

as

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Chapter 1

as

1.1 as

Using as

This file is a user guide to the GNU assembler 'as'.

* Menu:

* Overview	Overview
* Invoking	Command-Line Options
* Syntax	Syntax
* Sections	Sections and Relocation
* Symbols	Symbols
* Expressions	Expressions
* Pseudo Ops	Assembler Directives
* Machine Dependencies	Machine Dependent Features
* Acknowledgements	Who Did What
* Index	Index

1.2 Overview

Overview

Here is a brief summary of how to invoke 'as'. For details, *note Comand-Line Options: Invoking..

```
as [ -a[dhlns] ] [ -D ] [ -f ] [ -I PATH ]
[ -K ] [ -L ] [ -o OBJFILE ] [ -R ]
[ --statistics ] [ -v ] [ -W ] [ -Z ]
[ -Av6 | -Av7 | -Av8 | -Asparclite | -bump ]
[ -ACA | -ACA_A | -ACB | -ACC | -AKA | -AKB | -AKC | -AMC ]
[ -b ] [ -norelax ]
[ -l ] [ -m68000 | -m68010 | -m68020 | ... ]
[ -nocpp ] [ -EL ] [ -EB ] [ -G NUM ]
[ -mips1 ] [ -mips2 ] [ -mips3 ]
```

```
[ --trap ] [ --break ]  
[ -- | FILES ... ]
```

`'-a[dhlns]'`

Turn on listings, in any of a variety of ways:

`'-ad'`

omit debugging directives from listing

`'-ah'`

include high-level source

`'-al'`

assembly listing

`'-an'`

no forms processing

`'-as'`

symbols

You may combine these options; for example, use `'-aln'` for assembly listing without forms processing. By itself, `'-a'` defaults to `'-ahls'`--that is, all listings turned on.

`'-D'`

This option is accepted only for script compatibility with calls to other assemblers; it has no effect on `'as'`.

`'-f'`

"fast"--skip whitespace and comment preprocessing (assume source is compiler output)

`'-I PATH'`

Add PATH to the search list for `'include'` directives

`'-K'`

Issue warnings when difference tables altered for long displacements.

`'-L'`

Keep (in symbol table) local symbols, starting with `'L'`

`'-o OBJFILE'`

Name the object-file output from `'as'`

`'-R'`

Fold data section into text section

`'--statistics'`

Display maximum space (in bytes), and total time (in seconds), taken by assembly.

`'-v'`

Announce `'as'` version

`'-W'`

Suppress warning messages

`'-z'`

Generate object file even after errors

`'-- | FILES ...'`

Standard input, or source files to assemble.

The following options are available when `as` is configured for the Intel 80960 processor.

`'-ACA | -ACA_A | -ACB | -ACC | -AKA | -AKB | -AKC | -AMC'`

Specify which variant of the 960 architecture is the target.

`'-b'`

Add code to collect statistics about branches taken.

`'-norelax'`

Do not alter compare-and-branch instructions for long displacements; error if necessary.

The following options are available when `as` is configured for the Motorola 68000 series.

`'-l'`

Shorten references to undefined symbols, to one word instead of two.

`'-m68000 | -m68008 | -m68010 | -m68020 | -m68030 | -m68040'`

`'| -m68302 | -m68331 | -m68332 | -m68333 | -m68340 | -mcpu32'`

Specify what processor in the 68000 family is the target. The default is normally the 68020, but this can be changed at configuration time.

`'-m68881 | -m68882 | -mno-68881 | -mno-68882'`

The target machine does (or does not) have a floating-point coprocessor. The default is to assume a coprocessor for 68020, 68030, and `cpu32`. Although the basic 68000 is not compatible with the 68881, a combination of the two can be specified, since it's possible to do emulation of the coprocessor instructions with the main processor.

`'-m68851 | -mno-68851'`

The target machine does (or does not) have a memory-management unit coprocessor. The default is to assume an MMU for 68020 and up.

The following options are available when `'as'` is configured for the SPARC architecture:

`'-Av6 | -Av7 | -Av8 | -Asparclite'`

Explicitly select a variant of the SPARC architecture.

`'-bump'`

Warn when the assembler switches to another architecture.

The following options are available when `as` is configured for a MIPS

processor.

`'-G NUM'`

This option sets the largest size of an object that can be referenced implicitly with the `'gp'` register. It is only accepted for targets that use ECOFF format, such as a DECstation running Ultrix. The default value is 8.

`'-EB'`

Generate "big endian" format output.

`'-EL'`

Generate "little endian" format output.

`'-mips1'`

`'-mips2'`

`'-mips3'`

Generate code for a particular MIPS Instruction Set Architecture level. `'-mips1'` corresponds to the R2000 and R3000 processors, `'-mips2'` to the R6000 processor, and `'-mips3'` to the R4000 processor.

`'-nocpp'`

`'as'` ignores this option. It is accepted for compatibility with the native tools.

`'--trap'`

`'--no-trap'`

`'--break'`

`'--no-break'`

Control how to deal with multiplication overflow and division by zero. `'--trap'` or `'--no-break'` (which are synonyms) take a trap exception (and only work for Instruction Set Architecture level 2 and higher); `'--break'` or `'--no-trap'` (also synonyms, and the default) take a break exception.

* Menu:

* Manual	Structure of this Manual
* GNU Assembler	as, the GNU Assembler
* Object Formats	Object File Formats
* Command Line	Command Line
* Input Files	Input Files
* Object	Output (Object) File
* Errors	Error and Warning Messages

1.3 Manual

Structure of this Manual

=====

This manual is intended to describe what you need to know to use GNU `'as'`. We cover the syntax expected in source files, including notation for symbols, constants, and expressions; the directives that `'as'` understands; and of course how to invoke `'as'`.

This manual also describes some of the machine-dependent features of various flavors of the assembler.

On the other hand, this manual is **not** intended as an introduction to programming in assembly language--let alone programming in general! In a similar vein, we make no attempt to introduce the machine architecture; we do **not** describe the instruction set, standard mnemonics, registers or addressing modes that are standard to a particular architecture. You may want to consult the manufacturer's machine architecture manual for this information.

1.4 GNU Assembler

as, the GNU Assembler
=====

GNU *'as'* is really a family of assemblers. If you use (or have used) the GNU assembler on one architecture, you should find a fairly similar environment when you use it on another architecture. Each version has much in common with the others, including object file formats, most assembler directives (often called "pseudo-ops") and assembler syntax.

'as' is primarily intended to assemble the output of the GNU C compiler *'gcc'* for use by the linker *'ld'*. Nevertheless, we've tried to make *'as'* assemble correctly everything that other assemblers for the same machine would assemble. Any exceptions are documented explicitly (Machine Dependencies .). This doesn't mean *'as'* always uses the same syntax as another assembler for the same architecture; for example, we know of several incompatible versions of 680x0 assembly language syntax.

Unlike older assemblers, *'as'* is designed to assemble a source program in one pass of the source file. This has a subtle impact on the *'org'* directive (**note 'org': Org.*).

1.5 Object Formats

Object File Formats
=====

The GNU assembler can be configured to produce several alternative object file formats. For the most part, this does not affect how you write assembly language programs; but directives for debugging symbols are typically different in different file formats. **Note Symbol Attributes: Symbol Attributes.*

1.6 Command Line

Command Line

=====

After the program name `'as'`, the command line may contain options and file names. Options may appear in any order, and may be before, after, or between file names. The order of file names is significant.

`'--'` (two hyphens) by itself names the standard input file explicitly, as one of the files for `'as'` to assemble.

Except for `'--'` any command line argument that begins with a hyphen (`'-'`) is an option. Each option changes the behavior of `'as'`. No option changes the way another option works. An option is a `'-'` followed by one or more letters; the case of the letter is important. All options are optional.

Some options expect exactly one file name to follow them. The file name may either immediately follow the option's letter (compatible with older assemblers) or it may be the next command argument (GNU standard). These two command lines are equivalent:

```
as -o my-object-file.o mumble.s
as -omy-object-file.o mumble.s
```

1.7 Input Files

Input Files

=====

We use the phrase "source program", abbreviated "source", to describe the program input to one run of `'as'`. The program may be in one or more files; how the source is partitioned into files doesn't change the meaning of the source.

The source program is a concatenation of the text in all the files, in the order specified.

Each time you run `'as'` it assembles exactly one source program. The source program is made up of one or more files. (The standard input is also a file.)

You give `'as'` a command line that has zero or more input file names. The input files are read (from left file name to right). A command line argument (in any position) that has no special meaning is taken to be an input file name.

If you give `'as'` no file names it attempts to read one input file from the `'as'` standard input, which is normally your terminal. You may have to type `ctl-D` to tell `'as'` there is no more program to assemble.

Use `'--'` if you need to explicitly name the standard input file in your command line.

If the source is empty, `'as'` produces a small, empty object file.

Filename and Line-numbers

There are two ways of locating a line in the input file (or files) and either may be used in reporting error messages. One way refers to a line number in a physical file; the other refers to a line number in a "logical" file. *Note Error and Warning Messages: Errors.

"Physical files" are those files named in the command line given to 'as'.

"Logical files" are simply names declared explicitly by assembler directives; they bear no relation to physical files. Logical file names help error messages reflect the original source file, when 'as' source is itself synthesized from other files. *Note '.app-file': App-File.

1.8 Object

Output (Object) File

=====

Every time you run 'as' it produces an output file, which is your assembly language program translated into numbers. This file is the object file. Its default name is 'a.out', or 'b.out' when 'as' is configured for the Intel 80960. You can give it another name by using the '-o' option. Conventionally, object file names end with '.o'. The default name is used for historical reasons: older assemblers were capable of assembling self-contained programs directly into a runnable program. (For some formats, this isn't currently possible, but it can be done for the 'a.out' format.)

The object file is meant for input to the linker 'ld'. It contains assembled program code, information to help 'ld' integrate the assembled program into a runnable file, and (optionally) symbolic information for the debugger.

1.9 Errors

Error and Warning Messages

=====

'as' may write warnings and error messages to the standard error file (usually your terminal). This should not happen when a compiler runs 'as' automatically. Warnings report an assumption made so that 'as' could keep assembling a flawed program; errors report a grave problem that stops the assembly.

Warning messages have the format

file_name:NNN:Warning Message Text

(where NNN is a line number). If a logical file name has been given (*note ‘.app-file’: App-File.) it is used for the filename, otherwise the name of the current input file is used. If a logical line number was given (*note ‘.line’: Line.) then it is used to calculate the number printed, otherwise the actual line in the current source file is printed. The message text is intended to be self explanatory (in the grand Unix tradition).

Error messages have the format

file_name:NNN:FATAL:Error Message Text

The file name and line number are derived as for warning messages. The actual message text may be rather less explanatory because many of them aren’t supposed to happen.

1.10 Invoking

Command-Line Options

This chapter describes command-line options available in *all* versions of the GNU assembler; Machine Dependencies ., for options specific to particular machine architectures.

If you are invoking ‘as’ via the GNU C compiler (version 2), you can use the ‘-Wa’ option to pass arguments through to the assembler. The assembler arguments must be separated from each other (and the ‘-Wa’) by commas. For example:

```
gcc -c -g -O -Wa,-alh,-L file.c
```

emits a listing to standard output with high-level and assembly source.

Usually you do not need to use this ‘-Wa’ mechanism, since many compiler command-line options are automatically passed to the assembler by the compiler. (You can call the GNU compiler driver with the ‘-v’ option to see precisely what options it passes to each compilation pass, including the assembler.)

* Menu:

* a	-a[dhlms] enable listings
* D	-D for compatibility
* f	-f to work faster
* I	-I for .include search path
* K	-K for difference tables
* L	-L to retain local labels
* o	-o to name the object file
* R	-R to join data and text sections
* statistics	-statistics to see statistics about assembly
* v	-v to announce version
* W	-W to suppress warnings
* Z	-Z to make object file even after errors

1.11 a

Enable Listings: `'-a[dhlms]'`
=====

These options enable listing output from the assembler. By itself, `'-a'` requests high-level, assembly, and symbols listing. You can use other letters to select specific options for the list: `'-ah'` requests a high-level language listing, `'-al'` requests an output-program assembly listing, and `'-as'` requests a symbol table listing. High-level listings require that a compiler debugging option like `'-g'` be used, and that assembly listings (`'-al'`) be requested also.

Use the `'-ad'` option to omit debugging directives from the listing.

Once you have specified one of these options, you can further control listing output and its appearance using the directives `'.list'`, `'.nolist'`, `'.psize'`, `'.eject'`, `'.title'`, and `'.sbttl'`. The `'-an'` option turns off all forms processing. If you do not request listing output with one of the `'-a'` options, the listing-control directives have no effect.

The letters after `'-a'` may be combined into one option, *e.g.*, `'-alms'`.

1.12 D

`'-D'`
=====

This option has no effect whatsoever, but it is accepted to make it more likely that scripts written for other assemblers also work with `'as'`.

1.13 f

Work Faster: `'-f'`
=====

`'-f'` should only be used when assembling programs written by a (trusted) compiler. `'-f'` stops the assembler from doing whitespace and comment preprocessing on the input file(s) before assembling them.
*Note Preprocessing: Preprocessing.

Warning: if you use `'-f'` when the files actually need to be preprocessed (if they contain comments, for example), `'as'` does not work correctly.

1.14 l

``.include' search path: '-I' PATH`

=====

Use this option to add a PATH to the list of directories 'as' searches for files specified in ``.include'` directives (*note ``.include': Include.`). You may use `'-I'` as many times as necessary to include a variety of paths. The current working directory is always searched first; after that, 'as' searches any `'-I'` directories in the same order as they were specified (left to right) on the command line.

1.15 K

`Difference Tables: '-K'`

=====

'as' sometimes alters the code emitted for directives of the form ``.word SYM1-SYM2';` *note ``.word': Word..` You can use the `'-K'` option if you want a warning issued when this is done.

1.16 L

`Include Local Labels: '-L'`

=====

Labels beginning with 'L' (upper case only) are called "local labels". Normally you do not see such labels when debugging, because they are intended for the use of programs (like compilers) that compose assembler programs, not for your notice. Normally both 'as' and 'ld' discard such labels, so you do not normally debug with them.

This option tells 'as' to retain those 'L...' symbols in the object file. Usually if you do this you also tell the linker 'ld' to preserve symbols whose names begin with 'L'.

By default, a local label is any label beginning with 'L', but each target is allowed to redefine the local label prefix. On the HPPA local labels begin with 'L\$'.

1.17 o

`Name the Object File: '-o'`

=====

There is always one object file output when you run 'as'. By default it has the name 'a.out' (or 'b.out', for Intel 960 targets only). You use this option (which takes exactly one filename) to give the object file a different name.

Whatever the object file is called, 'as' overwrites any existing file of the same name.

1.18 R

Join Data and Text Sections: '-R'
=====

'-R' tells 'as' to write the object file as if all data-section data lives in the text section. This is only done at the very last moment: your binary data are the same, but data section parts are relocated differently. The data section part of your object file is zero bytes long because all its bytes are appended to the text section. (*Note Sections and Relocation: Sections.)

When you specify '-R' it would be possible to generate shorter address displacements (because we do not have to cross between text and data section). We refrain from doing this simply for compatibility with older versions of 'as'. In future, '-R' may work this way.

When 'as' is configured for COFF output, this option is only useful if you use sections named '.text' and '.data'.

'-R' is not supported for any of the HPPA targets. Using '-R' generates a warning from 'as'.

1.19 statistics

Display Assembly Statistics: '--statistics'
=====

Use '--statistics' to display two statistics about the resources used by 'as': the maximum amount of space allocated during the assembly (in bytes), and the total execution time taken for the assembly (in CPU seconds).

1.20 v

Announce Version: '-v'
=====

You can find out what version of as is running by including the option '-v' (which you can also spell as '-version') on the command line.

1.21 W

Suppress Warnings: `'-W'`
 =====

`'as'` should never give a warning or error message when assembling compiler output. But programs written by people often cause `'as'` to give a warning that a particular assumption was made. All such warnings are directed to the standard error file. If you use this option, no warnings are issued. This option only affects the warning messages: it does not change any particular of how `'as'` assembles your file. Errors, which stop the assembly, are still reported.

1.22 Z

Generate Object File in Spite of Errors: `'-Z'`
 =====

After an error message, `'as'` normally produces no output. If for some reason you are interested in object file output even after `'as'` gives an error message on your program, use the `'-Z'` option. If there are any errors, `'as'` continues anyways, and writes an object file after a final warning message of the form `'N errors, M warnings, generating bad object file.'`

1.23 Syntax

Syntax

This chapter describes the machine-independent syntax allowed in a source file. `'as'` syntax is similar to what many other assemblers use; it is inspired by the BSD 4.2 assembler, except that `'as'` does not assemble Vax bit-fields.

* Menu:

* Preprocessing	Preprocessing
* Whitespace	Whitespace
* Comments	Comments
* Symbol Intro	Symbols
* Statements	Statements
* Constants	Constants

1.24 Preprocessing

Preprocessing
 =====

The `'as'` internal preprocessor:

* adjusts and removes extra whitespace. It leaves one space or tab

before the keywords on a line, and turns any other whitespace on the line into a single space.

- * removes all comments, replacing them with a single space, or an appropriate number of newlines.
- * converts character constants into the appropriate numeric values.

It does not do macro processing, include file handling, or anything else you may get from your C compiler's preprocessor. You can do include file processing with the `'include'` directive (*note `'include'`: Include.). You can use the GNU C compiler driver to get other "CPP" style preprocessing, by giving the input file a `'.S'` suffix. *Note Options Controlling the Kind of Output: (gcc.info)Overall Options.

Excess whitespace, comments, and character constants cannot be used in the portions of the input text that are not preprocessed.

If the first line of an input file is `'#NO_APP'` or if you use the `'-f'` option, whitespace and comments are not removed from the input file. Within an input file, you can ask for whitespace and comment removal in specific portions of the by putting a line that says `'#APP'` before the text that may contain whitespace or comments, and putting a line that says `'#NO_APP'` after this text. This feature is mainly intend to support `'asm'` statements in compilers whose output is otherwise free of comments and whitespace.

1.25 Whitespace

Whitespace
=====

"Whitespace" is one or more blanks or tabs, in any order. Whitespace is used to separate symbols, and to make programs neater for people to read. Unless within character constants (*note Character Constants: Characters.), any whitespace means the same as exactly one space.

1.26 Comments

Comments
=====

There are two ways of rendering comments to `'as'`. In both cases the comment is equivalent to one space.

Anything from `'/*'` through the next `'*/'` is a comment. This means you may not nest these comments.

/*

The only way to include a newline (`'\n'`) in a comment

```
    is to use this sort of comment.
*/
```

```
/* This sort of comment does not nest. */
```

Anything from the "line comment" character to the next newline is considered a comment and is ignored. The line comment character is '#' on the Vax; '#' on the i960; '!' on the SPARC; '|' on the 680x0; ';' for the AMD 29K family; ';' for the H8/300 family; '!' for the H8/500 family; ';' for the HPPA; '!' for the Hitachi SH; '!' for the Z8000; see *Note Machine Dependencies .

On some machines there are two different line comment characters. One character only begins a comment if it is the first non-whitespace character on a line, while the other always begins a comment.

To be compatible with past assemblers, lines that begin with '#' have a special interpretation. Following the '#' should be an absolute expression (Expressions.): the logical line number of the *next* line. Then a string (*note Strings: Strings.) is allowed: if present it is a new logical file name. The rest of the line, if any, should be whitespace.

If the first non-whitespace characters on the line are not numeric, the line is ignored. (Just like a comment.)

```
                                # This is an ordinary comment.
# 42-6 "new_file_name"         # New logical file name
                                # This is logical line # 36.
```

This feature is deprecated, and may disappear from future versions of 'as'.

1.27 Symbol Intro

Symbols
=====

A "symbol" is one or more characters chosen from the set of all letters (both upper and lower case), digits and the three characters '_.\$'. On most machines, you can also use '\$' in symbol names; exceptions are noted in *Note Machine Dependencies . No symbol may begin with a digit. Case is significant. There is no length limit: all characters are significant. Symbols are delimited by characters not in that set, or by the beginning of a file (since the source program must end with a newline, the end of a file is not a possible symbol delimiter). *Note Symbols .

1.28 Statements

Statements
=====

A "statement" ends at a newline character ('\n') or line separator character. (The line separator is usually ';', unless this conflicts with the comment character; Machine Dependencies ..) The newline or separator character is considered part of the preceding statement. Newlines and separators within character constants are an exception: they do not end statements.

It is an error to end any statement with end-of-file: the last character of any input file should be a newline.

You may write a statement on more than one line if you put a backslash ('\') immediately in front of any newlines within the statement. When 'as' reads a backslashed newline both characters are ignored. You can even put backslashed newlines in the middle of symbol names without changing the meaning of your source program.

An empty statement is allowed, and may include whitespace. It is ignored.

A statement begins with zero or more labels, optionally followed by a key symbol which determines what kind of statement it is. The key symbol determines the syntax of the rest of the statement. If the symbol begins with a dot '.' then the statement is an assembler directive: typically valid for any computer. If the symbol begins with a letter the statement is an assembly language "instruction": it assembles into a machine language instruction. Different versions of 'as' for different computers recognize different instructions. In fact, the same symbol may represent a different instruction in a different computer's assembly language.

A label is a symbol immediately followed by a colon (':'). Whitespace before a label or after a colon is permitted, but you may not have whitespace between a label's symbol and its colon. *Note Labels .

For HPPA targets, labels need not be immediately followed by a colon, but the definition of a label must begin in column zero. This also implies that only one label may be defined on each line.

```
label:      .directive      followed by something
another_label:      # This is an empty statement.
                instruction  operand_1, operand_2, ...
```

1.29 Constants

Constants
=====

A constant is a number, written so that its value is known by inspection, without knowing any context. Like this:

```
.byte  74, 0112, 092, 0x4A, 0X4a, 'J, '\J # All the same value.
.ascii "Ring the bell\7"                # A string constant.
.octa  0x123456789abcdef0123456789ABCDEF0 # A bignum.
.float 0f-314159265358979323846264338327\
95028841971.693993751E-40                # - pi, a flonum.
```

* Menu:

* Characters	Character Constants
* Numbers	Number Constants

1.30 Characters

Character Constants

There are two kinds of character constants. A "character" stands for one character in one byte and its value may be used in numeric expressions. String constants (properly called string **literals**) are potentially many bytes and their values may not be used in arithmetic expressions.

* Menu:

* Strings	Strings
* Chars	Characters

1.31 Strings

Strings

.....

A "string" is written between double-quotes. It may contain double-quotes or null characters. The way to get special characters into a string is to "escape" these characters: precede them with a backslash `'\'` character. For example `'\'` represents one backslash: the first `'\'` is an escape which tells `'as'` to interpret the second character literally as a backslash (which prevents `'as'` from recognizing the second `'\'` as an escape character). The complete list of escapes follows.

`'\b'`

Mnemonic for backspace; for ASCII this is octal code 010.

`'\f'`

Mnemonic for FormFeed; for ASCII this is octal code 014.

`'\n'`

Mnemonic for newline; for ASCII this is octal code 012.

`'\r'`

Mnemonic for carriage-Return; for ASCII this is octal code 015.

`'\t'`

Mnemonic for horizontal Tab; for ASCII this is octal code 011.

`'\ DIGIT DIGIT DIGIT'`

An octal character code. The numeric code is 3 octal digits. For

compatibility with other Unix systems, 8 and 9 are accepted as digits: for example, `'\008'` has the value 010, and `'\009'` the value 011.

`'\x' HEX-DIGIT HEX-DIGIT'`

A hex character code. The numeric code is 2 hexadecimal digits. Either upper or lower case `'x'` works.

`'\'`

Represents one `'\'` character.

`'\"'`

Represents one `'\"'` character. Needed in strings to represent this character, because an unescaped `'\"'` would end the string.

`'\ ANYTHING-ELSE'`

Any other character when escaped by `'\'` gives a warning, but assembles as if the `'\'` was not present. The idea is that if you used an escape sequence you clearly didn't want the literal interpretation of the following character. However `'as'` has no other interpretation, so `'as'` knows it is giving you the wrong code and warns you of the fact.

Which characters are escapable, and what those escapes represent, varies widely among assemblers. The current set is what we think the BSD 4.2 assembler recognizes, and is a subset of what most C compilers recognize. If you are in doubt, do not use an escape sequence.

