

ASxxxx Assemblers

and

ASLINK Relocating Linker

Version 5.00
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P R E F A C E

The ASxxxx assemblers were written following the style of several unfinished cross assemblers found in the Digital Equipment Corporation Users Society (DECUS) distribution of the C programming language. The incomplete DECUS code was provided with no documentation as to the input syntax or the output format. I wish to thank the author for inspiring me to begin the development of this set of assemblers.

The ASLINK program was written as a companion to the ASxxxx assemblers, its design and implementation was not derived from any other work.

I would greatly appreciate receiving the details of any changes, additions, or errors pertaining to these programs and will attempt to incorporate any fixes or generally useful changes in a future update to these programs.

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ASxxxx Cross Assemblers, Version 5.00, April 2009

Submitted by Alan R. Baldwin,
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Operating System: Linux, Windows, MS-DOS
or other supporting ANSI C.

Source Language: C

Abstract:

The ASxxxx assemblers are a series of microprocessor assemblers written in the C programming language. This collection contains cross assemblers for the 1802, S2650, SC/MP, MPS430, 61860, 6500, 6800(6802/6808), 6801(6803/HD6303), 6804, 6805, 68HC(S)08, 6809, 68HC11, 68HC(S)12, 68HC16, 740, 8048(8041/8022/8021) 8051, 8085(8080), DS8xCxxx, AVR, EZ80, F2MC8L/FX, GameBoy(Z80), H8/3xx, Cypress PSoC(M8C), PIC, Rabbit 2000/3000, Z8, and Z80(HD64180) series microprocessors. Each assembler has a device specific section which includes: (1) device description, byte order, and file extension information, (2) a table of assembler general directives, special directives, assembler mnemonics and associated operation codes, (3) machine specific code for processing the device mnemonics, addressing modes, and special directives.

The assemblers have a common device independent section which handles the details of file input/output, symbol table generation, program/data areas, expression analysis, and assembler directive processing.

The assemblers provide the following features: (1) alphabetized, formatted symbol table listings, (2) relocatable object modules, (3) global symbols for linking object modules, (4) conditional assembly directives, (5) reusable local symbols, (6) include-file processing, and (7) a general macro processing facility.

The companion program ASLINK is a relocating linker performing the following functions: (1) bind multiple object modules into a single memory image, (2) resolve inter-module symbol references, (3) resolve undefined symbols from specified libraries of object modules, (4) process absolute, relative, concatenated, and overlay attributes in data and program sections, (5) perform byte and word program-counter relative (pc or pcr) addressing calculations, (6) define absolute symbol values at link time, (7) define absolute area base address values at link time, (8) produce an Intel Hex record, Motorola S record or Tandy CoCo Disk Basic output file, (9) produce a map of the linked memory image, and (10) update the ASxxxx assembler listing files with the absolute linked addresses and data.

The assemblers and linker have been tested using Linux and DJGPP, Cygwin, Symantec C/C++ V7.2, Borland Turbo C++ 3.0, Open Watcom V1.7a, VC6, and Visual Studio 2005. Complete source code and documentation for the assemblers and linker is included with the distribution. Additionally, test code for each assembler and several microprocessor monitors (ASSIST05 for the 6805, MONDEB and ASSIST09 for the 6809, and BUFFALO 2.5 for the 6811) are included as working examples of use of these assemblers.

CHAPTER 1

THE ASSEMBLER

1.1 THE ASXXXX ASSEMBLERS

The ASxxxx assemblers are a series of microprocessor assemblers written in the C programming language. Each assembler has a device specific section which includes:

1. device description, byte order, and file extension information
2. a table of the assembler general directives, special device directives, assembler mnemonics and associated operation codes
3. machine specific code for processing the device mnemonics, addressing modes, and special directives

The device specific information is detailed in the appendices.

The assemblers have a common device independent section which handles the details of file input/output, symbol table generation, program/data areas, expression analysis, and assembler directive processing.

The assemblers provide the following features:

1. Command string control of assembly functions
2. Alphabetized, formatted symbol table listing
3. Relocatable object modules
4. Global symbols for linking object modules
5. Conditional assembly directives

6. Program sectioning directives

ASxxxx assembles one or more source files into a single relocatable ascii object file. The output of the ASxxxx assemblers consists of an ascii relocatable object file(*.rel), an assembly listing file(*.lst), and a symbol file(*.sym).

1.1.1 Assembly Pass 1

During pass 1, ASxxxx opens all source files and performs a rudimentary assembly of each source statement. During this process all symbol tables are built, program sections defined, and number of bytes for each assembled source line is estimated.

At the end of pass 1 all undefined symbols may be made global (external) using the ASxxxx switch -g, otherwise undefined symbols will be flagged as errors during succeeding passes.

1.1.2 Assembly Pass 2

During pass 2 the ASxxxx assembler resolves forward references and determines the number of bytes for each assembled line. The number of bytes used by a particular assembler instruction may depend upon the addressing mode, whether the instruction allows multiple forms based upon the relative distance to the addressed location, or other factors. Pass 2 resolves these cases and determines the address of all symbols.

1.1.3 Assembly Pass 3

Pass 3 by the assembler generates the listing file, the relocatable output file, and the symbol tables. Also during pass 3 the errors will be reported.

The relocatable object file is an ascii file containing symbol references and definitions, program area definitions, and the relocatable assembled code, the linker ASLINK will use this information to generate an absolute load file (Intel, Motorola or Tandy CoCo Disk Basic formats).

1.2 SOURCE PROGRAM FORMAT

1.2.1 Statement Format

A source program is composed of assembly-language statements. Each statement must be completed on one line. A line may contain a maximum of 128 characters, longer lines are truncated and lost.

An ASxxxx assembler statement may have as many as four fields. These fields are identified by their order within the statement and/or by separating characters between fields. The general format of the ASxxxx statement is:

```
[label:]  Operator      Operand          [;Comment(s)]
```

The label and comment fields are optional. The operator and operand fields are interdependent. The operator field may be an assembler directive or an assembly mnemonic. The operand field may be optional or required as defined in the context of the operator.

ASxxxx interprets and processes source statements one at a time. Each statement causes a particular operation to be performed.

1.2.1.1 Label Field -

A label is a user-defined symbol which is assigned the value of the current location counter and entered into the user defined symbol table. The current location counter is used by ASxxxx to assign memory addresses to the source program statements as they are encountered during the assembly process. Thus a label is a means of symbolically referring to a specific statement.

When a program section is absolute, the value of the current location counter is absolute; its value references an absolute memory address. Similarly, when a program section is relocatable, the value of the current location counter is relocatable. A relocation bias calculated at link time is added to the apparent value of the current location counter to establish its effective absolute address at execution time. (The user can also force the linker to relocate sections defined as absolute. This may be required under special circumstances.)

If present, a label must be the first field in a source statement and must be terminated by a colon (:). For example,

if the value of the current location counter is absolute 01F0(H), the statement:

```
abcd:      nop
```

assigns the value 01F0(H) to the label abcd. If the location counter value were relocatable, the final value of abcd would be 01F0(H)+K, where K represents the relocation bias of the program section, as calculated by the linker at link time.

More than one label may appear within a single label field. Each label so specified is assigned the same address value. For example, if the value of the current location counter is 1FF0(H), the multiple labels in the following statement are each assigned the value 1FF0(H):

```
abcd:      aq:      $abc:  nop
```

Multiple labels may also appear on successive lines. For example, the statements

```
abcd:
aq:
$abc:      nop
```

likewise cause the same value to be assigned to all three labels.

A double colon (::) defines the label as a global symbol. For example, the statement

```
abcd::      nop
```

establishes the label abcd as a global symbol. The distinguishing attribute of a global symbol is that it can be referenced from within an object module other than the module in which the symbol is defined. References to this label in other modules are resolved when the modules are linked as a composite executable image.

The legal characters for defining labels are:

```
A through Z
a through z
0 through 9
. (Period)
$ (Dollar sign)
_ (underscore)
```

A label may be any length, however only the first 79 characters are significant and, therefore must be unique among all labels in the source program (not necessarily among

separately compiled modules). An error code(s) (m or p) will be generated in the assembly listing if the first 79 characters in two or more labels are the same. The m code is caused by the redeclaration of the symbol or its reference by another statement. The p code is generated because the symbols location is changing on each pass through the source file.

The label must not start with the characters 0-9, as this designates a reusable symbol with special attributes described in a later section.

The label must not start with the sequence \$\$, as this represents the temporary radix 16 for constants.

1.2.1.2 Operator Field -

The operator field specifies the action to be performed. It may consist of an instruction mnemonic (op code) or an assembler directive.

When the operator is an instruction mnemonic, a machine instruction is generated and the assembler evaluates the addresses of the operands which follow. When the operator is a directive ASxxxx performs certain control actions or processing operations during assembly of the source program.

Leading and trailing spaces or tabs in the operator field have no significance; such characters serve only to separate the operator field from the preceeding and following fields.

An operator is terminated by a space, tab or end of line.

1.2.1.3 Operand Field -

When the operator is an instruction mnemonic (op code), the operand field contains program variables that are to be evaluated/manipulated by the operator.

Operands may be expressions or symbols, depending on the operator. Multiple expressions used in the operand fields may be separated by a comma. An operand should be preceeded by an operator field; if it is not, the statement will give an error (q or o). All operands following instruction mnemonics are treated as expressions.

The operand field is terminated by a semicolon when the field is followed by a comment. For example, in the following statement:

```
label:   lda    abcd,x           ;Comment field
```

the tab between lda and abcd terminates the operator field and defines the beginning of the operand field; a comma separates the operands abcd and x; and a semicolon terminates the operand field and defines the beginning of the comment field. When no comment field follows, the operand field is terminated by the end of the source line.

1.2.1.4 Comment Field -

The comment field begins with a semicolon and extends through the end of the line. This field is optional and may contain any 7-bit ascii character except null.

Comments do not affect assembly processing or program execution.

1.3 SYMBOLS AND EXPRESSIONS

This section describes the generic components of the ASxxxx assemblers: the character set, the conventions observed in constructing symbols, and the use of numbers, operators, and expressions.

1.3.1 Character Set

The following characters are legal in ASxxxx source programs:

1. The letters A through Z. Both upper- and lower-case letters are acceptable. The assemblers, by default, are case sensitive, i.e. ABCD and abcd are not the same symbols. (The assemblers can be made case insensitive by using the -z command line option.)
2. The digits 0 through 9
3. The characters . (period), \$ (dollar sign), and _ (underscore).
4. The special characters listed in Tables 1 through 6.

Tables 1 through 6 describe the various ASxxxx label and field terminators, assignment operators, operand separators, assembly, unary, binary, and radix operators.

Table 1 Label Terminators and Assignment Operators

:	Colon	Label terminator.
::	Double colon	Label Terminator; defines the label as a global label.
=	Equal sign	Direct assignment operator.
==	Global equal	Direct assignment operator; defines the symbol as a global symbol.
=:	Local equal	Direct assignment operator; defines the symbol as a local symbol.

Table 2 Field Terminators and Operand Separators

	Tab	Item or field terminator.
	Space	Item or field terminator.
,	Comma	Operand field separator.
;	Semicolon	Comment field indicator.

Table 3 Assembler Operators

#	Number sign	Immediate expression indicator.
.	Period	Current location counter.
(Left parenthesis	Expression delimiter.
)	Right parenthesis	Expression delimiter.

Table 4 Unary Operators

<	Left bracket	<FEDC	Produces the lower byte value of the expression. (DC)
>	Right bracket	>FEDC	Produces the upper byte value of the expression. (FE)
+	Plus sign	+A	Positive value of A
-	Minus sign	-A	Produces the negative (2's complement) of A.
~	Tilde	~A	Produces the 1's complement of A.
'	Single quote	'D	Produces the value of the character D.
"	Double quote	"AB	Produces the double byte value for AB.
\	Backslash	'\n or '\001	Unix style characters \b, \f, \n, \r, \t or octal byte values.

Table 5 Binary Operators

<<	Double Left bracket	0800 << 4	Produces the 4 bit left-shifted value of 0800. (8000)
>>	Double Right bracket	0800 >> 4	Produces the 4 bit right-shifted value of 0800. (0080)
+	Plus sign	A + B	Arithmetic Addition operator.
-	Minus sign	A - B	Arithmetic Subtraction operator.
*	Asterisk	A * B	Arithmetic Multiplica- tion operator.
/	Slash	A / B	Arithmetic Division operator.
&	Ampersand	A & B	Logical AND operator.
	Bar	A B	Logical OR operator.
%	Percent sign	A % B	Modulus operator.
^	Up arrow or circumflex	A ^ B	EXCLUSIVE OR operator.

Table 6 Temporary Radix Operators

\$%,	0b, 0B	Binary radix operator.
\$&,	0o, 0O, 0q, 0Q	Octal radix operator.
\$#,	0d, 0D	Decimal radix operator.
\$\$,	0h, 0H, 0x, 0X	Hexidecimal radix operator.

Potential ambiguities arising from the use of 0b and 0d as temporary radix operators may be circumvented by

preceding all non-prefixed hexadecimal numbers with 00. Leading 0's are required in any case where the first hexadecimal digit is abcdef as the assembler will treat the letter sequence as a label.

1.3.2 User-Defined Symbols

User-defined symbols are those symbols that are equated to a specific value through a direct assignment statement or appear as labels. These symbols are added to the User Symbol Table as they are encountered during assembly.

The following rules govern the creation of user-defined symbols:

1. Symbols can be composed of alphanumeric characters, dollar signs (\$), periods (.), and underscores (_) only.
2. The first character of a symbol must not be a number (except in the case of reusable symbols).
3. The first 79 characters of a symbol must be unique. A symbol can be written with more than 79 legal characters, but the 80th and subsequent characters are ignored.
4. Spaces and Tabs must not be embedded within a symbol.

1.3.3 Reusable Symbols

Reusable symbols are specially formatted symbols used as labels within a block of coding that has been delimited as a reusable symbol block. Reusable symbols are of the form n\$, where n is a decimal integer from 0 to 65535, inclusive. Examples of reusable symbols are:

1\$
27\$
138\$
244\$

The range of a reusable symbol block consists of those statements between two normally constructed symbolic labels. Note that a statement of the form:

ALPHA = EXPRESSION

is a direct assignment statement but does not create a label and thus does not delimit the range of a reusable symbol block.

Note that the range of a reusable symbol block may extend across program areas.

Reusable symbols provide a convenient means of generating labels for branch instructions and other such references within reusable symbol blocks. Using reusable symbols reduces the possibility of symbols with multiple definitions appearing within a user program. In addition, the use of reusable symbols differentiates entry-point labels from other labels, since reusable labels cannot be referenced from outside their respective symbol blocks. Thus, reusable symbols of the same name can appear in other symbol blocks without conflict. Reusable symbols require less symbol table space than normal symbols. Their use is recommended.

The use of the same reusable symbol within a symbol block will generate one or both of the m or p errors.

Example of reusable symbols:

```
a:      ldx      #atable ;get table address
        lda      #0d48  ;table length
1$:      clr      ,x+    ;clear
        deca
        bne      1$

b:      ldx      #btable ;get table address
        lda      #0d48  ;table length
1$:      clr      ,x+    ;clear
        deca
        bne      1$
```


1.3.4 Current Location Counter

The period (.) is the symbol for the current location counter. When used in the operand field of an instruction, the period represents the address of the first byte of the instruction:

```
AS:      ldx      #.          ;The period (.) refers to
                                ;the address of the ldx
                                ;instruction.
```

When used in the operand field of an ASxxxx directive, it represents the address of the current byte or word:

```
QK = 0

.word    0xFFFFE, .+4, QK    ;The operand .+4 in the .word
                                ;directive represents a value
                                ;stored in the second of the
                                ;three words during assembly.
```

If we assume the current value of the program counter is 0H0200, then during assembly, ASxxxx reserves three words of storage starting at location 0H0200. The first value, a hexadecimal constant FFFE, will be stored at location 0H0200. The second value represented by .+4 will be stored at location 0H0202, its value will be 0H0206 (= 0H0202 + 4). The third value defined by the symbol QK will be placed at location 0H0204.

At the beginning of each assembly pass, ASxxxx resets the location counter. Normally, consecutive memory locations are assigned to each byte of object code generated. However, the value of the location counter can be changed through a direct assignment statement of the following form:

```
. = . + expression
```

The new location counter can only be specified relative to the current location counter. Neglecting to specify the current program counter along with the expression on the right side of the assignment operator will generate the (.) error. (Absolute program areas may use the .org directive to specify the absolute location of the current program counter.)

The following coding illustrates the use of the current location counter:

```
.area    CODE1      (ABS)      ;program area CODE1
                                ;is ABSOLUTE
```

```

        .org      0H100          ;set location to
                                ;0H100 absolute

num1:    ldx      #.+0H10        ;The label num1 has
                                ;the value 0H100.
                                ;X is loaded with
                                ;0H100 + 0H10

        .org      0H130          ;location counter
                                ;set to 0H130

num2:    ldy      #.             ;The label num2 has
                                ;the value 0H130.
                                ;Y is loaded with
                                ;value 0H130.

        .area     CODE2      (REL) ;program area CODE2
                                ;is RELOCATABLE

        . = . + 0H20            ;Set location counter
                                ;to relocatable 0H20 of
                                ;the program section.

num3:    .word     0             ;The label num3 has
                                ;the value
                                ;of relocatable 0H20.

        . = . + 0H40            ;will reserve 0H40
                                ;bytes of storage as will
        .blkb     0H40          ;or
        .blkw     0H20

```

The `.blkb` and `.blkw` directives are the preferred methods of allocating space.

1.3.5 Numbers

`ASxxxx` assumes that all numbers in the source program are to be interpreted in decimal radix unless otherwise specified. The `.radix` directive may be used to specify the default as octal, decimal, or hexadecimal. Individual numbers can be designated as binary, octal, decimal, or hexadecimal through the temporary radix prefixes shown in table 6.

Negative numbers must be preceded by a minus sign; `ASxxxx` translates such numbers into two's complement form. Positive numbers may (but need not) be preceded by a plus sign.

Numbers are always considered to be absolute values, therefore they are never relocatable.

1.3.6 Terms

A term is a component of an expression and may be one of the following:

1. A number.
2. A symbol:
 1. A period (.) specified in an expression causes the current location counter to be used.
 2. A User-defined symbol.
 3. An undefined symbol is assigned a value of zero and inserted in the User-Defined symbol table as an undefined symbol.
3. A single quote followed by a single ascii character, or a double quote followed by two ascii characters.
4. An expression enclosed in parenthesis. Any expression so enclosed is evaluated and reduced to a single term before the remainder of the expression in which it appears is evaluated. Parenthesis, for example, may be used to alter the left-to-right evaluation of expressions, (as in $A*B+C$ versus $A*(B+C)$), or to apply a unary operator to an entire expression (as in $-(A+B)$).
5. A unary operator followed by a symbol or number.

1.3.7 Expressions

Expressions are combinations of terms joined together by binary operators. Expressions reduce to a value. The evaluation of an expression includes the determination of its attributes. A resultant expression value may be one of three types (as described later in this section): relocatable, absolute, and external.

Expressions are evaluate with an operand hierarchy as follows:

*	/	%	multiplication, division, and modulus first.
+	-		addition and subtraction second.
<<	>>		left shift and right shift third.
^			exclusive or fourth.
&			logical and fifth.
			logical or last

except that unary operators take precedence over binary operators.

A missing or illegal operator terminates the expression analysis, causing error codes (o) and/or (q) to be generated depending upon the context of the expression itself.

At assembly time the value of an external (global) expression is equal to the value of the absolute part of that expression. For example, the expression `external+4`, where 'external' is an external symbol, has the value of 4. This expression, however, when evaluated at link time takes on the resolved value of the symbol 'external', plus 4.

Expressions, when evaluated by ASxxxx, are one of three types: relocatable, absolute, or external. The following distinctions are important:

1. An expression is relocatable if its value is fixed relative to the base address of the program area in which it appears; it will have an offset value added at link time. Terms that contain labels defined in relocatable program areas will have a relocatable value; similarly, a period (.) in a relocatable program area, representing the value of the current program location counter, will also have a relocatable value.
2. An expression is absolute if its value is fixed. An expression whose terms are numbers and ascii characters will reduce to an absolute value. A relocatable expression or term minus a relocatable term, where both elements being evaluated belong to the same program area, is an absolute expression. This is because every

term in a program area has the same relocation bias. When one term is subtracted from the other the relocation bias is zero.

3. An expression is external (or global) if it contains a single global reference (plus or minus an absolute expression value) that is not defined within the current program. Thus, an external expression is only partially defined following assembly and must be resolved at link time.

1.4 GENERAL ASSEMBLER DIRECTIVES

An ASxxxx directive is placed in the operator field of the source line. Only one directive is allowed per source line. Each directive may have a blank operand field or one or more operands. Legal operands differ with each directive.

1.4.1 .module Directive

Format:

.module name

The .module directive causes the name to be included in the assemblers output file as an identifier for this particular object module. The name may be from 1 to 79 characters in length. The name may not have any embedded white space (spaces or tabs). Only one identifier is allowed per assembled module. The main use of this directive is to allow the linker to report a modules' use of undefined symbols. At link time all undefined symbols are reported and the modules referencing them are listed.

1.4.2 .title Directive

Format:

.title string

The .title directive provides a character string to be placed on the second line of each page during listing. The string begins with the first non white space character (after any space or tab) and ends with the end of the line.

1.4.3 .sbttl Directive

Format:

```
.sbttl string
```

The .sbttl directive provides a character string to be placed on the third line of each page during listing. The string begins with the first non white space character (after any space or tab) and ends with the end of the line.

1.4.4 .list and .nlist Directives

Format:

```
.list                                ;Basic .list
.list expr                          ;with expression
.list (arg1,arg2,...,argn)          ;with sublist options
.nlist                              ;Basic .nlist
.nlist expr                         ;with expression
.nlist (arg1,arg2,...,argn)         ;with sublist options
```

The .list and .nlist directives control the listing output to the .lst file. The directives have the following sublist options:

err	-	errors
loc	-	program location
bin	-	binary output
eqt	-	symbol or .if evaluation
cyc	-	opcode cycle count
lin	-	source line number
src	-	source line text
pag	-	pagination
lst	-	.list/.nlist line listing
md	-	macro definition listing
me	-	macro expansion listing
meb	-	macro expansion binary listing
!	-	sets the listing mode to !(.list) or !(.nlist) before applying the sublist options

The 'normal' listing mode .list is the combination of err, loc,

bin, eqt, cyc, lin, src, pag, lst, and md enabled with me and meb disabled. The 'normal' listing mode .nlist has all sublist items disabled. When specifying sublist options the option list must be enclosed within parenthesis and multiple options seperated by commas.

The NOT option, !, is used to set the listing mode to the opposite of the .list or .nlist directive before applying the sublist options. For example:

```
.nlist (!)      is equivalent to .list  and
.list  (!)      is equivalent to .nlist
                any additional options will
                be applied normally
```

Normal .list/.nlist processing is disabled within false conditional blocks. However, the .list/.nlist with an expression can override this behavior if the expression has a non zero value.

Examples of listing options:

```
.list  (meb)    ; lists macro generated binary
.list  (me)     ; lists macro expansions
.nlist (src)    ; .nlist src lines not listed
.nlist (!,lst) ; list all except .nlist
.nlist          ; combination lists only
.list  (src)    ; the source line
.list  (!,src)  ; list only the source line
.list  1        ; enable listing even within
                ; a FALSE conditional block
```

1.4.5 .page Directive

Format:

```
.page
```

The .page directive causes a page ejection with a new heading to be printed. The new page occurs after the next line of the source program is processed, this allows an immediately following .sbttl directive to appear on the new page. The .page source line will not appear in the file listing. Paging may be disabled by invoking the -p directive or by using the directive:

```
.nlist (pag)
```

If the .page directive is followed by a non zero constant or an expression that evaluates to a non zero value then pagination will be enabled within a false condition range to allow extended textual information to be incorporated in the source program with out the need to use the comment delimiter (;):

```
.if      0

.page   1      ;Enable pagination within 'if' block.
This text will be bypassed during assembly
but appear in the listing file.
.
.
.

.endif
```

1.4.6 .msg Directive

Format:

```
.msg      /string/                or
.msg      ^/string/
```

where: string represents a text string. The string is printed to the console during the final assembly pass.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .msg directive will give the (q) error.

The .msg directive is useful to report assembly status or other information during the assembly process.

1.4.7 .error Directive

Format:

```
.error exp
```

where: exp represents an absolute expression. If the evaluation of the expression results in a non zero value then an 'e' error is reported and the text line is listed in the generated error.

The .error directive is useful to report configuration or value errors during the assembly process. (The .error directive is identical in function to the .assume directive, just perhaps more descriptive.)

1.4.8 .byte, .db, and .fcb Directives

Format:

```
.byte exp ;Stores the binary value
.db exp ;of the expression in the
.fcb exp ;next byte.

.byte exp1,exp2,expn ;Stores the binary values
.db exp1,exp2,expn ;of the list of expressions
.fcb exp1,exp2,expn ;in successive bytes.
```

where: exp, represent expressions that will be
exp1, truncated to 8-bits of data.
. Each expression will be calculated,
. the high-order byte will be truncated.
. Multiple expressions must be
expn separated by commas.

The .byte, .db, or .fcb directives are used to generate successive bytes of binary data in the object module.

1.4.9 .word, .dw, and .fdb Directives

Format:

```
.word    exp                ;Stores the binary value
.dw      exp                ;of the expression in
.fdb     exp                ;the next word.

.word    exp1,exp2,expn    ;Stores the binary values
.dw      exp1,exp2,expn    ;of the list of expressions
.fdb     exp1,exp2,expn    ;in successive words.
```

where: exp, represent expressions that will occupy two
 exp1, bytes of data. Each expression will be
 . calculated as a 16-bit word expression.
 . Multiple expressions must be
 expn separated by commas.

The .word, .dw, or .fdb directives are used to generate successive words of binary data in the object module.

1.4.10 .3byte and .triple Directives

Format:

```
.3byte   exp                ;Stores the binary value
.triple  exp                ;of the expression in
                           ;the next triple (3 bytes).

.3byte   exp1,exp2,expn    ;Stores the binary values
.triple  exp1,exp2,expn    ;of the list of expressions
                           ;in successive triples
                           ;(3 bytes).
```

where: exp, represent expressions that will occupy three
 exp1, bytes of data. Each expression will be
 . calculated as a 24-bit word expression.
 . Multiple expressions must be
 expn separated by commas.

The .3byte or .triple directive is used to generate successive triples of binary data in the object module. (These directives are only available in assemblers supporting 24-bit addressing.)

1.4.11 .4byte and .quad Directive

Format:

```
.4byte  exp           ;Stores the binary value
.quad   exp           ;of the expression in
                        ;the next quad (4 bytes).

.4byte  exp1,exp2,expn ;Stores the binary values
.quad   exp1,exp2,expn ;of the list of expressions
                        ;in successive quads
                        ;(4 bytes).
```

where: exp, represent expressions that will occupy three
exp1, bytes of data. Each expression will be
. calculated as a 32-bit word expression.
. Multiple expressions must be
expn separated by commas.

The .4byte or .quad directive is used to generate successive quads of binary data in the object module. (These directives are only available in assemblers supporting 32-bit addressing.)

1.4.12 .blkb, .ds, .rmb, and .rs Directives

Format:

```
.blkb   N             ;reserve N bytes of space
.ds     N             ;reserve N bytes of space
.rmb    N             ;reserve N bytes of space
.rs     N             ;reserve N bytes of space
```

The .blkb, .ds, .rmb, and .rs directives reserve byte blocks in the object module;

1.4.13 .blkw, .blk3, and .blk4 Directives

Format:

```
.blkw   N             ;reserve N words of space
.blk3   N             ;reserve N triples of space
.blk4   N             ;reserve N quads of space
```

The .blkw directive reserves word blocks; the .blk3 reserves 3 byte blocks (available in assemblers supporting 24-bit addressing); the .blk4 reserves 4 byte blocks (available in assemblers supporting 32-bit addressing).

1.4.14 .ascii, .str, and .fcc Directives

Format:

```
.ascii  /string/                or
.ascii  ^/string/
.fcc    /string/                or
.fcc    ^/string/
.str    /string/                or
.str    ^/string/
```

where: string is a string of printable ascii characters.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .ascii directive will give the (q) error.

The .ascii, .fcc, and .str directives place one binary byte of data for each character in the string into the object module.

1.4.15 .ascis and .strs Directives

Format:

```
.ascis  /string/                or
.ascis  ^/string/
.strs   /string/                or
.strs   ^/string/
```

where: string is a string of printable ascii characters.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .ascis and .strs directives will give the (q) error.

The .asciz and .strz directives place one binary byte of data for each character in the string into the object module. The last character in the string will have the high order bit set.

1.4.16 .asciz and .strz Directives

Format:

```
.asciz    /string/                or
.asciz    ^/string/
.strz     /string/                or
.strz     ^/string/
```

where: string is a string of printable ascii characters.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .asciz and .strz directive will give the (q) error.

The .asciz and .strz directives place one binary byte of data for each character in the string into the object module. Following all the character data a zero byte is inserted to terminate the character string.

1.4.17 .assume Directive

Format:

```
.assume exp
```

where: exp represents an absolute expression. If the evaluation of the expression results in a non zero value then an 'e' error is reported and the text line is listed in the generated error.

The .assume directive is useful to check assumptions about assembler values. (The .assume directive is identical in function to the .error directive, just perhaps more descriptive.)

1.4.18 .radix Directive

Format:

.radix character

where: character represents a single character specifying the default radix to be used for succeeding numbers. The character may be any one of the following:

B,b	Binary
O,o	Octal
Q,q	
D,d	Decimal
'blank'	
H,h	Hexidecimal
X,x	

1.4.19 .even Directive

Format:

.even

The .even directive ensures that the current location counter contains an even boundary value by adding 1 if the current location is odd.

1.4.20 .odd Directive

Format:

.odd

The .odd directive ensures that the current location counter contains an odd boundary value by adding one if the current location is even.

1.4.21 .bndry Directive

Format:

```
.bndry n
```

If the current location is not an integer multiple of n then the location counter is increased to the next integer multiple of n.

As an example:

```
.bndry 4
```

changes the current location to be at a multiple of 4, a 4-byte boundary.

The relocation and/or concatenation of an area containing .bndry directives to place code at specific boundaries will NOT maintain the specified boundaries. When relocating such code areas you must specify the base addresses to the linker manually and/or you must pad the allocated space of an area to match the boundary conditions.

As an example suppose you wish to link multiple assembled code sections, each of which has code for the same area and requires a 4 byte boundary. The starting address of the area must be specified to the linker on a 4 byte boundary and each assembled code section must be padded to fill out the area in each of the individually assembled files. The following code will provide the necessary area padding to allow a successful linking of files and maintain the boundary requirements:

```
.$end = .           ; end of area address
.bndry 4            ; set boundary
.if ne, . - .$end   ; is . the same ?
    . = . - 1       ; no: backup 1 byte
    .byte 0          ; place padding byte
.endif
```

If all files are assembled simultaneously then only the .bndry directive is required at the beginning of the area in each file and the initial area address must be specified to the linker.

1.4.22 .area Directive

Format:

```
.area  name    [(options)]
```

where: name represents the symbolic name of the program section. This name may be the same as any user-defined symbol or bank as the area names are independent of all symbols, labels, and banks.

options specify the type of program or data area:

ABS	absolute (automatically invokes OVR)
REL	relocatable
OVR	overlay
CON	concatenate
NOPAG	non-paged area
PAG	paged area

options specify a code or data segment:

CSEG	Code segment
DSEG	Data segment

option specifies the data area bank:

BANK	Named collection of areas
------	---------------------------

The .area directive provides a means of defining and separating multiple programming and data sections. The name is the area label used by the assembler and the linker to collect code from various separately assembled modules into one section. The name may be from 1 to 79 characters in length.

The options are specified within parenthesis and separated by commas as shown in the following example:

```
.area  TEST  (REL,CON)  ;This section is relocatable
                        ;and concatenated with other
                        ;sections of this program area.

.area  DATA  (REL,OVR) ;This section is relocatable
                        ;and overlays other sections
                        ;of this program area.

.area  SYS    (ABS,OVR) ;(CON not allowed with ABS)
                        ;This section is defined as
                        ;absolute. Absolute sections
                        ;are always overlayed with
                        ;other sections of this program
                        ;area.
```



```
.area PAGE (PAG) ;This is a paged section. The
                  ;section must be on a 256 byte
                  ;boundary and its length is
                  ;checked by the linker to be
                  ;no larger than 256 bytes.
                  ;This is useful for direct page
                  ;areas.
```

The default area type is REL|CON; i.e. a relocatable section which is concatenated with other sections of code with the same area name. The ABS option indicates an absolute area. The OVR and CON options indicate if program sections of the same name will overlay each other (start at the same location) or be concatenated with each other (appended to each other).

The area can be specified as either a code segment, CSEG, or a data segment, DSEG. The CSEG and DSEG descriptors are useful when the microprocessor code and data unit allocations are unequal: e.g. the executable code uses an allocation of 2 bytes for each instruction and is addressed at an increment of 1 for every instruction, and the data uses an allocation of 1 byte for each element and is addressed at an increment of 1 for each data byte. The allocation units are defined by the architecture of the particular microprocessor.

The .area directive also provides a means of specifying the bank this area is associated with. All areas associated with a particular bank are combined at link time into a block of code/data.

The CSEG, DSEG, and BANK options are specified within the parenthesis as shown in the following examples:

```
.area C_SEG (CSEG,BANK=C1)
                  ;This is a code section
                  ;and is included in bank C1
.area D_SEG (DSEG,BANK=D1)
                  ;This is a data section
                  ;and is included in bank D1.
```

Multiple invocations of the .area directive with the same name must specify the same options or leave the options field blank, this defaults to the previously specified options for this program area.

The ASxxxx assemblers automatically provide two program sections:

'_CODE'	This is the default code/data area. This program area is of type (REL,CON,CSEG).
'_DATA'	This is the default optional data area. This program area is of type (REL,CON,DSEG).

The ASxxxx assemblers also automatically generate two symbols for each program area:

's_<area>'	This is the starting address of the program area.
'l_<area>'	This is the length of the program area.

The .area names and options are never case sensitive.

1.4.23 .bank Directive

Format:

```
.bank name [(options)]
```

where: name represents the symbolic name of the bank section. This name may be the same as any user-defined symbol or area as the bank names are independent of all symbols, labels, and areas. The name may be from 1 to 79 characters in length.

options specify the parameters of the bank:

BASE	base address of bank
SIZE	maximum size of bank
FSFX	file suffix for this bank
MAP	NOICE mapping

The .bank directive allows an arbitrary grouping of program and/or data areas to be communicated to the linker. The bank parameters are all optional and are described as follows:

1. BASE, the starting address of the bank (default is 0) may be defined. This address can be overridden by using the linker -b option for the first area within the bank. The bank address is always specified in 'byte' addressing. A first area which is not 'byte' addressed

(e.g. a processor addressed by a 'word' of 2 or more bytes) has the area address scaled to begin at the 'byte' address.

2. SIZE, the maximum length of the bank specified in bytes. The size is always specified in terms of bytes.
3. FSFX, the file suffix to be used by the linker for this bank. The suffix may not contain embedded white space.
4. MAP, NOICE mapping parameter for this bank of code/data.

The options are specified within parenthesis and separated by commas as shown in the following example:

```
.BANK C1 (BASE=0x0100,SIZE=0x1000,FSFX=_C1)
           ;This bank starts at 0x0100,
           ;has a maximum size of 0x1000,
           ;and is to be placed into
           ;a file with a suffix of _C1
```

The parameters must be absolute (external symbols are not allowed.)

1.4.24 .org Directive

Format:

```
.org    exp
```

where: exp is an absolute expression that becomes the current location counter.

The .org directive is valid only in an absolute program section and will give a (q) error if used in a relocatable program area. The .org directive specifies that the current location counter is to become the specified absolute value.

1.4.25 .globl Directive

Format:

```
.globl  sym1,sym2,...,symn
```

where: sym1, represent legal symbolic names.
 sym2,... When multiple symbols are specified,
 symn they are separated by commas.

A .globl directive may also have a label field and/or a comment field.

The .globl directive is provided to export (and thus provide linkage to) symbols not otherwise defined as global symbols within a module. In exporting global symbols the directive .globl J is similar to:

```
J == expression or J::
```

Because object modules are linked by global symbols, these symbols are vital to a program. All internal symbols appearing within a given program must be defined at the end of pass 1 or they will be considered undefined. The assembly directive (-g) can be invoked to make all undefined symbols global at the end of pass 1.

The .globl directive and == construct can be overridden by a following .local directive.

NOTE

The ASxxxx assemblers use the last occurring symbol specification in the source file(s) as the type shown in the symbol table and output to the .rel file.

1.4.26 .local Directive

Format:

```
.local  sym1,sym2,...,symn
```

where: sym1, represent legal symbolic names.
 sym2,... When multiple symbols are specified,
 symn they are separated by commas.

A .local directive may also have a label field and/or a comment field.

The `.local` directive is provided to define symbols that are local to the current assembly process. Local symbols are not effected by the assembler option `-a` (make all symbols global). In defining local symbols the directive `.local J` is similar to:

```
J =: expression
```

The `.local` directive and the `=:` construct are useful in defining symbols and constants within a header or definition file that contains many symbols specific to the current assembly process that should not be exported into the `.rel` output file. A typical usage is in the definition of SFRs (Special Function Registers) for a microprocessor.

The `.local` directive and `=:` construct can be overridden by a following `.globl` directive.

NOTE

The ASxxxx assemblers use the last occurring symbol specification in the source file(s) as the type shown in the symbol table and output to the `.rel` file.

1.4.27 `.equ`, `.gblequ`, and `.lclequ` Directives

Format:

```
sym1    .equ    expr    ; equivalent to sym1 = expr
sym2    .gblequ expr    ; equivalent to sym2 == expr
sym3    .lclequ expr    ; equivalent to sym3 =: expr
```

or

```
.equ    sym1,    expr    ; equivalent to sym1 = expr
.gblequ sym2,    expr    ; equivalent to sym2 == expr
.lclequ sym3,    expr    ; equivalent to sym3 =: expr
```

These alternate forms of equivalence are provided for user convenience.

1.4.28 .if, .else, and .endif Directives

Format:

```
.if      expr
.          ;}
.          ;} range of true condition
.          ;}
.else
.          ;}
.          ;} range of false condition
.          ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The range of true condition will be processed if the expression 'expr' is not zero (i.e. true) and the range of false condition will be processed if the expression 'expr' is zero (i.e. false). The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .if/.else/.endif constructions:

```
.if      A-4          ;evaluate A-4
.byte    1,2          ;insert bytes if A-4 is
.endif              ;not zero

.if      K+3          ;evaluate K+3
.else
.byte    3,4          ;insert bytes if K+3
.endif              ;is zero

.if      J&3          ;evaluate J masked by 3
.byte    12           ;insert this byte if J&3
.else
.byte    13           ;insert this byte if J&3
.endif              ;is zero
```

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.29 .iff, .ift, and .iftf Directives

Format:

```
.if      expr      ;'if' range Condition is
                  ;TRUE when expr is not zero
.ift                                ;}
.      ;} range of true condition  ;}
.iff                                ;} if
.      ;} range of false condition ;} block
.iftf                                ;}
.      ;} unconditional range      ;}
.else      ;'else' range Condition is
          ;TRUE when expr is zero
.ift                                ;}
.      ;} range of true condition  ;}
.iff                                ;} else
.      ;} range of false condition ;} block
.iftf                                ;}
.      ;} unconditional range      ;}
.endif
```

The subconditional assembly directives may be placed within conditional assembly blocks to indicate:

1. The assembly of an alternate body of code when the condition of the block tests false.
2. The assembly of non-contiguous body of code within the conditional assembly block, depending upon the result of the conditional test in entering the block.
3. The unconditional assembly of a body of code within a conditional assembly block.

The use of the .iff, .ift, and .iftf directives makes the use of the .else directive redundant.

Note that the implementation of the .else directive causes the .if tested condition to be complemented. The TRUE and FALSE conditions are determined by the .if/.else conditional state.

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of the .iff, .ift, or .iftf directives outside of a conditional block results in a (i) error code.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.30 .ifxx Directives

Additional conditional directives are available to test the value of an evaluated expression:

```
.ifne    expr                ; true if expr != 0
.ifeq    expr                ; true if expr == 0
.ifgt    expr                ; true if expr >  0
.iflt    expr                ; true if expr <  0
.ifge    expr                ; true if expr >= 0
.ifle    expr                ; true if expr <= 0
```

Format:

```
.ifxx    expr
.          ;}
.          ;} range of true condition
.          ;}
.else
.          ;}
.          ;} range of false condition
.          ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The range of true condition will be processed if the expression 'expr' is not zero (i.e. true) and the range of false condition will be processed if the expression 'expr' is zero (i.e. false). The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifxx/.else/.endif constructions:

```
.ifne    A-4                ;evaluate A-4
.byte    1,2                ;insert bytes if A-4 is
.endif                                ;not zero

.ifeq    K+3                ;evaluate K+3
.byte    3,4                ;insert bytes if K+3
.endif                                ;is zero

.ifne    J&3                ;evaluate J masked by 3
.byte    12                 ;insert this byte if J&3
.else                                ;is not zero
```



```
.byte    13                ;insert this byte if J&3
.endif                    ;is zero
```

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.31 .ifdef Directive

Format:

```
.ifdef    sym
.          ;}
.          ;} range of true condition
.          ;}
.else
.          ;}
.          ;} range of false condition
.          ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The range of true condition will be processed if the symbol 'sym' has been defined with a .define directive or 'sym' is a variable with an assigned value else the false range will be processed. The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifdef/.else/.endif constructions:

```
.ifdef    sym$1            ;lookup symbol sym$1
.byte     1,2              ;insert bytes if sym$1
.endif                    ;is defined or
                           ;assigned a value

.ifdef    sym$2            ;lookup symbol sym$2
.else
.byte     3,4              ;insert bytes if sym$1
.endif                    ;is not defined and
                           ;not assigned a value

.ifdef    sym$3            ;lookup symbol sym$3
.byte     12               ;insert this byte if sym$3
.else
                           ;is defined/valued
.byte     13               ;insert this byte if sym$3
```

```
.endif                ;is not defined/valued
```

Note that the default assembler configuration of case sensitive means the testing for a defined symbol is also case sensitive.

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.32 .ifndef Directive

Format:

```
.ifndef sym
.                ;}
.                ;} range of true condition
.                ;}
.else
.                ;}
.                ;} range of false condition
.                ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the condition test.

