types, declarators and initializers depends on the context.

At least one of the type and storage–class specifiers must be present in a declaration and/or type specifier.

If a storage–class is allowed in a given context it can be omitted. If it is omitted, a default storage–class is chosen depending on the context. If a type is omitted, the default type of int is supplied.

A declarator is used to name the identifier being declared and provide any additional type information such as pointer, array or function types. The syntax of a declarator was designed to mimic the use of the identifier. The rule of thumb is that if an identifier is declared with some declarator, the same string of tokens in an expression has the same type as the type specifier of the declaration. Thus, in the following example ip is declared to be an array of 5 pointers to integers. The expression given produces a value of type int

```
int         * ip[5] ;
            ...
            * ip[3] ;
```

After a declarator, external and block declaration contexts allow an initializer to be supplied. This is a value to be assigned to the object being declared. For simple, scalar objects, the initializer is an expression. For arrays or structures, an initializer is a set of expressions, as many as one for each member of the composite object.

More than one declarator can be given in a single declaration by separating the declarators with commas. Thus in the following declaration, i is an int, j is a pointer to an int initialized to the address of i, and k is an array of 7 ints:

```
int         i, * j = &i, k[7] ;
```

Storage Class Specifiers

The allowed storage class specifiers are described.

Auto

The automatic (auto) storage class is the memory local to a function, created on entry to the function and destroyed on exit. This memory class is implemented on most workstations as a stack, and this is true of the 8086

implementations. Auto variables can only be declared in block declarations. If no storage class specifier is given in a block declaration, the storage class is set to auto.

Extern

Extern storage is the storage class of objects defined in the external definition context. These objects are defined in one source file, and can be referred to in other source files. The extern keyword is not used with the defining occurrence of an object. In any referring declaration of a data object, the extern keyword must be given. Referring declarations to functions can omit the extern keyword. A declaration containing the extern keyword can appear as an external declaration or as a block declaration.

In the defining source file for an object, the object must be declared with no storage–class specifier in an external definition. In all other source files referring to an external object, the storage class specifier extern must be included in a declaration for the object.

Register

Register variables are automatic or parameter objects which are kept in high–speed workstation registers during the execution of the program. Like automatic storage, register variables are created on entry to a function and destroyed on return. The number of register variables are limited by the hardware. In the BTOS C implementation, two register variables are supported. If you do not provide register keywords in a function, the compiler picks two register variables for you.

Any formal parameter, function prototype or block declaration can include the register storage class specifier. The only limitation in the use of register variables is that they have no workstation address, so the & operator cannot be applied to a register variable. Within this constraint any integer, short, or pointer object can be placed in a register. Depending on the memory model used, only pointers which are two bytes wide can be placed in a register.

In register declarations beyond the first two, or on a declaration of an object that cannot be placed in a register, the register keyword is ignored. If the register keyword is being ignored the declared object has auto storage class.

Static

Static declarations can be given in external definitions or in block declarations. Static objects exist for the duration of a program. The static keyword in an external definition limits the scope of the object so that it can not be referred to in another source file. Static objects declared in a block are known locally to the block containing the declaration.

Typedef

Typedef is not a true storage class. Any identifier declared as a typedef can be used afterward in the source file as a synonym for the type of the declaration. A typedef can occur in external or block declarations.

Only one storage class specifier can be given in a single declaration. Structure or union member declarations cannot have a storage class specifier. External definitions can have extern, static or typedef storage class specifiers. Formal parameter declarations can only have the register storage class. Block declarations can have any of the storage class specifiers.

In general, you can refer to an object only after the object has been declared in a file. In some situations you may prefer or be required to define an object, most often a function, after the first reference to the object. To do this, you must give a forward declaration for the object. This is only allowed for externally defined objects. A forward declaration is simply the declaration of an object occurring early in a source file and followed in the same file by the definition of the object. Both the forward declaration and the subsequent definition can include the static keyword.

Any declaration of a function, except for the function definition itself, is implicitly considered to have the extern storage class, even if the keyword is absent.

Type Specifiers

Basic Arithmetic Types

The seven keywords char, short, int, long, unsigned, float, and double are used to declare the arithmetic data types. These keywords can be given in any order and/or

combinations. You can use the list of combinations and their duplicates as follows:

char	
signed char	(same as char if –K not used)
unsigned char	(same as char if –K is used)
short	
signed short	(same as short)
unsigned short	
short int	(same as short)
unsigned short int	(same as unsigned short)
int	
signed int	(same as int)
unsigned int	
long	
long int	(same as long)
signed long	(same as long)
unsigned long	
unsigned long int	(same as unsigned long)
float	
long float	(same as double)
double	
long double	

Structures and Unions

The word structure in this subsection refers to both stuctures and unions, unless specifically stated otherwise.

Structures are defined by using the following:

- the keyword struct or union
- an optional identifier (the structure or union tag)
- the definitions of each of the members enclosed in curly braces

Structures including a tag identifier in the definition can be referred to in other declarations in the source file, possibly before the structure definition is encountered.

Named structures can be referred to by giving a type specifier of the struct or union keyword followed by only the tag of the structure.

Each distinctly named structure is a distinct type. No two structure definitions in the same scope can have the same tag. In addition, all references to a tag in subsequent

declarations must use the same struct or union keyword used in the original definition.

Unnamed structures are each distinct types, even if two structures have identically defined members.

The members of a structure are defined as a sequence of declarations, each of which can be any previously defined type, except the structure type being declared.

Normally, a member declaration is a normal declaration with a type and a list of one or more declarators, separated by commas. Storage class specifiers and initializers are not allowed in a member declaration.

A structure type can be declared containing only the tag identifier before the tag has been defined. This is only allowed in situations where the size of the structure is not needed. By the time the size is needed, the structure tag must have been defined. Typedefs defining a synonym for the structure, pointers to a structure, or declarations (but not definitions) of functions returning a structure are the allowed declarations of an undefined structure tag. In declaring a function returning a structure, the tag must be defined before the function is called or defined.

A structure or union must not contain itself, but can contain a pointer to itself.

Enumerations

An enumeration can be defined in a manner similar to that of defining a structure. The **enum** keyword is followed by an optional name, then a list of enumerator specifiers separated by commas and enclosed in curly braces.

An enumerator specifier is either a simple identifier, or an identifier followed by an = and a constant expression. For example, the following are valid enumeration definitions:

```
enum day_of_week { sunday, monday, tuesday,
wednesday, thursday, friday, saturday }

enum coins { penny = 1, nickel = 5, dime = 10,
quarter = 25 }
```

The identifiers in enumerator specifiers are defined to be integer valued constants (for all intents and purposes int type objects). BTOS C does not restrict the use of enumerators to objects. In effect, an enumeration is a

method for documenting a related set of constants and could be defined (a little less conveniently) using a preprocessor #define statement.

If no enumerators with = appear, the first identifier is given the value 0 and each subsequent identifier increases in value by 1. An identifier with = is assigned the value of the constant expression and subsequent identifiers continue the progression by 1 from the assigned value.

Void

The only declarations involving the void type specifier allowed are functions returning void and pointers to void. For example, to declare a function f returning void use the following:

```
void        f(...)
            ...
            {
            ...
            }
```

To declare a pointer to void, for example:

```
void        *malloc();
```

Declarators

Declarators are probably the most confusing and least understood aspect of C. Normally when one is discussing C types, one uses an English description like 'array of pointers to functions returning a pointer to a function returning long'. In C, declaring the variable x to this type is:

```
long        (*(*x[ ] )())();
```

This declaration is not at all clear. In fact, it is quite an exercise to figure out which pair of empty parentheses corresponds to which 'function' in the English-form type description.

The simplest form of declarator is an unadorned identifier. In this form, the identifier is declared to be of the type given by the type specifier in the declaration.

There are three basic type declarators which can accompany an identifier. A * and perhaps some pointer type modifiers before an identifier declares a pointer to some type. A possibly empty pair of parentheses possibly preceded by language modifiers after an identifier declares a function returning some type. A pair of square brackets, either empty or containing a constant expression, following an identifier declares an array of some type. Extra parentheses can be used to force grouping of declarators. In the following example, the four lines declare **a** to be an int, a pointer to an int, a function returning int, and an array of 5 integers, respectively:

```
int     a;
int     *a;
int     a();
int     a[5];
```

When more than one type declarator is used in a single declarator, you must use an inside–out reading rule. Beginning with the identifier, read each of the function or array modifiers from left to right. After any such modifiers, then read from right to left the pointer modifiers. Parentheses can be used to group type declarators and force precedence. Always read all the modifiers inside a given set of parentheses before working outside.

In the first example of a declarator, the [ ] are the array and are read first. Then the inner–most * corresponds to the first pointer in the description. So, inside the inner–most parentheses, you have an array of pointers. Then you reach the first (), corresponding to the first function in the description. Then you turn to the first *, which corresponds to the second pointer in the description. At this point you have an array of pointers to functions returning pointers. At last, you read the last (), and at last the type specifier, giving you the full type description in the example.

Pointer Declarators

A declarator beginning with a * optionally followed by pointer type modifiers declares a pointer. The following examples clarify the use of type modifiers.

```
char        *cp;
```

This specifies a pointer to a char (the memory model determines the size).

int * far cp ;

This specifies a far pointer to an integer.

const char *cp ;

This specifies a pointer to a constant char.

long * far const xp ;

This specifies a constant far pointer to a long.

long (* near q) plm () ;

This specifies a near pointer to a plm function returning a long.

int (* near g) far () ;

This specifies a near pointer to a far function returning an int.

Function Declarators

A function declarator is a declarator with a trailing optional set of language modifiers and a pair of possibly empty parentheses.

A function declarator with an empty parenthesis declares a function with no parameter information given. This is the only allowed function declarator.

All other legal function declarators are function prototypes. These are declarators that include information about the function parameters that are used by the compiler to check function calls for validity.

A function declarator with a parenthesis containing the single keyword void indicates a function that takes no arguments at all.

Otherwise, the parenthesis of a function declarator contains a list of parameter types separated by commas. These types can be any type allowed in a function parameter. The type declaration of a parameter can include a declarator. The type can be in the form of a cast and not include an identifier, or an identifier can be included. If an identifier is included it has no effect except to be included in the diagnostic messages when a parameter type mismatch occurs.

A function prototype normally defines a function accepting a fixed number of parameters. For C functions, such as printf, that accept a variable number of parameters a function prototype can end with an ellipsis (...). The fixed initial function parameters are included with their types and, after the last fixed parameter, the prototype is finished with a comma and ellipsis. With this form of prototype, the fixed parameters are checked at compile time and the variable parameters are passed as if no prototype were present.

The following examples should clarify this:

```
int     f();
```

This specifies a function returning an int with no parameter information.

```
int     p(int, long);
```

This specifies a function returning an int that accepts two parameters, the first an int and the second a long.

```
int     q plm(void);
```

This specifies a plm function returning an int that accepts no parameters at all.

```
char    *s far(char *source, int kind);
```

This specifies a far function returning a pointer to a char, and accepting two parameters, the first a pointer to a char and the second an int. The names **source** and **kind** appears in diagnostics if there is a parameter type mismatch.

```
int     printf(char *format, ...);
```

This specifies a function returning an int and accepting a pointer to a char fixed parameter and any number of additional parameters of unknown type.

```
int     (*fp)(int);
```

This specifies a pointer to a function returning an int and accepting a single int parameter.

Array Declarators

An array declarator is a declarator with a trailing pair of square braces, possibly enclosing an integral constant expression. If no expression is given the array has unknown size. Otherwise, the expression is the number of elements in the array.

These examples can help:

```
double      d[5];
```

This specifies an array of five doubles.

```
char        *p[4];
```

This specifies an array of four pointers to chars.

```
int         x[5][6];
```

This specifies a two–dimensional array of five rows and six columns of ints.

```
long        z[ ][7];
```

This specifies a two–dimensional array with an unspecified number of rows and 7 columns of longs. This declaration is only legal if it is given as the declaration of a function parameter (since it is converted to a pointer), or if the declaration includes an extern keyword (since it does not reserve storage), or if an initializer is included in the declaration. In the last case, the unspecified dimension of the array is determined from the number of initializers.

Bitfields

For structures only, not unions, special bit field declarations are allowed. These can be declared to be of int or unsigned int type only. The number of bits in a bit field is given by following the declarator of the field with a colon followed by a constant expression in the range from 1 to 16. Dummy, padding fields, can be defined by giving a type, followed immediately by a colon and a constant expression in the range from 1 to 16.

Unnamed bitfields ensure that the specified number of unused bits are reserved within a word. This is useful for defining externally specified bits in such things as hardware status bytes.

Bitfields are allocated from low–order to high–order bit within a word. Thus the following declarations are allocated as shown:

```
struct      a     {
            int           i : 2;
            unsigned      j : 5;
            int             : 4;
            unsigned      k : 4;
            };
```

```
15   14 13 12 11     10  9  8  7    6 5 4 3 2      1   0
x     x  x  x  x      x  x  x  x    x x x x x      x   x
     <-  k  ->     <-unused->      <-  j  ->      <-i->
```

You can force the next bit fields in a sequence to align to the next word by including a bit field declaration with a width of 0.

Integer fields are stored in two's complement form with the left–most bit being the sign bit. A signed integer bit field 1 bit wide can only hold the values -1 and 0, for example.

Type Names

A declaration with storage class typedef defines a typedef. Subsequent declarations can then use the identifier just declared as a synonym for the original type. For example, the following declarations are legal:

```
typedef struct { double real, imaginary; } complex;

static complex z[5];
```

The effect of a typedef in a declaration is as if you were to substitute the full type of the name into the declaration. In general, there is no difference between using a typedef name and explicitly including the full type in a declaration. The exception is that a structure with no tag in a typedef produces the same type in all uses of the typedef, but the two tag–less structures separately defined are considered distinct types. An example is the complex typedef. All complex objects are of the same type.

Type Equivalence

Two types are equivalent if, after substituting the definitions of all typedefs in the types, they are the same. Named structures, unions or enums are considered the same if the tags are the same. Unnamed structures, unions or enums are the same in two different types only if the structure, union or enum was defined under some typedef common to the expansion of the two original types.