1.32 Chars

Characters

.....

A single character may be written as a single quote immediately followed by that character. The same escapes apply to characters as to strings. So if you want to write the character backslash, you must write `'\\'` where the first `'\'` escapes the second `'\'`. As you can see, the quote is an acute accent, not a grave accent. A newline immediately following an acute accent is taken as a literal character and does not count as the end of a statement. The value of a character constant in a numeric expression is the machine's byte-wide code for that character. `'as'` assumes your character code is ASCII: `'A'` means 65, `'B'` means 66, and so on.

1.33 Numbers

Number Constants

`'as'` distinguishes three kinds of numbers according to how they are stored in the target machine. **Integers** are numbers that would fit into an `'int'` in the C language. **Bignums** are integers, but they are

stored in more than 32 bits. *Flonums* are floating point numbers, described below.

* Menu:

* Integers	Integers
* Bignums	Bignums
* Flonums	Flonums

1.34 Integers

Integers
.....

A binary integer is '0b' or '0B' followed by zero or more of the binary digits '01'.

An octal integer is '0' followed by zero or more of the octal digits ('01234567').

A decimal integer starts with a non-zero digit followed by zero or more digits ('0123456789').

A hexadecimal integer is '0x' or '0X' followed by one or more hexadecimal digits chosen from '0123456789abcdefABCDEF'.

Integers have the usual values. To denote a negative integer, use the prefix operator '-' discussed under expressions (*note Prefix Operators: Prefix Ops.).

1.35 Bignums

Bignums
.....

A "bignum" has the same syntax and semantics as an integer except that the number (or its negative) takes more than 32 bits to represent in binary. The distinction is made because in some places integers are permitted while bignums are not.

1.36 Flonums

Flonums
.....

A "flonum" represents a floating point number. The translation is indirect: a decimal floating point number from the text is converted by 'as' to a generic binary floating point number of more than sufficient precision. This generic floating point number is converted to a particular computer's floating point format (or formats) by a portion

of 'as' specialized to that computer.

A flonum is written by writing (in order)

- * The digit '0'. ('0' is optional on the HPPA.)
- * A letter, to tell 'as' the rest of the number is a flonum. 'e' is recommended. Case is not important.

On the H8/300, H8/500, Hitachi SH, and AMD 29K architectures, the letter must be one of the letters 'DFPRSX' (in upper or lower case).

On the Intel 960 architecture, the letter must be one of the letters 'DFT' (in upper or lower case).

On the HPPA architecture, the letter must be 'E' (upper case only).

- * An optional sign: either '+' or '-'.
- * An optional "integer part": zero or more decimal digits.
- * An optional "fractional part": '.' followed by zero or more decimal digits.
- * An optional exponent, consisting of:
 - * An 'E' or 'e'.
 - * Optional sign: either '+' or '-'.
 - * One or more decimal digits.

At least one of the integer part or the fractional part must be present. The floating point number has the usual base-10 value.

'as' does all processing using integers. Flonums are computed independently of any floating point hardware in the computer running 'as'.

1.37 Sections

Sections and Relocation

* Menu:

* Secs Background	Background
* Ld Sections	ld Sections
* As Sections	as Internal Sections
* Sub-Sections	Sub-Sections
* bss	bss Section

1.38 Secs Background

Background

=====

Roughly, a section is a range of addresses, with no gaps; all data "in" those addresses is treated the same for some particular purpose. For example there may be a "read only" section.

The linker `'ld'` reads many object files (partial programs) and combines their contents to form a runnable program. When `'as'` emits an object file, the partial program is assumed to start at address 0. `'ld'` assigns the final addresses for the partial program, so that different partial programs do not overlap. This is actually an oversimplification, but it suffices to explain how `'as'` uses sections.

`'ld'` moves blocks of bytes of your program to their run-time addresses. These blocks slide to their run-time addresses as rigid units; their length does not change and neither does the order of bytes within them. Such a rigid unit is called a **section**. Assigning run-time addresses to sections is called "relocation". It includes the task of adjusting mentions of object-file addresses so they refer to the proper run-time addresses. For the H8/300 and H8/500, and for the Hitachi SH, `'as'` pads sections if needed to ensure they end on a word (sixteen bit) boundary.

An object file written by `'as'` has at least three sections, any of which may be empty. These are named "text", "data" and "bss" sections.

When it generates COFF output, `'as'` can also generate whatever other named sections you specify using the `'.section'` directive (*note `'.section': Section`). If you do not use any directives that place output in the `'.text'` or `'.data'` sections, these sections still exist, but are empty.

When `'as'` generates SOM or ELF output for the HPPA, `'as'` can also generate whatever other named sections you specify using the `'.space'` and `'.subspace'` directives. See 'HP9000 Series 800 Assembly Language Reference Manual' (HP 92432-90001) for details on the `'.space'` and `'.subspace'` assembler directives.

Additionally, `'as'` uses different names for the standard text, data, and bss sections when generating SOM output. Program text is placed into the `'$CODE$'` section, data into `'$DATA$'`, and BSS into `'BSS'`.

Within the object file, the text section starts at address `'0'`, the data section follows, and the bss section follows the data section.

When generating either SOM or ELF output files on the HPPA, the text section starts at address `'0'`, the data section at address `'0x4000000'`, and the bss section follows the data section.

To let `'ld'` know which data changes when the sections are relocated, and how to change that data, `'as'` also writes to the object file details of the relocation needed. To perform relocation `'ld'` must know, each time an address in the object file is mentioned:

- * Where in the object file is the beginning of this reference to an address?
- * How long (in bytes) is this reference?
- * Which section does the address refer to? What is the numeric value of
 $(\text{ADDRESS}) - (\text{START-ADDRESS OF SECTION})$?
- * Is the reference to an address "Program-Counter relative"?

In fact, every address 'as' ever uses is expressed as
 $(\text{SECTION}) + (\text{OFFSET INTO SECTION})$

Further, most expressions 'as' computes have this section-relative nature. (For some object formats, such as SOM for the HPPA, some expressions are symbol-relative instead.)

In this manual we use the notation {SECNAME N} to mean "offset N into section SECNAME."

Apart from text, data and bss sections you need to know about the "absolute" section. When 'ld' mixes partial programs, addresses in the absolute section remain unchanged. For example, address '{absolute 0}' is "relocated" to run-time address 0 by 'ld'. Although the linker never arranges two partial programs' data sections with overlapping addresses after linking, *by definition* their absolute sections must overlap. Address '{absolute 239}' in one part of a program is always the same address when the program is running as address '{absolute 239}' in any other part of the program.

The idea of sections is extended to the "undefined" section. Any address whose section is unknown at assembly time is by definition rendered {undefined U}--where U is filled in later. Since numbers are always defined, the only way to generate an undefined address is to mention an undefined symbol. A reference to a named common block would be such a symbol: its value is unknown at assembly time so it has section *undefined*.

By analogy the word *section* is used to describe groups of sections in the linked program. 'ld' puts all partial programs' text sections in contiguous addresses in the linked program. It is customary to refer to the *text section* of a program, meaning all the addresses of all partial programs' text sections. Likewise for data and bss sections.

Some sections are manipulated by 'ld'; others are invented for use of 'as' and have no meaning except during assembly.

1.39 Ld Sections

Ld Sections
 =====

'ld' deals with just four kinds of sections, summarized below.

1.40 As Sections

as Internal Sections
=====

These sections are meant only for the internal use of 'as'. They have no meaning at run-time. You do not really need to know about these sections for most purposes; but they can be mentioned in 'as' warning messages, so it might be helpful to have an idea of their meanings to 'as'. These sections are used to permit the value of every expression in your assembly language program to be a section-relative address.

ASSEMBLER-INTERNAL-LOGIC-ERROR!

An internal assembler logic error has been found. This means there is a bug in the assembler.

expr section

The assembler stores complex expression internally as combinations of symbols. When it needs to represent an expression as a symbol, it puts it in the expr section.

1.41 Sub-Sections

Sub-Sections
=====

Assembled bytes conventionally fall into two sections: text and data. You may have separate groups of data in named sections that you want to end up near to each other in the object file, even though they are not contiguous in the assembler source. 'as' allows you to use "subsections" for this purpose. Within each section, there can be numbered subsections with values from 0 to 8192. Objects assembled into the same subsection go into the object file together with other objects in the same subsection. For example, a compiler might want to store constants in the text section, but might not want to have them interspersed with the program being assembled. In this case, the compiler could issue a '.text 0' before each section of code being output, and a '.text 1' before each group of constants being output.

Subsections are optional. If you do not use subsections, everything goes in subsection number zero.

Each subsection is zero-padded up to a multiple of four bytes. (Subsections may be padded a different amount on different flavors of 'as'.)

Subsections appear in your object file in numeric order, lowest numbered to highest. (All this to be compatible with other people's assemblers.) The object file contains no representation of subsections; 'ld' and other programs that manipulate object files see no trace of them. They just see all your text subsections as a text section, and all your data subsections as a data section.

To specify which subsection you want subsequent statements assembled

into, use a numeric argument to specify it, in a `'.text EXPRESSION'` or a `'.data EXPRESSION'` statement. When generating COFF output, you can also use an extra subsection argument with arbitrary named sections: `'.section NAME, EXPRESSION'`. `EXPRESSION` should be an absolute expression. (*Note Expressions .) If you just say `'.text'` then `'.text 0'` is assumed. Likewise `'.data'` means `'.data 0'`. Assembly begins in `'.text 0'`. For instance:

```
.text 0      # The default subsection is text 0 anyway.
.ascii "This lives in the first text subsection. *"
.text 1
.ascii "But this lives in the second text subsection."
.data 0
.ascii "This lives in the data section,"
.ascii "in the first data subsection."
.text 0
.ascii "This lives in the first text section,"
.ascii "immediately following the asterisk (*)."
```

Each section has a "location counter" incremented by one for every byte assembled into that section. Because subsections are merely a convenience restricted to `'as'` there is no concept of a subsection location counter. There is no way to directly manipulate a location counter--but the `'.align'` directive changes it, and any label definition captures its current value. The location counter of the section where statements are being assembled is said to be the "active" location counter.

1.42 bss

bss Section
=====

The bss section is used for local common variable storage. You may allocate address space in the bss section, but you may not dictate data to load into it before your program executes. When your program starts running, all the contents of the bss section are zeroed bytes.

Addresses in the bss section are allocated with special directives; you may not assemble anything directly into the bss section. Hence there are no bss subsections. *Note `'.comm'`: `Comm`, *note `'.lcomm'`: `lcomm..`

1.43 Symbols

Symbols

Symbols are a central concept: the programmer uses symbols to name things, the linker uses symbols to link, and the debugger uses symbols to debug.

Warning: `'as'` does not place symbols in the object file in the

same order they were declared. This may break some debuggers.

* Menu:

* Labels	Labels
* Setting Symbols	Giving Symbols Other Values
* Symbol Names	Symbol Names
* Dot	The Special Dot Symbol
* Symbol Attributes	Symbol Attributes

1.44 Labels

Labels

=====

A "label" is written as a symbol immediately followed by a colon `':'`. The symbol then represents the current value of the active location counter, and is, for example, a suitable instruction operand. You are warned if you use the same symbol to represent two different locations: the first definition overrides any other definitions.

On the HPPA, the usual form for a label need not be immediately followed by a colon, but instead must start in column zero. Only one label may be defined on a single line. To work around this, the HPPA version of `'as'` also provides a special directive `'.label'` for defining labels more flexibly.

1.45 Setting Symbols

Giving Symbols Other Values

=====

A symbol can be given an arbitrary value by writing a symbol, followed by an equals sign `'='`, followed by an expression (*note Expressions .). This is equivalent to using the `'.set'` directive.
 *Note `'.set'`: Set.

1.46 Symbol Names

Symbol Names

=====

Symbol names begin with a letter or with one of `['_']`. On most machines, you can also use `'$'` in symbol names; exceptions are noted in *Note Machine Dependencies . That character may be followed by any string of digits, letters, dollar signs (unless otherwise noted in *Note Machine Dependencies), and underscores. For the AMD 29K family, `'?'` is also allowed in the body of a symbol name, though not at its beginning.

Case of letters is significant: `'foo'` is a different symbol name than `'Foo'`.

Each symbol has exactly one name. Each name in an assembly language program refers to exactly one symbol. You may use that symbol name any number of times in a program.

Local Symbol Names

Local symbols help compilers and programmers use names temporarily. There are ten local symbol names, which are re-used throughout the program. You may refer to them using the names `'0'` `'1'` ... `'9'`. To define a local symbol, write a label of the form `'N:'` (where N represents any digit). To refer to the most recent previous definition of that symbol write `'Nb'`, using the same digit as when you defined the label. To refer to the next definition of a local label, write `'Nf'`--where N gives you a choice of 10 forward references. The `'b'` stands for "backwards" and the `'f'` stands for "forwards".

Local symbols are not emitted by the current GNU C compiler.

There is no restriction on how you can use these labels, but remember that at any point in the assembly you can refer to at most 10 prior local labels and to at most 10 forward local labels.

Local symbol names are only a notation device. They are immediately transformed into more conventional symbol names before the assembler uses them. The symbol names stored in the symbol table, appearing in error messages and optionally emitted to the object file have these parts:

`'L'`

All local labels begin with `'L'`. Normally both `'as'` and `'ld'` forget symbols that start with `'L'`. These labels are used for symbols you are never intended to see. If you use the `'-L'` option then `'as'` retains these symbols in the object file. If you also instruct `'ld'` to retain these symbols, you may use them in debugging.

`'DIGIT'`

If the label is written `'0:'` then the digit is `'0'`. If the label is written `'1:'` then the digit is `'1'`. And so on up through `'9:'`.

`'?A'`

This unusual character is included so you do not accidentally invent a symbol of the same name. The character has ASCII value `'\001'`.

`'*ordinal number*'`

This is a serial number to keep the labels distinct. The first `'0:'` gets the number `'1'`; The 15th `'0:'` gets the number `'15'`; *etc.*. Likewise for the other labels `'1:'` through `'9:'`.

For instance, the first `'1:'` is named `'L?A1'`, the 44th `'3:'` is named `'L?A44'`.

1.47 Dot

The Special Dot Symbol

=====

The special symbol `'.'` refers to the current address that `'as'` is assembling into. Thus, the expression `'melvin: .long .'` defines `'melvin'` to contain its own address. Assigning a value to `'.'` is treated the same as a `'org'` directive. Thus, the expression `'.=+4'` is the same as saying `'space 4'`.

1.48 Symbol Attributes

Symbol Attributes

=====

Every symbol has, as well as its name, the attributes "Value" and "Type". Depending on output format, symbols can also have auxiliary attributes.

If you use a symbol without defining it, `'as'` assumes zero for all these attributes, and probably won't warn you. This makes the symbol an externally defined symbol, which is generally what you would want.

* Menu:

* Symbol Value	Value
* Symbol Type	Type

* a.out Symbols	Symbol Attributes: 'a.out'
-----------------	----------------------------

* COFF Symbols	Symbol Attributes for COFF
----------------	----------------------------

* SOM Symbols	Symbol Attributes for SOM
---------------	---------------------------

1.49 Symbol Value

Value

The value of a symbol is (usually) 32 bits. For a symbol which labels a location in the text, data, bss or absolute sections the value is the number of addresses from the start of that section to the label. Naturally for text, data and bss sections the value of a symbol changes as `'ld'` changes section base addresses during linking. Absolute symbols' values do not change during linking: that is why they are called absolute.

The value of an undefined symbol is treated in a special way. If it is 0 then the symbol is not defined in this assembler source file, and `'ld'` tries to determine its value from other files linked into the same

program. You make this kind of symbol simply by mentioning a symbol name without defining it. A non-zero value represents a ``.comm'` common declaration. The value is how much common storage to reserve, in bytes (addresses). The symbol refers to the first address of the allocated storage.

1.50 Symbol Type

Type

The type attribute of a symbol contains relocation (section) information, any flag settings indicating that a symbol is external, and (optionally), other information for linkers and debuggers. The exact format depends on the object-code output format in use.

1.51 a.out Symbols

Symbol Attributes: ``a.out'`

* Menu:

* Symbol Desc	Descriptor
* Symbol Other	Other

1.52 Symbol Desc

Descriptor

.....

This is an arbitrary 16-bit value. You may establish a symbol's descriptor value by using a ``.desc'` statement (*note ``.desc': Desc.`). A descriptor value means nothing to ``as'`.

1.53 Symbol Other

Other

.....

This is an arbitrary 8-bit value. It means nothing to ``as'`.

1.54 COFF Symbols

Symbol Attributes for COFF

The COFF format supports a multitude of auxiliary symbol attributes; like the primary symbol attributes, they are set between ``.def`` and ``.endef`` directives.

Primary Attributes

The symbol name is set with ``.def``; the value and type, respectively, with ``.val`` and ``.type``.

Auxiliary Attributes

The ``.as`` directives ``.dim``, ``.line``, ``.scl``, ``.size``, and ``.tag`` can generate auxiliary symbol table information for COFF.

1.55 SOM Symbols

Symbol Attributes for SOM

The SOM format for the HPPA supports a multitude of symbol attributes set with the ``.EXPORT`` and ``.IMPORT`` directives.

The attributes are described in 'HP9000 Series 800 Assembly Language Reference Manual' (HP 92432-90001) under the ``.IMPORT`` and ``.EXPORT`` assembler directive documentation.

1.56 Expressions

Expressions

An "expression" specifies an address or numeric value. Whitespace may precede and/or follow an expression.

The result of an expression must be an absolute number, or else an offset into a particular section. If an expression is not absolute, and there is not enough information when ``.as`` sees the expression to know its section, a second pass over the source program might be necessary to interpret the expression--but the second pass is currently not implemented. ``.as`` aborts with an error message in this situation.

* Menu:

* Empty Exprs	Empty Expressions
* Integer Exprs	Integer Expressions

1.57 Empty Exprs

Empty Expressions
=====

An empty expression has no value: it is just whitespace or null. Wherever an absolute expression is required, you may omit the expression, and 'as' assumes a value of (absolute) 0. This is compatible with other assemblers.

1.58 Integer Exprs

Integer Expressions
=====

An "integer expression" is one or more **arguments** delimited by **operators**.

* Menu:

* Arguments	Arguments
* Operators	Operators
* Prefix Ops	Prefix Operators
* Infix Ops	Infix Operators

1.59 Arguments

Arguments

"Arguments" are symbols, numbers or subexpressions. In other contexts arguments are sometimes called "arithmetic operands". In this manual, to avoid confusing them with the "instruction operands" of the machine language, we use the term "argument" to refer to parts of expressions only, reserving the word "operand" to refer only to machine instruction operands.

Symbols are evaluated to yield {SECTION NNN} where SECTION is one of text, data, bss, absolute, or undefined. NNN is a signed, 2's complement 32 bit integer.

Numbers are usually integers.

A number can be a flonum or bignum. In this case, you are warned that only the low order 32 bits are used, and 'as' pretends these 32 bits are an integer. You may write integer-manipulating instructions that act on exotic constants, compatible with other assemblers.

Subexpressions are a left parenthesis '(' followed by an integer expression, followed by a right parenthesis ')'; or a prefix operator followed by an argument.

1.60 Operators

Operators

"Operators" are arithmetic functions, like '+' or '%'. Prefix operators are followed by an argument. Infix operators appear between their arguments. Operators may be preceded and/or followed by whitespace.

1.61 Prefix Ops

Prefix Operator

'as' has the following "prefix operators". They each take one argument, which must be absolute.

'-'
"Negation". Two's complement negation.

'~'
"Complementation". Bitwise not.

1.62 Infix Ops

Infix Operators

"Infix operators" take two arguments, one on either side. Operators have precedence, but operations with equal precedence are performed left to right. Apart from '+' or '-', both arguments must be absolute, and the result is absolute.

1. Highest Precedence

'*'
"Multiplication".

'/'
"Division". Truncation is the same as the C operator '/'

'%'
"Remainder".

'<'
'<<'
"Shift Left". Same as the C operator '<<'.

'>'
'>>'
"Shift Right". Same as the C operator '>>'.

2. Intermediate precedence

```
'|'
    "Bitwise Inclusive Or".
```

```
'&'
    "Bitwise And".
```

```
'^'
    "Bitwise Exclusive Or".
```

```
'!'
    "Bitwise Or Not".
```

3. Lowest Precedence

```
'+'
    "Addition". If either argument is absolute, the result has
    the section of the other argument. You may not add together
    arguments from different sections.
```

```
'-'
    "Subtraction". If the right argument is absolute, the result
    has the section of the left argument. If both arguments are
    in the same section, the result is absolute. You may not
    subtract arguments from different sections.
```

In short, it's only meaningful to add or subtract the **offsets** in an address; you can only have a defined section in one of the two arguments.

1.63 Pseudo Ops

Assembler Directives

```
*****
```

All assembler directives have names that begin with a period ('.'). The rest of the name is letters, usually in lower case.

This chapter discusses directives that are available regardless of the target machine configuration for the GNU assembler. Some machine configurations provide additional directives. **Note Machine Dependencies .*

* Menu:

* Abort '.abort'

* ABORT '.ABORT'

* Align '.align ABS-EXPR , ABS-EXPR'

* App-File '.app-file STRING'

* Ascii '.ascii "STRING"'...

* Asciz '.asciz "STRING"'...

* Byte	` .byte EXPRESSIONS'
* Comm	` .comm SYMBOL , LENGTH '
* Data	` .data SUBSECTION'
* Def	` .def NAME'
* Desc	` .desc SYMBOL, ABS-EXPRESSION'
* Dim	` .dim'
* Double	` .double FLONUMS'
* Eject	` .eject'
* Else	` .else'
* Endef	` .endef'
* Endif	` .endif'
* Equ	` .equ SYMBOL, EXPRESSION'
* Extern	` .extern'
* File	` .file STRING'
* Fill	` .fill REPEAT , SIZE , VALUE'
* Float	` .float FLONUMS'
* Global	` .global SYMBOL', ` .globl SYMBOL'
* hword	` .hword EXPRESSIONS'
* Ident	` .ident'
* If	` .if ABSOLUTE EXPRESSION'
* Include	` .include "FILE"'
* Int	` .int EXPRESSIONS'
* Lcomm	` .lcomm SYMBOL , LENGTH'
* Lflags	` .lflags'
* Line	` .line LINE-NUMBER'
* Ln	` .ln LINE-NUMBER'
* List	` .list'
* Long	` .long EXPRESSIONS'
* Nolist	` .nolist'
* Octa	` .octa BIGNUMS'
* Org	` .org NEW-LC , FILL'
* Psize	` .psize LINES, COLUMNS'
* Quad	` .quad BIGNUMS'
* Sbtatl	` .sbtatl "SUBHEADING"'
* Scl	` .scl CLASS'
* Section	` .section NAME, SUBSECTION'
* Set	` .set SYMBOL, EXPRESSION'
* Short	` .short EXPRESSIONS'
* Single	` .single FLONUMS'
* Size	` .size'
* Space	` .space SIZE , FILL'

```

* Stab          '.stabd, .stabn, .stabs'
* String        '.string "STR"'
* Tag           '.tag STRUCTNAME'
* Text          '.text SUBSECTION'
* Title         '.title "HEADING"'
* Type          '.type INT'
* Val           '.val ADDR'
* Word          '.word EXPRESSIONS'
* Deprecated    Deprecated Directives

```

1.64 Abort

```

'.abort'
=====

```

This directive stops the assembly immediately. It is for compatibility with other assemblers. The original idea was that the assembly language source would be piped into the assembler. If the sender of the source quit, it could use this directive tells 'as' to quit also. One day '.abort' will not be supported.

1.65 ABORT

```

'.ABORT'
=====

```

When producing COFF output, 'as' accepts this directive as a synonym for '.abort'.

When producing 'b.out' output, 'as' accepts this directive, but ignores it.

1.66 Align

```

'.align ABS-EXPR , ABS-EXPR'
=====

```

Pad the location counter (in the current subsection) to a particular storage boundary. The first expression (which must be absolute) is the number of low-order zero bits the location counter must have after advancement. For example '.align 3' advances the location counter until it a multiple of 8. If the location counter is already a multiple of 8, no change is needed.

For the HPPA, the first expression (which must be absolute) is the alignment request in bytes. For example ``.align 8`` advances the location counter until it is a multiple of 8. If the location counter is already a multiple of 8, no change is needed.