The range of true condition will be processed if the symbol 'sym' is not defined by a .define directive and a variable 'sym' has not been assigned a value else the range of false condition will be processed. The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifndef/.else/.endif constructions:

```
.ifndef sym$1        ;lookup symbol sym$1
.byte 1,2            ;insert bytes if sym$1 is
.endif               ;not defined and
                    ;not assigned a value

.ifndef sym$2        ;lookup symbol sym$2
.else
.byte 3,4            ;insert bytes if sym$1
.endif               ;is defined or
                    ;is assigned a value

.ifndef sym$3        ;lookup symbol sym$3
.byte 12             ;insert this byte if sym$3
```

```
.else                ;is not defined/valued
.byte    13          ;insert this byte if sym$3
.endif             ;is defined/valued
```

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.33 .ifb Directive

Format:

```
.ifb    sym
.                ;}
.                ;} range of true condition
.                ;}
.else
.                ;}
.                ;} range of false condition
.                ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The conditional .ifb is most useful when used in macro definitions to determine if the argument is blank. The range of true condition will be processed if the symbol 'sym' is blank. The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifb/.ifnb/.else/.endif constructions:

```
.ifb    sym$1        ;argument is not blank
.byte    1,2         ;insert bytes if argument
.endif             ;is blank

.ifb    sym$2        ;argument is not blank
.else
.byte    3,4         ;insert bytes if argument
.endif             ;is not blank

.ifb                ;argument is blank
.byte    12         ;insert this byte if
.else             ;argument is blank
.byte    13         ;insert this byte if
.endif           ;argument not blank
```

All `.if/.else/.endif` directives are limited to a maximum nesting of 10 levels.

The use of a `.else` directive outside a `.if/.endif` block will generate an (i) error. Assemblies having unequal `.if` and `.endif` counts will cause an (i) error.

1.4.34 `.ifnb` Directive

Format:

```
.ifnb    sym
.                ;}
.                ;} range of true condition
.                ;}
.else
.                ;}
.                ;} range of false condition
.                ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The conditional `.ifnb` is most useful when used in macro definitions to determine if the argument is not blank. The range of true condition will be processed if the symbol 'sym' is not blank. The range of true condition is optional as is the `.else` directive and the range of false condition. The following are all valid `.ifnb/.else/.endif` constructions:

```
.ifnb    sym$1          ;argument is not blank
.byte    1,2            ;insert bytes if argument
.endif                ;is not blank

.ifnb    sym$2          ;argument is not blank
.else
.byte    3,4            ;insert bytes if argument
.endif                ;is blank

.ifnb                ;argument is blank
.byte    12             ;insert this byte if
.else                ;argument is not blank
.byte    13             ;insert this byte if
.endif                ;argument is blank
```

All `.if/.else/.endif` directives are limited to a maximum nesting

of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.35 .ifidn Directive

Format:

```
.ifidn  sym$1,sym$2
.           ;}
.           ;} range of true condition
.           ;}
.else
.           ;}
.           ;} range of false condition
.           ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The conditional .ifidn is most useful when used in macro definitions to determine if the arguments are identical. The range of true condition will be processed if the symbol 'sym\$1' is identical to 'sym\$2' (i.e. the character strings for sym\$1 and sym\$2 are the same consistent with the case sensitivity flag). When this if statement occurs inside a macro where an argument substitution may be blank then an argument should be delimited with the form /symbol/ for each symbol. The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifidn/.else/.endif constructions:

```
.ifidn  sym$1,sym$1      ;arguments are the same
.byte   1,2             ;insert bytes if arguments
.endif                  ;are the sane

.ifidn  sym$1,sym$2      ;arguments are not the same
.else
.byte   3,4             ;insert bytes if arguments
.endif                  ;are not the same

.ifidn  sym$3,sym$3      ;arguments are the same
.byte   12               ;insert this byte if
.else                  ;arguments are the same
.byte   13               ;insert this byte if
.endif                  ;arguments are not the same
```

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.36 .ifdif Directive

Format:

```
.ifdif  sym$1,sym$2
.           ;}
.           ;} range of true condition
.           ;}
.else
.           ;}
.           ;} range of false condition
.           ;}
.endif
```

The conditional assembly directives allow you to include or exclude blocks of source code during the assembly process, based on the evaluation of the test condition.

The conditional .ifdif is most useful when used in macro definitions to determine if the arguments are different. The range of true condition will be processed if the symbol 'sym\$1' is different from 'sym\$2' (i.e. the character strings for sym\$1 and sym\$2 are not the same consistent with the case sensitivity flag). When this if statement occurs inside a macro where an argument substitution may be blank then an argument should be delimited with the form /symbol/ for each symbol. The range of true condition is optional as is the .else directive and the range of false condition. The following are all valid .ifdif/.else/.endif constructions:

```
.ifdif  sym$1,sym$2      ;arguments are different
.byte   1,2             ;insert bytes if arguments
.endif                  ;are different

.ifdif  sym$1,sym$1      ;arguments are identical
.else
.byte   3,4             ;insert bytes if arguments
.endif                  ;are different

.ifdif  sym$1,sym$3      ;arguments are different
.byte   12              ;insert this byte if
.else                  ;arguments are different
```

```
.byte    13                ;insert this byte if
.endsWith                ;arguments are identical
```

All .if/.else/.endif directives are limited to a maximum nesting of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.37 Alternate .if Directive Forms

Format:

```
.if      cnd(,)  arg1(, arg2)
```

where the cnd (followed by an optional comma) may be any of the following:

condition (complement)		Args	Assemble Block if:
eq	(ne)	expr	equal to zero (not equal to zero)
gt	(le)	expr	greater than zero (less than or equal to zero)
lt	(ge)	expr	less than zero (greater than or equal to zero)
def	(ndef)	symbol	.define'd or user set (not .define'd or user set)
b	(nb)	macro symbol	argument present (argument not present)
idn	(dif)	macro symbol	arguments identical (arguments not identical)
f	(t)	-----	only within a .if/.else/.endif conditional block
tf		-----	only within a .if/.else/.endif conditional block

All .if/.else/.endif directives are limited to a maximum nesting

of 10 levels.

The use of a .else directive outside a .if/.endif block will generate an (i) error. Assemblies having unequal .if and .endif counts will cause an (i) error.

1.4.38 Immediate Conditional Assembly Directives

The immediate conditional assembly directives allow a single line of code to be assembled without using a .if/.else/.endif construct. All of the previously described conditionals have immediate equivalents.

Format:

.iif	arg(,)	line_to_assemble
.iifeq	arg(,)	line_to_assemble
.iifne	arg(,)	line_to_assemble
.iifgt	arg(,)	line_to_assemble
.iifle	arg(,)	line_to_assemble
.iifge	arg(,)	line_to_assemble
.iiflt	arg(,)	line_to_assemble
.iifdef	arg(,)	line_to_assemble
.iifndef	arg(,)	line_to_assemble
.iifb	(,)arg(,)	line_to_assemble
.iifnb	(,)arg(,)	line_to_assemble
.iifidn	(,)arg1,arg2(,)	line_to_assemble
.iifdif	(,)arg1,arg2(,)	line_to_assemble
.iiff		line_to_assemble
.iift		line_to_assemble
.iiftf		line_to_assemble

Alternate Format:

.iif		arg(,)	line_to_assemble
.iif	eq	arg(,)	line_to_assemble
.iif	ne	arg(,)	line_to_assemble
.iif	gt	arg(,)	line_to_assemble
.iif	le	arg(,)	line_to_assemble
.iif	ge	arg(,)	line_to_assemble
.iif	lt	arg(,)	line_to_assemble
.iif	def	arg(,)	line_to_assemble
.iif	ndef	arg(,)	line_to_assemble
.iif	b	(,)arg(,)	line_to_assemble
.iif	nb	(,)arg(,)	line_to_assemble
.iif	idn	(,)arg1,arg2(,)	line_to_assemble


```
.iif      dif    (,)arg1,arg2(,)    line_to_assemble

.iiff                                line_to_assemble
.iift                                line_to_assemble
.iiftf                               line_to_assemble
```

The (,) indicates an optional comma.

The .iif types b, n, idn, and dif require the commas if the argument(s) may be blank. These commas may be removed if the arguments are delimited with the form ^/symbol/ for each symbol.

The immediate conditional directives donot change the .if/.else/.endif nesting level.

1.4.39 .include Directive

Format:

```
.include      /string/                or

.include      ^/string/
```

where: string represents a string that is the file specification of an ASxxxx source file.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .include directive will give the (q) error.

The .include directive is used to insert a source file within the source file currently being assembled. When this directive is encountered, an implicit .page directive is issued. When the end of the specified source file is reached, an implicit .page directive is issued and input continues from the previous source file. The maximum nesting level of source files specified by a .include directive is five.

The total number of separately specified .include files is unlimited as each .include file is opened and then closed during each pass made by the assembler.

The default directory path, if none is specified, for any .include file is the directory path of the current file. For example: if the current source file, D:\proj\file1.asm,

includes a file specified as "include1" then the file D:\proj\include1.asm is opened.

1.4.40 .define and .undefine Directives

Format:

```
.define      keyword  /string/          or
.define      keyword ^/string/
.undefine    keyword
```

where: keyword is the substitutable string which must start with a letter and may contain any combination of digits and letters.

where: string represents a string that is substituted for the keyword. The string may contain any sequence of characters including white space.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .define directive will give the (q) error.

The .define directive specifies a user defined string which is substituted for the keyword. The substitution string may itself contain other keywords that are substitutable. The assembler resumes the parse of the line at the point the keyword was found. Care must be excersized to avoid any circular references within .define directives, otherwise the assembler may enter a 'recursion runaway' resulting in an 's' error.

The .undefine directive removes the keyword as a substitutable string. No error is returned if the keyword was not defined.

1.4.41 .setdp Directive

Format:

```
.setdp [base [,area]]
```

The set direct page directive has a common format in all the assemblers supporting a paged mode. The .setdp directive is used to inform the assembler of the current direct page region and the offset address within the selected area. The normal invocation methods are:

```
.area    DIRECT    (PAG)  
.setdp
```

or

```
.setdp    0,DIRECT
```

for all the 68xx microprocessors (the 6804 has only the paged ram area). The commands specify that the direct page is in area DIRECT and its offset address is 0 (the only valid value for all but the 6809 microprocessor). Be sure to place the DIRECT area at address 0 during linking. When the base address and area are not specified, then zero and the current area are the defaults. If a .setdp directive is not issued the assembler defaults the direct page to the area "_CODE" at offset 0.

The assembler verifies that any local variable used in a direct variable reference is located in this area. Local variable and constant value direct access addresses are checked to be within the address range from 0 to 255.

External direct references are assumed by the assembler to be in the correct area and have valid offsets. The linker will check all direct page relocations to verify that they are within the correct area.

The 6809 microprocessor allows the selection of the direct page to be on any 256 byte boundary by loading the appropriate value into the dp register. Typically one would like to select the page boundary at link time, one method follows:

```
.area    DIRECT    (PAG)    ; define the direct page
.setdp
.
.
.
.area    PROGRAM
.
ldd      #DIRECT      ; load the direct page register
tfr      a,dp         ; for access to the direct page
```

At link time specify the base and global equates to locate the direct page:

```
-b DIRECT = 0x1000
-g DIRECT = 0x1000
```

Both the area address and offset value must be specified (area and variable names are independent). The linker will verify that the relocated direct page accesses are within the direct page.

The preceeding sequence could be repeated for multiple paged areas, however an alternate method is to define a non-paged area and use the .setdp directive to specify the offset value:

```
.area    DIRECT      ; define non-paged area
.
.
.
.area    PROGRAM
.
.setdp   0,DIRECT     ; direct page area
ldd      #DIRECT      ; load the direct page register
tfr      a,dp         ; for access to the direct page
.
.
.setdp   0x100,DIRECT ; direct page area
ldd      #DIRECT+0x100 ; load the direct page register
tfr      a,dp         ; for access to the direct page
```

The linker will verify that subsequent direct page references are in the specified area and offset address range. It is the programmers responsibility to load the dp register with the correct page segment corresponding to the .setdp base address specified.

For those cases where a single piece of code must access a defined data structure within a direct page and there are many pages, define a dummy direct page linked at address 0. This dummy page is used only to define the variable labels. Then load the dp register with the real base address but donot use a .setdp directive. This method is equivalent to indexed

addressing, where the dp register is the index register and the direct addressing is the offset.

1.4.42 .16bit, .24bit, and .32bit Directives

Format:

```
.16bit          ;specify 16-bit addressing
.24bit          ;specify 24-bit addressing
.32bit          ;specify 32-bit addressing
```

The .16bit, .24bit, and .32bit directives are special directives for assembler configuration when default values are not used.

1.4.43 .msb Directive

Format:

```
.msb    n
```

The .msb directive is only available in selected assemblers which support 24 or 32-bit addressing.

The assembler operator '>' selects the upper byte (MSB) when included in an assembler instruction. The default assembler mode is to select bits <15:8> as the MSB. The .msb directive allows the programmer to specify a particular byte as the 'MSB' when the address space is larger than 16-bits.

The assembler directive .msb n configures the assembler to select a particular byte as MSB. Given a 32-bit address of MNmn (M(3) is <31:24>, N(2) is <23:16>, m(1) is <15:8>, and n(0) is <7:0>) the following examples show how to select a particular address byte:

```
.msb 1          ;select byte 1 of address
                ;<M(3):N(2):m(1):n(0)>
LD A,>MNmn      ;byte m <15:8> ==>> A
...

.msb 2          ;select byte 2 of address
                ;<M(3):N(2):m(1):n(0)>
LD A,>MNmn      ;byte N <23:16> ==>> A
...

.msb 3          ;select byte 3 of address
                ;<M(3):N(2):m(1):n(0)>
```

```
LD A,>MNmn      ;byte M <31:24> ==>> A
...
```

1.4.44 .lohi and .hilo Directives

Format:

```
.lohi           ;specify LSB first output
.hilo           ;specify MSB first output
```

The .lohi and .hilo directives are special directives for assembler output configuration. These directives are currently only enabled in assembler 'ascheck'.

An 'm' error will be generated if the .lohi and .hilo directives are both used within the same assembly source file.

1.4.45 .end Directive

Format:

```
.end
.end    exp
```

where: exp represents any expression, including constants, symbols, or labels.

The .end directive is used to specify a code entry point to be included in the linker output file. Review the I86 and S record formats described in the linker section for details.

The .end directive without an expression is ignored.

1.5 INVOKING ASXXXX

Starting an ASxxxx assembler without any arguments provides the following option list and then exits:

```
Usage: [-Options] file
Usage: [-Options] outfile file1 [file2 file3 ...]
  -d   Decimal listing
  -q   Octal   listing
  -x   Hex     listing (default)
  -g   Undefined symbols made global
  -a   All user symbols made global
  -b   Display .define substitutions in listing
  -bb  and display without .define substitutions
  -c   Disable instruction cycle count in listing
  -j   Enable NoICE Debug Symbols
  -y   Enable SDCC  Debug Symbols
  -l   Create list  output (out)file[.lst]
  -o   Create object output (out)file[.rel]
  -s   Create symbol output (out)file[.sym]
  -p   Disable listing pagination
  -u   Disable .list/.nlist processing
  -w   Wide listing format for symbol table
  -z   Disable case sensitivity for symbols
  -f   Flag relocatable references by `  in listing file
  -ff  Flag relocatable references by mode in listing file
```

The ASxxxx assemblers are command line oriented. Most systems require the option(s) and file(s) arguments to follow the ASxxxx assembler name:

```
as6809 [-Options] file
as6809 [-Options] outfile file1 [file2 ...]
```

Some systems may request the arguments after the assembler is started at a system specific prompt:

```
as6809
argv: [-Options] file

as6809
argv: [-Options] outfile file1 [file2 ...]
```

The ASxxxx options in some more detail:

```
-d      decimal listing
```

- q octal listing
- x hex listing (default)

The listing radix affects the
.lst, .rel, and .sym files.

- g undefined symbols made global

Unresolved (external) variables
and symbols are flagged as global.

- a all user symbols made global

All defined (not local or external)
variables and symbols are flagged
as global.

- b display .define substitutions in listing

If a .define substitution has been applied
to an assembler source line the source
line is printed with the substitution.

- bb and display without .define substitutions

If a .define substitution has been applied
to an assembler source line the source
line is first printed without substitution
followed by the line with the substitution.

- c Disable instruction cycle count in listing

This option overrides the listing option
'cyc' in the .list and .nlist directives.
Instruction cycle counts cannot be enabled
if the -c option is specified.

- j enable NOICE debug symbols

- y enable SDCC debug symbols

- l create list output (out)file.lst

If -s (symbol table output) is not
specified the symbol table is included
at the end of the listing file.

- o create object output (out)file.rel

- s create symbol output (out)file.sym

- p disable listing pagination

This option inhibits the generation

of a form-feed character and its associated page header in the assembler listing.

-u disable .list/.nlist processing

This option disables all .list and .nlist directives. The listing mode is .list with the options err, loc, bin, eqt, cyc, lin, src, pag, lst, and md. The options cyc and pag are overridden by the -c and -p command line options.

-w wide listing format for symbol table

-z disable case sensitivity for symbols

-f by ` in the listing file

-ff by mode in the listing file

Relocatable modess are flagged by byte position (LSB, Byte 2, Byte 3, MSB)
*nMN paged,
uvUV unsigned,
rsRS signed,
pqPQ program counter relative.

The file name for the .lst, .rel, and .sym files is the first file name specified in the command line. All output files are ascii text files which may be edited, copied, etc. The output files are the concatenation of all the input files, if files are to be assembled independently invoke the assembler for each file.

The .rel file contains a radix directive so that the linker will use the proper conversion for this file. Linked files may have different radices.

1.6 ERRORS

The ASxxxx assemblers provide limited diagnostic error codes during the assembly process, these errors will be noted in the listing file and printed on the stderr device.

The assembler reports the errors on the stderr device as

?ASxxxx-Error-<*> in line nnn of filename

where * is the error code, nnn is the line number, and filename

is the source/include file.

The errors are:

- (.) This error is caused by an absolute direct assignment of the current location counter
 . = expression (incorrect)
 rather than the correct
 . = . + expression
- (a) Indicates a machine specific addressing or addressing mode error.
- (b) Indicates a direct page boundary error.
- (d) Indicates a direct page addressing error.
- (e) Caused by a .error or .assume directive.
- (i) Caused by an .include file error or an .if/.endif mismatch.
- (m) Multiple definitions of the same label, multiple .module directives, multiple conflicting attributes in an .area or .bank directive or the use of .hilo and lohi within the same assembly.
- (n) An .mexit, .endm, or .narg directive outside of a macro, repeat block or indefinite repeat block.
- (o) Directive or mnemonic error or the use of the .org directive in a relocatable area.
- (p) Phase error: label location changing between passes 2 and 3. Normally caused by having more than one level of forward referencing.
- (q) Questionable syntax: missing or improper operators, terminators, or delimiters.
- (r) Relocation error: logic operation attempted on a relocatable term, addition of two relocatable terms, subtraction of two relocatable terms not within the same programming area or external symbols.
- (s) String Substitution / recursion error.
- (u) Undefined symbol encountered during assembly.
- (z) Divide by 0 or Modulus by 0 error: result is 0.

1.7 LISTING FILE

The (-l) option produces an ascii output listing file. Each page of output contains a five line header:

1. The ASxxxx program name and page number
2. Assembler Radix and Address Bits
3. Title from a .title directive (if any)
4. Subtitle from a .sbttl directive (if any)
5. Blank line

Each succeeding line contains six fields:

1. Error field (first two characters of line)
2. Current location counter
3. Generated code in byte format
4. Opcode cycles count
5. Source text line number
6. Source text

The error field may contain upto 2 error flags indicating any errors encountered while assembling this line of source code.

The current location counter field displays the 16-bit, 24-bit, or 32-bit program position. This field will be in the selected radix.

The generated code follows the program location. The listing radix determines the number of bytes that will be displayed in this field. Hexidecimal listing allows six bytes of data within the field, decimal and octal allow four bytes within the field. If more than one field of data is generated from the assembly of a single line of source code, then the data field is repeated on successive lines.

The opcode cycles count is printed within the delimiters [] on the line with the source text. This reduces the number of

generated code bytes displayed on the line with the source listing by one. (The -c option disables all opcode cycle listing.)

The source text line number is printed in decimal and is followed by the source text. A Source line with a .page directive is never listed. (The -u option overrides this behavior.)

Two additional options are available for printing the source line text. If the -b option is specified then the listed source line contains all the .define substitutions. If the -bb option is specified then the original source line is printed before the source line with substitutions.

Two data field options are available to flag those bytes which will be relocated by the linker. If the -f option is specified then each byte to be relocated will be preceded by the `` character. If the -ff option is specified then each byte to be relocated will be preceded by one of the following characters:

1. * paged relocation
2. u low byte of unsigned word or unsigned byte
3. v high byte of unsigned word
4. p PCR low byte of word relocation or PCR byte
5. q PCR high byte of word relocation
6. r low byte relocation or byte relocation
7. s high byte relocation

Assemblers which use 24-bit or 32-bit addressing use an extended flagging mode:

1. * paged relocation
2. u 1st byte of unsigned value
3. v 2nd byte of unsigned value
4. U 3rd byte of unsigned value
5. V 4th byte of unsigned value
6. p PCR 1st byte of relocation value or PCR byte
7. q PCR 2nd byte of relocation value

- 8. P PCR 3rd byte of relocation value
- 9. Q PCR 4th byte of relocation value
- 10. r 1st byte of relocation value or byte relocation
- 11. s 2nd byte of relocation value
- 12. R 3rd byte of relocation value
- 13. S 4th byte of relocation value

1.8 SYMBOL TABLE FILE

The symbol table has two parts:

- 1. The alphabetically sorted list of symbols and/or labels defined or referenced in the source program.
- 2. A list of the program areas defined during assembly of the source program.

The sorted list of symbols and/or labels contains the following information:

- 1. Program area number (none if absolute value or external)
- 2. The symbol or label
- 3. Directly assigned symbol is denoted with an (=) sign
- 4. The value of a symbol, location of a label relative to the program area base address (=0), or a **** indicating the symbol or label is undefined.
- 5. The characters: G - global, L - local, R - relocatable, and X - external.

The list of program areas provides the correspondence between the program area numbers and the defined program areas, the size of the program areas, and the area flags (attributes).

1.9 OBJECT FILE

The object file is an ascii file containing the information needed by the linker to bind multiple object modules into a complete loadable memory image. The object module contains the following designators:

[XDQ][HL][234]		
X	Hexidecimal radix	
D	Decimal radix	
Q	Octal radix	
H	Most significant byte first	
L	Least significant byte first	
2	16-Bit Addressing	
3	24-Bit Addressing	
4	32-Bit Addressing	
H	Header	
M	Module	
G	Merge Mode	
B	Bank	
A	Area	
S	Symbol	
T	Object code	
R	Relocation information	
P	Paging information	

Refer to the linker for a detailed description of each of the designators and the format of the information contained in the object file.

CHAPTER 2

THE MACRO PROCESSOR

2.1 DEFINING MACROS

By using macros a programmer can use a single line to insert a sequence of lines into a source program.

A macro definition is headed by a `.macro` directive followed by the source lines. The source lines may optionally contain dummy arguments. If such arguments are used, each one is listed in the `.macro` directive.

A macro call is the statement used by the programmer to call the macro source program. It consists of the macro name followed by the real arguments needed to replace the dummy arguments used in the macro.

Macro expansion is the insertion of the macro source lines into the main program. Included in this insertion is the replacement of the dummy arguments by the real arguments.

Macro directives provide a means to manipulate the macro expansions. Only one directive is allowed per source line. Each directive may have a blank operand field or one or more operands. Legal operands differ with each directive. The macros and their associated directives are detailed in this chapter.

Macro directives can replace any machine dependent mnemonic associated with a specific assembler. However, the basic assembler directives cannot be replaced with a macro.

2.1.1 .macro Directive

Format:

```
[label:]      .macro  name, dummy argument list
```

where: label represents an optional statement label.

name represents the user-assigned symbolic name of the macro. This name may be any legal symbol and may be used as a label elsewhere in the program. The macro name is not case sensitive, name, NAME, or nAmE all refer to the same macro.

, represents a legal macro separator (comma, space, and/or tab).

dummy argument list represents a number of legal symbols that may appear anywhere in the body of the macro definition, even as a label. These dummy symbols can be used elsewhere in the program with no conflict of definition. Multiple dummy arguments specified in this directive may be separated by any legal separator. The detection of a duplicate or an illegal symbol in a dummy argument list terminates the scan and causes a 'q' error to be generated.

A comment may follow the dummy argument list in a .macro directive, as shown below:

```
.macro  abs      a,b      ;Defines macro abs
```

The first statement of a macro definition must be a .macro directive. Defining a macro with the same name as an existing macro will generate an 'm' error. The .mdelete directive should be used to delete the previous macro definition before redefining a macro.

2.1.2 .endm Directive

Format:

```
.endm
```

The .endm directive should not have a label. Because the directives .irp, .irpc, and .rept may repeat more than once the label will be defined multiple times resulting in 'm' and/or 'p' errors.

The .endm directive may be followed by a comment field, as shown below:

```
.endm          ;end of macro
```

A comment may follow the dummy argument list in a .macro directive, as shown below:

```
.macro  typemsg message ;Type a message.  
jsr     typemsg  
.word   message  
.endm                               ;End of typemsg
```

The final statement of every macro definition must be a .endm directive. The .endm directive is also used to terminate indefinite repeat blocks and repeat blocks. A .endm directive encountered outside a macro definition is flagged with an 'n' error.

2.1.3 .mexit Directive

Format:

```
.mexit
```

The .mexit directive may be used to terminate a macro expansion before the end of the macro is encountered. This directive is also legal within repeat blocks. It is most useful in nested macros. The .mexit directive terminates the current macro as though a .endm directive had been encountered. Using the .mexit directive bypasses the complexities of nested conditional directives and alternate assembly paths, as shown in the following example:

```
.macro  altr      N,A,B
.
.
.
.if eq,N          ;Start conditional Block
.
.
.
.mexit            ;Terminate macro expansion
.endif            ;End of conditional block
.
.
.
.endm              ;Normal end of macro
```

In an assembly where the symbol N is replaced by zero, the .mexit directive would assemble the conditional block and terminate the macro expansion. When macros are nested, a .mexit directive causes an exit to the next higher level of macro expansion. A .mexit directive encountered outside a macro definition is flagged with an 'n' error.

2.2 CALLING MACROS

Format:

```
[label:] name real arguments
```

where: label represents an optional statement label.

name represents the name of the macro, as specified in the macro definition.

real arguments represent symbolic arguments which replace the dummy arguments listed in the .macro definition. When multiple arguments occur, they are separated by any legal separator. Arguments to the macro call are treated as character strings, their usage is determined by the macro definition.

A macro definition must be established by means of the .macro directive before the macro can be called and expanded within the source program.

When a macro name is the same as a user label, the appearance of the symbol in the operator field designates the symbol as a

macro call; the appearance of the symbol in the operand field designates it as a label, as shown below:

```
LESS:  mov      @r0,r1          ;LESS is a label
      .
      .
      bra      LESS           ;LESS is considered a label
      .
      .
      LESS     sym1,sym2       ;LESS is a macro call
```

2.3 ARGUMENTS IN MACRO DEFINITIONS AND MACRO CALLS

Multiple arguments within a macro must be separated by one of the legal separating characters (comma, space, and/or tab).

Macro definition arguments (dummy) and macro call arguments (real) maintain a strict positional relationship. That is, the first real argument in a macro call corresponds with the first dummy argument in the macro definition.

For example, the following macro definition and its associated macro call contain multiple arguments:

```
.macro new      a,b,c
      .
      .
      .

new      phi,sig,^/C1,C2/
```

Arguments which themselves contain separating characters must be enclosed within the delimiter construct `^/ /` where the character `'/'` may be any character not in the argument string. For example, the macro call:

```
new      ^/exg      x,y/,#44,ij
```

causes the entire expression

```
exg      x,y
```

to replace all occurrences of the symbol `a` in the macro definition. Real arguments with a macro call are considered to be character strings and are treated as a single entity during macro expansion.

The up-arrow (^) construction also allows another up-arrow construction to be passed as part of the argument. This construction, for example, could have been used in the above macro call, as follows:

```
new      ^!/exg      x,y/!,#44,ij
```

causing the entire string ^/exg x,y/ to be passed as an argument.

2.3.1 Macro Nesting

Macro nesting occurs where the expansion of one macro includes a call to another macro. The depth of nesting is arbitrarily limited to 20.

To pass an argument containing legal argument delimiters to nested macros, enclose the argument in the macro definition within an up-arrow construction, as shown in the coding example below. This extra set of delimiters for each level of nesting is required in the macro definition, not the in the macro call.

```
.macro  level1  dum1,dum2
level2  ^/dum1/
level2  ^/dum2/
.endm

.macro  level2  dum3
dum3
add     #10,z
push    z
.endm
```

A call to the level1 macro, as shown below, for example:

```
level1  ^/leaz      0,x/,^/tfr      x,z/
```

causes the following macro expansion to occur:

```
leaz    0,x
add     #10,z
push    z
tfr     x,z
add     #10,z
push    z
```

When macro definitions are nested, the inner definition cannot be called until the outer macro has been called and expanded. For example, in the following code:

```
.macro  lv1      a,b
.
.
.
.macro  lv2      c
.
.
.
.endm
.endm
```

the lv2 macro cannot be called and expanded until the lv1 macro has been expanded. Likewise, any macro defined within the lv2 macro definition cannot be called and expanded until lv2 has also been expanded.

2.3.2 Special Characters in Macro Arguments

If an argument does not contain spaces, tabs, or commas it may include special characters without enclosing them in a delimited construction. For example:

```
.macro  push      arg
mov      arg,-(sp)
.endm
```

```
push      x+3(%2)
```

causes the following code to be generated:

```
mov      x+3(%2),-(sp)
```

2.3.3 Passing Numerical Arguments as Symbols

If the unary operator backslash (\) precedes an argument, the macro treats the argument as a numeric value in the current program radix. The ascii characters representing this value are inserted in the macro expansion, and their function is defined in the context of the resulting code, as shown in the following example:

```
        .macro  inc      a,b
        con    a,\b
        b = b + 1
        .endm

a'b:    .macro  con      a,b
        .word  4
        .endm

        ...

        c = 0          ;Initialize

        inc    x,c
```

The above macro call (inc) would thus expand to:

```
x0:      .word  4
```

In this expanded code, the label x0: results from the concatenation of two real arguments. The single quote (') character in the label a'b: concatenates the real argument x and 0 as they are passed during the expansion of the macro. This type of argument construction is described in more detail in a following section.

A subsequent call to the same macro would generate the following code:

```
x1:      .word  4
```

and so on, for later calls. The two macro definitions are necessary because the symbol associated with the dummy argument b (that is, symbol c) cannot be updated in the con macro definition, because the character 0 has replaced c in the argument string (inc x,c). In the con macro definition, the number passed is treated as a string argument. (Where the value of the real argument is 0, only a single 0 character is passed to the macro expansion.

2.3.4 Number of Arguments in Macro Calls

A macro can be defined with or without arguments. If more arguments appear in the macro call than in the macro definition, a 'q' error is generated. If fewer arguments appear in the macro call than in the macro definition, missing arguments are assumed to be null values. The conditional directives .if b and .if nb can be used within the macro to detect missing arguments. The number of arguments can be determined using the .narg directive.

2.3.5 Creating Local Symbols Automatically

A label is often required in an expanded macro. In the conventional macro facilities thus far described, a label must be explicitly specified as an argument with each macro call. The user must be careful in issuing subsequent calls to the same macro in order to avoid duplicating labels. This concern can be eliminated through a feature of the ASxxxx macro facility that creates a unique symbol where a label is required in an expanded macro.

ASxxxx allows temporary symbols of the form n\$, where n is a decimal integer. Automatically created symbols are created in numerical order beginning at 10000\$.

The automatic generation of local symbols is invoked on each call of a macro whose definition contains a dummy argument preceded by the question mark (?) character, as shown in the macro definition below:

```
        .macro  beta      a,?b      ;dummy argument b with ?
        tst     a
        beq     b
        add     #5,a
b:
        .endm
```

A local symbol is created automatically only when a real argument of the macro call is either null or missing, as shown in Example 1 below. If the real argument is specified in the macro call, however, generation of the local symbol is inhibited and normal argument replacement occurs, as shown in Example 2 below. (Examples 1 and 2 are both expansions of the beta macro defined above.)

Example 1: Create a Local Symbol for the Missing Argument

```
        beta    flag    ;Second argument is missing.
        tst     flag
        beq     10000$   ;Local symbol is created.
        add     #5,flag
10000$:
```

Example 2: Do Not Create a Local Symbol

```
        beta    r3,xyz
        tst     r3
        beq     xyz
        add     #5,r3
xyz:
```

Automatically created local symbols resulting from the expansion of a macro, as described above, do not establish a local symbol block in their own right.

When a macro has several arguments earmarked for automatic local symbol generation, substituting a specific label for one such argument risks assembly errors because the arguments are constructed at the point of macro invocation. Therefore, the appearance of a label in the macro expansion will create a new local symbol block. The new local symbol block could leave local symbol references in the previous block and their symbol definitions in the new one, causing error codes in the assembly listing. Furthermore a later macro expansion that creates local symbols in the new block may duplicate one of the symbols in question, causing an additional error code 'p' in the assembly listing.

2.3.6 Concatenation of Macro Arguments

The apostrophe or single quote character (') operates as a legal delimiting character in macro definitions. A single quote that precedes and/or follows a dummy argument in a macro definition is removed, and the substitution of the real argument occurs at that point. For example, in the following statements:

```
        .macro  def      A,B,C
A'B:    asciz   "C"
        .byte   'A','B
        .endm
```

when the macro def is called through the statement:


```
def      x,y,^/V05.00/
```

it is expanded, as follows:

```
xy:      asciz   "V05.00"  
        .byte   'x','y'
```

In expanding the first line, the scan for the first argument terminates upon finding the first apostrophe (') character. Since A is a dummy argument, the apostrophe (') is removed. The scan then resumes with B; B is also noted as another dummy argument. The two real arguments x and y are then concatenated to form the label xy:. The third dummy argument is noted in the operand field of the .asciz directive, causing the real argument V05.00 to be substituted in this field.

When evaluating the arguments of the .byte directive during expansion of the second line, the scan begins with the first apostrophe (') character. Since it is neither preceded nor followed by a dummy argument, this apostrophe remains in the macro expansion. The scan then encounters the second apostrophe, which is followed by a dummy argument and is therefore discarded. The scan of argument A is terminated upon encountering the comma (,). The third apostrophe is neither preceded nor followed by a dummy argument and again remains in the macro expansion. The fourth (and last) apostrophe is followed by another dummy argument and is likewise discarded. (Four apostrophe (') characters were necessary in the macro definition to generate two apostrophe (') characters in the macro expansion.)

2.4 MACRO ATTRIBUTE DIRECTIVES

The ASxxxx assemblers have four directives that allow the user to determine certain attributes of macro arguments: .narg, .nchr, .ntyp, and .nval. The use of these directives permits selective modifications of a macro expansion, depending on the nature of the arguments being passed. These directives are described below.

2.4.1 .narg Directive

Format:

```
[label:]      .narg    symbol
```

where: label represents an optional statement label.

symbol represents any legal symbol. This symbol is equated to the number of arguments in the macro call currently being expanded. If a symbol is not specified, the .narg directive is flagged with a 'q' error.

The .narg directive is used to determine the number of arguments in the macro call currently being expanded. Hence, the .narg directive can appear only within a macro definition; if it appears elsewhere, an 'n' error is generated.

The argument count includes null arguments as shown in the following:

```
.macro  pack    A,B,C
.narg   cnt
.
.
.
.endm

pack    arg1,,arg3
pack    arg1
```

When the first macro pack is invoked .narg will assign a value of three (3) to the number of arguments cnt, which includes the empty argument. The second invocation of macro pack has only a single argument specified and .narg will assign a value of one (1) to cnt.

2.4.2 .nchr Directive

Format:

```
[label:]      .nchr    symbol,string
```

where: label represents an optional statement label.

symbol represents any legal symbol. This symbol is equated to the number of characters in the string of the macro call currently being expanded. If a symbol is not specified, the .nchr directive is flagged with a 'q' error.

, represents any legal separator (comma, space, and/or tab).

string represents a string of printable 7-bit ascii characters. If the character string contains a legal separator (comma, space and/or tab) the whole string must be delimited using the up-arrow (^) construct ^/ / . If the delimiting characters do not match or if the ending delimiter cannot be detected because of a syntactical error in the character string, the .nchr directive reports a 'q' error.

The .nchr directive, which can appear anywhere in an ASxxxx program, is used to determine the number of characters in a specified character string. This directive is useful in calculating the length of macro arguments.

2.4.3 .ntyp Directive

Format:

[label:] .ntyp symbol,arg

where: label represents an optional statement label.

symbol represents any legal symbol. The symbol is made absolute and equated to 0 if arg is an absolute value or a non relocatable symbol. The symbol is made absolute and equated to 1 if arg is a relocatable symbol. If a symbol is not specified then the .ntyp directive is flagged with a 'q' error.

, represents any legal separator (comma, space, and/or tab).

arg represents any legal expression or symbol. If arg is not specified then the .ntyp directive is flagged with a 'q' error.

The .ntyp directive, which can appear anywhere in an ASxxxx program, is used to determine the symbol or expression type as absolute (0) or relocatable (1).

2.4.4 .nval Directive

Format:

[label:] .nval symbol,arg

where: label represents an optional statement label.

symbol represents any legal symbol. The symbol is equated to the value of arg and made absolute. If a symbol is not specified then the .nval directive is flagged with a 'q' error.

, represents any legal separator (comma, space, and/or tab).

arg represents any legal expression or symbol. If arg is not specified then the .nval directive is flagged

with a 'q' error.

The .nval directive, which can appear anywhere in an ASxxxx program, is used to determine the value of arg and make the result an absolute value.

2.5 INDEFINITE REPEAT BLOCK DIRECTIVES

An indefinite repeat block is similar to a macro definition with only one dummy argument. At each expansion of the indefinite repeat range, this dummy argument is replaced with successive elements of a real argument list. Since the repeat directive and its associated range are coded in-line within the source program, this type of macro definition and expansion does not require calling the macro by name, as required in the expansion of the conventional macros previously described.

An indefinite repeat block can appear within or outside another macro definition, indefinite repeat block, or repeat block. The rules specifying indefinite repeat block arguments are the same as for specifying macro arguments.

2.5.1 .irp Directive

Format:

```
[label:]      .irp      sym,argument_list
              .
              .
              (range of indefinite repeat block)
              .
              .
              .endm
```

where: label represents an optional statement label.

sym represents a dummy argument that is replaced with successive real arguments from the argument list. If the dummy argument is not specified, the .irp directive is flagged with a 'q' error.

, represents any legal separator (comma, space, and/or tab).

argument_list represents a list of real arguments that are to be used in the expansion of the indefinite repeat range. A real argument may consist of one or more 7-bit ascii characters; multiple arguments must be separated by any legal separator (comma, space, and/or tab). If an argument must contain a legal separator then the up-arrow (_^_) construct is required for that argument. If no real arguments are specified, no action is taken.

range represents the block of code to be repeated once for each occurrence of a real argument in the list. The range may contain other macro definitions, repeat ranges and/or the .mexit directive.

.endm indicates the end of the indefinite repeat block range.

The .irp directive is used to replace a dummy argument with successive real arguments specified in an argument list. This replacement process occurs during the expansion of an indefinite repeat block range.

2.5.2 .irpc Directive

Format:

```
[label:]    .irpc    sym,string
            .
            .
            (range of indefinite repeat block)
            .
            .
            .endm
```

where: label represents an optional statement label.

sym represents a dummy argument that is replaced with successive real characters from the argument string. If the dummy argument is not specified, the .irpc directive is flagged with a 'q' error.

, represents any legal separator (comma, space, and/or tab).

string represents a list of 7-bit ascii characters. If the string contains legal separator characters (comma, space, and/or tab) then the up-arrow (_^_) construct must delimit the string.

range represents the block of code to be repeated once for each occurrence of a real argument in the list. The range may contain other macro definitions, repeat ranges and/or the .mexit directive.

.endm indicates the end of the indefinite repeat block range.

The .irpc directive is available to permit single character substitution. On each iteration of the indefinite repeat range, the dummy argument is replaced with successive characters in the specified string.

2.6 REPEAT BLOCK DIRECTIVE

A repeat block is similar to a macro definition with only one argument. The argument specifies the number of times the repeat block is inserted into the assembly stream. Since the repeat directive and its associated range are coded in-line within the source program, this type of macro definition and expansion does not require calling the macro by name, as required in the expansion of the conventional macros previously described.

A repeat block can appear within or outside another macro definition, indefinite repeat block, or repeat block.

2.6.1 .rept

Format:

```
[label:]    .rept    exp
            .
            .
            (range of repeat block)
            .
            .
            .endm
```

where: label represents an optional statement label.

exp represents any legal expression. This value controls the number of times the block of code is to be assembled within the program. When the expression value is less than or equal to zero (0), the repeat block is not assembled. If this value is not an absolute value, the .rept directive is flagged with an 'r' error.

range represents the block of code to be repeated. The range may contain other macro definitions, repeat ranges and/or the .mexit directive.

.endm indicates the end of the repeat block range.

The .rept directive is used to duplicate a block of code, a certain number of times, in line with other source code.

2.7 MACRO DELETION DIRECTIVE

The `.mdelete` directive deletes the definitions of the the specified macro(s).

2.7.1 `.mdelete`

Format:

```
.mdelete      name1,name2,...,namen
```

where: `name1`, represent legal macro names. When multiple
`name2`, names are specified, they are separated
`...`, by any legal separator (comma, space, and/or
`namen` tab).

2.8 MACRO INVOCATION DETAILS

The invocation of a macro, indefinite repeat block, or repeat block has specific implications for `.if-.else-.endif` constructs and for `.list-.nlist` directives.

At the point a macro, indefinite repeat block, or repeat block is called the following occurs:

- 1) The initial `.if-.else-.endif` state is saved.
- 2) The initial `.list-.nlist` state is saved.
- 3) The macro, indefinite repeat block, or repeat block is inserted into the assembler source code stream. All argument substitution is performed at this point.

When the macro completes and after each pass through an indefinite repeat block or repeat block the `.if-.else-.endif` and `.list-.nlist` state is reset to the initial state.

The reset of the `.if-.else-.endif` state means that the invocation of a macro, indefinite repeat block, or repeat block cannot change the `.if-.else-.endif` state of the calling code. For example the following code does not change the `.if-.else-.endif` condition at macro completion:

```
.macro fnc      A
  .if nb,^!A!
    ...
    .list (meb)
    .mexit
  .else
    ...
    .nlist
    .mexit
  .endif
.endm
```

code: fnc

Within the macro the .if condition becomes false but the condition is not propagated outside the macro.

Similarly, when the .list-.nlist state is changed within a macro the change is not propagated outside the macro.

The normal .if-.else-.endif processing verifies that every .if has a corresponding .endif. When a macro, indefinite repeat block, or repeat block terminates by using the .mexit directive the .if-.endif checking is bypassed because all source lines between the .mexit and .endm directives are skipped.

2.9 BUILDING A MACRO LIBRARY

Using the macro facilities of the ASxxxx assemblers a simple macro library can be built. The macro library is built by combining individual macros, sets of macros, or include file directives into a single file. Each macro entity is enclosed within a .if/.endif block that selects the desired macro definitions.

The selection of specific macros to be imported in a program is performed by three macros, .mlib, .mcall, and .mload, contained in the file mlib.def.

2.9.1 .mlib Macro Directive

Format:

```
.mlib  file
```

where: file represents the macro library file name.
If the file name does not include a path
then the path of the current assembly
file is used. If the file name (and/or
path) contains white space then the
path/name must be delimited with the
up-arrow (^) construct ^/ /.

The .mlib directive defines two macros, .mcall and .mload, which when invoked will read a file, importing specific macro definitions. Any previous .mcall and/or .mload directives will be deleted before the new .mcall and .mload directives are defined.

The .mload directive is an internal directive which simply includes the macro library file with the listing disabled.

The following is the mlib.def file which defines the macros .mlib, .mcall, and .mload.

```

;*****
;*
;*      A simple Macro Library Implementation
;*
;*      December 2008
;*
;*****

.macro .mlib      FileName
    .if b,^!FileName!
        .error 1      ; File Name Required
        .mexit
    .endif
    .mdelete      .mcall
    .macro      .mcall  a,b,c,d,e,f,g,h
        .irp sym      ^!a!,^!b!,^!c!,^!d!,^!e!,^!f!,^!g!,^!h!
            .iif nb,^!sym!      .define      .$$.'sym
        .endm
    .mload
        .irp sym      ^!a!,^!b!,^!c!,^!d!,^!e!,^!f!,^!g!,^!h!
            .if nb,^!sym!
                .iif ndef,sym'.'$$      .error 1      ; macro not found
                .undefine      .$$.'sym
                .undefine      sym'.'$$
            .endif
        .endm
    .endm ;.mcall
    .mdelete      .mload
    .macro      .mload
        .nlist
        .include ^!FileName!
        .list
    .endm ;.mload
.endm      ;.mlib

```

2.9.2 .mcall Macro Directive

Format:

```
.mcall  macro1,macro2,...,macro8
```

where:

```

macro1, represents from 1 to 8 macro library
macro2, references to a macro definition or
...,    set of macro definitions included in
macro8  the file specified with the .mlib macro.

```

As can be seen from the macro definition of .mlib and .mcall shown above, when .mcall is invoked temporary symbols are

defined for each macro or macro set that is to be imported. The macro `.mload` is then invoked to load the macro library file specified in the call to `.mlib`.

For example, when the following macros are invoked:

```
.mlib  crossasm.sml      ; Cross Assembler Macros
.mcall M6809             ; M6809 Macro Group
```

The `.mlib` macro defines the `.mload` macro to access the system macro file `crossasm.sml`. Invoking the `.mcall` macro creates a temporary symbol, `'.$$M6809'`, and then invokes the macro `.mload` to import the system macro file `crossasm.sml`. The file `crossasm.sml` contains conditional statements that define the required macros and creates a temporary symbol `'M6809.$$.'` to indicate the macro group was found. If the macro is not found an error message is generated.

The following is a small portion of the `crossasm.sml` system macro file which shows the M6809 macro group:

```
.title  Cross Assembler Macro Library

; This MACRO Library is Case Insensitive.
;

...