Thus, in the following example, types dog and cat are the same, but bird is not.

```
typedef struct      { int legs; int ears; } body;

typedef body        dog;
typedef body        cat;

typedef struct      { int legs; int ears; } bird;
```

Initialization

An initial value can be given for block defined objects or externally defined objects. After the declarator for a given object, an initializer is represented by an = followed by the initializer. Unions cannot be initialized.

The simplest initializer is a simple expression. When initializing arrays or structures, the initializer can be a list of other initializers enclosed in curly braces and separated by commas. The array elements or structure members are given in increasing element or member order. If an aggregate object contains subaggregates, this rule applies recursively to the members of the aggregate.

Curly braces can be omitted in an initializer if the initializer begins with a left brace. Then the succeeding comma–separated list of initializers initializes the members of the aggregate. If however, the initializer does not begin with a left brace, only as many initializers as needed to fill the aggregate are used, and any extra initializers are used

to initialize the next element of the parent aggregate of which the current aggregate is a part. For example, the following is a completely enclosed initializer:

```
double      z[4][3] = {         3.3 },
                      { 1.5,    2.4,
                      { 7,      5.0,      6.2 },
                      { 45.55, 1e4,       100.0 },
                      } ;
```

Note that in the above example, the list of initializers can have a trailing comma. This comma has no effect but is allowed for convenience in editing tables of initializers.

This initializer can be abbreviated as:

```
double    [4][3] =

    { 1.5, 2.4, 3.3, 7, 5.0, 6.2, 45.55, 1e4, 100.0 } ;
```

Note that the fourth row of the above array is set to zero.

If too few initializers are given to name all the members of an aggregate, the remaining members are set to zero.

Static or global objects must be initialized to arithmetic constant expressions, or to the address of a static or global object or function plus or minus a constant offset. Static initializations are stored at compile and link time into the executable file of the program and are present when the program is started. These values can be subsequently changed during the execution of the program, unless the object being initialized is declared with a const type modifier.

Scalar (automatic or register) objects can be initialized to any valid expression. Auto aggregate objects can be initialized in exactly the same manner as static aggregates. Auto aggregate initializers must be constant, or an address of a static object plus or minus a constant. The initialization occurs at the entry to each block as if an assignment statement were being executed. Auto aggregate initializations are accomplished by making a static image of the initializer and then copying it into the auto on entry to the block. If a block is entered via a goto or a switch statement, the initializers are not executed.

When initializing a scalar object, such as an int or a pointer, a single expression is given, possibly enclosed by curly braces. The initial value of the object is the value of the expression. The same conversions as for assignment are performed.

When an initializer is present in the definition of an array, the size of the array can be omitted. The size is set to the number of elements in the initializer. For example:

```
int     x[ ] = { 1, 3, 7 } ;
```

In this example, x has type array of 3 integers.

When initializing an array of characters you can use a string literal as a shorthand. If the array has a definite size given, the string literal can be up to as long as the array. If the literal is exactly the same length as the array, a null byte is not appended to the end of the array. If the array has no size given, a null byte is appended to the literal and the array size is set to the length of the literal plus one for the null byte. For example:

```
char a[5] = "abcde";          /* array of 5 characters */

char b[ ] = "sample";         /* array of 7 characters */
```

Scope of Identifiers

This implementation is more liberal in allowing non–unique identifiers than Kernighan and Ritchie specify in a *C Programming Language*.

There are four distinct classes of identifiers in this implementation as follows:

1 Variables, typedefs, and enumeration members

  Each member must be unique within the block in which they are defined. Externally declared identifiers must be unique among externally declared variables.

2 Structure, union, and enumeration tags

  Each tag must be unique within the block in which they are defined. Tags declared outside of any function must be unique within all tags defined externally.

3 Structure and union members

Member names must only be unique within the structure or union in which they are defined. There is no restriction on the type or offset of members in different structures with the same identifier.

4 Goto labels

Goto labels must be unique within the function in which they are declared.

For identifiers declared within a block, an externally declared identifier can be redeclared. This new identifier masks the outer definition for the duration of the current block. Similarly, inner blocks can redefine identifiers declared in outer blocks.

Linkage

This implementation follows the external declaration rules of Kernighan and Ritchie. In a multiple file program, each global variable can be declared with the keyword extern in any of the source files, but the global variable can only be declared once without that keyword. The file in which the variable declaration occurs without extern is the file where space is reserved for the variable, and the only place where an initializer can be supplied.

Global variables use the first thirty–two characters of the identifier, just as local variables do (and this length can be changed by the –i command line option). Because the linker does not distinguish between upper– and lowercase, all global variable identifiers have lowercase letters mapped to uppercase. Care should be taken to ensure that identifiers are kept unique.

Expressions

This implementation definitely evaluates subexpressions in an order intended to minimize the number of registers needed. For this reason side effects do not occur in an easily predictable manner except for those operators (comma, && and ||) where the order of evaluation is required by the language definition.

Operators involving side effects (such as assignments) can be evaluated in any order the compiler chooses to produce the most efficient code. The only constraint is that any side

effect is accomplished by the time the expression evaluation is done. Function calls occurring within a parameter to another function call are completed before the outer function call is begun.

Because floating point computations are sensitive to round–off errors, most floating point algorithms need to control the order and grouping of operations. For this reason, floating point operations are carried out as grouped by parentheses and, for expressions without parentheses, by operator precedence, even though the operations can be commutative or associative.

Lvalues

The term lvalue is used to mean any expression which can appear on the left–hand–side of an assignment. Expressions of type array or function are never lvalues.

Simple non–array and non–function identifiers are lvalues. In addition certain operators produce lvalues and other operators require lvalues as operands. In the discussion of specific operators that follows, any requirements with regard to lvalues are specified.

Primary Expressions

A primary expression is the simplest component of an expression in C.

An identifier is a primary expression, provided it has been suitably declared. Any extern, auto, static or register object, formal parameter or enumerator can appear as a primary expression. The type of an identifier is the type given in its declaration, except for functions and arrays. Identifiers of these types are implicitly converted when they are used. An identifier of type function is converted to pointer to function. An identifier of type array of A is converted to type pointer to A. This conversion is performed in all contexts except when the identifier is an operand of a sizeof operator.

A constant is a primary expression. Its type depends on its form as described.

A string is a primary expression. The type of a string is 'array of const char', and except in a sizeof expression is converted to 'pointer to const char'. The value is a pointer to the initial character of the string.

An expression within parentheses is a primary expression. The type is the type of the enclosed expression.

A sizeof keyword followed by a cast is a primary expression. The type is in bytes, of the type named by the cast.

Postfix Operators

The postfix operators are ++, --, function call, subscript, and member-access (. and ->). These operators are evaluated from left to right following the primary expression which acts as the operand of the expression.

Postfix Increment and Decrement Operators

The operand of a postfix increment or decrement (++ or --) operator must have integral or pointer type and must be an lvalue. The value of the expression is the value of the operand.

After that value is extracted, the lvalue is incremented or decremented by 1.

Function Calls

A function call is a primary expression of type function followed by a possibly empty list of assignment expressions, separated by commas and enclosed in parentheses. The list of expressions in parentheses are the actual arguments to the function call. These arguments correspond to the formal arguments declared in the function definition being called. The value of a function call is the value returned by the function. The type of a function call is **a** if the type of the primary expression operand is function returning **a**.

The language modifiers for a function definition must match the modifiers used in the declaration of the function at all calls to the function.

If the primary expression in a function call is an identifier that has not been declared previously, it is implicitly declared as if it had been declared in the innermost block containing the call with the following declaration:

```
extern  int  identifier();
```

Integral arguments to a function call when a function prototype has not been previously declared are converted according to the integral widening rules. Float type arguments are converted to double before being passed. (For more information, refer to Conversions.) When a function prototype is in scope, the argument given is converted to the type of the declared parameter as if by assignment.

When a function prototype includes an ellipsis (...), all function arguments given up to the ellipsis are converted normally and any arguments given beyond the fixed parameters are widened according to the normal rules for function arguments when a prototype is not present.

A function can modify the values of its formal parameters, but this has no effect on the actual arguments supplied, except for interrupt functions. If a pointer is passed as an argument, the object the pointer points to can be changed in all functions.

If the type and number of arguments passed to a function do not match the formal parameters of the function without a function prototype, the results are unpredictable, except that in this implementation extra arguments beyond the formal parameters are ignored. In this implementation, if fewer arguments are supplied than there are formal parameters, there is no harm as long as the unsupplied formal parameters are not actually accessed.

If a prototype is present the number of arguments must match (unless an ellipsis is present in the prototype). The types must be compatible only to the extent that an assignment can legally convert them. An explicit cast can always be used to convert an argument to a type acceptable to a function prototype.

The following example should clarify these points:

```
int             strcmp(char *s1, char *s2);
                        /* Full prototype */
char            *strcpy();
                        /* No prototype */
int             samp1(float, int, ...);
                        /* Full prototype */
samp2()
                {
                char      *sx, *cp;
                double     z;
                long       a;
                float      q;

                if         (strcmp(sx, cp))
                                /*1. Correct */
                           strcpy(sx, cp, 44);
                                /* 2. OK in C, not portable */
                samp1(3, a, q);      /* 3. Correct */
                strcpy(cp);          /* 4. Bad */
                samp1(2);            /* 5. Compile Error */
                }
```

The five calls illustrate different points about function calls as follows.

- In point 1, the use of strcmp exactly matches the prototype and everything is proper.
- In point 2, the call to strcpy has an extra argument (strcpy is defined for two arguments). In this case, BTOS wastes a little time and code pushing an extra argument but there is no syntax error because the compiler has not been told about the arguments to strcpy. A lint compile complains about the extra argument and it is certainly not portable. In fact, if you compile this file using the –p compile option (and recompile the library to be compatible), the extra parameter almost certainly causes the program to crash.
- In point 3, the prototype directs that the first argument to samp1 be converted to a float and the second argument to an int. The compiler warns about possible loss of significant digits because a conversion from long to int chops the upper bits. An explicit cast to int eliminates the warning. The third argument, q, lines up with the ellipsis in the prototype so it is converted to double according to the default rules and the whole call

is correct. Even if a -p compile option is used, this call correctly passes the arguments.

- In point 4, strcpy is again called now with too few arguments. This causes an execution error and knowing how strcpy works it can crash the program. A lint compile uncovers the error, but a normal compile says nothing even though the number of parameters differs from that in a previous call to the same function.
- In point 5, sampl is called with too few arguments. Since sampl requires a minimum of two arguments, this statement is an error and produces a message about too few arguments in a call. This error happens both in lint compiles and in normal compiles.

It should be noted that if any of the prototypes given do not match the function definition, this fact is not known in a normal compile. You must run a lint compile to be sure that what you say a function accepts is really accurate.

PL/M Functions

A function declared with the plm language modifier uses the PL/M calling sequence. This calling convention alters several different aspects of function calling. The order the arguments are pushed onto the stack is reversed from the normal C calling conventions. Also, the registers used to return certain data types (such as pointers) differ from the C convention. Finally, the function itself is responsible for removing the function arguments at return time where the normal C calling convention has the caller remove the arguments. This last point effectively eliminates the possibility of using an ellipsis (i.e. a variable arguments function) in a plm function definition.

Since PL/M does not support register variables, a C function calling a plm function must save the values of the register variables before each call and restore them on each return.

Using the -p compile time option effectively turns all non-variable arguments functions into plm functions with one important exception. As long as a function does not explicitly carry the plm language modifier it uses register variables, even if the -p option is present in the compile.

Interrupt Functions

Interrupt functions normally should be declared to be of type void. An interrupt function is compiled with extra function entry and exit code so that registers AX, BX, CX, DX, SI, DI, ES and DS are preserved. The other registers of BP, SP, SS, CS and IP are preserved as part of the C calling sequence or as part of the interrupt handling itself. A typical definition might be:

```
static      void      handler interrupt()
  {
  ...
  }
```

Interrupt functions can be declared in any memory model. As in the Huge model, DS is set to the program data segment. Note that for Small and Medium Model programs, there is no guarantee that SS is currently set to the program data segment (if the interrupt is connected to a device), since the interrupt could have occurred during the execution of another program or during the execution of BTOS itself.

For this reason, Small and Medium model programs must observe the following restriction when coding functions which are interrupt handlers, or can be called by interrupt handlers. Interrupt handling code in the Small and Medium model can assign the address of a function parameter or automatic variable to a _ss or far pointer only. Most runtime library routines obey this restriction, but notably the printf family of functions do use an array on the stack with unqualified pointers.

Floating point arithmetic can be used by interrupt handlers in all memory models but should not use any 8087 without saving the state of the chip and restoring it on exit from the handler. If the handler is not using inline 8087 instructions, you can force use of the emulation routines by setting _8087 to 0 at entry to the handler, and restoring _8087 to its prior value on leaving the handler.

An interrupt handler routine can be defined with parameters in order to access the registers of the interrupted routine. This is particularly useful for

interrupt services designed to be called via INT instructions. The layout of the parameters are:

```
void        handler interrupt(bp, di, si, ds, es, dx, cx, bx,
                              ax, ip, cs, flags, caller stack)
```

An interrupt function can modify its parameters and changing the declared parameters modify the corresponding register when the interrupt handler returns.

Array Subscripts

A postfix expression followed by an expression enclosed in square brackets is a subscripting expression. The postfix expression preceding the square brackets must be of array or pointer type (since arrays are implicitly cast to pointers the two are equivalent). If the type of the postfix expression operand is 'pointer to A', the type of the result is 'A'.

The expression enclosed in square brackets is converted to type int or long depending on the memory model used to compile the program. If the -ml or -mh command line options are used to compile the file, the expression is converted to long, otherwise to int.

A subscripting expression is an lvalue unless the resulting type is an array.

A subscripting expression E1 [E2] is defined to be equivalent to the expression (* (E1 + E2)). The two forms are freely interchangeable. As a degenerate case E1 [0] is equivalent to (* E1).