The second expression (also absolute) gives the value to be stored in the padding bytes. It (and the comma) may be omitted. If it is omitted, the padding bytes are zero.

1.67 App-File

```
`.app-file STRING'
=====
```

``.app-file`` (which may also be spelled ``.file``) tells `as` that we are about to start a new logical file. `STRING` is the new file name. In general, the filename is recognized whether or not it is surrounded by quotes `""`; but if you wish to specify an empty file name is permitted, you must give the quotes-`""`. This statement may go away in future: it is only recognized to be compatible with old `as` programs.

1.68 Ascii

```
`.ascii "STRING" '...
=====
```

``.ascii`` expects zero or more string literalStrings .) separated by commas. It assembles each string (with no automatic trailing zero byte) into consecutive addresses.

1.69 Asciz

```
`.asciz "STRING" '...
=====
```

``.asciz`` is just like ``.ascii``, but each string is followed by a zero byte. The `"z"` in ``.asciz`` stands for `"zero"`.

1.70 Byte

```
`.byte EXPRESSIONS'
=====
```

``.byte`` expects zero or more expressions, separated by commas. Each expression is assembled into the next byte.

1.71 Comm

```
`.comm SYMBOL , LENGTH '  
=====
```

`.comm' declares a named common area in the bss section. Normally 'ld' reserves memory addresses for it during linking, so no partial program defines the location of the symbol. Use 'comm' to tell 'ld' that it must be at least LENGTH bytes long. 'ld' allocates space for each 'comm' symbol that is at least as long as the longest 'comm' request in any of the partial programs linked. LENGTH is an absolute expression.

The syntax for 'comm' differs slightly on the HPPA. The syntax is 'SYMBOL .comm, LENGTH'; SYMBOL is optional.

1.72 Data

```
`.data SUBSECTION'  
=====
```

`.data' tells 'as' to assemble the following statements onto the end of the data subsection numbered SUBSECTION (which is an absolute expression). If SUBSECTION is omitted, it defaults to zero.

1.73 Def

```
`.def NAME'  
=====
```

Begin defining debugging information for a symbol NAME; the definition extends until the 'endef' directive is encountered.

This directive is only observed when 'as' is configured for COFF format output; when producing 'b.out', 'def' is recognized, but ignored.

1.74 Desc

```
`.desc SYMBOL, ABS-EXPRESSION'  
=====
```

This directive sets the descriptor of the symbol (*note Symbol Attributes .) to the low 16 bits of an absolute expression.

The 'desc' directive is not available when 'as' is configured for COFF output; it is only for 'a.out' or 'b.out' object format. For the sake of compatibility, 'as' accepts it, but produces no output, when configured for COFF.

1.75 Dim

```
`dim'  
=====
```

This directive is generated by compilers to include auxiliary debugging information in the symbol table. It is only permitted inside ``.def'/'`.endef'` pairs.

``.dim'` is only meaningful when generating COFF format output; when ``as'` is generating ``b.out'`, it accepts this directive but ignores it.

1.76 Double

```
`double FLONUMS'  
=====
```

``.double'` expects zero or more flonums, separated by commas. It assembles floating point numbers. The exact kind of floating point numbers emitted depends on how ``as'` is configured. *Note Machine Dependencies .

1.77 Eject

```
`eject'  
=====
```

Force a page break at this point, when generating assembly listings.

1.78 Else

```
`else'  
=====
```

``.else'` is part of the ``as'` support for conditional assembly; *note ``.if': If..` It marks the beginning of a section of code to be assembled if the condition for the preceding ``.if'` was false.

1.79 Endef

```
`endef'  
=====
```

This directive flags the end of a symbol definition begun with ``.def'`.

``.endef'` is only meaningful when generating COFF format output; if

'as' is configured to generate 'b.out', it accepts this directive but ignores it.

1.80 Endif

```
'.endif'
=====
```

'.endif' is part of the 'as' support for conditional assembly; it marks the end of a block of code that is only assembled conditionally. *Note '.if': If.

1.81 Equ

```
'.equ SYMBOL, EXPRESSION'
=====
```

This directive sets the value of SYMBOL to EXPRESSION. It is synonymous with '.set'; *note '.set': Set..

The syntax for 'equ' on the HPPA is 'SYMBOL .equ EXPRESSION'.

1.82 Extern

```
'.extern'
=====
```

'.extern' is accepted in the source program--for compatibility with other assemblers--but it is ignored. 'as' treats all undefined symbols as external.

1.83 File

```
'.file STRING'
=====
```

'.file' (which may also be spelled '.app-file') tells 'as' that we are about to start a new logical file. STRING is the new file name. In general, the filename is recognized whether or not it is surrounded by quotes ''; but if you wish to specify an empty file name, you must give the quotes-"". This statement may go away in future: it is only recognized to be compatible with old 'as' programs. In some configurations of 'as', '.file' has already been removed to avoid conflicts with other assemblers. *Note Machine Dependencies .

1.84 Fill

```
`.fill REPEAT , SIZE , VALUE'
=====
```

RESULT, SIZE and VALUE are absolute expressions. This emits REPEAT copies of SIZE bytes. REPEAT may be zero or more. SIZE may be zero or more, but if it is more than 8, then it is deemed to have the value 8, compatible with other people's assemblers. The contents of each REPEAT bytes is taken from an 8-byte number. The highest order 4 bytes are zero. The lowest order 4 bytes are VALUE rendered in the byte-order of an integer on the computer 'as' is assembling for. Each SIZE bytes in a repetition is taken from the lowest order SIZE bytes of this number. Again, this bizarre behavior is compatible with other people's assemblers.

SIZE and VALUE are optional. If the second comma and VALUE are absent, VALUE is assumed zero. If the first comma and following tokens are absent, SIZE is assumed to be 1.

1.85 Float

```
`.float FLONUMS'
=====
```

This directive assembles zero or more flonums, separated by commas. It has the same effect as 'single'. The exact kind of floating point numbers emitted depends on how 'as' is configured. *Note Machine Dependencies .

1.86 Global

```
`.global SYMBOL', `globl SYMBOL'
=====
```

'global' makes the symbol visible to 'ld'. If you define SYMBOL in your partial program, its value is made available to other partial programs that are linked with it. Otherwise, SYMBOL takes its attributes from a symbol of the same name from another file linked into the same program.

Both spellings ('globl' and 'global') are accepted, for compatibility with other assemblers.

On the HPPA, 'global' is not always enough to make it accessible to other partial programs. You may need the HPPA-only 'EXPORT' directive as well. *Note HPPA Assembler Directives: HPPA Directives.

1.87 hword

```
\.hword EXPRESSIONS'
=====
```

This expects zero or more EXPRESSIONS, and emits a 16 bit number for each.

This directive is a synonym for ``.short'`; depending on the target architecture, it may also be a synonym for ``.word'`.

1.88 Ident

```
\.ident'
=====
```

This directive is used by some assemblers to place tags in object files. ``.as'` simply accepts the directive for source-file compatibility with such assemblers, but does not actually emit anything for it.

1.89 If

```
\.if ABSOLUTE EXPRESSION'
=====
```

``.if'` marks the beginning of a section of code which is only considered part of the source program being assembled if the argument (which must be an ABSOLUTE EXPRESSION) is non-zero. The end of the conditional section of code must be marked by ``.endif'` (*note ``.endif'`: Endif.); optionally, you may include code for the alternative condition, flagged by ``.else'` (*note ``.else'`: Else..

The following variants of ``.if'` are also supported:

```
\.ifdef SYMBOL'
```

Assembles the following section of code if the specified SYMBOL has been defined.

```
\.ifndef SYMBOL'
```

```
\.ifnotdef SYMBOL'
```

Assembles the following section of code if the specified SYMBOL has not been defined. Both spelling variants are equivalent.

1.90 Include

```
\.include "FILE"
=====
```

This directive provides a way to include supporting files at specified points in your source program. The code from FILE is assembled as if it followed the point of the ``.include'`; when the end of the included file is reached, assembly of the original file

continues. You can control the search paths used with the `'-I'` command-line option (*note Command-Line Options: Invoking.). Quotation marks are required around FILE.

1.91 Int

```
'.int EXPRESSIONS'  
=====
```

Expect zero or more EXPRESSIONS, of any section, separated by commas. For each expression, emit a number that, at run time, is the value of that expression. The byte order and bit size of the number depends on what kind of target the assembly is for.

1.92 Lcomm

```
'.lcomm SYMBOL , LENGTH'  
=====
```

Reserve LENGTH (an absolute expression) bytes for a local common denoted by SYMBOL. The section and value of SYMBOL are those of the new local common. The addresses are allocated in the bss section, so that at run-time the bytes start off zeroed. SYMBOL is not declared global (*note `'.global'`: Global.), so is normally not visible to `'ld'`.

The syntax for `'.lcomm'` differs slightly on the HPPA. The syntax is `'SYMBOL .lcomm, LENGTH';` SYMBOL is optional.

1.93 Lflags

```
'.lflags'  
=====
```

`'as'` accepts this directive, for compatibility with other assemblers, but ignores it.

1.94 Line

```
'.line LINE-NUMBER'  
=====
```

Change the logical line number. LINE-NUMBER must be an absolute expression. The next line has that logical line number. Therefore any other statements on the current line (after a statement separator character) are reported as on logical line number LINE-NUMBER - 1. One day `'as'` will no longer support this directive: it is recognized only for compatibility with existing assembler programs.

Warning: In the AMD29K configuration of as, this command is not available; use the synonym ``.ln`` in that context.

Even though this is a directive associated with the ``.a.out`` or ``.b.out`` object-code formats, ``.as`` still recognizes it when producing COFF output, and treats ``.line`` as though it were the COFF ``.ln`` *if* it is found outside a ``.def`/`.endef`` pair.

Inside a ``.def``, ``.line`` is, instead, one of the directives used by compilers to generate auxiliary symbol information for debugging.

1.95 Ln

```
`.ln LINE-NUMBER`  
=====
```

``.ln`` is a synonym for ``.line``.

1.96 List

```
`.list`  
=====
```

Control (in conjunction with the ``.nolist`` directive) whether or not assembly listings are generated. These two directives maintain an internal counter (which is zero initially). ``.list`` increments the counter, and ``.nolist`` decrements it. Assembly listings are generated whenever the counter is greater than zero.

By default, listings are disabled. When you enable them (with the ``.a`` command line option; *note Command-Line Options: Invoking.), the initial value of the listing counter is one.

1.97 Long

```
`.long EXPRESSIONS`  
=====
```

``.long`` is the same as ``.int``, *note ``.int``: Int..

1.98 Nolist

```
`.nolist`  
=====
```

Control (in conjunction with the ``.list`` directive) whether or not

assembly listings are generated. These two directives maintain an internal counter (which is zero initially). ``.list'` increments the counter, and ``.nolist'` decrements it. Assembly listings are generated whenever the counter is greater than zero.

1.99 Octa

```
`.octa BIGNUMS'  
=====
```

This directive expects zero or more bignums, separated by commas. For each bignum, it emits a 16-byte integer.

The term "octa" comes from contexts in which a "word" is two bytes; hence `*octa*-word` for 16 bytes.

1.100 Org

```
`.org NEW-LC , FILL'  
=====
```

Advance the location counter of the current section to NEW-LC. NEW-LC is either an absolute expression or an expression with the same section as the current subsection. That is, you can't use ``.org'` to cross sections: if NEW-LC has the wrong section, the ``.org'` directive is ignored. To be compatible with former assemblers, if the section of NEW-LC is absolute, `as` issues a warning, then pretends the section of NEW-LC is the same as the current subsection.

``.org'` may only increase the location counter, or leave it unchanged; you cannot use ``.org'` to move the location counter backwards.

Because `as` tries to assemble programs in one pass, NEW-LC may not be undefined. If you really detest this restriction we eagerly await a chance to share your improved assembler.

Beware that the origin is relative to the start of the section, not to the start of the subsection. This is compatible with other people's assemblers.

When the location counter (of the current subsection) is advanced, the intervening bytes are filled with FILL which should be an absolute expression. If the comma and FILL are omitted, FILL defaults to zero.

1.101 Psize

```
`.psize LINES , COLUMNS'  
=====
```

Use this directive to declare the number of lines--and, optionally,

the number of columns--to use for each page, when generating listings.

If you do not use ``.psize'`, listings use a default line-count of 60. You may omit the comma and COLUMNS specification; the default width is 200 columns.

``.as'` generates formfeeds whenever the specified number of lines is exceeded (or whenever you explicitly request one, using ``.eject'`).

If you specify LINES as ``.0'`, no formfeeds are generated save those explicitly specified with ``.eject'`.

1.102 Quad

```
`.quad BIGNUMS'  
=====
```

``.quad'` expects zero or more bignums, separated by commas. For each bignum, it emits an 8-byte integer. If the bignum won't fit in 8 bytes, it prints a warning message; and just takes the lowest order 8 bytes of the bignum.

The term "quad" comes from contexts in which a "word" is two bytes; hence `*quad*`-word for 8 bytes.

1.103 Sbttl

```
`.sbttl "SUBHEADING"  
=====
```

Use SUBHEADING as the title (third line, immediately after the title line) when generating assembly listings.

This directive affects subsequent pages, as well as the current page if it appears within ten lines of the top of a page.

1.104 Scl

```
`.scl CLASS'  
=====
```

Set the storage-class value for a symbol. This directive may only be used inside a ``.def'/.endef'` pair. Storage class may flag whether a symbol is static or external, or it may record further symbolic debugging information.

The ``.scl'` directive is primarily associated with COFF output; when configured to generate ``.b.out'` output format, ``.as'` accepts this directive but ignores it.

1.105 Section

```
\.section NAME, SUBSECTION'
=====
```

Assemble the following code into end of subsection numbered SUBSECTION in the COFF named section NAME. If you omit SUBSECTION, 'as' uses subsection number zero. '.section .text' is equivalent to the '.text' directive; '.section .data' is equivalent to the '.data' directive.

1.106 Set

```
\.set SYMBOL, EXPRESSION'
=====
```

Set the value of SYMBOL to EXPRESSION. This changes SYMBOL's value and type to conform to EXPRESSION. If SYMBOL was flagged as external, it remains flagged. (*Note Symbol Attributes .)

You may '.set' a symbol many times in the same assembly.

If you '.set' a global symbol, the value stored in the object file is the last value stored into it.

The syntax for 'set' on the HPPA is 'SYMBOL .set EXPRESSION'.

1.107 Short

```
\.short EXPRESSIONS'
=====
```

'.short' is normally the same as '.word'. *Note '.word': Word.

In some configurations, however, '.short' and '.word' generate numbers of different lengths; Machine Dependencies ..

1.108 Single

```
\.single FLONUMS'
=====
```

This directive assembles zero or more flonums, separated by commas. It has the same effect as '.float'. The exact kind of floating point numbers emitted depends on how 'as' is configured. *Note Machine Dependencies .

1.109 Size

```
`.size'
=====
```

This directive is generated by compilers to include auxiliary debugging information in the symbol table. It is only permitted inside ``.def'/'`.endef'` pairs.

``.size'` is only meaningful when generating COFF format output; when ``as'` is generating ``b.out'`, it accepts this directive but ignores it.

1.110 Space

```
`.space SIZE , FILL'
=====
```

This directive emits SIZE bytes, each of value FILL. Both SIZE and FILL are absolute expressions. If the comma and FILL are omitted, FILL is assumed to be zero.

Warning: ``.space'` has a completely different meaning for HPPA targets; use ``.block'` as a substitute. See ``HP9000 Series 800 Assembly Language Reference Manual'` (HP 92432-90001) for the meaning of the ``.space'` directive. **Note** HPPA Assembler Directives: HPPA Directives, for a summary.

On the AMD 29K, this directive is ignored; it is accepted for compatibility with other AMD 29K assemblers.

Warning: In most versions of the GNU assembler, the directive ``.space'` has the effect of ``.block'` **Note** Machine Dependencies .

1.111 Stab

```
`.stabd, .stabn, .stabs'
=====
```

There are three directives that begin ``.stab'`. All emit symbols (Symbols .), for use by symbolic debuggers. The symbols are not entered in the ``as'` hash table: they cannot be referenced elsewhere in the source file. Up to five fields are required:

STRING

This is the symbol's name. It may contain any character except ``\000'`, so is more general than ordinary symbol names. Some debuggers used to code arbitrarily complex structures into symbol names using this field.

TYPE

An absolute expression. The symbol's type is set to the low 8 bits of this expression. Any bit pattern is permitted, but ``ld'`

and debuggers choke on silly bit patterns.

OTHER

An absolute expression. The symbol's "other" attribute is set to the low 8 bits of this expression.

DESC

An absolute expression. The symbol's descriptor is set to the low 16 bits of this expression.

VALUE

An absolute expression which becomes the symbol's value.

If a warning is detected while reading a `'.stabd'`, `'.stabn'`, or `'.stabs'` statement, the symbol has probably already been created; you get a half-formed symbol in your object file. This is compatible with earlier assemblers!

`'.stabd TYPE , OTHER , DESC'`

The "name" of the symbol generated is not even an empty string. It is a null pointer, for compatibility. Older assemblers used a null pointer so they didn't waste space in object files with empty strings.

The symbol's value is set to the location counter, relocatably. When your program is linked, the value of this symbol is the address of the location counter when the `'.stabd'` was assembled.

`'.stabn TYPE , OTHER , DESC , VALUE'`

The name of the symbol is set to the empty string `''`.

`'.stabs STRING , TYPE , OTHER , DESC , VALUE'`

All five fields are specified.

1.112 String

`'.string' "STR"`

=====

Copy the characters in STR to the object file. You may specify more than one string to copy, separated by commas. Unless otherwise specified for a particular machine, the assembler marks the end of each string with a 0 byte. You can use any of the escape sequences described in **Note Strings: Strings*.

1.113 Tag

`'.tag STRUCTNAME'`

=====

This directive is generated by compilers to include auxiliary debugging information in the symbol table. It is only permitted inside

``.def'/'`.endef'` pairs. Tags are used to link structure definitions in the symbol table with instances of those structures.

``.tag'` is only used when generating COFF format output; when ``as'` is generating ``b.out'`, it accepts this directive but ignores it.

1.114 Text

```
`.text SUBSECTION'  
=====
```

Tells ``as'` to assemble the following statements onto the end of the text subsection numbered SUBSECTION, which is an absolute expression. If SUBSECTION is omitted, subsection number zero is used.

1.115 Title

```
`.title "HEADING"  
=====
```

Use HEADING as the title (second line, immediately after the source file name and pagenumber) when generating assembly listings.

This directive affects subsequent pages, as well as the current page if it appears within ten lines of the top of a page.

1.116 Type

```
`.type INT'  
=====
```

This directive, permitted only within ``.def'/'`.endef'` pairs, records the integer INT as the type attribute of a symbol table entry.

``.type'` is associated only with COFF format output; when ``as'` is configured for ``b.out'` output, it accepts this directive but ignores it.

1.117 Val

```
`.val ADDR'  
=====
```

This directive, permitted only within ``.def'/'`.endef'` pairs, records the address ADDR as the value attribute of a symbol table entry.

``.val'` is used only for COFF output; when ``as'` is configured for ``b.out'`, it accepts this directive but ignores it.

1.118 Word

``.word EXPRESSIONS'`
=====

This directive expects zero or more EXPRESSIONS, of any section, separated by commas.

The size of the number emitted, and its byte order, depend on what target computer the assembly is for.

Warning: Special Treatment to support Compilers

Machines with a 32-bit address space, but that do less than 32-bit addressing, require the following special treatment. If the machine of interest to you does 32-bit addressing (or doesn't require it; **note Machine Dependencies .*), you can ignore this issue.

In order to assemble compiler output into something that works, `'as'` occasionally does strange things to ``.word'` directives. Directives of the form ``.word sym1-sym2'` are often emitted by compilers as part of jump tables. Therefore, when `'as'` assembles a directive of the form ``.word sym1-sym2'`, and the difference between `'sym1'` and `'sym2'` does not fit in 16 bits, `'as'` creates a "secondary jump table", immediately before the next label. This secondary jump table is preceded by a short-jump to the first byte after the secondary table. This short-jump prevents the flow of control from accidentally falling into the new table. Inside the table is a long-jump to `'sym2'`. The original ``.word'` contains `'sym1'` minus the address of the long-jump to `'sym2'`.

If there were several occurrences of ``.word sym1-sym2'` before the secondary jump table, all of them are adjusted. If there was a ``.word sym3-sym4'`, that also did not fit in sixteen bits, a long-jump to `'sym4'` is included in the secondary jump table, and the ``.word'` directives are adjusted to contain `'sym3'` minus the address of the long-jump to `'sym4'`; and so on, for as many entries in the original jump table as necessary.

1.119 Deprecated

Deprecated Directives
=====

One day these directives won't work. They are included for compatibility with older assemblers.

`.abort`
`.app-file`
`.line`

1.120 Machine Dependencies

Machine Dependent Features

The machine instruction sets are (almost by definition) different on each machine where 'as' runs. Floating point representations vary as well, and 'as' often supports a few additional directives or command-line options for compatibility with other assemblers on a particular platform. Finally, some versions of 'as' support special pseudo-instructions for branch optimization.

This chapter discusses most of these differences, though it does not include details on any machine's instruction set. For details on that subject, see the hardware manufacturer's manual.

* Menu:

* Vax-Dependent	VAX Dependent Features
* AMD29K-Dependent	AMD 29K Dependent Features
* H8/300-Dependent	Hitachi H8/300 Dependent Features
* H8/500-Dependent	Hitachi H8/500 Dependent Features
* HPPA-Dependent	HPPA Dependent Features
* SH-Dependent	Hitachi SH Dependent Features
* i960-Dependent	Intel 80960 Dependent Features
* M68K-Dependent	M680x0 Dependent Features
* Sparc-Dependent	SPARC Dependent Features
* Z8000-Dependent	Z8000 Dependent Features
* MIPS-Dependent	MIPS Dependent Features
* i386-Dependent	80386 Dependent Features

1.121 Vax-Dependent

VAX Dependent Features

=====

* Menu:

* Vax-Opts	VAX Command-Line Options
* VAX-float	VAX Floating Point
* VAX-directives	Vax Machine Directives
* VAX-opcodes	VAX Opcodes
* VAX-branch	VAX Branch Improvement
* VAX-operands	VAX Operands

* VAX-no

Not Supported on VAX

1.122 Vax-Opts

VAX Command-Line Options

The Vax version of 'as' accepts any of the following options, gives a warning message that the option was ignored and proceeds. These options are for compatibility with scripts designed for other people's assemblers.

'-D' (Debug)'

'-S' (Symbol Table)'

'-T' (Token Trace)'

These are obsolete options used to debug old assemblers.

'-d' (Displacement size for JUMPs)'

This option expects a number following the '-d'. Like options that expect filenames, the number may immediately follow the '-d' (old standard) or constitute the whole of the command line argument that follows '-d' (GNU standard).

'-V' (Virtualize Interpass Temporary File)'

Some other assemblers use a temporary file. This option commanded them to keep the information in active memory rather than in a disk file. 'as' always does this, so this option is redundant.

'-J' (JUMPify Longer Branches)'

Many 32-bit computers permit a variety of branch instructions to do the same job. Some of these instructions are short (and fast) but have a limited range; others are long (and slow) but can branch anywhere in virtual memory. Often there are 3 flavors of branch: short, medium and long. Some other assemblers would emit short and medium branches, unless told by this option to emit short and long branches.

'-t' (Temporary File Directory)'

Some other assemblers may use a temporary file, and this option takes a filename being the directory to site the temporary file. Since 'as' does not use a temporary disk file, this option makes no difference. '-t' needs exactly one filename.

The Vax version of the assembler accepts two options when compiled for VMS. They are '-h', and '-+'. The '-h' option prevents 'as' from modifying the symbol-table entries for symbols that contain lowercase characters (I think). The '-+' option causes 'as' to print warning messages if the FILENAME part of the object file, or any symbol name is larger than 31 characters. The '-+' option also inserts some code following the '_main' symbol so that the object file is compatible with Vax-11 "C".

1.123 VAX-float

VAX Floating Point

Conversion of flonums to floating point is correct, and compatible with previous assemblers. Rounding is towards zero if the remainder is exactly half the least significant bit.

'D', 'F', 'G' and 'H' floating point formats are understood.