; Macro Based 6809 Cross Assembler

.$$.SML.$$. =: 0
.if      idn      a,A
  .iif   def,.$$$.m6809  .$$.SML.$$. = -1
.else
  .iif   def,.$$$.m6809  .$$.SML.$$. = -1
  .iif   def,.$$$.M6809  .$$.SML.$$. =  1
.endif
.iif     lt,$$.SML.$$.   .define      m6809.$$.
.iif     gt,$$.SML.$$.   .define      M6809.$$.
.iif     ne,$$.SML.$$.   .include      "m6809.mac"

...
```

2.10 EXAMPLE MACRO CROSS ASSEMBLERS

The 'ascheck' subdirectory 'macroasm' contains 7 assemblers written using only the general macro processing facility of the ASxxxx assemblers:

i8085.mac	-	8085 Microprocessor
m6800.mac	-	6800 Microprocessor
m6801.mac	-	6801 Microprocessor
m6804.mac	-	6804 Microprocessor
m6805.mac	-	6805 Microprocessor
m6809.mac	-	6809 Microprocessor
s2650.mac	-	2650 Microprocessor

These absolute macro cross assemblers are included to illustrate the functionality of the general macro processing facility of the ASxxxx assemblers. In general they are useful examples of actual macro implementations.

CHAPTER 3

THE LINKER

3.1 ASLINK RELOCATING LINKER

ASLINK is the companion linker for the ASxxxx assemblers. The linker supports versions 3.xx, 4.xx, and 5.xx of the ASxxxx assemblers. Object files from version 3, 4, and 5 may be freely mixed while linking. Note that version 3 object files contain only a subset of the options available in versions 4 and 5.

The program ASLINK is a general relocating linker performing the following functions:

1. Bind multiple object modules into a single memory image
2. Resolve inter-module symbol references
3. Combine code belonging to the same area from multiple object files into a single contiguous memory region
4. Search and import object module libraries for undefined global variables
5. Perform byte and word program counter relative (pc or pcr) addressing calculations
6. Define absolute symbol values at link time
7. Define absolute area base address values at link time
8. Produce Intel Hex, Motorola S, or Tandy CoCo Disk Basic output files
9. Produce a map of the linked memory image
10. Produce an updated listing file with the relocated addresses and data

3.2 INVOKING ASLINK

Starting ASlink without any arguments provides the following option list and then exits:

```
Usage: [-Options] [-Option with arg] file
Usage: [-Options] [-Option with arg] outfile file [file ...]
  -p    Echo commands to stdout (default)
  -n    No echo of commands to stdout
Alternates to Command Line Input:
  -c                    ASlink >> prompt input
  -f file[.lnk]        Command File input
Librarys:
  -k    Library path specification, one per -k
  -l    Library file specification, one per -l
Relocation:
  -b    area base address=expression
  -g    global symbol=expression
Map format:
  -m    Map output generated as (out)file[.map]
  -w    Wide listing format for map file
  -x    Hexidecimal (default)
  -d    Decimal
  -q    Octal
Output:
  -i    Intel Hex as (out)file[.i--]
  -s    Motorola S Record as (out)file[.s--]
  -t    Tandy CoCo Disk BASIC binary as (out)file[.bi-]
  -j    NoICE Debug output as (out)file[.noi]
  -y    SDCDB Debug output as (out)file[.cdb]
  -o    Linked file/library object output enable (default)
  -v    Linked file/library object output disable
List:
  -u    Update listing file(s) with link data as file(s)[.rst]
Case Sensitivity:
  -z    Disable Case Sensitivity for Symbols
End:
  -e    or null line terminates input
```

NOTE

When ASlink is invoked with a single filename the created output file will have the same filename as the .rel file.

When ASlink is invoked with multiple filenames the first filename is the output filename and the remaining filenames are linked together into the output

filename.

Most systems require the options to be entered on the command line:

```
aslink [-Options] [-Options with args] file
```

```
aslink [-Options] [-Options with args] outfile file1 [file2  
...]
```

Some systems may request the arguments after the linker is started at a system specific prompt:

```
aslink  
argv: [-options] [-option arg] file
```

```
aslink  
argv: [-Options] [-Options with args] outfile file1 [file2  
...]
```

The linker commands are explained in some more detail:

1. -c ASlink >> prompt mode.
The ASlink >> prompt mode reads linker commands from stdin.
2. -f file Command file mode.
The command file mode imports linker commands from the specified file (extension must be .lnk), imported -c and -f commands are ignored. If the directory path, for a file to be linked, is not specified in the command file then the path defaults to the .lnk file directory path.
3. -p/-n enable/disable echoing commands to stdout.
4. -i/-s/-t Intel Hex (file.i--), Motorola S (file.s--), or Tandy Color Computer Disk Basic (file.bi-) image output file.
5. -o/-v Specifies that subsequent linked files/libraries will generate object output (default) or suppress object output. (if option -i, -s, or -t was specified)
6. -z Disable Case Sensitivity for Symbols

7. -m Generate a map file (file.map). This file contains a list of the symbols (by area) with absolute addresses, sizes of linked areas, and other linking information.
8. -w Specifies that a wide listing format be used for the map file.
9. -xdq Specifies the number radix for the map file (Hexidecimal, Decimal, or Octal).
10. -u Generate an updated listing file (file.rst) derived from the relocated addresses and data from the linker.
11. file File(s) to be linked. Files may be on the same line as the above options or on a separate line(s) one file per line or multiple files separated by spaces or tabs.
12. -b area=expression
(one definition per line in a linker command file.)
This specifies an area base address where the expression may contain constants and/or defined symbols from the linked files.
13. -g symbol=expression
(one definition per line in a linker command file.)
This specifies the value for the symbol where the expression may contain constants and/or defined symbols from the linked files.
14. -k library directory path
(one definition per line in a linker command file.)
This specifies one possible path to an object library. More than one path is allowed.
15. -l library file specification
(one definition per line in a linker command file.)
This specifies a possible library file. More than one file is allowed.
16. -e or null line, terminates input to the linker.

3.3 LIBRARY PATH(S) AND FILE(S)

The process of resolving undefined symbols after scanning the input object files includes the scanning of object module libraries. The linker will search through all combinations of the library path specifications (input by the -k option) and the library file specifications (input by the -l option) that lead to an existing library file. Each library file contains a list (one file per line) of modules included in this particular library. Each existing object module is scanned for a match to the undefined symbol. The first module containing the symbol is then linked with the previous modules to resolve the symbol definition. The library object modules are rescanned until no more symbols can be resolved. The scanning algorithm allows resolution of back references. No errors are reported for non-existent library files or object modules.

The library file specification may be formed in one of two ways:

1. If the library file contained an absolute path/file specification then this is the object module's path/file.
(i.e. C:\... or C:/...)
2. If the library file contains a relative path/file specification then the concatenation of the path and this file specification becomes the object module's path/file.
(i.e. \... or /...)

As an example, assume there exists a library file `termio.lib` in the `syslib` directory specifying the following object modules:

```
\6809\io_disk      first object module
d:\special\io_comm second object module
```

and the following parameters were specified to the linker:

```
-k c:\iosystem\    the first path
-k c:\syslib\      the second path

-l termio          the first library file
-l io              the second library file (no such file)
```

The linker will attempt to use the following object modules to resolve any undefined symbols:

```
c:\syslib\6809\io_disk.rel    (concatenated path/file)
d:\special\io_comm.rel        (absolute path/file)
```

all other path(s)/file(s) don't exist. (No errors are reported for non existant path(s)/file(s).)

3.4 ASLINK PROCESSING

The linker processes the files in the order they are presented. The first pass through the input files is used to define all program areas, the section area sizes, and symbols defined or referenced. Undefined symbols will initiate a search of any specified library file(s) and the importing of the module containing the symbol definition. After the first pass the -b (area base address) definitions, if any, are processed and the areas linked.

The area linking proceeds by first examining the area types ABS, CON, REL, OVR and PAG. Absolute areas (ABS) from separate object modules are always overlayed and have been assembled at a specific address, these are not normally relocated (if a -b command is used on an absolute area the area will be relocated). Relative areas (normally defined as REL|CON) have a base address of 0x0000 as read from the object files, the -b command specifies the beginning address of the area. All subsequent relative areas will be concatenated with proceeding relative areas. Where specific ordering is desired, the first linker input file should have the area definitions in the desired order. At the completion of the area linking all area addresses and lengths have been determined. The areas of type PAG are verified to be on a 256 byte boundary and that the length does not exceed 256 bytes. Any errors are noted on stderr and in the map file.

Next the global symbol definitions (-g option), if any, are processed. The symbol definitions have been delayed until this point because the absolute addresses of all internal symbols are known and can be used in the expression calculations.

Before continuing with the linking process the symbol table is scanned to determine if any symbols have been referenced but not defined. Undefined symbols are listed on the stderr device. if a .module directive was included in the assembled file the module making the reference to this undefined variable will be printed.

Constants defined as global in more than one module will be flagged as multiple definitions if their values are not identical.

After the preceeding processes are complete the linker may output a map file (-m option). This file provides the following information:

1. Global symbol values and label absolute addresses
2. Defined areas and there lengths
3. Remaining undefined symbols
4. List of modules linked
5. List of library modules linked
6. List of -b and -g definitions

The final step of the linking process is performed during the second pass of the input files. As the xxx.rel files are read the code is relocated by substituting the physical addresses for the referenced symbols and areas and may be output in Intel, Motorola, or Tandy CoCo Disk Basic formats. The number of files linked and symbols defined/referenced is limited by the processor space available to build the area/symbol lists. If the -u option is specified then the listing files (file.lst) associated with the relocation files (file.rel) are scanned and used to create a new file (file.rst) which has all addresses and data relocated to their final values.

The -o/-v options allow the simple creation of loadable or overlay modules. Loadable and overlay modules normally need to be linked with a main module(s) to resolve external symbols. The -o/-v options can be used to enable object output for the loadable or overlay module(s) and suppress the object code from the linked main module(s). The -o/-v options can be applied repeatedly to specify a single linked file, groups of files, or libraries for object code inclusion or suppression.

3.5 ASXXXX VERSION 5.XX (4.XX) LINKING

The linkers' input object file is an ascii file containing the information needed by the linker to bind multiple object modules into a complete loadable memory image.

The object module contains the following designators:

[XDQ][HL][234]		
X	Hexidecimal radix	
D	Decimal radix	
Q	Octal radix	
H	Most significant byte first	
L	Least significant byte first	
2	16-Bit Addressing	
3	24-Bit Addressing	
4	32-Bit Addressing	
H	Header	
M	Module	
G	Merge Mode	
B	Bank	
A	Area	
S	Symbol	
T	Object code	
R	Relocation information	
P	Paging information	

3.5.1 Object Module Format

The first line of an object module contains the [XDQ][HL][234] format specifier (i.e. XH2 indicates a hexadecimal file with most significant byte first and 16-bit addressing) for the following designators.

3.5.2 Header Line

H aa areas gg global symbols

The header line specifies the number of areas(aa) and the number of global symbols(gg) defined or referenced in this object module segment.

3.5.3 Module Line

M name

The module line specifies the module name from which this header segment was assembled. The module line will not appear if the .module directive was not used in the source program.

3.5.4 Merge Mode Line

G nn ii 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

The mode structure contains the specification (or partial specification) of one of the assemblers' merge modes. Sixteen bits may be specified on a single line. Each assembler must specify at least one merge mode. The merging specification allows arbitrarily defined active bits and bit positions. The 32 element arrays are indexed from 0 to 31. Index 0 corresponds to bit 0, ..., and 31 corresponds to bit 31 of a normal integer value.

1. nn is merge mode number
2. ii is the beginning bit position of the following data
3. 00 ... merge mode bit elements

The value of the element specifies if the normal integer bit is active (bit <7> is set, 0x80) and what destination bit (bits <4:0>, 0 - 31) should be loaded with this normal integer bit.

3.5.5 Bank Line

B name base nn size nn map nn flags nn fsfx string

The B line defines a bank identifier as name. A bank is a structure containing a collection of areas. The bank is treated as a unique linking structure separate from other banks. Each bank can have a unique base address (starting address). The size specification may be used to signal the overflow of the banks' allocated space. The Linker combines all areas included within a bank as separate from other areas. The code from a bank may be output to a unique file by specifying the File Suffix parameter (fsfx). This allows the separation of multiple data and code segments into isolated output files. The map parameter is for NOICE processing. The flags indicate if the parameters have been set.

3.5.6 Area Line

A label size ss flags ff

The area line defines the area label, the size (ss) of the area in bytes, and the area flags (ff). The area flags specify the ABS, REL, CON, OVR, and PAG parameters:

OVR/CON (0x04/0x00 i.e. bit position 2)

ABS/REL (0x08/0x00 i.e. bit position 3)

PAG (0x10 i.e. bit position 4)

3.5.7 Symbol Line

S name Defnnnn

or

S name Refnnnn

The symbol line defines (Def) or references (Ref) the identifier name with the value nnnn. The defined value is relative to the current area base address. References to constants and external global symbols will always appear before the first area definition. References to external symbols will have a value of zero.

3.5.8 T Line

T xx xx nn nn nn nn nn ...

The T line contains the assembled code output by the assembler with xx xx being the offset address from the current area base address and nn nn being the assembled instructions and data in byte format. (xx xx and nn nn can be 2, 3, or 4 bytes as specified by the .REL file header.)

3.5.9 R Line

R 0 0 nn nn n1 n2 xx xx ...

The R line provides the relocation information to the linker. The nn nn value is the current area index, i.e. which area the current values were assembled. Relocation information is encoded in groups of 4 bytes:

1. n1 is the relocation mode and object format.
 1. bits <1:0> specify the number of bytes to output
 2. bits <2:3> normal(0x00) / MSB (0x0C)
signed(0x04) / unsigned(0x08)
 3. bit 4 normal(0x00)/page '0' (0x10) reference
 4. bit 5 normal(0x00)/page 'nnn' (0x20) reference
PAGX mode if both bits are set (0x30)
 5. bit 6 normal(0x00)/PC relative(0x40) relocation
 6. bit 7 relocatable area(0x00)/symbol(0x80)
2. n2 is a byte index and a merge mode index
 1. bits <3:0> are a byte index into the corresponding (i.e. preceeding) T line data (i.e. a pointer to the data to be updated by the relocation).
 2. bits <7:4> are an index into a selected merge mode. Currently mode 0 simply specifies to use standard byte processing modes and merging is ignored.
3. xx xx is the area/symbol index for the area/symbol being referenced. the corresponding area/symbol is found in the header area/symbol lists.

The groups of 4 bytes are repeated for each item requiring relocation in the preceeding T line.

3.5.10 P Line

P 0 0 nn nn n1 n2 xx xx

The P line provides the paging information to the linker as specified by a .setdp directive. The format of the relocation information is identical to that of the R line. The corresponding T line has the following information:

T xx xx aa aa bb bb

Where aa aa is the area reference number which specifies the selected page area and bb bb is the base address of the page. bb bb will require relocation processing if the 'n1 n2 xx xx' is specified in the P line. The linker will verify that the base address is on a 256 byte boundary and that the page length of an area defined with the PAG type is not larger than 256 bytes.

The linker defaults any direct page references to the first area defined in the input REL file. All ASxxxx assemblers will specify the _CODE area first, making this the default page area.

3.5.11 24-Bit and 32-Bit Addressing

When 24-bit or 32-bit addressing is specified in the file format line [XDQ][HL][234] then the S and T Lines have modified formats:

S name Defnnnnnnnn	(24-bit)
S name Refnnnnnnnn	(24-bit)
T xx xx xx nn nn nn nn ...	(24-bit)
S name Defnnnnnnnnnn	(32-bit)
S name Refnnnnnnnnnn	(32-bit)
T xx xx xx xx nn nn nn nn ...	(32-bit)

The multibyte formats for byte data replace the 2-byte form for 16-bit data with 3-byte or 4-byte data for 24-bit or 32-bit data respectively. The 2nd byte format (also named MSB) always uses the second byte of the 2, 3, or 4-byte data.

3.5.12 ASlink V5.xx (V4.xx) Error Messages

The linker provides detailed error messages allowing the programmer to quickly find the errant code. As the linker completes pass 1 over the input file(s) it reports any page boundary or page length errors as follows:

?ASlink-Warning-Paged Area PAGE0 Boundary Error

and/or

?ASlink-Warning-Paged Area PAGE0 Length Error

where PAGE0 is the paged area.

Also during Pass 1 any bank size (length) errors will be reported as follows:

?ASlink-Warning-Size limit exceeded in bank BANK

where BANK is the bank name.

During Pass two the linker reads the T, R, and P lines performing the necessary relocations and outputting the absolute code. Various errors may be reported during this process. The P line processing can produce only one possible error:

?ASlink-Warning-Page Definition Boundary Error

	file	module	pgarea	pgoffset
PgDef	t68091	t68091	PAGE0	0001

The error message specifies the file and module where the .setdp direct was issued and indicates the page area and the page offset value determined after relocation.

The R line processing produces various error messages:

?ASlink-Warning-Signed value error

?ASlink-Warning-Unsigned value error

?ASlink-Warning-Byte PCR relocation error

?ASlink-Warning-Word PCR relocation error

?ASlink-Warning-3-Byte PCR relocation error

?ASlink-Warning-4-Byte PCR relocation error

?ASlink-Warning-Page0 relocation error

?ASlink-Warning-PageN relocation error

?ASlink-Warning-PageX relocation error

?ASlink-Warning-Signed Merge Bit Range error

?ASlink-Warning-Unsigned/Overflow Merge Bit Range error

These error messages also specify the file, module, area, and offset within the area of the code referencing (Refby) and

defining (Defin) the symbol:

```
?ASlink-Warning-Signed value error for symbol two56
      file      module      area      offset
Refby  t        Pagetest    PROGRAM    0006
Defin  t        Pagetest    DIRECT     0100
```

If the symbol is defined in the same module as the reference the linker is unable to report the symbol name. The assembler listing file(s) should be examined at the offset from the specified area to locate the offending code.

The errors are:

1. The Signed value error indicates an indexing value exceeded the maximum negative or maximum positive value for the current variable size.
2. The Unsigned value error indicates an indexing value was greater than maximum positive value for the current variable size.
3. The byte PCR error is caused by exceeding the pc relative byte branch range.
4. The word PCR error is caused by exceeding the pc relative word branch range.
5. The 3-byte PCR error is caused by exceeding the pc relative 3-byte branch range.
6. The 4-byte PCR error is caused by exceeding the pc relative 4-byte branch range.
7. The Page0 error is generated if the direct page variable is not in the page0 range of 0 to 255.
8. The PageN error is generated if the direct page variable is not within the Nth page range of 0 to 255.
9. The PageX error is generated if the direct page variable is not within the extended page range.
10. The Signed Merge Bit Range error indicates an indexing value exceeded the maximum negative or maximum positive value for the current signed merge variable size.
11. The Unsigned/Overflow Merge Bit Range error indicates an indexing value was greater than maximum positive value for the current unsigned merge variable size.

3.6 ASXXXX VERSION 3.XX LINKING

The linkers' input object file is an ascii file containing the information needed by the linker to bind multiple object modules into a complete loadable memory image.

The object module contains the following designators:

[XDQ][HL][234]		
X	Hexidecimal radix	
D	Decimal radix	
Q	Octal radix	
H	Most significant byte first	
L	Least significant byte first	
2	16-Bit Addressing	
3	24-Bit Addressing	
4	32-Bit Addressing	
H	Header	
M	Module	
A	Area	
S	Symbol	
T	Object code	
R	Relocation information	
P	Paging information	

3.6.1 Object Module Format

The first line of an object module contains the [XDQ][HL][234] format specifier (i.e. XH2 indicates a hexadecimal file with most significant byte first and 16-bit addressing) for the following designators.

3.6.2 Header Line

H aa areas gg global symbols

The header line specifies the number of areas(aa) and the number of global symbols(gg) defined or referenced in this object module segment.

3.6.3 Module Line

M name

The module line specifies the module name from which this header segment was assembled. The module line will not appear if the .module directive was not used in the source program.

3.6.4 Area Line

A label size ss flags ff

The area line defines the area label, the size (ss) of the area in bytes, and the area flags (ff). The area flags specify the ABS, REL, CON, OVR, and PAG parameters:

OVR/CON (0x04/0x00 i.e. bit position 2)

ABS/REL (0x08/0x00 i.e. bit position 3)

PAG (0x10 i.e. bit position 4)

3.6.5 Symbol Line

S name Defnnnn

or

S name Refnnnn

The symbol line defines (Def) or references (Ref) the identifier name with the value nnnn. The defined value is relative to the current area base address. References to constants and external global symbols will always appear before the first area definition. References to external symbols will have a value of zero.

3.6.6 T Line

T xx xx nn nn nn nn ...

The T line contains the assembled code output by the assembler with xx xx being the offset address from the current area base address and nn being the assembled instructions and data in byte format.

3.6.7 R Line

R 0 0 nn nn n1 n2 xx xx ...

The R line provides the relocation information to the linker. The nn nn value is the current area index, i.e. which area the current values were assembled. Relocation information is encoded in groups of 4 bytes:

1. n1 is the relocation mode and object format, for the adhoc extension modes refer to asxxxx.h or aslink.h
 1. bit 0 word(0x00)/byte(0x01)
 2. bit 1 relocatable area(0x00)/symbol(0x02)
 3. bit 2 normal(0x00)/PC relative(0x04) relocation
 4. bit 3 1-byte(0x00)/2-byte(0x08) object format
 5. bit 4 signed(0x00)/unsigned(0x10) byte data
 6. bit 5 normal(0x00)/page '0'(0x20) reference
 7. bit 6 normal(0x00)/page 'nnn'(0x40) reference
 8. bit 7 LSB byte(0x00)/MSB byte(0x80)
2. n2 is a byte index into the corresponding (i.e. preceeding) T line data (i.e. a pointer to the data to be updated by the relocation). The T line data may be 1-byte or 2-byte byte data format or 2-byte word format.
3. xx xx is the area/symbol index for the area/symbol being referenced. the corresponding area/symbol is found in the header area/symbol lists.

The groups of 4 bytes are repeated for each item requiring relocation in the preceeding T line.

3.6.8 P Line

P 0 0 nn nn n1 n2 xx xx

The P line provides the paging information to the linker as specified by a .setdp directive. The format of the relocation information is identical to that of the R line. The corresponding T line has the following information:

T xx xx aa aa bb bb

Where aa aa is the area reference number which specifies the selected page area and bb bb is the base address of the page. bb bb will require relocation processing if the 'n1 n2 xx xx' is specified in the P line. The linker will verify that the base address is on a 256 byte boundary and that the page length of an area defined with the PAG type is not larger than 256 bytes.

The linker defaults any direct page references to the first area defined in the input REL file. All ASxxxx assemblers will specify the `_CODE` area first, making this the default page area.

3.6.9 24-Bit and 32-Bit Addressing

When 24-bit or 32-bit addressing is specified in the file format line `[XDQ][HL][234]` then the S and T Lines have modified formats:

S name Defnnnnnnn	(24-bit)
S name Refnnnnnnn	(24-bit)
T xx xx xx nn nn nn nn ...	(24-bit)
S name Defnnnnnnnnn	(32-bit)
S name Refnnnnnnnnn	(32-bit)
T xx xx xx xx nn nn nn nn ...	(32-bit)

The multibyte formats for byte data replace the 2-byte form for 16-bit data with 3-byte or 4-byte data for 24-bit or 32-bit data respectively. The 2nd byte format (also named MSB) always uses the second byte of the 2, 3, or 4-byte data.

3.6.10 ASlink V3.xx Error Messages

The linker provides detailed error messages allowing the programmer to quickly find the errant code. As the linker completes pass 1 over the input file(s) it reports any page boundary or page length errors as follows:

?ASlink-Warning-Paged Area PAGE0 Boundary Error

and/or

?ASlink-Warning-Paged Area PAGE0 Length Error

where PAGE0 is the paged area.

During Pass two the linker reads the T, R, and P lines performing the necessary relocations and outputting the absolute code. Various errors may be reported during this process

The P line processing can produce only one possible error:

?ASlink-Warning-Page Definition Boundary Error

	file	module	pgarea	pgoffset
PgDef	t68091	t68091	PAGE0	0001

The error message specifies the file and module where the .setdp direct was issued and indicates the page area and the page offset value determined after relocation.

The R line processing produces various errors:

?ASlink-Warning-Byte PCR relocation error for symbol bra2
?ASlink-Warning-Unsigned Byte error for symbol two56
?ASlink-Warning-Page0 relocation error for symbol ltwo56
?ASlink-Warning-Page Mode relocation error for symbol two56
?ASlink-Warning-Page Mode relocation error
?ASlink-Warning-2K Page relocation error
?ASlink-Warning-512K Page relocation error

These error messages also specify the file, module, area, and offset within the area of the code referencing (Refby) and defining (Defin) the symbol:

?ASlink-Warning-Unsigned Byte error for symbol two56

	file	module	area	offset
Refby	t68001	t68001	DIRECT	0015
Defin	tconst	tconst	. .ABS.	0100

If the symbol is defined in the same module as the reference the linker is unable to report the symbol name. The assembler listing file(s) should be examined at the offset from the specified area to locate the offending code.

The errors are:

1. The byte PCR error is caused by exceeding the pc relative byte branch range.
2. The Unsigned byte error indicates an indexing value was negative or larger than 255.
3. The Page0 error is generated if the direct page variable is not in the page0 range of 0 to 255.
4. The page mode error is generated if the direct variable is not within the current direct page (6809).
5. The 2K Page relocation error is generated if the destination is not within the current 2K page (8051, DS8xCxxx).

6. The 512K Page relocation error is generated if the destination is not within the current 512K page (DS80C390).

3.7 INTEL IHX OUTPUT FORMAT (16-BIT)

- Record Mark Field - This field signifies the start of a record, and consists of an ascii colon (:).
- Record Length Field - This field consists of two ascii characters which indicate the number of data bytes in this record. The characters are the result of converting the number of bytes in binary to two ascii characters, high digit first. An End of File record contains two ascii zeros in this field.
- Load Address Field - This field consists of the four ascii characters which result from converting the the binary value of the address in which to begin loading this record. The order is as follows:
- High digit of high byte of address.
 - Low digit of high byte of address.
 - High digit of low byte of address.
 - Low digit of low byte of address.
- In an End of File record this field consists of either four ascii zeros or the program entry address.
- Record Type Field - This field identifies the record type, which is either 0 for data records or 1 for an End of File record. It consists of two ascii characters, with the high digit of the record type first, followed by the low digit of the record type.
- Data Field - This field consists of the actual data, converted to two ascii characters, high digit first. There are no data bytes in the End of File record.
- Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, the record type field, and the data field. This sum is then negated (2's complement) and converted to two ascii characters, high digit first.

3.8 INTEL I86 OUTPUT FORMAT (24 OR 32-BIT)

- Record Mark Field - This field signifies the start of a record, and consists of an ascii colon (:).
- Record Length Field - This field consists of two ascii characters which indicate the number of data bytes in this record. The characters are the result of converting the number of bytes in binary to two ascii characters, high digit first. An End of File record contains two ascii zeros in this field.
- Load Address Field - This field consists of the four ascii characters which result from converting the the binary value of the address in which to begin loading this record. The order is as follows:
- High digit of high byte of address.
 - Low digit of high byte of address.
 - High digit of low byte of address.
 - Low digit of low byte of address.
- In an End of File record this field consists of either four ascii zeros or the program entry address.
- Record Type Field - This field identifies the record type, which is either 0 for data records, 1 for an End of File record, or 4 for a segment record. It consists of two ascii characters, with the high digit of the record type first, followed by the low digit of the record type.
- Data Field - This field consists of the actual data, converted to two ascii characters, high digit first. There are no data bytes in the End of File record.
- Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, the record type field, and the data field. This sum is then negated (2's complement) and converted to two ascii characters, high digit first.

3.9 MOTORLA S1-S9 OUTPUT FORMAT (16-BIT)

Record Type Field - This field signifies the start of a record and identifies the the record type as follows:

Ascii S1 - Data Record
Ascii S9 - End of File Record

Record Length Field - This field specifies the record length which includes the address, data, and checksum fields. The 8 bit record length value is converted to two ascii characters, high digit first.

Load Address Field - This field consists of the four ascii characters which result from converting the the binary value of the address in which to begin loading this record. The order is as follows:

High digit of high byte of address.
Low digit of high byte of address.
High digit of low byte of address.
Low digit of low byte of address.

In an End of File record this field consists of either four ascii zeros or the program entry address.

Data Field - This field consists of the actual data, converted to two ascii characters, high digit first. There are no data bytes in the End of File record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, and the data field. This sum is then complemented (1's complement) and converted to two ascii characters, high digit first.

3.10 MOTORLA S2-S8 OUTPUT FORMAT (24-BIT)

Record Type Field - This field signifies the start of a record and identifies the the record type as follows:

Ascii S2 - Data Record
Ascii S8 - End of File Record

Record Length Field - This field specifies the record length which includes the address, data, and checksum fields. The 8 bit record length value is converted to two ascii characters, high digit first.

Load Address Field - This field consists of the six ascii characters which result from converting the the binary value of the address in which to begin loading this record. The order is as follows:

High digit of 3rd byte of address.
Low digit of 3rd byte of address.
High digit of high byte of address.
Low digit of high byte of address.
High digit of low byte of address.
Low digit of low byte of address.

In an End of File record this field consists of either six ascii zeros or the program entry address.

Data Field - This field consists of the actual data, converted to two ascii characters, high digit first. There are no data bytes in the End of File record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, and the data field. This sum is then complemented (1's complement) and converted to two ascii characters, high digit first.

3.11 MOTORLA S3-S7 OUTPUT FORMAT (32-BIT)

Record Type Field - This field signifies the start of a record and identifies the the record type as follows:

Ascii S3 - Data Record
Ascii S7 - End of File Record

Record Length Field - This field specifies the record length which includes the address, data, and checksum fields. The 8 bit record length value is converted to two ascii characters, high digit first.

Load Address Field - This field consists of the eight ascii characters which result from converting the the binary value of the address in which to begin loading this record. The order is as follows:

High digit of 4th byte of address.
Low digit of 4th byte of address.
High digit of 3rd byte of address.
Low digit of 3rd byte of address.
High digit of high byte of address.
Low digit of high byte of address.
High digit of low byte of address.
Low digit of low byte of address.

In an End of File record this field consists of either eight ascii zeros or the program entry address.

Data Field - This field consists of the actual data, converted to two ascii characters, high digit first. There are no data bytes in the End of File record.

Checksum Field - The checksum field is the 8 bit binary sum of the record length field, the load address field, and the data field. This sum is then complemented (1's complement) and converted to two ascii characters, high digit first.

3.12 TANDY COLOR COMPUTER DISK BASIC FORMAT

- Record Preamble - This field is either \$00 (for start of new record) or \$FF (for last record in file).
- Record Length Field - This field specifies the number of data bytes which follows the address field. The length is in binary MSB to LSB order.
- 16-Bit Length - 2-bytes
24-Bit Length - 3-bytes
32-Bit Length - 4-bytes
- Load Address Field - This field consists of the address where the record will be loaded into memory. The address is in binary MSB to LSB order.
- 16-Bit Address - 2-bytes
24-Bit Address - 3-bytes
32-Bit Address - 4-bytes
- Data Field - This field consists of the actual binary data.

After the last code segment, a final record like the one above is placed. In this final segment, the Record Preamble is \$FF, the Record Length Field is \$0000 and the Load Address Field is the execution address.

CHAPTER 4

BUILDING ASXXXX AND ASLINK

The assemblers and linker have been successfully compiled for Linux, DOS, and various flavors of Windows using the Linux GCC, the Cygwin environment, the DJGPP environment, and the graphical user interfaces and command line environments of MS Visual C++ V6.0, MS Visual Studio 2005, Open Watcom V1.7, Symantec C/C++ V7.2, and Turbo C 3.0.

Makefiles for Linux, Cygwin, DJGPP, project files and a makefile for Turbo C and psuedo makefiles and project files for VC6, VS2005, Open Watcom and Symantec are available to build all the assemblers and the linker.

Unpack the asxv5pxx.zip file into an appropriate directory using the utility appropriate to your environment. For DOS or Windows the following command line will unpack the distribution zip file:

```
pkunzip -d asxv5pxx.zip
```

The distribution file has been packed with DOS style end of lines (CR/LF), and UPPER CASE file names. The Linux make file assumes all lower case directories and file names. For Linux the unpacking utility you choose should have an option to force all lower case directories / file names and convert the ascii files to local format. On most systems the following command should do the trick:

```
unzip -L -a asxv5pxx.zip
```

Some systems may require a -LL option to force all lower case.

The distribution will be unpacked into the base directory 'asxv5pxx' which will contain source directories for each supported processor (as6800, asz80, ...), the machine independent source (asxxsrc), the linker source (linksrc), and the miscellaneous sources (asxxmisc). Other directories include the

documentation (asxdoc), test file directory (asxtst), html documentation (asxhtml), NoICE support files (noice), various debug monitors that can be assembled with the ASxxxx assemblers (asmasm), project files for an application that uses the AS6809 assembler and ASlink linker (project), and the packaging directory (zipper).

4.1 BUILDING ASXXXX AND ASLINK WITH LINUX

The Linux build directory is /asxv5pxx/asxmak/linux/build. The makefile in this directory is compatible with the Linux GNU make and GCC. The command

```
make clean
```

will remove all the current executable files in directory /asxv5pxx/asxmak/linux/exe and all the compiled object modules from the /asxv5pxx/asxmak/linux/build directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

4.2 BUILDING ASXXXX AND ASLINK UNDER CYGWIN

The Cygwin build directory is \asxv5pxx\asxmak\cygwin\build. The makefile in this directory is compatible with the Cygwin GNU make and GCC. The command

```
make clean
```

will remove all the current executable files in directory \asxv5pxx\asxmak\cygwin\exe and all the compiled object modules from the \asxv5pxx\asxmak\cygwin\build directory. The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

4.3 BUILDING ASXXXX AND ASLINK WITH DJGPP

The DJGPP build directory is \asxv5pxx\asxmak\djgpp\build. The makefile in this directory is compatible with the DJGPP GNU make and GCC. The command

```
make clean
```

will remove all the current executable files in directory \asxv5pxx\asxmak\djgpp\exe and all the compiled object modules from the \asxv5pxx\asxmak\djgpp\build directory. The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

4.4 BUILDING ASXXXX AND ASLINK WITH BORLAND'S TURBO C++ 3.0

The Borland product is available in the Borland Turbo C++ Suite which contains C++ Builder 1.0, Turbo C++ 4.5 for Windows and Turbo C++ 3.0 for DOS. The DOS IDE will install and run on any version of Windows (including Windows Vista [Longhorn]).

4.4.1 Graphical User Interface

Each ASxxxx Assembler has two project specific files (*.dsk and *.prj) located in the subdirectory \asxv5pxx\asxmak\turboc30\build. You must enter the .prj filename into the Turbo C++ IDE: enter Options->Directories and change the include and output directories to match your configuration. After these changes have been made you will be able to compile the selected project. These changes must be manually entered for each project.

4.4.2 Command Line Interface

Before the command line interface can be used you must perform the steps outlined in the 'Graphical User Interface' instructions above for each project you wish to build.

Open a command prompt window in the \asxv5pxx\asxmak\turboc30\build directory. Assuming the Turbo C compiler has been installed in the default location (C:\TC) the file _setpath.bat will set the PATH variable. If this is not the case then the line

```
PATH=C:\TC;C:\TC\BIN;C:\TC\INCLUDE
```

must be changed to match your environment. The compiled object code modules will be placed in the \asxv5pxx\asxmak\turboc30\build\ directory and the executable files will be placed in the \asxv5pxx\asxmak\turboc30\exe directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

The Turbo C make utility uses the information in the corresponding .prj and .dsk files to compile and link the programs.

The file _makeall.bat found in the directory can also be used to invoke the Turbo C command line compiler. The _makeall.bat file calls the _setpath.bat file to set the path to the compiler directories in the environment variable PATH and then invokes 'make all'.

The command file _clean.bat may be used to remove all compiled .obj files and linked .exe executables.

4.5 BUILDING ASXXXX AND ASLINK WITH MS VISUAL C++ 6.0

4.5.1 Graphical User Interface

Each ASxxxx Assembler has a VC6 project file (*.dsw) located in a subdirectory of \asxv5pxx\asxmak\vc6\build. Simply enter this project filename into the VC6 IDE and build/rebuild the assembler.

4.5.2 Command Line Interface

Open a command prompt window in the \asxv5pxx\asxmak\vc6\build directory. The file make.bat found in the directory can be used to invoke the VC6 command line compiler. The make.bat file assumes that the Visual C++ compiler has been installed in the default location. If this is not the case then the line

```
SET MS$DEV="C:\Program Files\Microsoft Visual Studio\  
Common\MSDev98\Bin\msdev.exe"
```

must be changed to match your environment. The compiled object code modules will be placed in the \asxv5pxx\asxmak\vc6\build\as----\release directory and the executable files will be placed in the \asxv5pxx\asxmak\vc6\exe directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

The VC6 command line compiler uses the information in the corresponding .dsw/.dsp files to compile and link the programs.

The command 'make clean' is not required or valid as a make of anything does a complete rebuild of the program.

4.6 BUILDING ASXXXX AND ASLINK WITH MS VISUAL STUDIO 2005

4.6.1 Graphical User Interface

Each ASxxxx Assembler has a VS05 project file (*.vcproj) located in a subdirectory of \asxv5pxx\asxmak\vs05\build. Simply enter this project filename into the VS05 IDE and build/rebuild the assembler.

4.6.2 Command Line Interface

Open a command prompt window in the \asxv5pxx\asxmak\vs05\build directory. The file make.bat found in the directory can be used to invoke the VS05 command line compiler. The make.bat file assumes that the Visual C++ compiler has been installed in the default location. If this is not the case then the line

```
SET VC$BUILD="C:\Program Files\Microsoft Visual Studio 8\  
Common\MSDev98\Bin\msdev.exe"
```

must be changed to match your environment. The compiled object code modules will be placed in the \asxv5pxx\asxmak\vs05\build\as----\release directory and the executable files will be placed in the \asxv5pxx\asxmak\vs05\exe directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

The VS05 command line compiler uses the information in the corresponding .vcproj file to compile and link the programs.

The command 'make clean' is not required or valid as a make of anything does a complete rebuild of the program.

4.7 BUILDING ASXXXX AND ASLINK WITH OPEN WATCOM V1.7

4.7.1 Graphical User Interface

Each ASxxxx Assembler has a set of project files (.prj, .tgt, .mk, .mk1, and .lk1) located in the subdirectory \asxv5pxx\asxmak\watcom\build. You will have to edit the project files to match your local file locations.

4.7.2 Command Line Interface

Open a command prompt window in the \asxv5pxx\asxmak\watcom\build directory. Assuming the Watcom compiler has been installed in the default location (C:\WATCOM) the file _setpath.bat will set the PATH variable. If this is not the case then the line

```
PATH=C:\WATCOM\BINNT;C:\WATCOM\BINW
```

must be changed to match your environment. The compiled object code modules will be placed in the \asxv5pxx\asxmak\watcom\build\ directory and the executable files will be placed in the \asxv5pxx\asxmak\watcom\exe directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

The Watcom command line compiler wmake.exe uses the information in the corresponding project files to compile and link the programs.

The file _makeall.bat found in the directory can also be used to invoke the Watcom command line compiler. The _makeall.bat file calls the _setpath.bat file to set the path to the compiler

directories in the environment variable PATH and then invokes 'make all'.

The command 'make clean' is not required or valid as a make of anything does a complete rebuild of the program.

4.8 BUILDING ASXXXX AND ASLINK WITH SYMANTEC C/C++ V7.2

The Symantec product is no longer available but is included for historical reasons (the final version, 7.5, was introduced in 1996). The product had an excellent graphical user interface, built in editor, project manager, and supported DOS, Extended DOS (the executable contained a built in DOS extender which was rendered unusable in Windows 2000, after service pack 2, or in Windows XP), Win95, and Windows NT.

4.8.1 Graphical User Interface

Each ASxxxx Assembler has a series of project specific files (*.bro, *.def, *.dpd, *.lnk, *.mak, *.opn, and *.prj) located in the subdirectory \asxv5pxx\asxmak\symantec\build. You must enter the .prj filename into the Symantec IDE and then select Project->Settings->Directories and change the include, target, and compiler output directories to match your configuration. After these changes have been made you will be able to compile the selected project. These changes must be manually entered for each project.

4.8.2 Command Line Interface

Before the command line interface can be used you must perform the steps outlined in the 'Graphical User Interface' instructions above for each project you wish to build.

Open a command prompt window in the \asxv5pxx\asxmak\symantec\build directory. The file make.bat found in the directory can be used to invoke the Symantec command line compiler. The make.bat file assumes that the path to the compiler directories has been set in the environment variable PATH. Assuming the Symantec compiler has been installed in the default location (C:\SC) the file _setpath.bat will set the PATH variable. If this is not the case then the line

```
PATH=C:\SC;C:\SC\BIN;C:\SC\INCLUDE;C:\SC\LIB
```

must be changed to match your environment. The compiled object

code modules will be placed in the \asxv5pxx\asxmak\symantec\build directory and the executable files will be placed in the \asxv5pxx\asxmak\symantec\exe directory.

The command

```
make all
```

will compile and link all the ASxxxx assemblers, the ASlink program, and the utility programs asxscn and asxcnv. The make file can make a single program by invoking make with the specific assembler, linker, or utility you wish to build:

```
make aslink
```

The Symantec make utility, smake.exe, uses the information in the corresponding .mak files to compile and link the programs.

The file _makeall.bat found in the directory can also be used to invoke the Symantec command line compiler. The _makeall.bat file calls the _setpath.bat file to set the path to the compiler directories in the environment variable PATH and then invokes 'make all'.

The command file _clean.bat may be used to remove all compiled .obj files and linked .exe executables.

APPENDIX A

ASXSCN LISTING FILE SCANNER

The program ASXSCN is a debugging utility program used to verify ASxxxx assembler code generation. The program may be invoked with any of the following options:

```
Usage: [-dqx234i] file
  d    decimal listing
  q    octal   listing
  x    hex     listing (default)
  2    16-Bit  address (default)
  3    24-Bit  address
  4    32-Bit  address
  i    ignore  relocation flags
```

Select one of the -d, -q, or -x options to match the listing file format and select only one of the -2, -3, or -4 options to match the addressing range of the listing file. The -i option inhibits the verification of the assembler relocation flags generated by the ASxxxx assemblers -f or -ff options.

Each source assembly line selected for verification must include the expected output code in the comment field of the line. The following has been extracted from the ASF2MC8 test file tf2mc8.asm:

```
reti          ; 30
call  ext     ; 31s12r34
subc  a       ; 32
subcw a       ; 33
subc  a,#v22  ; 34r22
subc  a,*dir  ; 35*33
subc  a,@ix+off ; 36r44
subc  a,@ep   ; 37
```

The r, s, and * are specific address relocation flags created when the -ff option is specified with any ASxxxx assembler.

Invoking the assembler:

```
asf2mc8 -gloaxff tf2mc8
```

produces a listing file:

```
033B 30          677      reti          ; 30
033C 31s12r34    678      call   ext      ; 31s12r34
033F 32          679      subc   a         ; 32
0340 33          680      subcw  a         ; 33
0341 34r22       681      subc   a,#v22    ; 34r22
0343 35*33       682      subc   a,*dir     ; 35*33
0345 36r44       683      subc   a,@ix+off ; 36r44
0347 37          684      subc   a,@ep     ; 37
```

The expected code can be compared with the generated code by invoking the scanning program:

```
asxscn tf2mc8.lst
0 code error(s) found in file tf2mc8.lst
```

The assembled code can also be linked:

```
aslink -u ...options... t2fc8
```

to create an updated listing file:

```
033B 30          677      reti          ; 30
033C 31 12 34    678      call   ext      ; 31s12r34
033F 32          679      subc   a         ; 32
0340 33          680      subcw  a         ; 33
0341 34 22       681      subc   a,#v22    ; 34r22
0343 35 33       682      subc   a,*dir     ; 35*33
0345 36 44       683      subc   a,@ix+off ; 36r44
```

which resolves all relocations and removes the relocation flags. This file can also be verified:

```
asxscn -i tf2mc8.rst
0 code error(s) found in file tf2mc8.rst
```

The verification of both the .lst and .rst files from the same assembler test file requires careful definition of external variables so that the assembler listing file and the linker listing file have the same code values.

APPENDIX B

ASXCNV LISTING CONVERTER

The program ASXCNV is a debugging utility program used to create an assembler file with verification data. The program may be invoked with any of the following options:

```
Usage: [-dqx234] file
      d    decimal listing
      q    octal   listing
      x    hex     listing (default)
      2    16-Bit  address (default)
      3    24-Bit  address
      4    32-Bit  address
```

Select one of the -d, -q, or -x options to match the listing file format and select only one of the -2, -3, or -4 options to match the addressing range of the listing file.

Each source assembly line which creates output data will have the data appended to the source line as a comment. The appended comment will contain the relocation codes if they are present in the listing file. Any existing comment on the line will be overwritten.

Given an existing listing file, a.lst, containing:

```
033B 30          677    reti
033C 31s12r34    678    call  ext
033F 32          679    subc  a
0340 33          680    subcw a
0341 34r22       681    subc  a,#v22
0343 35*33       682    subc  a,*dir
0345 36r44       683    subc  a,@ix+off
0347 37          684    subc  a,@ep
```

A converted listing file can be created using the following command:

```
asxcnv -d2 a.lst
```

The created output file, a.out, is a new assembly file now contain the verification data in the comments:

```
reti          ; 30
call  ext     ; 31s12r34
subc  a       ; 32
subcw a       ; 33
subc  a,#v22  ; 34r22
subc  a,*dir  ; 35*33
subc  a,@ix+off ; 36r44
subc  a,@ep   ; 37
```

APPENDIX C

S19OS9 CONVERSION UTILITY

C.1 BACKGROUND

OS9 is an Operating System for the TRS-80/Tandy Color Computers based on the 6809/6309 processors. The open source version of the OS9 operating system is NitroS-9 and is available at:

The NitroS-9 Project
<http://www.nitros9.org>

The s19os9 utility package contains the following:

- 1) OS9 definition files and an OS9 assembler module which creates the OS9 header, code and data areas, and the module CRC block:

os9_mod.def	OS9 Module Definitions
os9_sys.def	OS9 Sytem Definitions
os9_mod.asm	OS9 Module Begin / End Code

- 2) a program, s19os9, to post-process assembled OS9 modules from S19 format into binary OS9 modules with the appropriate header checksum and module CRC values calculated.

The file os9_mod.def contains module definitions used in the header of OS9 binary files and was derived from the NitroS-9 file os9_mod.def.

The file os9_sys.def contains system definitions pertaining to system service request codes, system reserved calls, I/O service request calls, file access modes, signal codes, get/put

status codes, module offsets, and error codes. This file was derived from the NitroS-9 file os9defs.a.

C.2 CREATING AN OS9 MODULE

This section describes how to create an OS9 module using the files os9_mod.def, os9_sys.def, and os9_mod.asm.

When creating an OS9 module certain parameters are required by the os9_mod.asm file to create the appropriate headers. The list of supported parameters is listed here:

Basic Header:

```
.define OS9_ModNam,      "Module_Name"
.define OS9_Typ,         "Type_Value"
.define OS9_Lng,         "Language_Value"
.define OS9_Att,         "Attributes_Value"
.define OS9_Rev,         "Revision_Value"
```

General Parameters:

```
.define OS9_ModExe,      "Module Entry Point Offset"
.define OS9_ModMem,      "Module Permanent Storage"
```

Device Driver Parameters:

```
.define OS9_Mod,         "Module Mode"
```

Descriptor Parameters:

```
.define OS9_FMN,         "Device Driver Name Label"
.define OS9_DDR,         "Device Driver Name Label"
.define OS9_AbsAdr02,    "Device Absolute Address <23:16>"
.define OS9_AbsAdr01,    "Device Absolute Address <15:08>"
.define OS9_AbsAdr00,    "Device Absolute Address <07:00>"
.define OS9_Opt,         "Descriptor Option"
.define OS9_DType,       "Descriptor Data Type"
```

The OS9 Module file os9_mod.asm supports the creation of the following simple module types:

SYSTM	-	System Module
PRGRM	-	Program Module
SBTRN	-	Subroutine Module
DRIVR	-	Device Driver Module
FLMGR	-	File Manager Module
DEVIC	-	Device Descriptor Module

The following code shows the steps required when creating an OS9 program using the os9_mod.asm file. os9_mod.asm loads the os9_mod.def and os9_sys.def files, defines the software interrupt macro os9, and creates the os9 program header and crc blocks.

C.2.1 Step 1: Define Header Values

```

;****
; Step 1:
; Use the .define assembler directive
; to insert the parameters into the
; os9_mod.asm's header structure.
;
;      Note:   See the file os9_mod.asm for
;              parameter names and definitions.
;
.title          List Program

.sbttl          Header Definitions

.define OS9_ModNam,      "LSTNAM"
.define OS9_Typ,         "PRGRM"
.define OS9_Lng,         "OBJECT"
.define OS9_Att,         "REENT"
.define OS9_Rev,         "1"
.define OS9_ModExe,      "LSTENT"
.define OS9_ModMem,      "LSTMEM"

```

C.2.2 Step 2: Create The Module Header

```

; Step 2:
; Set the symbol OS9_Module equal to 1
; and .include the file os9_mod.asm.

OS9_Module = 1          ; OS9 Module Begin (==1)
; .include              "os9_mod.asm"
; .nlist
; .include              "os9_mod.asm"
; .list

```

With OS9_Module = 1 the following code is inserted into the code stream:

```

.define os9,      "swi2 .byte" ; os9 macro

; Include OS9 Definition Files
; os9_sys.def Listing Disabled

```



```
.nlist
.include      "os9_sys.def"
.list
; os9_mod.def Listing Disabled
.nlist
.include      "os9_mod.def"
.list

; Define The OS9 Module Bank and Areas.
;
; Place the module program code in area OS9_Module
; and the module data in area OS9_Data.
;

.bank   OS9_Module      (BASE=0,FSFX=_OS9)
.area   OS9_Module      (REL,CON,BANK=OS9_Module)

.bank   OS9_Data        (BASE=0,FSFX=_DAT)
.area   OS9_Data        (REL,CON,BANK=OS9_Data)

.area   OS9_Module

OS9_ModBgn = .

.byte   OS9_ID0, OS9_ID1
        ; OS9 Module Sync Bytes
.word   OS9_ModEnd - OS9_ModBgn
        ; Length (Includes 3 CRC Bytes)
.word   OS9_ModNam - OS9_ModBgn
        ; Offset to Module Name String
.byte   OS9_Typ | OS9_Lng
        ; Type / Language
.byte   OS9_Att | OS9_Rev
        ; Attributes / Revision
.byte   0xFF
        ; Header Parity
.word   OS9_ModExe - OS9_ModBgn
        ; Execution Entry Offset
.word   OS9_ModMem
        ; Storage Requirement
;       OS9_ModData
        ; Module Data
```

C.2.3 Step 3: Allocate Storage

The next step is to add the program data storage space for the program. Note that the space is only allocated here and no initialization is done.

```

;*****-----*****-----*****-----*****-----*****
; LIST UTILITY COMMAND
; Syntax: list <pathname>
; COPIES INPUT FROM SPECIFIED FILE TO STANDARD OUTPUT

; Step 3:
; Allocate the storage in .area OS9_Data

.area    OS9_Data

; STATIC STORAGE OFFSETS

BUFSIZ   .equ    200      ; size of input buffer

Base = .
IPATH = . - Base
        .rmb     1          ; input path number
PRMPTR = . - Base
        .rmb     2          ; parameter pointer
BUFFER = . - Base
        .rmb     BUFSIZ     ; allocate line buffer
        .rmb     200        ; allocate stack
        .rmb     200        ; room for parameter list
LSTMEM = . - Base

```

C.2.4 Step 4: Insert The Program Code

Once the data storage space has been allocated then the program code is added to .area OS9_Module:

```

; Step 4:
; Insert the Module Code into .area OS9_Module

.area    OS9_Module

LSTNAM: .strs    "List"      ; String with last byte
                                ; or'd with 0x80
LSTENT: stx      *PRMPTR     ; save parameter ptr
        lda      #READ.     ; select read access mode
        os9      I$OPEN     ; open input file
        bcs      LIST50     ; exit if error
        sta      *IPATH     ; save input path number
        stx      *PRMPTR    ; save updated param ptr

```

```

LIST20:  lda      *IPATH          ; load input path number
         leax     *BUFFER,U      ; load buffer pointer
         ldy     #BUFSIZ        ; maximum bytes to read
         os9      I$READLN       ; read line of input
         bcs     LIST30         ; exit if error
         lda      #1             ; load std. out. path #
         os9      I$WRITLN       ; output line
         bcc     LIST20         ; Repeat if no error
         bra     LIST50         ; exit if error

LIST30:  cmpb     #E$EOF          ; at end of file?
         bne     LIST50         ; branch if not
         lda      *IPATH          ; load input path number
         os9      I$CLOSE        ; close input path
         bcs     LIST50         ; ..exit if error
         ldx     *PRMPTR         ; restore parameter ptr
         lda      ,X
         cmpa     #0x0D          ; End of parameter line?
         bne     LSTENT         ; ..no, list next file
         clrb
LIST50:  os9      F$EXIT          ; ... terminate

```

C.2.5 Step 5: End Assembly By Inserting CRC

```

; Step 5:
; Set the symbol OS9_Module equal to 0
; and .include the file os9_mod.asm.

