as

COLLABORATORS			
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Chapter 1

as

1.1 as

```
                Using as
********

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

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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 ]
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      [ -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:

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.

Filenames 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[dhlns] 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[dhlns]'
============================
```

   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.*, '-aln'.

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 I

'.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
          (ADDRESS) - (START-ADDRESS OF SECTION)?

   * Is the reference to an address "Program-Counter relative"?

   In fact, every address ‘as’ ever uses is expressed as
     (SECTION) + (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.
```

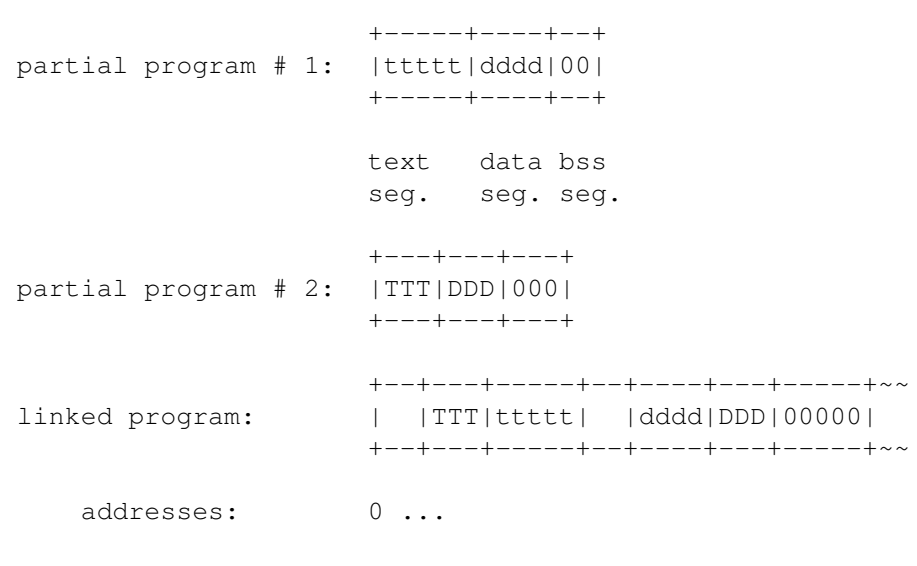
named sections
text section
data section
These sections hold your program. ‘as’ and ‘ld’ treat them as separate but equal sections. Anything you can say of one section is true another. When the program is running, however, it is customary for the text section to be unalterable. The text section is often shared among processes: it contains instructions, constants and the like. The data section of a running program is usually alterable: for example, C variables would be stored in the data section.

bss section
This section contains zeroed bytes when your program begins running. It is used to hold unitialized variables or common storage. The length of each partial program’s bss section is important, but because it starts out containing zeroed bytes there is no need to store explicit zero bytes in the object file. The bss section was invented to eliminate those explicit zeros from object files.

absolute section
Address 0 of this section is always "relocated" to runtime address 0. This is useful if you want to refer to an address that ‘ld’ must not change when relocating. In this sense we speak of absolute addresses being "unrelocatable": they do not change during relocation.

undefined section
This "section" is a catch-all for address references to objects not in the preceding sections.

An idealized example of three relocatable sections follows. The example uses the traditional section names ‘.text’ and ‘.data’. Memory addresses are on the horizontal axis.



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'
```

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:

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:

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'
*
                Sbttl
                                       '.sbttl "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 literal
Strings
.)
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’ occasionlly 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', 'bcci', '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)
               OPCODE ..., foo ;
               brb bar ;
               foo: jmp ... ;
               bar:

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

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

```
          'OPCODE ...'

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

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

'aobleq'
'aoblss'
'sobgeq'
'sobgtr'
    (byte displacement)
          'OPCODE ...'

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

    (long displacement)
                OPCODE ..., 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:

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:

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                bsr  pcrel:8
   bmi  pcrel:8                 bsr  pcrel:16
*  bmi  pcrel:16                bst  #imm,rd
   bge  pcrel:8                 bst  #imm,@rd
*  bge  pcrel:16                bst  #imm,@abs:8
   blt  pcrel:8                 btst #imm,rd
*  blt  pcrel:16                btst #imm,@rd
   bgt  pcrel:8                 btst #imm,@abs:8
*  bgt  pcrel:16                btst rs,rd
   ble  pcrel:8                 btst rs,@rd
*  ble  pcrel:16                btst rs,@abs:8
   bclr #imm,rd                 bxor #imm,rd
   bclr #imm,@rd                bxor #imm,@rd
   bclr #imm,@abs:8             bxor #imm,@abs:8
   bclr rs,rd                   cmp.b #imm,rd
   bclr rs,@rd                  cmp.b rs,rd
   bclr rs,@abs:8               cmp.w rs,rd
   biand #imm,rd                cmp.w rs,rd
   biand #imm,@rd            *  cmp.w #imm,rd
   biand #imm,@abs:8         *  cmp.l #imm,rd
   bild #imm,rd              *  cmp.l rs,rd
   bild #imm,@rd                daa  rs
   bild #imm,@abs:8             das  rs
   bior #imm,rd                 dec.b rs
   bior #imm,@rd             *  dec.w #imm,rd
   bior #imm,@abs:8          *  dec.l #imm,rd
   bist #imm,rd                 divxu.b rs,rd
   bist #imm,@rd             *  divxu.w rs,rd
   bist #imm,@abs:8          *  divxs.b rs,rd
   bixor #imm,rd             *  divxs.w rs,rd
   bixor #imm,@rd               eepmov
   bixor #imm,@abs:8         *  eepmovw

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

```
.endm           .liston
.enter          .locct
.leave          .macro
.listoff
```

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), 'hpux_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
  div1 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                  mova @(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.

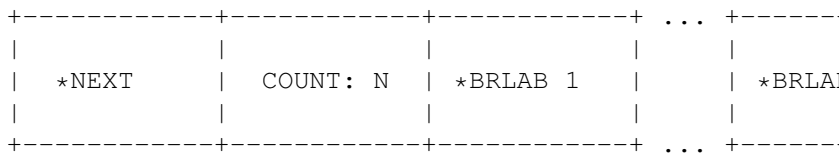
'-b'

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 differenc 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.



__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:

* callj-i960 ‘callj’
* Compare-and-branch-i960 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
bbc		chkbit; bno
bbs		chkbit; bo
cmpibe	cmpije	cmpi; be
cmpibg	cmpijg	cmpi; bg
cmpibge	cmpijge	cmpi; bge
cmpibl	cmpijl	cmpi; bl
cmpible	cmpijle	cmpi; ble
cmpibno	cmpijno	cmpi; bno
cmpibne	cmpijne	cmpi; bne
cmpibo	cmpijo	cmpi; bo
cmpobe	cmpoje	cmpo; be
cmpobg	cmpojg	cmpo; bg
cmpobge	cmpojge	cmpo; bge
cmpobl	cmpojl	cmpo; bl
cmpoble	cmpojle	cmpo; ble
cmpobne	cmpojne	cmpo; bne

1.178 M68K-Dependent

M680x0 Dependent Features
=========================

* Menu:

*
M68K-Opts
M680x0 Options
*

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 ‘l’). 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:

```
               Displacement
               +-----------------------------------------------
               |                68020   68000/10
    Pseudo-Op  |BYTE    WORD    LONG    LONG      non-PC relative
               +-----------------------------------------------
         jbsr  |bsrs    bsr     bsrl    jsr       jsr
          jra  |bras    bra     bral    jmp       jmp
    *     jXX  |bXXs    bXX     bXXl    bNXs;jmpl bNXs;jmp
    *    dbXX  |dbXX    dbXX        dbXX; bra; jmpl
    *    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 oo1
               bra oo2
           oo1:jmpl 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 undelimited (Intel 'push 4' is AT&T 'pushl $4'). AT&T register operands are preceded by '%'; Intel register operands are undelimited. AT&T absolute (as opposed to PC relative) jump/call operands are prefixed by '*'; they are undelimited 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 prefixes 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