The value of the expression E1 [E2] is the E2-th element of the E1 array (counting from zero).

Member Access Operations

An expression followed by a dot (.) or an arrow (->) and an identifier is a postfix expression. The identifier following the dot or arrow must be the name of a structure or union member.

In the case of dot, the operand before the dot should have structure or union type (although any type is accepted) and must be an lvalue. In the case of an arrow, the operand before the arrow should be a pointer to a structure or a union, but can be any pointer type. Proper usage requires

that the member name given be a valid member of the structure given on the left. The value of the expression is the value of the member named. The expression is an lvalue.

If the member name does not belong to the structure on the left (or the left-hand side is not a structure at all), the expression may still be legal. If the named member is unique among all structures defined in the current scope, or if all members of the same name have the same type and structure offset, only a warning is given and the expression is allowed. The left-hand side is implicitly converted to the appropriate structure type. If two or more members of the same name, with different offsets or types, are known then the reference is ambiguous and is an error.

Unary Operators

A postfix expression can be preceded by one or more unary operators. Unary operators are evaluated from right to left.

Prefix Increment and Decrement Operators

The operand of a prefix increment or decrement must have integral or pointer type and must be an lvalue. The value 1 is added to or subtracted from (depending on the operator) the operand. The value of the expression is the value of the operand after the operation.

The ++i is fully equivalent to (i += 1), and --i is equivalent to (i -= 1).

Address and Indirection

The value of the unary & operator is the address of the object that is the operand. Unary & requires an lvalue. A register variable cannot be used with the unary & operator. The type of the result is 'pointer to A' where the type of the operand is 'A'.

Unary & is redundant with objects of type array or function. While these types are not normally lvalues, you can use unary & with objects of these types, but the compiler warns you that the operator is superfluous.

The operand unary *, or indirection operator, must be a pointer. The result is the object pointed to by the pointer.

The expression is an lvalue. If the pointer points to a function the result is an expression that can be used to call the function.

If P is a pointer type, and *A is a valid lvalue, then *(P)A is an lvalue of the type pointed to by P.

Another identity is that if A is an lvalue, *&A is an lvalue equal to A. Similarly, if A has pointer type, &*A is equal to A.

Unary Arithmetic Operators

The unary arithmetic operators are: unary + operator, unary – operator, unary ~ operator, ! operator, and sizeof operator. A description of how they function follows:

- The result of the unary + operator is the value of its operand. The operand must have arithmetic type. The integral widening conversions are performed and the result has the widened type. The compiler does not reorganize expressions across a unary plus. Normally the compiler regroups expressions, rearranging commutative operators such as binary + in an effort to create an efficiently compilable expression. This means that a floating point expression that is sensitive to precision errors or overflow can becontrolled by means of a unary + operator, without having to be split up into separate expressions involving assignments to temporaries.
- The unary – operator produces the arithmetic negative of the operand. The normal arithmetic widening conversions are performed and the result has the widened type. The operand must have arithmetic type. Unary – of an unsigned expression still has unsigned type.
- The unary ~ operator produces the bitwise complement of the operand. The operand must have integral type. The integral widening conversions are applied and the result has the widened type. For signed objects, ~E is equivalent to (–E + 1). For unsigned types, ~E is equivalent to (MAX_UNSIGNED – E) where MAX_UNSIGNED is the maximum unsigned value for the widened type. Its effect is to reverse each 0 bit to 1 and each 1 bit to 0.

- The ! operator is the logical negation operator. If the value of the operand is zero, the result is 1. If the value of the operand is non–zero, the result is 0. The result is always type int.
- The sizeof operator, with a cast following, can be used with any prefix expression following. The result is of type unsigned int and has the value of the size in bytes of the type of the operand. The operand itself, even if it contains a function call or other side effects, does not produce executable code.

Casts

A cast is an abstract type enclosed in parentheses. Casts can appear following a sizeof keyword or can be used as a unary operator to convert the operand expression to the named type. Both the operand and the cast must have scalar type.

In the following example, the usage is an error:

```
sizeof (int) x
```

This is an error because the (int) binds to the sizeof, and the result appears as two consecutive primary expressions, a syntax error.

An abstract type is a type specifier followed by an abstract declarator. The abstract declarator can usually be formed by first writing a normal declarator, then removing the identifier. In the following example, this produces an ambiguous result:

```
int       (i);                  /* declares an int */

( int () )                      /* constructs a function
                                        returning int */
```

must be coded as:

```
( int )
```

In general, if the model declaration is written with a minimum of parentheses, the result obtained by removing the identifier is an abstract type producing the same type as the model.

Binary Operators

The binary operators bind unary expressions or other binary expressions as left and right operands to form binary expressions. The following is a table of the operators and their precedences:

operator	precedence
*	10
/	10
%	10
+	9
-	9
<<	8
>>	8
<	7
>	7
<=	7
>=	7
==	6
!=	6
&	5
^	4
|	3
&&	2
||	1

When there is a choice of binding unary operands to one of two binary operators, the operands bind first to the operator with the highest precedence. If the two operators have equal precedence, the left–hand operator binds first.

Normal Arithmetic Operators

Each of the operands must have an arithmetic type, except for the % operator which must have integral type. The + and – operators also allow pointer types as described. The operands of the +, -, /, * and % operators are converted according to the usual arithmetic conversions as follows:

- The * operator multiplies the two operands and produces the product, with the type of the converted type of the operands.
- The / operator divides the two operands and produces the quotient, with the type of the converted type of the operands.

- The % operator divides the two operands and produces the remainder, with the type of the converted type of the operands.
- The + operator adds the two operands and produces the sum, with the type of the converted type of the operands.

  The + operator can have one, but not both, of the operands be of pointer type. The other operand must be of integral type. The integral operand is multiplied by the size of the object pointed to by the pointer operand and then added to the pointer. The result has the type of the pointer.
- The - operator subtracts the two operands and produces the difference, with the type of the converted type of the operands.

  The - operator can have one or both of the operands be of pointer type. If only one operand is of pointer type the other operand must be of integral type. The integral operand is multiplied by the size of the object pointed to by the pointer operand and then subtracted from the pointer. The result has the type of the pointer.

  If both operands of - are pointers, they must be pointers to the same type. The difference is computed and the result is divided by the size of the object pointed to by the pointers. The result has int or long type depending on the memory model used. If the memory model option given in the compile is -ml or -mh, the result type is long.

Shift Operators

The operands of a shift operator must be of integral type. The normal integral widening rules are applied to the left-hand operand. The right-hand operand is converted to int. The result is the widened type of the left-hand operand.

Shift operators shift the bits of the integral quantity on the left either to the left (<<)or right (>>) by the amount given in the right side operand.

The largest meaningful shift value for an int object, signed or not, is 15. The largest meaningful shift value for a long object, signed or unsigned, is 31.

A left shift zeroes fill on the right side. A right shift zeroes fill on the left if the left operand is unsigned. A right shift of a signed quantity fills from the left with the sign bit.

Negative shift values or values larger than the largest meaningful value produces zero on all left shifts and unsigned right shifts. Signed right shifts set all bits to the value of the sign bit (thus giving a result of -1 or 0).

Relational Operators

The operands can have arithmetic type, or can both be pointers. If one operand is the constant 0, the other can be any kind of pointer. The result is always of type int and has the value of either 0 or 1.

If both operands have arithmetic type, the usual arithmetic conversions are applied.

If two pointers are compared, the result depends on the relative positions of the objects pointed to. The comparison is done as if they were unsigned integers. The only way to guarantee that the comparison of two pointers is meaningful is if they point to the same aggregate object.

Each of the operators < (less than), > (greater than), <= (less than or equal), >= (greater than or equal), == (equal), and != (not equal) produce the value 1 if the relation is true, the value 0 if false.

Bitwise Boolean Operators

The binary & (and), ^ (exclusive–or) and | (inclusive–or) operators perform boolean arithmetic. Both operands must have integral type. The normal arithmetic conversions are applied. The result is the converted type of the operands.

Logical Operators

The && (logical and) and || (logical or) operators are used to do logical testing, where the order of the tests is important. The operands must have scalar type.

If the first operand of && is zero, the result of the operation is 0 (false) and the right–hand operand is not evaluated. If the result of the left–hand operand is non–zero (true) the result is the result of the right–hand operand.

If the first operand of | is non-zero (true), the result of the operation is 1 (true) and the right-hand operand is not evaluated. If the result of the left-hand operand is zero (false) the result is the result of the right-hand operand.

Conditional Expressions

At a lower precedence than any previous operator, the ? : ternary operator allows conditional computation of a value in an expression. A conditional expression is of the form:

test ? true_expression : false_expression

Each of the operands can have any scalar type. If the value is non-zero, the true_expression is evaluated, otherwise the false_expression is evaluated. The true_expression and false_expression have the usual arithmetic conversions applied. The type of the result is the type of the converted expressions. The value is the value of the true or false expression actually evaluated.

Simple Assignment

The basic assignment operator (=) is used to copy a value from one object or expression to a destination object. The left-hand operand must be an lvalue.

The type of the right-hand side is converted to that of the left.

Any arithmetic type can be assigned.

Assignment of a pointer must be to a pointer of the same type. If not, the compiler produces a warning message. Assigning a long quantity to an integer variable produces a warning message about possible loss of significant digits. On some computers integer quantities are the same size as long quantities and when moving code from such a workstation to an 8086, this can be a cause for error.

Structures and unions can be assigned. The structures or unions being assigned must have the same type.

The type of the result is the type of the left-hand side, and the value is the value of the right-hand side converted to the type of the left.

Compound Assignment

The compound assignments correspond to the binary operators as follows:

*	*=
/	/=
%	%=
+	+
-	-=
&	&=
^=	^
|	|=
<<	<<=
>>	>>=

An expression of the form A op= B is equivalent to (A = A op (B)), except that any side effects caused by operators in A are performed only once.

The types allowed are the same as those allowed for the binary operators. In addition, for += and -= only, the left–hand side can be a pointer. In this case, the right–hand side must have integral type.

Comma Operator

At the lowest precedence of all operators, the comma operator can be used to connect two other expressions. It is guaranteed that the left–hand operand is executed first, followed by the right–hand operand. The result value and type is that of the right–hand operand.

In function call arguments a comma operator must be enclosed in parentheses to distinguish it from an argument separator. For example:

f(i, (t = 2, t - 5), c);

This call passes three arguments, the second with the value -3.

Constant Expressions

Any expression exclusively involving constant operands and/or sizeof operators are evaluated at compile time. A function call, ++, --, unary *, array subscripting, member access (. and –>), the unary & or any assignment operator cannot appearin a constant expression.

Integral constant expressions cannot include floating point constants, unless the expression is explicitly cast to an integral type.

Preprocessor directives involving constant expressions cannot include the sizeof operator, any casts nor any floating point constants.

Conversions

Conversion can be caused explicitly by means of a cast, or implicitly as part of some operator. Some conversions do not affect the actual bit value of the object being converted, such as converting from signed int to unsigned int. Other conversions, such as from double to float cause a transformation of the data.

Integral Widening Conversions

When converting a type according to the integral widening rules, the following conversions are performed.

If the starting type is char, signed char, unsigned char, short or any enumerated type, it is converted to int. Signed char type data is sign extended to int size. Char type are signed extended if the –K option is not used, otherwise it is zero filled. Unsigned char type is always zero filled.

If the starting type is unsigned short, it is converted to unsigned int.

Usual Arithmetic Conversions

When performing the usual arithmetic conversions, two types are present. Before matching up the two types each type is individually widened according to the following rules:

If the starting type is char, signed char, unsigned char, short or an enumerated type, it is converted to int. Char and signed char type data is sign extended to int size.

Note that if the –K option is selected, converting char type to int does not sign extend, instead they zero–fill.

If the starting type is unsigned short it is converted to unsigned int.

If the starting type is float, is converted to double.

Once these conversions are performed, the following conversions are performed (the order of the two types in the operands is unimportant):

- If either operand is of type long double, the other operand is converted to long double
- otherwise, if either operand is of type double, the other operand is converted to double
- otherwise, if either operand is of type unsigned long, the other operand is converted to unsigned long
- otherwise, if either operand is of type long, the other operand is converted to long
- otherwise, if either operand is of type unsigned, the other operand is converted to unsigned
- otherwise both operands are of type int

Other types

Pointers to functions and pointers to data cannot be meaningfully converted to one another. Pointers to data type can be freely converted from one to another. There are no alignment restrictions on the 8086 family of processors. On an 8086 word accesses on an odd address boundary are somewhat slower, but work correctly. On an 8088, word accesses are always the same speed regardless of alignment. The compiler makes no attempt to align data. Structures, in particular, are not padded after an odd number of bytes. If alignment is desired, the programmer should take care to declare structures appropriately or use the –a option.

Enumeration data is implicitly converted to or from int as used. Enumerators are equivalent to integers in all respects.

Statements

Statements are the executable instructions of a program. Each statement is executed in order within a statement list unless directed to otherwise by control–flow statements.

Labeled Statements

identifier :
case constant_expression :
default :

Any statement can be preceded by an identifier and a colon, declaring the identifier to be a statement label. This identifier can only be used as a target of a goto statement. The identifier can be used in a goto anywhere in the function where the label is defined.

Inside switch statements, only, you can supply case and/or default labels. A case label begins with the case keyword, is followed by an integral constant expression and a colon. A default label consists of the default keyword followed by a colon.

Blocks

{ declarations statements }

A block (or compound statement) allows you to group a statement list into a single unit. Each block can also have its own set of declarations. All of the declarations of a block must precede any of the statements in the block.

Objects declared with automatic storage and initialized are created and initialized on each entry to the block.

Expression Statement

expression ;

An expression statement is simply an expression followed by a semicolon. This expression is evaluated for its side effects (assignments and function calls).

Null Statement

A null statement is simply a semicolon with no expression before or after it. It is most commonly used as the body of an iteration statement. A null statement does nothing.

Alternation Statements

if (expression) statement

if (expression) statement
else statement

switch (expression) statement

The expression controlling an if statement must have scalar type. An else is associated with the nearest previous else–less **if** statement that is in the same block and not any enclosing block.