OS9_Module = 0          ; OS9 Module End (==0)
; .include      "os9_mod.asm"
; .nlist
; .include      "os9_mod.asm"
; .list

.end

```

With OS9_Module = 0 the following code is the last code inserted into the code stream:

```

.area    OS9_Module

; The 3-Byte Module CRC
.byte    OS9_CRC0, OS9_CRC1, OS9_CRC2

OS9_ModEnd = .          ; End of OS9 Module

```

C.3 THE CONVERSION UTILITY: S19OS9

Once you have assembled your module into an .S19 file use the program s19os9 to create the binary OS9 module file.

The program s19os9 is invoked from the command line:

```
s19os9 mod.s19 -o mod.bin
```

where mod.s19 is the input S19 file and mod.bin is the OS9 binary output file.

The conversion utility s19os9 reads the .S19 file into an internal buffer (48K bytes maximum). As each line is read from the .S19 file the record length, address, data, and checksum values are processed checking for invalid characters and a valid checksum.

After the .S19 file has been loaded into the internal buffer the OS9 module is checked for correct length, and the OS9 Module ID, OS9 Initial Header Checksum, and OS9 Initial Module CRC are verified. After these parameters have been checked then the actual header checksum and module CRC values are calculated and replace the Initial Module Checksum and CRC values. The finalized module is then written to the file mod.bin.

APPENDIX D

CHANGE LOG

Summary of changes/additions to the ASxxxx Assemblers from Version 4.11 to Version 5.00.

2009_04_01 (Version 5.00)

Added a general purpose macro processor to the ASxxxx assemblers with the following mnemonics:

.macro	define a general macro
.irp	define an indefinite repeat macro by arguments
.irpc	define an indefinite repeat macro by characters
.rept	define a repeating macro
.mexit	exit to end of macro
.endm	end of macro
.nchr	assign number of characters to a symbol
.narg	assign number of expansion arguments to a symbol
.ntyp	assign 0/1 if argument is absolute/relocatable
.nval	assign value of argument to an absolute symbol
.mdelete	delete a macro definition

The following additional conditionals provide testing of string arguments most useful within macros:

.ifb	if argument blank
.ifnb	if argument not blank
.ifidn	if arguments are identical
.ifdif	if arguments are different

Added true (t), false (f), and true or false (tf) conditionals to the .if / .else / .endif construct. The conditionals .ift, .iff, and .iftf allow replacement of the .else directive making the .if / .endif construct more readable.

.ift	if condition is true
.iff	if condition is false
.iftf	if condition is true or false

An alternate .if construction has been added to the ASxxxx assemblers:

.if	eq,...	if argument == 0
.if	ne,...	if argument != 0
.if	lt,...	if argument < 0
.if	ge,...	if argument >= 0
.if	le,...	if argument <= 0
.if	gt,...	if argument > 0

.if	def,...	if argument is defined
.if	ndef,...	if argument is not defined
.if	b,...	if argument is blank
.if	nb,...	if argument is not blank
.if	idn,...,...	if arguments are the same
.if	dif,...,...	if arguments are not the same
.if	t	if condition is true
.if	f	if condition is false
.if	tf	if condition is true or false

The immediate conditional statements have been added to the ASxxxx assemblers. These conditionals can replace the .if / ... / .endif construct for a single assembler source line:

e.g. .iifeq arg label: .word 0x1234

.iif	if argument != 0
.iifeq	if argument == 0
.iifne	if argument != 0
.iiflt	if argument < 0
.iifge	if argument >= 0
.iifle	if argument <= 0
.iifgt	if argument > 0
.iifdef	if argument is defined
.iifndef	if argument is not defined
.iifb	if argument is blank
.iifnb	if argument is not blank
.iifidn	if arguments are the same
.iifdif	if arguments are not the same
.iift	if condition is true
.iiff	if condition is false
.iiftf	if condition is true or false

The alternate immediate conditional statements have also been added to the ASxxxx assemblers:

e.g. .iif eq,arg label: .word 0x1234

.iif	eq,...	if argument == 0
.iif	ne,...	if argument != 0
.iif	lt,...	if argument < 0
.iif	ge,...	if argument >= 0
.iif	le,...	if argument <= 0
.iif	gt,...	if argument > 0

```

.iif  def,...      if argument is defined
.iif  undef,...    if argument is not defined

.iif  b,...        if argument is blank
.iif  nb,...       if argument is not blank
.iif  idn,...,...  if arguments are the same
.iif  dif,...,...  if arguments are not the same

.iif  t            if condition is true
.iif  f            if condition is false
.iif  tf           if condition is true or false

```

The listing options for the ASxxxx assemblers has been updated to enable/disable any of the following parameters from being output to a generated listing file:

```

err      error codes
loc      code location
bin      assembler binary code
eqt      symbolic equates / if evaluations
cyc      machine cycles
lin      assembler source line number
src      assembler source code
pag      paging control
lst      listing of .list / .nlist
md       macro definition
me       macro expansion
meb      macro expansion binary code

!        sets the listing mode to
          !(.list) or !(.nlist) before
          applying the sublist options

```

```

e.g.     .nlist  (lst,pag)      ; disable .list/.nlist listing
                               ; and pagination

```

The NOT parameter, !, is used to set the listing mode to the opposite sense of the .list or .nlist directive. For example:

```

.nlist (!)  is equivalent to .list and
.list  (!)  is equivalent to .nlist

```

To enable listing and simultaneously disable the cycle count use the directive:

```

.nlist  (!,cyc)

```

or if you wish to suppress the listing of the .list / .nlist directives:


```
.nlist          ; disables all listing
.nlist (!,lst)  ; enables all listing except
                : .list (...) and .nlist
```

Normally the .list and .nlist directives are not evaluated when encountered within a FALSE conditional block. This default behavior can be modified by specifying a non zero argument in the .list or .nlist directive:

```
.nlist 1,(!,lst) ; enables listing even within
                ; a FALSE conditional block
```

The .bndry assembler directive has been added to ASxxxx. The .bndry directive changes the current location address to be evenly divisible by a specified integer value.

```
e.g.  .org      0
      .bndry    4
      ; . == 0

      .org      1
      .bndry    4
      ; . == 4
```

2009_02

Added the Cypress PSoc (M8C) ASM8C assembler to ASxxxx.

2008_09

Added the 8048 (8021, 8022, and 8041) AS8048 assembler to ASxxxx.

2008_02

Added the SC/MP ASSCMP assembler to ASxxxx.

2008_02_03 (Version 4.11 Update 4)

An update to the AS2650 assembler to fix the following errors:

- 1) The indexed addressing mode generates invalid code by using the first argument register as the index register: (addr = 0x1234)

```
loda    r0,[addr,r1]           0C F2 34
      this should give       0D F2 34
```

- 2) The index addressing mode did not generate an addressing error when the first argument register was not r0:

```
stra    r1,[addr,r2]  should give an 'a'
      error, the source must be r0
```

```
loda    r2,[addr,r3]  should give an 'a'
      error, the destination must be r0
```

- 3) The S2650 auto increment and decrement indexing modes always perform the register update before the register is used. i.e. +Rn or -Rn. The assembler now accepts +Rn or Rn+ as meaning pre-increment and -Rn or Rn- as meaning pre-decrement.

The AS2650 assembler tstscn files have been updated for testing the assemblers.

2007_10_21 (Version 4.11 Fix)

In the AS6816 assembler the instruction ANDP gives wrong object code. Changed from 37 2A to 37 3A.

2007_04_01 (Version 4.11 Update 3)

An update to the ASPIC assembler and associated fix to ASLINK:

- 1) Change the pic addressing to lo/hi from hi/lo byte ordering.
- 2) The update fixes an error in the pic17 series LCALL instruction.
- 3) A rewrite of the pic18 series assembler to change the PC addressing from 1 per 16-bit word to 1 per 8-bit byte and add the extended instruction set.
- 4) Modify the Linker Merge Mode processing to take into account the discarded low order bits for PC Relative Addressing.
- 5) New tstscn files for testing the assemblers.

2006_11_01 (Version 4.11 Optional Update 2)

- 1) OS9 definition files and an OS9 assembler module which creates the OS9 header, code and data areas, and the module CRC block:

os9_mod.def	OS9 Module Definitions
os9_sys.def	OS9 Sytem Definitions
os9_mod.asm	OS9 Module Begin / End Code

- 2) a program, s19os9, to post-process assembled OS9 modules in S19 format into binary OS9 modules with the appropriate header checksum and module CRC values calculated.
- 3) new make and project files which may be used to compile the s19os9 program.

2006_11_01 (Version 4.11 Optional Update 01)

The `.list` and `.nlist` directives are now modified by `.if` / `.else` / `.endif` processing so that they are active only in a `TRUE` clause.

The `.page` and `.include` directives are now modified by the `.list` and `.nlist` directives so that pagination occurs only when listing is active.

The new default functionality for the `.list`, `.nlist` and `.page` directives may be modified by including an optional argument in the directive as shown here for the `.list` directive:

```
.list    arg
```

a non-zero argument invokes the directive irrespective of the `.if` / `.else` / `.endif` status.

2006_07_26 (Version 4.11 Patch 01)

The assembly of a direct page instruction with a numeric constant causes a program crash when a `.rel` file is created. e.g.:

```
andb     *0x02
```

The use of a symbolic constant or symbol plus a constant compiles normally.

```
val = 0x02
```

```
andb     *val
andb     *extern+0x01
```

The assemblers effected are:

```
as6809
as6812
ash8
aspic
```

Summary of changes/additions to the ASxxxx Assemblers from Version 4.10 to Version 4.11.

1. Incorporated the patches contained in p01410.zip which corrected a coding error that affected BANKS containing multiple ABS areas or mixed AREA types.
2. Incorporated the patches contained in p02410.zip which corrected improper use of R_USGN in most addressing modes in AS6500. This caused unexpected 'a' errors in V4.xx because of the ASxxxx core change to 32-bit integers and arithmetic.
3. Incorporated the patches contained in p03410.zip which corrected errors in the .local and .globl assembler directive processing routine that introduced unwanted side effects for variable and symbol definition files. These effects included improper definitions and incorrect error warnings.
4. The following new subdirectories and their files have been added to the asxtst directory:
 - * areabank Area and Bank Processing Test
This directory contains several test programs: ts.asm (single file - multiple areas), tml.asm and tm2.asm (multiple file - multiple areas), and tbm.asm, tbml.asm, and tbm2.asm (multiple file - multiple areas within a bank) and several other files which verify the correct operation of the linker when used with a single linked file, multiple linked files having no banking, and multiple linked files with banking. These reference files show in detail how the .area and .bank directives work together.
 - * equstst Equate Processing Test
This directory contains a test file for verifying the operation of the .globl, .local, .equ, .gblequ, and .lclequ directives and the =, ==, and := equalities.
 - * inctst Nested Include File Test
 - * itst Include File Error Reporting Test
5. Incorporated the updates contained in u01410.zip which added 10 undocumented 8085 instructions to the AS8085 assembler.

Summary of changes/additions to the ASxxxx Assemblers from Version 4.00 to Version 4.10.

1. Added new assemblers for the Zilog EZ80, Zilog Z8, Signetics 2650, and Fujitsu F2MC8(L,FX) processors.
2. Added the processor cycle count option (-c) to all processors.
3. Several of the assemblers (ASZ80, ASRAB, AS6805, AS6808, AS6812, ASF2MC8, ...) now support subsets or supersets of their basic opcodes by the use of assembler specific directives.
4. Added .ifeq, .ifne, .iflt, .ifgt, .ifle, and .ifge conditional assembly directives.
5. Added support for the Tandy Color Computer Disc Basic binary file format to ASLINK.
6. Updated the assembler and linker source code to support 16-Bit and 32-Bit compilers. Tested with Borland Turbo C++ 3.0 and Symantec 7.2 C/C++ 16-Bit compilers, and with Visual C++ 6.0, Cygwin, DJGPP V02.03, and Linux 32-Bit compilers.
7. Problem:
When an area size is equal to the 'address space size' the size parameter is reported as 0. (A normal condition caused by address rollover to 0.) Aslink interpreted this as a 0 size.

Fix:
A new area 'Output Code Flag' bit was defined to indicate when data is defined in an area. ASxxxx and Aslink have been updated to set and process this area flag bit.
8. Problem:
The use of the .end assembler directive in an ASxxxx assembler would cause Aslink to output the optional start address in all output files.

Fix:
Updated Aslink to output the optional start address only in the output file associated with the area/bank containing the .end directive.

9. Problem:
Aslink creates output files for banks with no output data.

Fix:
Aslink now deletes any created output file for banks with no data.
10. Incorporated the patches contained in p01400.zip for files t1802.asm and 1802pst.c to correct for an error in the opcodes generated for the BM, BL, and BNF mnemonics.
11. Incorporated the patches contained in p02400.zip for file ds8adr.c to correct for an error in the direct page addressing mode of AS8xCxxx.
12. Incorporated the patches contained in p03400.zip for file rabmch.c to correct for an error in the processing of the "ret cc" instruction.
13. Made many corrections to internal code comments.

APPENDIX AA

ASCHECK ASSEMBLER

The ASxxxx assembler ASCHECK is used to test the machine independent features of the ASxxxx assemblers. The source files for the ASCHECK assembler are also useful as a template for the development of a new ASxxxx assembler.

The ASCHECK assembler has all the ASxxxx directives enabled for testing all features of the assemblers.

AA.1 .opcode DIRECTIVE

Format:

.opcode n

The .opcode directive creates a single byte of code having the value n and having cycle counts defined in the following table:

```
/*--*--* 0 1 2 3 4 5 6 7 8 9 A B C D E F */
/*--*--* - - - - - - - - - - - - - */
/*00*/ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15,
/*10*/ UN, 1,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,
/*20*/ UN,UN, 2,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,
/*30*/ UN,UN,UN, 3,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,
/*40*/ UN,UN,UN,UN, 4,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,
/*50*/ UN,UN,UN,UN,UN, 5,UN,UN,UN,UN,UN,UN,UN,UN,UN,
/*60*/ UN,UN,UN,UN,UN,UN, 6,UN,UN,UN,UN,UN,UN,UN,UN,
/*70*/ UN,UN,UN,UN,UN,UN,UN, 7,UN,UN,UN,UN,UN,UN,UN,
/*80*/ UN,UN,UN,UN,UN,UN,UN,UN, 8,UN,UN,UN,UN,UN,UN,
/*90*/ UN,UN,UN,UN,UN,UN,UN,UN,UN, 9,UN,UN,UN,UN,UN,
/*A0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,10,UN,UN,UN,UN,
/*B0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,11,UN,UN,UN,
/*C0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,12,UN,UN,
/*D0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,13,UN,
/*E0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,14,
/*F0*/ UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,UN,15
```


The UN symbols indicate 'undefined cycles' where no cycle count will be output.

APPENDIX AB

AS1802 ASSEMBLER

AB.1 ACKNOWLEDGMENT

Thanks to Shujen Chen for his contribution of the AS1802 cross assembler.

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AB.2 1802 REGISTER SET

The following is a list of the 1802 registers used by AS1802:

r0-r15	-	8-bit registers
sp	-	register r2
pc	-	register r3
call	-	register r4
return	-	register r5
argr	-	register r6

AB.3 1802 INSTRUCTION SET

The following tables list all 1802 mnemonics recognized by the AS1802 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS1802:

#data	immediate data byte or word data
expr	expression

Rn	register addressing
label	branch label

The terms data, expr, and label may be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 1802 technical data for valid modes.

AB.3.1 1802 Inherent Instructions

adc	add	and
dis	idl	irx
ldx	ldxa	lsdf
lsie	lskp	lsnf
lsnq	lsnz	lsq
lsz	mark	nop
or	req	ret
rshl	rshr	sav
sd	sdb	seq
shl	shlc	shr
shrc	skp	sm
smb	stxd	xor

AB.3.2 1802 Short Branch Instructions

b1	label	b2	label
b3	label	b4	label
bdf	label	bge	label
b1	label	bm	label
bn1	label	bn2	label
bn3	label	bn4	label
bnf	label	bnq	label
bnz	label	bpz	label
bq	label	br	label
bz	label	nbr	label

AB.3.3 1802 Long Branch Instructions

lbdf	label	lbnf	label
lbnq	label	lbnz	label
lbq	label	lbr	label
lbz	label	nlbr	label

AB.3.4 1802 Immediate Instructions

adci	#data	adi	#data
ani	#data	ldi	#data
ori	#data	sdbi	#data
sdi	#data	smbi	#data
smi	#data	xri	#data

AB.3.5 1802 Register Instructions

dec	Rn	ghi	Rn
glo	Rn	inc	Rn
lda	Rn	ldn	Rn
phi	Rn	plo	Rn
sep	Rn	sex	Rn
str	Rn		

AB.3.6 1802 Input and Output Instructions

inp	expr
out	expr

AB.3.7 CDP1802 COSMAC Microprocessor Instruction Set Summary

RCA

1	88888	000	22222
11	8 8	0 0	2 2
1	8 8	0 0 0	2
1	88888	0 0 0	222
1	8 8	0 0 0	2
1	8 8	0 0	2
111	88888	000	2222222

CDP1802 COSMAC Microprocessor Instruction Set Summary

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CDP1802 COSMAC Microprocessor Pinout

--> CLOCK		1		40		Vdd
--> $\overline{\text{WAIT}}$		2		39		$\overline{\text{XTAL}}$ -->
--> $\overline{\text{CLEAR}}$		3		38		$\overline{\text{DMA IN}}$ <--
<-- Q		4		37		$\overline{\text{DMA OUT}}$ <--
<-- SC1		5		36		$\overline{\text{INTERRUPT}}$ <--
<-- SC0		6		35		$\overline{\text{MWR}}$ <--
<-- $\overline{\text{MRD}}$		7		34		TPA -->
<--> BUS 7		8		33		TPB -->
<--> BUS 6		9		32		MA7 -->
<--> BUS 5		10	1802	31		MA6 -->
<--> BUS 4		11		30		MA5 -->
<--> BUS 3		12		29		MA4 -->
<--> BUS 2		13		28		MA3 -->
<--> BUS 1		14		27		MA2 -->
<--> BUS 0		15		26		MA1 -->
Vcc		16		25		MA0 -->
<-- N2		17		24		$\overline{\text{EF1}}$ <--
<-- N1		18		23		$\overline{\text{EF2}}$ <--
<-- N0		19		22		$\overline{\text{EF3}}$ <--
Vss		20		21		$\overline{\text{EF4}}$ <--

Mnem.	Op	F	Description	Notes
ADC	74	*	Add with Carry	{DF,D}=mx+D+DF
ADCI	i 7C	*	Add with Carry Immediate	{DF,D}=mp+D+DF,p=p+1
ADD	F4	*	Add	{DF,D}=mx+D
ADI	i FC	*	Add Immediate	{DF,D}=mp+D,p=p+1
AND	F2	*	Logical AND	D={mx}&D
ANI	i FA	*	Logical AND Immediate	D={mp}&D,p=p+1
B1	a 34	-	Branch if EF1	If EF1=1 BR else NBR
B2	a 35	-	Branch if EF2	If EF2=1 BR else NBR
B3	a 36	-	Branch if EF3	If EF3=1 BR else NBR
B4	a 37	-	Branch if EF4	If EF4=1 BR else NBR
BDF	a 33	-	Branch if DF	If DF=1 BR else NBR
BGE	a 33	-	Branch if Greater or Equal	See BDF
BL	a 38	-	Branch if Less	See BNF BR else NBR
BM	a 38	-	Branch if Minus	See BNF
BN1	a 3C	-	Branch if Not EF1	If EF1=0 BR else NBR
BN2	a 3D	-	Branch if Not EF2	If EF2=0 BR else NBR
BN3	a 3E	-	Branch if Not EF3	If EF3=0 BR else NBR
BN4	a 3F	-	Branch if Not EF4	If EF4=0 BR else NBR
BNF	a 38	-	Branch if Not DF	If DF=0 BR else NBR
BNQ	a 39	-	Branch if Not Q	If Q=0 BR else NBR
BNZ	a 3A	-	Branch if D Not Zero	If D=1 BR else NBR
BPZ	a 33	-	Branch if Positive or Zero	See BDF
BQ	a 31	-	Branch if Q	If Q=1 BR else NBR
BR	a 30	-	Branch	pl=mp
BZ	a 32	-	Branch if D Zero	If D=0 BR else NBR
DEC	r 2N	-	Decrement register N	n=n-1
DIS	71	-	Disable	{X,P}=mx,x=x+1,IE=0
GHI	r 9N	-	Get High register N	D=nh
GLO	r 8N	-	Get Low register N	D=nl
IDL	00	-	Idle (wait for DMA or int.)	Bus=m0
INC	r 1N	-	Increment register N	n=n+1
INP	d 6N	-	Input (N=d+8=9-F)	mx=Bus,D=Bus,Nlines=d
IRX	60	-	Increment register X	x=x+1
LBDF	a C3	-	Long Branch if DF	If DF=1 LBR else LNBR
LBNF	a C8	-	Long Branch if Not DF	If DF=0 LBR else LNBR
LBNQ	a C9	-	Long Branch if Not Q	If Q=0 LBR else LNBR
LBNZ	a CA	-	Long Branch if D Not Zero	If D=1 LBR else LNBR
LBQ	a C1	-	Long Branch if Q	If Q=1 LBR else LNBR
LBR	a C0	-	Long Branch	p=mp
LBZ	a C2	-	Long Branch if D Zero	If D=0 LBR else LNBR
LDA	r 4N	-	Load advance	D=mn,n=n+1
LDI	i F8	-	Load Immediate	D=mp,p=p+1
LDN	r 0N	-	Load via N (except N=0)	D=mn
LDX	F0	-	Load via X	D=mx
LDXA	72	-	Load via X and Advance	D=mx,x=x+1
LSDF	CF	-	Long Skip if DF	If DF=1 LSKP else NOP

Mnem.	Op	F	Description	Notes
LSIE	CC	-	Long Skip if IE	If IE=1 LSKP else NOP
LSKP	C8	-	Long Skip	See NLBR
LSNF	C7	-	Long Skip if Not DF	If DF=0 LSKP else NOP
LSNQ	C5	-	Long Skip if Not Q	If Q=0 LSKP else NOP
LSNZ	C6	-	Long Skip if D Not Zero	If D=1 LSKP else NOP
LSQ	CD	-	Long Skip if Q	If Q=1 LSKP else NOP
LSZ	CE	-	Long Skip if D Zero	If D=0 LSKP else NOP
MARK	79	-	Push X,P to stack (T={X,P})	m2={X,P},X=P,r2=r2-1
NBR	38	-	No short Branch (see SKP)	p=p+1
NLBR	a C8	-	No Long Branch (see LSKP)	p=p+2
NOP	C4	-	No Operation	Continue
OR	F1	*	Logical OR	D={mx}vD
ORI	i F9	*	Logical OR Immediate	D={mp}vD,p=p+1
OUT	d 6N	-	Output (N=d=1-7)	Bus=mx,x=x+1,Nlines=d
PLO	r AN	-	Put Low register N	nl=D
PHI	r BN	-	Put High register N	nh=D
REQ	7A	-	Reset Q	Q=0
RET	70	-	Return	{X,P}=mx,x=x+1,IE=1
RSHL	7E	*	Ring Shift Left	See SHLC
RSHR	76	*	Ring Shift Right	See SHRC
SAV	78	-	Save	mx=T
SDB	75	*	Subtract D with Borrow	{DF,D}=mx-D-DF
SDBI	i 7D	*	Subtract D with Borrow Imm.	{DF,D}=mp-D-DF,p=p+1
SD	F5	*	Subtract D	{DF,D}=mx-D
SDI	i FD	*	Subtract D Immediate	{DF,D}=mp-D,p=p+1
SEP	r DN	-	Set P	P=N
SEQ	7B	-	Set Q	Q=1
SEX	r EN	-	Set X	X=N
SHL	FE	*	Shift Left	{DF,D}={DF,D,0}<-
SHLC	7E	*	Shift Left with Carry	{DF,D}={DF,D}<-
SHR	F6	*	Shift Right	{D,DF}=->{0,D,DF}
SHRC	76	*	Shift Right with Carry	{D,DF}=->{D,DF}
SKP	38	-	Short Skip	See NBR
SMB	77	*	Subtract Memory with Borrow	{DF,D}=D-mx-{~DF}
SMBI	i 7F	*	Subtract Mem with Borrow Imm	{DF,D}=D-mp-~DF,p=p+1
SM	F7	*	Subtract Memory	{DF,D}=D-mx
SMI	i FF	*	Subtract Memory Immediate	{DF,D}=D-mp,p=p+1
STR	r 5N	-	Store via N	mn=D
STXD	73	-	Store via X and Decrement	mx=D,x=x-1
XOR	F3	*	Logical Exclusive OR	D={mx}.D
XRI	i FB	*	Logical Exclusive OR Imm.	D={mp}.D,p=p+1
		-	Interrupt action	T={X,P},P=1,X=2,IE=0
	??		8-bit hexadecimal opcode	
	?N		Opcode with register/device in low 4/3 bits	
		-	DF flag unaffected	
		*	DF flag affected	

Arguments	Notes
mn	Register addressing
mx	Register-indirect addressing
mp	Immediate addressing
R()	Stack addressing (implied addressing)
D	Data register (accumulator, 8-bit)
DF	Data Flag (ALU carry, 1-bit)
I	High-order instruction digit (4-bit)
IE	Interrupt Enable (1-bit)
N	Low-order instruction digit (4-bit)
P	Designates Program Counter register (4-bit)
Q	Output flip-flop (1-bit)
R	1 of 16 scratchpad Registers(16-bit)
T	Holds old {X,P} after interrupt (X high, 8-bit)
X	Designates Data Pointer register (4-bit)
mn	Memory byte addressed by R(N)
mp	Memory byte addressed by R(P)
mx	Memory byte addressed by R(X)
m?	Memory byte addressed by R(?)
n	Short form for R(N)
nh	High-order byte of R(N)
nl	Low-order byte of R(N)
p	Short form for R(P)
pl	Low-order byte of R(P)
r?	Short form for R(?)
x	Short form for R(X)
R(N)	Register specified by N
R(P)	Current program counter
R(X)	Current data pointer
R(?)	Specific register

Arguments	Notes
a	Address expression
d	Device number (1-7)
i	Immediate expression
n	Expression
r	Register (hex digit or an R followed by hex digit)
+	Arithmetic addition
-	Arithmetic subtraction
*	Arithmetic multiplication
/	Arithmetic division
&	Logical AND
~	Logical NOT
v	Logical inclusive OR
.	Logical exclusive OR
<-	Rotate left
->	Rotate right
{ }	Combination of operands
?	Hexadecimal digit (0-F)
-->	Input pin
<--	Output pin
<-->	Input/output pin

APPENDIX AC

AS2650 ASSEMBLER

AC.1 2650 REGISTER SET

The following is a list of the 2650 registers used by AS2650:

r0,r1	-	8-bit accumulators
r2,r3		

AC.2 2650 INSTRUCTION SET

The following tables list all 2650 mnemonics recognized by the AS2650 assembler. The designation [] refers to a required addressing mode argument. The designation CC refers to a required condition code argument: .eq., .gt., .lt., .un., or value of 0-3. The following list specifies the format for each addressing mode supported by AS2650:

#data		immediate byte data
r0,r1,r2,r3		registers
addr		location/branch address
[addr]	or	indirect addressing
@addr		
[addr,r0]	or	register indexed
@addr,r0		indirect addressing
[addr,-r0]	or	autodecrement register indexed
@addr,-r0		indirect addressing
[addr,r0+]	or	autoincrement register indexed
@addr,r0+		indirect addressing

.eq.	CC: equal	(== 0)
.gt.	CC: greater than	(== 1)
.lt.	CC: less than	(== 2)
.un.	CC: unconditional	(== 3)

The terms data, label, and addr may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 2650 technical data for valid modes.

AC.2.1 Load / Store Instructions

lodz	r	lodi	#data
lodr	[]	loda	[]
stoz	r		
stor	[]	stoa	[]

AC.2.2 Arithmetic / Compare Instructions

addz	r	addi	#data
addr	[]	adda	[]
subz	r	subi	#data
subr	[]	suba	[]
comz	r	comi	#data
comr	[]	coma	[]
dar	r		

AC.2.3 Logical / Rotate Instructions

andz	r	andi	#data
andr	[]	anda	[]
iorz	r	iori	#data
iorr	[]	iora	[]
eorz	r	eori	#data
eorr	[]	eora	[]
rrr	r		
rrl	r		

AC.2.4 Condition Code Branches

bctr	CC,[]	bcta	CC,[]
bcfr	CC,[]	bcfa	CC,[]
bstr	CC,[]	bstb	CC,[]
bsfr	CC,[]	bsba	CC,[]

AC.2.5 Register Test Branches

brnr	r,[]	brna	r,[]
birr	r,[]	bira	r,[]
bdrb	r,[]	bdra	r,[]
bsnr	r,[]	bsna	r,[]

AC.2.6 Branches (to Subroutines) / Returns

bxr	[]	bsxr	[]
zbrb	[]	zbsr	[]
retc	CC	rete	CC

AC.2.7 Input / Output

redc	r	wrtc	r
redd	r	wrtd	r
rede	r,addr	wrte	r,addr

AC.2.8 Miscellaneous

halt		nop	
tmi	r,#data		

AC.2.9 Program Status

lpsl		lpsu	
spsl		spsu	
cpsl	#data	cpsu	#data
ppsl	#data	ppsu	#data
tpsl	#data	tpsu	#data

APPENDIX AD

AS430 ASSEMBLER

AD.1 MPS430 REGISTER SET

The following is a list of the MPS430 registers used by AS430:

Sixteen 16-bit registers provide address, data, and special functions:

pc	/	r0	-	program counter
sp	/	r1	-	stack pointer
sr	/	r2	-	status register
cg1	/	r2	-	constant generator 1
cg2	/	r3	-	constant generator 2
		r4	-	working register r4
		r5	-	working register r5
		...		
		r14	-	working register r14
		r15	-	working register r15

AD.2 MPS430 ADDRESSING MODES

The following list specifies the format for each addressing mode supported by AS430:

Source/Destination Operand Addressing Modes			
As/Ad	Addressing Mode	Syntax	Description
00/0	Register mode	Rn	Register contents are operand.
01/1	Indexed mode	X(Rn)	(Rn + X) points to the operand, X is stored in the next word.
01/1	Symbolic mode	ADDR	(PC + X) points to the operand, X is stored in the next word, Indexed mode X(PC) is used.
01/1	Absolute mode	&ADDR	The word following the instruction, contains the absolute address.
10/-	Indirect register mode	@Rn	Rn is used as a pointer to the operand.
11/-	Indirect autoincrement	@Rn+	Rn is used as a pointer to the operand. Rn is incremented afterwards.
11/-	Immediate mode	#N	The word following the instruction contains the immediate constant N. Indirect autoincrement mode @PC+ is used.

The terms ADDR, X and N may all be expressions. Note that not all addressing modes are valid with every instruction, refer to the MPS430 technical data for valid modes.

AD.2.1 MPS430 Instruction Mnemonics

The following table lists all MPS430 family mnemonics recognized by the AS430 assembler. The designations src and dst refer to required source and/or destination addressing mode arguments.

* ADC[.W];ADC.B	dst	dst + C -> dst
ADD[.W];ADD.B	src,dst	src + dst -> dst
ADDC[.W];ADDC.B		src,dst src + dst + C -> dst
AND[.W];AND.B	src,dst	src .and. dst -> dst
BIC[.W];BIC.B	src,dst	.not.src .and. dst -> dst
BIS[.W];BIS.B	src,dst	src .or. dst -> dst
BIT[.W];BIT.B	src,dst	src .and. dst
* BR	dst	Branch to
* BRANCH	dst	Branch to
CALL	dst	PC+2 -> stack, dst -> PC
* CLR[.W];CLR.B	dst	Clear destination
* CLRC		Clear carry bit
* CLRN		Clear negative bit
* CLRZ		Clear zero bit
CMP[.W];CMP.B	src,dst	dst - src
* DADC[.W];DADC.B	dst	dst + C -> dst (decimal)
DADD[.W];DADD.B	src,dst	src + dst + C -> dst (decimal)
* DEC[.W];DEC.B	dst	dst - 1 -> dst
* DECD[.W];DECD.B	dst	dst - 2 -> dst
* DINT		Disable interrupt
* EINT		Enable interrupt
* INC[.W];INC.B	dst	dst + 1 -> dst
* INCD[.W];INCD.B	dst	dst + 2 -> dst
* INV[.W];INV.B	dst	Invert destination
JC/JHS	Label	Jump to Label if Carry-bit is set
JEQ/JZ	Label	Jump to Label if Zero-bit is set
JGE	Label	Jump to Label if (N .XOR. V) = 0
JL	Label	Jump to Label if (N .XOR. V) = 1
JMP	Label	Jump to Label unconditionally
JN	Label	Jump to Label if Negative-bit is set
JNC/JLO	Label	Jump to Label if Carry-bit is reset
JNE/JNZ	Label	Jump to Label if Zero-bit is reset
MOV[.W];MOV.B	src,dst	src -> dst
* NOP		No operation

```
* POP[.W];POP.B dst      Item from stack, SP+2 -> SP
  PUSH[.W];PUSH.B src    SP - 2 -> SP, src -> @SP
  RETI                  Return from interrupt
                        TOS -> SR, SP + 2 -> SP
                        TOS -> PC, SP + 2 -> SZP
* RET                  Return from subroutine
                        TOS -> PC, SP + 2 -> SP
* RLA[.W];RLA.B dst      Rotate left arithmetically
* RLC[.W];RLC.B dst      Rotate left through carry
  RRA[.W];RRA.B dst      MSB -> MSB . ....LSB -> C
  RRC[.W];RRC.B dst      C -> MSB . ....LSB -> C
* SBC[.W];SBC.B dst      Subtract carry from destination
* SETC                  Set carry bit
* SETN                  Set negative bit
* SETZ                  Set zero bit
  SUB[.W];SUB.B src,dst   dst + .not.src + 1 -> dst
  SUBC[.W];SUBC.B src,dst dst + .not.src + C -> dst
  SBB[.W];SBB.B src,dst   dst + .not.src + C -> dst
  SWPB dst               swap bytes
  SXT dst                Bit7 -> Bit8 ..... Bit15
* TST[.W];TST.B dst      Test destination
  XOR[.W];XOR.B src,dst   src .xor. dst -> dst
```

Note: Asterisked Instructions

Asterisked (*) instructions are emulated.
They are replaced with coreinstructions
by the assembler.

APPENDIX AE

AS61860 ASSEMBLER

AE.1 ACKNOWLEDGMENT

Thanks to Edgar Puehringer for his contribution of the AS61860 cross assembler.

Edgar Puehringer
edgar_pue at yahoo dot com

AE.2 61860 REGISTER SET

The SC61860 from Sharp has 96 bytes of internal RAM which are used as registers and hardware stack. The last four bytes of the internal RAM are special purpose registers (I/O, timers ...). Here is a list of the 61860 registers:

Reg	Address	Common use
---	-----	-----
i, j	0, 1	Length of block operations
a, b	2, 3	Accumulator
xl, xh	4, 5	Pointer for read operations
yl, yh	6, 7	Pointer for write operations
k - n	8 - 0x0b	General purpose (counters ...)
-	0x0c - 0x5b	Stack
ia	0x5c	Inport A
ib	0x5d	Inport B
fo	0x5e	Outport F
cout	0x5f	Control port

Other parts of the 61860 are the 16 bit program counter (pc) and 16 bit data pointer (dp). The ALU has a carry flag (c) and a zero flag (z). There is an internal register d which can't be accessed with machine instructions. It is filled from i or j when executing block operations.

In addition there are three 7 bit registers p, q, and r which are used to address the internal RAM (r is the stack pointer, p and q are used for block operations).

AE.3 PROCESSOR SPECIFIC DIRECTIVES

The AS61860 cross assembler has two (2) processor specific assembler directives which are used for the etc mnemonic (which is a kind of a built-in switch/case statement):

.default	A 16 bit address (same as .dw)
.case	One byte followed by a 16 bit address

Here is an example how this should be used (cut from a lst file)::

022B 7A 05 02 18	614	PTC	0x05,	CONT16
022F 69	615	DTC		
0230 4C 01 25	616	.CASE	0x4C,	SLOADI
0233 4D 01 2F	617	.CASE	0x4D,	SMERGI
0236 51 01 D2	618	.CASE	0x51,	QUITI
0239 53 00 CD	619	.CASE	0x53,	LLISTI
023C 56 01 D5	620	.CASE	0x56,	VERI
023F 01 D1	621	.DEFAULT		CONT9

AE.4 61860 INSTRUCTION SET

The following tables list all 61860 family mnemonics recognized by the AS61860 assembler. Most of the mnemonics are converted into 8 bit machine instructions with no argument or a one- or two-byte argument. There are some exceptions for this:

Mnemonic	Description
-----	-----
jp	2 bit instruction, 6 bit argument
cal	3 bit instruction, 13 bit argument
ptc *)	1 byte instruction, 3 byte argument
dtc *)	1 byte instruction, n bytes argument

*) Not mentioned in the CPU specification from Sharp

AE.4.1 Load Immediate Register

LII n	(n --> I)
LIJ n	
LIA n	
LIB n	
LIP n	
LIQ n	
LIDP nm	
LIDL n	(DL is the low byte of DP)
LP	(One byte version of LIP)
RA	(Same as LIA 0, but only one byte)
CLRA	(synonym for RA)

AE.4.2 Load Accumulator

LDP	(P --> A)
LDQ	
LDR	
LDM	((P) --> A)
LDD	((DP) --> A)

AE.4.3 Store Accumulator

STP	(A --> P)
STQ	
STR	
STD	(A --> (DP))

AE.4.4 Move Data

MVDM	((P) --> (DP))
MVMD	((DP) --> (P))

AE.4.5 Exchange Data

EXAB	(A <--> B)
EXAM	(A <--> (P))

AE.4.6 Stack Operations

PUSH	(R - 1 --> R, A --> (R))
POP	((R) --> A, R + 1 --> R)
LEAVE	(0 --> (R))

AE.4.7 Block Move Data

MVW	((Q) --> (P), I+1 bytes)
MVB	((Q) --> (P), J+1 bytes)
MVWD	((DP) --> (P), I+1 bytes)
MVBD	((DP) --> (P), J+1 bytes)
DATA	((B,A) --> (P), I+1 bytes, reads CPU ROM also)

AE.4.8 Block Exchange Data

EXW	((Q) <--> (P), I+1 bytes)
EXB	((Q) <--> (P), J+1 bytes)
EXWD	((DP) <--> (P), I+1 bytes)
EXBD	((DP) <--> (P), J+1 bytes)

AE.4.9 Increment and Decrement

INCP	(P + 1 --> P)
DECP	
INCI	
DECI	
INCJ	
DECJ	
INCA	
DECA	
INCB	
DECB	
INCK	
DECK	
INCL	
DECL	
IX	(X + 1 --> X, X --> DP)
DX	
IY	
DY	
INCM *)	
DECM *)	
INCN *)	
DECN *)	

*) Not mentioned in the CPU specification from Sharp

AE.4.10 Increment/Decrement with Load/Store

IXL	(Same as IX plus LDD)
DXL	
IYS	(Same as IY plus STD)
DYS	

AE.4.11 Fill

FILM	(A --> (P), I+1 bytes)
FILD	(A --> (DP), I+1 bytes)

AE.4.12 Addition and Subtraction

ADIA n	(A + n --> A)
SBIA n	
ADIM n	((P) + n --> (P))
SBIM n	
ADM n	((P) + A --> (P))
SBM n	
ADCM n	((P) + A --> (P), with carry)
SBCM	
ADB	(like ADM, but 16 bit)
SBB	
ADN	(like ADM, BCD addition, I+1 bytes)
SBN	
ADW	((P) + (Q) --> (P), BCD, I+1 bytes)
SBW	

AE.4.13 Shift Operations

SRW	(shift I+1 bytes in (P) 4 bits right)
SLW	
SR	(shift A 1 bit, with carry)
SL	
SWP	(exchange low and high nibble of A)

AE.4.14 Boolean Operations

ANIA n	(A & n --> A)
ORIA n	
ANIM n	((P) & n --> (P))
ORIM n	
ANID n	((DP) & n --> (DP))
ORID n	
ANMA	((P) & A --> (P))
ORMA	

AE.4.15 Compare

CPIA n	(A - n --> c,z)
CPIM n	((P) - n --> c,z)
CPMA	((P) - A --> c,z)
TSIA n	(A & n --> z)
TSIM n	((P) & n --> z)
TSID n	((DP) & n --> z)
TSIP	((P) & A --> z)

AE.4.16 CPU Control

SC	(Set carry)
RC	
NOPW	(no op)
NOPT	
WAIT n	(wait 6+n cycles)
WAITJ	(wait 5+4*I cycles)
CUP	(synonym for WAITJ)

AE.4.17 Absolute Jumps

JP nm	
JPZ nm	(on zero)
JPNZ nm	
JPC nm	
JPNC nm	
PTC/DTC	(see 'Processor Specific Directives')
PTJ/DTJ	(synonym for PTD/DTC)
CPCAL/DTLRA	(synonym for PTC/DTC)
CASE1/CASE2	(synonym for PTC/DTC)
SETT/JST	(synonym for PTC/DTC)

AE.4.18 Relative Jumps

These operations handle a jump relative to PC forward and back with a maximum distance of 255 byte. The assembler resolves 16 bit addresses to 8 bit relative addresses. If the target address is too far away, an error will be generated. Note that relative jumps need 1 byte less than absolute jumps.

JRP nm	
JRZP nm	
JRNZP nm	(jump relative non zero plus direction)
JRCP nm	
JRNCP nm	
JRM nm	
JRZM nm	
JRNZM nm	
JRCM nm	(jump relative on carry minus direction)
JRNCM nm	
LOOP nm	(decrements (R) and makes a JRNCM)

AE.4.19 Calls

CALL nm	
CAL nm	(nm must be <= 0x1fff, 1 byte less code than CALL)
RTN	

AE.4.20 Input and output

INA	(IA --> A)
INB	
OUTA	
OUTB	
OUTF	(A --> FO)
OUTC	(control port)
TEST n	(timers, pins & n --> z)

AE.4.21 Unknown Commands

READ	((PC+1) -> A)
READM	((PC+1) -> (P))
WRIT	(???)

APPENDIX AF

AS6500 ASSEMBLER

AF.1 ACKNOWLEDGMENT

Thanks to Marko Makela for his contribution of the AS6500 cross assembler.

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Several additions and modifications were made to his code to support the following families of 6500 processors:

- (1) 650X and 651X processor family
- (2) 65F11 and 65F12 processor family
- (3) 65C00/21 and 65C29 processor family
- (4) 65C02, 65C102, and 65C112 processor family

The instruction syntax of this cross assembler contains two peculiarities: (1) the addressing indirection is denoted by the square brackets [] and (2) the `bbrx' and `bbsx' instructions are written `bbr0 memory,label'.

AF.2 6500 REGISTER SET

The following is a list of the 6500 registers used by AS6500:

a	-	8-bit accumulator
x,y	-	index registers

AF.3 6500 INSTRUCTION SET

The following tables list all 6500 family mnemonics recognized by the AS6500 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6500:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) $0 \leq \text{dir} \leq 255$
offset,x	indexed addressing
offset,y	indexed addressing $\text{address} = (\text{offset} + (\text{x or y}))$
[offset,x]	pre-indexed indirect addressing $0 \leq \text{offset} \leq 255$ $\text{address} = \text{contents of location}$ $(\text{offset} + (\text{x or y})) \bmod 256$
[offset],y	post-indexed indirect addressing $\text{address} = \text{contents of location at offset}$ plus the value of the y register
[address]	indirect addressing
ext	extended addressing
label	branch label
address,label	direct page memory location branch label bbrx and bbsx instruction addressing

The terms data, dir, offset, address, ext, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 65xx technical data for valid modes.

AF.3.1 Processor Specific Directives

The AS6500 cross assembler has four (4) processor specific assembler directives which define the target 65xx processor family:

.r6500	Core 650X and 651X family (default)
.r65f11	Core plus 65F11 and 65F12
.r65c00	Core plus 65C00/21 and 65C29
.r65c02	Core plus 65C02, 65C102, and 65C112

AF.3.2 65xx Core Inherent Instructions

brk	clc
cld	cli
clv	dex
dey	inx
iny	nop
pha	php
pla	plp
rti	rts
sec	sed
sei	tax
tay	tsx
txa	txs
tya	

AF.3.3 65xx Core Branch Instructions

bcc	label	bhs	label
bcs	label	blo	label
beq	label	bmi	label
bne	label	bpl	label
bvc	label	bvs	label

AF.3.4 65xx Core Single Operand Instructions

asl	[]
dec	[]
inc	[]
lsr	[]
rol	[]
ror	[]

AF.3.5 65xx Core Double Operand Instructions

adc	[]
and	[]
bit	[]
cmp	[]
eor	[]
lda	[]
ora	[]
sbc	[]
sta	[]

AF.3.6 65xx Core Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AF.3.7 65xx Core Miscellaneous X and Y Register Instructions

cpx	[]
cpy	[]
ldx	[]
stx	[]
ldy	[]
sty	[]

AF.3.8 65F11 and 65F12 Specific Instructions

bbr0	[],label	bbr1	[],label
bbr2	[],label	bbr3	[],label
bbr4	[],label	bbr5	[],label
bbr6	[],label	bbr7	[],label
bbs0	[],label	bbs1	[],label
bbs2	[],label	bbs3	[],label
bbs4	[],label	bbs5	[],label
bbs6	[],label	bbs7	[],label
rmb0	[]	rmb1	[]
rmb2	[]	rmb3	[]
rmb4	[]	rmb5	[]
rmb6	[]	rmb7	[]
smb0	[]	smb1	[]
smb2	[]	smb3	[]
smb4	[]	smb5	[]
smb6	[]	smb7	[]

AF.3.9 65C00/21 and 65C29 Specific Instructions

bbr0	[],label	bbr1	[],label
bbr2	[],label	bbr3	[],label
bbr4	[],label	bbr5	[],label
bbr6	[],label	bbr7	[],label
bbs0	[],label	bbs1	[],label
bbs2	[],label	bbs3	[],label
bbs4	[],label	bbs5	[],label
bbs6	[],label	bbs7	[],label
bra	label		
phx		phy	
plx		ply	
rmb0	[]	rmb1	[]
rmb2	[]	rmb3	[]
rmb4	[]	rmb5	[]
rmb6	[]	rmb7	[]
smb0	[]	smb1	[]
smb2	[]	smb3	[]
smb4	[]	smb5	[]
smb6	[]	smb7	[]

AF.3.10 65C02, 65C102, and 65C112 Specific Instructions

bbr0	[],label	bbr1	[],label
bbr2	[],label	bbr3	[],label
bbr4	[],label	bbr5	[],label
bbr6	[],label	bbr7	[],label
bbs0	[],label	bbs1	[],label
bbs2	[],label	bbs3	[],label
bbs4	[],label	bbs5	[],label
bbs6	[],label	bbs7	[],label
bra	label		
phx		phy	
plx		ply	
rmb0	[]	rmb1	[]
rmb2	[]	rmb3	[]
rmb4	[]	rmb5	[]
rmb6	[]	rmb7	[]
smb0	[]	smb1	[]
smb2	[]	smb3	[]
smb4	[]	smb5	[]
smb6	[]	smb7	[]
stz	[]		
trb	[]		
tsb	[]		

Additional addressing modes for the following core instructions are also available with the 65C02, 65C102, and 65C112 processors.

adc	[]	and	[]
cmp	[]	eor	[]
lda	[]	ora	[]
sbc	[]	sta	[]
bit	[]	jmp	[]
dec		inc	

APPENDIX AG

AS6800 ASSEMBLER

AG.1 6800 REGISTER SET

The following is a list of the 6800 registers used by AS6800:

a,b	-	8-bit accumulators
x	-	index register

AG.2 6800 INSTRUCTION SET

The following tables list all 6800/6802/6808 mnemonics recognized by the AS6800 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6800:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255
,x	register indirect addressing zero offset
offset,x	register indirect addressing 0 <= offset <= 255
ext	extended addressing
label	branch label

The terms data, dir, offset, ext, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 6800 technical data for valid modes.

AG.2.1 Inherent Instructions

aba	cba
clc	cli
clv	daa
des	dex
ins	inx
nop	rti
rts	sba
sec	sei
sev	swi
tab	tap
tba	tpa
tsx	txs
wai	
psha	pshb
psh a	psh b
pula	pulb
pul a	pul b

AG.2.2 Branch Instructions

bra	label	bhi	label
bls	label	bcc	label
bhs	label	bcs	label
blo	label	bne	label
beq	label	bvc	label
bvs	label	bpl	label
bmi	label	bge	label
blt	label	bgt	label
ble	label	bsr	label

AG.2.3 Single Operand Instructions

asla		aslb
asl a		asl b
asl	[]	
asra		asrb
asr a		asr b
asr	[]	
clra		clrb
clr a		clr b
clr	[]	
coma		comb
com a		com b
com	[]	
deca		decb
dec a		dec b
dec	[]	
inca		incb
inc a		inc b
inc	[]	
lsla		lslb
lsl a		lsl b
lsl	[]	
lsra		lsrb
lsr a		lsr b
lsr	[]	
nega		negb
neg a		neg b
neg	[]	
rola		rolb
rol a		rol b
rol	[]	
rora		rorb
ror a		ror b
ror	[]	
tsta		tstb
tst a		tst b
tst	[]	

AG.2.4 Double Operand Instructions

adca	[]	adcb	[]
adc a	[]	adc b	[]
adda	[]	addb	[]
add a	[]	add b	[]
anda	[]	andb	[]
and a	[]	and b	[]
bita	[]	bitb	[]
bit a	[]	bit b	[]
cmpa	[]	cmpb	[]
cmp a	[]	cmp b	[]
eora	[]	eorb	[]
eor a	[]	eor b	[]
ldaa	[]	ldab	[]
lda a	[]	lda b	[]
oraa	[]	orab	[]
ora a	[]	ora b	[]
sbca	[]	sbc b	[]
sbc a	[]	sbc b	[]
staa	[]	stab	[]
sta a	[]	sta b	[]
suba	[]	subb	[]
sub a	[]	sub b	[]

AG.2.5 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AG.2.6 Long Register Instructions

cpx	[]		
lds	[]	sts	[]
ldx	[]	stx	[]

APPENDIX AH

AS6801 ASSEMBLER

AH.1 .hd6303 DIRECTIVE

Format:

```
.hd6303
```

The .hd6303 directive enables processing of the HD6303 specific mnemonics not included in the 6801 instruction set. HD6303 mnemonics encountered without the .hd6303 directive will be flagged with an 'o' error.

AH.2 6801 REGISTER SET

The following is a list of the 6801 registers used by AS6801:

a,b	-	8-bit accumulators
d	-	16-bit accumulator <a:b>
x	-	index register

AH.3 6801 INSTRUCTION SET

The following tables list all 6801/6803/6303 mnemonics recognized by the AS6801 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6801:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255

,x	register indirect addressing zero offset
offset,x	register indirect addressing 0 <= offset <= 255
ext	extended addressing
label	branch label

The terms data, dir, offset, ext, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 6801/6303 technical data for valid modes.

AH.3.1 Inherent Instructions

aba	abx
cba	clc
cli	clv
daa	des
dex	ins
inx	mul
nop	rti
rts	sba
sec	sei
sev	swi
tab	tap
tba	tpa
tsx	txs
wai	

AH.3.2 Branch Instructions

bra	label	brn	label
bhi	label	bls	label
bcc	label	bhs	label
bcs	label	blo	label
bne	label	beq	label
bvc	label	bvs	label
bpl	label	bmi	label
bge	label	blt	label
bgt	label	ble	label
bsr	label		

AH.3.3 Single Operand Instructions

asla		aslb		asld
asl a		asl b		asl d
asl	[]			
asra		asrb		
asr a		asr b		
asr	[]			
clra		clrb		
clr a		clr b		
clr	[]			
coma		comb		
com a		com b		
com	[]			
deca		dec b		
dec a		dec b		
dec	[]			
eora		eorb		
eor a		eor b		
eor	[]			
inca		incb		
inc a		inc b		
inc	[]			
lsla		lslb		lsld
lsl a		lsl b		lsl d
lsl	[]			
lsra		lsrb		lsrd
lsr a		lsr b		lsr d
lsr	[]			
nega		negb		
neg a		neg b		
neg	[]			
psha		pshb		pshx
psh a		psh b		psh x
pula		pulb		pulx
pul a		pul b		pul x
rola		rolb		
rol a		rol b		
rol	[]			

rora		rorb	
ror a		ror b	
ror	[]		
tsta		tstb	
tst a		tst b	
tst	[]		

AH.3.4 Double Operand Instructions

adca	[]	adcb	[]		
adc a	[]	adc b	[]		
adda	[]	addb	[]	addd	[]
add a	[]	add b	[]	add d	[]
anda	[]	andb	[]		
and a	[]	and b	[]		
bita	[]	bitb	[]		
bit a	[]	bit b	[]		
cmpa	[]	cmpb	[]		
cmp a	[]	cmp b	[]		
ldaa	[]	ldab	[]		
lda a	[]	lda b	[]		
oraa	[]	orab	[]		
ora a	[]	ora b	[]		
sbca	[]	sbc b	[]		
sbc a	[]	sbc b	[]		
staa	[]	stab	[]		
sta a	[]	sta b	[]		
suba	[]	subb	[]	subd	[]
sub a	[]	sub b	[]	sub d	[]

AH.3.5 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AH.3.6 Long Register Instructions

cpx	[]	ldd	[]
lds	[]	ldx	[]
std	[]	sts	[]
stx	[]		

AH.3.7 6303 Specific Instructions

aim	#data, []	eim	#data, []
oim	#data, []	tim	#data, []
xgdx		slp	

APPENDIX AI

AS6804 ASSEMBLER

Requires the `.setdp` directive to specify the ram area.

AI.1 6804 REGISTER SET

The following is a list of the 6804 registers used by AS6804:

<code>x,y</code>	-	index registers
------------------	---	-----------------

AI.2 6804 INSTRUCTION SET

The following tables list all 6804 mnemonics recognized by the AS6804 assembler. The designation `[]` refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6804:

<code>#data</code>	immediate data byte or word data
<code>,x</code>	register indirect addressing
<code>dir</code>	direct addressing (see <code>.setdp</code> directive) <code>0 <= dir <= 255</code>
<code>ext</code>	extended addressing
<code>label</code>	branch label

The terms `data`, `dir`, and `ext` may be expressions. The label for the short branches `beq`, `bne`, `bcc`, and `bcs` must not be external.

Note that not all addressing modes are valid with every instruction, refer to the 6804 technical data for valid modes.

AI.2.1 Inherent Instructions

coma	decx
decy	incx
incy	rola
rti	rts
stop	tax
tay	txa
tya	wait

AI.2.2 Branch Instructions

bne	label	beq	label
bcc	label	bcs	label

AI.2.3 Single Operand Instructions

add	[]
and	[]
cmp	[]
dec	[]
inc	[]
lda	[]
sta	[]
sub	[]

AI.2.4 Jump and Jump to Subroutine Instructions

jsr	[]
jmp	[]

AI.2.5 Bit Test Instructions

brclr	#data,[],label
brset	#data,[],label
bclr	#label,[]
bset	#label,[]

AI.2.6 Load Immediate data Instruction

```
mvi    [],#data
```

AI.2.7 6804 Derived Instructions

```
asla  
bam    label  
bap    label  
bxmi   label  
bxpl   label  
bymi   label  
bypl   label  
clra  
clrx  
clry  
deca  
decx  
decy  
inca  
incx  
incy  
ldxi   #data  
ldyi   #data  
nop  
tax  
tay  
txa  
tya
```

APPENDIX AJ

AS68(HC)05 ASSEMBLER

AJ.1 .6805 DIRECTIVE

Format:

.6805

The .6805 directive selects the MC6805 specific cycles count to be output.

AJ.2 .hc05 DIRECTIVE

Format:

.hc05

The .hc05 directive selects the MC68HC05/146805 specific cycles count to be output.

AJ.3 THE .__.CPU. VARIABLE

The value of the pre-defined symbol '.__.CPU.' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASZ80 assembler:

Processor Type	.__.CPU. Value
-----	-----
.6805	0
.hc05	1

The variable '.__.CPU.' is by default defined as local and will not be output to the created .rel file. The assembler command line options -g or -a will not cause the local symbol to be output to the created .rel file.

The assembler .globl directive may be used to change the variable type to global causing its definition to be output to the .rel file. The inclusion of the definition of the variable '.__.CPU.' might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AJ.4 6805 REGISTER SET

The following is a list of the 6805 registers used by AS6805:

a	-	8-bit accumulator
x	-	index register

AJ.5 6805 INSTRUCTION SET

The following tables list all 6805 mnemonics recognized by the AS6805 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6805:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255
,x	register indirect addressing zero offset
offset,x	register indirect addressing 0 <= offset <= 255 --- byte mode 256 <= offset <= 65535 --- word mode (an externally defined offset uses the word mode)
ext	extended addressing
label	branch label

The terms data, dir, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 6805 technical data for valid modes.

AJ.5.1 Control Instructions

clc	cli
nop	rsp
rti	rts
sec	sei
stop	swi
tax	txa
wait	

AJ.5.2 Bit Manipulation Instructions

brset	#data,*dir,label
brclr	#data,*dir,label
bset	#data,*dir
bclr	#data,*dir

AJ.5.3 Branch Instructions

bra	label	brn	label
bhi	label	bls	label
bcc	label	bcs	label
bne	label	beq	label
bhcc	label	bhcs	label
bpl	label	bmi	label
bmc	label	bms	label
bil	label	bih	label
bsr	label		

AJ.5.4 Read-Modify-Write Instructions

nega		negx
neg	[]	
coma		comx
com	[]	
lsra		lsrx
lsr	[]	
rora		rorx
ror	[]	
asra		asrx
asr	[]	
lsla		lslx
lsl	[]	
rola		rolx
rol	[]	
deca		decx
dec	[]	
inca		incx
inc	[]	
tsta		tstx
tst	[]	
clra		clrx
clr	[]	

AJ.5.5 Register\Memory Instructions

sub	[]	cmp	[]
sbc	[]	cpx	[]
and	[]	bit	[]
lda	[]	sta	[]
eor	[]	adc	[]
ora	[]	add	[]
ldx	[]	stx	[]

AJ.5.6 Jump and Jump to Subroutine Instructions

jmp [] jsr []

APPENDIX AK

AS68(HC[S])08 ASSEMBLER

AK.1 PROCESSOR SPECIFIC DIRECTIVES

The MC68HC(S)08 processor is a superset of the MC6805 processors. The AS6808 assembler supports the HC08, HCS08, 6805, and HC05 cores.

AK.1.1 .hc08 Directive

Format:

```
.hc08
```

The .hc08 directive enables processing of only the HC08 specific mnemonics. 6805/HC05/HCS08 mnemonics encountered without the .hc08 directive will be flagged with an 'o' error.

The .hc08 directive also selects the HC08 specific cycles count to be output.

AK.1.2 .hcs08 Directive

Format:

```
.hcs08
```

The .hcs08 directive enables processing of the HCS08 specific mnemonics.

The .hcs08 directive also selects the HCS08 specific cycles count to be output.

AK.1.3 .6805 Directive

Format:

.6805

The .6805 directive enables processing of only the 6805/HC05 specific mnemonics. HC08/HCS08 mnemonics encountered without the .hc08/.hcs08 directives will be flagged with an 'o' error.

The .6805 directive also selects the MC6805 specific cycles count to be output.

AK.1.4 .hc05 Directive

Format:

.hc05

The .hc05 directive enables processing of only the 6805/HC05 specific mnemonics. HC08/HCS08 mnemonics encountered without the .hc08/.hcs08 directives will be flagged with an 'o' error.

The .hc05 directive also selects the MC68HC05/146805 specific cycles count to be output.

AK.1.5 The .__.CPU. Variable

The value of the pre-defined symbol '.__.CPU.' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the AS6808 assembler:

Processor Type	.__.CPU. Value
-----	-----
.hc08	0
.hcs08	1
.6805	2
.hc05	3

The variable '.__.CPU.' is by default defined as local and will not be output to the created .rel file. The assembler command line options -g or -a will not cause the local symbol to be output to the created .rel file.

The assembler .globl directive may be used to change the variable type to global causing its definition to be output to

the .rel file. The inclusion of the definition of the variable '.__.CPU.' might be a useful means of validating that seperately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AK.2 68HC(S)08 REGISTER SET

The following is a list of the 68HC(S)08 registers used by AS6808:

a	-	8-bit accumulator
x	-	index register <H:X>
s	-	stack pointer

AK.3 68HC(S)08 INSTRUCTION SET

The following tables list all 68HC(S)08 mnemonics recognized by the AS6808 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6808:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255
,x	register indexed addressing zero offset
offset,x	register indexed addressing 0 <= offset <= 255 --- byte mode 256 <= offset <= 65535 --- word mode (an externally defined offset uses the word mode)
,x+	register indexed addressing zero offset with post increment
offset,x+	register indexed addressing unsigned byte offset with post increment
offset,s	stack pointer indexed addressing 0 <= offset <= 255 --- byte mode 256 <= offset <= 65535 --- word mode (an externally defined offset uses the word mode)

ext	extended addressing
label	branch label

The terms data, dir, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 68HC(S)08 technical data for valid modes.

AK.3.1 Control Instructions

clc	cli	daa	div
mul	nop	nsa	psha
pshh	pshx	pula	pulh
pulx	rsp	rti	rts
sec	sei	stop	swi
tap	tax	tpa	tsx
txa	txs	wait	

AK.3.2 Bit Manipulation Instructions

brset	#data,*dir,label
brclr	#data,*dir,label
bset	#data,*dir
bclr	#data,*dir

AK.3.3 Branch Instructions

bra	label	brn	label
bhi	label	bls	label
bcc	label	bcs	label
bne	label	beq	label
bhcc	label	bhcs	label
bpl	label	bmi	label
bmc	label	bms	label
bil	label	bih	label
bsr	label	bge	label
blt	label	bgt	label
ble	label		

AK.3.4 Complex Branch Instructions

cbeqa	[],label
cbeqx	[],label
cbeq	[],label
dbnza	label
dbnzx	label
dbnz	[],label

AK.3.5 Read-Modify-Write Instructions

nega		negx
neg	[]	
coma		comx
com	[]	
lsra		lsrx
lsr	[]	
rora		rorx
ror	[]	
asra		asrx
asr	[]	
asla		aslx
asl	[]	
lsla		lslx
lsl	[]	
rola		rolx
rol	[]	
deca		decx
dec	[]	
inca		incx
inc	[]	
tsta		tstx
tst	[]	
clra		clrx
clr	[]	clrh
aix	#data	
ais	#data	

AK.3.6 Register\Memory Instructions

sub	[]	cmp	[]
sbc	[]	cpx	[]
and	[]	bit	[]
lda	[]	sta	[]
eor	[]	adc	[]
ora	[]	add	[]
ldx	[]	stx	[]

AK.3.7 Double Operand Move Instruction

mov [],[]

AK.3.8 16-Bit <H:X> Index Register Instructions

cphx	[]
ldhx	[]
sthx	[]

AK.3.9 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

APPENDIX AL
AS6809 ASSEMBLER

AL.1 6809 REGISTER SET

The following is a list of the 6809 registers used by AS6809:

a,b	-	8-bit accumulators
d	-	16-bit accumulator <a:b>
x,y	-	index registers
s,u	-	stack pointers
pc	-	program counter
cc	-	condition code
dp	-	direct page

AL.2 6809 INSTRUCTION SET

The following tables list all 6809 mnemonics recognized by the AS6809 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6809:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255
label	branch label
r,r1,r2	registers cc,a,b,d,dp,x,y,s,u,pc
, -x , --x	register indexed autodecrement

,x+ ,x++	register indexed autoincrement
,x	register indexed addressing zero offset
offset,x	register indexed addressing -16 <= offset <= 15 --- 5-bit -128 <= offset <= -17 --- 8-bit 16 <= offset <= 127 --- 8-bit -32768 <= offset <= -129 --- 16-bit 128 <= offset <= 32767 --- 16-bit (external definition of offset uses 16-bit mode)
a,x	accumulator offset indexed addressing
ext	extended addressing
ext,pc	pc addressing (pc <- pc + ext)
ext,pcr	pc relative addressing
[,--x]	register indexed indirect autodecrement
[,x++]	register indexed indirect autoincrement
[,x]	register indexed indirect addressing zero offset
[offset,x]	register indexed indirect addressing -128 <= offset <= 127 --- 8-bit -32768 <= offset <= -129 --- 16-bit 128 <= offset <= 32767 --- 16-bit (external definition of offset uses 16-bit mode)
[a,x]	accumulator offset indexed indirect addressing
[ext]	extended indirect addressing
[ext,pc]	pc indirect addressing ([pc <- pc + ext])
[ext,pcr]	pc relative indirect addressing

The terms data, dir, label, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 6809 technical data for valid modes.

AL.2.1 Inherent Instructions

abx	daa
mul	nop
rti	rts
sex	swi
swi1	swi2
swi3	sync

AL.2.2 Short Branch Instructions

bcc	label	bcs	label
beq	label	bge	label
bgt	label	bhi	label
bhis	label	bhs	label
ble	label	blo	label
blos	label	bls	label
blt	label	bmi	label
bne	label	bpl	label
bra	label	brn	label
bvc	label	bvs	label
bsr	label		

AL.2.3 Long Branch Instructions

lbcc	label	lbcs	label
lbeq	label	lbge	label
lbgt	label	lbhi	label
lbhis	label	lbhs	label
lble	label	lblo	label
lblos	label	bls	label
lblt	label	lbmi	label
lbne	label	lbpl	label
lbra	label	lbrn	label
lbvc	label	lbvs	label
lbsr	label		

AL.2.4 Single Operand Instructions

asla		aslb
asl	[]	
asra		asrb
asr	[]	
clra		clrb
clr	[]	
coma		comb
com	[]	
deca		dec b
dec	[]	
inca		inc b
inc	[]	
lsla		lsl b
lsl	[]	
lsra		lsr b
lsr	[]	
nega		neg b
neg	[]	
rola		rol b
rol	[]	
rora		ror b
ror	[]	
tsta		tst b
tst	[]	

AL.2.5 Double Operand Instructions

adca	[]	adcb	[]
adda	[]	addb	[]
anda	[]	andb	[]
bita	[]	bitb	[]
cmpa	[]	cmpb	[]
eora	[]	eorb	[]
lda	[]	ldb	[]
ora	[]	orb	[]
sbca	[]	sbc b	[]
sta	[]	stb	[]
suba	[]	subb	[]

AL.2.6 D-register Instructions

addd	[]	subd	[]
cmpd	[]	ldd	[]
std	[]		

AL.2.7 Index/Stack Register Instructions

cmps	[]	cmpu	[]
cmpx	[]	cmpy	[]
lds	[]	ldu	[]
ldx	[]	ldy	[]
leas	[]	leau	[]
leax	[]	leay	[]
sts	[]	stu	[]
stx	[]	sty	[]
pshs	r	pshu	r
puls	r	pulu	r

AL.2.8 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AL.2.9 Register - Register Instructions

exg	r1,r2	tfr	r1,r2
-----	-------	-----	-------

AL.2.10 Condition Code Register Instructions

andcc	#data	orcc	#data
cwai	#data		

AL.2.11 6800 Compatibility Instructions

aba		cba	
clc		cli	
clv		des	
dex		ins	
inx			
ldaa	[]	ldab	[]
oraa	[]	orab	[]
psha		pshb	
pula		pulb	
sba		sec	
sei		sev	
staa	[]	stab	[]
tab		tap	
tba		tpa	
tsx		txs	
wai			

APPENDIX AM

AS6811 ASSEMBLER

AM.1 68HC11 REGISTER SET

The following is a list of the 68HC11 registers used by AS6811:

a,b	-	8-bit accumulators
d	-	16-bit accumulator <a:b>
x,y	-	index registers

AM.2 68HC11 INSTRUCTION SET

The following tables list all 68HC11 mnemonics recognized by the AS6811 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6811:

#data	immediate data byte or word data
*dir	direct page addressing (see .setdp directive) 0 <= dir <= 255
,x	register indirect addressing zero offset
offset,x	register indirect addressing 0 <= offset <= 255
ext	extended addressing
label	branch label

The terms data, dir, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 68HC11 technical data for valid modes.

AM.2.1 Inherent Instructions

aba	abx
aby	cba
clc	cli
clv	daa
des	dex
dey	fdiv
idiv	ins
inx	iny
mul	nop
rti	rts
sba	sec
sei	sev
stop	swi
tab	tap
tba	tpa
tsx	txs
wai	xgdx
xgdy	
psha	pshb
psh a	psh b
pshx	pshy
psh x	psh y
pula	pulb
pul a	pul b
pulx	puly
pul x	pul y

AM.2.2 Branch Instructions

bra	label	brn	label
bhi	label	bls	label
bcc	label	bhs	label
bcs	label	blo	label
bne	label	beq	label
bvc	label	bvs	label
bpl	label	bmi	label
bge	label	blt	label
bgt	label	ble	label
bsr	label		

AM.2.3 Single Operand Instructions

asla		aslb		asld
asl a		asl b		asl d
asl	[]			
asra		asrb		
asr a		asr b		
asr	[]			
clra		clrb		
clr a		clr b		
clr	label			
coma		comb		
com a		com b		
com	[]			
deca		dec b		
dec a		dec b		
dec	[]			
inca		inc b		
inc a		inc b		
inc	[]			
lsla		lslb		lsld
lsl a		lsl b		lsl d
lsl	[]			
lsra		lsrb		lsrd
lsr a		lsr b		lsr d
lsr	[]			
nega		negb		
neg a		neg b		
neg	[]			
rola		rolb		
rol a		rol b		
rol	[]			
rora		rorb		
ror a		ror b		
ror	[]			
tsta		tstb		
tst a		tst b		
tst	[]			

AM.2.4 Double Operand Instructions

adca	[]	adcb	[]		
adc a	[]	adc b	[]		
adda	[]	addb	[]	addd	[]
add a	[]	add b	[]	add d	[]
anda	[]	andb	[]		
and a	[]	and b	[]		
bita	[]	bitb	[]		
bit a	[]	bit b	[]		
cmpa	[]	cmpb	[]		
cmp a	[]	cmp b	[]		
eora	[]	eorb	[]		
eor a	[]	eor b	[]		
ldaa	[]	ldab	[]		
lda a	[]	lda b	[]		
oraa	[]	orab	[]		
ora a	[]	ora b	[]		
sbca	[]	sbc b	[]		
sbc a	[]	sbc b	[]		
staa	[]	stab	[]		
sta a	[]	sta b	[]		
suba	[]	subb	[]	subd	[]
sub a	[]	sub b	[]	sub d	[]

AM.2.5 Bit Manipulation Instructions

bclr	[],#data
bset	[],#data
brclr	[],#data,label
brset	[],#data,label

AM.2.6 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AM.2.7 Long Register Instructions

cpx	[]	cpy	[]
ldd	[]	lds	[]
ldx	[]	ldy	[]
std	[]	sts	[]
stx	[]	sty	[]

APPENDIX AN

AS68(HC[S])12 ASSEMBLER

AN.1 PROCESSOR SPECIFIC DIRECTIVES

The AS6812 assembler supports the 68HC(S)12 series of microprocessors which includes the 68HC(S)8xx and 68HC(S)9xx series.

AN.1.1 .hc12 Directive

Format:

```
.hc12
```

The .hc12 directive selects the HC12 core specific cycles count to be output.

AN.1.2 .hcs12 Directive

Format:

```
.hcs12
```

The .hcs12 directive selects the HCS12 core specific cycles count to be output.

AN.1.3 The `.__.CPU.` Variable

The value of the pre-defined symbol '`.__.CPU.`' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the AS6812 assembler:

Processor Type	<code>.__.CPU.</code> Value
-----	-----
<code>.hc12</code>	0
<code>.hcs12</code>	1

The variable '`.__.CPU.`' is by default defined as local and will not be output to the created `.rel` file. The assembler command line options `-g` or `-a` will not cause the local symbol to be output to the created `.rel` file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable '`.__.CPU.`' might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AN.2 68HC(S)12 REGISTER SET

The following is a list of the 68HC(S)12 registers used by AS6812:

<code>a,b</code>	-	8-bit accumulators
<code>d</code>	-	16-bit accumulator <a:b>
<code>x,y</code>	-	index registers
<code>sp,s</code>	-	stack pointer
<code>pc</code>	-	program counter
<code>ccr,cc</code>	-	condition code register

AN.3 68HC(S)12 INSTRUCTION SET

The following tables list all 68HC(S)12 mnemonics recognized by the AS6812 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6812:

#data		immediate data byte or word data
ext		extended addressing
pg		memory page number
*dir		direct page addressing (see .setdp directive) 0 <= dir <= 255
label		branch label
r,r1,r2		registers ccr,a,b,d,x,y,sp,pc
-x	x-	register indexed, pre or
, -x	, x-	post autodecrement by 1
n, -x	n, x-	register indexed, pre or post autodecrement by 1 - 8
+x	x+	register indexed, pre or
, +x	, x+	post autoincrement by 1
n, +x	n, x+	register indexed, pre or post autoincrement by 1 - 8
offset,x		register indexed addressing -16 <= offset <= 15 --- 5-bit -256 <= offset <= -17 --- 9-bit 16 <= offset <= 255 --- 9-bit -32768 <= offset <= -257 --- 16-bit 256 <= offset <= 32767 --- 16-bit (external definition of offset uses 16-bit mode)
[offset,x]		register indexed indirect addressing -32768 <= offset <= 32767 --- 16-bit
[,x]		register indexed indirect addressing zero offset
a,x		accumulator offset indexed addressing

[d,x] d accumulator offset indexed
 indirect addressing

The terms data, dir, label, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 68HC(S)12 technical data for valid modes.

AN.3.1 Inherent Instructions

aba	bgnd	cba
daa	dex	dey
ediv	edivs	emul
emuls	fdiv	idiv
idivs	inx	iny
mem	mul	nop
psha	pshb	pshc
pshd	pshx	pshy
pula	pulb	pulc
puld	pulx	puly
rev	revw	rtc
rti	rts	sba
stop	swi	tab
tba	wai	wav
wavr		

AN.3.2 Short Branch Instructions

bcc	label	bcs	label
beq	label	bge	label
bgt	label	bhi	label
bhis	label	bhs	label
ble	label	blo	label
blos	label	bls	label
blt	label	bmi	label
bne	label	bpl	label
bra	label	brn	label
bvc	label	bvs	label
bsr	label		

AN.3.3 Long Branch Instructions

lbcc	label	lbcs	label
lbeq	label	lbge	label
lbgt	label	lbhi	label
lbhis	label	lbhs	label
lble	label	lblo	label
lblos	label	lbls	label
lblt	label	lbmi	label
lbne	label	lbpl	label
lbra	label	lbrn	label
lbvc	label	lbvs	label

AN.3.4 Branch on Decrement, Test, or Increment

dbeq	r,label	dbne	r,label
ibeq	r,label	ibne	r,label
tbeq	r,label	tbne	r,label

AN.3.5 Bit Clear and Set Instructions

bclr	[],#data
bset	[],#data

AN.3.6 Branch on Bit Clear or Set

brclr	[],#data,label
brset	[],#data,label

AN.3.7 Single Operand Instructions

asla		aslb
asl	[]	
asra		asrb
asr	[]	
clra		clrb
clr	[]	
coma		comb
com	[]	
deca		dec b
dec	[]	
inca		inc b
inc	[]	
lsla		lsl b
lsl	[]	
lsra		lsr b
lsr	[]	
nega		neg b
neg	[]	
rola		rol b
rol	[]	
rora		ror b
ror	[]	
tsta		tst b
tst	[]	

AN.3.8 Double Operand Instructions

adca	[[adcb	[[
adda	[[addb	[[
anda	[[andb	[[
bita	[[bitb	[[
cmpa	[[cmpb	[[
eora	[[eorb	[[
ldaa	[[<=>	lda	[[
ldab	[[<=>	ldb	[[
oraa	[[<=>	ora	[[
orab	[[<=>	orb	[[
sbca	[[sbc b	[[
staa	[[<=>	sta	[[
stab	[[<=>	stb	[[
suba	[[subb	[[

AN.3.9 Move Instructions

movb	[[,[[movw	[[,[[
------	-------	------	-------

AN.3.10 D-register Instructions

addd	[[subd	[[
cpd	[[<=>	cmpd	[[
ldd	[[std	[[

AN.3.11 Index/Stack Register Instructions

cps	[]	<=>	cmps	[]
cpx	[]	<=>	cmpx	[]
cpy	[]	<=>	cmpy	[]
lds	[]			
ldx	[]		ldy	[]
leas	[]			
leax	[]		leay	[]
sts	[]			
stx	[]		sty	[]

AN.3.12 Jump and Jump/Call to Subroutine Instructions

call	[],pg		
jmp	[]	jsr	[]

AN.3.13 Other Special Instructions

emacs	[]		
emaxd	[]	emaxm	[]
emind	[]	eminm	[]
etbl	[]		
maxa	[]	maxm	[]
mina	[]	minm	[]
tbl	[]	trap	#data

AN.3.14 Register - Register Instructions

exg	r1,r2	sex	r1,r2
tfr	r1,r2		

AN.3.15 Condition Code Register Instructions

andcc	#data	orcc	#data
-------	-------	------	-------

AN.3.16 M68HC11 Compatibility Mode Instructions

abx	aby	clc
cli	clv	des
ins	sec	sei
sev	tap	tpa
tsx	tsy	txs
tys	xgdx	xgdy

APPENDIX AO

AS6816 ASSEMBLER

AO.1 68HC16 REGISTER SET

The following is a list of the 68HC16 registers used by AS6816:

a,b	-	8-bit accumulators
d	-	16-bit accumulator <a:b>
e	-	16-bit accumulator
x,y,z	-	index registers
k	-	address extension register
s	-	stack pointer
ccr	-	condition code

AO.2 68HC16 INSTRUCTION SET

The following tables list all 68HC16 mnemonics recognized by the AS6816 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS6816:

#data	immediate data byte or word data
#xo,#yo	local immediate data (mac / rmac)
label	branch label
r	register ccr,a,b,d,e,x,y,z,s
,x ,x8 ,x16	zero offset register indexed addressing
offset,x	register indexed addressing

	0 <= offset <= 255	---	8-bit
	-32768 <= offset <= -1	---	16-bit
	256 <= offset <= 32767	---	16-bit
	(external definition of offset uses 16-bit mode)		
offset,x8	unsigned 8-bit offset indexed addressing		
offset,x16	signed 16-bit offset indexed addressing		
e,x	accumulator offset indexed addressing		
ext	extended addressing		
bank	64K bank number (jmp / jsr)		

The terms data, label, offset, bank, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 6816 technical data for valid modes.

AO.2.1 Inherent Instructions

aba	abx	aby	abz
ace	aced	ade	adx
ady	adz	aex	aey
aez	bgnd	cba	daa
ediv	edivs	emul	emuls
fdiv	fmuls	idiv	ldhi
lpstop	mul	nop	psha
pshb	pshmac	pula	pulb
pulmac	rtr	rts	sba
sde	sted	swi	sxt
tab	tap	tba	tbek
tbsk	tbxk	tbyk	tbzk
tde	tdmsk	tdp	ted
tedm	tekb	tem	tmer
tmet	tmxed	tpa	tpd
tskb	tsx	tsy	tsz
txkb	txs	txy	txz
tykb	tys	tyx	tyz
tzkb	tzs	tzx	tzy
wai	xgab	xgde	xgdx
xgdy	xgdz	xgex	xgey
xgez			

AO.2.2 Push/Pull Multiple Register Instructions

pshm	r,...	pulm	r,...
------	-------	------	-------

AO.2.3 Short Branch Instructions

bcc	label	bcs	label
beq	label	bge	label
bgt	label	bhi	label
bhis	label	bhs	label
ble	label	blo	label
blos	label	bls	label
blt	label	bmi	label
bne	label	bpl	label
bra	label	brn	label
bvc	label	bvs	label
bsr	label		

AO.2.4 Long Branch Instructions

lbcc	label	lbcs	label
lbeq	label	lbge	label
lbgt	label	lbhi	label
lbhis	label	lbhs	label
lble	label	lblo	label
lblos	label	lbls	label
lblt	label	lbmi	label
lbne	label	lbpl	label
lbra	label	lbrn	label
lbvc	label	lbvs	label
lbsr	label		

AO.2.5 Bit Manipulation Instructions

bclr	[],#data
bset	[],#data
brclr	[],#data,label
brset	[],#data,label

AO.2.6 Single Operand Instructions

asla		aslb	
asld		asle	
aslm			
asl	[]	aslw	[]
asra		asrb	
asrd		asre	
asrm			
asr	[]	asrw	[]
clra		clrb	
clrd		clre	
		clrm	
clr	[]	clrw	[]
coma		comb	
comd		come	
com	[]	comw	[]
deca		decb	
dec	[]	decw	[]
inca		incb	
inc	[]	incw	[]
lsla		lslb	
lsld		lsle	
lslm			
lsl	[]	lslw	[]
lsra		lsrb	
lsrd		lsre	
lsr	[]	lsrw	[]
nega		negb	
negd		nege	
neg	[]	negw	[]
rola		rolb	
rold		role	
rol	[]	rolw	[]
rora		rorb	
rord		rore	
ror	[]	rorw	[]
tsta		tstb	
tsta		tste	
tst	[]	tstw	[]

AO.2.7 Double Operand Instructions

adca	[[adcb	[[
adcd	[[adce	[[
adda	[[addb	[[
addd	[[adde	[[
anda	[[andb	[[
andd	[[ande	[[
bita	[[bitb	[[
cmpa	[[cmpb	[[
cpd	[[cpe	[[
eora	[[eorb	[[
eord	[[eore	[[
ldaa	[[ldab	[[
ldd	[[lde	[[
oraa	[[orab	[[
ord	[[ore	[[
sbca	[[sbc b	[[
s bcd	[[sbce	[[
staa	[[stab	[[
std	[[ste	[[
suba	[[subb	[[
subd	[[sube	[[

AO.2.8 Index/Stack Register Instructions

cps	[[cp x	[[
cpy	[[cpz	[[
lds	[[ldx	[[
ldy	[[ldz	[[
sts	[[stx	[[
sty	[[stz	[[

AO.2.9 Jump and Jump to Subroutine Instructions

jmp	bank,[]	jsr	bank,[]
-----	---------	-----	---------

AO.2.10 Condition Code Register Instructions

andp	#data	orp	#data
------	-------	-----	-------

AO.2.11 Multiply and Accumulate Instructions

mac	#data	rmac	#data
mac	#xo,#yo	rmac	#xo,#yo

APPENDIX AP

AS740 ASSEMBLER

AP.1 ACKNOWLEDGMENT

Thanks to Uwe Steller for his contribution of the AS740 cross assembler.

Uwe Steller
Uwe dot Steller at t-online dot de

The instruction syntax of this cross assembler uses the square brackets [] to denote addressing indirection.

AP.2 740 REGISTER SET

The following is a list of the 740 registers used by AS740:

a	-	8-bit accumulator
x,y	-	index registers

AP.3 740 INSTRUCTION SET

The following tables list all 740 family mnemonics recognized by the AS740 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by AS740:

#data	immediate data byte
#data,*zp	immediate data to zero page
a	accumulator addressing

*zp	zero page addressing (see .setdp directive) $0 \leq \text{dir} \leq 255$
*zp,x	zero page x addressing
*zp,y	zero page y addressing $\text{address} = (\text{offset} + (\text{x or y}))$
[*zp,x]	indirect x addressing $0 \leq \text{offset} \leq 255$ $\text{address} = 2 \text{ bytes at location } [(\text{offset} + (\text{x or y})) \bmod 256]$
[*zp],y	indirect y addressing $\text{address} = 2 \text{ byte value at offset plus the value of the y register}$
abs	absolute addressing (2 byte)
abs,x	absolute x addressing (2 byte + x)
abs,y	absolute y addressing (2 byte + y)
[abs]	indirect addressing (2 byte)
label	branch label
\special	low order byte of address 0xFFnn
BIT#,*zp	bit set/clear zero page
BIT#,A	bit set/clear accumulator
BIT#,*zp,label	branch on bit set/clear in zero page
BIT#,A,label	branch on bit set/clear in accumulator

The terms data, zp, abs, BIT , special, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 740 technical data for valid modes.

AP.3.1 Inherent Instructions

brk	clc
cld	cli
clt	clv
dex	dey
inx	iny
nop	pha
php	pla
plp	rti
rts	sec
sed	sei
set	stp
tax	tay
tsx	txa
txs	tya
wit	

AP.3.2 Branch Instructions

bcc	label	bhs	label
bcs	label	blo	label
beq	label	bmi	label
bne	label	bpl	label
bvc	label	bvs	label
bra	label		

AP.3.3 Single Operand Instructions

asl	[]
dec	[]
inc	[]
lsr	[]
rol	[]
ror	[]

AP.3.4 Double Operand Instructions

adc	[]
and	[]
bit	[]
cmp	[]
eor	[]
lda	[]
ora	[]
sbc	[]
sta	[]

AP.3.5 Jump and Jump to Subroutine Instructions

jmp	[]	jsr	[]
-----	----	-----	----

AP.3.6 Miscellaneous X and Y Register Instructions

cpx	[]
cpy	[]
ldx	[]
stx	[]
ldy	[]
sty	[]

AP.3.7 Bit Instructions

bit	[]		
bbc	BIT#,[],label	bbs	BIT#,[],label
clb	BIT#,[],	seb	BIT#,[],

AP.3.8 Other Instructions

div	[]	mul	[]
ldm	#imm,[]	com	[]
tst	[]	rrf	[]

APPENDIX AQ

AS8048 ASSEMBLER

AS8048 supports the 8048, 8041, 8022, and 8021 variations of the 8048 microprocessor family.

AQ.1 .8048 DIRECTIVE

Format:

.8048

The .8048 directive enables processing of only the 8048 specific mnemonics. 8041/8022/8021 mnemonics encountered will be flagged with an 'o' error.

AQ.2 .8041 DIRECTIVE

Format:

.8041

The .8041 directive enables processing of the 8041 specific mnemonics. 8041 mnemonics encountered without the .8041 directive will be flagged with an 'o' error.

AQ.3 .8022 DIRECTIVE

Format:

.8022

The .8022 directive enables processing of the 8022 specific mnemonics. 8022 mnemonics encountered without the .8022 directive will be flagged with an 'o' error.

AQ.4 .8021 DIRECTIVE

Format:

.8021

The .8021 directive enables processing of the 8021 specific mnemonics. 8021 mnemonics encountered without the .8021 directive will be flagged with an 'o' error.

AQ.5 THE .___.CPU. VARIABLE

The value of the pre-defined symbol '.___.CPU.' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the AS8048 assembler:

Processor Type	.___.CPU. Value
-----	-----
.8048	0
.8041	1
.8022	2
.8021	3

The variable '.___.CPU.' is by default defined as local and will not be output to the created .rel file. The assembler command line options -g or -a will not cause the local symbol to be output to the created .rel file.

The assembler .globl directive may be used to change the variable type to global causing its definition to be output to the .rel file. The inclusion of the definition of the variable '.___.CPU.' might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AQ.6 8048 REGISTER SET

The following is a list of the 8048 registers used by AS8048:

a	-	8-bit accumulator
r0,r1,r2,r3	-	8-bit registers
r4,r5,r6,r7		
bus,p1,p2	-	bus and ports
p4,p5,p6,p7		
an0,an1	-	analog input select
rb0,rb1	-	register bank select
mb0,mb1	-	memory bank select
c	-	carry (bit in status word)
clk	-	timer
cnt	-	counter
dbb	-	data bus buffer
f0	-	f0 bit in psw
f1	-	f1 bit in psw
i	-	interrupt
psw	-	program status word
t	-	timer register
tcnt	-	timer counter
tcnti	-	timer interrupt

AQ.7 8048 INSTRUCTION SET

The following tables list all 8048 mnemonics recognized by the AS8048 assembler. The following list specifies the format for each addressing mode supported by AS8048:

#data	immediate data byte or word data
r	register r0,r1
rn	register r0,r1,r2,r3,r4,r5,r6, or r7
@r	indirect on register r0 or r1
@a	indirect on accumulator
addr	direct memory address
addr8	current page 8-bit jmp address
#data	immediate data
pn	ports p1 or p2
port	ports p1,p2 or bus
ep	ports p4,p5,p6, or p7
bus	i/o bus

s	f0 or f1 bits in psw
bitaddr	bit address
label	call or jump label

The terms data, addr, and label may all be expressions.

Note that not all addressing modes are valid with every instruction. Refer to the 8048, 8041, 8022, and 8021 technical data for valid modes.

AQ.7.1 Alphabetical Instruction Listing

		8021	8022	8041	8048
add	a,@r	x	x	x	x
add	a,#data	x	x	x	x
add	a,rn	x	x	x	x
addc	a,@r	x	x	x	x
addc	a,#data	x	x	x	x
addc	a,rn	x	x	x	x
anl	port,#data			x	x
anl	bus,#data				x
anl	a,@r	x	x	x	x
anl	a,rn	x	x	x	x
anld	ep,a	x	x	x	x
call	addr	x	x	x	x
clr	a	x	x	x	x
clr	c	x	x	x	x
clr	s			x	x
cpl	a	x	x	x	x
cpl	c	x	x	x	x
cpl	s			x	x
daa	a	x	x	x	x
dec	rn			x	x
dec	a	x	x	x	x
dis	tcnti			x	x
dis	i			x	x
djnz	rn,addr8	x	x	x	x
en	tcnti			x	x
en	i			x	x
ent0	clk				x

		8021	8022	8041	8048
in	a,dbb			x	
in	a,pn	x	x	x	x
inc	a	x	x	x	x
inc	a,@r			x	x
inc	rn	x	x	x	x
ins	a,bus				x
jmp	addr	x	x	x	x
jmp	@a	x	x	x	x
jb0	addr8			x	x
jb1	addr8			x	x
jb2	addr8			x	x
jb3	addr8			x	x
jb4	addr8			x	x
jb5	addr8			x	x
jb6	addr8			x	x
jb7	addr8			x	x
jc	addr8	x	x	x	x
jf0	addr8			x	x
jf1	addr8			x	x
jnc	addr8	x	x	x	x
jni	addr8				x
jnibf	addr8			x	
jnt0	addr8			x	x
jnt1	addr8			x	x
jnz	addr8	x	x	x	x
jobf	addr8				x
jtf	addr8	x	x	x	x
jt0	addr8			x	x
jt1	addr8	x	x	x	x
jz	addr8	x	x	x	x

		8021	8022	8041	8048
mov	a,#data	x	x	x	x
mov	a,psw			x	x
mov	a,@r	x	x	x	x
mov	a,rn	x	x	x	x
mov	a,t	x	x	x	x
mov	psw,a			x	x
mov	rn,a	x	x	x	x
mov	@r,a	x	x	x	x
mov	rn,#data	x	x	x	x
mov	@r,#data	x	x	x	x
mov	t,a	x	x	x	x
movd	a,ep	x	x	x	x
movd	ep,a	x		x	x
movp	a,@a	x	x	x	x
movp3	a,@a			x	x
movx	a,@r				x
movx	@r,a				x
nop		x		x	x
orl	a,#data	x	x	x	x
orl	a,rn	x	x	x	x
orl	a,@r	x	x	x	x
orl	bus,#data				x
orl	port,#data			x	x
orld	ep,a	x	x	x	x
out	dbb,a			x	
outl	bus,a		x		
outl	port,a	x	x	x	x
rad	a		x		
ret		x	x	x	x
retr				x	x

		8021	8022	8041	8048
rl	a	x	x	x	x
rlc	a	x	x	x	x
rr	a	x	x	x	x
rrc	a	x	x	x	x
sel	an0		x		
sel	an1		x		
sel	mb0				x
sel	mb1				x
sel	rb0				x
sel	rb1				x
swap	a	x	x	x	x
stop	tcnt	x	x	x	x
strt	cnt	x	x	x	x
strt	t	x	x	x	x
xch	a,@r	x	x	x	x
xchd	a,@r	x	x	x	x
xrl	a,@r	x	x	x	x
xrl	a,#data	x	x	x	x
xch	a,rn	x	x	x	x
xrl	a,rn	x	x	x	x

APPENDIX AR

AS8051 ASSEMBLER

AR.1 ACKNOWLEDGMENT

Thanks to John Hartman for his contribution of the AS8051 cross assembler.

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noice at noicedebugger dot com

AR.2 8051 REGISTER SET

The following is a list of the 8051 registers used by AS8051:

a,b	-	8-bit accumulators
r0,r1,r2,r3	-	8-bit registers
r4,r5,r6,r7		
dptr	-	data pointer
sp	-	stack pointer
pc	-	program counter
psw	-	status word
c	-	carry (bit in status word)

AR.3 8051 INSTRUCTION SET

The following tables list all 8051 mnemonics recognized by the AS8051 assembler. The following list specifies the format for each addressing mode supported by AS8051:

#data	immediate data byte or word data
r,r1,r2	register r0,r1,r2,r3,r4,r5,r6, or r7
@r	indirect on register r0 or r1
@dptr	indirect on data pointer
@a+dptr	indirect on accumulator plus data pointer
@a+pc	indirect on accumulator plus program counter
addr	direct memory address
bitaddr	bit address
label	call or jump label

The terms data, addr, bitaddr, and label may all be expressions.

Note that not all addressing modes are valid with every instruction. Refer to the 8051 technical data for valid modes.

AR.3.1 Inherent Instructions

nop

AR.3.2 Move Instructions

mov	a,#data	mov	a,addr
mov	a,r	mov	a,@r
mov	r,#data	mov	r,addr
mov	r,a		
mov	addr,a	mov	addr,#data
mov	addr,r	mov	addr,@r
mov	addr1,addr2	mov	bitaddr,c
mov	@r,#data	mov	@r,addr
mov	@r,a		
mov	c,bitaddr		
mov	dptr,#data		
movc	a,@a+dptr	movc	a,@a+pc
movx	a,@dptr	movx	a,@r
movx	@dptr,a	movx	@r,a

AR.3.3 Single Operand Instructions

clr	a	clr	c
clr	bitaddr		
cpl	a	cpl	c
cpl	bitaddr		
setb	c	setb	bitaddr
da	a		
rr	a	rrc	a
rl	a	rlc	a
swap	a		
dec	a	dec	r
dec	@r		
inc	a	inc	r
inc	dptr	inc	@r
div	ab	mul	ab
pop	addr	push	addr

AR.3.4 Two Operand Instructions

add	a,#data	add	a,addr
add	a,r	add	a,@r
addc	a,#data	addc	a,addr
addc	a,r	addc	a,@r
subb	a,#data	subb	a,addr
subb	a,r	subb	a,@r
orl	a,#data	orl	a,addr
orl	a,r	orl	a,@r
orl	addr,a	orl	addr,#data
orl	c,bitaddr	orl	c,/bitaddr
anl	a,#data	anl	a,addr
anl	a,r	anl	a,@r
anl	addr,a	anl	addr,#data
anl	c,bitaddr	anl	c,/bitaddr
xrl	a,#data	xrl	a,addr
xrl	a,r	xrl	a,@r
xrl	addr,a	xrl	addr,#data
xrl	c,bitaddr	xrl	c,/bitaddr
xch	a,addr	xch	a,r
xch	a,@r	xchd	a,@r

AR.3.5 Call and Return Instructions

acall	label	lcall	label
ret		reti	
in	data		
out	data		
rst	data		

AR.3.6 Jump Instructions

ajmp	label		
cjne	a,#data,label	cjne	a,addr,label
cjne	r,#data,label	cjne	@r,#data,label
djnz	r,label	djnz	addr,label
jbc	bitadr,label		
jb	bitadr,label	jnb	bitadr,label
jc	label	jnc	label
jz	label	jnz	label
jmp	@a+dptr		
ljmp	label	sjmp	label

AR.3.7 Predefined Symbols: SFR Map

----- 4 Bytes -----					
----	----	----	----	----	----
FC					FF
F8					FB
F4					F7
F0	B				F3
EC					EF
E8					EB
E4					E7
E0	ACC				E3
DC					DF
D8					DB
D4					D7
D0	PSW				D3
CC	[TL2	TH2			CF
C8	[T2CON		RCAP2L	RCAP2H]	CB
C4					C7
C0					C3
BC					BF
B8	IP				BB
B4					B7
B0	P3				B3
AC					AF
A8	IE				AB
A4					A7
A0	P2				A3
9C					9F
98	SCON	SBUF			9B
94					97
90	P1				93
8C	TH0	TH1			8F
88	TCON	TMOD	TL0	TL1	8B
84				PCON	87
80	P0	SP	DPL	DPH	83

[...] Indicates Resident in 8052, not 8051
A is an allowed alternate for ACC.

AR.3.8 Predefined Symbols: SFR Bit Addresses

----- 4 BITS -----					
----	----	----	----	----	
FC					FF
F8					FB
F4	B.4	B.5	B.6	B.7	F7
F0	B.0	B.1	B.2	B.3	F3
EC					EF
E8					EB
E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
DC					DF
D8					DB
D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
CC	[T2CON.4	T2CON.5	T2CON.6	T2CON.7]	CF
C8	[T2CON.0	T2CON.1	T2CON.2	T2CON.3]	CB
C4					C7
C0					C3
BC	IP.4	IP.5	IP.6	IP.7	BF
B8	IP.0	IP.1	IP.2	IP.3	BB
B4	P3.4	P3.5	P3.6	P3.7	B7
B0	P3.0	P3.1	P3.2	P3.3	B3
AC	IE.4	IE.5	IE.6	IE.7	AF
A8	IE.0	IE.1	IE.2	IE.3	AB
A4	P2.4	P2.5	P2.6	P2.7	A7
A0	P2.0	P2.1	P2.2	P2.3	A3
9C	SCON.4	SCON.5	SCON.6	SCON.7	9F
98	SCON.0	SCON.1	SCON.2	SCON.3	9B
94	P1.4	P1.5	P1.6	P1.7	97
90	P1.0	P1.1	P1.2	P1.3	93
8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
88	TCON.0	TCON.1	TCON.2	TCON.3	8B
84	P0.4	P0.5	P0.6	P0.7	87
80	P0.0	P0.1	P0.2	P0.3	83

[...] Indicates Resident in 8052, not 8051
A is an allowed alternate for ACC.

AR.3.9 Predefined Symbols: Control Bits

----- 4 BITS -----					
----	----	----	----	----	----
FC					FF
F8					FB
F4					F7
F0					F3
EC					EF
E8					EB
E4					E7
E0					E3
DC					DF
D8					DB
D4	RS1	F0	AC	CY	D7
D0	P		OV	RS0	D3
CC	[TLCK	RCLK	EXF2	TF2] CF
C8	[CPRL2	CT2	TR2	EXEN2] CB
C4					C7
C0					C3
BC	PS	PT2			BF
B8	PX0	PT0	PX1	PT1	BB
B4					B7
B0	RXD	TXD	INT0	INT1	B3
AC	ES	ET2		EA	AF
A8	EX0	ET0	EX1	ET1	AB
A4					A7
A0					A3
9C	REN	SM2	SM1	SM0	9F
98	RI	TI	RB8	TB8	9B
94					97
90					93
8C	TR0	TF0	TR1	TF1	8F
88	IT0	IE0	IT1	IE1	8B
84					87
80					83

[...] Indicates Resident in 8052, not 8051

APPENDIX AS

AS8085 ASSEMBLER

AS.1 8085 REGISTER SET

The following is a list of the 8080/8085 registers used by AS8085:

a,b,c,d,e,h,l	-	8-bit accumulators
m	-	memory through (hl)
sp	-	stack pointer
psw	-	status word

AS.2 8085 INSTRUCTION SET

The following tables list all 8080/8085 mnemonics recognized by the AS8085 assembler. The following list specifies the format for each addressing mode supported by AS8085:

#data	immediate data byte or word data
r,r1,r2	register or register pair psw,a,b,c,d,e,h,l bc,de,hl,sp,pc
m	memory address using (hl)
addr	direct memory addressing
label	call or jump label

The terms data, m, addr, and label may be expressions.

Note that not all addressing modes are valid with every instruction, refer to the 8080/8085 technical data for valid modes.

AS.2.1 Inherent Instructions

cma	cmc
daa	di
ei	hlt
nop	pchl
ral	rar
ret	rim
rrc	rlc
sim	sphl
stc	xchg
xthl	

AS.2.2 Register/Memory/Immediate Instructions

adc	r	adc	m	aci	#data
add	r	add	m	adi	#data
ana	r	ana	m	ani	#data
cmp	r	cmp	m	cpi	#data
ora	r	ora	m	ori	#data
sbb	r	sbb	m	sbi	#data
sub	r	sub	m	sui	#data
xra	r	xra	m	xri	#data

AS.2.3 Call and Return Instructions

cc	label	rc
cm	label	rm
cnc	label	rnc
cnz	label	rnz
cp	label	rp
cpe	label	rpe
cpo	label	rpo
cz	label	rz
call	label	

AS.2.4 Jump Instructions

jc	label
jm	label
jnc	label
jnz	label
jp	label
jpe	label
jpo	label
jz	label
jmp	label

AS.2.5 Input/Output/Reset Instructions

in	data
out	data
rst	data

AS.2.6 Move Instructions

mov	r1,r2
mov	r,m
mov	m,r
mvi	r,#data
mvi	m,#data

AS.2.7 Other Instructions

dcr	r	dcr	m
incr	r	incr	m
dad	r	dcx	r
inx	r	ldax	r
pop	r	push	r
stax	r		
lda	addr	lhld	addr
shld	addr	sta	addr
lxi	r,#data		

AS.2.8 Unspecified Instructions

arhl	
dsub	
jnx5	addr
jx5	addr
ldhi	#data
ldsi	#data
hlx	
rdel	
rstv	
shlx	

AS.3 UNSPECIFIED OPCODE ARTICLE

Engineer's Notebook,
"Electronics" magazine, 1980

Unspecified 8085 Op Codes Enhance Programming

by Wolfgang Dehnhardt and Villy M. Sorenson
GSI, Dermstat, and Sorenson Software,
Seeheim, West Germany

Ten operating codes and two flag bits previously unknown to most users of the 8085 microprocessor will enable programmers to write more efficient routines. The new members of the instruction set, which were stumbled upon during the testing of an assembler-disassembler module, include seven opcodes that involve the processing of register pairs, two that involve jump operations with one new flag, and one that performs a conditional restart on the overflow indication of the other flag bit.

The seven register pair instructions (all with 16-bit operands) consist of a double subtraction, a rotate, a shift, indirect loading and storing of a word, and two offset operations. Either BC, DE, HL, or SP are the designated register pairs used in these opcodes.

The mnemonic names of the instructions have been selected to be compatible with the 8085's existing mnemonics. In the double subtraction (DSUB), register pair BC is subtracted from HL. This instruction thus performs the opposite task of DAD B, a well-known instruction. The instruction RDEL rotates register pair DE left 1 bit through the carry. ARHL is an arithmetic shift to the right of HL. It serves to divide HL by 2, except in cases where HL is -1.

All 16 bits of register pair HL can be stored indirectly at the address contained in the DE pair by specifying instruction SHLX. To load HL, LHLX must be employed.

As an example of how this instruction can be used to cut instruction steps, consider the common sequence used for a routine table jump shown in part (a) of the figure. By assigning the

register DE for HL and using the LHLX instruction, this sequence can be replaced by the much simpler arrangement shown at the bottom of part (a).

As for adding the contents of register pairs with an additional byte (offset), DE can be loaded with HL plus the byte by selecting the instruction LDHI, which simplifies array addressing. Usually, the architecture of the 8080-type systems dictate addressing of arrays in what are called pages of 256 bytes. This restriction means that the starting address of an array must be placed near the beginning of a page. A typical call is shown in part (b) of the figure.

The page limitation is by passed using th LDHI instruction code and constant indexes. The starting address of the array can now be placed anywhere, and addressing occurs as shown at the bottom of part (b).

An additional byte can be combined with register pair SP in DE if instruction LDSI is specified. This instruction is designed for operating system routines that transfer arguments on the stack. An example sequence, shown in (c), stores HL into a 16-bit word located as the second item below the top of the stack.

The jump and restart instructions work in conjunction with the two discovered flag bits, X5 and V. Op codes JX5 and JNX5 jump depending on the state of th X5 flag. Op code RSTV makes a restart call to hexadecimal address 40 if the V flag is set; otherwise it functions as a no-operation instruction.

Flag bit V indicates a 2's complement overflow condition for 8- and 16-bit arithmetic operations. Flag bit X5 has been named for its position in the condition code byte and not for its function. It does not resemble any normal flag bit. The only use for this bit found thus far are as an unsigned overflow indicator resulting from a data change of FFFF to 0000 on executing DCX.

The new 8085 instructions are outlined in the table.

Figure:

part (a)	
Sourec Statement	Comment
MOV E,M	;Routine ADR Low Byte
INX H	;HL = Table ADR
MOV D,M	;Routine ADR High Byte
XCHG	;DE = Routine ADR
PCHL	;Go to Routine ADR
----	----
	\/
----	----
LHLX	;DE = Table ADR
PCHL	;HL = Routine ADR
----	----
part (b)	
Sourec Statement	Comment
LXI H,ARRAY	;ARRAY Base ADR
MVI L,INDEX	;8-Bit INDEX, HL=ARRAY ADR
----	----
	\/
----	----
LXI H,ARRAY	;ARRAY Base ADR
LDHI L,INDEX	;8-Bit INDEX, HL=ARRAY ADR
----	----
part (c)	
Sourec Statement	Comment
LDSI 2	;DE = SP + 2
SHLX	;Replace 2, Item on Stack
----	----
Options. Newly discovered operating codes for 8085 shown in table enables the writing of more efficient programs. Program for table jump (a, top) can be reduced significantly when new instructions (a, bottom) are implemented. Array routine (b, top) can be rewritten (b, Bottom) so that arrays can be addressed across page boundaries. Data words can be entered at any point in a stack register (c).	

Condition Code Format								
S	Z	X5	AC	O	P	V	CY	