Immediate floating literals (*e.g.* 'S'\$6.9') are rendered correctly. Again, rounding is towards zero in the boundary case.

The '.float' directive produces 'f' format numbers. The '.double' directive produces 'd' format numbers.

1.124 VAX-directives

Vax Machine Directives

The Vax version of the assembler supports four directives for generating Vax floating point constants. They are described in the table below.

'**.dfloat**'

This expects zero or more flonums, separated by commas, and assembles Vax 'd' format 64-bit floating point constants.

'**.ffloat**'

This expects zero or more flonums, separated by commas, and assembles Vax 'f' format 32-bit floating point constants.

'**.gfloat**'

This expects zero or more flonums, separated by commas, and assembles Vax 'g' format 64-bit floating point constants.

'**.hfloat**'

This expects zero or more flonums, separated by commas, and assembles Vax 'h' format 128-bit floating point constants.

1.125 VAX-opcodes

VAX Opcodes

All DEC mnemonics are supported. Beware that 'case...' instructions have exactly 3 operands. The dispatch table that follows the 'case...' instruction should be made with '.word' statements. This is compatible with all unix assemblers we know of.

1.126 VAX-branch

VAX Branch Improvement

Certain pseudo opcodes are permitted. They are for branch instructions. They expand to the shortest branch instruction that reaches the target. Generally these mnemonics are made by substituting 'j' for 'b' at the start of a DEC mnemonic. This feature is included both for compatibility and to help compilers. If you do not need this feature, avoid these opcodes. Here are the mnemonics, and the code they can expand into.

`'jbsb'`

`'Jsb'` is already an instruction mnemonic, so we chose `'jbsb'`.

(byte displacement)

`'bsbb ...'`

(word displacement)

`'bsbw ...'`

(long displacement)

`'jsb ...'`

`'jbr'`

`'jr'`

Unconditional branch.

(byte displacement)

`'brb ...'`

(word displacement)

`'brw ...'`

(long displacement)

`'jmp ...'`

`'jCOND'`

COND may be any one of the conditional branches `'neq'`, `'nequ'`, `'eql'`, `'eqlu'`, `'gtr'`, `'geq'`, `'lss'`, `'gtru'`, `'lequ'`, `'vc'`, `'vs'`, `'gequ'`, `'cc'`, `'lssu'`, `'cs'`. COND may also be one of the bit tests `'bs'`, `'bc'`, `'bss'`, `'bcs'`, `'bsc'`, `'bcc'`, `'bssi'`, `'bccu'`, `'lbs'`, `'lbc'`. NOTCOND is the opposite condition to COND.

(byte displacement)

`'bCOND ...'`

(word displacement)

`'bNOTCOND foo ; brw ... ; foo:'`

(long displacement)

`'bNOTCOND foo ; jmp ... ; foo:'`

`'jacbX'`

X may be one of `'b d f g h l w'`.

(word displacement)

`'OPCODE ...'`

```

(long displacement)
    OP CODE ..., foo ;
    brb bar ;
    foo: jmp ... ;
    bar:

`jaobYYY'
    YYY may be one of `lss leq'.

`jsobZZZ'
    ZZZ may be one of `geq gtr'.
(byte displacement)
    `OP CODE ...'

(word displacement)
    OP CODE ..., foo ;
    brb bar ;
    foo: brw DESTINATION ;
    bar:

(long displacement)
    OP CODE ..., foo ;
    brb bar ;
    foo: jmp DESTINATION ;
    bar:

`aobleq'
`aoblss'
`sobgeq'
`sobgtr'
(byte displacement)
    `OP CODE ...'

(word displacement)
    OP CODE ..., foo ;
    brb bar ;
    foo: brw DESTINATION ;
    bar:

(long displacement)
    OP CODE ..., foo ;
    brb bar ;
    foo: jmp DESTINATION ;
    bar:

```

1.127 VAX-operands

VAX Operands

The immediate character is '\$' for Unix compatibility, not '#' as DEC writes it.

The indirect character is '*' for Unix compatibility, not '@' as DEC writes it.

The displacement sizing character is `` (an accent grave) for Unix compatibility, not `^` as DEC writes it. The letter preceding `` may have either case. `G` is not understood, but all other letters (`b i l s w`) are understood.

Register names understood are `r0 r1 r2 ... r15 ap fp sp pc`. Upper and lower case letters are equivalent.

For instance
`tstb *w`$4(r5)`

Any expression is permitted in an operand. Operands are comma separated.

1.128 VAX-no

Not Supported on VAX

Vax bit fields can not be assembled with `as`. Someone can add the required code if they really need it.

1.129 AMD29K-Dependent

AMD 29K Dependent Features
 =====

* Menu:

* AMD29K Options	Options
* AMD29K Syntax	Syntax
* AMD29K Floating Point	Floating Point
* AMD29K Directives	AMD 29K Machine Directives
* AMD29K Opcodes	Opcodes

1.130 AMD29K Options

Options

`as` has no additional command-line options for the AMD 29K family.

1.131 AMD29K Syntax

Syntax

* Menu:

* AMD29K-Chars	Special Characters
* AMD29K-Regs	Register Names

1.132 AMD29K-Chars

Special Characters

.....

';' is the line comment character.

'@' can be used instead of a newline to separate statements.

The character '?' is permitted in identifiers (but may not begin an identifier).

1.133 AMD29K-Regs

Register Names

.....

General-purpose registers are represented by predefined symbols of the form 'GRNNN' (for global registers) or 'LRNNN' (for local registers), where NNN represents a number between '0' and '127', written with no leading zeros. The leading letters may be in either upper or lower case; for example, 'gr13' and 'LR7' are both valid register names.

You may also refer to general-purpose registers by specifying the register number as the result of an expression (prefixed with '%%' to flag the expression as a register number):

```
%%EXPRESSION
```

--where EXPRESSION must be an absolute expression evaluating to a number between '0' and '255'. The range [0, 127] refers to global registers, and the range [128, 255] to local registers.

In addition, 'as' understands the following protected special-purpose register names for the AMD 29K family:

vab	chd	pc0
ops	chc	pc1
cps	rbp	pc2
cfg	tmc	mmu
cha	tmr	lru

These unprotected special-purpose register names are also recognized:

ipc	alu	fpe
ipa	bp	inte
ipb	fc	fps
q	cr	exop

1.134 AMD29K Floating Point

Floating Point

The AMD 29K family uses IEEE floating-point numbers.

1.135 AMD29K Directives

AMD 29K Machine Directives

``.block SIZE , FILL'`

This directive emits SIZE bytes, each of value FILL. Both SIZE and FILL are absolute expressions. If the comma and FILL are omitted, FILL is assumed to be zero.

In other versions of the GNU assembler, this directive is called ``.space'`.

``.cputype'`

This directive is ignored; it is accepted for compatibility with other AMD 29K assemblers.

``.file'`

This directive is ignored; it is accepted for compatibility with other AMD 29K assemblers.

Warning: in other versions of the GNU assembler, ``.file'` is used for the directive called ``.app-file'` in the AMD 29K support.

``.line'`

This directive is ignored; it is accepted for compatibility with other AMD 29K assemblers.

``.sect'`

This directive is ignored; it is accepted for compatibility with other AMD 29K assemblers.

``.use SECTION NAME'`

Establishes the section and subsection for the following code; SECTION NAME may be one of ``.text'`, ``.data'`, ``.data1'`, or ``.lit'`. With one of the first three SECTION NAME options, ``.use'` is equivalent to the machine directive SECTION NAME; the remaining case, ``.use .lit'`, is the same as ``.data 200'`.

1.136 AMD29K Opcodes

Opcodes

'as' implements all the standard AMD 29K opcodes. No additional pseudo-instructions are needed on this family.

For information on the 29K machine instruction set, see 'Am29000 User's Manual', Advanced Micro Devices, Inc.

1.137 H8/300-Dependent

H8/300 Dependent Features

=====

* Menu:

* H8/300 Options	Options
* H8/300 Syntax	Syntax
* H8/300 Floating Point	Floating Point
* H8/300 Directives	H8/300 Machine Directives
* H8/300 Opcodes	Opcodes

1.138 H8/300 Options

Options

'as' has no additional command-line options for the Hitachi H8/300 family.

1.139 H8/300 Syntax

Syntax

* Menu:

* H8/300-Chars	Special Characters
* H8/300-Regs	Register Names
* H8/300-Addressing	Addressing Modes

1.140 H8/300-Chars

Special Characters

.....

``;'` is the line comment character.

``$'` can be used instead of a newline to separate statements.
Therefore *you may not use ``$'` in symbol names* on the H8/300.

1.141 H8/300-Regs

Register Names

.....

You can use predefined symbols of the form ``rNh'` and ``rNl'` to refer to the H8/300 registers as sixteen 8-bit general-purpose registers. N is a digit from ``0'` to ``7'`); for instance, both ``r0h'` and ``r7l'` are valid register names.

You can also use the eight predefined symbols ``rN'` to refer to the H8/300 registers as 16-bit registers (you must use this form for addressing).

On the H8/300H, you can also use the eight predefined symbols ``erN'` (``er0'` ... ``er7'`) to refer to the 32-bit general purpose registers.

The two control registers are called ``pc'` (program counter; a 16-bit register, except on the H8/300H where it is 24 bits) and ``ccr'` (condition code register; an 8-bit register). ``r7'` is used as the stack pointer, and can also be called ``sp'`.

1.142 H8/300-Addressing

Addressing Modes

.....

as understands the following addressing modes for the H8/300:

``rN'`

Register direct

``@rN'`

Register indirect

``@(D, rN)'`

``@(D:16, rN)'`

``@(D:24, rN)'`

Register indirect: 16-bit or 24-bit displacement D from register N. (24-bit displacements are only meaningful on the H8/300H.)

``@rN+'`

Register indirect with post-increment

``@-rN'`

Register indirect with pre-decrement

```@'AA'`

```@'AA:8'`

```@'AA:16'`

```@'AA:24'`

Absolute address `'aa'`. (The address size `':24'` only makes sense on the H8/300H.)

``#XX'`

``#XX:8'`

``#XX:16'`

``#XX:32'`

Immediate data XX. You may specify the `':8'`, `':16'`, or `':32'` for clarity, if you wish; but `'as'` neither requires this nor uses it--the data size required is taken from context.

```@' '@'AA'`

```@' '@'AA:8'`

Memory indirect. You may specify the `':8'` for clarity, if you wish; but `'as'` neither requires this nor uses it.

1.143 H8/300 Floating Point

Floating Point

The H8/300 family has no hardware floating point, but the `'.float'` directive generates IEEE floating-point numbers for compatibility with other development tools.

1.144 H8/300 Directives

H8/300 Machine Directives

`'as'` has only one machine-dependent directive for the H8/300:

``.h300h'`

Recognize and emit additional instructions for the H8/300H variant, and also make `'.int'` emit 32-bit numbers rather than the usual (16-bit) for the H8/300 family.

On the H8/300 family (including the H8/300H) `'.word'` directives generate 16-bit numbers.

1.145 H8/300 Opcodes

Opcodes

For detailed information on the H8/300 machine instruction set, see 'H8/300 Series Programming Manual' (Hitachi ADE-602-025). For information specific to the H8/300H, see 'H8/300H Series Programming Manual' (Hitachi).

'as' implements all the standard H8/300 opcodes. No additional pseudo-instructions are needed on this family.

The following table summarizes the H8/300 opcodes, and their arguments. Entries marked '*' are opcodes used only on the H8/300H.

Legend:

Rs source register
 Rd destination register
 abs absolute address
 imm immediate data
 disp:N N-bit displacement from a register
 pcrel:N N-bit displacement relative to program counter

add.b #imm,rd	* andc #imm,ccr
add.b rs,rd	band #imm,rd
add.w rs,rd	band #imm,@rd
* add.w #imm,rd	band #imm,@abs:8
* add.l rs,rd	bra pcrel:8
* add.l #imm,rd	* bra pcrel:16
adds #imm,rd	bt pcrel:8
addx #imm,rd	* bt pcrel:16
addx rs,rd	brn pcrel:8
and.b #imm,rd	* brn pcrel:16
and.b rs,rd	bf pcrel:8
* and.w rs,rd	* bf pcrel:16
* and.w #imm,rd	bhi pcrel:8
* and.l #imm,rd	* bhi pcrel:16
* and.l rs,rd	bls pcrel:8
* bls pcrel:16	bld #imm,rd
bcc pcrel:8	bld #imm,@rd
* bcc pcrel:16	bld #imm,@abs:8
bhs pcrel:8	bnot #imm,rd
* bhs pcrel:16	bnot #imm,@rd
bcs pcrel:8	bnot #imm,@abs:8
* bcs pcrel:16	bnot rs,rd
blo pcrel:8	bnot rs,@rd
* blo pcrel:16	bnot rs,@abs:8
bne pcrel:8	bor #imm,rd
* bne pcrel:16	bor #imm,@rd
beq pcrel:8	bor #imm,@abs:8
* beq pcrel:16	bset #imm,rd
bvc pcrel:8	bset #imm,@rd
* bvc pcrel:16	bset #imm,@abs:8
bvs pcrel:8	bset rs,rd
* bvs pcrel:16	bset rs,@rd
bpl pcrel:8	bset rs,@abs:8

```

* bpl pcrel:16
* bmi pcrel:8
* bmi pcrel:16
* bge pcrel:8
* bge pcrel:16
* blt pcrel:8
* blt pcrel:16
* bgt pcrel:8
* bgt pcrel:16
* ble pcrel:8
* ble pcrel:16
  bclr #imm,rd
  bclr #imm,@rd
  bclr #imm,@abs:8
  bclr rs,rd
  bclr rs,@rd
  bclr rs,@abs:8
  biand #imm,rd
  biand #imm,@rd
  biand #imm,@abs:8
  bild #imm,rd
  bild #imm,@rd
  bild #imm,@abs:8
  bior #imm,rd
  bior #imm,@rd
  bior #imm,@abs:8
  bist #imm,rd
  bist #imm,@rd
  bist #imm,@abs:8
  bixor #imm,rd
  bixor #imm,@rd
  bixor #imm,@abs:8

* exts.w rd
* exts.l rd
* extu.w rd
* extu.l rd
  inc rs
* inc.w #imm,rd
* inc.l #imm,rd
  jmp @rs
  jmp abs
  jmp @@abs:8
  jsr @rs
  jsr abs
  jsr @@abs:8
  ldc #imm,ccr
  ldc rs,ccr
* ldc @abs:16,ccr
* ldc @abs:24,ccr
* ldc @(disp:16,rs),ccr
* ldc @(disp:24,rs),ccr
* ldc @rs+,ccr
* ldc @rs,ccr
* mov.b @(disp:24,rs),rd
* mov.b rs,@(disp:24,rd)
  mov.b @abs:16,rd

  bsr pcrel:8
  bsr pcrel:16
  bst #imm,rd
  bst #imm,@rd
  bst #imm,@abs:8
  btst #imm,rd
  btst #imm,@rd
  btst #imm,@abs:8
  btst rs,rd
  btst rs,@rd
  btst rs,@abs:8
  bxor #imm,rd
  bxor #imm,@rd
  bxor #imm,@abs:8
  cmp.b #imm,rd
  cmp.b rs,rd
  cmp.w rs,rd
  cmp.w rs,rd
* cmp.w #imm,rd
* cmp.l #imm,rd
* cmp.l rs,rd
  daa rs
  das rs
  dec.b rs
* dec.w #imm,rd
* dec.l #imm,rd
  divxu.b rs,rd
* divxu.w rs,rd
* divxs.b rs,rd
* divxs.w rs,rd
  eepmov
* eepmovw

  mov.w rs,@abs:16
* mov.l #imm,rd
* mov.l rs,rd
* mov.l @rs,rd
* mov.l @(disp:16,rs),rd
* mov.l @(disp:24,rs),rd
* mov.l @rs+,rd
* mov.l @abs:16,rd
* mov.l @abs:24,rd
* mov.l rs,@rd
* mov.l rs,@(disp:16,rd)
* mov.l rs,@(disp:24,rd)
* mov.l rs,@-rd
* mov.l rs,@abs:16
* mov.l rs,@abs:24
  movfpe @abs:16,rd
  movtpe rs,@abs:16
  mulxu.b rs,rd
* mulxu.w rs,rd
* mulxs.b rs,rd
* mulxs.w rs,rd
  neg.b rs
* neg.w rs
* neg.l rs

```

mov.b rs,rd	nop
mov.b @abs:8,rd	not.b rs
mov.b rs,@abs:8	* not.w rs
mov.b rs,rd	* not.l rs
mov.b #imm,rd	or.b #imm,rd
mov.b @rs,rd	or.b rs,rd
mov.b @(disp:16,rs),rd	* or.w #imm,rd
mov.b @rs+,rd	* or.w rs,rd
mov.b @abs:8,rd	* or.l #imm,rd
mov.b rs,@rd	* or.l rs,rd
mov.b rs,@(disp:16,rd)	orc #imm,ccr
mov.b rs,@-rd	pop.w rs
mov.b rs,@abs:8	* pop.l rs
mov.w rs,@rd	push.w rs
* mov.w @(disp:24,rs),rd	* push.l rs
* mov.w rs,@(disp:24,rd)	rotl.b rs
* mov.w @abs:24,rd	* rotl.w rs
* mov.w rs,@abs:24	* rotl.l rs
mov.w rs,rd	rotr.b rs
mov.w #imm,rd	* rotr.w rs
mov.w @rs,rd	* rotr.l rs
mov.w @(disp:16,rs),rd	rotxl.b rs
mov.w @rs+,rd	* rotxl.w rs
mov.w @abs:16,rd	* rotxl.l rs
mov.w rs,@(disp:16,rd)	rotxr.b rs
mov.w rs,@-rd	* rotxr.w rs
* rotxr.l rs	* stc ccr,@(disp:24,rd)
bpt	* stc ccr,@-rd
rte	* stc ccr,@abs:16
rts	* stc ccr,@abs:24
shal.b rs	sub.b rs,rd
* shal.w rs	sub.w rs,rd
* shal.l rs	* sub.w #imm,rd
shar.b rs	* sub.l rs,rd
* shar.w rs	* sub.l #imm,rd
* shar.l rs	subs #imm,rd
shll.b rs	subx #imm,rd
* shll.w rs	subx rs,rd
* shll.l rs	* trapa #imm
shlr.b rs	xor #imm,rd
* shlr.w rs	xor rs,rd
* shlr.l rs	* xor.w #imm,rd
sleep	* xor.w rs,rd
stc ccr,rd	* xor.l #imm,rd
* stc ccr,@rs	* xor.l rs,rd
* stc ccr,@(disp:16,rd)	xorc #imm,ccr

Four H8/300 instructions ('add', 'cmp', 'mov', 'sub') are defined with variants using the suffixes '.b', '.w', and '.l' to specify the size of a memory operand. 'as' supports these suffixes, but does not require them; since one of the operands is always a register, 'as' can deduce the correct size.

For example, since 'r0' refers to a 16-bit register,
 mov r0,@foo
 is equivalent to

```
mov.w  r0,@foo
```

If you use the size suffixes, 'as' issues a warning when the suffix and the register size do not match.

1.146 H8/500-Dependent

H8/500 Dependent Features

=====

* Menu:

* H8/500 Options	Options
* H8/500 Syntax	Syntax
* H8/500 Floating Point	Floating Point
* H8/500 Directives	H8/500 Machine Directives
* H8/500 Opcodes	Opcodes

1.147 H8/500 Options

Options

'as' has no additional command-line options for the Hitachi H8/500 family.

1.148 H8/500 Syntax

Syntax

* Menu:

* H8/500-Chars	Special Characters
* H8/500-Regs	Register Names
* H8/500-Addressing	Addressing Modes

1.149 H8/500-Chars

Special Characters

.....

'!' is the line comment character.

';' can be used instead of a newline to separate statements.

Since '\$' has no special meaning, you may use it in symbol names.

1.150 H8/500-Regs

Register Names

.....

You can use the predefined symbols `'r0'`, `'r1'`, `'r2'`, `'r3'`, `'r4'`, `'r5'`, `'r6'`, and `'r7'` to refer to the H8/500 registers.

The H8/500 also has these control registers:

```
'cp'
    code pointer

'dp'
    data pointer

'bp'
    base pointer

'tp'
    stack top pointer

'ep'
    extra pointer

'sr'
    status register

'ccr'
    condition code register
```

All registers are 16 bits long. To represent 32 bit numbers, use two adjacent registers; for distant memory addresses, use one of the segment pointers (`'cp'` for the program counter; `'dp'` for `'r0'`-`'r3'`; `'ep'` for `'r4'` and `'r5'`; and `'tp'` for `'r6'` and `'r7'`).

1.151 H8/500-Addressing

Addressing Modes

.....

as understands the following addressing modes for the H8/500:

```
'RN'
    Register direct

'@RN'
    Register indirect

'@(d:8, RN)'
    Register indirect with 8 bit signed displacement

'@(d:16, RN)'
    Register indirect with 16 bit signed displacement
```

```

`@-RN'
    Register indirect with pre-decrement

`@RN+'
    Register indirect with post-increment

`@AA:8'
    8 bit absolute address

`@AA:16'
    16 bit absolute address

`#XX:8'
    8 bit immediate

`#XX:16'
    16 bit immediate

```

1.152 H8/500 Floating Point

Floating Point

The H8/500 family uses IEEE floating-point numbers.

1.153 H8/500 Directives

H8/500 Machine Directives

`as' has no machine-dependent directives for the H8/500. However, on this platform the `.int' and `.word' directives generate 16-bit numbers.

1.154 H8/500 Opcodes

Opcodes

For detailed information on the H8/500 machine instruction set, see 'H8/500 Series Programming Manual' (Hitachi M21T001).

`as' implements all the standard H8/500 opcodes. No additional pseudo-instructions are needed on this family.