The expression controlling a switch statement must have integral type and is converted to int. The switch body statement is normally a block. Control is transferred to the case label matching the value of the switch control expression. If no case label matches, control transfers to any default label supplied. If no default label is present, control passes to the next statement after a switch.

Initializers in auto declarations in a block that is a switch body have no effect since they occur before any case labels.

Iteration Statements

while (expression) statement

do statement

while (expression) ;

for (expr1 ; expr2 ; expr3) statement

In a while statement the controlling expression is evaluated, and if non–zero, the statement body is executed. The controlling expression is then evaluated again and this is repeated until the controlling expression evaluates to zero. If the controlling expression is zero on the first evaluation, the loop body is not executed. The type of the controlling expression must have scalar type.

In a do statement the loop body statement is executed, then the controlling expression is evaluated, and if non–zero, the statement body is repeated. This is repeated until the controlling expression evaluates to zero. The loop body is always executed at least once. The type of the controlling expression must have scalar type.

In a for statement, expr1 is evaluated once. This is the initialization expression. Then expr2 is evaluated as a loop control expression. If non-zero, the loop body statement is executed. Then expr3 is executed (the increment part). The control test expr2 is then re-evaluated and the loop repeated until expr2 has value 0.

Expr1 and expr3 can have any type, including void. Expr2 must have scalar type.

Any of the three expressions can be omitted. If expr1 or expr3 is omitted, nothing is done at that point in the loop. If expr2 is omitted, there is no test performed and the loop continues forever, unless some method is used to explicitly exit the loop, such as a break or return.

A for loop is equivalent to the following sequence involving a while loop:

```
expr1;
while       (expr2){
            statement;

            expr3;
            }
```

A for loop differs from this construct in that expr2 is allowed to be null, where a while statement must have some expression. Second, a continue statement within the loop body transfers control to expr3 in a for loop, but to expr2 in a while loop.

Jump Statements

The jump statements are as follows:

- goto identifier ;

  A goto statement immediately transfers control to the label given by identifier. The label must be within the same function as the goto statement.

- break ;

  A break statement can only occur inside a switch, while, do or for statement. The statement causes control to immediately transfer to the statement following the inner-most enclosing switch, while, do or for statement.

- continue ;

  A continue statement can only occur inside a while, do or for loop statement. Control is immediately transferred to the controlling expression in a do or while statement, and to the increment expression of a for loop.

- return ;

  A return statement causes the current function to immediately return to the caller. If control reaches the closing curly brace of a function, an equivalent of a return statement is executed with no return value.

- return expression ;

  A return statement can include an expression. The value of that expression is converted to the type of the function and the value becomes the value of the function call in the calling point of the program.

  If a return with no expression is executed and the call to the function expects a value to be returned, the results are undefined.

Inline Assembly Statements

The two inline assembly statements are as follows:

asm char_sequence newline
asm char_sequence ;

The BTOS C Compiler supports the use of inline assembly language. An inline assembly language statement is introduced with the keyword asm. From the asm keyword to either the end of the current source line or a semicolon is treated as a single assembly statement. Assembly statements cannot be continued across more than a single line. The statement is passed through unmodified to the assembly output file. Assembly statements count as a statement when used with if or while. For example:

```
int       i;
register int      x;

if        (i > 0)
           asm        mov        x,4

else
           i = 7;
```

This construct is a valid C if statement. Asm statements are the only statements in C which depend upon the occurrence of an end-of-line. This is admittedly not in keeping with the rest of the language, but this is the convention adopted by most C compilers.

Assembly statements can be used as an executable statement inside a function, or as an external declaration outside a function. When used outside a function, the assembly statements are inserted in the data segment portion of the program, while assembly statements inside a function are inserted in the code segment.

Variables can be referred to by name if the programmer uses the following conventions.

Using Inline Assembly Language

C is very good for most tasks, but for some things on the 8086, assembly language is necessary. Rather than force the programmer to create a completely separate assembly language module, BTOS C allows the programmer to intermix assembly language statements in the C source. Also, with these statements you can use C symbols, including structure offsets.

The inline assembly facility of the compiler is intended for the programmer who has some experience with assembly language programming, especially the 8086 BTOS Assembler. How to include assembly language programming in C source programs follows.

An inline assembly statement consists of the asm keyword followed by white space, followed by an opcode, followed by white space, then the instruction operands, if any.

The instructions are copied to the output, substituting any C symbols with appropriate assembly language equivalents. The inline assembly facility is not a complete assembler so many errors are not immediately detected. The -S option and the assembler must be used to compile programs with inline assembly language. Any errors are caught by the assembler. The assembler is not very good at identifying the location of errors, since the original C source line number is lost.

Inline assembly statements located outside any function are placed in the DATA segment, and assembly statements located inside functions are placed in the CODE segment.

Instruction Opcodes

Any of the 8086 instruction opcodes can be included as inline assembly statements. There are four classes of instructions allowed by the BTOS C Compiler: normal instructions, string instructions, jump instructions and assembly directives. Regardless of instruction type, operands are allowed by the compiler, even if they are erroneous or disallowed by the assembler. The exact format of the operands is not enforced by the compiler.

The following is a summary list of the opcodes which can be used as normal instructions:

aaa	aam	aas	adc	add
and	arpl	bound	call	cbw
clc	cld	cli	cmc	cmp
cts	cwd	daa	das	dec
div	enter	f2xm1	fabs	fad
faddp	fbld	fbstp	fchs	fclex
fcom	fcomp	fcompp	fdecstp	fdisi
fdiv	fdivp	fdivr	fdivrp	feni
ffree	fiadd	ficom	ficomp	fidiv
fidivr	fist	fimul	fincstp	finit
fild	fistp	fisub	fisubr	fld
fld1	fldcw	fldenv	fldl2e	fldl2t
fldig2	fldln2	fldpi	flde	fmul
fmulp	fnclex	fndisi	fneni	fninit
fnop	fnsave	fnstcw	fnstenv	fmstsw
fpatan	fprem	fptan	frndint	frstor
fsave	fscale	fsqrt	fst	fstcw
fstenv	fstp	fstsw	fsub	fsubp
fsubr	fsubrp	ftst	fwait	fxam
fxch	fxtract	fyl2x	fyl2xp1	hlt
idiv	imul	in	inc	ins
int	into	iret	lahf	lar
lds	lea	leave	les	lgdt
lidt	lldt	lmsw	lsl	ltr
mov	mul	neg	not	or
out	outs	pop	popa	popf
push	pusha	pushf	rcl	rcr
ret	rol	ror	sahf	sal
sar	sbb	sgdt	shl	shr
sidt	sldt	smsw	stc	std
sti	str	sub	test	verr
verw	wait	xchg	xlat	xor

Note that the assembler does not support 8087, 80286, or 80386 instruction mnemonics.

In addition to the opcodes the following string instructions can be used alone or with repeat prefixes:

cmps	cmpsb	cmpsw	lods	lods
lodsw	movs	movsb	movsw	bscas
scasb	scasw	stos	stosb	stosw

The following repeat prefixes can be used:

rep	repe	repne	repnz	repz

Jump instructions are treated specially. Since a label cannot be included on the instruction itself, jumps must go to C labels. The allowed jump instructions are:

ja	jae	jb	jbe	jc
jcxz	je	jg	jge	jl
jle	jmp	jna	jnae	jnb
jnbe	jnc	jne	jng	jnge
jnl	jnle	jno	jnp	jns
jnz	jo	jp	jpe	jpo
js	jz	loop	loope	loopne
loopnz	loopz			

The following assembly directives are allowed in inline assembly statements:

db	dd	dw	extrn

Inline Assembler References to Data and Functions

C symbols can be used in inline assembly code and are automatically converted to appropriate assembly language operands. Any symbol can be used, including automatic variables, register variables and function parameters. In general, a C symbol can be used in any position where an address operand would be legal. A register variable can be used wherever a register would be a legal operand.

If an identifier is encountered in parsing the operands of an inline assembly instruction, the identifier is searched for in the C symbol table. The names of the 8086 registers are excluded from this search. Either upper- or lowercase forms of the register names can be used.

The first two register declarations in a function are treated as register variables and all subsequent register declarations are treated as automatic variables. If the register keyword occurs in a declaration which cannot be a register, the keyword is ignored. Only short, integer (or the corresponding unsigned types) or 2–byte pointer variables can be placed in a register. SI and DI are the 8086 registers used for register variables. Inline assembly code can freely use SI or DI as scratch registers if no register declarations are given in the function. The C function entry and exit code automatically saves and restores the caller of the SI and DI. If there is a register declaration in a function, inline assembly can use or change the value of the register variable by using SI or DI, but the preferred method is to use the C symbol in case the internal implementation of register variables ever changes.

The BP register is used in C functions as a base address for arguments and automatic variables. Parameters have positive offsets which vary depending on the memory model and the number of registers saved on function entry. BP always points to the saved previous BP value. Functions that have no parameters and declare no arguments do not use or save BP at all.

Automatic variables are given negative offsets from BP, with the first automatic variables having the smallest magnitude negative offset and subsequent variables given increasing magnitude offsets.

For example, a function with the following automatic declarations at the beginning of the function would generate the corresponding offsets:

int	i;	BP–02
long	il;	BP–06
char	c[5];	BP–11
short	*p;	BP–13

Note that if the –a flag is present in the command line for compiling the above declarations, the pointer p is given an offset of BP–14, leaving one unused byte.

A programmer need not be concerned with the exact offsets of local variables, however. Simply using the name includes the correct offsets.

It can be necessary to include appropriate WORD PTR, BYTE PTR or other size overrides on assembly instruction. These overrides are often needed when using static or global C symbols (since the compiler defines all static and global variables as BYTE objects). A DWORD PTR override is needed on LES or indirect far call instructions.

Using C Structure Members

Any member of any C structure can be used in an inline assembly statement (assuming the reference is in the scope of the declaration). The member name can be used in any position where a numeric constant is allowed in an assembly statement operand. The structure member must be preceded by a dot (.) to signal that a member name is being used and not a normal C symbol.

Thus:

```
                        {
struct          a       a_b;
                int     a_c;
                int
                ...
                } ;

subroutine      ()
                {
                ...     mov     ax,[di].a_c
                asm
                ...
                }
```

In the above sequence, the assembler statement would be the equivalent of the following:

```
asm     mov     ax,2[di]
```

Member names are replaced in the assembly output by the numeric offset of the structure member, but no type information is retained. Thus members can be used indiscriminately as compile time constants in assembly statements.

Using Jump Instructions and Labels

Any of the conditional and unconditional jump instructions, plus the loop instructions, can be used in inline assembly. They are only valid inside a function. Since no labels can be given in the asm statements, jump instructions must use C goto labels as the object of the jump. Direct far jumps cannot be generated.

Indirect jumps are also allowed. To use an indirect jump, use either a register name as the operand of the jump instruction or else include an operand defining the address to jump to inside square brackets.

Thus in the following code the first jump goes to the C goto label a. The second jump goes to the address contained in the integer a.

```
int             x()
        {
        int     a;

        ...

        a:
        ...

        asm     jmp     a
        asm     jmp     [a]

        ...
        }
```

Comments on Inline Assembly Statements

Assembly style comments cannot be used. When commenting inline assembly statements, you should use C style comments. Assembly style comments begin with a semicolon and continue to the end of the current line. Using this convention can cause the compiler to become confused, since it tries to interpret the comments as Assembly language operands.

External Definitions

External definitions are the function and data definitions described.

Function Definitions

An old style function definition consists of a function declaration, which is like any other declaration producing type 'function returning A', except that instead of empty parentheses to denote the function, the parentheses contain the names of any formal parameters, listed separated by commas. After the function declaration, an optional set of declarations can be given for the formal parameters. After the formal parameter declarations, the function body is given.

In an old style function definition, a typedef name cannot be given as a parameter name. If the compiler encounters a typedef name in the parameter list it assumes that the name is a type and begins some form of function prototype.

A formal parameter declaration can only include a register storage class specifier. A formal parameter can be declared to have any type, except void and function. Formal parameters declared to be array of A are converted to pointer to A. Sizeof reports the correct size of all formal parameter types, except array declarations converted to pointer. These return sizeof as the sizeof a pointer.

A formal parameter declared to be float is converted on function entry, since the normal widening rules of function arguments require that arguments of type float must be passed as double. A float formal argument is converted from double to float on function entry.

A formal parameter with no declaration is implicitly declared to have type int.

As an alternative to the Kernighan and Ritchie syntax, a function can be defined using the function prototype syntax. In this case, the list of types given with the function declarator being defined must be accompanied by the parameter name identifiers. The parameter name identifiers are treated exactly like those of the old style function definition.

The normal widening rules for function parameters apply for most types. However, for float type parameters defined using the new syntax the parameter passes as a float and takes up less room on the stack. Note that when you define a function using the new syntax, you should also declare it using a prototype wherever the function is called. Float types are the only types affected by this new syntax now.

In general, if all types in the prototype definition are widened (that is, there are no char, short or float types, either signed or unsigned), then the function can be called without a prototype being in scope of the call.

The function body is a block containing the executable code of the function.

Data Definitions

There must be one data definition for each object declared with storage class specifier extern. This definition must be given without the extern keyword.

If no initializer is given for a data object it is initialized to zero.

Portability Considerations

This implementation supports two 16–bit register variables, with excess register declarations ignored.

The size of each basic type is as follows:

char, unsigned char, signed char	1 byte
short, unsigned short	2 bytes
int, unsigned	2 bytes
long, unsigned long	4 bytes
float	4 bytes
double, long float	8 bytes
far pointer	4 bytes
near pointer	2 bytes
enumerated data	2 bytes

Obsolete Syntax

The obsolete syntax described in Kernighan and Ritchie is not supported.

Appendix A

Diagnostic Messages

This appendix describes the diagnostic messages that you may encounter while compiling or executing your C program. Also refer to the *BTOS II Systems Status Codes Reference Manual* for operating system and other errors.

C Compiler diagnostic messages fall into three classes: Fatal, Error and Warning Messages.