1.202 Z8000 Options

Options

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

1.203 Z8000 Syntax

Syntax
------

* Menu:

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 r1h r1l r2h r2l r3h r3l
r4h r4l r5h r5l r6h r6l r7h r7l
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’
     Synonum 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:

```
rs   16 bit source register
rd   16 bit destination register
rbs   8 bit source register
rbd   8 bit destination register
rrs   32 bit source register
rrd   32 bit destination register
rqs   64 bit source register
rqd   64 bit destination register
addr 16/24 bit address
imm  immediate data
```

```
adc rd,rs               clrb addr               cpsir @rd,@rs,rr,cc
adcb rbd,rbs            clrb addr(rd)           cpsirb @rd,@rs,rr,cc
add rd,@rs              clrb rbd                dab rbd
add rd,addr             com @rd                 dbjnz rbd,disp7
add rd,addr(rs)         com addr                dec @rd,imm4m1
add rd,imm16            com addr(rd)            dec addr(rd),imm4m1
add rd,rs               com rd                  dec addr,imm4m1
addb rbd,@rs            comb @rd                dec rd,imm4m1
addb rbd,addr           comb addr               decb @rd,imm4m1
addb rbd,addr(rs)       comb addr(rd)           decb addr(rd),imm4m1
addb rbd,imm8           comb rbd                decb addr,imm4m1
addb rbd,rbs            comflg flags            decb rbd,imm4m1
addl rrd,@rs            cp @rd,imm16            di i2
addl rrd,addr           cp addr(rd),imm16       div rrd,@rs
addl rrd,addr(rs)       cp addr,imm16           div rrd,addr
addl rrd,imm32          cp rd,@rs               div rrd,addr(rs)
addl rrd,rrs            cp rd,addr              div rrd,imm16
and rd,@rs              cp rd,addr(rs)          div rrd,rs
and rd,addr             cp rd,imm16             divl rqd,@rs
and rd,addr(rs)         cp rd,rs                divl rqd,addr
and rd,imm16            cpb @rd,imm8            divl rqd,addr(rs)
and rd,rs               cpb addr(rd),imm8       divl rqd,imm32
andb rbd,@rs            cpb addr,imm8           divl rqd,rrs
andb rbd,addr           cpb rbd,@rs             djnz rd,disp7
andb rbd,addr(rs)       cpb rbd,addr            ei i2
andb rbd,imm8           cpb rbd,addr(rs)        ex rd,@rs
andb rbd,rbs            cpb rbd,imm8            ex rd,addr
bit @rd,imm4            cpb rbd,rbs             ex rd,addr(rs)
```

```
bit addr(rd),imm4
bit addr,imm4
bit rd,imm4
bit rd,rs
bitb @rd,imm4