The following table summarizes H8/500 opcodes and their operands:

```

Legend:
abs8      8-bit absolute address
abs16     16-bit absolute address

```

abs24 24-bit absolute address
 crb 'ccr', 'br', 'ep', 'dp', 'tp', 'dp'
 disp8 8-bit displacement
 ea 'rn', '@rn', '@(d:8, rn)', '@(d:16, rn)',
 '@-rn', '@rn+', '@aa:8', '@aa:16',
 '#xx:8', '#xx:16'
 ea_mem '@rn', '@(d:8, rn)', '@(d:16, rn)',
 '@-rn', '@rn+', '@aa:8', '@aa:16'
 ea_noimm 'rn', '@rn', '@(d:8, rn)', '@(d:16, rn)',
 '@-rn', '@rn+', '@aa:8', '@aa:16'
 fp r6
 imm4 4-bit immediate data
 imm8 8-bit immediate data
 imm16 16-bit immediate data
 pcrel8 8-bit offset from program counter
 pcrel16 16-bit offset from program counter
 qim '-2', '-1', '1', '2'
 rd any register
 rs a register distinct from rd
 rlist comma-separated list of registers in parentheses;
 register ranges 'rd-rs' are allowed
 sp stack pointer ('r7')
 sr status register
 sz size; '.b' or '.w'. If omitted, default '.w'

ldc[.b] ea,crb	bcc[.w] pcrel16
ldc[.w] ea,sr	bcc[.b] pcrel8
add[:q] sz qim,ea_noimm	bhs[.w] pcrel16
add[:g] sz ea,rd	bhs[.b] pcrel8
adds sz ea,rd	bcs[.w] pcrel16
addx sz ea,rd	bcs[.b] pcrel8
and sz ea,rd	blo[.w] pcrel16
andc[.b] imm8,crb	blo[.b] pcrel8
andc[.w] imm16,sr	bne[.w] pcrel16
bpt	bne[.b] pcrel8
bra[.w] pcrel16	beq[.w] pcrel16
bra[.b] pcrel8	beq[.b] pcrel8
bt[.w] pcrel16	bvc[.w] pcrel16
bt[.b] pcrel8	bvc[.b] pcrel8
brn[.w] pcrel16	bvs[.w] pcrel16
brn[.b] pcrel8	bvs[.b] pcrel8
bf[.w] pcrel16	bpl[.w] pcrel16
bf[.b] pcrel8	bpl[.b] pcrel8
bhi[.w] pcrel16	bmi[.w] pcrel16
bhi[.b] pcrel8	bmi[.b] pcrel8
bls[.w] pcrel16	bge[.w] pcrel16
bls[.b] pcrel8	bge[.b] pcrel8
blt[.w] pcrel16	mov[:g][.b] imm8,ea_mem
blt[.b] pcrel8	mov[:g][.w] imm16,ea_mem
bgt[.w] pcrel16	movfpe[.b] ea,rd
bgt[.b] pcrel8	movtpe[.b] rs,ea_noimm
ble[.w] pcrel16	mulxu sz ea,rd
ble[.b] pcrel8	neg sz ea
bclr sz imm4,ea_noimm	nop
bclr sz rs,ea_noimm	not sz ea
bnot sz imm4,ea_noimm	or sz ea,rd

bnot sz rs,ea_noimm	orc[.b] imm8,crb
bset sz imm4,ea_noimm	orc[.w] imm16,sr
bset sz rs,ea_noimm	pjmp abs24
bsr[.b] pcrel8	pjmp @rd
bsr[.w] pcrel16	pjsr abs24
btst sz imm4,ea_noimm	pjsr @rd
btst sz rs,ea_noimm	prtd imm8
clr sz ea	prtd imm16
cmp[:e][.b] imm8,rd	prts
cmp[:i][.w] imm16,rd	rotl sz ea
cmp[:g].b imm8,ea_noimm	rotr sz ea
cmp[:g][.w] imm16,ea_noimm	rotxl sz ea
Cmp[:g] sz ea,rd	rotxr sz ea
dadd rs,rd	rtd imm8
divxu sz ea,rd	rtd imm16
dsub rs,rd	rts
exts[.b] rd	scb/f rs,pcrel8
extu[.b] rd	scb/ne rs,pcrel8
jmp @rd	scb/eq rs,pcrel8
jmp @(imm8,rd)	shal sz ea
jmp @(imm16,rd)	shar sz ea
jmp abs16	shll sz ea
jsr @rd	shlr sz ea
jsr @(imm8,rd)	sleep
jsr @(imm16,rd)	stc[.b] crb,ea_noimm
jsr abs16	stc[.w] sr,ea_noimm
ldm @sp+, (rlist)	stm (rlist),@-sp
link fp,imm8	sub sz ea,rd
link fp,imm16	subs sz ea,rd
mov[:e][.b] imm8,rd	subx sz ea,rd
mov[:i][.w] imm16,rd	swap[.b] rd
mov[:l][.w] abs8,rd	tas[.b] ea
mov[:l].b abs8,rd	trapa imm4
mov[:s][.w] rs,abs8	trap/vs
mov[:s].b rs,abs8	tst sz ea
mov[:f][.w] @(disp8,fp),rd	unlk fp
mov[:f][.w] rs,@(disp8,fp)	xch[.w] rs,rd
mov[:f].b @(disp8,fp),rd	xor sz ea,rd
mov[:f].b rs,@(disp8,fp)	xorc.b imm8,crb
mov[:g] sz rs,ea_mem	xorc.w imm16,sr
mov[:g] sz ea,rd	

1.155 HPPA-Dependent

HPPA Dependent Features

=====

* Menu:

* HPPA Notes	Notes
* HPPA Options	Options
* HPPA Syntax	Syntax
* HPPA Floating Point	Floating Point
* HPPA Directives	HPPA Machine Directives

* HPPA Opcodes

Opcodes

1.156 HPPA Notes

Notes

As a back end for GNU CC 'as' has been thoroughly tested and should work extremely well. We have tested it only minimally on hand written assembly code and no one has tested it much on the assembly output from the HP compilers.

The format of the debugging sections has changed since the original 'as' port (version 1.3X) was released; therefore, you must rebuild all HPPA objects and libraries with the new assembler so that you can debug the final executable.

The HPPA 'as' port generates a small subset of the relocations available in the SOM and ELF object file formats. Additional relocation support will be added as it becomes necessary.

1.157 HPPA Options

Options

'as' has no machine-dependent command-line options for the HPPA.

1.158 HPPA Syntax

Syntax

The assembler syntax closely follows the HPPA instruction set reference manual; assembler directives and general syntax closely follow the HPPA assembly language reference manual, with a few noteworthy differences.

First, a colon may immediately follow a label definition. This is simply for compatibility with how most assembly language programmers write code.

Some obscure expression parsing problems may affect hand written code which uses the 'spop' instructions, or code which makes significant use of the '!' line separator.

'as' is much less forgiving about missing arguments and other similar oversights than the HP assembler. 'as' notifies you of missing arguments as syntax errors; this is regarded as a feature, not a bug.

Finally, `'as'` allows you to use an external symbol without explicitly importing the symbol. `*Warning:*` in the future this will be an error for HPPA targets.

Special characters for HPPA targets include:

`';` is the line comment character.

`'!' can be used instead of a newline to separate statements.`

Since `'$'` has no special meaning, you may use it in symbol names.

1.159 HPPA Floating Point

Floating Point

The HPPA family uses IEEE floating-point numbers.

1.160 HPPA Directives

HPPA Assembler Directives

`'as'` for the HPPA supports many additional directives for compatibility with the native assembler. This section describes them only briefly. For detailed information on HPPA-specific assembler directives, see `'HP9000 Series 800 Assembly Language Reference Manual'` (HP 92432-90001).

`'as'` does `*not*` support the following assembler directives described in the HP manual:

<code>.endm</code>	<code>.liston</code>
<code>.enter</code>	<code>.locct</code>
<code>.leave</code>	<code>.macro</code>
<code>.listoff</code>	

Beyond those implemented for compatibility, `'as'` supports one additional assembler directive for the HPPA: `'.param'`. It conveys register argument locations for static functions. Its syntax closely follows the `'.export'` directive.

These are the additional directives in `'as'` for the HPPA:

`'.block N'`

`'.blockz N'`

Reserve N bytes of storage, and initialize them to zero.

`'.call'`

Mark the beginning of a procedure call. Only the special case with `*no arguments*` is allowed.

``.callinfo [PARAM=VALUE, ...] [FLAG, ...]'`

Specify a number of parameters and flags that define the environment for a procedure.

PARAM may be any of `'frame'` (frame size), `'entry_gr'` (end of general register range), `'entry_fr'` (end of float register range), `'entry_sr'` (end of space register range).

The values for FLAG are `'calls'` or `'caller'` (proc has subroutines), `'no_calls'` (proc does not call subroutines), `'save_rp'` (preserve return pointer), `'save_sp'` (proc preserves stack pointer), `'no_unwind'` (do not unwind this proc), `'hpx_int'` (proc is interrupt routine).

``.code'`

Assemble into the standard section called `'$TEXT$'`, subsection `'$CODE$'`.

``.copyright "STRING"'`

In the SOM object format, insert STRING into the object code, marked as a copyright string.

``.copyright "STRING"'`

In the ELF object format, insert STRING into the object code, marked as a version string.

``.enter'`

Not yet supported; the assembler rejects programs containing this directive.

``.entry'`

Mark the beginning of a procedure.

``.exit'`

Mark the end of a procedure.

``.export NAME [,TYP] [,PARAM=R]'`

Make a procedure NAME available to callers. TYP, if present, must be one of `'absolute'`, `'code'` (ELF only, not SOM), `'data'`, `'entry'`, `'data'`, `'entry'`, `'millicode'`, `'plabel'`, `'pri_prog'`, or `'sec_prog'`.

PARAM, if present, provides either relocation information for the procedure arguments and result, or a privilege level. PARAM may be `'argwN'` (where N ranges from '0' to '3', and indicates one of four one-word arguments); `'rtnval'` (the procedure's result); or `'priv_lev'` (privilege level). For arguments or the result, R specifies how to relocate, and must be one of `'no'` (not relocatable), `'gr'` (argument is in general register), `'fr'` (in floating point register), or `'fu'` (upper half of float register). For `'priv_lev'`, R is an integer.

``.half N'`

Define a two-byte integer constant N; synonym for the portable `'as'` directive ``.short'`.

``.import NAME [,TYP]'`

Converse of ``.export``; make a procedure available to call. The arguments use the same conventions as the first two arguments for ``.export``.

``.label NAME``

Define NAME as a label for the current assembly location.

``.leave``

Not yet supported; the assembler rejects programs containing this directive.

``.origin LC``

Advance location counter to LC. Synonym for the `{No Value For "as"}` portable directive ``.org``.

``.param NAME [,TYP] [,PARAM=R]``

Similar to ``.export``, but used for static procedures.

``.proc``

Use preceding the first statement of a procedure.

``.procend``

Use following the last statement of a procedure.

``.LABEL .reg EXPR``

Synonym for ``.equ``; define LABEL with the absolute expression EXPR as its value.

``.space SECNAME [,PARAMS]``

Switch to section SECNAME, creating a new section by that name if necessary. You may only use PARAMS when creating a new section, not when switching to an existing one. SECNAME may identify a section by number rather than by name.

If specified, the list PARAMS declares attributes of the section, identified by keywords. The keywords recognized are ``.spnum=EXP`` (identify this section by the number EXP, an absolute expression), ``.sort=EXP`` (order sections according to this sort key when linking; EXP is an absolute expression), ``.unloadable`` (section contains no loadable data), ``.notdefined`` (this section defined elsewhere), and ``.private`` (data in this section not available to other programs).

``.spnum SECNAM``

Allocate four bytes of storage, and initialize them with the section number of the section named SECNAM. (You can define the section number with the HPPA ``.space`` directive.)

``.string "STR"``

Copy the characters in the string STR to the object file. *Note Strings: Strings, for information on escape sequences you can use in ``.as`` strings.

Warning! The HPPA version of ``.string`` differs from the usual ``.as`` definition: it does *not* write a zero byte after copying STR.

``.stringz "STR"``

Like ``.string``, but appends a zero byte after copying STR to object

file.

``.subspa NAME [,PARAMS]'`

Similar to ``.space'`, but selects a subsection NAME within the current section. You may only specify PARAMS when you create a subsection (in the first instance of ``.subspa'` for this NAME).

If specified, the list PARAMS declares attributes of the subsection, identified by keywords. The keywords recognized are ``.quad=EXPR'` ("quadrant" for this subsection), ``.align=EXPR'` (alignment for beginning of this subsection; a power of two), ``.access=EXPR'` (value for "access rights" field), ``.sort=EXPR'` (sorting order for this subspace in link), ``.code_only'` (subsection contains only code), ``.unloadable'` (subsection cannot be loaded into memory), ``.common'` (subsection is common block), ``.dup_comm'` (initialized data may have duplicate names), or ``.zero'` (subsection is all zeros, do not write in object file).

``.version "STR"'`

Write STR as version identifier in object code.

1.161 HPPA Opcodes

Opcodes

For detailed information on the HPPA machine instruction set, see 'PA-RISC Architecture and Instruction Set Reference Manual' (HP 09740-90039).

1.162 SH-Dependent

Hitachi SH Dependent Features

=====

* Menu:

* SH Options	Options
* SH Syntax	Syntax
* SH Floating Point	Floating Point
* SH Directives	SH Machine Directives
* SH Opcodes	Opcodes

1.163 SH Options

Options

'as' has no additional command-line options for the Hitachi SH family.

1.164 SH Syntax

Syntax

* Menu:

* SH-Chars	Special Characters
* SH-Regs	Register Names
* SH-Addressing	Addressing Modes

1.165 SH-Chars

Special Characters

.....

'!' is the line comment character.

You can use ';' instead of a newline to separate statements.

Since '\$' has no special meaning, you may use it in symbol names.

1.166 SH-Regs

Register Names

.....

You can use the predefined symbols 'r0', 'r1', 'r2', 'r3', 'r4', 'r5', 'r6', 'r7', 'r8', 'r9', 'r10', 'r11', 'r12', 'r13', 'r14', and 'r15' to refer to the SH registers.

The SH also has these control registers:

'pr'
 procedure register (holds return address)

'pc'
 program counter

'mach'
'macl'
 high and low multiply accumulator registers

'sr'
 status register

'gbr'
 global base register

'vbr'
 vector base register (for interrupt vectors)

1.167 SH-Addressing

Addressing Modes

.....

'as' understands the following addressing modes for the SH. 'RN' in the following refers to any of the numbered registers, but **not** the control registers.

'RN'

Register direct

'@RN'

Register indirect

'@-RN'

Register indirect with pre-decrement

'@RN+'

Register indirect with post-increment

'@(DISP, RN)'

Register indirect with displacement

'@(R0, RN)'

Register indexed

'@(DISP, GBR)'

'GBR' offset

'@(R0, GBR)'

GBR indexed

'ADDR'

'@(DISP, PC)'

PC relative address (for branch or for addressing memory). The 'as' implementation allows you to use the simpler form ADDR anywhere a PC relative address is called for; the alternate form is supported for compatibility with other assemblers.

'#IMM'

Immediate data

1.168 SH Floating Point

Floating Point

The SH family uses IEEE floating-point numbers.

1.169 SH Directives

SH Machine Directives

'as' has no machine-dependent directives for the SH.

1.170 SH Opcodes

Opcodes

For detailed information on the SH machine instruction set, see 'SH-Microcomputer User's Manual' (Hitachi Micro Systems, Inc.).

'as' implements all the standard SH opcodes. No additional pseudo-instructions are needed on this family. Note, however, that because 'as' supports a simpler form of PC-relative addressing, you may simply write (for example)

```
mov.l bar,r0
```

where other assemblers might require an explicit displacement to 'bar' from the program counter:

```
mov.l @(DISP, PC)
```

Here is a summary of SH opcodes:

Legend:

Rn a numbered register
Rm another numbered register
#imm immediate data
disp displacement
disp8 8-bit displacement
disp12 12-bit displacement

add #imm,Rn	lds.l @Rn+,PR
add Rm,Rn	mac.w @Rm+,@Rn+
addc Rm,Rn	mov #imm,Rn
addv Rm,Rn	mov Rm,Rn
and #imm,R0	mov.b Rm,@(R0,Rn)
and Rm,Rn	mov.b Rm,@-Rn
and.b #imm,@(R0,GBR)	mov.b Rm,@Rn
bf disp8	mov.b @(disp,Rm),R0
bra disp12	mov.b @(disp,GBR),R0
bsr disp12	mov.b @(R0,Rm),Rn
bt disp8	mov.b @Rm+,Rn
clrmac	mov.b @Rm,Rn
clrt	mov.b R0,@(disp,Rm)
cmp/eq #imm,R0	mov.b R0,@(disp,GBR)
cmp/eq Rm,Rn	mov.l Rm,@(disp,Rn)
cmp/ge Rm,Rn	mov.l Rm,@(R0,Rn)
cmp/gt Rm,Rn	mov.l Rm,@-Rn
cmp/hi Rm,Rn	mov.l Rm,@Rn
cmp/hs Rm,Rn	mov.l @(disp,Rn),Rm

cmp/pl Rn	mov.l @(disp,GBR),R0
cmp/pz Rn	mov.l @(disp,PC),Rn
cmp/str Rm,Rn	mov.l @(R0,Rm),Rn
div0s Rm,Rn	mov.l @Rm+,Rn
div0u	mov.l @Rm,Rn
divl Rm,Rn	mov.l R0,@(disp,GBR)
exts.b Rm,Rn	mov.w Rm,@(R0,Rn)
exts.w Rm,Rn	mov.w Rm,@-Rn
extu.b Rm,Rn	mov.w Rm,@Rn
extu.w Rm,Rn	mov.w @(disp,Rm),R0
jmp @Rn	mov.w @(disp,GBR),R0
jsr @Rn	mov.w @(disp,PC),Rn
ldc Rn,GBR	mov.w @(R0,Rm),Rn
ldc Rn,SR	mov.w @Rm+,Rn
ldc Rn,VBR	mov.w @Rm,Rn
ldc.l @Rn+,GBR	mov.w R0,@(disp,Rm)
ldc.l @Rn+,SR	mov.w R0,@(disp,GBR)
ldc.l @Rn+,VBR	mov.a @(disp,PC),R0
lds Rn,MACH	movt Rn
lds Rn,MACL	muls Rm,Rn
lds Rn,PR	mulu Rm,Rn
lds.l @Rn+,MACH	neg Rm,Rn
lds.l @Rn+,MACL	negc Rm,Rn
nop	stc VBR,Rn
not Rm,Rn	stc.l GBR,@-Rn
or #imm,R0	stc.l SR,@-Rn
or Rm,Rn	stc.l VBR,@-Rn
or.b #imm,@(R0,GBR)	sts MACH,Rn
rotcl Rn	sts MACL,Rn
rotcr Rn	sts PR,Rn
rotl Rn	sts.l MACH,@-Rn
rotr Rn	sts.l MACL,@-Rn
rte	sts.l PR,@-Rn
rts	sub Rm,Rn
sett	subc Rm,Rn
shal Rn	subv Rm,Rn
shar Rn	swap.b Rm,Rn
shll Rn	swap.w Rm,Rn
shll16 Rn	tas.b @Rn
shll2 Rn	trapa #imm
shll8 Rn	tst #imm,R0
shlr Rn	tst Rm,Rn
shlr16 Rn	tst.b #imm,@(R0,GBR)
shlr2 Rn	xor #imm,R0
shlr8 Rn	xor Rm,Rn
sleep	xor.b #imm,@(R0,GBR)
stc GBR,Rn	xtrct Rm,Rn
stc SR,Rn	

1.171 i960-Dependent

Intel 80960 Dependent Features

=====

* Menu:

* Options-i960	i960 Command-line Options
* Floating Point-i960	Floating Point
* Directives-i960	i960 Machine Directives
* Opcodes for i960	i960 Opcodes

1.172 Options-i960

i960 Command-line Options

'-ACA | -ACA_A | -ACB | -ACC | -AKA | -AKB | -AKC | -AMC'

Select the 80960 architecture. Instructions or features not supported by the selected architecture cause fatal errors.

'-ACA' is equivalent to '-ACA_A'; '-AKC' is equivalent to '-AMC'. Synonyms are provided for compatibility with other tools.

If you do not specify any of these options, 'as' generates code for any instruction or feature that is supported by *some* version of the 960 (even if this means mixing architectures!). In principle, 'as' attempts to deduce the minimal sufficient processor type if none is specified; depending on the object code format, the processor type may be recorded in the object file. If it is critical that the 'as' output match a specific architecture, specify that architecture explicitly.

'-b'

Add code to collect information about conditional branches taken, for later optimization using branch prediction bits. (The conditional branch instructions have branch prediction bits in the CA, CB, and CC architectures.) If BR represents a conditional branch instruction, the following represents the code generated by the assembler when '-b' is specified:

```

                call    INCREMENT ROUTINE
                .word   0          # pre-counter
Label: BR
                call    INCREMENT ROUTINE
                .word   0          # post-counter
```

The counter following a branch records the number of times that branch was *not* taken; the difference between the two counters is the number of times the branch *was* taken.

A table of every such 'Label' is also generated, so that the external postprocessor 'gbr960' (supplied by Intel) can locate all the counters. This table is always labelled '__BRANCH_TABLE__'; this is a local symbol to permit collecting statistics for many separate object files. The table is word aligned, and begins with a two-word header. The first word, initialized to 0, is used in maintaining linked lists of branch tables. The second word is a count of the number of entries in the table, which follow immediately: each is a word, pointing to one of the labels

illustrated above.

```

+-----+-----+-----+ ... +-----+
|      |      |      |      |      |
| *NEXT | COUNT: N | *BRLAB 1 |      | *BRLAB N |
|      |      |      |      |      |
+-----+-----+-----+ ... +-----+

```

__BRANCH_TABLE__ layout

The first word of the header is used to locate multiple branch tables, since each object file may contain one. Normally the links are maintained with a call to an initialization routine, placed at the beginning of each function in the file. The GNU C compiler generates these calls automatically when you give it a '-b' option. For further details, see the documentation of 'gbr960'.

'-norelax'

Normally, Compare-and-Branch instructions with targets that require displacements greater than 13 bits (or that have external targets) are replaced with the corresponding compare (or 'chkbit') and branch instructions. You can use the '-norelax' option to specify that 'as' should generate errors instead, if the target displacement is larger than 13 bits.

This option does not affect the Compare-and-Jump instructions; the code emitted for them is **always** adjusted when necessary (depending on displacement size), regardless of whether you use '-norelax'.

1.173 Floating Point-i960

Floating Point

'as' generates IEEE floating-point numbers for the directives '.float', '.double', '.extended', and '.single'.

1.174 Directives-i960

i960 Machine Directives

'.bss SYMBOL, LENGTH, ALIGN'

Reserve LENGTH bytes in the bss section for a local SYMBOL, aligned to the power of two specified by ALIGN. LENGTH and ALIGN must be positive absolute expressions. This directive differs from '.lcomm' only in that it permits you to specify an alignment. *Note '.lcomm': Lcomm.

'.extended FLONUMS'

'.extended' expects zero or more flonums, separated by commas; for

each flonum, ``.extended`` emits an IEEE extended-format (80-bit) floating-point number.

``.leafproc CALL-LAB, BAL-LAB``

You can use the ``.leafproc`` directive in conjunction with the optimized ``.callj`` instruction to enable faster calls of leaf procedures. If a procedure is known to call no other procedures, you may define an entry point that skips procedure prolog code (and that does not depend on system-supplied saved context), and declare it as the BAL-LAB using ``.leafproc``. If the procedure also has an entry point that goes through the normal prolog, you can specify that entry point as CALL-LAB.

A ``.leafproc`` declaration is meant for use in conjunction with the optimized call instruction ``.callj``; the directive records the data needed later to choose between converting the ``.callj`` into a ``.bal`` or a ``.call``.

CALL-LAB is optional; if only one argument is present, or if the two arguments are identical, the single argument is assumed to be the ``.bal`` entry point.

``.sysproc NAME, INDEX``

The ``.sysproc`` directive defines a name for a system procedure. After you define it using ``.sysproc``, you can use NAME to refer to the system procedure identified by INDEX when calling procedures with the optimized call instruction ``.callj``.

Both arguments are required; INDEX must be between 0 and 31 (inclusive).

1.175 Opcodes for i960

i960 Opcodes

All Intel 960 machine instructions are supported; *note i960 Command-line Options: Options-i960. for a discussion of selecting the instruction subset for a particular 960 architecture.

Some opcodes are processed beyond simply emitting a single corresponding instruction: ``.callj``, and Compare-and-Branch or Compare-and-Jump instructions with target displacements larger than 13 bits.

* Menu:

* <code>callj-i960</code>	<code>`.callj`</code>
* <code>Compare-and-branch-i960</code>	Compare-and-Branch

1.176 `callj-i960`

```
`callj'
.....
```

You can write ``callj'` to have the assembler or the linker determine the most appropriate form of subroutine call: ``call'`, ``bal'`, or ``calls'`. If the assembly source contains enough information--a ``.leafproc'` or ``.sysproc'` directive defining the operand--then ``as'` translates the ``callj'`; if not, it simply emits the ``callj'`, leaving it for the linker to resolve.

1.177 Compare-and-branch-i960

```
Compare-and-Branch
.....
```

The 960 architectures provide combined Compare-and-Branch instructions that permit you to store the branch target in the lower 13 bits of the instruction word itself. However, if you specify a branch target far enough away that its address won't fit in 13 bits, the assembler can either issue an error, or convert your Compare-and-Branch instruction into separate instructions to do the compare and the branch.

Whether ``as'` gives an error or expands the instruction depends on two choices you can make: whether you use the ``.norelax'` option, and whether you use a "Compare and Branch" instruction or a "Compare and Jump" instruction. The "Jump" instructions are **always** expanded if necessary; the "Branch" instructions are expanded when necessary **unless** you specify ``.norelax'`--in which case ``as'` gives an error instead.