Fatal errors typically involve bad file names, disk write errors or the compiler running out of core memory. A fatal error may also indicate a compiler error of some sort. When a fatal error occurs, compilation immediately stops. Appropriate action must be taken and then compilation may be restarted.

Errors will indicate some sort of syntax or semantic error in the source program. The compiler will complete the current phase of the compilation and then stop. An attempt is made to find as many real errors in the source program as possible during each phase.

Warnings do not prevent the compilation from finishing. They indicate conditions which are suspicious, but which are legitimate as part of the language. Also, use of obsolete syntax or machine–dependent constructs will generate warnings.

Messages are printed by the compiler with the message class first, then the source file name and line number where the condition was detected, and finally the text of the message itself. In this appendix, messages are presented alphabetically within message classes. With each message a probable cause and remedy are provided.

Messages are only generated as they are detected. Because C does not force any restrictions on placing statements on a line of text, the true cause of the error may be one or more lines before the line number mentioned. In the following message list, the messages which often are displayed on lines after the real cause are indicated.

Fatal Messages

Error directive: XXXX

This message is issued when a #error directive is processed in the source file. The text of the directive is displayed in the message.

Error writing assembler file

This indicates some sort of system error writing the assembler output file. Most often this indicates a full disk or diskette.

Error writing lint file

This error occurs most often when the work disk is full. It could also indicate a faulty diskette. If the diskette is full, try deleting unneeded files and restart the compilation.

Error writing output file

This error most often occurs when the work disk is full. It could also indicate a faulty diskette. If the diskette is full, try deleting unneeded files and restart the compilation.

Expression table full

An extremely complicated expression was parsed. You should break the statement up into multiple expressions. A total of 1000 expression tree nodes are allocated. (As reference, a function call with two simple arguments takes about 7 nodes).

Identifier table full

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re-execute the compile in a partition with more memory (at least 250 Kb).

Incorrect command line arguments

This error occurs if CCOMPILER is executed with incorrect command line arguments.

Inline assembly cannot generate object code

This error occurs only in generating object files. It is generated when an inline assembly language statement is encountered. The object file generator currently does not have the facilities to translate assembly language statements.

Irreducible expression tree

This is a sign of some form of compiler error. Some expression on the indicated line of the source file has caused the code generator to be unable to generate code. The offending expression should be avoided. Consult Unisys Customer Support if this error is ever encountered.

Lint file bad format

The lint file being read contains some bad information. Either the file is not really a lint file or the file was somehow corrupted.

Must have one filename

A source file was not specified in the CCOMPILER command form. Re-execute the compile, specifying a source file to be compiled.

Out of Memory

This error occurs when the total working storage has been exhausted. You should try compiling this program on a workstation with more memory.

Pass did not finish properly

This error indicates that some pass either was not run for the named file or it encountered errors.

Register allocation failure

This is a sign of some form of compiler error. Some expression on the indicated line of the source file was too complicated for the code generator to be able to generate code for it. Simplify the offending expression, and if this fails, avoid it. Contact Unisys Customer Support if you encounter this error.

Too many goto labels

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re-execute the compile in a partition with more memory (at least 250 Kb).

Too many members of structures/unions

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re-execute the compile in a partition with more memory (at least 250 Kb).

Too many structure/union tags

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re–execute the compile in a partition with more memory (at least 250 Kb).

Too many variables

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re–execute the compile in a partition with more memory (at least 250 Kb).

Type table full

The compiler needs more memory to complete the compilation. Either modify the source file to reduce the number of symbols that caused this message, or re–execute the compile in a partition with more memory (at least 250 Kb).

Unable to create assembler file 'XXXXXXXXX.XXX'

This is probably caused by a full disk or diskette directory, or else the named assembler file already exists with the read–only bit set on.

Unable to create output 'XXXXXXXXX.XXX'

This error occurs if the work directory is full. If the directory is full, delete unneeded files and restart the compilation.

Unable to create temp file 'XXXXXXXXX.XXX'

This error occurs if the work directory is full. If the directory is full, delete unneeded files and restart the compilation.

Unable to open lint file 'XXXXXXXX.XXX'

This error occurs if the work directory is full. If the directory is full, delete unneeded files and restart the compilation.

Unable to open source file 'XXXXXXXXX.XXX'

This error occurs if the source file cannot be found. Check the spelling of the name and whether the file is in the proper directory.

unexpected end of file in intermediate file

A format problem was detected in the intermediate file written by the parser. Try re–executing the compile to recreate the intermediate file. If the problem persists, notify Unisys Customer Support.

Error Messages

 # operator not followed by macro argument name

In a macro definition, the # may be used to indicate 'string–izing' a macro argument. The # must be followed by a macro argument name.

'XXXXXXXX' not an argument

The named identifier was declared as a function argument but was not in the function argument list.

Ambiguous symbol 'XXXXXXXX'

The named structure field occurs in more than one structure with different offsets and/or types. The variable or expression used to refer to the field is not a structure containing the field. Cast the structure to the correct type, or correct the field name if it is wrong.

Argument ## in call to 'XXXXXXXX' has wrong type

The argument given by number (argument 1 is the left–most in the call) disagrees with the type declared in the function. The source filename and line number given in the diagnostic is the location of the call.

Argument list syntax error

An argument was followed by a character other than comma or right parenthesis. Arguments to a function call must be separated by spaces and closed with a right parenthesis.

Array bounds missing]

An array was declared in which the array bounds were not terminated by a right bracket.

Array size too large

The declared array would be too large to fit in the available memory of the processor.

Assembler statement too long

Inline assembly statements may not be longer than 512 bytes.

Bad filename format in include statement

#Include filenames must be surrounded by quotes or angle brackets. The filename was missing the opening quote or angle bracket.

Bad ifdef statement syntax

An #ifdef statement must contain a single identifier and nothing else as the body of the statement.

Bad ifndef statement syntax

An #ifndef statement must contain a single identifier and nothing else as the body of the statement.

Bad undef statement syntax

An #undef statement must contain a single identifier and nothing else as the body of the statement.

Bit field size syntax

A bit field must be defined by a constant expression between 1 and 16 bits in width.

Call of non-function

The function being called is declared as a non-function. This is commonly caused by incorrectly declaring the function or misspelling the function name.

Call to undefined function 'XXXXXXXX'

The named function has no declaration in the files.

Case outside of switch

A case statement was encountered outside a switch statement. This is often caused by mismatched curly braces.

Case statement missing :

A case statement must have a constant expression followed by a colon. The expression in the case statement was either missing a colon or had some extra symbol before the colon.

Cast syntax error

A cast contains some incorrect symbol.

Character constant too long

Character constants may only be one or two characters long.

Compound statement missing }

The end of the source file was reached and no closing brace was found. This is most commonly caused by mismatched braces.

Conflicting type modifiers

This occurs when a declaration is given that includes, for example, both near and far keywords on the same pointer. Only one addressing modifier may be given for a single pointer, and only one language modifier may be given on a function.

Constant expression required

Arrays must be declared with constant size. This error is commonly caused by misspelling a define constant.

Declaration missing ;

A struct or union field declaration was not followed by a semi–colon.

Declaration needs type or storage class

A declaration must include at least a type or a storage class. This means a statement like the following is not legal:

```
i[ ] = { 4, 5, 6 } ;
```

Declaration syntax error

A declaration was missing some symbol or had an extra symbol added to it.

Default outside of switch

A default statement was encountered outside a switch statement. This is most commonly caused by mismatched curly braces.

Define statement needs an identifier

The first non–white space characters after a #define must be an identifier. A different character was found.

Division by zero

A divide or remainder in an #if statement has a zero divisor.

Do statement must have while

The closing while keyword was missing from a do statement.

Do–while statement missing (

No left parenthesis was found after the while keyword in a do statement.

Do–while statement missing)

No right parenthesis was found after the test expression in a do statement.

Do–while statement missing ;

No semi–colon was found after the closing parenthesis in a do statement test expression.

Duplicate case

Each case of a switch statement must have a unique constant expression value.

Duplicate declaration of 'XXXXXXXX'

The named global variable is declared in more than one source file. The source filename given in the diagnostic is the source file of the second declaration found.

Duplicate declaration of function 'XXXXXXXX', also in 'XXXXXXXX.XXX'

The named function is declared in more than one file. The two source filenames are given in the diagnostic.

Duplicate definition of 'XXXXXXXX'

The #define statement is for an already defined identifier. The new definition supercedes the old.

Enum syntax error

An enum declaration did not contain a properly formed list of identifiers.

Enumeration constant syntax error

The expression given for a enumerator value was not a constant.

Expression syntax

This is a general error message that appears when an expression is being parsed and some serious error was encountered. This is most commonly caused by two consecutive operators, mismatched or missing parentheses, or a missing semi–colon on the previous statement.

Expression syntax error in #elif statement

The expression in an #elif statement is badly formed: a mismatched parenthesis, extra or missing operator, or missing or extra constant.

Expression syntax error in #if statement

The expression in an #if statement is badly formed due to a mismatched parenthesis, extra or missing operator, or missing or extra constant.

External declaration type mismatch for 'XXXXXXXX'

The external declaration on the given line of the named source file disagrees with the declaration of the global variable.

Extra parameter in call

A call to a function via a pointer defined with a prototype had too many arguments given.

Extra parameter in call to XXXXXXXX

A call to the named function (which was defined with a prototype) had too many arguments given in the call.

For statement missing (

No left parenthesis was found after the For keyword in a For statement.

For statement missing)

No right parenthesis was found after the control expressions in a For statement.

For statement missing ;

No semi–colon was found after one of the expressions in a For statement.

Function 'XXXXXXXX' undefined

The named function is called or referred to and no definition for the function was found in the files being checked.

Function 'XXXXXXXX' return value declared inconsistently

The named function has been declared to return some type in the calling file (indicated by the source filename and line number) different from that declared with the function itself. This is often caused by neglecting to declare external functions which return non–integer values, such as the math functions.

Function call missing)

The function call argument list had some sort of syntax error such as a missing or mismatched closing parenthesis.

Function declarator missing left parenthesis

A function declaration had a language modifier, but not left parenthesis.

Function definition out of place

A function definition may not be placed inside another function. Any declaration inside a function that looks like the beginning of a function with an argument list is considered a function definition.

Function doesn't take a variable number of arguments

The va_start macro was used inside a function that does not accept a variable number of arguments.

Goto statement missing label

The goto keyword must be followed by an identifier.

If statement missing (

No left parenthesis was found after the if keyword in an if statement.

If statement missing)

No right parenthesis was found after the test expression in an if statement.

Illegal character 'C' (0xXX)

Some invalid character was encountered in the input file. The octal value of the offending character is printed.

Illegal character in constant expression 'X'

Some character not allowed in a constant expression was encountered. If a letter is the character, this indicates a probably misspelled identifier.

Illegal initialization

Initializations must be either constant expressions, or else the address of a global, external or static variable plus or minus a constant.

Illegal octal constant

An octal constant was found containing a digit of 8 or 9.

Illegal pointer subtraction

This is caused by attempting to subtract a pointer from a non–pointer.

Illegal storage class

Register or auto was used in a declaration outside a function. Or typedef, extern, auto or static was used in a function argument declaration.

Illegal structure operation

Structures may only be used with dot (.), address–of (&) or assignment (=) operators, or be passed to or from a function. A structure was encountered being used with some other operator.

Illegal use of floating point

Floating point operands are not allowed in shift, bitwise boolean, conditional (? :), indirection or certain other operators. A floating point operand was found with one of these prohibited operators.

Illegal use of pointer

Pointers may only be used with addition, subtraction, assignment, comparison, indirection or arrow (–>) operators. A pointer was used with some other operator.

Improper use of a typedef symbol

A typedef symbol was used where a variable should appear in an expression. Check for the declaration of the symbol and possible misspellings.

Incompatible storage class

The extern keyword was used on a function definition. Only static or no storage class at all is allowed.

Incompatible type conversion

An attempt was made to convert one type to another which were not convertible. These include converting a function to or from a non–function, converting a structure or array to or from a scalar type, or converting a floating point value to or from a pointer type.

Incorrect macro call of 'XXXXXXXX'

The named #define macro was used without a left parenthesis immediately following. Only white space may occur between a macro name and its arguments, and the arguments must be given with every call.

Incorrect number format

A decimal point was encountered in a hexadecimal number.

Incorrect use of default

No colon was found after the default keyword.

Initializer syntax error

An initializer has a missing or extra operator, mismatched parenthesis, or is otherwise malformed.

Invalid indirection

The indirection operator (*) requires a pointer as the operand.

Invalid macro argument separator

In a macro definition arguments must be separated by commas. Some other character was encountered after an argument name.

Invalid pointer addition

An attempt was made to add two pointers together.

Invalid use of arrow

An identifier must immediately follow an arrow operator (->).

Invalid use of dot

An identifier must immediately follow a dot operator (.).

Left side must be an address

The left hand side of an assignment operator must be an addressable expression. These include numeric or pointer variables, structure field references or indirection through a pointer, or a subscripted array element.

Macro argument syntax error

An argument in a macro definition must be an identifier. Some non-identifier character was encountered where an argument was expected.

Macro expansion too long

A macro may not expand to more than 4096 characters. This error often occurs if a macro recursively expands itself. A macro cannot legally expand to itself.

'main' needs 2 arguments: argc and argv

The function main is allowed to be declared in two ways; with no parameters at all, or with argc and argv. The following is a sample declaration of main using the parameters:

```
main(argc, argv)
int          argc ;
char         *argv[ ] ;
{
...
}
```

The two parameters do not have to be named argc and argv, but their types must match.

Misplaced break

A break statement was encountered outside a switch or looping construct.

Misplaced continue

A continue statement was encountered outside a switch or looping construct.

Misplaced decimal point

A decimal point was encountered in a floating point constant as part of the exponent.

Misplaced elif statement

An #elif directive was encountered without any matching #if, #ifdef or #ifndef directive.

Misplaced else

An else statement was encountered without a matching if statement. This could be caused by an extra semi–colon, missing curly braces, or some syntax error in a previous if statement that is not just an extra else.