```
V = Bit 1      2's complement overflow
X5 = bit 5      Underflow (DCX) or Overflow (INX)
X5 = O1*O2 + O1*R + O2*R, where
* == AND, + == OR
O1 = sign of operand 1
O2 = sign of operand 2
R = sign of result.
For subtraction and comparisons
replace O2 with ~O2.
```

(H)(L)=(H)(L)-(B)(C)
The contents of register pair B and C are subtracted from the contents of register pair H and L. The result is placed in register pair H and L. All condition flags are affected.

```
cycles:          3
states:          10
addressing:      register
flags:           Z,S,P,CY,AC,X5,V
```

ARHL (arithmetic shift of H and L to the right)

$(H7=H7); (Hn-1)=(Hn)$

$(L7=H0); (Ln-1)=(Ln); (CY)=(L0)$

The contents of register pair H and L are shifted right one bit. The uppermost bit is duplicated and the lowest bit is shifted into the carry bit.

The result is placed in register pair H and L.

Note: only the CY flag is affected.

```
-----  
[ 0 0 0 1 0 0 0 0 ] (10)  
-----
```

cycles: 3
states: 7
addressing: register
flags: CY

RDEL (rotate D and E left through carry)

$(Dn+1)=(Dn); (D0)=(E7)$

$(CY)=(D7); (En+1)=(En); (E0)=(CY)$

The contents of register pair D and E are rotated left one position through the carry flag. The low order bit is set equal to the CY flag and the CY flag is set to the value shifted out of the high-order bit. Only the CY and V flags are affected.

```
-----  
[ 0 0 0 1 1 0 0 0 ] (18)  
-----
```

cycles: 3
states: 10
addressing: register
flags: CY, V

LDHI (load D and E with H and L plus immediate byte)

$(D)(E) = ((H)(L) + (\text{byte } 2))$

The contents of register pair H and L are added to the immediate byte. The result is placed in register pair D and E.

Note: no condition flags are affected.

```

-----
[ 0 0 1 0 1 0 0 0 ] (28)
-----
[      data      ]
-----

```

cycles: 3
states: 10
addressing: immediate register
flags: none

LDSI (load D and E with SP plus immediate byte)

$(D)(E); (D0) = (E7)$

$(CY) = (D7); (SPH)(SPL) + (\text{byte } 2)$

The contents of register pair H and L are added to the immediate byte. The result is placed in register pair D and E.

Note: no condition flags are affected.

```

-----
[ 0 0 1 1 1 0 0 0 ] (38)
-----
[      data      ]
-----

```

cycles: 3
states: 10
addressing: immediate register
flags: none

RSTV (restart on overflow)

```
if (V):
    ((SP)-1)=(PCH)
    ((SP)-2)=(PCL)
    (SP)=(SP)-2
    (PC)=40 hex
```

If the overflow flag V is set, the actions specified above are performed; otherwise control continues sequentially.

```
-----
[  1 1 0 0 1 0 1 1  ]          (CB)
-----
```

cycles: 1 or 3
states: 6 or 12
addressing: register indirect
flags: none

SHLX (store H and L indirect through D and E)

```
((D)(E))=(L)
((D)(E)+1)=(H)
```

The contents of register L are moved to the memory-location whose address is in register pair D and E. The contents of register H are moved to the succeeding memory location.

```
-----
[  1 1 0 1 1 0 0 1  ]          (D9)
-----
```

cycles: 3
states: 10
addressing: register indirect
flags: none

JNX5 (jump on not X5)

if (not X5)
 (PC)=(byte 3)(byte 2)

If the X5 flag is reset, control is transferred to the instruction whose address is specified in byte 3 and byte 2 of the current instruction; otherwise control continues sequentially.

```
-----  
[ 1 1 0 1 1 1 0 1 ]                    (DD)  
-----  
[ lo-order address ]  
-----  
[ hi-order address ]  
-----
```

cycles: 2 or 3
states: 7 or 10
addressing: immediate
flags: none

LHLX (load H and L indirect through D and E))

(L)=((D)(E))
(H)=((D)(E)+1)

The content of the memory location whose address is in D and E, are moved to register L. The contents of the succeeding memory location are moved to register H.

```
-----  
[ 1 1 1 0 1 1 0 1 ]                    (ED)  
-----
```

cycles: 3
states: 10
addressing: register indirect
flags: none

JX5 (jump on X5)

if (X5)
 (PC)=(byte 3)(byte 2)

If the X5 flag is set, control is transferred to the instruction whose address is specified in byte 3 and byte 2 of the current instruction; otherwise control continues sequentially.

```
-----  
[ 1 1 1 1 1 1 0 1 ]                    (FD)  
-----  
[ lo-order address ]  
-----  
[ hi-order address ]  
-----
```

cycles:	2 or 3
states:	7 or 10
addressing:	immediate
flags:	none

APPENDIX AT

AS8XCXXX ASSEMBLER

AT.1 ACKNOWLEDGMENTS

Thanks to Bill McKinnon for his contributions to the AS8XCXXX cross assembler.

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This assembler was derived from the AS8051 cross assembler contributed by John Hartman.

John L. Hartman
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noice at noicedebugger dot com

AT.2 AS8XCXXX ASSEMBLER DIRECTIVES

AT.2.1 Processor Selection Directives

The AS8XCXXX assembler contains directives to specify the processor core SFR (Special Function Registers) and enable the SFR Bit Register values during the assembly process. The following directives are supported:

.DS8XCXXX	;80C32 core
.DS80C310	;Dallas Semiconductor
.DS80C320	;Microprocessors
.DS80C323	
.DS80C390	
.DS83C520	
.DS83C530	

```
.DS83C550  
.DS87C520  
.DS87C530  
.DS87C550
```

The invocation of one of the processor directives creates a processor specific symbol and an SFR-Bits symbol. For example the directive

```
.DS80C390
```

creates the global symbols '__DS80C390' and '__SFR_BITS' each with a value of 1. If the microprocessor core selection directive is followed by an optional argument then the symbol '__SFR_BITS' is given the value of the argument. The file DS8XCXXX.SFR contains the SFR and SFR register bit values for all the microprocessor selector directives. This file may be modified to create a new SFR for other microprocessor types.

If a microprocessor selection directive is not specified then no processor symbols will be defined. This mode allows the SFR and SFR register bit values to be defined by the assembly source file.

AT.2.2 .cpu Directive

The .cpu directive is similar to the processor selection directives. This directive defines a new processor type and creates a user defined symbol:

```
.cpu      "CP84C331"      2
```

creates the symbol '__CP84C331' with a value of 1 and the symbol '__SFR_BITS' with a value of 2. These values can be used to select the processor SFR and SFR register bits from an include file. If the optional final argument, 2, is omitted then the value of the symbol '__SFR_BITS' is 1.

AT.2.3 Processor Addressing Range Directives

If one of the .DS8... microprocessor selection directives is not specified then the following address range assembler directives are accepted:

.16bit	;16-Bit Addressing
.24bit	;24-Bit Addressing
.32bit	;32-Bit Addressing

These directives specify the assembler addressing space and effect the output format for the .lst, .sym, and .rel files.

The default addressing space for defined microprocessors is 16-Bit except for the DS80C390 microprocessor which is 24-Bit.

The .cpu directive defaults to the 16-Bit addressing range but this can be changed using these directives.

AT.2.4 The .__.CPU. Variable

The value of the pre-defined symbol '.__.CPU.' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the AS8XCXXX assembler:

Processor Type	.__.CPU. Value
-----	-----
.cpu	0
.DS8XCXXX	1
.DS80C310	2
.DS80C320	3
.DS80C323	4
.DS80C390	5
.DS83C520	6
.DS83C530	7
.DS83C550	8
.DS87C520	9
.DS87C530	10
.DS87C550	11

The variable '.__.CPU.' is by default defined as local and will not be output to the created .rel file. The assembler command line options -g or -a will not cause the local symbol to be output to the created .rel file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable `'__CPU.'` might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AT.2.5 DS80C390 Addressing Mode Directive

The DS80C390 microprocessor supports 16-Bit and 24-Bit addressing modes. The `.amode` assembler directive provides a method to select the addressing mode used by the `ajmp`, `acall`, `ljmp`, and `lcall` instructions. These four instructions support 16 and 24 bit addressing modes selected by bits AM0 and AM1 in the ACON register. The assembler is 'informed' about the addressing mode selected by using the `.amode` directive:

```
.amode 2          ;mode 2 is 24-bit addressing
```

If a second argument is specified and its value is non-zero, then a three instruction sequence is inserted at the `.amode` location loading the mode bits into the ACON register:

```
.amode 2,1        ;mode 2 is 24-bit addressing, load ACON
;mov    ta,#0xAA
;mov    ta,#0x55
;mov    acon,#amode
```

AT.2.6 The `.msb` Directive

The `.msb` directive is available in the AS8XCXXX assembler.

The assembler operator `'>'` selects the upper byte (MSB) when included in an assembler instruction. The default assembler mode is to select bits `<15:8>` as the MSB. The `.msb` directive allows the programmer to specify a particular byte as the 'MSB' when the address space is larger than 16-bits.

The assembler directive `.msb n` configures the assembler to select a particular byte as MSB. Given a 24-bit address of `Nmn` (`N(2)` is `<23:16>`, `m(1)` is `<15:8>`, and `n(0)` is `<7:0>`) the following examples show how to select a particular address byte:

```
.msb 1            ;select byte 1 of address
                  ;<M(3):N(2):m(1):n(0)>
LD A,>MNmn        ;byte m <15:8> ==>> A
```

...

.msb 2 ;select byte 2 of address
; <M(3):N(2):m(1):n(0)>

LD A,>MNmn ;byte N <23:16> ==> A

...

AT.3 DS8XCXXX REGISTER SET

The AS8XCXXX cross assembler supports the Dallas Semiconductor DS8XCXXX series of 8051-compatible devices. These microprocessors retain instruction set and object code compatibility with the 8051 microprocessor. The DS8XCXXX family is updated with several new peripherals while providing all the standard features of the 80C32 microprocessor.

The following is a list of the registers used by AS8XCXXX:

a,b	-	8-bit accumulators
r0,r1,r2,r3	-	8-bit registers
r4,r5,r6,r7		
dptr	-	data pointer
sp	-	stack pointer
pc	-	program counter
psw	-	status word
c	-	carry (bit in status word)

AT.4 DS8XCXXX INSTRUCTION SET

The following tables list all DS8XCXXX mnemonics recognized by the AS8XCXXX assembler. The following list specifies the format for each addressing mode supported by AS8XCXXX:

#data	immediate data byte or word data
r,r1,r2	register r0,r1,r2,r3,r4,r5,r6, or r7
@r	indirect on register r0 or r1
@dptr	indirect on data pointer
@a+dptr	indirect on accumulator plus data pointer
@a+pc	indirect on accumulator plus program counter
addr	direct memory address
bitaddr	bit address
label	call or jump label

The terms data, addr, bitaddr, and label may all be expressions.

Note that not all addressing modes are valid with every instruction. Refer to the DS8XCXXX technical data for valid modes.

AT.4.1 Inherent Instructions

nop

AT.4.2 Move Instructions

mov	a,#data	mov	a,addr
mov	a,r	mov	a,@r
mov	r,#data	mov	r,addr
mov	r,a		
mov	addr,a	mov	addr,#data
mov	addr,r	mov	addr,@r
mov	addr1,addr2	mov	bitaddr,c
mov	@r,#data	mov	@r,addr
mov	@r,a		
mov	c,bitaddr		
mov	dptr,#data		
movc	a,@a+dptr	movc	a,@a+pc
movx	a,@dptr	movx	a,@r
movx	@dptr,a	movx	@r,a

AT.4.3 Single Operand Instructions

clr	a	clr	c
clr	bitaddr		
cpl	a	cpl	c
cpl	bitaddr		
setb	c	setb	bitaddr
da	a		
rr	a	rrc	a
rl	a	rlc	a
swap	a		
dec	a	dec	r
dec	@r		
inc	a	inc	r
inc	dptr	inc	@r
div	ab	mul	ab
pop	addr	push	addr

AT.4.4 Two Operand Instructions

add	a,#data	add	a,addr
add	a,r	add	a,@r
addc	a,#data	addc	a,addr
addc	a,r	addc	a,@r
subb	a,#data	subb	a,addr
subb	a,r	subb	a,@r
orl	a,#data	orl	a,addr
orl	a,r	orl	a,@r
orl	addr,a	orl	addr,#data
orl	c,bitaddr	orl	c,/bitaddr
anl	a,#data	anl	a,addr
anl	a,r	anl	a,@r
anl	addr,a	anl	addr,#data
anl	c,bitaddr	anl	c,/bitaddr
xrl	a,#data	xrl	a,addr
xrl	a,r	xrl	a,@r
xrl	addr,a	xrl	addr,#data
xrl	c,bitaddr	xrl	c,/bitaddr
xch	a,addr	xch	a,r
xch	a,@r	xchd	a,@r

AT.4.5 Call and Return Instructions

acall	label	lcall	label
ret		reti	
in	data		
out	data		
rst	data		

AT.4.6 Jump Instructions

ajmp	label		
cjne	a,#data,label	cjne	a,addr,label
cjne	r,#data,label	cjne	@r,#data,label
djnz	r,label	djnz	addr,label
jbc	bitadr,label		
jb	bitadr,label	jnb	bitadr,label
jc	label	jnc	label
jz	label	jnz	label
jmp	@a+dptr		
ljmp	label	sjmp	label

AT.5 DS8XCXXX SPECIAL FUNCTION REGISTERS

The 80C32 core Special Function Registers are selected using the .DS8XCXXX assembler directive.

AT.5.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80		SP	DPL	DPH	83
84				PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1			8F
90	P1				93
94					97
98	SCON	SBUF			9B
9C					9F
A0	P2				A3
A4					A7
A8	IE	SADDR0			AB
AC					AF
B0	P3				B3
B4					B7
B8	IP	SADEN0			BB
BC					BF
C0					C3
C4		STATUS			C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2			CF
D0	PSW				D3
D4					D7
D8					DB
DC					DF
E0	ACC				E3
E4					E7
E8					EB
EC					EF
F0	B				F3
F4					F7
F8					FB
FC					FF

AT.5.2 Bit Addressable Registers: Generic

		----- 4 BITS -----				
		----	----	----	----	
	80					83
	84					87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
P1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
	C0					C3
	C4					C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
	D8					DB
	DC					DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
	E8					EB
	EC					EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
	F8					FB
	FC					FF

AT.5.3 Bit Addressable Registers: Specific

		----- 4 BITS -----				
		-----	-----	-----	-----	
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SM0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2		EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2			BF
	C0					C3
	C4					C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
	D8					DB
	DC					DF
	E0					E3
	E4					E7
	E8					EB
	EC					EF
	F0					F3
	F4					F7
	F8					FB
	FC					FF

Alternates:

SCON	98					9B
	9C				FE	9F
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.5.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x01	
		-----	-----	-----	-----	
PCON	0x80	SMOD	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
STATUS	0x80		HIP	LIP		0x10
	0x08					0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01

AT.6 DS80C310 SPECIAL FUNCTION REGISTERS

The DS80C310 Special Function Registers are selected using the .DS80C310 assembler directive.

AT.6.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80		SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	P1	EXIF			93
94					97
98	SCON	SBUF			9B
9C					9F
A0	P2				A3
A4					A7
A8	IE	SADDR0			AB
AC					AF
B0	P3				B3
B4					B7
B8	IP	SADEN0			BB
BC					BF
C0					C3
C4		STATUS			C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2			CF
D0	PSW				D3
D4					D7
D8	WDCON				DB
DC					DF
E0	ACC				E3
E4					E7
E8	EIE				EB
EC					EF
F0	B				F3
F4					F7
F8	EIP				FB
FC					FF

AT.6.2 Bit Addressable Registers: Generic

		----- 4 BITS -----				
		----	----	----	----	
	80					83
	84					87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
P1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
	C0					C3
	C4					C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
WDCON	D8	WDCON.0	WDCON.1	WDCON.2	WDCON.3	DB
	DC	WDCON.4	WDCON.5	WDCON.6	WDCON.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

AT.6.3 Bit Addressable Registers: Specific

		----- 4 BITS -----				
		----	----	----	----	
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SM0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2		EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2			BF
	C0					C3
	C4					C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
WDCON	D8					DB
	DC			POR		DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC					EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC					FF

Alternates:

SCON	98					9B
	9C				FE	9F
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.6.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x10	
		-----	-----	-----	-----	
DPS	0x80					0x10
	0x08				SEL	0x01
PCON	0x80	SMOD	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80			T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
EXIF	0x80	IE5	IE4	IE3	IE2	0x10
	0x08					0x01
STATUS	0x80		HIP	LIP		0x10
	0x08					0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01
Alternates:						
PCON	0x80	SMOD_0				0x10
	0x08					0x01

AT.7 DS80C320/DS80C323 SPECIAL FUNCTION REGISTERS

The DS80C320/DS80C323 Special Function Registers are selected using the .DS80C320 or DS80C323 assembler directives.

AT.7.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80		SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	P1	EXIF			93
94					97
98	SCON0	SBUF0			9B
9C					9F
A0	P2				A3
A4					A7
A8	IE	SADDR0			AB
AC					AF
B0	P3				B3
B4					B7
B8	IP	SADEN0			BB
BC					BF
C0	SCON1	SBUF1			C3
C4		STATUS		TA	C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2			CF
D0	PSW				D3
D4					D7
D8	WDCON				DB
DC					DF
E0	ACC				E3
E4					E7
E8	EIE				EB
EC					EF
F0	B				F3
F4					F7
F8	EIP				FB
FC					FF

Alternates:

98	SCON	SBUF			9B
----	------	------	--	--	----

AT.7.2 Bit Addressable Registers: Generic

		----- 4 BITS -----				
		----	----	----	----	
	80					83
	84					87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
P1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON0	98	SCON0.0	SCON0.1	SCON0.2	SCON0.3	9B
	9C	SCON0.4	SCON0.5	SCON0.6	SCON0.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
SCON1	C0	SCON1.0	SCON1.1	SCON1.2	SCON1.3	C3
	C4	SCON1.4	SCON1.5	SCON1.6	SCON1.7	C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
WDCON	D8	WDCON.0	WDCON.1	WDCON.2	WDCON.3	DB
	DC	WDCON.4	WDCON.5	WDCON.6	WDCON.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

Alternates:

SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F

AT.7.3 Bit Addressable Registers: Specific

----- 4 BITS -----						

	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON0	98	RI_0	TI_0	RB8_0	TB8_0	9B
	9C	REN_0	SM2_0	SM1_0	SMO_0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2		EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2			BF
SCON1	C0	RI_1	TI_1	RB8_1	TB8_1	C3
	C4	REN_1	SM2_1	SM1_1	SMO_1	C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
WDCON	D8	RWT	EWT	WTRF	WDIF	DB
	DC	PFI	EPFI	POR	SMOD_1	DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC	EWDI				EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC	PWDI				FF

Alternates:

SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SMO	9F
SCON	98					9B
	9C				FE	9F
SCON0	98					9B
	9C				FE_0	9F
SCON1	C0					C3
	C4				FE_1	C7
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.7.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x10	
		-----	-----	-----	-----	
DPS	0x80					0x10
	0x08				SEL	0x01
PCON	0x80	SMOD_0	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80	WD1	WD0	T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
EXIF	0x80	IE5	IE4	IE3	IE2	0x10
	0x08		RGMD	RGSL	BGS	0x01
STATUS	0x80	PIP	HIP	LIP		0x10
	0x08					0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01
Alternates:						
PCON	0x80	SMOD				0x10
	0x08					0x01

AT.8 DS80C390 SPECIAL FUNCTION REGISTERS

The DS80C390 Special Function Registers are selected using the .DS80C390 assembler directive.

AT.8.1 SFR Map

----- 4 Bytes -----					
	----	----	----	----	
80	P4	SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	P1	EXIF	P4CNT	DPX	93
94		DPX1	C0RMS0	C0RMS1	97
98	SCON0	SBUF0		ESP	9B
9C	AP	ACON	C0TMA0	C0TMA1	9F
A0	P2	P5	P5CNT	C0C	A3
A4	C0S	C0IR	C0TE	C0RE	A7
A8	IE	SADDR0	SADDR1	C0M1C	AB
AC	C0M2C	C0M3C	C0M4C	C0M5C	AF
B0	P3			C0M6C	B3
B4	C0M7C	C0M8C	C0M9C	C0M10C	B7
B8	IP	SADEN0	SADEN1	C0M11C	BB
BC	C0M12C	C0M13C	C0M14C	C0M15C	BF
C0	SCON1	SBUF1			C3
C4	PMR	STATUS	MCON	TA	C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2	COR		CF
D0	PSW	MCNT0	MCNT1	MA	D3
D4	MB	MC	C1RMS0	C1RMS1	D7
D8	WDCON				DB
DC			C1TMA0	C1TMA1	DF
E0	ACC			C1C	E3
E4	C1S	C1IR	C1TE	C1RE	E7
E8	EIE		MXAX	C1M1C	EB
EC	C1M2C	C1M3C	C1M4C	C1M5C	EF
F0	B			C1M6C	F3
F4	C1M7C	C1M8C	C1M9C	C1M10C	F7
F8	EIP			C1M11C	FB
FC	C1M12C	C1M13C	C1M14C	C1M15C	FF

Alternates:

98	SCON	SBUF			9B
----	------	------	--	--	----

AT.8.2 Bit Addressable Registers: Generic

----- 4 BITS -----						
		----	----	----	----	
P4	80	P4.0	P4.1	P4.2	P4.3	83
	84	P4.4	P4.5	P4.6	P4.7	87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
P1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON0	98	SCON0.0	SCON0.1	SCON0.2	SCON0.3	9B
	9C	SCON0.4	SCON0.5	SCON0.6	SCON0.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
SCON1	C0	SCON1.0	SCON1.1	SCON1.2	SCON1.3	C3
	C4	SCON1.4	SCON1.5	SCON1.6	SCON1.7	C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
WDCON	D8	WDCON.0	WDCON.1	WDCON.2	WDCON.3	DB
	DC	WDCON.4	WDCON.5	WDCON.6	WDCON.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

Alternates:

SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F

AT.8.3 Bit Addressable Registers: Specific

----- 4 BITS -----						
---- ---- ---- ----						
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
P1	90	T2	T2EX	RXD1	TXD1	93
	94	INT2	INT3	INT4	INT5	97
SCON0	98	RI_0	TI_0	RB8_0	TB8_0	9B
	9C	REN_0	SM2_0	SM1_0	SMO_0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2	ES1	EA	AF
P3	B0	RXD0	TXD0	INT0	INT1	B3
	B4	T0	T1			B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2	PS1		BF
SCON1	C0	RI_1	TI_1	RB8_1	TB8_1	C3
	C4	REN_1	SM2_1	SM1_1	SMO_1	C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
WDCON	D8	RWT	EWT	WTRF	WDIF	DB
	DC	PFI	EPFI	POR	SMOD_1	DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC	EWDI	C1IE	C0IE	CANBIE	EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC	PWDI	C1IP	C0IP	CANBIP	FF

Alternates:

SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SMO	9F
SCON	98					9B
	9C				FE	9F
SCON0	98					9B
	9C				FE_0	9F
SCON1	C0					C3
	C4				FE_1	C7
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.8.4 Optional Symbols: Control Bits

----- 4 BITS -----						
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x10	
		-----	-----	-----	-----	
DPS	0x80	ID1	ID0	TSL		0x10
	0x08				SEL	0x01
PCON	0x80	SMOD_0	SMOD0	OFDF	OFDE	0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80	WD1	WD0	T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
EXIF	0x80	IE5	IE4	IE3	IE2	0x10
	0x08	CKRY	RGMD	RGSL	BGS	0x01
P4CNT	0x80		SBCAN			0x10
	0x08					0x01
ESP	0x80					0x10
	0x08			ESP.1	ESP.0	0x01
ACON	0x80					0x10
	0x08		SA	AM1	AM0	0x01
P5	0x80	P5.7	P5.6	P5.5	P5.4	0x10
	0x08	P5.3	P5.2	P5.1	P5.0	0x01
P5CNT	0x80	CAN1BA	CAN0BA	SP1EC	C1_IO	0x10
	0x08	C0_IO	P5CNT.2	P5CNT.1	P5CNT.0	0x01
CxC	0x80	ERIE	STIE	PDE	SIESTA	0x10
	0x08	CRST	AUTOB	ERCS	SWINT	0x01
CxS	0x80	BSS	EC96_128	WKS	RXS	0x10
	0x08	TXS	ER2	ER1	ER0	0x01
CxIR	0x80	INTIN7	INTIN6	INTIN5	INTIN4	0x10
	0x08	INTIN3	INTIN2	INTIN1	INTIN0	0x01
CxCxxC	0x80	MSRDY	ET1	ER1	INTRQ	0x10
	0x08	EXTRQ	MTRQ	ROW_TIH	DTUP	0x01
PMR	0x80	CD1	CD0	SWB	CTM	0x10
	0x08	4X_2X	ALEOFF			0x01
STATUS	0x80	PIP	HIP	LIP		0x10
	0x08	SPTA1	SPRA1	SPTA0	SPRA0	0x01
MCON	0x80	IDM1	IDM0	CMA		0x10
	0x08	PDCE3	PDCE2	PDCE1	PDCE0	0x01
T2MOD	0x80				D13T1	0x10
	0x08	D13T2		T2OE	DCEN	0x01
COR	0x80	IRDACK	C1BPR7	C1BPR6	C0BPR7	0x10
	0x08	C0BPR6	COD1	COD0	CLKOE	0x01
MCNT0	0x80	_LSHIFT	CSE	SCB	MAS4	0x10
	0x08	MAS3	MAS2	MAS1	MAS0	0x01
MCNT1	0x80	MST	MOF		CLM	0x10
	0x08					0x01

Alternates:

PCON	0x80	SMOD	0x10
	0x08		0x01

AT.9 DS83C520/DS87C520 SPECIAL FUNCTION REGISTERS

The DS83C520/DS87C520 Special Function Registers are selected using the .DS83C520 or DS87C520 assembler directives.

AT.9.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80	P0	SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	PORT1	EXIF			93
94					97
98	SCON0	SBUF0			9B
9C					9F
A0	P2				A3
A4					A7
A8	IE	SADDR0	SADDR1		AB
AC					AF
B0	P3				B3
B4					B7
B8	IP	SADEN0	SADEN1		BB
BC					BF
C0	SCON1	SBUF1	ROMSIZE		C3
C4	PMR	STATUS		TA	C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2			CF
D0	PSW				D3
D4					D7
D8	WDCON				DB
DC					DF
E0	ACC				E3
E4					E7
E8	EIE				EB
EC					EF
F0	B				F3
F4					F7
F8	EIP				FB
FC					FF

Alternates:

98	SCON	SBUF			9B
----	------	------	--	--	----

AT.9.2 Bit Addressable Registers: Generic

----- 4 BITS -----						
		----	----	----	----	
P0	80	P0.7	P0.6	P0.5	P0.4	83
	84	P0.3	P0.2	P0.1	P0.0	87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
PORT1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON0	98	SCON0.0	SCON0.1	SCON0.2	SCON0.3	9B
	9C	SCON0.4	SCON0.5	SCON0.6	SCON0.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
SCON1	C0	SCON1.0	SCON1.1	SCON1.2	SCON1.3	C3
	C4	SCON1.4	SCON1.5	SCON1.6	SCON1.7	C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
WDCON	D8	WDCON.0	WDCON.1	WDCON.2	WDCON.3	DB
	DC	WDCON.4	WDCON.5	WDCON.6	WDCON.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

Alternates:

PORT1	90	PORT1.0	PORT1.1	PORT1.2	PORT1.3	93
	94	PORT1.4	PORT1.5	PORT1.6	PORT1.7	97
SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F

AT.9.3 Bit Addressable Registers: Specific

----- 4 BITS -----						
---- ---- ---- ----						
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON0	98	RI_0	TI_0	RB8_0	TB8_0	9B
	9C	REN_0	SM2_0	SM1_0	SMO_0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2	ES1	EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2	PS1		BF
SCON1	C0	RI_1	TI_1	RB8_1	TB8_1	C3
	C4	REN_1	SM2_1	SM1_1	SMO_1	C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
WDCON	D8	RWT	EWT	WTRF	WDIF	DB
	DC	PFI	EPFI	POR	SMOD_1	DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC	EWDI				EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC	PWDI				FF

Alternates:

SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SMO	9F
SCON	98					9B
	9C				FE	9F
SCON0	98					9B
	9C				FE_0	9F
SCON1	C0					C3
	C4				FE_1	C7
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.9.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x10	
		-----	-----	-----	-----	
DPS	0x80					0x10
	0x08				SEL	0x01
PCON	0x80	SMOD_0	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80	WD1	WD0	T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
EXIF	0x80	IE5	IE4	IE3	IE	0x10
	0x08	XT_RG	RGMD	RGSL	BGS	0x01
SBUF1	0x80	SB7	SB6	SB5	SB4	0x10
	0x08	SB3	SB2	SB1	SB0	0x01
ROMSIZE	0x80					0x10
	0x08		RMS2	RMS1	RMS0	0x01
PMR	0x80	CD1	CD0	SWB		0x10
	0x08	XTOFF	ALEOFF	DME1	DME0	0x01
STATUS	0x80	PIP	HIP	LIP	XTUP	0x10
	0x08	SPTA1	SPRA1	SPTA0	SPRA0	0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01

Alternates:

PCON	0x80	SMOD				0x10
	0x08					0x01

AT.10 DS83C530/DS87C530 SPECIAL FUNCTION REGISTERS

The DS83C530/DS87C530 Special Function Registers are selected using the .DS83C530 or DS87C530 assembler directives.

AT.10.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80	P0	SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	P1	EXIF			93
94			TRIM		97
98	SCON0	SBUF0			9B
9C					9F
A0	P2				A3
A4					A7
A8	IE	SADDR0	SADDR1		AB
AC					AF
B0	P3				B3
B4					B7
B8	IP	SADEN0	SADEN1		BB
BC					BF
C0	SCON1	SBUF1	ROMSIZE		C3
C4	PMR	STATUS		TA	C7
C8	T2CON	T2MOD	RCAP2L	RCAP2H	CB
CC	TL2	TH2			CF
D0	PSW				D3
D4					D7
D8	WDCON				DB
DC					DF
E0	ACC				E3
E4					E7
E8	EIE				EB
EC					EF
F0	B		RTASS	RTAS	F3
F4	RTAM	RTAH			F7
F8	EIP	RTCC	RTCSS	RTCS	FB
FC	RTCM	RTCH	RTCD0	RTCD1	FF

Alternates:

98	SCON	SBUF			9B
----	------	------	--	--	----

AT.10.2 Bit Addressable Registers: Generic

----- 4 BITS -----						
		----	----	----	----	
P0	80	P0.7	P0.6	P0.5	P0.4	83
	84	P0.3	P0.2	P0.1	P0.0	87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
P1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON0	98	SCON0.0	SCON0.1	SCON0.2	SCON0.3	9B
	9C	SCON0.4	SCON0.5	SCON0.6	SCON0.7	9F
P2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
P3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
SCON1	C0	SCON1.0	SCON1.1	SCON1.2	SCON1.3	C3
	C4	SCON1.4	SCON1.5	SCON1.6	SCON1.7	C7
T2CON	C8	T2CON.0	T2CON.1	T2CON.2	T2CON.3	CB
	CC	T2CON.4	T2CON.5	T2CON.6	T2CON.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
WDCON	D8	WDCON.0	WDCON.1	WDCON.2	WDCON.3	DB
	DC	WDCON.4	WDCON.5	WDCON.6	WDCON.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

Alternates:

SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F

AT.10.3 Bit Addressable Registers: Specific

----- 4 BITS -----						
---- ---- ---- ----						
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON0	98	RI_0	TI_0	RB8_0	TB8_0	9B
	9C	REN_0	SM2_0	SM1_0	SMO_0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2	ES1	EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PT2	PS1		BF
SCON1	C0	RI_1	TI_1	RB8_1	TB8_1	C3
	C4	REN_1	SM2_1	SM1_1	SMO_1	C7
T2CON	C8	CPRL2	CT2	TR2	EXEN2	CB
	CC	TCLK	RCLK	EXF2	TF2	CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
WDCON	D8	RWT	EWT	WTRF	WDIF	DB
	DC	PFI	EPFI	POR	SMOD_1	DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC	EWDI	ERTCI			EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC	PWDI	PRTCI			FF

Alternates:

SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SMO	9F
SCON	98					9B
	9C				FE	9F
SCON0	98					9B
	9C				FE_0	9F
SCON1	C0					C3
	C4				FE_1	C7
T2CON	C8	CP_RL2	C_T2			CB
	CC					CF

AT.10.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x01	
		-----	-----	-----	-----	
DPS	0x80					0x10
	0x08				SEL	0x01
PCON	0x80	SMOD_0	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80	WD1	WD0	T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
EXIF	0x80	IE5	IE4	IE3	IE	0x10
	0x08	XT_RG	RGMD	RGSL	BGS	0x01
TRIM	0x80	E4K	X12_6	TRM2	_TRM2	0x10
	0x08	TRM1	_TRM1	TRM0	_TRM0	0x01
SBUF1	0x80	SB7	SB6	SB5	SB4	0x10
	0x08	SB3	SB2	SB1	SB0	0x01
ROMSIZE	0x80					0x10
	0x08		RMS2	RMS1	RMS0	0x01
PMR	0x80	CD1	CD0	SWB		0x10
	0x08	XTOFF	ALEOFF	DME1	DME0	0x01
STATUS	0x80	PIP	HIP	LIP	XTUP	0x10
	0x08	SPTA1	SPRA1	SPTA0	SPRA0	0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01
RTCC	0x80	SSCE	SCE	MCE	HCE	0x10
	0x08	RTCRE	RTCWE	RTCIF	RTCE	0x01

Alternates:

PCON	0x80	SMOD				0x10
	0x08					0x01

AT.11 DS83C550/DS87C550 SPECIAL FUNCTION REGISTERS

The DS83C550/DS87C550 Special Function Registers are selected using the .DS83C550 or DS87C550 assembler directives.

AT.11.1 SFR Map

----- 4 Bytes -----					
----	----	----	----	----	
80	PORT0	SP	DPL	DPH	83
84	DPL1	DPH1	DPS	PCON	87
88	TCON	TMOD	TL0	TL1	8B
8C	TH0	TH1	CKCON		8F
90	PORT1	RCON			93
94					97
98	SCON0	SBUF0			9B
9C				PMR	9F
A0	PORT2	SADDR0	SADDR1		A3
A4					A7
A8	IE	CMPL0	CMPL1	CMPL2	AB
AC	CPTL0	CPTL1	CPTL2	CPTL3	AF
B0	PORT3		ADCON1	ADCON2	B3
B4	ADMSB	ADLSD	WINHI	WINLO	B7
B8	IP	SADEN0	SADEN1		BB
BC			T2CON	T2MOD	BF
C0	PORT4		ROMSIZE		C3
C4	PORT5	STATUS		TA	C7
C8	T2IR	CMPH0	CMPH1	CMPH2	CB
CC	CPTH0	CPTH1	CPTH2	CPTH3	CF
D0	PSW		PW0FG	PW1FG	D3
D4	PW2FG	PW3FG	PWMADR		D7
D8	SCON1	SBUF1			DB
DC	PWM0	PWM1	PWM2	PWM3	DF
E0	ACC	PW01CS	PW23CS	PW01CON	E3
E4	PW23CON		RLOADL	RLOADH	E7
E8	EIE		T2SEL	CTCON	EB
EC	TL2	TH2	SETR	RSTR	EF
F0	B	PORT6			F3
F4					F7
F8	EIP				FB
FC				WDCON	FF

Alternates:

80	P0				83
90	P1				93
98	SCON	SBUF			9B
A0	P2				A3
B0	P3				B3
C0	P4				C3

C4
F0

P5

PORT6

C7
F3

AT.11.2 Bit Addressable Registers: Generic

----- 4 BITS -----						
		-----	-----	-----	-----	
PORT0	80	P0.7	P0.6	P0.5	P0.4	83
	84	P0.3	P0.2	P0.1	P0.0	87
TCON	88	TCON.0	TCON.1	TCON.2	TCON.3	8B
	8C	TCON.4	TCON.5	TCON.6	TCON.7	8F
PORT1	90	P1.0	P1.1	P1.2	P1.3	93
	94	P1.4	P1.5	P1.6	P1.7	97
SCON0	98	SCON0.0	SCON0.1	SCON0.2	SCON0.3	9B
	9C	SCON0.4	SCON0.5	SCON0.6	SCON0.7	9F
PORT2	A0	P2.0	P2.1	P2.2	P2.3	A3
	A4	P2.4	P2.5	P2.6	P2.7	A7
IE	A8	IE.0	IE.1	IE.2	IE.3	AB
	AC	IE.4	IE.5	IE.6	IE.7	AF
PORT3	B0	P3.0	P3.1	P3.2	P3.3	B3
	B4	P3.4	P3.5	P3.6	P3.7	B7
IP	B8	IP.0	IP.1	IP.2	IP.3	BB
	BC	IP.4	IP.5	IP.6	IP.7	BF
PORT4	C0	P4.0	P4.1	P4.2	P4.3	C3
	C4	P4.4	P4.5	P4.6	P4.7	C7
T2IR	C8	T2IR.0	T2IR.1	T2IR.2	T2IR.3	CB
	CC	T2IR.4	T2IR.5	T2IR.6	T2IR.7	CF
PSW	D0	PSW.0	PSW.1	PSW.2	PSW.3	D3
	D4	PSW.4	PSW.5	PSW.6	PSW.7	D7
SCON1	D8	SCON1.0	SCON1.1	SCON1.2	SCON1.3	DB
	DC	SCON1.4	SCON1.5	SCON1.6	SCON1.7	DF
ACC	E0	ACC.0	ACC.1	ACC.2	ACC.3	E3
	E4	ACC.4	ACC.5	ACC.6	ACC.7	E7
EIE	E8	EIE.0	EIE.1	EIE.2	EIE.3	EB
	EC	EIE.4	EIE.5	EIE.6	EIE.7	EF
B	F0	B.0	B.1	B.2	B.3	F3
	F4	B.4	B.5	B.6	B.7	F7
EIP	F8	EIP.0	EIP.1	EIP.2	EIP.3	FB
	FC	EIP.4	EIP.5	EIP.6	EIP.7	FF

Alternates:

PORT0	80	PORT0.7	PORT0.6	PORT0.5	PORT0.4	83
	84	PORT0.3	PORT0.2	PORT0.1	PORT0.0	87
PORT1	90	PORT1.0	PORT1.1	PORT1.2	PORT1.3	93
	94	PORT1.4	PORT1.5	PORT1.6	PORT1.7	97
SCON	98	SCON.0	SCON.1	SCON.2	SCON.3	9B
	9C	SCON.4	SCON.5	SCON.6	SCON.7	9F
PORT2	A0	PORT2.0	PORT2.1	PORT2.2	PORT2.3	A3
	A4	PORT2.4	PORT2.5	PORT2.6	PORT2.7	A7
PORT3	B0	PORT3.0	PORT3.1	PORT3.2	PORT3.3	B3
	B4	PORT3.4	PORT3.5	PORT3.6	PORT3.7	B7
PORT4	C0	PORT4.0	PORT4.1	PORT4.2	PORT4.3	C3
	C4	PORT4.4	PORT4.5	PORT4.6	PORT4.7	C7

AT.11.3 Bit Addressable Registers: Specific

----- 4 BITS -----						
	80					83
	84					87
TCON	88	IT0	IE0	IT1	IE1	8B
	8C	TR0	TF0	TR1	TF1	8F
	90					93
	94					97
SCON0	98	RI_0	TI_0	RB8_0	TB8_0	9B
	9C	REN_0	SM2_0	SM1_0	SMO_0	9F
	A0					A3
	A4					A7
IE	A8	EX0	ET0	EX1	ET1	AB
	AC	ES0	ET2	ES1	EA	AF
	B0					B3
	B4					B7
IP	B8	PX0	PT0	PX1	PT1	BB
	BC	PS0	PS1	PAD		BF
PORT4	C0	CMSR0	CMSR1	CMSR2	CMSR3	C3
	C4	CMSR4	CMSR5	CMT0	CMT1	C7
T2IR	C8	CF0	CF1	CF2	CF3	CB
	CC	CM0F	CM1F	CM2F		CF
PSW	D0	P	FL	OV	RS0	D3
	D4	RS1	F0	AC	CY	D7
SCON1	D8	RI_1	TI_1	RB8_1	TB8_1	DB
	DC	REN_1	SM2_1	SM1_1	SMO_1	DF
	E0					E3
	E4					E7
EIE	E8	EX2	EX3	EX4	EX5	EB
	EC	ECM0	ECM1	ECM2	ET2	EF
	F0					F3
	F4					F7
EIP	F8	PX2	PX3	PX4	PX5	FB
	FC	PCM0	PCM1	PCM2	PT2	FF

Alternates:

SCON	98	RI	TI	RB8	TB8	9B
	9C	REN	SM2	SM1	SMO	9F
SCON	98					9B
	9C				FE	9F
SCON0	98					9B
	9C				FE_0	9F
T2IR	C8	IE2	IE3	IE4	IE5	CB
	CC					CF
SCON1	D8					DB
	DC				FE_1	DF
EIE	E8	EC0	EC1	EC2	EC3	EB
	EC					EF
EIP	F8	PC0	PC1	PC2	PC3	FB

FC

FF

AT.11.4 Optional Symbols: Control Bits

		----- 4 BITS -----				
		-----	-----	-----	-----	
		0x80	0x40	0x20	0x10	
		0x08	0x04	0x02	0x10	
		-----	-----	-----	-----	
DPS	0x80	ID1	ID0	TSL		0x10
	0x08				SEL	0x01
PCON	0x80	SMOD_0	SMOD0			0x10
	0x08	GF1	GF0	STOP	IDLE	0x01
TMOD	0x80	T1GATE	T1C_T	T1M1	T1M0	0x10
	0x08	T0GATE	T0C_T	T0M1	T0M0	0x01
CKCON	0x80	WD1	WD0	T2M	T1M	0x10
	0x08	T0M	MD2	MD1	MD0	0x01
RCON	0x80					0x10
	0x08	CKRDY	RGMD	RGSL	BGS	0x01
PMR	0x80	CD1	CD0	SWB	CTM	0x10
	0x08	4X_2X	ALEOFF	DEM1	DEM0	0x01
ADCON1	0x80	STRT_BSY	EOC	CONT_SS	ADEX	0x10
	0x08	WCQ	WCM	ADON	WCIO	0x01
ADCON2	0x80	OUTCF	MUX2	MUX1	MUX0	0x10
	0x08	APS3	APS2	APS1	APS0	0x01
T2CON	0x80	TF2	EXF2	RCLK	TCLK	0x10
	0x08	EXEN2	TR2	CT2	CPRL2	0x01
T2MOD	0x80					0x10
	0x08			T2OE	DCEN	0x01
PORT5	0x80	ADC7	ADC6	ADC5	ADC4	0x10
	0x08	ADC3	ADC2	ADC1	ADC0	0x01
ROMSIZE	0x80					0x10
	0x08		RMS2	RMS1	RMS0	0x01
STATUS	0x80	PIP	HIP	LIP	XTUP	0x10
	0x08	SPTA1	SPRA1	SPTA0	SPRA0	0x01
PWMADR	0x80	ADRS				0x10
	0x08			PWE1	PWE0	0x01
PW01CS	0x80	PW0S2	PW0S1	PW0S0	PW0EN	0x10
	0x08	PW1S2	PW1S1	PW1S0	PW1EN	0x01
PW23CS	0x80	PW2S2	PW2S1	PW2S0	PW2EN	0x10
	0x08	PW3S2	PW3S1	PW3S0	PW3EN	0x01
PW01CON	0x80	PW0F	PW0DC	PW0OE	PW0T_C	0x10
	0x08	PW1F	PW1DC	PW1OE	PW1T_C	0x01
PW23CON	0x80	PW2F	PW2DC	PW2OE	PW2T_C	0x10
	0x08	PW3F	PW3DC	PW3OE	PW3T_C	0x01
T2SEL	0x80	TF2S	TF2BS		TF2B	0x10
	0x08			T2P1	T2P0	0x01
CTCON	0x80	_CT3	CT3	_CT2	CT2	0x10
	0x08	_CT1	CT1	_CT0	CT0	0x01
SETR	0x80	TGFF1	TGFF0	CMS5	CMS4	0x10
	0x08	CMS3	CMS2	CMS1	CMS0	0x01
RSTR	0x80	CMTE1	CMTE0	CMR5	CMR4	0x10
	0x08	CMR3	CMR2	CMR1	CMR0	0x01
PORT6	0x80	STADC		PWMC1	PWMC0	0x10

DS83C550/DS87C550 SPECIAL FUNCTION REGISTERS

	0x08	PWMO3	PWMO2	PWMO1	PWMO0	0x01
WDCON	0x80	SMOD_1	POR	EPF1	PF1	0x10
	0x08	WDIF	WTRF	EWT	RWT	0x01

Alternates:

PCON	0x80	SMOD				0x10
	0x08					0x01
T2CON	0x80					0x10
	0x08			C_T2	_RL2	0x01

APPENDIX AU

ASAVR ASSEMBLER

AU.1 AVR ASSEMBLER NOTES

The AVR series of processors uses a non unified addressing scheme: the instruction addressing is 1 per instruction word, each instruction uses 2 bytes of memory. The processor data is addressed as 1 per byte of data. To properly address the program/data spaces you, the programmer, must separate your program and data into separate code and data areas. The data area is addressed as 1 per byte and the code area is addressed as 1 per word.

The assembler/linker processes the instruction code so that the linker will output 2 bytes for each instruction word. The instruction word address will be the file encoded address divided by 2.

The default address space is assumed to be 64K (16-bits). The larger address space (ATmega...) processors must specify the 32-Bit addressing assembler directive '.32bit' in order to process the JMP instruction.

AU.1.1 Processor Specific Directives

The normal PC relative addressing is -2047 to +2048 relative to the current PC. For a processor with less than 4K words of program space the AVR relative jump/call can access any location due to address wrap around.

The ASAVR cross assembler has one (1) processor specific assembler directive which tells the assembler that the AVR has 4K words or less of program space.

.avr_4k	0	Normal PC Relative addressing
.avr_4k	1	AVR with <= 4K of Memory

The remaining processor specific directives specify the AVR processor type.