These are the Compare-and-Branch instructions, their "Jump" variants, and the instruction pairs they may expand into:

Compare and Branch	Jump	Expanded to
-----	-----	-----
<code>bbc</code>		<code>chkbit; bno</code>
<code>bbs</code>		<code>chkbit; bo</code>
<code>cmpibe</code>	<code>cmpije</code>	<code>cmpi; be</code>
<code>cmpibg</code>	<code>cmpijg</code>	<code>cmpi; bg</code>
<code>cmpibge</code>	<code>cmpijge</code>	<code>cmpi; bge</code>
<code>cmpibl</code>	<code>cmpijl</code>	<code>cmpi; bl</code>
<code>cmpible</code>	<code>cmpijle</code>	<code>cmpi; ble</code>
<code>cmpibno</code>	<code>cmpijno</code>	<code>cmpi; bno</code>
<code>cmpibne</code>	<code>cmpijne</code>	<code>cmpi; bne</code>
<code>cmpibo</code>	<code>cmpijo</code>	<code>cmpi; bo</code>
<code>cmpobe</code>	<code>cmpoje</code>	<code>cmpo; be</code>
<code>cmpobg</code>	<code>cmpojg</code>	<code>cmpo; bg</code>
<code>cmpobge</code>	<code>cmpojge</code>	<code>cmpo; bge</code>
<code>cmpobl</code>	<code>cmpojl</code>	<code>cmpo; bl</code>
<code>cmpoble</code>	<code>cmpojle</code>	<code>cmpo; ble</code>
<code>cmpobne</code>	<code>cmpojne</code>	<code>cmpo; bne</code>

1.178 M68K-Dependent

M680x0 Dependent Features

=====

* Menu:

* M68K-Opts	M680x0 Options
* M68K-Syntax	Syntax
* M68K-Moto-Syntax	Motorola Syntax
* M68K-Float	Floating Point
* M68K-Directives	680x0 Machine Directives
* M68K-opcodes	Opcodes

1.179 M68K-Opts

M680x0 Options

The Motorola 680x0 version of 'as' has two machine dependent options. One shortens undefined references from 32 to 16 bits, while the other is used to tell 'as' what kind of machine it is assembling for.

You can use the '-l' option to shorten the size of references to undefined symbols. If you do not use the '-l' option, references to undefined symbols are wide enough for a full 'long' (32 bits). (Since 'as' cannot know where these symbols end up, 'as' can only allocate space for the linker to fill in later. Since 'as' does not know how far away these symbols are, it allocates as much space as it can.) If you use this option, the references are only one word wide (16 bits). This may be useful if you want the object file to be as small as possible, and you know that the relevant symbols are always less than 17 bits away.

The 680x0 version of 'as' is most frequently used to assemble programs for the Motorola MC68020 microprocessor. Occasionally it is used to assemble programs for the mostly similar, but slightly different MC68000 or MC68010 microprocessors. You can give 'as' the options '-m68000', '-mc68000', '-m68010', '-mc68010', '-m68020', and '-mc68020' to tell it what processor is the target.

1.180 M68K-Syntax

Syntax

This syntax for the Motorola 680x0 was developed at MIT.

The 680x0 version of 'as' uses syntax compatible with the Sun assembler. Intervening periods are ignored; for example, 'movl' is equivalent to 'move.l'.

In the following table "apc" stands for any of the address registers ('a0' through 'a7'), nothing, (''), the Program Counter ('pc'), or the zero-address relative to the program counter ('zpc').

The following addressing modes are understood:

"Immediate"

'#DIGITS'

"Data Register"

'd0' through 'd7'

"Address Register"

'a0' through 'a7'

'a7' is also known as 'sp', i.e. the Stack Pointer. 'a6' is also known as 'fp', the Frame Pointer.

"Address Register Indirect"

'a0@' through 'a7@'

"Address Register Postincrement"

'a0@+' through 'a7@+'

"Address Register Predecrement"

'a0@-' through 'a7@-'

"Indirect Plus Offset"

'APC@(DIGITS)'

"Index"

'APC@(DIGITS,REGISTER:SIZE:SCALE)'

or 'APC@(REGISTER:SIZE:SCALE)'

"Postindex"

'APC@(DIGITS)@(DIGITS,REGISTER:SIZE:SCALE)'

or 'APC@(DIGITS)@(REGISTER:SIZE:SCALE)'

"Preindex"

'APC@(DIGITS,REGISTER:SIZE:SCALE)@(DIGITS)'

or 'APC@(REGISTER:SIZE:SCALE)@(DIGITS)'

"Memory Indirect"

'APC@(DIGITS)@(DIGITS)'

"Absolute"

'SYMBOL', or 'DIGITS'

For some configurations, especially those where the compiler normally does not prepend an underscore to the names of user variables, the assembler requires a '%' before any use of a register name. This is intended to let the assembler distinguish between user variables and registers named 'a0' through 'a7', and so on. The '%' is always accepted, but is only required for some configurations, notably 'm68k-coff'.

1.181 M68K-Moto-Syntax

Motorola Syntax

The standard Motorola syntax for this chip differs from the syntax already discussed (*note Syntax: M68K-Syntax.). 'as' can accept both kinds of syntax, even within a single instruction. The two kinds of syntax are fully compatible.

In particular, you may write or generate M68K assembler with the following conventions:

(In the following table "apc" stands for any of the address registers ('a0' through 'a7'), nothing, (''), the Program Counter ('pc'), or the zero-address relative to the program counter ('zpc').)

The following additional addressing modes are understood:

"Address Register Indirect"

'a0' through 'a7'

'a7' is also known as 'sp', i.e. the Stack Pointer. 'a6' is also known as 'fp', the Frame Pointer.

"Address Register Postincrement"

'(a0)+' through '(a7)+'

"Address Register Predecrement"

'-(a0)' through '-(a7)'

"Indirect Plus Offset"

'DIGITS(APC)'

"Index"

'DIGITS(APC, (REGISTER.SIZE*SCALE))'

or '(APC, REGISTER.SIZE*SCALE)'

In either case, SIZE and SCALE are optional (SCALE defaults to '1', SIZE defaults to '1'). SCALE can be '1', '2', '4', or '8'. SIZE can be 'w' or 'l'. SCALE is only supported on the 68020 and greater.

1.182 M68K-Float

Floating Point

The floating point code is not too well tested, and may have subtle bugs in it.

Packed decimal (P) format floating literals are not supported. Feel free to add the code!

The floating point formats generated by directives are these.

'float'

'Single' precision floating point constants.

'double'

'Double' precision floating point constants.

There is no directive to produce regions of memory holding extended precision numbers, however they can be used as immediate operands to floating-point instructions. Adding a directive to create extended precision numbers would not be hard, but it has not yet seemed necessary.

1.183 M68K-Directives

680x0 Machine Directives

In order to be compatible with the Sun assembler the 680x0 assembler understands the following directives.

'data1'

This directive is identical to a '.data 1' directive.

'data2'

This directive is identical to a '.data 2' directive.

'even'

This directive is identical to a '.align 1' directive.

'skip'

This directive is identical to a '.space' directive.

1.184 M68K-opcodes

Opcodes

* Menu:

* M68K-Branch	Branch Improvement
* M68K-Chars	Special Characters

1.185 M68K-Branch

Branch Improvement

Certain pseudo opcodes are permitted for branch instructions. They expand to the shortest branch instruction that reach the target. Generally these mnemonics are made by substituting 'j' for 'b' at the start of a Motorola mnemonic.

The following table summarizes the pseudo-operations. A '*' flags cases that are more fully described after the table:

Pseudo-Op	Displacement				
	+-----+-----+-----+-----+-----+				
			68020	68000/10	
	BYTE	WORD	LONG	LONG	non-PC relative
+-----+-----+-----+-----+-----+					
jbsr	bsrs	bsr	bsrl	jsr	jsr
jra	bras	bra	bral	jmp	jmp
*	jXX	bXXs	bXX	bXXl	bNXs; jmp
*	dbXX	dbXX	dbXX	dbXX; bra;	jmp
*	fjXX	fbXXw	fbXXw	fbXXl	fbNXw; jmp

XX: condition

NX: negative of condition XX

'* '--see full description below

'jbsr'

'jra'

These are the simplest jump pseudo-operations; they always map to one particular machine instruction, depending on the displacement to the branch target.

'jXX'

Here, 'jXX' stands for an entire family of pseudo-operations, where XX is a conditional branch or condition-code test. The full list of pseudo-ops in this family is:

```
jhi  jls  jcc  jcs  jne  jeq  jvc
jvs  jpl  jmi  jge  jlt  jgt  jle
```

For the cases of non-PC relative displacements and long displacements on the 68000 or 68010, 'as' issues a longer code fragment in terms of NX, the opposite condition to XX. For example, for the non-PC relative case:

```
jXX foo
```

gives

```
bNXs oof
jmp foo
oof:
```

'dbXX'

The full family of pseudo-operations covered here is

```
dbhi  dbls  dbcc  dbcs  dbne  dbeq  dbvc
dbvs  dbpl  dbmi  dbge  dblt  dbgt  dble
dbf   dbra  dbt
```

Other than for word and byte displacements, when the source reads 'dbXX foo', 'as' emits

```
dbXX ool
bra oo2
ool: jmp foo
oo2:
```

'fjXX'

This family includes

```
fjne  fjeq  fjge  fjlt  fjgt  fjle  fjf
fjt   fjgl  fjgle fjnge fjngl fjngle fjngt
fjnle fjnlt fjoge fjogl fjogt fjole fjolt
fjor  fjseq fjsf  fjsne fjst  fjueq fjuge
fjugt fjule fjult fjun
```

For branch targets that are not PC relative, 'as' emits

```
fbNX oof
    jmp foo
oof:
when it encounters 'fjXX foo'.
```

1.186 M68K-Chars

Special Characters

.....

The immediate character is '#' for Sun compatibility. The line-comment character is '|'. If a '#' appears at the beginning of a line, it is treated as a comment unless it looks like '# line file', in which case it is treated normally.

1.187 Sparc-Dependent

SPARC Dependent Features
=====

* Menu:

* Sparc-Opts	Options
* Sparc-Float	Floating Point
* Sparc-Directives	Sparc Machine Directives

1.188 Sparc-Opts

Options

The SPARC chip family includes several successive levels (or other variants) of chip, using the same core instruction set, but including a few additional instructions at each level.

By default, 'as' assumes the core instruction set (SPARC v6), but "bumps" the architecture level as needed: it switches to successively higher architectures as it encounters instructions that only exist in the higher levels.

'-Av6 | -Av7 | -Av8 | -Asparclite'

Use one of the '-A' options to select one of the SPARC

architectures explicitly. If you select an architecture explicitly, 'as' reports a fatal error if it encounters an instruction or feature requiring a higher level.

'-bump'

Permit the assembler to "bump" the architecture level as required, but warn whenever it is necessary to switch to another level.

1.189 Sparc-Float

Floating Point

The Sparc uses IEEE floating-point numbers.

1.190 Sparc-Directives

Sparc Machine Directives

The Sparc version of 'as' supports the following additional machine directives:

'common'

This must be followed by a symbol name, a positive number, and '"bss"'. This behaves somewhat like '.comm', but the syntax is different.

'half'

This is functionally identical to '.short'.

'proc'

This directive is ignored. Any text following it on the same line is also ignored.

'reserve'

This must be followed by a symbol name, a positive number, and '"bss"'. This behaves somewhat like '.lcomm', but the syntax is different.

'seg'

This must be followed by '"text"', '"data"', or '"data1"'. It behaves like '.text', '.data', or '.data 1'.

'skip'

This is functionally identical to the '.space' directive.

'word'

On the Sparc, the .word directive produces 32 bit values, instead of the 16 bit values it produces on many other machines.

1.191 i386-Dependent

80386 Dependent Features

=====

* Menu:

* i386-Options	Options
* i386-Syntax	AT&T Syntax versus Intel Syntax
* i386-Opcodes	Opcode Naming
* i386-Regs	Register Naming
* i386-prefixes	Opcode Prefixes
* i386-Memory	Memory References
* i386-jumps	Handling of Jump Instructions
* i386-Float	Floating Point
* i386-Notes	Notes

1.192 i386-Options

Options

The 80386 has no machine dependent options.

1.193 i386-Syntax

AT&T Syntax versus Intel Syntax

In order to maintain compatibility with the output of 'gcc', 'as' supports AT&T System V/386 assembler syntax. This is quite different from Intel syntax. We mention these differences because almost all 80386 documents used only Intel syntax. Notable differences between the two syntaxes are:

- * AT&T immediate operands are preceded by '\$'; Intel immediate operands are unlimited (Intel 'push 4' is AT&T 'pushl \$4'). AT&T register operands are preceded by '%'; Intel register operands are unlimited. AT&T absolute (as opposed to PC relative) jump/call operands are prefixed by '*'; they are unlimited in Intel syntax.
- * AT&T and Intel syntax use the opposite order for source and destination operands. Intel 'add eax, 4' is 'addl \$4, %eax'. The 'source, dest' convention is maintained for compatibility with previous Unix assemblers.
- * In AT&T syntax the size of memory operands is determined from the last character of the opcode name. Opcode suffixes of 'b', 'w', and 'l' specify byte (8-bit), word (16-bit), and long (32-bit) memory references. Intel syntax accomplishes this by prefixes memory operands (*not* the opcodes themselves) with 'byte ptr',

'word ptr', and 'dword ptr'. Thus, Intel 'mov al, byte ptr FOO' is 'movb FOO, %al' in AT&T syntax.

- * Immediate form long jumps and calls are 'lcall/ljmp \$SECTION, \$OFFSET' in AT&T syntax; the Intel syntax is 'call/jmp far SECTION:OFFSET'. Also, the far return instruction is 'lret \$STACK-ADJUST' in AT&T syntax; Intel syntax is 'ret far STACK-ADJUST'.
- * The AT&T assembler does not provide support for multiple section programs. Unix style systems expect all programs to be single sections.

1.194 i386-Opcodes

Opcode Naming

Opcode names are suffixed with one character modifiers which specify the size of operands. The letters 'b', 'w', and 'l' specify byte, word, and long operands. If no suffix is specified by an instruction and it contains no memory operands then 'as' tries to fill in the missing suffix based on the destination register operand (the last one by convention). Thus, 'mov %ax, %bx' is equivalent to 'movw %ax, %bx'; also, 'mov \$1, %bx' is equivalent to 'movw \$1, %bx'. Note that this is incompatible with the AT&T Unix assembler which assumes that a missing opcode suffix implies long operand size. (This incompatibility does not affect compiler output since compilers always explicitly specify the opcode suffix.)

Almost all opcodes have the same names in AT&T and Intel format. There are a few exceptions. The sign extend and zero extend instructions need two sizes to specify them. They need a size to sign/zero extend *from* and a size to zero extend *to*. This is accomplished by using two opcode suffixes in AT&T syntax. Base names for sign extend and zero extend are 'movs...' and 'movz...' in AT&T syntax ('movsx' and 'movzx' in Intel syntax). The opcode suffixes are tacked on to this base name, the *from* suffix before the *to* suffix. Thus, 'movsbl %al, %edx' is AT&T syntax for "move sign extend *from* %al *to* %edx." Possible suffixes, thus, are 'bl' (from byte to long), 'bw' (from byte to word), and 'wl' (from word to long).

The Intel-syntax conversion instructions

- * 'cbw' -- sign-extend byte in '%al' to word in '%ax',
- * 'cwde' -- sign-extend word in '%ax' to long in '%eax',
- * 'cwd' -- sign-extend word in '%ax' to long in '%dx:%ax',
- * 'cdq' -- sign-extend dword in '%eax' to quad in '%edx:%eax',

are called 'cbtw', 'cwtl', 'cwtd', and 'cltd' in AT&T naming. 'as' accepts either naming for these instructions.

Far call/jump instructions are `'lcall'` and `'ljmp'` in AT&T syntax, but are `'call far'` and `'jump far'` in Intel convention.

1.195 i386-Regs

Register Naming

Register operands are always prefixed with `'%'`. The 80386 registers consist of

- * the 8 32-bit registers `'%eax'` (the accumulator), `'%ebx'`, `'%ecx'`, `'%edx'`, `'%edi'`, `'%esi'`, `'%ebp'` (the frame pointer), and `'%esp'` (the stack pointer).
- * the 8 16-bit low-ends of these: `'%ax'`, `'%bx'`, `'%cx'`, `'%dx'`, `'%di'`, `'%si'`, `'%bp'`, and `'%sp'`.
- * the 8 8-bit registers: `'%ah'`, `'%al'`, `'%bh'`, `'%bl'`, `'%ch'`, `'%cl'`, `'%dh'`, and `'%dl'` (These are the high-bytes and low-bytes of `'%ax'`, `'%bx'`, `'%cx'`, and `'%dx'`)
- * the 6 section registers `'%cs'` (code section), `'%ds'` (data section), `'%ss'` (stack section), `'%es'`, `'%fs'`, and `'%gs'`.
- * the 3 processor control registers `'%cr0'`, `'%cr2'`, and `'%cr3'`.
- * the 6 debug registers `'%db0'`, `'%db1'`, `'%db2'`, `'%db3'`, `'%db6'`, and `'%db7'`.
- * the 2 test registers `'%tr6'` and `'%tr7'`.
- * the 8 floating point register stack `'%st'` or equivalently `'%st(0)'`, `'%st(1)'`, `'%st(2)'`, `'%st(3)'`, `'%st(4)'`, `'%st(5)'`, `'%st(6)'`, and `'%st(7)'`.

1.196 i386-prefixes

Opcode Prefixes

Opcode prefixes are used to modify the following opcode. They are used to repeat string instructions, to provide section overrides, to perform bus lock operations, and to give operand and address size (16-bit operands are specified in an instruction by prefixing what would normally be 32-bit operands with a "operand size" opcode prefix). Opcode prefixes are usually given as single-line instructions with no operands, and must directly precede the instruction they act upon. For example, the `'scas'` (scan string) instruction is repeated with:

```
repne
scas
```

Here is a list of opcode prefixes:

- * Section override prefixes `'cs'`, `'ds'`, `'ss'`, `'es'`, `'fs'`, `'gs'`. These are automatically added by specifying using the `SECTION:MEMORY-OPERAND` form for memory references.
- * Operand/Address size prefixes `'data16'` and `'addr16'` change 32-bit operands/addresses into 16-bit operands/addresses. Note that 16-bit addressing modes (i.e. 8086 and 80286 addressing modes) are not supported (yet).
- * The bus lock prefix `'lock'` inhibits interrupts during execution of the instruction it precedes. (This is only valid with certain instructions; see a 80386 manual for details).
- * The wait for coprocessor prefix `'wait'` waits for the coprocessor to complete the current instruction. This should never be needed for the 80386/80387 combination.
- * The `'rep'`, `'repe'`, and `'repne'` prefixes are added to string instructions to make them repeat `'%ecx'` times.

1.197 i386-Memory

Memory References

An Intel syntax indirect memory reference of the form

```
SECTION:[BASE + INDEX*SCALE + DISP]
```

is translated into the AT&T syntax

```
SECTION:DISP(BASE, INDEX, SCALE)
```

where BASE and INDEX are the optional 32-bit base and index registers, DISP is the optional displacement, and SCALE, taking the values 1, 2, 4, and 8, multiplies INDEX to calculate the address of the operand. If no SCALE is specified, SCALE is taken to be 1. SECTION specifies the optional section register for the memory operand, and may override the default section register (see a 80386 manual for section register defaults). Note that section overrides in AT&T syntax *must* have be preceded by a `'%'`. If you specify a section override which coincides with the default section register, `'as'` does *not* output any section register override prefixes to assemble the given instruction. Thus, section overrides can be specified to emphasize which section register is used for a given memory operand.

Here are some examples of Intel and AT&T style memory references:

AT&T: `'-4(%ebp)'`, Intel: `'[ebp - 4]'`

BASE is `'%ebp'`; DISP is `'-4'`. SECTION is missing, and the default section is used (`'%ss'` for addressing with `'%ebp'` as the base register). INDEX, SCALE are both missing.

AT&T: `'foo(%eax,4)'`, Intel: `'[foo + eax*4]'`
 INDEX is `'%eax'` (scaled by a SCALE 4); DISP is `'foo'`. All other fields are missing. The section register here defaults to `'%ds'`.

AT&T: `'foo(,1)'`; Intel `'[foo]'`
 This uses the value pointed to by `'foo'` as a memory operand. Note that BASE and INDEX are both missing, but there is only **one** `','`. This is a syntactic exception.

AT&T: `'%gs:foo'`; Intel `'gs:foo'`
 This selects the contents of the variable `'foo'` with section register SECTION being `'%gs'`.

Absolute (as opposed to PC relative) call and jump operands must be prefixed with `'*'`. If no `'*'` is specified, `'as'` always chooses PC relative addressing for jump/call labels.

Any instruction that has a memory operand **must** specify its size (byte, word, or long) with an opcode suffix (`'b'`, `'w'`, or `'l'`, respectively).

1.198 i386-jumps

Handling of Jump Instructions

Jump instructions are always optimized to use the smallest possible displacements. This is accomplished by using byte (8-bit) displacement jumps whenever the target is sufficiently close. If a byte displacement is insufficient a long (32-bit) displacement is used. We do not support word (16-bit) displacement jumps (i.e. prefixing the jump instruction with the `'addr16'` opcode prefix), since the 80386 insists upon masking `'%eip'` to 16 bits after the word displacement is added.

Note that the `'jcxz'`, `'jecxz'`, `'loop'`, `'loopz'`, `'loope'`, `'loopnz'` and `'loopne'` instructions only come in byte displacements, so that if you use these instructions (`'gcc'` does not use them) you may get an error message (and incorrect code). The AT&T 80386 assembler tries to get around this problem by expanding `'jcxz foo'` to

```

        jcxz cx_zero
        jmp  cx_nonzero
cx_zero: jmp  foo
cx_nonzero:
```

1.199 i386-Float

Floating Point

All 80387 floating point types except packed BCD are supported. (BCD support may be added without much difficulty). These data types

are 16-, 32-, and 64- bit integers, and single (32-bit), double (64-bit), and extended (80-bit) precision floating point. Each supported type has an opcode suffix and a constructor associated with it. Opcode suffixes specify operand's data types. Constructors build these data types into memory.

- * Floating point constructors are ``.float'`` or ``.single'``, ``.double'``, and ``.tfloat'`` for 32-, 64-, and 80-bit formats. These correspond to opcode suffixes `'s'`, `'l'`, and `'t'`. `'t'` stands for temporary real, and that the 80387 only supports this format via the `'fldt'` (load temporary real to stack top) and `'fstpt'` (store temporary real and pop stack) instructions.
- * Integer constructors are ``.word'``, ``.long'`` or ``.int'``, and ``.quad'`` for the 16-, 32-, and 64-bit integer formats. The corresponding opcode suffixes are `'s'` (single), `'l'` (long), and `'q'` (quad). As with the temporary real format the 64-bit `'q'` format is only present in the `'fildq'` (load quad integer to stack top) and `'fistpq'` (store quad integer and pop stack) instructions.

Register to register operations do not require opcode suffixes, so that `'fst %st, %st(1)'` is equivalent to `'fstl %st, %st(1)'`.

Since the 80387 automatically synchronizes with the 80386 `'fwait'` instructions are almost never needed (this is not the case for the 80286/80287 and 8086/8087 combinations). Therefore, `'as'` suppresses the `'fwait'` instruction whenever it is implicitly selected by one of the `'fn...'` instructions. For example, `'fsave'` and `'fnsave'` are treated identically. In general, all the `'fn...'` instructions are made equivalent to `'f...'` instructions. If `'fwait'` is desired it must be explicitly coded.

1.200 i386-Notes

Notes

There is some trickery concerning the `'mul'` and `'imul'` instructions that deserves mention. The 16-, 32-, and 64-bit expanding multiplies (base opcode `'0xf6'`; extension 4 for `'mul'` and 5 for `'imul'`) can be output only in the one operand form. Thus, `'imul %ebx, %eax'` does *not* select the expanding multiply; the expanding multiply would clobber the `'%edx'` register, and this would confuse `'gcc'` output. Use `'imul %ebx'` to get the 64-bit product in `'%edx:%eax'`.

We have added a two operand form of `'imul'` when the first operand is an immediate mode expression and the second operand is a register. This is just a shorthand, so that, multiplying `'%eax'` by 69, for example, can be done with `'imul $69, %eax'` rather than `'imul $69, %eax, %eax'`.

1.201 Z8000-Dependent

Z8000 Dependent Features

=====

The Z8000 as supports both members of the Z8000 family: the unsegmented Z8002, with 16 bit addresses, and the segmented Z8001 with 24 bit addresses.

When the assembler is in unsegmented mode (specified with the 'unsegm' directive), an address takes up one word (16 bit) sized register. When the assembler is in segmented mode (specified with the 'segm' directive), a 24-bit address takes up a long (32 bit) register. *Note Assembler Directives for the Z8000: Z8000 Directives, for a list of other Z8000 specific assembler directives.

* Menu:

* Z8000 Options	No special command-line options for Z8000
* Z8000 Syntax	Assembler syntax for the Z8000
* Z8000 Directives	Special directives for the Z8000
* Z8000 Opcodes	Opcodes

1.202 Z8000 Options

Options

'as' has no additional command-line options for the Zilog Z8000 family.