Misplaced else statement

An #else directive was encountered without any matching #if, #ifdef or #ifndef directive.

Misplaced endif statement

An #endif directive was encountered without any matching #if, #ifdef or #ifndef directive.

Must take address of memory location

The address–of operator (&) was used with an expression which cannot be used that way, for example a register variable.

No filename ending

The filename in an include statement was missing the correct closing quote or angle bracket.

Non–portable pointer assignment

An assignment was made of a pointer to a non–pointer, or vice versa. An assignment of a constant zero to a pointer is allowed as a special case. A cast should be used to suppress this warning if the assignment is proper.

Non–portable pointer comparison

A comparison was made between a pointer and a non–pointer other than the constant zero. A cast should be used to suppress this warning if the comparison is proper.

Non–portable return type conversion

The expression in a return statement was not the same type as the function declaration. This is only triggered if the function or the return expression is a pointer. The exception to this is that a function returning a pointer may return a constant zero. The zero will be converted to an appropriate pointer value.

Not an allowed type

Some sort of forbidden type was declared, for example a function returning a function or array.

Redeclaration of 'XXXXXXXX'

The named identifier was previous declared.

Size of structure or array not known

Some expression (such as a sizeof or storage declaration) occurred with an undefined structure or array of empty length. Structures may be referenced before they are defined as long as their size is not needed. Arrays may be declared with empty length if the declaration does not reserve storage or if the declaration is followed by an initializer giving the length.

Statement missing ;

An expression statement was encountered without a semi–colon following it.

Structure or union syntax error

The struct or union keyword was encountered without an identifier or opening curly brace following it.

Structure size too large

A structure was declared which reserved too much storage to fit in the memory available.

Subscripting missing]

A subscripting expression was encountered which was missing its closing bracket. This could be caused by a missing or extra operator or mismatched parentheses.

Switch statement missing (

No left parenthesis was found after the switch keyword in a switch statement.

Switch statement missing)

No right parenthesis was found after the test expression in a switch statement.

Too few arguments in call to 'XXXXXXXX'

The call to the named function has too few arguments. For a function which takes a variable number of arguments, this diagnostic implies that fewer than the minimum number of arguments were passed. When too few arguments are passed, only the arguments actually passed are checked for consistency.

Too few parameters in call

A call to a function with a prototype via a function pointer had too few arguments. Prototypes require that all parameters are given.

Too few parameters in call to 'XXXXXXXX'

A call to the named function (declared using a prototype) had too few arguments.

Too many arguments in call to 'XXXXXXXX'

The call to the named function contains more arguments than were declared. Strictly speaking this will not cause a program to fail if the function is a normal C function, since any extra arguments are ignored, but this often implies that the call was not coded correctly.

Too many cases

A switch statement is limited to 256 cases.

Too many decimal points

A floating point constant was encountered with more than one decimal point.

Too many default cases

More than one default statement was encountered in a single switch.

Too many exponents

More than one exponent was encountered in a floating point constant.

Too many initializers

More initializers were encountered than were allowed by the declaration being initialized.

Too many storage classes in declaration

A declaration may never have more than one storage class.

Too many types in declaration

A declaration may never have more than one of the basic types: char, int, float, double, struct, union, enum or typedef–name.

Too much auto memory in function

More automatic storage was declared in the current function than there is room for in the memory available.

Too much global data defined in file

The sum of the global data declarations exceeds 64 Kb. Check the declarations for any array that may be too large. Also consider reorganizing the program if all the declarations are needed.

Two consecutive dots

An ellipsis contains three dots, and a decimal point or member selection operator uses one dot. Two consecutive dots cannot legally occur in a program.

Type mismatch in parameter ##

The function called via a function pointer was declared with a prototype and the given parameter (counting left–to–right from 1) could not be converted to the declared parameter type.

Type mismatch in parameter ## in call to 'XXXXXXXX'

The named function was declared with a prototype and the given parameter (counting left–to–right from 1) could not be converted to the declared parameter type.

Type mismatch in parameter 'XXXXXXXX'

The function called via a function pointer was declared with a prototype and the named parameter could not be converted to the declared parameter type.

Type mismatch in parameter 'XXXXXXXX' in call to 'XXXXXXXX'

The named function was declared with a prototype and the named parameter could not be converted to the declared parameter type.

Type mismatch in redeclaration

A variable was redeclared with a different type than was originally declared for the variable. This can occur if a function is called and subsequently declared to return a value other than an integer. If this has happened, an extern declaration of the function must be inserted before the first call to it.

Unable to open file 'XXXXXXXX.XXX'

The lint file named in the command line argument could not be opened. Check for misspellings.

Unable to open #include file 'XXXXXXXXX.XXX'

The named file could not be found. This could also be caused if an #include file included itself. Check whether the named file exists.

Undefined label 'XXXXXXXX'

The named label has a goto in the function, but no label definition.

Undefined structure 'XXXXXXXX'

The named structure was used in the source file on a line previous to the indicated location of the error, probably on a pointer to a structure, but had no definition in the source file. This is probably caused by a misspelled structure name or a missing declaration.

Undefined symbol 'XXXXXXXX'

The named identifier has no declaration. This could be caused by a misspelling either at the point of the error or at the declaration. This could also be caused if there was an error in the declaration of the identifier.

Unexpected end of file in comment started on line #

The source file ended in the middle of a comment. This is normally caused by a missing close of comment.

Unexpected end of file in conditional started on line #

The source file ended before a #endif was encountered. The #endif was either missing or misspelled.

Unknown preprocessor statement

A # character was encountered at the beginning of a line, and the statement name following was not define, undef, line, if, ifdef, ifndef, include, else or endif.

Unterminated character constant

An unmatched apostrophe was encountered.

Unterminated string

An unmatched quote character was encountered.

Unterminated string or character constant

A string or character constant was begun and no terminating quote was found.

Variable 'XXXXXXXX' undefined

External declarations were found for the named variable, but no global declaration was found.

While statement missing (

No left parenthesis was found after the while keyword in a while statement.

While statement missing)

No right parenthesis was found after the test expression in a while statement.

Wrong number of arguments in call of 'XXXXXXXX'

The named macro was called with an incorrect number of arguments.

Warning Messages

'XXXXXXXX' declared but never used

The named variable was declared as part of the block just ending, but was never used at all. The error is indicated when the closing curly brace of the compound statement or function is encountered. The declaration of the variable occurs at the beginning of the compound statement or function.

'XXXXXXXX' is assigned a value which is never used

The variable appears in an assignment, but is never used anywhere else in the function just ending. The warning is indicated only when the closing curly brace is encountered.

'XXXXXXXX' not part of structure

The named field was not part of the structure on the left hand side of the dot (.) or arrow (–>), or else the left hand side was not a structure or a pointer to a structure, respectively.

'XXXXXXX' return value is ignored

This message is displayed if the function is declared to return a value and the value is ignored by a function call. The message is flagged on the call. Void functions will produce no such warning, even if the call to the function was not declared to be void. This warning message may be suppressed by explicitly casting the return value to void, such as the following:

(void)printf("hello world\ n");

Note that printf does return a value which is almost always ignored. This can produce many extra warning messages.

Ambiguous operators need parentheses

This warning is displayed whenever two shift, relational or bitwise–boolean operators are used together without parentheses. Also, if an addition or subtraction operator appears unparenthesized with a shift operator this warning appears.

Both return and return of a value used

This warning is issued when a return statement is encountered which disagrees with some previous return statement in the function. It is almost certainly an error for a function to not return a value in only some of the return statements.

Code has no effect

This warning is issued when a statement is found with some operators which have no effect. For example the statement:

```
a + b ;
```

has no effect on either variable. The operation is unnecessary and probably indicates a bug.

Constant is long

A decimal constant greater than 32767 or an octal or hexadecimal constant greater than 65535 was encountered without a letter L following it. The constant is treated as a long.

Conversion may lose significant digits

A conversion from long or unsigned long to int or unsigned int type is required for an assignment operator or other circumstance. Since on some workstations integer type and long type variables have the same size, this kind of conversion may alter the behavior of a program being ported to a new workstation.

Degenerate constant expression

A comparison involving either two constant sub–expressions, or one constant sub–expression which was outside the range allowed by the other sub–expression type. For example, comparing an unsigned quantity to -1 makes no sense. To get an unsigned constant greater than 32767 (in decimal), you should either cast the constant to unsigned (i.e. (unsigned)65535) or append a 'U' to the constant (i.e. 65535u).

Whenever this message is issued, the compiler will still generate code to do the comparison. If this code ends up always giving the same result, such as comparing a char expression to 4000, the code will still perform the test. This also means that comparing an unsigned expression to -1 will do something useful, since an unsigned can have the same bit pattern as a -1 on the 8086.

Duplicate definition of 'XXXXXXXX'

The named macro was redefined using text that was not exactly the same as the first definition of the macro. The new text replaces the old.

Function 'XXXXXXXX' unused

The named function is not called in the lint files given. The function may be removed from the program to save space.

Function should return a value

The current function was declared to return some type other than int or void, but a return with no value was encountered. This is usually some sort of error.

Non–portable pointer assignment

An assignment was made of a pointer to a non–pointer, or vice versa. An assignment of a constant zero to a pointer is allowed as a special case. A cast should be used to suppress this warning if the assignment is proper.

Non–portable pointer comparison

A comparison was made between a pointer and a non–pointer other than the constant zero. A cast should be used to suppress this warning if the comparison is proper.

Non–portable return type conversion

The expression in a return statement was not the same type as the function declaration. This is only triggered if the function or the return expression is a pointer. The exception to this is that a function returning a pointer may return a constant zero. The zero will be converted to an appropriate pointer value.

Parameter 'XXXXXXXX' is never used

The named parameter, declared in the function, was never used in the body of the function. This may or may not be an error and is often caused by a misspelling of the parameter. This warning can also occur if the identifier is redeclared as an automatic variable in the body of the function. The parameter is masked by the automatic variable and remains unused.

Possible use of 'XXXXXXXX' before definition

The named variable was used in an expression before it was assigned a value. The compiler performs a simple scan of the program to determine this condition. If the use of a variable occurs physically before any assignment, this warning will be generated. Of course, the actual flow of the program may assign the value before the use.

Possibly incorrect assignment

This warning is generated when an assignment operator is encountered as the main operator of a conditional expression (i.e. part of an if, while or do–while statement). This more often than not is a typographical error for the equality operator. If you wish to suppress this warning, enclose the assignment in parentheses and compare the whole thing to zero explicitly. For example:

if (a = b) should be rewritten as:

if ((a = b) != 0) ...

Structure passed by value

If the –s flag is provided on the compile command line, this warning is generated anytime a structure is passed by value as an argument. It is a frequent error to leave an & operator off a structure when passing it as an argument. Because structures can be passed by value, this omission is not an error. The –s flag provides a way for the programmer to be warned of this mistake.

Superfluous & with function or array

An address–of–operator (&) is not needed with an array name or function name. Any such operators are discarded.

Suspicious pointer conversion

Some conversion of a pointer to point to a different type was encountered. A cast should be used to suppress this warning if the conversion is proper.

Undefined structure 'XXXXXXXX'

The named structure was used in the source file, probably on a pointer to a structure, but had no definition in the source file. This is probably caused by a misspelled structure name or a missing declaration.

Unknown assembler instruction

An inline assembly statement was encountered with a disallowed opcode. Check the spelling of the opcode. Also check the list of allowed opcodes to see if the instruction is acceptable.

Unreachable Code

A break, continue, goto or return statement was not followed by a label or the end of a loop or function. While, do and for loops with a constant test condition are checked and an attempt is made to recognize loops which cannot fall through.

Void functions may not return a value

The current function was declared as returning void, but a return statement with a value was encountered. The value of the return statement will be ignored.

Zero length structure

A structure was declared whose total size was zero. Any use of this structure would be an error.

Appendix B

Command Line Options Summary

This appendix provides an alphabetical list of compiler options beginning with uppercase, then lowercase, and then numeric options. Each one is briefly described. Refer to section 3 for a more detailed discussion of each option and when to use it.

Note: Compiler options must be separated by one or more spaces.

-A	Compile using no BTOS C extensions.
-C	Allow nested comments.
-Didentifier	Defines identifier to '1'.
-Diden=string	Defines identifier to string.
-E	Allow elastic type matches.
-G	Generate code for speed rather than size.
-Idirectory	Define an include directory.
-K	Treat char type as unsigned.
-L	Do a lint cross-check.
-Lfilename	Do a lint compile to lint file filename.
-N	Generate stack overflow logic.
-O	Compile with optimizer.
-Q	Place only definitions in lint files.
-S	Compile to assembly source and stop.
-T	Warn about explicit casts.
-Uidentifier	Undefine identifier.
-Y	Generate full function entry and exit code.
-Z	Suppress redundant register loads.
-a	Force word alignment of integers.

-b	Do not warn about unreachable breaks.
-d	Suppress long to int conversion warnings.
-f	Generate inline 8087 instructions.
-g	Make all code and data segments PUBLIC, allowing segments with the same name to share the same segment/selector.
-h	Suppress heuristic test warnings.
-i#	Set identifier length.
-mh	Generate huge model, 20-bit pointer arithmetic.
-mhf	Generate huge model, 16-bit pointer arithmetic.
-ml	Generate large model, 20-bit pointer arithmetic.
-mlf	Generate large model, 16-bit pointer arithmetic.
-mm	Generate medium model, 20-bit pointer arithmetic.
-mmf	Generate medium model, 16-bit pointer arithmetic.
-ms	Generate small model, 20-bit pointer arithmetic.
-msf	Generate small model, 16-bit pointer arithmetic.
-n1path	Place CC0 output in named path directory.
-n2path	Place CC1 output in named path directory.
-nopath	Place CC3 output in named path directory.

-p	Generate PL/M calling sequence.
-q	Suppress undefined symbols in lint executions.
-r	Suppress register variables.
-s	Warn about passing structures as arguments.
-w	Suppress all warnings.
-wxxx	Suppress the specified warning.
-x	Warn about unused externs.
-y	Generate source line numbers in object code.
-zAname	Set code segment class.
-zBname	Set data segment class.
-zCname	Set code segment name.
-zDname	Set uninitialized data segment name.
-zGname	Set data group name.
-zPname	Set code group name.
-1	Generate 80186 instructions.
-2	Generate 80286 code.