```
.AT90SXXXX
.AT90S1200
.AT90S2313
.AT90S2323
.AT90S2343
.AT90S2333
.AT90S4433
.AT90S4414
.AT90S4434
.AT90S8515
.AT90C8534
.AT90S8535
.ATmega103
.ATmega603
.ATmega161
.ATmega163
.ATtiny10
.ATtiny11
.ATtiny12
.ATtiny15
.ATtiny22
.ATtiny28
```

A file, avr.sfr, contains definitions for the Special Function Registers for all the defined processors. Edit the file to make your selection of processor and then .include the file at the beginning of your assembler file.

AU.1.2 The `__CPU__` Variable

The value of the pre-defined symbol '`__CPU__`' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASAVR assembler:

Processor Type	<code>__CPU__</code> Value
-----	-----
Undefined	0
AT90SXXXX (User Defined)	1
AT90S1200	2
AT90S2313	3
AT90S2323	4
AT90S2343	5
AT90S2333	6
AT90S4433	7
AT90S4414	8

AT90S4434	9
AT90S8515	10
AT90C8534	11
AT90S8535	12
ATmega103	13
ATmega603	14
ATmega161	15
ATmega163	16
ATtiny10	17
ATtiny11	18
ATtiny12	19
ATtiny15	20
ATtiny22	21
ATtiny28	22

The variable `'.__.CPU.'` is by default defined as local and will not be output to the created `.rel` file. The assembler command line options `-g` or `-a` will not cause the local symbol to be output to the created `.rel` file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable `'.__.CPU.'` might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AU.2 AVR REGISTER SET

The following is a list of the AVR registers used by ASAVR:

r0-r31	-	8-bit registers
x	-	index register (x = r27:r26)
y	-	index register (y = r29:r28)
z	-	index register (z = r31:r30)

AU.3 AVR INSTRUCTION SET

The following tables list all AVR mnemonics recognized by the ASAVR assembler. The designation `[]` refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by ASAVR:

<code>#data</code>	immediate data
<code>expr</code>	expression

Rd	destination register (0-31)
Rd, Rs	destination register (0-31) source register (0-31)
Rd, #data	destination register (0-31) immediate data
addr	address
addr, Rs	destination address source register
Rd, addr	destination register source address
Rs, b	source register bit position
Rd, b	destination register bit position
A	an I/O register (0-31)
A, b	an I/O register (0-31) bit position
A, Rs	source register to output register
Rd, A	input register to destination register
Rd, X Rd, Y Rd, Z	load indirect
Rd, -X Rd, -Y Rd, -Z	load indirect pre-decrement
Rd, X+ Rd, Y+ Rd, Z+	load indirect post-increment
Rd, Z+Q	load indirect with displacement
X, Rs Y, Rs Z, Rs	store indirect
-X, Rs	store indirect pre-decrement

-Y,Rs
-Z,Rs

X+,Rs store indirect post increment
Y+,Rs
Z+,Rs

Z+Q,Rs store indirect with displacement

label branch label

The terms data, expr, displacement, bit position, A, and label may be expressions.

Note that not all instructions are available with every processor type. Not all addressing modes are valid with every instruction, refer to the AVR technical data for valid instructions and modes.

AU.3.1 AVR Arithmetic and Logical Instructions

add	Rd,Rs	adc	Rd,Rs
adiw	Rd,#data	sub	Rd,Rs
subi	Rd,#data	sbc	Rd,Rs
sbc	Rd,#data	sbiw	Rd,#data
and	Rd,Rs	andi	Rd,#data
or	Rd,Rs	ori	Rd,#data
cp	Rd,Rs	eor	Rd,Rs
cpi	Rd,#data	cpc	Rd,Rs
cbr	Rd,#data	sbr	Rd,#data
clr	Rd	com	Rd
dec	Rd	inc	Rd
neg	Rd	ser	Rd
tst	Rd		
mul	Rd,Rs	fmul	Rd,Rs
muls	Rd,Rs	fmuls	Rd,Rs
mulsu	Rd,Rs	fmulsu	Rd,Rs

AU.3.2 AVR Bit and Bit-Test Instructions

lsl	Rd	lsr	Rd
rol	Rd	ror	Rd
asr	Rd	swap	Rd
bset	b	bclr	b
sbi	A,b	cbi	A,b
bst	Rs,b	bld	Rd,b
sec		sez	
sen		sev	
ses		seh	
set		sei	
clc		clz	
cln		clv	
cls		clh	
clt		cli	
nop		sleep	
wdr			

AU.3.3 AVR Skip on Test Instructions

cpse	Rd,Rs		
sbrc	Rs,b	sbrs	Rs,b
sbic	A,b	sbis	A,b

AU.3.4 AVR Jump/Call/Return Instructions

jmp	addr	rjmp	addr
ijmp		eijmp	
call	addr	rcall	addr
icall		eicall	
ret		reti	

AU.3.5 AVR Short Branch Instructions

brcc	label	brcs	label
breq	label	brge	label
brhc	label	brhs	label
brid	label	brie	label
brlo	label	brlt	label
brmi	label	brne	label
brpl	label	brsh	label
brtc	label	brts	label
brvc	label	brvs	label

AU.3.6 AVR Short Branch Instructions with Bit Test

brbc	b,label	brbs	b,label
------	---------	------	---------

AU.3.7 AVR Data Transfer Instructions

mov	Rd,Rs	movw	Rd,Rs
ldi	Rd,#data		
ld	[]	st	[]
ldd	[]	std	[]
lds	Rd,addr	sts	addr,Rs
lpm	[]	elpm	[]
spm			
push	Rs	pop	Rd
in	Rd,A	out	A,Rs

APPENDIX AV

ASEZ80 ASSEMBLER

AV.1 ACKNOWLEDGMENT

Thanks to Patrick Head for his contribution of the ASEZ80 cross assembler.

Patrick Head

patrick at phead dot net

AV.2 PROCESSOR SPECIFIC DIRECTIVES

The ASEZ80 assembler is a port of the ASZ80 assembler. This assembler can process EZ80 code in Z80 and ADL modes in any combination within the source file. The following processor specific assembler directives specify which mode the assembler is to process the assembler source code. The default mode of the assembler is Z80.

AV.2.1 .z80 Directive

Format:

.z80 (value)

The .z80 directive without an argument selects the 16-bit Z80 compatible mode of the EZ80 processor. The .z80 directive with the optional argument may be used to select the Z80 16-Bit mode (value != 0) or the EZ80 24-bit mode (value == 0). Mnemonics not allowed in the selected mode will generate m (mode) and/or a (addressing) errors.

AV.2.2 .adl Directive

Format:

```
.adl      (value)
```

The .adl directive without an argument selects the 24-bit EZ80 mode of the EZ80 processor. The .adl directive with the optional argument may be used to select the EZ80 24-Bit mode (value != 0) or the Z80 16-bit mode (value == 0). Mnemonics not allowed in the selected mode will generate m (mode) and/or a (addressing) errors.

AV.2.3 .msb Directive

Format:

```
.msb      n
```

The assembler operator '>' selects the upper byte (MSB) when included in an assembler instruction. The normal assembler mode is to select bits <15:8> as the MSB. The .msb directive allows the programmer to specify a particular byte as the 'MSB' when the address space is larger than 16-bits.

For a 24-bit EZ80 address the assembler directive .msb n configures the assembler to select a particular byte as MSB. Given a 24-bit address of Mmn (M is <23:16>, m is <15:8>, and n is <7:0>) the following examples show how to select a particular address byte:

```
.msb 1                ;select byte 1 of address
<M(2):m(1):n(0)>
LD A,>Mmn              ;byte m <15:8> ==>> A
...

.msb 2                ;select byte 2 of address
<M(2):m(1):n(0)>
LD A,>Mmn              ;byte M <23:16> ==>> A
LD MB,A               ;place in MBASE register
```

AV.3 EZ80 ADDRESSING AND INSTRUCTIONS

AV.3.1 Instruction Symbols

b	Bit select (000 = bit 0, 001 = bit 1, 010 = bit 2, 011 = bit 3, 100 = bit 4, 101 = bit 5, 110 = bit 6, 111 = bit 7)
cc	condition code C, NC, Z, NZ, P, M, PE, PO test of single bit in FLAGS register
cc'	condition code C, NC, Z, NZ test of single bit in FLAGS register
d	an 8-bit two's complement displacement with value from -128 to 127.
I	Interrupt Page Address Register
ir or ir'	8-bit CPU register IXH (IX:[15:8]), IXL (IX:[7:0]), IYH (IY:[15:8]), IYL (IY:[7:0])
IX/Y	CPU register IX or IY
(IX/Y+d)	A location in memory with address formed by the sum of the contents of the Index Register, IX or IY, and the two's complement displacement d.
MB	Z80 Memory Mode Base Address Register
Mmn	A 24-bit immediate data value
(Mmn)	A 24-bit value indicating a location in memory at this address.
mn	A 16-bit immediate data value
(mn)	A 16-bit value indicating a location in memory at this address.
n	8-bit immediate data value
R	Refresh Counter Register
r or r'	8-bit CPU register A, B, C, D, E, H, L
rr	16 or 24-bit CPU register BC, DE, HL
rx y	16 or 24-bit CPU register BC, DE, HL, IX, IY
SP	Stack Pointer, Can indicate either the StackPointer Short register (SPS) or the StackPointer Long register (SPL).

C	-	carry bit set
NC	-	carry bit clear
Z	-	zero bit set
NZ	-	zero bit clear
M	-	sign bit set
P	-	sign bit clear
PE	-	parity even
PO	-	parity odd

The terms b, d, Mmn, mn, n, and ss may all be expressions.

AV.3.2 EZ80 Instructions

The following list of instructions (with explicit addressing modes) are available for the EZ80.

ADC A,(HL)	DEC (HL)	INI
ADC A,ir	DEC ir	INI2
ADC A,(IX/Y+d)	DEC IX/Y	INI2R
ADC A,n	DEC (IX/Y+d)	
ADC A,r	DEC r	INIM
ADC HL,rr	DEC rr	INIMR
ADC HL,SP	DEC SP	
		INIR
ADD A,(HL)	DI	INIRX
ADD A,ir		
ADD A,(IX/Y+d)	DJNZ d	JP cc,Mmn
ADD A,n		JP HL
ADD A,r	EI	JP IX/Y
ADD HL,rr		JP Mmn
ADD HL,SP	EX AF,AF'	
ADD IX/Y,rr	EX DE,HL	JR cc',d
ADD IX/Y,SP	EX (SP),HL	JR d
	EX (SP),IX/Y	
AND A,HL		LD A,I
AND A,ir	EXX	LD A,(IX/Y+d)
AND A,(IX/Y+d)		LD A,MB
AND A,n	HALT	LD A,(Mmn)
AND A,r		LD A,R
	IM n	LD A,(rr)
BIT b,(HL)	IM A,(n)	LD (HL),IX/Y
BIT b,(IX/Y+d)	IN r,(BC)	LD (HL),n
BIT b,r		LD (HL),r
	IN0 r,(n)	LD (HL),rr
CALL cc,Mmn		LD IY,(SP+n)
CALL mn	INC (HL)	LD I,HL
	INC ir	LD I,A
CP A,(HL)	INC IX/Y	LD ir,ir'
CP A,ir	INC (IX/Y+d)	LD ir,n
CP A,(IX/Y+d)	INC r	LD ir,r
CP A,r	INC SP	LD IX/Y,(HL)
		LD IX/Y,(IX/Y+d)
CPD	IND	LD IX/Y,Mmn
CPDR	IND2	LD IX/Y,(Mmn)
	IND2R	LD (IX/Y+d),IX/Y
CPI		LD (IX/Y+d),n
CPIR	INDM	LD (IX/Y+d),r
	INDMR	LD (IX/Y+d),rr
CPL		LD MB,A
	INDR	LD (Mmn),A
DAA	INDRX	LD (Mmn),IX/Y

LD (Mmn),rr	OTDR	RL r
LD (Mmn),SP	OTDRX	
LD R,A		RLA
LD r,(HL)	OTI2R	
LD r,ir		RLC (HL)
LD r,(IX/Y+d)	OTIM	RLC (IX/Y+d)
LD r,n	OTIMR	RLC r
LD r,r'		
LD rr,(HL)	OTIR	RLCA
LD rr,(IX/Y+d)	OTIRX	
LD rr,Mmn		RLD
LD rr,(Mmn)	OUT (BC),r	
LD (rr),A	OUT (C),r	RR (HL)
LD SP,HL	OUT (n),A	RR (IX/Y+d)
LD SP,IX/Y		RR r
LD SP,Mmn	OUTD	
LD SP,(Mmn)	OUTD2	RRA
LDD	OUTI	RRC (HL)
LDDR	OUTI2	RRC (IX/Y+d)
	RL (IX+d)	RRC r
LDI	RL (IY+d	
LDIR		RRCA
	PEA IX+d	
LEA IX/Y,IX+d	PEA IY+d	RRD
LEA IX/Y,IY+d		
LEA rr,IX+d	POP AF	RSMIX
LEA rr,IY+d	POP IX/Y	
	POP rr	RST n
MLT rr		
MLT SP	PUSH AF	SBC A,(HL)
	PUSH IX/Y	SBC A,ir
NEG	PUSH rr	SBC A,(IX/Y+d)
		SBC A,n
NOP	RES b,(IX/Y+d)	SBC A,r
	RES b,r	SBC HL,rr
OR A,(HL)		SBC HL,SP
OR A,ir	RET	
OR A,(IX/Y+d)	RET cc	SCF
OR A,n		
OR A,r	RETI	SET b,(HL)
		SET b,(IX/Y+d)
OTD2R	RETN	SET b,r
OTDM	RL (HL)	SLA (HL)
OTDMR	RL (IX/Y+d)	SLA (IX/Y+d)

SLA r	STMIX	TSTIO n
SLP	SUB A,(HL)	XOR A,(HL)
	SUB A,ir	XOR A,ir
SRA (HL)	SUB A,(IX/Y+d)	XOR A,(IX/Y+d)
SRA (IX/Y+d)	SUB A,n	XOR A,n
SRA r	SUB A,r	XOR A,r
SRL (HL)	TST A,(HL)	
SRL (IX/Y+d)	TST A,n	
SRL r	TST A,r	

The accumulator 'A' argument is optional in all of the following instructions:

ADC A,...	CP A,...	SUB A,...
ADD A,...	OR A,...	TST A,...
AND A,...	SBC A,...	XOR A,...

The following tables, organized by instruction type, lists all possible EZ80/Z80 mnemonic extensions recognized by the ASEZ80 assembler. The designation [] refers to a required addressing mode argument shown in the table above. The allowed mnemonic suffixes are denoted within the enclosing delimiters (). Mnemonics specified with illegal or unrecognized suffixs will be flagged with q or a errors.

AV.3.3 Arithmetic Instructions

adc (.l, .s)	[],[]
add (.l, .s)	[],[]
cp (.l, .s)	[],[]
daa	
dec (.l, .s)	[]
inc (.l, .s)	[]
mlt (.l, .s)	[]
neg	
sbc (.l, .s)	[],[]
sub (.l, .s)	[],[]

AV.3.4 Bit Manipulation Instructions

```
bit (.l, .s)    [],[]  
res (.l, .s)    [],[]  
set (.l, .s)    [],[]
```

AV.3.5 Block Transfer and Compare Instructions

```
cpd (.l, .s)          cpdr (.l, .s)  
cpi (.l, .s)          cpir (.l, .s)  
ldd (.l, .s)          lddr (.l, .s)  
ldi (.l, .s)          ldir (.l, .s)
```

AV.3.6 Exchange Instructions

```
ex (.l, .s)    [],[]  
exx
```

AV.3.7 Input/Output Instructions

```
in      [],[]          in0      [],[]  
ind      (.l, .s)      indr      (.l, .s)  
indx      (.l, .s)  
ind2      (.l, .s)      ind2r      (.l, .s)  
indm      (.l, .s)      indmr      (.l, .s)  
ini      (.l, .s)      inir      (.l, .s)  
inim      (.l, .s)      inimr      (.l, .s)  
otdm      (.l, .s)      otdmr      (.l, .s)  
otdrx      (.l, .s)  
otim      (.l, .s)      otimr      (.l, .s)  
otirx      (.l, .s)  
out      (.l, .s)      [],[]  
out0      (.l, .s)      [],[]  
outd      (.l, .s)      otdr      (.l, .s)  
outd2      (.l, .s)      otdr2      (.l, .s)  
outi      (.l, .s)      otir      (.l, .s)  
outi2      (.l, .s)      oti2r      (.l, .s)  
tstio      []
```

AV.3.8 Load Instructions

```
ld    (.l, .s, .il, .is, .lil, .sis)    [],[]
lea   (.l, .s)    []    pea   (.l, .s)    []
pop   (.l, .s)    []    push (.l, .s)    []
```

AV.3.9 Logical Instructions

```
and   (.l, .s)    [],[]
cpl   (.l, .s)
or    (.l, .s)    [],[]
tst   (.l, .s)    [],[]
xor   (.l, .s)    [],[]
```

AV.3.10 Processor Control Instructions

```
ccf          di          ei
halt         im          nop
rsmix        stmix
scf          slp
```

AV.3.11 Program Flow Instructions

```
call (.il, .is)          []
call (.il, .is)          CC,[]
djnz  []
jp    (.l, .s, .lil, .sis)    []
jp    (.l, .s, .lil, .sis)    CC,[]
jr    []
jr    CC,[]
ret   (.l)
ret   (.l)    CC
reti (.l)
retn (.l)
rst  (.l, .s)    []
```

AV.3.12 Shift and Rotate Instructions

```
rl   (.l, .s)    []    rla
rlc  (.l, .s)    []    rlca
rld          rrd
rr   (.l, .s)    []    rra
rrc  (.l, .s)    []    rrca
sla  (.l, .s)    []
sra  (.l, .s)    []
srl  (.l, .s)    []
```

APPENDIX AW

ASF2MC8 ASSEMBLER

AW.1 PROCESSOR SPECIFIC DIRECTIVES

The ASF2MC8 assembler supports the F2MC8L and F2MC8FX processor cores.

AW.1.1 .8L Directive

Format:

.8L

The .8L directive selects the F2MC8L processor cycle counts to be listed. This is the default selection if no processor directive is specified in the source assembly file.

AW.1.2 .8FX Directive

Format:

.8FX

The .8FX directive selects the F2MC8FX processor cycle counts to be listed. .8L is the default selection if no processor directive is specified in the source assembly file.

AW.1.3 The `.__.CPU.` Variable

The value of the pre-defined symbol '`.__.CPU.`' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASF2MC8 assembler:

Processor Type	<code>.__.CPU.</code> Value
-----	-----
<code>.8L</code>	0
<code>.8FX</code>	1

The variable '`.__.CPU.`' is by default defined as local and will not be output to the created `.rel` file. The assembler command line options `-g` or `-a` will not cause the local symbol to be output to the created `.rel` file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable '`.__.CPU.`' might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

AW.2 F2MC8L/F2MC8FX REGISTERS

The following is a list of register designations recognized by the ASF2MC8 assembler:

<code>pc</code>	-	Program Counter
<code>a</code>	-	Accumulator
<code>t</code>	-	Temporary Accumulator
<code>ix</code>	-	Index Register
<code>ep</code>	-	Extra Pointer
<code>sp</code>	-	Stack Pointer
<code>ps</code>	-	Program Status
<code>r0,r1,r2,r3,</code> <code>r4,r5,r6,r7</code>	-	Memory Registers 32 banks of 8 registers each

AW.3 F2MC8L/F2MC8FX INSTRUCTION SET

The following list specifies the format for each addressing mode supported by ASF2MC8:

#data	immediate data byte or word data
*dir	direct page addressing
*dir:b	bit addressing to a direct page address
ext	extended addressing
a,t pc,sp,ix,ep	register addressing
@a	accumulator indexed
@ix+d	indexed addressing plus offset
@ix	indexed addressing with a zero offset
@ep	pointer addressing
r	General-purpose registers
label	call/jmp/branch label

The terms data, dir, ext, b, d, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the F2MC8L/F2MC8FX technical data for valid modes.

The following tables list all F2MC8L/F2MC8FX mnemonics recognized by the ASF2MC8 assembler. The designation [] refers to a required addressing mode argument.

AW.3.1 Transfer Instructions

mov	[],[]	movw	[],[]
xch	[],[]	xchw	[],[]
clrb	[]	setb	[]
swap	[]		

AW.3.2 Operation Instructions

addc	a,[],[]	addcw	a
subc	a,[],[]	subcw	a
inc	r	incw	[]
dec	r	decw	[]
mulu	a	divu	a
and	a,[],[]	andw	a
cmp	a,[],[]	cmpw	a
or	a,[],[]	orw	a
xor	a,[],[]	xorw	a
rolc	a	rorc	a
daa		das	

AW.3.3 Branch/Jump/Call Instructions

bz	label	bew	label
bnz	label	bne	label
bc	label	blo	label
bnc	label	bhs	label
bn	label	bp	label
blt	label	bge	label
bbc	*dir:b,label	bbs	*dir:b,label
jmp	[]	call	label
callv	#data	xchw	a,pc
ret		reti	

AW.3.4 Other Instructions

pushw	[]	popw	[]
nop			
clrc		setc	
clri		seti	

APPENDIX AX

ASGB ASSEMBLER

AX.1 ACKNOWLEDGEMENT

Thanks to Roger Ivie for his contribution of the ASGB cross assembler.

Roger Ivie
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AX.2 INTRODUCTION

The Gameboy uses an 8-bit processor which is closely related to the 8080. It is usually described as a modified Z80, but may be more closely understood as an enhanced 8080; it has the 8080 register set and many, but not all, enhanced Z80 instructions. However, even this is not accurate, for the Gameboy also lacks some basic 8080 instructions (most annoyingly SHLD and LHLD). ASGB is based on ASZ80 and therefore uses the Z80 mnemonic set.

AX.3 GAMEBOY REGISTER SET AND CONDITIONS

The following is a complete list of register designations and condition mnemonics:

byte registers - a,b,c,d,e,h,l
register pairs - af, bc, de, hl
word registers - pc, sp

C - carry bit set
NC - carry bit clear
NZ - zero bit clear
Z - zero bit set

AX.4 GAMEBOY INSTRUCTION SET

The following tables list all Gameboy mnemonics recognized by the ASGB assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by ASGB:

#data	immediate data byte or word data
n	byte value
rg	a byte register a,b,c,d,e,h,l
rp	a register pair or 16-bit register bc,de,hl
(hl)	implied addressing or register indirect addressing
(label)	direct addressing
label	call/jmp/jr label

The terms data, dir, and ext may all be expression. The term dir is not allowed to be an external reference.

Note that not all addressing modes are valid with every instruction. Although official information is not, as far as I know, publically available for the Gameboy processor, many unofficial sources are available on the internet.

AX.4.1 .tile Directive

Format:

```
.tile /string/           or  
.tile ^/string/
```

where: string is a string of ascii characters taken from the set ' ', '.', '+', '*', '0', '1', '2', and '3'. The string must be a multiple of eight characters long.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .tile directive will give the (q) error.

The Gameboy displays information on the screen using a programmable character set (referred to as "tiles" among Gameboy developers). The ASGB cross assembler has a processor-specific assembler directive to aid in the creation of the game's character set.

Each character is created from an 8x8 grid of pixels, each pixel of which is composed of two bits. The .tile directive accepts a single string argument which is processed to create the byte values corresponding to the lines of pixels in the character. The string argument must be some multiple of 8 characters long, and be one of these characters:

' ' or '0' - for the pixel value 00
'.' or '1' - for the pixel value 01
'+' or '2' - for the pixel value 10
'*' or '3' - for the pixel value 11

The .tile directive processes each 8-character group of its string argument to create the two-byte value corresponding to that line of pixels. The example in the popular extant literature could be done using ASGB like this:

0000 7C 7C	1	.tile " ***** "
0002 00 C6	2	.tile "++ ++ "
0004 C6 00	3	.tile ".. .. "
0006 00 FE	4	.tile "+++++++ "
0008 C6 C6	5	.tile "*** ** "
000A 00 C6	6	.tile "++ ++ "
000C C6 00	7	.tile ".. .. "
000E 00 00	8	.tile " "

Or, using the synonym character set, as:

0010 7C 7C	10	.tile "03333300"
0012 00 C6	11	.tile "22000220"
0014 C6 00	12	.tile "11000110"
0016 00 FE	13	.tile "22222220"
0018 C6 C6	14	.tile "33000330"
001A 00 C6	15	.tile "22000220"
001C C6 00	16	.tile "11000110"
001E 00 00	17	.tile "00000000"

Since .tile is perfectly willing to assemble multiple lines of a character at once (as long as it is given complete rows of pixels), it could even be done as:

```
.tile " ***** ++ ++ .. .. ++++++ "  
.tile "***  ** ++ ++ .. .. "
```

AX.4.2 Potentially Controversial Mnemonic Selection

Although the Gameboy processor is based on the Z80, it does include some features which are not present in the Z80. The Z80 mnemonic set is not sufficient to describe these additional operations; mnemonics must be created for the new operations. The mnemonics ASGB uses are not the same as those used by other publically-available Gameboy assemblers.

AX.4.2.1 Auto-Indexing Loads -

The Gameboy provides instructions to load or store the accumulator indirectly via HL and then subsequently increment or decrement HL. ASGB uses the mnemonic 'ldd' for the instructions which decrement HL and 'ldi' for the instructions which increment HL. Because the Gameboy lacks the Z80's block moves, the mnemonics are not otherwise needed by ASGB.

```
ldd a,(hl)      ldd (hl),a  
ldi a,(hl)      ldi (hl),a
```

AX.4.2.2 Input and Output Operations -

The Gameboy replaces the Z80's separate address space for I/O with a mechanism similar to the zero page addressing of processors such as the 6800 or 6502. All I/O registers in the Gameboy reside in the address range between 0xff00 and 0xffff. The Gameboy adds special instructions to load and store the accumulator from and into this page of memory. The instructions are analogous to the Z80's in and out instructions and ASGB retains the 'in' and 'out' mnemonics for them.