1.203 Z8000 Syntax

Syntax

* Menu:

* Z8000-Chars	Special Characters
* Z8000-Regs	Register Names
* Z8000-Addressing	Addressing Modes

1.204 Z8000-Chars

Special Characters

.....

'!' is the line comment character.

You can use ';' instead of a newline to separate statements.

1.205 Z8000-Regs

Register Names

.....

The Z8000 has sixteen 16 bit registers, numbered 0 to 15. You can refer to different sized groups of registers by register number, with the prefix 'r' for 16 bit registers, 'rr' for 32 bit registers and 'rq' for 64 bit registers. You can also refer to the contents of the first eight (of the sixteen 16 bit registers) by bytes. They are named 'rNh' and 'rNl'.

byte registers

r0l r0h r1l r1h r2l r2h r3l r3h
r4l r4h r5l r5h r6l r6h r7l r7h

word registers

r0 r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11 r12 r13 r14 r15

long word registers

rr0 rr2 rr4 rr6 rr8 rr10 rr12 rr14

quad word registers

rq0 rq4 rq8 rq12

1.206 Z8000-Addressing

Addressing Modes

.....

as understands the following addressing modes for the Z8000:

'rN'

Register direct

'@rN'

Indirect register

'ADDR'

Direct: the 16 bit or 24 bit address (depending on whether the assembler is in segmented or unsegmented mode) of the operand is in the instruction.

'address(rN)'

Indexed: the 16 or 24 bit address is added to the 16 bit register to produce the final address in memory of the operand.

'rN(#IMM)'

Base Address: the 16 or 24 bit register is added to the 16 bit sign extended immediate displacement to produce the final address in memory of the operand.

'rN(rM)'

Base Index: the 16 or 24 bit register rN is added to the sign extended 16 bit index register rM to produce the final address in memory of the operand.

```
`#XX'
    Immediate data XX.
```

1.207 Z8000 Directives

Assembler Directives for the Z8000

The Z8000 port of as includes these additional assembler directives, for compatibility with other Z8000 assemblers. As shown, these do not begin with `.' (unlike the ordinary as directives).

```
`segm'
    Generates code for the segmented Z8001.
```

```
`unsegm'
    Generates code for the unsegmented Z8002.
```

```
`name'
    Synonym for `.file'
```

```
`global'
    Synonym for `.global'
```

```
`wval'
    Synonym for `.word'
```

```
`lval'
    Synonym for `.long'
```

```
`bval'
    Synonym for `.byte'
```

```
`sval'
    Assemble a string. `sval' expects one string literal, delimited by
    single quotes. It assembles each byte of the string into
    consecutive addresses. You can use the escape sequence `%XX'
    (where XX represents a two-digit hexadecimal number) to represent
    the character whose ASCII value is XX. Use this feature to
    describe single quote and other characters that may not appear in
    string literals as themselves. For example, the C statement
    `char *a = "he said \"it's 50% off\"";' is represented in Z8000
    assembly language (shown with the assembler output in hex at the
    left) as
```

```
68652073    sval    'he said %22it%27s 50%25 off%22%00'
61696420
22697427
73203530
25206F66
662200
```

```
`rsect'
    synonym for `.section'
```

``block'`
synonym for ``.space'`

``even'`
synonym for ``.align 1'`

1.208 Z8000 Opcodes

Opcodes

For detailed information on the Z8000 machine instruction set, see `'Z8000 Technical Manual'`.

The following table summarizes the opcodes and their arguments:

<code>rs</code>	16 bit source register	
<code>rd</code>	16 bit destination register	
<code>rbs</code>	8 bit source register	
<code>rbd</code>	8 bit destination register	
<code>rrs</code>	32 bit source register	
<code>rrd</code>	32 bit destination register	
<code>rqs</code>	64 bit source register	
<code>rqd</code>	64 bit destination register	
<code>addr</code>	16/24 bit address	
<code>imm</code>	immediate data	
<code>adc rd,rs</code>	<code>clrb addr</code>	<code>cpsir @rd,@rs,rr,cc</code>
<code>adcb rbd,rbs</code>	<code>clrb addr(rd)</code>	<code>cpsirb @rd,@rs,rr,cc</code>
<code>add rd,@rs</code>	<code>clrb rbd</code>	<code>dab rbd</code>
<code>add rd,addr</code>	<code>com @rd</code>	<code>dbjnz rbd,disp7</code>
<code>add rd,addr(rs)</code>	<code>com addr</code>	<code>dec @rd,imm4m1</code>
<code>add rd,imm16</code>	<code>com addr(rd)</code>	<code>dec addr(rd),imm4m1</code>
<code>add rd,rs</code>	<code>com rd</code>	<code>dec addr,imm4m1</code>
<code>addb rbd,@rs</code>	<code>comb @rd</code>	<code>dec rd,imm4m1</code>
<code>addb rbd,addr</code>	<code>comb addr</code>	<code>decb @rd,imm4m1</code>
<code>addb rbd,addr(rs)</code>	<code>comb addr(rd)</code>	<code>decb addr(rd),imm4m1</code>
<code>addb rbd,imm8</code>	<code>comb rbd</code>	<code>decb addr,imm4m1</code>
<code>addb rbd,rbs</code>	<code>comflg flags</code>	<code>decb rbd,imm4m1</code>
<code>addl rrd,@rs</code>	<code>cp @rd,imm16</code>	<code>di i2</code>
<code>addl rrd,addr</code>	<code>cp addr(rd),imm16</code>	<code>div rrd,@rs</code>
<code>addl rrd,addr(rs)</code>	<code>cp addr,imm16</code>	<code>div rrd,addr</code>
<code>addl rrd,imm32</code>	<code>cp rd,@rs</code>	<code>div rrd,addr(rs)</code>
<code>addl rrd,rrs</code>	<code>cp rd,addr</code>	<code>div rrd,imm16</code>
<code>and rd,@rs</code>	<code>cp rd,addr(rs)</code>	<code>div rrd,rs</code>
<code>and rd,addr</code>	<code>cp rd,imm16</code>	<code>divl rqd,@rs</code>
<code>and rd,addr(rs)</code>	<code>cp rd,rs</code>	<code>divl rqd,addr</code>
<code>and rd,imm16</code>	<code>cpb @rd,imm8</code>	<code>divl rqd,addr(rs)</code>
<code>and rd,rs</code>	<code>cpb addr(rd),imm8</code>	<code>divl rqd,imm32</code>
<code>andb rbd,@rs</code>	<code>cpb addr,imm8</code>	<code>divl rqd,rrs</code>
<code>andb rbd,addr</code>	<code>cpb rbd,@rs</code>	<code>djnz rd,disp7</code>
<code>andb rbd,addr(rs)</code>	<code>cpb rbd,addr</code>	<code>ei i2</code>
<code>andb rbd,imm8</code>	<code>cpb rbd,addr(rs)</code>	<code>ex rd,@rs</code>
<code>andb rbd,rbs</code>	<code>cpb rbd,imm8</code>	<code>ex rd,addr</code>
<code>bit @rd,imm4</code>	<code>cpb rbd,rbs</code>	<code>ex rd,addr(rs)</code>

bit addr(rd),imm4	cpd rd,@rs,rr,cc	ex rd,rs
bit addr,imm4	cpdb rbd,@rs,rr,cc	exb rbd,@rs
bit rd,imm4	cpdr rd,@rs,rr,cc	exb rbd,addr
bit rd,rs	cpdrb rbd,@rs,rr,cc	exb rbd,addr(rs)
bitb @rd,imm4	cpir rd,@rs,rr,cc	exb rbd,rs
bitb addr(rd),imm4	cpib rbd,@rs,rr,cc	ext0e imm8
bitb addr,imm4	cpir rd,@rs,rr,cc	ext0f imm8
bitb rbd,imm4	cpirb rbd,@rs,rr,cc	ext8e imm8
bitb rbd,rs	cpl rrd,@rs	ext8f imm8
bpt	cpl rrd,addr	exts rrd
call @rd	cpl rrd,addr(rs)	extsb rd
call addr	cpl rrd,imm32	extsl rqd
call addr(rd)	cpl rrd,rrs	halt
calr displ2	cpsd @rd,@rs,rr,cc	in rd,@rs
clr @rd	cpsdb @rd,@rs,rr,cc	in rd,imm16
clr addr	cpsdr @rd,@rs,rr,cc	inb rbd,@rs
clr addr(rd)	cpsdrb @rd,@rs,rr,cc	inb rbd,imm16
clr rd	cpssi @rd,@rs,rr,cc	inc @rd,imm4m1
clrb @rd	cpsib @rd,@rs,rr,cc	inc addr(rd),imm4m1
inc addr,imm4m1	ldb rbd,rs(rx)	mult rrd,addr(rs)
inc rd,imm4m1	ldb rd(imm16),rbs	mult rrd,imm16
incb @rd,imm4m1	ldb rd(rx),rbs	mult rrd,rs
incb addr(rd),imm4m1	ldctl ctrl,rs	multl rqd,@rs
incb addr,imm4m1	ldctl rd,ctrl	multl rqd,addr
incb rbd,imm4m1	ldd @rs,@rd,rr	multl rqd,addr(rs)
ind @rd,@rs,ra	lddb @rs,@rd,rr	multl rqd,imm32
indb @rd,@rs,rba	lddr @rs,@rd,rr	multl rqd,rrs
inib @rd,@rs,ra	lddrb @rs,@rd,rr	neg @rd
inibr @rd,@rs,ra	ldi @rd,@rs,rr	neg addr
iret	ldib @rd,@rs,rr	neg addr(rd)
jp cc,@rd	ldir @rd,@rs,rr	neg rd
jp cc,addr	ldirb @rd,@rs,rr	negb @rd
jp cc,addr(rd)	ldk rd,imm4	negb addr
jr cc,disp8	ldl @rd,rrs	negb addr(rd)
ld @rd,imm16	ldl addr(rd),rrs	negb rbd
ld @rd,rs	ldl addr,rrs	nop
ld addr(rd),imm16	ldl rd(imm16),rrs	or rd,@rs
ld addr(rd),rs	ldl rd(rx),rrs	or rd,addr
ld addr,imm16	ldl rrd,@rs	or rd,addr(rs)
ld addr,rs	ldl rrd,addr	or rd,imm16
ld rd(imm16),rs	ldl rrd,addr(rs)	or rd,rs
ld rd(rx),rs	ldl rrd,imm32	orb rbd,@rs
ld rd,@rs	ldl rrd,rrs	orb rbd,addr
ld rd,addr	ldl rrd,rs(imm16)	orb rbd,addr(rs)
ld rd,addr(rs)	ldl rrd,rs(rx)	orb rbd,imm8
ld rd,imm16	ldm @rd,rs,n	orb rbd,rs
ld rd,rs	ldm addr(rd),rs,n	out @rd,rs
ld rd,rs(imm16)	ldm addr,rs,n	out imm16,rs
ld rd,rs(rx)	ldm rd,@rs,n	outb @rd,rs
lda rd,addr	ldm rd,addr(rs),n	outb imm16,rs
lda rd,addr(rs)	ldm rd,addr,n	outd @rd,@rs,ra
lda rd,rs(imm16)	ldps @rs	outdb @rd,@rs,rba
lda rd,rs(rx)	ldps addr	outib @rd,@rs,ra
ldar rd,displ6	ldps addr(rs)	outibr @rd,@rs,ra
ldb @rd,imm8	ldr displ6,rs	pop @rd,@rs
ldb @rd,rs	ldr rd,displ6	pop addr(rd),@rs
ldb addr(rd),imm8	ldrb displ6,rs	pop addr,@rs

ldb addr(rd), rbs	ldrb rbd, displ6	pop rd, @rs
ldb addr, imm8	ldrl displ6, rrs	popl @rd, @rs
ldb addr, rbs	ldrl rrd, displ6	popl addr(rd), @rs
ldb rbd, @rs	mbit	popl addr, @rs
ldb rbd, addr	mreq rd	popl rrd, @rs
ldb rbd, addr(rs)	mres	push @rd, @rs
ldb rbd, imm8	mset	push @rd, addr
ldb rbd, rbs	mult rrd, @rs	push @rd, addr(rs)
ldb rbd, rs(imm16)	mult rrd, addr	push @rd, imm16
push @rd, rs	set addr, imm4	subl rrd, imm32
pushl @rd, @rs	set rd, imm4	subl rrd, rrs
pushl @rd, addr	set rd, rs	tcc cc, rd
pushl @rd, addr(rs)	setb @rd, imm4	tccb cc, rbd
pushl @rd, rrs	setb addr(rd), imm4	test @rd
res @rd, imm4	setb addr, imm4	test addr
res addr(rd), imm4	setb rbd, imm4	test addr(rd)
res addr, imm4	setb rbd, rs	test rd
res rd, imm4	setflg imm4	testb @rd
res rd, rs	sinb rbd, imm16	testb addr
resb @rd, imm4	sinb rd, imm16	testb addr(rd)
resb addr(rd), imm4	sind @rd, @rs, ra	testb rbd
resb addr, imm4	sindb @rd, @rs, rba	testl @rd
resb rbd, imm4	sinib @rd, @rs, ra	testl addr
resb rbd, rs	sinibr @rd, @rs, ra	testl addr(rd)
resflg imm4	sla rd, imm8	testl rrd
ret cc	slab rbd, imm8	trdb @rd, @rs, rba
rl rd, imm1or2	slal rrd, imm8	trdrb @rd, @rs, rba
rlb rbd, imm1or2	sll rd, imm8	trib @rd, @rs, rbr
rlc rd, imm1or2	sllb rbd, imm8	trirb @rd, @rs, rbr
rlcb rbd, imm1or2	slll rrd, imm8	trtdrb @ra, @rb, rbr
rldb rbb, rba	sout imm16, rs	trtib @ra, @rb, rr
rr rd, imm1or2	soutb imm16, rbs	trtirb @ra, @rb, rbr
rrb rbd, imm1or2	soutd @rd, @rs, ra	trtrb @ra, @rb, rbr
rrc rd, imm1or2	soutdb @rd, @rs, rba	tset @rd
rrcb rbd, imm1or2	soutib @rd, @rs, ra	tset addr
rrdb rbb, rba	soutibr @rd, @rs, ra	tset addr(rd)
rsvd36	sra rd, imm8	tset rd
rsvd38	srab rbd, imm8	tsetb @rd
rsvd78	sral rrd, imm8	tsetb addr
rsvd7e	srl rd, imm8	tsetb addr(rd)
rsvd9d	srlb rbd, imm8	tsetb rbd
rsvd9f	srlr rrd, imm8	xor rd, @rs
rsvdb9	sub rd, @rs	xor rd, addr
rsvdbf	sub rd, addr	xor rd, addr(rs)
sbc rd, rs	sub rd, addr(rs)	xor rd, imm16
sbc b rbd, rbs	sub rd, imm16	xor rd, rs
sc imm8	sub rd, rs	xorb rbd, @rs
sda rd, rs	subb rbd, @rs	xorb rbd, addr
sdab rbd, rs	subb rbd, addr	xorb rbd, addr(rs)
sdal rrd, rs	subb rbd, addr(rs)	xorb rbd, imm8
sdl rd, rs	subb rbd, imm8	xorb rbd, rbs
sdlb rbd, rs	subb rbd, rbs	xorb rbd, rbs
sdll rrd, rs	subl rrd, @rs	
set @rd, imm4	subl rrd, addr	
set addr(rd), imm4	subl rrd, addr(rs)	

1.209 MIPS-Dependent

MIPS Dependent Features

=====

GNU 'as' for MIPS architectures supports the MIPS R2000, R3000, R4000 and R6000 processors. For information about the MIPS instruction set, see 'MIPS RISC Architecture', by Kane and Heindrich (Prentice-Hall). For an overview of MIPS assembly conventions, see "Appendix D: Assembly Language Programming" in the same work.

* Menu:

- * MIPS Opts Assembler options
- * MIPS Object ECOFF object code
- * MIPS Stabs Directives for debugging information
- * MIPS ISA Directives to override the ISA level

1.210 MIPS Opts

Assembler options

The MIPS configurations of GNU 'as' support these special options:

'-G NUM'

This option sets the largest size of an object that can be referenced implicitly with the 'gp' register. It is only accepted for targets that use ECOFF format. The default value is 8.

'-EB'

'-EL'

Any MIPS configuration of 'as' can select big-endian or little-endian output at run time (unlike the other GNU development tools, which must be configured for one or the other). Use '-EB' to select big-endian output, and '-EL' for little-endian.

'-mips1'

'-mips2'

'-mips3'

Generate code for a particular MIPS Instruction Set Architecture level. '-mips1' corresponds to the R2000 and R3000 processors, '-mips2' to the R6000 processor, and '-mips3' to the R4000 processor. You can also switch instruction sets during the assembly; see *Note Directives to override the ISA level: MIPS ISA.

'-nocpp'

This option is ignored. It is accepted for command-line compatibility with other assemblers, which use it to turn off C style preprocessing. With GNU 'as', there is no need for '-nocpp', because the GNU assembler itself never runs the C preprocessor.

'--trap'

`--no-break`

`'as'` automatically macro expands certain division and multiplication instructions to check for overflow and division by zero. This option causes `'as'` to generate code to take a trap exception rather than a break exception when an error is detected. The trap instructions are only supported at Instruction Set Architecture level 2 and higher.

`--break`

`--no-trap`

Generate code to take a break exception rather than a trap exception when an error is detected. This is the default.

1.211 MIPS Object

MIPS ECOFF object code

Assembling for a MIPS ECOFF target supports some additional sections besides the usual `.text`, `.data` and `.bss`. The additional sections are `.rdata`, used for read-only data, `.sdata`, used for small data, and `.sbss`, used for small common objects.

When assembling for ECOFF, the assembler uses the `$gp` (`$28`) register to form the address of a "small object". Any object in the `.sdata` or `.sbss` sections is considered "small" in this sense. For external objects, or for objects in the `.bss` section, you can use the `'gcc'` `-G` option to control the size of objects addressed via `$gp`; the default value is 8, meaning that a reference to any object eight bytes or smaller uses `$gp`. Passing `-G 0` to `'as'` prevents it from using the `$gp` register on the basis of object size (but the assembler uses `$gp` for objects in `.sdata` or `.sbss` in any case). The size of an object in the `.bss` section is set by the `.comm` or `.lcomm` directive that defines it. The size of an external object may be set with the `.extern` directive. For example, `.extern sym,4` declares that the object at `sym` is 4 bytes in length, while leaving `sym` otherwise undefined.

Using small ECOFF objects requires linker support, and assumes that the `$gp` register is correctly initialized (normally done automatically by the startup code). MIPS ECOFF assembly code must not modify the `$gp` register.

1.212 MIPS Stabs

Directives for debugging information

MIPS ECOFF `'as'` supports several directives used for generating debugging information which are not supported by traditional MIPS assemblers. These are `.def`, `.endef`, `.dim`, `.file`, `.scl`, `.size`, `.tag`, `.type`, `.val`, `.stabd`, `.stabsn`, and `.stabs`.

The debugging information generated by the three ``.stab'` directives can only be read by GDB, not by traditional MIPS debuggers (this enhancement is required to fully support C++ debugging). These directives are primarily used by compilers, not assembly language programmers!

1.213 MIPS ISA

Directives to override the ISA level

GNU `as` supports an additional directive to change the MIPS Instruction Set Architecture level on the fly: ``.set mipsN'`. `N` should be a number from 0 to 3. A value from 1 to 3 makes the assembler accept instructions for the corresponding ISA level, from that point on in the assembly. ``.set mipsN'` affects not only which instructions are permitted, but also how certain macros are expanded. ``.set mips0'` restores the ISA level to its original level: either the level you selected with command line options, or the default for your configuration. You can use this feature to permit specific R4000 instructions while assembling in 32 bit mode. Use this directive with care!

Traditional MIPS assemblers do not support this directive.

1.214 Acknowledgements

Acknowledgements

If you have contributed to `as` and your name isn't listed here, it is not meant as a slight. We just don't know about it. Send mail to the maintainer, and we'll correct the situation. Currently (January 1994), the maintainer is Ken Raeburn (email address `raeburn@cygnus.com`).

Dean Elsner wrote the original GNU assembler for the VAX.(1)

Jay Fenlason maintained GAS for a while, adding support for GDB-specific debug information and the 68k series machines, most of the preprocessing pass, and extensive changes in `messages.c`, `input-file.c`, `write.c`.

K. Richard Pixley maintained GAS for a while, adding various enhancements and many bug fixes, including merging support for several processors, breaking GAS up to handle multiple object file format back ends (including heavy rewrite, testing, an integration of the coff and b.out back ends), adding configuration including heavy testing and verification of cross assemblers and file splits and renaming, converted GAS to strictly ANSI C including full prototypes, added support for m680[34]0 and cpu32, did considerable work on i960 including a COFF port (including considerable amounts of reverse

engineering), a SPARC opcode file rewrite, DECstation, rs6000, and hp300hpux host ports, updated "know" assertions and made them work, much other reorganization, cleanup, and lint.

Ken Raeburn wrote the high-level BFD interface code to replace most of the code in format-specific I/O modules.

The original VMS support was contributed by David L. Kashtan. Eric Youngdale has done much work with it since.

The Intel 80386 machine description was written by Eliot Dresselhaus.

Minh Tran-Le at IntelliCorp contributed some AIX 386 support.

The Motorola 88k machine description was contributed by Devon Bowen of Buffalo University and Torbjorn Granlund of the Swedish Institute of Computer Science.

Keith Knowles at the Open Software Foundation wrote the original MIPS back end ('tc-mips.c', 'tc-mips.h'), and contributed Rose format support (which hasn't been merged in yet). Ralph Campbell worked with the MIPS code to support a.out format.

Support for the Zilog Z8k and Hitachi H8/300 and H8/500 processors (tc-z8k, tc-h8300, tc-h8500), and IEEE 695 object file format (obj-ieee), was written by Steve Chamberlain of Cygnus Support. Steve also modified the COFF back end to use BFD for some low-level operations, for use with the H8/300 and AMD 29k targets.

John Gilmore built the AMD 29000 support, added '.include' support, and simplified the configuration of which versions accept which directives. He updated the 68k machine description so that Motorola's opcodes always produced fixed-size instructions (e.g. 'jsr'), while synthetic instructions remained shrinkable ('jbsr'). John fixed many bugs, including true tested cross-compilation support, and one bug in relaxation that took a week and required the proverbial one-bit fix.

Ian Lance Taylor of Cygnus Support merged the Motorola and MIT syntax for the 68k, completed support for some COFF targets (68k, i386 SVR3, and SCO Unix), added support for MIPS ECOFF and ELF targets, and made a few other minor patches.

Steve Chamberlain made 'as' able to generate listings.

Hewlett-Packard contributed support for the HP9000/300.

Jeff Law wrote GAS and BFD support for the native HPPA object format (SOM) along with a fairly extensive HPPA testsuite (for both SOM and ELF object formats). This work was supported by both the Center for Software Science at the University of Utah and Cygnus Support.

Support for ELF format files has been worked on by Mark Eichin of Cygnus Support (original, incomplete implementation for SPARC), Pete Hoogenboom and Jeff Law at the University of Utah (HPPA mainly), Michael Meissner of the Open Software Foundation (i386 mainly), and Ken Raeburn of Cygnus Support (sparc, and some initial 64-bit support).

Several engineers at Cygnus Support have also provided many small bug fixes and configuration enhancements.

Many others have contributed large or small bugfixes and enhancements. If you have contributed significant work and are not mentioned on this list, and want to be, let us know. Some of the history has been lost; we are not intentionally leaving anyone out.

----- Footnotes -----

(1) Any more details?

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* float directive:	Float.
* float directive, i386:	i386-Float.
* float directive, M680x0:	M68K-Float.
* float directive, VAX:	VAX-float.
* fwait instruction, i386:	i386-Float.