Library Summary

This library summary provides a short description of each function in the library, grouped by general category.

Input/Output Functions

Input/output can be done in any of several ways. It is important to be consistent in the methods used for any given file. For example, if a file is opened using UNIX I/O, UNIX I/O should be used for all operations whenever possible.

Standard I/O

clearerr	Clears the error status of a file.
fclose	Closes a file.
feof	Returns whether end–of–file was reached on the last input operation to a file.
ferror	Returns whether error status has been set on a given file.
fflush	Flushes any incomplete output buffers by writing them to the disk or device.
fgetc	Reads a character from a file.
fgets	Gets a text line from a file.
fopen	Opens an existing or new file.
fprintf	Does a formatted print to a file.
fputc	Writes a character to a file.
fputs	Writes a string to a file.
fread	Reads one or more records from a file.
freopen	Closes and reopens a file using the same file pointer.
fscanf	Does a formatted read from a file.

fseek	Changes the position of the next read or write in a file, for random access.
ftell	Reports the current position of a file.
fwrite	Writes one or more records to a file.
getc	Reads a character from a file.
getchar	Reads a character from the standard input file.
gets	Gets a text line from the standard input file.
getw	Reads a word (two bytes) from a file.
printf	Does a formatted print to the standard output.
putc	Writes a character to a file.
putchar	Writes a character to the standard output.
puts	Writes a line of text to the standard output.
putw	Writes a word to a file.
rewind	Returns the position of a file to the beginning.
scanf	Does a formatted read from the standard input.
setbuf	Sets a buffer for file activities.
setvbuf	Sets buffering method for file operations.
ungetc	Push a character back onto an input file to be read later.
vfprintf	Does a formatted print to a file with the argument list supplied as an array.
vfscanf	Extracts formatted values from a file with the argument list supplied as an array.
vprintf	Does a formatted print to the standard output with the argument list supplied as an array.
vscanf	Extracts formatted values from the standard input with the argument list supplied as an array.

UNIX I/O

close Closes a file.

creat Creates a file.

lseek Changes the current position of a file for random access.

open Open an existing file or create a new one.

read Reads from a file.

write Writes to a file.

File Management

unlink Deletes a file.

String Handling

index Searches a string for the first occurrence of a second string.

isalnum Tests whether a character is alphanumeric.

isalpha Tests whether a character is alphabetic.

isascii Tests whether a character is ASCII.

iscntrl Tests whether a character is an ASCII control character.

isdigit Tests whether a character is a digit.

isgraph Tests whether a character is a non–blank printable character.

islower Tests whether a character is a lowercase letter.

isprint Tests whether a character is a printable character.

ispunct Tests whether a character is a punctuation.

isspace Tests whether a character is a space, tab or newline.

isupper	Tests whether a character is an uppercase letter.
isxdigit	Tests whether a character is a hexadecimal digit.
memchr	Searches an array for a given character.
memcmp	Compares to fixed size arrays.
memcpy	Copies a fixed size block of memory.
memset	Sets a block of memory to a given value.
movmem	Copies a fixed size block of memory.
rindex	Searches a string for the last occurance of a second string.
setmem	Sets a block of memory to a particular value.
sprintf	Formats values into a string.
sscanf	Extracts formatted values from a string.
strcat	Concatenates two strings.
strchr	Returns a pointer to the first occurrence of a character in a string.
strcmp	Compares two strings.
strcpy	Copies a string into another.
strcspn	Returns the length of the initial string not containing any characters from a given set.
strlen	Returns the length of a string.
strncat	Concatenates two strings with a maximum length.
strncmp	Compares two strings up to a maximum length.
strncpy	Copies a string up to a maximum length into another string.
strpbrk	Returns the first occurrence of any of a set of characters in a string.

strrchr	Finds the last occurrence of a character in a string.
strspn	Returns the length of the initial string composed of characters from a given set.
strtok	Scans through a string extracting tokens.
swab	Swaps the bytes of a string. Used for moving data between incompatible systems.
toascii	Strips any eighth bit from a character to make it a 7-bit ASCII character.
tolower	Converts uppercase letters to lowercase and leaves other values unchanged.
_tolower	Converts uppercase letters to lowercase. Only works for uppercase letters.
toupper	Converts lowercase letters to uppercase and leaves other values unchanged.
_toupper	Converts lowercase letters to uppercase. Only works for lowercase letters.
vsprintf	Formats values into a string with the argument list supplied as an array.
vsscanf	Extracts formatted values from a string with the argument list supplied as an array.

Memory Management

calloc	Allocate a block from the heap and clear it to zero.
cfree	Free a block back to the heap.
free	Free a block back to the heap.
malloc	Allocate a block from the heap.
realloc	Change the size of a block on the heap.

Miscellaneous Arithmetic

abs	Computes the absolute value of a number.
atof	Converts an ASCII string to a floating point number.
atoi	Converts an ASCII string to an integer.
atol	Converts an ASCII string to a long integer.
ecvt	Convert a floating point number to a string in the printf %e form.
fcvt	Convert a floating point number to a string in the printf %f form.
gcvt	Convert a floating point number to a string in the printf %g form.
rand	Returns a random integer.
srand	Sets the random number generator seed.
strtod	Converts an ASCII string to a floating point number.
strtol	Converts an ASCII string to a long integer.

Searching and Sorting

bsearch	Performs a binary search of a table.
lsearch	Performs a linear search of a table and updates it.
qsort	Sorts a table using a quick–sort algorithm.
ssort	Sorts a table using a shell–sort algorithm.

Program Control

assert	Debugging test macro, aborts program if a test fails.
exit	Exits the current program, closing all open files and flushing any incomplete output buffers.

_exit	Exits the current program without closing files and flushing output buffers.
gsignal	Generate a software signal.
longjmp	Perform a jump out of the normal function call sequence.
setjmp	Set a location for a long jump to later jump to.
ssignal	Set to catch a software signal.

Date and Time Management

asctime	Converts a date and time structure to an ASCII string.
ctime	Converts a BTOS date/time to an ASCII string.
gmtime	Converts a BTOS date/time to a date and time structure in Greenwich Mean Time.
localtime	Converts a BTOS date/time to a date and time structure in Local Mean Time.
stime	Set the date and time using a BTOS date/time.
time	Returns the current date and time as a BTOS date/time.

Hardware Functions

check8087	Determine if 8087 or 80287 coprocessor is present.
init8087	Initialize 8087 or 80287 coprocessor.
inport	Input a word value from a hardware port.
inportb	Input a byte value from a hardware port.
outport	Output a word value to a hardware port.
outportb	Output a byte value to a hardware port.
peek	Fetch a word value from anywhere in memory.

peekb Fetch a byte value from anywhere in memory.

poke Set a word value anywhere in memory.

pokeb Set a byte value anywhere in memory.

segread Store the segment registers in a C structure.

Mathematical Library

acos Computes the arc-cosine of a floating point number.

asin Computes the arc-sine of a floating point number.

atan Computes the arc-tangent of a floating point number.

atan2 Computes the arc-tangent given a cartesian point of two floating point numbers.

ceil Returns the smallest integer not less than the parameter. Returns a floating point value.

cos Computes the cosine of a floating point number.

cosh Computes the hyperbolic cosine of a floating point number.

exp Computes the exponential function of a floating point number.

fabs Returns the absolute value of the floating point parameter.

floor Returns the largest integer not greater than the parameter. Returns a floating point value.

fmod Returns the fractional part of x modulo y, where x and y are the two parameters.

frexp Split a floating point number to fractional part and exponent.

ldexp Load an exponent and fractional part into a single floating point number.

log	Computes the natural logarithm of a floating point number.
log10	Computes the base 10 logarithm of a floating point number.
modf	Splits a floating point number into integer and fractional parts.
pow	Computes the power function (x raised to the y power) for two floating point numbers.
sin	Computes the sine of a floating point number.
sinh	Computes the hyperbolic sine of a floating point number.
sqrt	Computes the square root of a floating point number.
tan	Computes the tangent of a floating point number.
tanh	Computes the hyperbolic tangent of a floating point value.

C Grammar Summary

This appendix gives you a grammar summary for the C language. The C grammar notation is derived from the Backus–Naur Form commonly used to describe programming languages.

A program conforms to the grammar given below if a derivation can be constructed for the source program. A derivation is a sequence of substitutions. All derivations begin with a string consisting of the non–terminal symbol 'program'. A substitution consists of replacing any non–terminal symbol in the derivation string. A non–terminal symbol can be replaced by the right–hand side of its own production in the grammar.

There are, in fact, two grammars used in C. The C preprocessing grammar describes the substitutions performed by the preprocessor. During preprocessing, spaces and new lines are significant. After this phase the parser does the C–formal grammar substitutions on the output of the preprocessor. In this phase, spaces and new lines are ignored. If the C source program conforms to both grammars, BTOS C considers it syntactically correct. Type checking and certain other semantic restrictions (such as initializing an automatic array) are enforced by the parser with separate checks after the syntax has been verified.

The grammar below is described as a set of productions. Each production consists of a single name, followed by a ::= symbol, followed by a string of other symbols or punctuation. All names on the left hand side of a ::= production are in normal text and are called non–terminal symbols, because they are replaced in a real program by a string of other symbols.

Any string of ASCII characters that are underlined must appear literally in the source program. These literal strings are the terminal symbols of the grammar.

The right–hand side of a production consists of a string of non–terminals, terminals and punctuation. The right–hand side is a list of alternative constructions. Each possibility of an alternative is a unit separated by vertical bar characters (|). A unit is a non–terminal or terminal symbol or a sequence of symbols enclosed in parentheses, or

square brackets. A unit can be followed by an ellipsis (...). A sequence of symbols enclosed in parentheses must appear as given. A sequence of symbols enclosed in square braces can optionally appear. A unit followed by an ellipsis can appear one or more times.

Lexical Rules

These lexical conventions are used in both the preprocessor grammar and the C–formal grammar. Note that a symbol can appear as either an operator or punctuation, depending on context.

```
identifier      ::= letter [ letter | digit ] ...
constant        ::= int_constant |
                    float_constant |
                    char_constant |
                    enum_constant |
int_constant    ::= ( dec_constant | octal_constant |
                          hex_constant ) suffix
dec_constant    ::= non_zero [ digit ... ]
octal_constant  ::= 0 [octal_digit ... ]
hex_constant    ::= ( 0x | 0X ) hex_digit ...
suffix          ::= long_suffix |
                    unsigned_suffix |
                    long_suffix unsigned_suffix |
                    unsigned_suffix long_suffix
long_suffix     ::= l | L
unsigned_suffix ::= u | U
float_constant  ::= fraction [ exponent ] f_suffix
f_suffix        ::= f | F | l | L
fraction        ::= [ digit ... ] . digit ... |
                    digit ... .
exponent        ::= ( e | E ) [ + | - ] digit ...
enum_constant   ::= identifier
letter          ::= a | b | c | d | e | f | g | h | i | j |
                    k | l | m | n | o | p | q | r | s | t |
                    u | v | w | x | y | z |
                    A | B | C | D | E | F | G | H | I | J |
                    K | L | M | N | O | P | Q | R | S | T |
                    U | V | W | X | Y | Z |
digit           ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
non_zero        ::= 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9
operator        ::= ! | % | ^ | & | * | + | = | - | : | ~ |
                    | | < | > | . | , | ? | / | != | %= |
                    ^= | &= | *= | -= | += | |= | /= | == |
                    <= | >= | -> | && | || | << | >> | <<= |
                    >>= | -- | ++ | sizeof
punctuator      ::= [ | ] | { | } | ( | ) | * | , | : | = | ;
octal_digit     ::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7
hex_digit       ::= digit | a | b | c | d | e | f |
                          | A | B | C | D | E | F
string_literal  ::= string_unit ...
```

```
string_unit      ::=  " [ s_char | escape ] ... "
char_constant    ::=  ' [ c_char | escape ] ... '
escape           ::=  \' | \" | \? | \\ | \a | \b | \f | \n |
                      \r | \t | \v |
                      \ octal_digit octal_digit octal_digit |
                      \x hex_digit hex_digit hex_digit
f_char           ::=  any ascii character except >
f2_char          ::=  any ascii character except "
s_char           ::=  any ascii character except \, new_line or "
c_char           ::=  any ascii character except \, new_line or '
new_line         ::=  ascii new-line
asm_char         ::=  any ascii character except new_line
space            ::=  ascii space | ascii tab |
                      ascii form-feed |
                      /* comment_char */ |
                      \ new_line
comment_char     ::=  any ascii character not including *
                          followed by /
```