bitb addr(rd),imm4
bitb addr,imm4
bitb rbd,imm4
bitb rbd,rs
bpt
call @rd
call addr
call addr(rd)
calr disp12
clr @rd
clr addr
clr addr(rd)
clr rd
clrb @rd
inc addr,imm4m1
inc rd,imm4m1
incb @rd,imm4m1
incb addr(rd),imm4m1
incb addr,imm4m1
incb rbd,imm4m1
ind @rd,@rs,ra
indb @rd,@rs,rba
inib @rd,@rs,ra
inibr @rd,@rs,ra
iret
jp cc,@rd
jp cc,addr
jp cc,addr(rd)
jr cc,disp8
ld @rd,imm16
ld @rd,rs
ld addr(rd),imm16
ld addr(rd),rs
ld addr,imm16
ld addr,rs
ld rd(imm16),rs
ld rd(rx),rs
ld rd,@rs
ld rd,addr
ld rd,addr(rs)
ld rd,imm16
ld rd,rs
ld rd,rs(imm16)
ld rd,rs(rx)
lda rd,addr
lda rd,addr(rs)
lda rd,rs(imm16)
lda rd,rs(rx)
ldar rd,disp16
ldb @rd,imm8
ldb @rd,rbs
ldb addr(rd),imm8
cpd rd,@rs,rr,cc
cpdb rbd,@rs,rr,cc
cpdr rd,@rs,rr,cc
cpdrb rbd,@rs,rr,cc
cpi rd,@rs,rr,cc
cpib rbd,@rs,rr,cc
cpir rd,@rs,rr,cc
cpirb rbd,@rs,rr,cc
cpl rrd,@rs
cpl rrd,addr
cpl rrd,addr(rs)
cpl rrd,imm32
cpl rrd,rrs
cpsd @rd,@rs,rr,cc
cpsdb @rd,@rs,rr,cc
cpsdr @rd,@rs,rr,cc
cpsdrb @rd,@rs,rr,cc
cpsi @rd,@rs,rr,cc
cpsib @rd,@rs,rr,cc
ldb rbd,rs(rx)
ldb rd(imm16),rbs
ldb rd(rx),rbs
ldctl ctrl,rs
ldctl rd,ctrl
ldd @rs,@rd,rr
lddb @rs,@rd,rr
lddr @rs,@rd,rr
lddrb @rs,@rd,rr
ldi @rd,@rs,rr
ldib @rd,@rs,rr
ldir @rd,@rs,rr
ldirb @rd,@rs,rr
ldk rd,imm4
ldl @rd,rrs
ldl addr(rd),rrs
ldl addr,rrs
ldl rd(imm16),rrs
ldl rd(rx),rrs
ldl rrd,@rs
ldl rrd,addr
ldl rrd,addr(rs)
ldl rrd,imm32
ldl rrd,rrs
ldl rrd,rs(imm16)
ldl rrd,rs(rx)
ldm @rd,rs,n
ldm addr(rd),rs,n
ldm addr,rs,n
ldm rd,@rs,n
ldm rd,addr(rs),n
ldm rd,addr,n
ldps @rs
ldps addr
ldps addr(rs)
ldr disp16,rs
ldr rd,disp16
ldrb disp16,rbs
ex rd,rs
exb rbd,@rs
exb rbd,addr
exb rbd,addr(rs)
exb rbd,rbs
ext0e imm8
ext0f imm8
ext8e imm8
ext8f imm8
exts rrd
extsb rd
extsl rqd
halt
in rd,@rs
in rd,imm16
inb rbd,@rs
inb rbd,imm16
inc @rd,imm4m1
inc addr(rd),imm4m1
mult rrd,addr(rs)
mult rrd,imm16
mult rrd,rs
multl rqd,@rs
multl rqd,addr
multl rqd,addr(rs)
multl rqd,imm32
multl rqd,rrs
neg @rd
neg addr
neg addr(rd)
neg rd
negb @rd
negb addr
negb addr(rd)
negb rbd
nop
or rd,@rs
or rd,addr
or rd,addr(rs)
or rd,imm16
or rd,rs
orb rbd,@rs
orb rbd,addr
orb rbd,addr(rs)
orb rbd,imm8
orb rbd,rbs
out @rd,rs
out imm16,rs
outb @rd,rbs
outb imm16,rbs
outd @rd,@rs,ra
outdb @rd,@rs,rba
outib @rd,@rs,ra
outibr @rd,@rs,ra
pop @rd,@rs
pop addr(rd),@rs
pop addr,@rs
```

```
ldb addr(rd),rbs
ldb addr,imm8
ldb addr,rbs
ldb rbd,@rs
ldb rbd,addr
ldb rbd,addr(rs)
ldb rbd,imm8
ldb rbd,rbs
ldb rbd,rs(imm16)
push @rd,rs
pushl @rd,@rs
pushl @rd,addr