* gbr960, i960 postprocessor:	Options-i960.
* gfloat directive, VAX:	VAX-directives.
* global directive:	Global.
* gp register, MIPS:	MIPS Object.
* half directive, SPARC:	Sparc-Directives.
* hfloat directive, VAX:	VAX-directives.
* hword directive:	hword.
* ident directive:	Ident.
* ifdef directive:	If.
* ifndef directive:	If.
* ifnotdef directive:	If.
* if directive:	If.
* imul instruction, i386:	i386-Notes.
* include directive:	Include.
* include directive search path:	I.
* int directive:	Int.
* int directive, H8/300:	H8/300 Directives.
* int directive, H8/500:	H8/500 Directives.
* int directive, i386:	i386-Float.
* int directive, SH:	SH Directives.
* lcomm directive:	Lcomm.
* leafproc directive, i960:	Directives-i960.
* lflags directive (ignored):	Lflags.
* line directive:	Line.
* line directive, AMD 29K:	AMD29K Directives.
* list directive:	List.
* ln directive:	Ln.
* long directive:	Long.
* long directive, i386:	i386-Float.
* mul instruction, i386:	i386-Notes.
* nolist directive:	Nolist.
* octa directive:	Octa.
* org directive:	Org.
* proc directive, SPARC:	Sparc-Directives.
* psize directive:	Psize.
* quad directive:	Quad.
* quad directive, i386:	i386-Float.
* reserve directive, SPARC:	Sparc-Directives.
* sbttl directive:	Sbttl.
* scl directive:	Scl.
* section directive:	Section.
* sect directive, AMD 29K:	AMD29K Directives.
* seg directive, SPARC:	Sparc-Directives.
* set directive:	Set.
* short directive:	Short.
* single directive:	Single.
* single directive, i386:	i386-Float.
* size directive:	Size.
* skip directive, M680x0:	M68K-Directives.
* skip directive, SPARC:	Sparc-Directives.
* space directive:	Space.
* stabX directives:	Stab.
* stabd directive:	Stab.
* stabn directive:	Stab.
* stabs directive:	Stab.
* string directive:	String.
* string directive on HPPA:	HPPA Directives.

* sysproc directive, i960:	Directives-i960.
* tag directive:	Tag.
* text directive:	Text.
* tfloat directive, i386:	i386-Float.
* title directive:	Title.
* type directive:	Type.
* use directive, AMD 29K:	AMD29K Directives.
* val directive:	Val.
* word directive:	Word.
* word directive, H8/300:	H8/300 Directives.
* word directive, H8/500:	H8/500 Directives.
* word directive, i386:	i386-Float.
* word directive, SH:	SH Directives.
* word directive, SPARC:	Sparc-Directives.
* \" (doublequote character):	Strings.
* \DDD (octal character code):	Strings.
* \XDD (hex character code):	Strings.
* \b (backspace character):	Strings.
* \f (formfeed character):	Strings.
* \n (newline character):	Strings.
* \r (carriage return character):	Strings.
* \t (tab):	Strings.
* \ (\\ character):	Strings.
* MIT:	M68K-Syntax.
* a.out:	Object.
* absolute section:	Ld Sections.
* addition, permitted arguments:	Infix Ops.
* addresses:	Expressions.
* addresses, format of:	Secs Background.
* addressing modes, H8/300:	H8/300-Addressing.
* addressing modes, H8/500:	H8/500-Addressing.
* addressing modes, M680x0:	M68K-Syntax.
* addressing modes, M680x0:	M68K-Moto-Syntax.
* addressing modes, SH:	SH-Addressing.
* addressing modes, Z8000:	Z8000-Addressing.
* advancing location counter:	Org.
* altered difference tables:	Word.
* alternate syntax for the 680x0:	M68K-Moto-Syntax.
* AMD 29K floating point (IEEE):	AMD29K Floating Point.
* AMD 29K identifiers:	AMD29K-Chars.
* AMD 29K line comment character:	AMD29K-Chars.
* AMD 29K line separator:	AMD29K-Chars.
* AMD 29K machine directives:	AMD29K Directives.
* AMD 29K opcodes:	AMD29K Opcodes.
* AMD 29K options (none):	AMD29K Options.
* AMD 29K protected registers:	AMD29K-Regs.
* AMD 29K register names:	AMD29K-Regs.
* AMD 29K special purpose registers:	AMD29K-Regs.
* AMD 29K statement separator:	AMD29K-Chars.
* AMD 29K support:	AMD29K-Dependent.
* architecture options, i960:	Options-i960.
* architecture options, M680x0:	M68K-Opts.
* architectures, SPARC:	Sparc-Opts.
* arguments for addition:	Infix Ops.
* arguments for subtraction:	Infix Ops.
* arguments in expressions:	Arguments.
* arithmetic functions:	Operators.

* arithmetic operands:	Arguments.
* assembler internal logic error:	As Sections.
* assembler, and linker:	Secs Background.
* assembly listings, enabling:	a.
* assigning values to symbols:	Equ.
* assigning values to symbols:	Setting Symbols.
* attributes, symbol:	Symbol Attributes.
* auxiliary attributes, COFF symbols:	COFF Symbols.
* auxiliary symbol information, COFF:	Dim.
* Av7:	Sparc-Opts.
* backslash (\):	Strings.
* backspace (\b):	Strings.
* big endian output, MIPS:	Overview.
* big-endian output, MIPS:	MIPS Opts.
* bignums:	Bignums.
* binary integers:	Integers.
* bitfields, not supported on VAX:	VAX-no.
* block:	Z8000 Directives.
* branch improvement, M680x0:	M68K-Branch.
* branch improvement, VAX:	VAX-branch.
* branch recording, i960:	Options-i960.
* branch statistics table, i960:	Options-i960.
* bss section:	Ld Sections.
* bss section:	bss.
* bus lock prefixes, i386:	i386-prefixes.
* bval:	Z8000 Directives.
* call instructions, i386:	i386-Opcodes.
* carriage return (\r):	Strings.
* character constants:	Characters.
* character escape codes:	Strings.
* character, single:	Chars.
* characters used in symbols:	Symbol Intro.
* COFF auxiliary symbol information:	Dim.
* COFF named section:	Section.
* COFF structure debugging:	Tag.
* COFF symbol attributes:	COFF Symbols.
* COFF symbol descriptor:	Desc.
* COFF symbol storage class:	Scl.
* COFF symbol type:	Type.
* COFF symbols, debugging:	Def.
* COFF value attribute:	Val.
* command line conventions:	Command Line.
* command-line options ignored, VAX:	Vax-Opts.
* comments:	Comments.
* comments, M680x0:	M68K-Chars.
* comments, removed by preprocessor:	Preprocessing.
* common variable storage:	bss.
* compare and jump expansions, i960:	Compare-and-branch-i960.
* compare/branch instructions, i960:	Compare-and-branch-i960.
* conditional assembly:	If.
* constant, single character:	Chars.
* constants:	Constants.
* constants, bignum:	Bignums.
* constants, character:	Characters.
* constants, converted by preprocessor:	Preprocessing.
* constants, floating point:	Flonums.
* constants, integer:	Integers.

* constants, number:	Numbers.
* constants, string:	Strings.
* continuing statements:	Statements.
* conversion instructions, i386:	i386-Opcodes.
* coprocessor wait, i386:	i386-prefixes.
* current address:	Dot.
* current address, advancing:	Org.
* data and text sections, joining:	R.
* data section:	Ld Sections.
* debuggers, and symbol order:	Symbols.
* debugging COFF symbols:	Def.
* decimal integers:	Integers.
* deprecated directives:	Deprecated.
* descriptor, of a.out symbol:	Symbol Desc.
* difference tables altered:	Word.
* difference tables, warning:	K.
* directives and instructions:	Statements.
* directives, M680x0:	M68K-Directives.
* directives, machine independent:	Pseudo Ops.
* directives, Z8000:	Z8000 Directives.
* displacement sizing character, VAX:	VAX-operands.
* dot (symbol):	Dot.
* doublequote ("\"):	Strings.
* ECOFF sections:	MIPS Object.
* eight-byte integer:	Quad.
* empty expressions:	Empty Exprs.
* endianness, MIPS:	Overview.
* EOF, newline must precede:	Statements.
* error messsages:	Errors.
* errors, continuing after:	Z.
* escape codes, character:	Strings.
* even:	Z8000 Directives.
* expr (internal section):	As Sections.
* expression arguments:	Arguments.
* expressions:	Expressions.
* expressions, empty:	Empty Exprs.
* expressions, integer:	Integer Exprs.
* faster processing (-f):	f.
* file name, logical:	File.
* file name, logical:	App-File.
* files, including:	Include.
* files, input:	Input Files.
* filling memory:	Space.
* floating point numbers:	Flonums.
* floating point numbers (double):	Double.
* floating point numbers (single):	Float.
* floating point numbers (single):	Single.
* floating point, AMD 29K (IEEE):	AMD29K Floating Point.
* floating point, H8/300 (IEEE):	H8/300 Floating Point.
* floating point, H8/500 (IEEE):	H8/500 Floating Point.
* floating point, HPPA (IEEE):	HPPA Floating Point.
* floating point, i386:	i386-Float.
* floating point, i960 (IEEE):	Floating Point-i960.
* floating point, M680x0:	M68K-Float.
* floating point, SH (IEEE):	SH Floating Point.
* floating point, SPARC (IEEE):	Sparc-Float.
* floating point, VAX:	VAX-float.

* flonums:	Flonums.
* format of error messages:	Errors.
* format of warning messages:	Errors.
* formfeed (\f):	Strings.
* functions, in expressions:	Operators.
* global:	Z8000 Directives.
* grouping data:	Sub-Sections.
* H8/300 addressing modes:	H8/300-Addressing.
* H8/300 floating point (IEEE):	H8/300 Floating Point.
* H8/300 line comment character:	H8/300-Chars.
* H8/300 line separator:	H8/300-Chars.
* H8/300 machine directives (none):	H8/300 Directives.
* H8/300 opcode summary:	H8/300 Opcodes.
* H8/300 options (none):	H8/300 Options.
* H8/300 registers:	H8/300-Regs.
* H8/300 size suffixes:	H8/300 Opcodes.
* H8/300 support:	H8/300-Dependent.
* H8/300H, assembling for:	H8/300 Directives.
* H8/500 addressing modes:	H8/500-Addressing.
* H8/500 floating point (IEEE):	H8/500 Floating Point.
* H8/500 line comment character:	H8/500-Chars.
* H8/500 line separator:	H8/500-Chars.
* H8/500 machine directives (none):	H8/500 Directives.
* H8/500 opcode summary:	H8/500 Opcodes.
* H8/500 options (none):	H8/500 Options.
* H8/500 registers:	H8/500-Regs.
* H8/500 support:	H8/500-Dependent.
* hex character code (\XDD):	Strings.
* hexadecimal integers:	Integers.
* HPPA directives not supported:	HPPA Directives.
* HPPA floating point (IEEE):	HPPA Floating Point.
* HPPA Syntax:	HPPA Options.
* HPPA-only directives:	HPPA Directives.
* i386 fwait instruction:	i386-Float.
* i386 mul, imul instructions:	i386-Notes.
* i386 conversion instructions:	i386-Opcodes.
* i386 floating point:	i386-Float.
* i386 immediate operands:	i386-Syntax.
* i386 jump optimization:	i386-jumps.
* i386 jump, call, return:	i386-Syntax.
* i386 jump/call operands:	i386-Syntax.
* i386 memory references:	i386-Memory.
* i386 opcode naming:	i386-Opcodes.
* i386 opcode prefixes:	i386-prefixes.
* i386 options (none):	i386-Options.
* i386 register operands:	i386-Syntax.
* i386 registers:	i386-Regs.
* i386 sections:	i386-Syntax.
* i386 size suffixes:	i386-Syntax.
* i386 source, destination operands:	i386-Syntax.
* i386 support:	i386-Dependent.
* i386 syntax compatibility:	i386-Syntax.
* i80306 support:	i386-Dependent.
* i960 callj pseudo-opcode:	callj-i960.
* i960 architecture options:	Options-i960.
* i960 branch recording:	Options-i960.
* i960 compare and jump expansions:	Compare-and-branch-i960.

* i960 compare/branch instructions:	Compare-and-branch-i960.
* i960 floating point (IEEE):	Floating Point-i960.
* i960 machine directives:	Directives-i960.
* i960 opcodes:	Opcodes for i960.
* i960 options:	Options-i960.
* i960 support:	i960-Dependent.
* identifiers, AMD 29K:	AMD29K-Chars.
* immediate character, M680x0:	M68K-Chars.
* immediate character, VAX:	VAX-operands.
* immediate operands, i386:	i386-Syntax.
* indirect character, VAX:	VAX-operands.
* infix operators:	Infix Ops.
* inhibiting interrupts, i386:	i386-prefixes.
* input:	Input Files.
* input file linenumbers:	Input Files.
* instruction set, M680x0:	M68K-opcodes.
* instruction summary, H8/300:	H8/300 Opcodes.
* instruction summary, H8/500:	H8/500 Opcodes.
* instruction summary, SH:	SH Opcodes.
* instruction summary, Z8000:	Z8000 Opcodes.
* instructions and directives:	Statements.
* integer expressions:	Integer Exprs.
* integer, 16-byte:	Octa.
* integer, 8-byte:	Quad.
* integers:	Integers.
* integers, 16-bit:	hword.
* integers, 32-bit:	Int.
* integers, binary:	Integers.
* integers, decimal:	Integers.
* integers, hexadecimal:	Integers.
* integers, octal:	Integers.
* integers, one byte:	Byte.
* internal as sections:	As Sections.
* invocation summary:	Overview.
* joining text and data sections:	R.
* jump instructions, i386:	i386-Opcodes.
* jump optimization, i386:	i386-jumps.
* jump/call operands, i386:	i386-Syntax.
* label (:):	Statements.
* labels:	Labels.
* ld:	Object.
* length of symbols:	Symbol Intro.
* line comment character:	Comments.
* line comment character, AMD 29K:	AMD29K-Chars.
* line comment character, H8/300:	H8/300-Chars.
* line comment character, H8/500:	H8/500-Chars.
* line comment character, M680x0:	M68K-Chars.
* line comment character, SH:	SH-Chars.
* line comment character, Z8000:	Z8000-Chars.
* line numbers, in input files:	Input Files.
* line numbers, in warnings/errors:	Errors.
* line separator character:	Statements.
* line separator, AMD 29K:	AMD29K-Chars.
* line separator, H8/300:	H8/300-Chars.
* line separator, H8/500:	H8/500-Chars.
* line separator, SH:	SH-Chars.
* line separator, Z8000:	Z8000-Chars.

* lines starting with #:	Comments.
* linker:	Object.
* linker, and assembler:	Secs Background.
* listing control, turning off:	Nolist.
* listing control, turning on:	List.
* listing control: new page:	Eject.
* listing control: paper size:	Psize.
* listing control: subtitle:	Sbttl.
* listing control: title line:	Title.
* listings, enabling:	a.
* little endian output, MIPS:	Overview.
* little-endian output, MIPS:	MIPS Opts.
* local common symbols:	Lcomm.
* local labels, retaining in output:	L.
* local symbol names:	Symbol Names.
* location counter:	Dot.
* location counter, advancing:	Org.
* logical file name:	File.
* logical file name:	App-File.
* logical line number:	Line.
* logical line numbers:	Comments.
* lval:	Z8000 Directives.
* M680x0 addressing modes:	M68K-Syntax.
* M680x0 addressing modes:	M68K-Moto-Syntax.
* M680x0 architecture options:	M68K-Opts.
* M680x0 branch improvement:	M68K-Branch.
* M680x0 directives:	M68K-Directives.
* M680x0 floating point:	M68K-Float.
* M680x0 immediate character:	M68K-Chars.
* M680x0 line comment character:	M68K-Chars.
* M680x0 opcodes:	M68K-opcodes.
* M680x0 options:	M68K-Opts.
* M680x0 pseudo-opcodes:	M68K-Branch.
* M680x0 size modifiers:	M68K-Syntax.
* M680x0 support:	M68K-Dependent.
* M680x0 syntax:	M68K-Moto-Syntax.
* M680x0 syntax:	M68K-Syntax.
* machine dependencies:	Machine Dependencies.
* machine directives, AMD 29K:	AMD29K Directives.
* machine directives, H8/300 (none):	H8/300 Directives.
* machine directives, H8/500 (none):	H8/500 Directives.
* machine directives, i960:	Directives-i960.
* machine directives, SH (none):	SH Directives.
* machine directives, SPARC:	Sparc-Directives.
* machine directives, VAX:	VAX-directives.
* machine independent directives:	Pseudo Ops.
* machine instructions (not covered):	Manual.
* machine-independent syntax:	Syntax.
* manual, structure and purpose:	Manual.
* memory references, i386:	i386-Memory.
* merging text and data sections:	R.
* messages from as:	Errors.
* minus, permitted arguments:	Infix Ops.
* MIPS architecture options:	MIPS Opts.
* MIPS big-endian output:	MIPS Opts.
* MIPS debugging directives:	MIPS Stabs.
* MIPS ECOFF sections:	MIPS Object.

* MIPS endianness:	Overview.
* MIPS ISA:	Overview.
* MIPS ISA override:	MIPS ISA.
* MIPS little-endian output:	MIPS Opts.
* MIPS R2000:	MIPS-Dependent.
* MIPS R3000:	MIPS-Dependent.
* MIPS R4000:	MIPS-Dependent.
* MIPS R6000:	MIPS-Dependent.
* mnemonics for opcodes, VAX:	VAX-opcodes.
* mnemonics, H8/300:	H8/300 Opcodes.
* mnemonics, H8/500:	H8/500 Opcodes.
* mnemonics, SH:	SH Opcodes.
* mnemonics, Z8000:	Z8000 Opcodes.
* Motorola syntax for the 680x0:	M68K-Moto-Syntax.
* multi-line statements:	Statements.
* name:	Z8000 Directives.
* named section (COFF):	Section.
* named sections:	Ld Sections.
* names, symbol:	Symbol Names.
* naming object file:	o.
* new page, in listings:	Eject.
* newline (\n):	Strings.
* newline, required at file end:	Statements.
* null-terminated strings:	Asciz.
* number constants:	Numbers.
* numbered subsections:	Sub-Sections.
* numbers, 16-bit:	hword.
* numeric values:	Expressions.
* object file:	Object.
* object file format:	Object Formats.
* object file name:	o.
* object file, after errors:	Z.
* obsolescent directives:	Deprecated.
* octal character code (\DDD):	Strings.
* octal integers:	Integers.
* opcode mnemonics, VAX:	VAX-opcodes.
* opcode naming, i386:	i386-Opcodes.
* opcode prefixes, i386:	i386-prefixes.
* opcode suffixes, i386:	i386-Syntax.
* opcode summary, H8/300:	H8/300 Opcodes.
* opcode summary, H8/500:	H8/500 Opcodes.
* opcode summary, SH:	SH Opcodes.
* opcode summary, Z8000:	Z8000 Opcodes.
* opcodes for AMD 29K:	AMD29K Opcodes.
* opcodes, i960:	Opcodes for i960.
* opcodes, M680x0:	M68K-opcodes.
* operand delimiters, i386:	i386-Syntax.
* operand notation, VAX:	VAX-operands.
* operands in expressions:	Arguments.
* operator precedence:	Infix Ops.
* operators, in expressions:	Operators.
* operators, permitted arguments:	Infix Ops.
* option summary:	Overview.
* options for AMD29K (none):	AMD29K Options.
* options for i386 (none):	i386-Options.
* options for SPARC:	Sparc-Opts.
* options for VAX/VMS:	Vax-Opts.

* options, all versions of as:	Invoking.
* options, command line:	Command Line.
* options, H8/300 (none):	H8/300 Options.
* options, H8/500 (none):	H8/500 Options.
* options, i960:	Options-i960.
* options, M680x0:	M68K-Opts.
* options, SH (none):	SH Options.
* options, Z8000:	Z8000 Options.
* other attribute, of a.out symbol:	Symbol Other.
* output file:	Object.
* padding the location counter:	Align.
* page, in listings:	Eject.
* paper size, for listings:	Psize.
* paths for .include:	I.
* patterns, writing in memory:	Fill.
* plus, permitted arguments:	Infix Ops.
* precedence of operators:	Infix Ops.
* precision, floating point:	Flonums.
* prefix operators:	Prefix Ops.
* prefixes, i386:	i386-prefixes.
* preprocessing:	Preprocessing.
* preprocessing, turning on and off:	Preprocessing.
* primary attributes, COFF symbols:	COFF Symbols.
* protected registers, AMD 29K:	AMD29K-Regs.
* pseudo-opcodes, M680x0:	M68K-Branch.
* pseudo-ops for branch, VAX:	VAX-branch.
* pseudo-ops, machine independent:	Pseudo Ops.
* purpose of GNU as:	GNU Assembler.
* register names, AMD 29K:	AMD29K-Regs.
* register names, H8/300:	H8/300-Regs.
* register names, VAX:	VAX-operands.
* register operands, i386:	i386-Syntax.
* registers, H8/500:	H8/500-Regs.
* registers, i386:	i386-Regs.
* registers, SH:	SH-Regs.
* registers, Z8000:	Z8000-Regs.
* relocation:	Sections.
* relocation example:	Ld Sections.
* repeat prefixes, i386:	i386-prefixes.
* return instructions, i386:	i386-Syntax.
* rsect:	Z8000 Directives.
* search path for .include:	I.
* section override prefixes, i386:	i386-prefixes.
* section-relative addressing:	Secs Background.
* sections:	Sections.
* sections in messages, internal:	As Sections.
* sections, i386:	i386-Syntax.
* sections, named:	Ld Sections.
* segm:	Z8000 Directives.
* SH addressing modes:	SH-Addressing.
* SH floating point (IEEE):	SH Floating Point.
* SH line comment character:	SH-Chars.
* SH line separator:	SH-Chars.
* SH machine directives (none):	SH Directives.
* SH opcode summary:	SH Opcodes.
* SH options (none):	SH Options.
* SH registers:	SH-Regs.

* SH support:	SH-Dependent.
* single character constant:	Chars.
* sixteen bit integers:	hword.
* sixteen byte integer:	Octa.
* size modifiers, M680x0:	M68K-Syntax.
* size prefixes, i386:	i386-prefixes.
* size suffixes, H8/300:	H8/300 Opcodes.
* sizes operands, i386:	i386-Syntax.
* small objects, MIPS ECOFF:	MIPS Object.
* SOM symbol attributes:	SOM Symbols.
* source program:	Input Files.
* source, destination operands; i386:	i386-Syntax.
* space used, maximum for assembly:	statistics.
* SPARC architectures:	Sparc-Opts.
* SPARC floating point (IEEE):	Sparc-Float.
* SPARC machine directives:	Sparc-Directives.
* SPARC options:	Sparc-Opts.
* SPARC support:	Sparc-Dependent.
* special characters, M680x0:	M68K-Chars.
* special purpose registers, AMD 29K:	AMD29K-Regs.
* standard as sections:	Secs Background.
* standard input, as input file:	Command Line.
* statement on multiple lines:	Statements.
* statement separator character:	Statements.
* statement separator, AMD 29K:	AMD29K-Chars.
* statement separator, H8/300:	H8/300-Chars.
* statement separator, H8/500:	H8/500-Chars.
* statement separator, SH:	SH-Chars.
* statement separator, Z8000:	Z8000-Chars.
* statements, structure of:	Statements.
* statistics, about assembly:	statistics.
* stopping the assembly:	Abort.
* string constants:	Strings.
* string literals:	Ascii.
* string, copying to object file:	String.
* structure debugging, COFF:	Tag.
* subexpressions:	Arguments.
* subtitles for listings:	Sbttl.
* subtraction, permitted arguments:	Infix Ops.
* summary of options:	Overview.
* support:	HPPA-Dependent.
* supporting files, including:	Include.
* suppressing warnings:	W.
* sval:	Z8000 Directives.
* symbol attributes:	Symbol Attributes.
* symbol attributes, a.out:	a.out Symbols.
* symbol attributes, COFF:	COFF Symbols.
* symbol attributes, SOM:	SOM Symbols.
* symbol descriptor, COFF:	Desc.
* symbol names:	Symbol Names.
* symbol names, \$ in:	SH-Chars.
* symbol names, \$ in:	H8/500-Chars.
* symbol names, local:	Symbol Names.
* symbol names, temporary:	Symbol Names.
* symbol storage class (COFF):	Scl.
* symbol type:	Symbol Type.
* symbol type, COFF:	Type.

* symbol value:	Symbol Value.
* symbol value, setting:	Set.
* symbol values, assigning:	Setting Symbols.
* symbol, common:	Comm.
* symbol, making visible to linker:	Global.
* symbolic debuggers, information for:	Stab.
* symbols:	Symbols.
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