Preprocessing Directives

This is the preprocessor grammar.

```
include         ::= include opt_space filename
filename        ::= < f_char ... > |
                    " f2_char ... "
test            ::= control_prefix ( def_test | if_test)
def_test        ::= ( ifdef | ifndef ) space ...
                        identifier opt_space
undefine        ::= undef space ... identifier opt_space
if_test         ::= if p_const_expr
elif_test       ::= control_prefix elif p_const_expr
else_part       ::= control_prefix else opt_space
endif_part      ::= control_prefix endif opt_space
text_line       ::= [ token_string ] new_line
white_space     ::= space | new_line
opt_space       ::= [ space ... ]
p_const_expr    ::= opt_space p_conditional
p_conditional   ::= p_binary [ ? opt_space p_binary
                        :opt_space p_conditional ]
p_binary        ::= p_unary
                    [ p_binop opt_space p_binary ] ...
p_binop         ::= + | - | * | / | % | & | | | ^ | << |
                    >> | || | && | != | == | < | > | >= |
                    <=
p_unary         ::= [ ( p_unop opt_space ) ... ]
                        p_primary opt_space
p_unop          ::= - | + | ~ | !
p_primary       ::= simple_call |
                    complex_call |
                    constant |
                    (p_const_expr ) |
                    defined space ... identifier |
                    defined opt_space ( opt_space
                        identifier opt_space )
```

```
program          ::= [ source_line ] ...
source_line      ::= control_line | text_line | conditional
control_line     ::= control_prefix directive new_line
control_prefix   ::= opt_space # opt_space
conditional      ::= test new_line [ source_line ] ...
                       [ elif_test [ source_line ] ... ] ...
                       [ else_part [ source_line ] ...]
                       endif_part
directive        ::= simple_macro |
                     complex_macro |
                     include |
                     undefine
simple_macro     ::= define space ... identifier (
                             [ token_string ]
complex_macro    ::= define space ... identifier
                             [identifier_list ] )
                             [ m_token_string ]
identifier_list  ::= opt_space identifier
                             [ ( opt_space , opt_space
                             identifier opt_space ) ... ]
                             opt_space
m_token_string   ::= [ m_token ... ]
m_token          ::= simple_call |
                     complex_call |
                     identifier |
                     constant |
                     string_literal |
                     # identifier
                     m_token ## m_token |
                     space
token_string     ::= [ token ... ]
token            ::= simple_call |
                     complex_call |
                     identifier |
                     constant |
                     string_literal |
                     space
simple_call      ::= identifier
complex_call     ::= identifier [ white_space ... ] (
                           [ m_arg_list ] )
m_arg_list       ::= [ n_token_string
                             [ , n_token_string ] ... ]
n_token_string   ::= new_line | token_string
```

Expressions

```
expression      ::= [ expression , ] assignment
assignment      ::= conditional | ( uanary asgop assignment )
asgop           ::= = | += | -= | /= | %= | &= | |= |
                    ^= | <<= | >>=
constant_expr   ::= conditional
conditional     ::= binary [ ? binary : conditional ]
binary          ::= unary [ binop binary ] ...
binop           ::= + | - | * | / | % | & | | | ^ | << |
                    >> | | | | && | |= | == | < | > | >= |
                    <=
unary           ::= [ unop ... ] postfix
unop            ::= & | * | - | + | ~ | ! | cast | ++ | -- |
                    sizeof
postfix         ::= primary [ postop ... ]
postop          ::= ++ | -- |
                    ( [ assignment [ , assignment ] ] ) |
                    [ expression ] |
                    . identifier |
                    -> identifier
primary         ::= identifier |
                    constant |
                    string_literal |
                    ( expression ) |
                    sizeof cast
cast            ::= ( type ... [ abstract_decl ] )
abstract_decl   ::= [ ptr_decl ... ] [ ( abstract_decl ) ]
                          [ [ [ constant expr ] ] |
                              func_decl ) |
                               func_decl proto_parms ) ] ...
```

Declarations

```
declaration     ::= decl_specifiers
                        [ init_decl [ , init_decl ] ... ] ;
decl_specifiers ::= ( storage_class | type ) ...
storage_class   ::= typedef | extern | static | auto |
                    register
type            ::= char | short | int | long | float |
                    double | unsigned | void |
                    const | volatile |
                    struct_union | enum_type | typedef_name
type_modifier   ::= near | far | _ss | _cs | _ds | _es |
                    const | volatile
struct_union    ::= ( struct | union ) ( identifier |
                      [ identifier ] {struct_decl ] ... } )
struct_decl     ::= type ... st_decl [ , st_decl ] ... ;
st_decl         ::= declarator |
                    [ declarator ] : constant_expr
enum_type       ::= enum ( identifier | [ identifier ] {
                           enum_decl [ , enum_decl ] ...
                           } )
enum_decl       ::= identifier [ = constant_expr ]
typedef_name    ::= identifier
init_decl       ::= declarator [ = initializer ]
declarator      ::= [ptr_decl ... ] ( identifier |
                          ( declarator ) )
                          [ [ [ constant_expr ] ] |
                            func_decl)
                            func_decl proto_parms ) ] ...
ptr_decl        ::= * [ type_modifier ... ]
proto_parms     ::= void |
                    proto_parm [ , proto_parm ] ...
proto_parm      ::= type ... declarator |
                    type ... abstract_decl
f_declarator    ::= [ ptr_decl ... ] ( identifier |
                          ( f_declarator ) )
                          [ [ [ constant expr ] ] |
                            func_decl [ iden_list ] ) |
                            func_decl proto_parms ) ] ...
func_decl       ::= ( |
                    fortran ( |
                    plm ( | near plm ( | far plm ( |
                    plm near ( | plm far ( |
                    interrupt ( |
                    near ( | far ( |
iden_list       ::= identifier [ , identifier ] ...
initializer     ::= assigment |
                    { initializer
                          [ , initializer ] ... [ , ] }
```

Statements

```
block           ::= { [ declaration ... ] [ statement ... ] }
statement       ::= [ label ... ] basic_statement
label           ::= identifier : |
                    case constant_expr : |
                    default :
basic_statement ::= expression ; |
                    asm [ asm_char ... ] new_line |
                    asm [ asm_char ... ] ; |
                    if ( expression ) statement |
                    if ( expression ) statement
                          else statement |
                    switch ( expression ) statement |
                    while ( expression ) statement |
                    do statement while ( expression ) ; |
                    for ( expression ; expression ;
                                        expression ) statement |
                    goto identifier ; |
                    continue ; |
                    break ; |
                    return [ expression ] ;
```

External Definitions

```
program       ::= [ external_def ... ]
external_def  ::= declaration |
                  asm [ asm_char ... ] new_line |
                  asm [ asm_char ... ] ; |
                  [ decl_specifiers ] f_declarator
                                        function_body
function_body ::= [ declaration ... ] block
```

Glossary

Application partition. An application partition is a section of user memory reserved for the execution of an application.

Arithmetic operators. An arithmetic operator is a symbol used in an arithmetic expression to indicate the type of arithmetic operation to be performed: the standard operators are add (+), subtract (-), multiply (*), and divide (/).

Array declarator. An array declarator is a declarator with a trailing pair of square braces, possibly enclosing an integral constant expression. If no expression is given, the array has unknown size. Otherwise, the expression is the number of elements in the array.

ASCII. ASCII, the American Standard Code for Information Interchange, defines the character set codes used for information exchange between equipment.

Assemble. ASSEMBLE is the Executive command you use to display the Assembler command form.

Assembler. The Assembler translates Assembly 8086 programs into BTOS object modules (machine code).

Binary operators. A binary operator binds unary expressions or other binary expressions as left and right operands to form binary expressions.

Bind. Bind is a command that activates the Linker to create a version 6 run file. Version 6 run files are required for protected mode compatability.

BSWA. See Byte stream work area.

Byte stream work area. The Byte stream work area (BSWA) is a 130–byte memory work area for the exclusive use of SAM procedures.

Cast. A cast is an abstract type enclosed in parentheses. Casts can appear following a sizeof keyword, or can be used as a unary operator to convert the operand expression to the named type. Both the operand and the cast must have scalar type.

Class name. A class name is a symbol used to designate a class.

Code listing. A code listing is an English–language display of compiled code.

Code segment. A code segment is a variable–length (up to 64 Kb) logical entity consisting of reentrant code, and containing one or more complete procedures.

Compiler. BTOS compilers translate high level language programs into BTOS object modules (machine code).

Configuration file. Configuration files specify the options for the C Compiler.

CTOS.lib. The CTOS.lib is part of the Language Development software; it is a library of object modules that provide operating system runtime suport.

DGroup. DGroup usually includes data, constant, and stack Linker segments.

8086 assembly. 8086 assembly language is the low level language you can use to write BTOS programs. You use the BTOS Assembler to convert the programs into BTOS object modules.

Executive. The Executive is the BTOS user interface program; it provides access to many convenient utilities for file management.

Expressions. In a program, an expression is a combination of various constants, variables, operators, and parentheses, used to perform a desired computation.

External reference. An external reference is a reference from one object module to variable and entry points of other object modules.

File access methods. Several file access methods augment the file management system capabilities. File access methods are object module procedures located in the standard BTOS library. They provide buffering and use the asynchronous input/output capabilities of the file management system to overlap input/output and computation.

Function declarators. A function declarator is a declarator with a trailing optional set of language modifiers and a pair of possibly empty parentheses.

Group. A group is a named collection of linker segments that the BTOS loader addresses at runtime with a common hardware segment register. To make the addressing work, all the bytes within a group must be within 64 Kb of each other.

Identifiers. An identifer is a sequence of upper– and lowercase letters, digits, and the underbar (_) character. An identifier must begin with a letter or the underbar. It can be of any length, but only the first 32 characters are significant.

Language development. The BTOS Language development software provides the Linker, Librarian, and Assembler programs (BIND, LINK, LIBRARIAN, and ASSEMBLE Executive commands).

.lib. .lib is the standard file name suffix for library files.

Librarian. The Librarian is a program that creates and maintains object module libraries. The Linker can search automatically in such libraries to select only those object modules that a program calls.

Library. A library is a stored collection of object modules (complete routines or subroutines) that are available for linking into run files.

Library file. A library file can contain one or more object modules. The file name normally includes the suffix .lib.

Link. LINK is the Executive command that activates the linker to create version 4 run filles. Version 4 run files are not protected mode compatible.

Linked–list data structure. A linked–list data structure contains elements that link words or link pointers connect.

Linker. The Linker is a program that combines object modules (files that Compilers and Assemblers produce) into run files.

Linker segment. A Linker segment is a single entity consisting of all segment elements with the same segment name.

List file. The Linker list file (suffix .map) contains an entry for each Linker segment, identifying the segment relative address and length in the memory image. You can direct the Linker to list public symbols and line numbers.

Macros. A macro (short for macroinstruction) is a single instruction that represents a given sequence of instructions. The macro is defined to represent a set of instructions and can be used each time to represent that set.

.map. .map is the standard file name suffix for Linker list files.

.obj. .obj is the standard file name suffix for object module files.

Object module. An object module is the result of a single Compiler or Assembler function. You can link the object module with other object modules into BTOS run files.

Overlay. An overlay is a code segment made up of the code from one or more object modules. An overlay is loaded into memory as a unit and is not permanently memory–resident. See also Virtual code segment management.

Parameter. A parameter is a variable or constant that is transferred to and from a subroutine or program.

Physical address. A physical address is an address that does not specify a segment base and is relative to memory location 0.

Pointer. A pointer is an address that specifies a storage location for data.

Pointer declarators. A pointer declarator is a declaration beginning with an asterisk (*), optionally followed by pointer type modifiers.

Postfix expressions. A postfix expression is an expression followed by a dot(.) or an arrow (-->) and an identifier. The identifier must be the name of a structure or union member.

Process. A process is a program that is running.

Public procedure. A public procedure is a procedure that has a public address; a module other than the defining module can reference the address.

Public symbol. A public symbol is an ASCII character string associated with a public variable, a public value, or a public procedure.

Public value. A public value is a value that has a public address; a module other than the defining module can reference the address.

Public variable. A public variable is a variable that has a public address; a module other than the defining module can reference the address.

Relocation. The BTOS Loader relocates a task image in available memory by supplying physical addresses for the logical addresses in the run file.

Relocation directory. The relocation directory is an array of locators that the BTOS Loader uses to relocate the task image.

Resident. The resident portion of a program remains in memory throughout execution.

.run. .run is the standard file name suffix for run files.

Run file. A run file is a complete program: a memory image of a task in relocatable form, linked into the standard format BTOS requires. You use the Linker to create run files.

Run–file checksum. The Run–file checksum is a number the Linker produces based on the summation of words in the file. The system uses the checksum to check the validity of the run file.

Segment. A segment is a contiguous area of memory that consists of an integral number of paragraphs. Segments are usually classified into one of three types: code, static data, or dynamic data. Each kind can be either shared or nonshared.

Segment address. The segment address is the segment base address. For an 8086/80186 microprocessor, a segment address refers to a paragraph (16 bytes).

Segmented address. A segmented address is an address that specifies both a segment base and an offset.

Segment element. A segment element is a section of an object module. Each segment element has a segment name.

Segment override. Segment override is operating code that causes the 8086/80186 to use the segment register specified by the prefix instead of the segment register that it would normally use when executing an instruction.

Shift operators. A shift operator must have operands of integral type. A shift operator shifts the bits of the integral quantity on the left either to the left(<<) or right(>>) by the amount given in the right side operand.

Short–lived memory. Short–lived memory is the memory area in an application partition. When BTOS loads a task, it allocates short–lived memory to contain the task code and data. A client process can also load short–lived memory in its own partition.

Stack. A stack is a region of memory accessible from one end by means of a stack pointer.

Stack frame. The stack frame is a region of a stack corresponding to the dynamic invocation of a procedure. It consists of procedural parameters, a return address, a saved–frame pointer, and local variables.

Stack pointer. A stack pointer is the indicator to the top of a stack. The stack pointer is stored in the registers SS:SP.

Statements. A statement is an executable instruction. Each statement is executed in order within a statement list unless otherwise directed by control–flow statements.

.sym. .sym is the standard file name suffix for the symbol file.

Symbol. Symbols can be alphanumeric and/or any other characters, such as underscore, period, dollar sign, pound sign, or exclamation mark.

Symbol file. The Linker symbol file (suffix .sym) contains a list of all public symbols.

Symbolic instructions. Symbolic instructions are instructions containing mnenomic characters corresponding to Assembly language instructions. These instructions cannot contain user–defined public symbols.

Task. A task consists of executable code, data, and one or more processes.

Task image. A task image is a program stored in a run file that contains code segments and/or static data segments.

Text file. A text file contains bytes that represent printable characters or control characters (such as tab, newline, etc.).

Virtual code segment management. Virtual code segment management is the virtual memory method BTOS supports (overlays).

The method works as follows: The Linker divides the code into task segments that reside on disk (in the run file). As the run file executes, only the task segments that are required at a particular time reside in the application partition's main memory; the other task segments remain on disk until the application requires them. When the application no longer requires a task segment, another task segment overlays it.

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Address (Street, City, State, Zip)

Telephone Number

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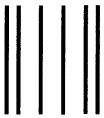

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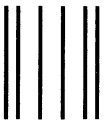

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