```
in a,(n)        out (n),a  
in a,(c)        out (c),a
```

From ASGB's perspective, the RAM available from 0xff80 through 0xffff is composed of unused I/O locations rather than direct-page RAM.

AX.4.2.3 The 'stop' Instruction -

The publically-available documentation for the Gameboy lists the 'stop' instruction as the two-byte instruction 10 00, and the other freely-available Gameboy assemblers assemble it in that manner. As far as I can tell, the only rationale for this is that the corresponding Z80 instruction ('djnz label') is a two-byte instruction. ASGB assembles 'stop' as the one-byte instruction 10.

AX.4.3 Inherent Instructions

ccf	cpl
daa	di
ei	nop
halt	rla
rlca	rra
rrca	scf
reti	stop
swap	

AX.4.4 Implicit Operand Instructions

adc a,[]	adc []
add a,[]	add []
and a,[]	and []
cp a,[]	cp []
dec a,[]	dec []
inc a,[]	inc []
or a,[]	or []
rl a,[]	rl []
rlc a,[]	rlc []
rr a,[]	rr []
rrc a,[]	rrc []
sbc a,[]	sbc []
sla a,[]	sla []
sra a,[]	sra []
srl a,[]	srl []
sub a,[]	sub []
xor a,[]	xor []

AX.4.5 Load Instructions

ld rg,[]	ld [],rg
ld (bc),a	ld a,(bc)
ld (de),a	ld a,(de)
ld (label),a	ld a,(label)
ld (label),sp	ld rp,#data
ld sp,hl	ld hl,sp
ldd a,(hl)	ldd (hl),a
ldi a,(hl)	ldi (hl),a

AX.4.6 Call/Return Instructions

call C,label	ret C
call NC,label	ret NC
call Z,label	ret Z
call NZ,label	ret NZ
call label	ret

rst n

AX.4.7 Jump Instructions

jp C,label	jp NC,label
jp Z,label	jp NZ,label
jp (hl)	jp label
jr C,label	jr NC,label
jr Z,label	jr NZ,label
jr label	

AX.4.8 Bit Manipulation Instructions

bit n,[]
res n,[]
set n,[]

AX.4.9 Input and Output Instructions

in a,(n)	in a,(c)
out (n),a	out (c),a

AX.4.10 Register Pair Instructions

add hl,rp	add hl,sp
add sp,#data	
push rp	pop rp

APPENDIX AY
ASH8 ASSEMBLER

AY.1 H8/3XX REGISTER SET

The following is a list of the H8 registers used by ASH8:

r0 - r7,sp	16-bit accumulators
r0L - r7L,spL	8-bit accumulators
r0H - r7H,spH	8-bit accumulators
spL,spH,sp	stack pointers
ccr	condition code

AY.2 H8/3XX INSTRUCTION SET

The following tables list all H8/3xx mnemonics recognized by the ASH8 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by ASH8:

#xx:3	immediate data (3 bit)
#xx:8	immediate data (8 bit)
#xx:16	immediate data (16 bit)
*dir	direct page addressing (see .setdp directive) 0xFF00 <= dir <= 0xFFFF
label	branch label
rn	registers (16 bit) r0-r7,sp
rnB	registers (8 bit) r0H-r7H,r0L-r7L,spH,spL

ccr	condition code register
@rn	register indirect
@-rn	register indirect (auto pre-decrement)
@rn+	register indirect (auto post-increment)
@[offset,rn]	register indirect, 16-bit displacement
@@offset	memory indirect, (8-bit address)
ext	extended addressing (16-bit)

The terms data, dir, label, offset, and ext may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the H8/3xx technical data for valid modes.

AY.2.1 Inherent Instructions

eepmov
nop
sleep
rte
rts

AY.2.2 Branch Instructions

bcc	label	bcs	label
beq	label	bf	label
bge	label	bgt	label
bhi	label	bhis	label
bhs	label	ble	label
blo	label	blos	label
bls	label	blt	label
bmi	label	bne	label
bpl	label	bra	label
brn	label	bt	label
bvc	label	bvs	label
bsr	label		

AY.2.3 Single Operand Instructions

Free Form

daa	rnB	das	rnB
dec	rnB	inc	rnB
neg	rnB	not	rnB
rotxl	rnB	rotxr	rnB
rotl	rnB	rotr	rnB
shal	rnB	shar	rnB
shll	rnB	shlr	rnB
push	rn	pop	rn

Byte / Word Form

daa.b	rnB	das.b	rnB
dec.b	rnB	inc.b	rnB
neg.b	rnB	not.b	rnB
rotxl.b	rnB	rotxr.b	rnB
rotl.b	rnB	rotr.b	rnB
shal.b	rnB	shar.b	rnB
shll.b	rnB	shlr.b	rnB
push.w	rn	pop.w	rn

AY.2.4 Double Operand Instructions

Free Form

add	rnB, rnB	add	#xx:8, rnB
add	rn, rn		
adds	#1, rn	adds	#2, rn
addx	rnB, rnB	addx	#xx:8, rnB
cmp	rnB, rnB	cmp	#xx:8, rnB
cmp	rn, rn		
sub	rnB, rnB		
sub	rn, rn		
subs	#1, rn	subs	#2, rn
subx	rnB, rnB	subx	#xx:8, rnB
and	rnB, rnB	and	#xx:8, rnB
		and	#xx:8, ccr
or	rnB, rnB	or	#xx:8, rnB
		or	#xx:8, ccr
xor	rnB, rnB	xor	#xx:8, rnB
		xor	#xx:8, ccr

Byte / Word Form

add.b	rnB, rnB	add.b	#xx:8, rnB
add.w	rn, rn		
cmp.b	rnB, rnB	cmp.b	#xx:8, rnB
cmp.w	rn, rn		
sub.b	rnB, rnB		
sub.w	rn, rn		
addx.b	rnB, rnB	addx.b	#xx:8, rnB
and.b	rnB, rnB	and.b	#xx:8, rnB
		and.b	#xx:8, ccr
or.b	rnB, rnB	or.b	#xx:8, rnB
		or.b	#xx:8, ccr
subx.b	rnB, rnB	subx.b	#xx:8, rnB
xor.b	rnB, rnB	xor.b	#xx:8, rnB
		xor.b	#xx:8, ccr

AY.2.5 Mov Instructions

Free Form

mov	rnB,rnB	mov	rn,rn
mov	#xx:8,rnB	mov	#xx:16,rn
mov	@rn,rnB	mov	@rn,rn
mov	@[offset,rn],rnB	mov	@[offset,rn],rn
mov	@rn+,rnB	mov	@rn+,rn
mov	@dir,rnB		
mov	dir,rnB		
mov	*@dir,rnB		
mov	*dir,rnB		
mov	@label,rnB	mov	@label,rn
mov	label,rnB	mov	label,rn
mov	rnB,@rn	mov	rn,@rn
mov	rnB,@[offset,rn]	mov	rn,@[offset,rn]
mov	rnB,@-rn	mov	rn,@-rn
mov	rnB,@dir		
mov	rnB,dir		
mov	rnB,*@dir		
mov	rnB,*dir		
mov	rnB,@label	mov	rn,@label
mov	rnB,label	mov	rn,label

Byte / Word Form

mov.b	rnB,rnB	mov.w	rn,rn
mov.b	#xx:8,rnB	mov.w	#xx:16,rn
mov.b	@rn,rnB	mov.w	@rn,rn
mov.b	@[offset,rn],rnB	mov.w	@[offset,rn],rn
mov.b	@rn+,rnB	mov.w	@rn+,rn
mov.b	@dir,rnB		
mov.b	dir,rnB		
mov.b	*@dir,rnB		
mov.b	*dir,rnB		
mov.b	@label,rnB	mov.w	@label,rn
mov.b	label,rnB	mov.w	label,rn
mov.b	rnB,@rn	mov.w	rn,@rn
mov.b	rnB,@[offset,rn]	mov.w	rn,@[offset,rn]
mov.b	rnB,@-rn	mov.w	rn,@-rn
mov.b	rnB,@dir		
mov.b	rnB,dir		
mov.b	rnB,*@dir		
mov.b	rnB,*dir		
mov.b	rnB,@label	mov.w	rn,@label
mov.b	rnB,label	mov.w	rn,label

AY.2.6 Bit Manipulation Instructions

bld	#xx:3,rnB	bld	#xx:3,@rn
bld	#xx:3,@dir	bld	#xx:3,dir
bld	#xx:3,*@dir	bld	#xx:3,*dir
bild	#xx:3,rnB	bild	#xx:3,@rn
bild	#xx:3,@dir	bild	#xx:3,dir
bild	#xx:3,*@dir	bild	#xx:3,*dir
bst	#xx:3,rnB	bst	#xx:3,@rn
bst	#xx:3,@dir	bst	#xx:3,dir
bst	#xx:3,*@dir	bst	#xx:3,*dir
bist	#xx:3,rnB	bist	#xx:3,@rn
bist	#xx:3,@dir	bist	#xx:3,dir
bist	#xx:3,*@dir	bist	#xx:3,*dir
band	#xx:3,rnB	band	#xx:3,@rn
band	#xx:3,@dir	band	#xx:3,dir
band	#xx:3,*@dir	band	#xx:3,*dir
biand	#xx:3,rnB	biand	#xx:3,@rn
biand	#xx:3,@dir	biand	#xx:3,dir
biand	#xx:3,*@dir	biand	#xx:3,*dir
bor	#xx:3,rnB	bor	#xx:3,@rn
bor	#xx:3,@dir	bor	#xx:3,dir
bor	#xx:3,*@dir	bor	#xx:3,*dir
bior	#xx:3,rnB	bior	#xx:3,@rn
bior	#xx:3,@dir	bior	#xx:3,dir
bior	#xx:3,*@dir	bior	#xx:3,*dir
bxor	#xx:3,rnB	bxor	#xx:3,@rn
bxor	#xx:3,@dir	bxor	#xx:3,dir
bxor	#xx:3,*@dir	bxor	#xx:3,*dir
bixor	#xx:3,rnB	bixor	#xx:3,@rn
bixor	#xx:3,@dir	bixor	#xx:3,dir
bixor	#xx:3,*@dir	bixor	#xx:3,*dir

AY.2.7 Extended Bit Manipulation Instructions

bset	#xx:3,rnB	bset	#xx:3,@rn
bset	#xx:3,@dir	bset	#xx:3,dir
bset	#xx:3,*@dir	bset	#xx:3,*dir
bset	rnB,rnB	bset	rnB,@rn
bset	rnB,@dir	bset	rnB,dir
bset	rnB,*@dir	bset	rnB,*dir
bclr	#xx:3,rnB	bclr	#xx:3,@rn
bclr	#xx:3,@dir	bclr	#xx:3,dir
bclr	#xx:3,*@dir	bclr	#xx:3,*dir
bclr	rnB,rnB	bclr	rnB,@rn
bclr	rnB,@dir	bclr	rnB,dir
bclr	rnB,*@dir	bclr	rnB,*dir
bnot	#xx:3,rnB	bnot	#xx:3,@rn
bnot	#xx:3,@dir	bnot	#xx:3,dir
bnot	#xx:3,*@dir	bnot	#xx:3,*dir
bnot	rnB,rnB	bnot	rnB,@rn
bnot	rnB,@dir	bnot	rnB,dir
bnot	rnB,*@dir	bnot	rnB,*dir
btst	#xx:3,rnB	btst	#xx:3,@rn
btst	#xx:3,@dir	btst	#xx:3,dir
btst	#xx:3,*@dir	btst	#xx:3,*dir
btst	rnB,rnB	btst	rnB,@rn
btst	rnB,@dir	btst	rnB,dir
btst	rnB,*@dir	btst	rnB,*dir

AY.2.8 Condition Code Instructions

andc	#xx:8,ccr	andc	#xx:8
and	#xx:8,ccr	and.b	#xx:8,ccr
ldc	#xx:8,ccr	ldc	#xx:8
ldc	rnB,ccr	ldc	rnB
orc	#xx:8,ccr	orc	#xx:8
or	#xx:8,ccr	or.b	#xx:8,ccr
xorc	#xx:8,ccr	xorc	#xx:8
xor	#xx:8,ccr	xor.b	#xx:8,ccr
stc	ccr,rnB	stc	rnB

AY.2.9 Other Instructions

divxu	rnB,rn	divxu.b	rnB,rn
mulxu	rnB,rn	mulxu.b	rnB,rn
movfpe	@label,rnB	movfpe	label,rnB
movfpe.b	@label,rnB	movfpe.b	label,rnB
movtpe	@label,rnB	movtpe	label,rnB
movtpe.b	@label,rnB	movtpe.b	label,rnB

AY.2.10 Jump and Jump to Subroutine Instructions

jmp	@rn	jmp	@@dir
jmp	@label	jmp	label
jsr	@rn	jsr	@@dir
jsr	@label	jsr	label

APPENDIX AZ

ASM8C ASSEMBLER

AZ.1 M8C REGISTER SET

The following is a list of the M8C registers used by ASM8C:

A	-	Accumulator
X	-	Index
SP	-	Stack Pointer
F	-	Flags

AZ.2 M8C ADDRESSING MODES

The M8C instructions may have none, one, or two operands selected from the registers listed above or an addressing mode from the following list:

expr	-	immediate argument
	-	In the lcall, ljmp, index, and pc relative branching instructions expr is an address expression.
#expr	-	immediate argument
[expr]	-	argument at location expr
[x+expr]	-	argument at location x + expr
reg[expr]	-	argument at location expr in register space
reg[x+expr]	-	argument at location x + expr in register space
[[expr]++]	-	The value in memory at address expr (the indirect address) points to a memory location in RAM. The value in memory at address expr is then incremented. This addressing mode is used only by the mvi instruction and

allows the short form [expr]
for this addressing mode.

AZ.3 M8C INSTRUCTION SET

The following tables list all M8C mnemonics and addressing modes recognized by the ASM8C assembler.

AZ.3.1 Double Operand Arithmetic Instructions

adc	a,expr		
adc	a,[expr]	adc	[expr],a
adc	a,[x+expr]	adc	[x+expr],a
adc	[expr],expr	adc	[x+expr],expr
add	a,expr		
add	a,[expr]	add	[expr],a
add	a,[x+expr]	add	[x+expr],a
add	[expr],expr	add	[x+expr],expr
add	sp,expr		
cmp	a,expr		
cmp	a,[expr]		
cmp	a,[x+expr]		
cmp	[expr],expr	cmp	[x+expr],expr
sbb	a,expr		
sbb	a,[expr]	sbb	[expr],a
sbb	a,[x+expr]	sbb	[x+expr],a
sbb	[expr],expr	sbb	[x+expr],expr
sub	a,expr		
sub	a,[expr]	sub	[expr],a
sub	a,[x+expr]	sub	[x+expr],a
sub	[expr],expr	sub	[x+expr],expr

AZ.3.2 Double Operand Logic Instructions

and	a,expr	and	f,expr
and	a,[expr]	and	[expr],a
and	a,[x+expr]	and	[x+expr],a
and	[expr],expr	and	[x+expr],expr
and	reg[expr],expr	and	reg[x+expr],expr
or	a,expr	or	f,expr
or	a,[expr]	or	[expr],a
or	a,[x+expr]	or	[x+expr],a
or	[expr],expr	or	[x+expr],expr
or	reg[expr],expr	or	reg[x+expr],expr
xor	a,expr	xor	f,expr
xor	a,[expr]	xor	[expr],a
xor	a,[x+expr]	xor	[x+expr],a
xor	[expr],expr	xor	[x+expr],expr
xor	reg[expr],expr	xor	reg[x+expr],expr

AZ.3.3 Miscellaneous Double Operand Instructions

swap	a,x	swap	a,sp
swap	a,[expr]	swap	a,[x+expr]
tst	[expr]	tst	[x+expr]
tst	reg[expr]	tst	reg[x+expr]

AZ.3.4 Single Operand Shift/Rotate Instructions

asl	a	asl	[x+expr]
asl	[expr]		
asr	a	asr	[x+expr]
asr	[expr]		
rlc	a	rlc	[x+expr]
rlc	[expr]		
rrc	a	rrc	[x+expr]
rrc	[expr]		

AZ.3.5 Miscellaneous Single Operand Instructions

cpl	a		
dec	a	dec	x
dec	[expr]	dec	[x+expr]
inc	a	inc	x
inc	[expr]	inc	[x+expr]
pop	a	pop	x
push	a	push	x
tst	[expr]	tst	[x+expr]
tst	reg[expr]	tst	reg[x+expr]

AZ.3.6 Move Instructions

mov	a,x		
mov	a,expr		
mov	a,[expr]	mov	[expr],a
mov	a[x+expr]	mov	[x+expr],a
mov	x,a	mov	x,sp
mov	x,expr		
mov	x,[expr]	mov	[expr],x
mov	x,[x+expr]		
mov	[expr],expr	mov	[x+expr],expr
mov	[expr],[expr]		
mov	a,reg[expr]	mov	a,reg[x+expr]
mov	reg[expr],a	mov	reg[x+expr],a
mov	reg[expr],expr	mov	reg[x+expr],expr
mvi	a,[expr]	==	mvi a,[[expr]++]
mvi	[expr],a	==	mvi [[expr]++],a

AZ.3.7 Inherent Instructions

halt	nop
romx	ssc
ret	reti

AZ.3.8 Branching Instructions

lcall expr	ljmp expr
jz expr	jnz expr
jc expr	jnc expr
jacc expr	

AZ.3.9 Relative Table Read Instruction

index expr

APPENDIX BA

ASPIC ASSEMBLER

BA.1 PIC ASSEMBLER NOTES

The PIC series of processors uses a non unified addressing scheme: the instruction addressing is 1 per instruction word, each instruction uses a word of memory varying from 12 to 16 bits in length. The processor data is addressed as 1 per byte of data. To properly address the program/data spaces you, the programmer, must separate your program and data into separate code and data areas. The data area is addressed as 1 per byte and the code area is addressed as 1 per instruction.

The assembler/linker processes the instruction code so that the linker will output 2 bytes for each instruction word. The instruction word address will be the file encoded address divided by 2.

BA.2 PROCESSOR SPECIFIC DIRECTIVES

The ASPIC assembler has several processor specific assembler directives. These directives specify a processor name, select a PIC processor family type, define the maximum ram address, specify ram addresses that should not be accessed, and define the register file address page.

BA.2.1 .pic Directive

Format:

```
.pic      /string/                or  
.pic      ^/string/
```

where: string represents a text string. The string is the pic processor type.

/ / represent the delimiting characters. These delimiters may be any paired printing characters, as long as the characters are not contained within the string itself. If the delimiting characters do not match, the .pic directive will give the (q) error.

The assembler uses the delimited string to define a processor specific symbol. e.g: "p12c508" produces the symbol __12c508 having a value of 1. This symbol can then be used in an .ifdef/.else/.endif construct.

The assembler should be configured by including directives similiar to the folowing at the beginning of your assembly file:

```
.pic          "p12c508"          ; Set PIC Name  
.pic12bit     ; Select PIC Type
```

The ASPIC assembler will then be configured for the PIC processor type "p12c508". The .pic directive must precede the PIC type directive. The PIC type directive configures the assembler based on the processor name and type selection.

An alternate method to configure the ASPIC assembler is as follows:

```
.pic          "p12c508"          ; Set PIC Name  
.include      "piccpu.def"       ; Selects PIC Type
```

To define the special function register names, bit values, and memory constraints for a specific processor include the appropriate definition file:

```
.include      "p12c508.def"      ; Definitions
```

BA.2.2 .picnopic Directive

Format:

```
.picnopic
```

This directive deselects all processor specific mnemonics.

BA.2.3 .pic12bit Directive

Format:

```
.pic12bit
```

This directive selects the 12-bit instruction word mnemonics and opcode values to be used during the assembly process.

BA.2.4 .pic14bit Directive

Format:

```
.pic14bit
```

This directive selects the 14-bit instruction word mnemonics and opcode values to be used during the assembly process.

BA.2.5 .pic16bit Directive

Format:

```
.pic16bit
```

This directive selects the 16-bit instruction word mnemonics and opcode values to be used during the assembly process.

BA.2.6 .pic20bit Directive

Format:

```
.pic20bit
```

This directive selects 20-bit addressing and the 16-bit instruction word mnemonics and opcode values to be used during the assembly process.

BA.2.7 The `.__.CPU.` Variable

The value of the pre-defined symbol '`.__.CPU.`' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASPIC assembler:

Processor Type	<code>.__.CPU.</code> Value
-----	-----
<code>.picnopic</code>	0
<code>.pic12bit</code>	1
<code>.pic14bit</code>	2
<code>.pic16bit</code>	3
<code>.pic20bit</code>	4

The variable '`.__.CPU.`' is by default defined as local and will not be output to the created `.rel` file. The assembler command line options `-g` or `-a` will not cause the local symbol to be output to the created `.rel` file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable '`.__.CPU.`' might be a useful means of validating that separately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

BA.2.8 `.picfix` Directive

Format:

```
.picfix chip,    mnemonic,    value
```

This directive can be used to "fix" or change the opcode value of any pic instruction of the currently selected pic type. e.g.:

```
.picfix    "p12c671",    "clrw", 0x0103
```

will change the `"clrw"` instruction's opcode to 0x0103 if the current pic type is `"p12c671"`.

BA.2.9 .maxram Directive

Format:

```
.maxram value
```

Where value is the highest allowed ram address

BA.2.10 .badram Directive

Format:

```
.badram address
```

```
.badram lo:hi
```

Where address is a single location and lo:hi is a range of addresses that should not be used. Multiple locations and/or ranges may be specified by seperating the arguments with a comma:

```
.badram          0x23, 0x28:0x2F, ...
```

The ASPIC assembler will report an error for any absolute register file address in the badram range.

BA.2.11 .setdmm Directive

Format:

```
.setdmm value
```

The .setdmm (set Data Memory Map) directive is used to inform the assembler and linker about which ram bank has been selected for access. The PIC17Cxxx microprocessor family allows upto 2 (or more) banks of 256 byte ram blocks. The PIC18Cxxx microprocessor family allows upto 16 banks of 256 byte ram blocks. The data memory map value must be set on a 256 byte boundary. e.g.:

```
.setdmm    0x0F00
```

The assembler verifies that any absolute address to the register file is within the 256 byte page. External direct references are assumed by the assembler to be in the correct area and have valid offsets. The linker will check all page relocations to verify that they are within the correct addressing range.

BA.3 12-BIT OPCODE PIC

The 12-bit opcode family of PIC processors support the following assembler arguments:

(*)f
(*)f,(#)d
(*)f,(#)b
(#)k
label

where: f register file address
 d destination select:
 (0, -> w), (1 -> f)
 the letters w or f may be used
 to select the destination
 b bit address in an 8-bit file register
 k literal constant
 label label name

Items enclosed in () are optional.

The terms f, d, b, k, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the processor specific technical data for valid modes.

PIC12C5XX CPU Type		
PIC12C508,	PIC12C509,	PIC12CE518
PIC12C508A,	PIC12C509A,	PIC12CE519
PIC12CR509A		

BA.4 14-BIT OPCODE PIC

The 14-bit opcode family of PIC processors support the following assembler arguments:

(*)f
(*)f,(#)d
(*)f,(#)b
(#)k
label

where: f register file address
 d destination select:
 (0, -> w), (1 -> f)
 the letters w or f may be used
 to select the destination

b	bit address in an 8-bit file register
k	literal constant
label	label name

Items enclosed in () are optional.

The terms f, d, b, k, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the processor specific technical data for valid modes.

PIC12C67X CPU Type

PIC12C671,	PIC12C672,	PIC12LC671,
PIC12LC672		
PIC12CE673,	PIC12CE674,	PIC12LCE673,
PIC12LCE674		

PIC14000 CPU Type

PIC14000

PIC16C15X CPU Type

PIC16C154,	PIC16C156,	PIC16C158
PIC16CR154,	PIC16CR156,	PIC16CR158

PIC16C5X CPU Type

PIC16C52		
PIC16C54,	PIC16C54A,	PIC16C54B,
PIC16C54C		
PIC16CR54,	PIC16CR54A,	PIC16C54B,
PIC16CR54C		
PIC16C55,	PIC16C55A,	PIC16C56,
PIC16C56A		
PIC16CR56A		
PIC16C57,	PIC16CR57A,	PIC16C57B,
PIC16C57C		
PIC16C58A,	PIC16CR58A,	PIC16C58B,
PIC16CR58B		

PIC16C55X CPU Type

PIC16C554,	PIC16C556,	PIC16C558
------------	------------	-----------

PIC16C62X, PIC16C64X and, PIC16C66X CPU Types

PIC16C620,	PIC16C621,	PIC16C622
PIC16C642,	PIC16C662	

PIC16C7XX CPU Type

PIC16C71,	PIC16C72,	PIC16CR72	
PIC16C73A,	PIC16C74A,	PIC16C76,	PIC16C77
PIC16C710,	PIC16C711,	PIC16C715	

PIC16C8X CPU Type		
PIC16F83,	PIC16CR83,	PIC16F84,
PIC16CR84		
PIC16HV540		
PIC16F627,	PIC16F628	
PIC16F870,	PIC16F871,	PIC16F872,
PIC16F873		
PIC16F874,	PIC16F876,	PIC16F877
PIC16C9XX CPU Type		
PIC16C923,	PIC16C924	

BA.5 16-BIT OPCODE PIC

The 16-bit opcode family of PIC processors support the following assembler arguments:

```
(*)f
(*)f,(#)d
(*)f,(#)s
(*)f,(#)b
(*)f,(*)p      /      (*)p,(*)f
(#)t,(*)f
(#)t,(#)i,(*)f
{#}k
label
```

where:	f	register file address
	d	destination select:
		(0, -> w), (1 -> f)
		the letters w or f may be used
		to select the destination
	s	destination select:
		(0, -> f and w), (1, -> f)
		the letters w or f may be used
		to select the destination
	t	table byte select:
		(0, -> lower byte)
		(1, -> upper byte)
	i	table pointer control
		(0, -> no change)
		(1, -> post increment)
	b	bit address of an 8-bit file register
	p	peripheral register file address
	k	literal constant
	label	label name

Items enclosed in () are optional.

The terms f, d, s, t, i, b, p, k, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the processor specific technical data for valid modes.

PIC17CXXX CPU Type

PIC17C42,	PIC17C42A,	PIC17C43,	PIC17C44
PIC17C752,	PIC17C756,	PIC17C756A	
PIC17C762,	PIC17C766,	PIC17CR42,	
PIC17CR43			

BA.6 20-BIT ADDRESSING PIC

The 20-bit addressing family of PIC processors support the following assembler arguments:

```
(*)f(,a)
(*)f,(#)d(,(#)a)
(*)f,(#)s
(*)f,(#)b(,(#)a)
(*)fs,(*)fd
(#)t,(*)f
(#)t,(#)i,(*)f
{#}k
label(,(#)s)
((#)s)
mm
```

where:	f	register file address
	fs	register file source
	fd	register file destination
	a	ram access bit (0, -> ACCESS RAM) (1, -> RAM BANK)
	d	destination select: (0, -> w), (1 -> f) the letters w or f may be used to select the destination
	s	fast call/return mode: (0, -> SLOW), (1, -> FAST)
	b	bit address of an 8-bit file register
	mm	TBLRD and TBLWT suffixs ('*', -> no change) ('*+', -> post-increment) ('*-', -> post-decrement) ('+*', -> pre-increment)
	k	literal constant
	label	label name

Items enclosed in () are optional.

The terms f, fs, fd, a, b, d, s, k, and label may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the processor specific technical data for valid modes.

PIC18CXXX CPU Type

PIC18C242,	PIC18C252
PIC18C442,	PIC18C452
PIC18C658,	PIC18C858

BA.7 PIC OPCODES

The following table contains all the mnemonics recognized by the ASPIC assembler. The processors supporting each mnemonic are indicated by the code 'PIC:12:14:16:20' after each instruction type. The designation [] refers to a required addressing mode argument.

addwf	[]	PIC:12:14:16:20
addwfc	[]	PIC:--:--:16:20
andwf	[]	PIC:12:14:16:20
comf	[]	PIC:12:14:16:20
decf	[]	PIC:12:14:16:20
decfsz	[]	PIC:12:14:16:20
dcfsnz	[]	PIC:--:--:16:20
incf	[]	PIC:12:14:16:20
incfsz	[]	PIC:12:14:16:20
infsnz	[]	PIC:--:--:16:20
iorwf	[]	PIC:12:14:16:20
movf	[]	PIC:12:14:--:20
negw	[]	PIC:--:--:16:--
rlf	[]	PIC:12:14:--:--
rlcf	[]	PIC:--:--:16:20
rlncf	[]	PIC:--:--:16:20
rrf	[]	PIC:12:14:--:--
rrcf	[]	PIC:--:--:16:20
rrncf	[]	PIC:--:--:16:20
subfwb	[]	PIC:--:--:--:20
subwf	[]	PIC:12:14:16:20
subwfb	[]	PIC:--:--:16:20
swapf	[]	PIC:12:14:16:20
xorwf	[]	PIC:12:14:16:20

movfp	[[PIC:--:--:16:--
movpf	[[PIC:--:--:16:--
movlb	[[PIC:--:--:16:20
movlr	[[PIC:--:--:16:--
movff	[[PIC:--:--:--:20
lfsr	[[PIC:--:--:--:20
clrf	[[PIC:12:14:16:20
cpfseq	[[PIC:--:--:16:20
cpfsgt	[[PIC:--:--:16:20
cpfslt	[[PIC:--:--:16:20
movwf	[[PIC:12:14:16:20
mulwf	[[PIC:--:--:16:20
negf	[[PIC:--:--:--:20
setf	[[PIC:--:--:16:20
tstfsz	[[PIC:--:--:16:20
bcf	[[PIC:12:14:16:20
bsf	[[PIC:12:14:16:20
btfsc	[[PIC:12:14:16:20
btfss	[[PIC:12:14:16:20
btg	[[PIC:--:--:16:20
addlw	[[PIC:--:14:16:20
andlw	[[PIC:12:14:16:20
iorlw	[[PIC:12:14:16:20
movlw	[[PIC:12:14:16:20
mullw	[[PIC:--:--:16:20
retlw	[[PIC:12:14:16:20
sublw	[[PIC:--:14:16:20
xorlw	[[PIC:12:14:16:20
call	[[PIC:12:14:16:20
goto	[[PIC:12:14:16:20
lcall	[[PIC:--:--:16:--
bc	[[PIC:--:--:--:20
bn	[[PIC:--:--:--:20
bnc	[[PIC:--:--:--:20
bnn	[[PIC:--:--:--:20
bnov	[[PIC:--:--:--:20
bnc	[[PIC:--:--:--:20
bov	[[PIC:--:--:--:20
bz	[[PIC:--:--:--:20
bra	[[PIC:--:--:--:20
rcall	[[PIC:--:--:--:20

tablrd	[]	PIC:--:--:16:--
tablwt	[]	PIC:--:--:16:--
tlrd	[]	PIC:--:--:16:--
tlwt	[]	PIC:--:--:16:--
tblrd	[]	PIC:--:--:--:20
tblwt	[]	PIC:--:--:--:20
clrwdt	[]	PIC:12:14:--:--
clrwdt		PIC:12:14:16:20
daw		PIC:--:--:16:20
nop		PIC:12:14:16:20
option		PIC:12:14:--:--
pop		PIC:--:--:--:20
push		PIC:--:--:--:20
retfie	[]	PIC:--:14:16:20
return	[]	PIC:--:14:16:20
sleep		PIC:12:14:16:20
trist	[]	PIC:12:14:--:--

APPENDIX BB

ASRAB ASSEMBLER

BB.1 ACKNOWLEDGMENT

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BB.2 PROCESSOR SPECIFIC DIRECTIVES

The ASRAB assembler is a port of the ASZ80 assembler. This assembler can process Z80, HD64180 (Z180), and Rabbit 2000/3000 (default) code. The following processor specific assembler directives specify which processor to target when processing the input assembler files.

BB.2.1 .r2k Directive

Format:

.r2k

The .r2k directive enables processing of the Rabbit 2000/3000 specific mnemonics. Mnemonics not associated with the Rabbit 2000/3000 processor will be flagged with an 'o' error. Addressing modes not supported by the Rabbit 2000/3000 will be flagged with an 'a' error. A synonym of .r2k is .r3k. The default assembler mode is .r2k.

The .r2k directive also selects the Rabbit 2000/3000 specific cycles count to be output.

BB.2.2 .hd64 Directive

Format:

.hd64

The .hd64 directive enables processing of the HD64180 (Z180) specific mnemonics not included in the Z80 instruction set. Rabbit 2000/3000 mnemonics encountered will be flagged with an 'o' error. Addressing modes not supported by the HD64180 (Z180) will be flagged with an 'a' error. A synonym of .hd64 is .z180.

The .hd64 directive also selects the HD64180/Z180 specific cycles count to be output.

BB.2.3 .z80 Directive

Format:

.z80

The .z80 directive enables processing of the Z80 specific mnemonics. HD64180 and Rabbit 2000/3000 specific mnemonics will be flagged with an 'o' error. Addressing modes not supported by the z80 will be flagged with an 'a' error.

The .z80 directive also selects the Z80 specific cycles count to be output.

BB.2.4 The `.__.CPU.` Variable

The value of the pre-defined symbol '`.__.CPU.`' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASRAB assembler:

Processor Type	<code>.__.CPU.</code> Value
-----	-----
.r2k / .r3k	0
.hd64 / .z180	1
.z80	2

The variable '`.__.CPU.`' is by default defined as local and will not be output to the created `.rel` file. The assembler command line options `-g` or `-a` will not cause the local symbol to be output to the created `.rel` file.

The assembler `.globl` directive may be used to change the variable type to global causing its definition to be output to the `.rel` file. The inclusion of the definition of the variable '`.__.CPU.`' might be a useful means of validating that seperately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

BB.3 RABBIT 2000/3000 ADDRESSING AND INSTRUCTIONS

BB.3.1 Instruction Symbols

b	Bit select (000 = bit 0, 001 = bit 1, 010 = bit 2, 011 = bit 3, 100 = bit 4, 101 = bit 5, 110 = bit 6, 111 = bit 7)
cc	Condition code select (00 = NZ, 01 = Z, 10 = NC, 11 = C)
d	8-bit (signed) displacement. Expressed in two's complement.
dd	word register select-destination (00 = BC, 01 = DE, 10 = HL, 11 = SP)
dd'	word register select-alternate (00 = BC', 01 = DE', 10 = HL')
e	8-bit (signed) displacement added to PC.
f	condition code select (000 = NZ, 001 = Z, 010 = NC, 011 = C, 100 = LZ/NV, 101 = LO/V, 110 = P, 111 = M)
m	the most significant bits(MSB) of a 16-bit constant
mn	16-bit constant
n	8-bit constant or the least significant bits(LSB) of a 16-bit constant
r, g	byte register select (000 = B, 001 = C, 010 = D, 011 = E, 100 = H, 101 = L, 111 = A)
ss	word register select-source (00 = BC, 01 = DE, 10 = HL, 11 = SP)
v	Restart address select (010 = 0020h, 011 = 0030h, 100 = 0040h, 101 = 0050h, 111 = 0070h)
x	an 8-bit constant to load into the XPC
xx	word register select (00 = BC, 01 = DE, 10 = IX, 11 = SP)
yy	word register select (00 = BC, 01 = DE, 10 = IY, 11 = SP)
zz	word register select (00 = BC, 01 = DE, 10 = HL, 11 = AF)

C	-	carry bit set
M	-	sign bit set
NC	-	carry bit clear
NZ	-	zero bit clear
P	-	sign bit clear
PE	-	parity even
V	-	overflow bit set
PO	-	parity odd
NV	-	overflow bit clear
Z	-	zero bit set

The terms m, mn, n, and x may all be expressions. The terms b and v are not allowed to be external references.

BB.3.2 Rabbit Instructions

The following list of instructions (with explicit addressing modes) are available in the Rabbit 2000/3000 assembler mode. Those instructions denoted by an asterisk (*) are additional instructions not available in the HD64180 or Z80 assembler mode.

ADC A,n	DEC IX	LD A,EIR
ADC A,r	DEC IY	LD A,IIR
ADC A,(HL)	DEC r	*LD A,XPC
ADC A,(IX+d)	DEC ss	LD A,(BC)
ADC A,(IY+d)	DEC (HL)	LD A,(DE)
ADC HL,ss	DEC (IX+d)	LD A,(mn)
ADD A,n	DEC (IY+d)	*LD dd,BC
ADD A,r	DJNZ e	*LD dd,DE
ADD A,(HL)		LD dd,mn
ADD A,(IX+d)	EX AF,AF	LD dd,(mn)
ADD A,(IY+d)	EX DE,HL	LD EIR,A
ADD HL,ss	EX DE,HL	*LD HL,IX
ADD IX,xx	EX (SP),HL	*LD HL,IY
ADD IY,yy	EX (SP),IX	*LD HL,(HL+d)
*ADD SP,d	EX (SP),IY	*LD HL,(IX+d)
*ALTD	EXX	*LD HL,(IY+d)
*AND HL,DE		LD HL,(mn)
*AND IX,DE	INC IX	*LD HL,(SP+n)
*AND IY,DE	INC IY	LD IIR,A
AND n	INC r	*LD IX,HL
AND r	INC ss	LD IX,mn
AND (HL)	INC (HL)	LD IX,(mn)
AND (IX+d)	INC (IX+d)	*LD IX,(SP+n)
AND (IY+d)	INC (IY+d)	*LD IY,HL
	*IOE	LD IY,mn
BIT b,r	*IOI	LD IY,(mn)
BIT b,(HL)	*IPRES	*LD IY,(SP+n)
BIT b,(IX+d)	*IPSET 0	LD r,g
BIT b,(IY+d)	*IPSET 1	LD r,n
*BOOL HL	*IPSET 2	LD r,(HL)
*BOOL IX	*IPSET 3	LD r,(IX+d)
*BOOL IY		LD r,(IY+d)
	JP f,mn	LD SP,HL
CALL mn	JP mn	LD SP,IX
CCF	JP (HL)	LD SP,IY
CP n	JP (IX)	*LD XPC,A
CP r	JP (IY)	LD (BC),A
CP (HL)	JR cc,e	LD (DE),A
CP (IX+d)	JR e	LD (HL),n
CP (IY+d)		LD (HL),r
CPL	*LCALL x,mn	

*LD (HL+d),HL	*POP IP	SBC A,n
*LD (IX+d),HL	POP IX	SBC A,r
LD (IX+d),n	POP IY	SBC A,(HL)
LD (IX+d),r	POP zz	SBC HL,ss
*LD (IY+d),HL	*PUSH IP	SBC (IX+d)
LD (IY+d),n	PUSH IX	SBC (IY+d)
LD (IY+d),r	PUSH IY	SCF
LD (mn),A	PUSH zz	SET b,r
LD (mn),HL	RA	SET b,(HL)
LD (mn),IX	RES b,r	SET b,(IX+d)
LD (mn),IY	RES b,(HL)	SET b,(IY+d)
LD (mn),ss	RES b,(IX+d)	SLA r
*LD (SP+n),HL	RES b,(IY+d)	SLA (HL)
*LD (SP+n),IX	RET	SLA (IX+d)
*LD (SP+n),IY	RET f	SLA (IY+d)
LDD	*RETI	SRA r
LDDR	*RL DE	SRA (HL)
LDI	RL r	SRA (IX+d)
LDIR	RL (HL)	SRA (IY+d)
*LDP HL,(HL)	RL (IX+d)	SRL r
*LDP HL,(IX)	RL (IY+d)	SRL (HL)
*LDP HL,(IY)	RLA	SRL (IX+d)
*LDP HL,(mn)	RLC r	SRL (IY+d)
*LDP IX,(mn)	RLC (HL)	SUB n
*LDP IY,(mn)	RLC (IX+d)	SUB r
*LDP (HL),HL	RLC (IY+d)	SUB (HL)
*LDP (IX),HL	RLCA	SUB (IX+d)
*LDP (IY),HL	*RR DE	SUB (IY+d)
*LDP (mn),HL	*RR HL	XOR n
*LDP (mn),IX	*RR IX	XOR r
*LDP (mn),IY	*RR IY	XOR (HL)
LJP x,mn	RR r	XOR (IX+d)
LRET	RR (HL)	XOR (IY+d)
*MUL	RR (IX+d)	
	RR (IY+d)	
NEG	RRC r	
NOP	RRC (HL)	
	RRC (IX+d)	
*OR HL,DE	RRC (IY+d)	
*OR IX,DE	RRCA	
*OR IY,DE	RST v	
OR n		
OR r		
OR (HL)		
OR (IX+d)		
OR (IY+d)		

BB.4 Z80/HD64180 ADDRESSING AND INSTRUCTIONS

The following list specifies the format for each Z80/HD64180 addressing mode supported by ASZ80:

#data	immediate data byte or word data
n	byte value
rg	a byte register a,b,c,d,e,h,l
rp	a register pair bc,de,hl
(hl)	implied addressing or register indirect addressing
(label)	direct addressing
(ix+offset) offset(ix)	indexed addressing with an offset
label	call/jmp/jr label

The terms data, n, label, and offset, may all be expressions. The terms dir and offset are not allowed to be external references.

The following tables list all Z80/HD64180 mnemonics recognized by the ASRAB assembler. The designation [] refers to a required addressing mode argument. Note that not all addressing modes are valid with every instruction, refer to the Z80/HD64180 technical data for valid modes.

BB.4.1 Inherent Instructions

ccf	cpd
cpdr	cpi
cpir	cpl
daa	di
ei	exx
halt	neg
nop	reti
retn	rla
rlca	rld
rra	rrca
rrd	scf

BB.4.2 Implicit Operand Instructions

adc	a,[]	adc	[]
add	a,[]	add	[]
and	a,[]	and	[]
cp	a,[]	cp	[]
dec	a,[]	dec	[]
inc	a,[]	inc	[]
or	a,[]	or	[]
rl	a,[]	rl	[]
rlc	a,[]	rlc	[]
rr	a,[]	rr	[]
rrc	a,[]	rrc	[]
sbc	a,[]	sbc	[]
sla	a,[]	sla	[]
sra	a,[]	sra	[]
srl	a,[]	srl	[]
sub	a,[]	sub	[]
xor	a,[]	xor	[]

BB.4.3 Load Instruction

ld	rg,[]	ld	[],rg
ld	(bc),a	ld	a,(bc)
ld	(de),a	ld	a,(de)
ld	(label),a	ld	a,(label)
ld	(label),rp	ld	rp,(label)
ld	i,a	ld	r,a
ld	a,i	ld	a,r
ld	sp,hl	ld	sp,ix
ld	sp,iy	ld	rp,#data
ldd		laddr	
ldi		ldir	

BB.4.4 Call/Return Instructions

call	C,label	ret	C
call	M,label	ret	M
call	NC,label	ret	NC
call	NZ,label	ret	NZ
call	P,label	ret	P
call	PE,label	ret	PE
call	PO,label	ret	PO
call	Z,label	ret	Z
call	label	ret	

BB.4.5 Jump and Jump to Subroutine Instructions

jp	C,label	jp	M,label
jp	NC,label	jp	NZ,label
jp	P,label	jp	PE,label
jp	PO,label	jp	Z,label
jp	(hl)	jp	(ix)
jp	(iy)	jp	label
djnz	label		
jr	C,label	jr	NC,label
jr	NZ,label	jr	Z,label
jr	label		

BB.4.6 Bit Manipulation Instructions

```
bit    n,[]  
res    n,[]  
set    n,[]
```

BB.4.7 Interrupt Mode and Reset Instructions

```
im     n  
im     n  
im     n  
rst    n
```

BB.4.8 Input and Output Instructions

```
in      a,(n)          in      rg,(c)  
ind      indr  
ini      inir  
out      (n),a         out      (c),rg  
outd     otdr  
outi     otir
```

BB.4.9 Register Pair Instructions

```
add      hl,rp          add      ix,rp  
add      iy,rp  
adc      hl,rp          sbc      hl,rp  
ex      (sp),hl        ex      (sp),ix  
ex      (sp),iy  
ex      de,hl  
ex      af,af'  
push     rp            pop      rp
```

BB.4.10 HD64180 Specific Instructions

in0	rg,(n)		
out0	(n),rg		
otdm		otdmr	
otim		otimr	
mlt	bc	mlt	de
mlt	hl	mlt	sp
slp			
tst	a		
tstio	#data		

APPENDIX BC

ASSCMP ASSEMBLER

BC.1 SC/MP REGISTER SET

The following is a list of the SC/MP registers used by ASSCMP:

p0,pc	-	16-bit program counter
p1,p2,p3	-	16-bit pointer registers

BC.2 SC/MP ADDRESSING MODES

The general addressing modes are normally described in the form @DISP(X) which correspond to these specific modes:

DISP	a PC relative address
DISP(X)	a DISplacement from a pointer register
@DISP(X)	An auto-increment DISplacement from a pointer register

The ASSCMP assembler also allows the (and) designators to be replaced by the [and] designators.

The ASSCMP assembler also allows several shorthand notations for the addressing modes as shown here:

(X)	==>>	0(X)
@(X)	==>>	@0(X)
@DISP	==>>	@DISP(PC)

The xpal, xpah, and xppc instructions require only a pointer register - p0, p1, p2, p3, or pc.

The standard memory reference instructions: ld, and, or, xor, dad, add, and cad also allow an alternate immediate mode instruction using the following format:

```
ld  #DATA
```

The # is required otherwise DATA will be treated as a PC relative address.

The immediate mode instructions: ldi, ani, ori, xri, dai, adi, and cai allow either of these forms:

```
ldi #DATA
ldi DATA
```

BC.3 SC/MP INSTRUCTION SET

The following tables list all SC/MP mnemonics recognized by the ASSCMP assembler.

BC.3.1 Memory Reference Instructions

ld	@DISP(X) / #data	Load
st	@DISP(X) -----	Store
and	@DISP(X) / #data	AND
or	@DISP(X) / #data	OR
xor	@DISP(X) / #data	Exclusive OR
dad	@DISP(X) / #data	Decimal Add
add	@DISP(X) / #data	Add
cad	@DISP(X) / #data	Complement and Add

BC.3.2 Immediate Instructions

ldi	#data / data	Load Immediate
ld	#data	
ani	#data / data	AND Immediate
and	#data	
ori	#data / data	Or Immediate
or	#data	
xri	#data / data	Exclusive Or Immediate
xor	#data	
dai	#data / data	Decimal Add Immediate
dad	#data	
adi	#data / data	Add Immediate
add	#data	
cai	#data / data	Complement and Add Immediate
cad	#data	

BC.3.3 Extension Register Instructions

lde	Load AC from Extension
xae	Exchange AC and Extension
ane	AND Extension
ore	OR Extension
xre	Exclusive Or Extension
dae	Decimal Add Extension
ade	Add Extension
cae	Complement and Add Extension

BC.3.4 Memory Increment/Decrement Instructions

dld	DISP(X)	Increment and Load
ild	DISP(X)	Decrement and Load

BC.3.5 Transfer Instructions

jmp	DISP(X)	Jump
jp	DISP(X)	Jump if Positive
jz	DISP(X)	Jump if Zero
jnz	DISP(X)	Jump if Not Zero

BC.3.6 Pointer Register Move Instructions

xpal	X	Exchange Pointer Low
xpah	X	Exchange Pointer High
xppc	X	Exchange Pointer with PC

BC.3.7 Shift, Rotate, Serial I/O Instructions

sio	Serial Input/Output
sr	Shift Right
srl	Shift Right with Link
rr	Rotate Right
rrl	Rotate Right with Link

BC.3.8 Single-Byte Miscellaneous Instructions

halt	Halt
ccl	Clear Carry Link
scl	Set Carry Link
dint	Disable Interrupt
ien	Enable Interrupt
csa	Copy Status to AC
cas	Copy AC to Status
nop	No Operation

BC.3.9 Double-Byte Miscellaneous Instruction

dly	#data / data	Delay
-----	--------------	-------

APPENDIX BD
ASZ8 ASSEMBLER

BD.1 Z8 REGISTER SET

The following is a list of the Z8 registers used by ASZ8:

r0 ... r15	-	8-bit accumulators
rr0 ... rr15	-	16-bit accumulators

BD.2 Z8 INSTRUCTION SET

The following tables list all Z8 mnemonics recognized by the ASZ8 assembler. The designation [] refers to a required addressing mode argument. The following list specifies the format for each addressing mode supported by ASZ8:

#data		immediate byte data
addr		location/branch address
r0 ... r15		8-bit registers
rr0 ... rr15		16-bit registers
@rn	or	register indirect addressing
(rn)		
@rrn	or	register indirect addressing
(rrn)		
@addr	or	indirect addressing
(addr)		
offset(rn)		indexed register addressing

The terms data, addr, and offset may all be expressions.

The designation CC refers to a condition code argument. The following table contains all the valid condition codes supported by ASZ8:

f	Always False	-
t	Always True	-
c	Carry	C=1
nc	No Carry	C=0
z	Zero	Z=1
nz	Non-Zero	Z=0
pl	Plus	S=0
mi	Minus	S=1
ov	Overflow	V=1
nov	No Overflow	V=0
eq	Equal	Z=1
ne	Not Equal	Z=0
ge	Greater Than or Equal	(S XOR V)=0
lt	Less Than	(S XOR V)=1
gt	Greater Than	(Z OR (S XOR V))=0
le	Less Than or Equal	(Z OR (S XOR V))=1
uge	Unsigned ge	C=0
ult	Unsigned lt	C=1
ugt	Unsigned gt	(C=0 AND Z=0)=1
ule	Unsigned le	(C OR Z)=1

Note that not all addressing modes are valid with every instruction, refer to the Z8 technical data for valid modes.

BD.2.1 Load Instructions

clr	[[
ld	[[,[[ldc	[[,[[
pop	[[push	[[

BD.2.2 Arithmetic Instructions

adc	[[,[[add	[[,[[
cp	[[,[[da	[[
dec	[[decw	[[
inc	[[incw	[[
sbc	[[,[[sub	[[,[[

BD.2.3 Logical Instructions

and	[],[]	com	[]
or	[],[]	xor	[],[]

BD.2.4 Program Control Instructions

call	[]	djnz	[],[]
iret		jp	CC,[]
jr	CC,[]	ret	

BD.2.5 Bit Manipulation Instructions

tcm	[],[]	tm	[],[]
and	[],[]	or	[],[]
xor	[],[]		

BD.2.6 Block Transfer Instructions

ldci	[],[]
------	-------

BD.2.7 Rotate and Shift Instructions

rl	[]	rlc	[]
rr	[]	rrc	[]
sra	[]	swap	[]

BD.2.8 Cpu Control Instructions

ccf		ei	
di		nop	
halt		scf	
rcf			
srp	[]	wait	
stop			

APPENDIX BE
ASZ80 ASSEMBLER

BE.1 .z80 DIRECTIVE

Format:

.z80

The .z80 directive enables processing of only the z80 specific mnemonics. HD64180/Z180 mnemonics encountered without the .hd64 directive will be flagged with an 'o' error.

The .z80 directive also selects the Z80 specific cycles count to be output.

BE.2 .hd64 DIRECTIVE

Format:

.hd64

The .hd64 directive enables processing of the HD64180/Z180 specific mnemonics not included in the Z80 instruction set. HD64180/Z180 mnemonics encountered without the .hd64 directive will be flagged with an 'o' error. A synonym of .hd64 is .z180.

The .hd64 directive also selects the HD64180/Z180 specific cycles count to be output.

BE.3 THE .__.CPU. VARIABLE

The value of the pre-defined symbol '.__.CPU.' corresponds to the selected processor type. The default value is 0 which corresponds to the default processor type. The following table lists the processor types and associated values for the ASZ80 assembler:

Processor Type	.__.CPU. Value
-----	-----
.z80	0
.hd64 / .z180	1

The variable '.__.CPU.' is by default defined as local and will not be output to the created .rel file. The assembler command line options -g or -a will not cause the local symbol to be output to the created .rel file.

The assembler .globl directive may be used to change the the variable type to global causing its definition to be output to the .rel file. The inclusion of the definition of the variable '.__.CPU.' might be a useful means of validating that seperately assembled files have been compiled for the same processor type. The linker will report an error for variables with multiple non equal definitions.

BE.4 Z80 REGISTER SET AND CONDITIONS

The following is a complete list of register designations and condition mnemonics:

byte registers	-	a,b,c,d,e,h,l,i,r
register pairs	-	af,af',bc,de,hl
word registers	-	pc,sp,ix,iy

C	-	carry bit set
M	-	sign bit set
NC	-	carry bit clear
NZ	-	zero bit clear
P	-	sign bit clear
PE	-	parity even
PO	-	parity odd
Z	-	zero bit set

BE.5 Z80 INSTRUCTION SET

The following list specifies the format for each addressing mode supported by ASZ80:

#data	immediate data byte or word data
n	byte value
rg	a byte register a,b,c,d,e,h,l
rp	a register pair bc,de,hl
(hl)	implied addressing or register indirect addressing
(label)	direct addressing
offset(ix)	indexed addressing with an offset
label	call/jmp/jr label

The terms data, n, label, and offset may all be expressions.

Note that not all addressing modes are valid with every instruction, refer to the Z80/HD64180/Z180 technical data for valid modes.

The following tables list all Z80/HD64180/Z180 mnemonics recognized by the ASZ80 assembler. The designation [] refers to a required addressing mode argument.

BE.5.1 Inherent Instructions

ccf	cpd
cpdr	cpi
cpir	cpl
daa	di
ei	exx
halt	neg
nop	reti
retn	rla
rlca	rld
rra	rrca
rrd	scf

BE.5.2 Implicit Operand Instructions

adc	a,[]	adc	[]
add	a,[]	add	[]
and	a,[]	and	[]
cp	a,[]	cp	[]
dec	a,[]	dec	[]
inc	a,[]	inc	[]
or	a,[]	or	[]
rl	a,[]	rl	[]
rlc	a,[]	rlc	[]
rr	a,[]	rr	[]
rrc	a,[]	rrc	[]
sbc	a,[]	sbc	[]
sla	a,[]	sla	[]
sra	a,[]	sra	[]
srl	a,[]	srl	[]
sub	a,[]	sub	[]
xor	a,[]	xor	[]

BE.5.3 Load Instruction

ld	rg,[]	ld	[],rg
ld	(bc),a	ld	a,(bc)
ld	(de),a	ld	a,(de)
ld	(label),a	ld	a,(label)
ld	(label),rp	ld	rp,(label)
ld	i,a	ld	r,a
ld	a,i	ld	a,r
ld	sp,hl	ld	sp,ix
ld	sp,iy	ld	rp,#data
ldd		lddr	
ldi		ldir	

BE.5.4 Call/Return Instructions

call	C,label	ret	C
call	M,label	ret	M
call	NC,label	ret	NC
call	NZ,label	ret	NZ
call	P,label	ret	P
call	PE,label	ret	PE
call	PO,label	ret	PO
call	Z,label	ret	Z
call	label	ret	

BE.5.5 Jump and Jump to Subroutine Instructions

jp	C,label	jp	M,label
jp	NC,label	jp	NZ,label
jp	P,label	jp	PE,label
jp	PO,label	jp	Z,label
jp	(hl)	jp	(ix)
jp	(iy)	jp	label
djnz	label		
jr	C,label	jr	NC,label
jr	NZ,label	jr	Z,label
jr	label		

BE.5.6 Bit Manipulation Instructions

```
bit    n,[]  
res    n,[]  
set    n,[]
```

BE.5.7 Interrupt Mode and Reset Instructions

```
im     n  
im     n  
im     n  
rst    n
```

BE.5.8 Input and Output Instructions

in	a,(n)	in	rg,(c)
ind		indr	
ini		inir	
out	(n),a	out	(c),rg
outd		otdr	
outi		otir	

BE.5.9 Register Pair Instructions

add	hl,rp	add	ix,rp
add	iy,rp		
adc	hl,rp	sbc	hl,rp
ex	(sp),hl	ex	(sp),ix
ex	(sp),iy		
ex	de,hl		
ex	af,af'		
push	rp	pop	rp

BE.5.10 HD64180/Z180 Specific Instructions

in0 rg,(n)
out0 (n),rg

otdm otdmr
otim otimr

mlt bc mlt de
mlt hl mlt sp

slp

tst a
tstio #data