pushl @rd,addr(rs)
pushl @rd,rrs
res @rd,imm4
res addr(rd),imm4
res addr,imm4
res rd,imm4
res rd,rs
resb @rd,imm4
resb addr(rd),imm4
resb addr,imm4
resb rbd,imm4
resb rbd,rs
resflg imm4
ret cc
rl rd,imm1or2
rlb rbd,imm1or2
rlc rd,imm1or2
rlcb rbd,imm1or2
rldb rbb,rba
rr rd,imm1or2
rrb rbd,imm1or2
rrc rd,imm1or2
rrcb rbd,imm1or2
rrdb rbb,rba
rsvd36
rsvd38
rsvd78
rsvd7e
rsvd9d
rsvd9f
rsvdb9
rsvdbf
sbc rd,rs
sbcb rbd,rbs
sc imm8
sda rd,rs
sdab rbd,rs
sdal rrd,rs
sdl rd,rs
sdlb rbd,rs
sdll rrd,rs
set @rd,imm4
set addr(rd),imm4
ldrb rbd,disp16
ldrl disp16,rrs
ldrl rrd,disp16
mbit
mreq rd
mres
mset
mult rrd,@rs
mult rrd,addr
set addr,imm4
set rd,imm4
set rd,rs
setb @rd,imm4
setb addr(rd),imm4
setb addr,imm4
setb rbd,imm4
setb rbd,rs
setflg imm4
sinb rbd,imm16
sinb rd,imm16
sind @rd,@rs,ra
sindb @rd,@rs,rba
sinib @rd,@rs,ra
sinibr @rd,@rs,ra
sla rd,imm8
slab rbd,imm8
slal rrd,imm8
sll rd,imm8
sllb rbd,imm8
slll rrd,imm8
sout imm16,rs
soutb imm16,rbs
soutd @rd,@rs,ra
soutdb @rd,@rs,rba
soutib @rd,@rs,ra
soutibr @rd,@rs,ra
sra rd,imm8
srab rbd,imm8
sral rrd,imm8
srl rd,imm8
srlb rbd,imm8
srll rrd,imm8
sub rd,@rs
sub rd,addr
sub rd,addr(rs)
sub rd,imm16
sub rd,rs
subb rbd,@rs
subb rbd,addr
subb rbd,addr(rs)
subb rbd,imm8
subb rbd,rbs
subl rrd,@rs
subl rrd,addr
subl rrd,addr(rs)
pop rd,@rs
popl @rd,@rs
popl addr(rd),@rs
popl addr,@rs
popl rrd,@rs
push @rd,@rs
push @rd,addr
push @rd,addr(rs)
push @rd,imm16
subl rrd,imm32
subl rrd,rrs
tcc cc,rd
tccb cc,rbd
test @rd
test addr
test addr(rd)
test rd
testb @rd
testb addr
testb addr(rd)
testb rbd
testl @rd
testl addr
testl addr(rd)
testl rrd
trdb @rd,@rs,rba
trdrb @rd,@rs,rba
trib @rd,@rs,rbr
trirb @rd,@rs,rbr
trtdrb @ra,@rb,rbr
trtib @ra,@rb,rr
trtirb @ra,@rb,rbr
trtrb @ra,@rb,rbr
tset @rd
tset addr
tset addr(rd)
tset rd
tsetb @rd
tsetb addr
tsetb addr(rd)
tsetb rbd
xor rd,@rs
xor rd,addr
xor rd,addr(rs)
xor rd,imm16
xor rd,rs
xorb rbd,@rs
xorb rbd,addr
xorb rbd,addr(rs)
xorb rbd,imm8
xorb rbd,rbs
xorb rbd,rbs
```

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:

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```

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, whie 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 support by traditional MIPS assemblers. These are ‘.def’, ‘.endef’, ‘.dim’, ‘.file’, ‘.scl’, ‘.size’, ‘.tag’, ‘.type’, ‘.val’, ‘.stabd’, ‘.stabn’, 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?

1.215 Index

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* Menu: