



ImageCraft Assembly Language Guide

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1. Introduction

The PSoC Designer Assembly Language Guide documents the assembly language instruction set for the M8C microcontroller as well as other compatible assembly practices. It covers the ImageCraft Assembler.

The PSoC Designer Integrated Development Environment (IDE) software is available free of charge and supports development in assembly language. For customers interested in developing in C, compilers are available. Please contact your local distributor if you are interested in purchasing a C Compiler for PSoC Designer. For more information about developing in C for the PSoC device, please read the *PSoC Designer C Language Compiler Guide* available at the Cypress web site at www.cypress.com.

1.1 Chapter Overviews

Table 1-1. Overview of the Assembly Language Guide

Chapter	Description
Introduction (on page 7)	Describes the purpose of this guide, overviews each chapter, supplies product support and upgrade information, and lists documentation conventions.
M8C Microprocessor (on page 11)	Discusses the microprocessor and explains address spaces, instruction format, and destination of instruction results. It also lists all addressing modes and provides examples of each.
ImageCraft Assembler (on page 25)	Provides assembly language source syntax including labels, mnemonics, operands, comments, and directives. Describes the various file formats created by the ImageCraft Assembler, along with the convention for restoring internal registers and compiling a file into a library module.
M8C Instruction Set (on page 37)	Provides a detailed list of all M8C instructions. Information about individual M8C instructions is also available via *PSoC Designer Online Help*.
Assembler Directives (on page 75)	Provides a detailed list of all ImageCraft Assembler directives.
Builds and Error Messages (on page 97)	Supplies several lists of assembler-related errors and warnings, along with their possible solutions.
Appendix A Reference Tables Appendix (on page 99)	Serves as a quick reference to the M8C instruction set, and assembler directives and syntax expressions, along with an ASCII code table.

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1.2 Support

Free support for PSoC Designer is available online, just click on PSoC Mixed-Signal Controllers then Technical Support. Resources include Training Seminars, Discussion Forums, Application Notes, PSoC Consultants, TightLink Technical Support Email/Knowledge Base, and Application Support Technicians.

Before utilizing the Cypress support services, know the version of PSoC Designer installed on your system. To quickly determine the version, build, or service pack of your current installation of PSoC Designer, click Help > About PSoC Designer.

Support for the ImageCraft C Compiler and Assembler is available from ImageCraft.
http://www.imagecraft.com/

1.2.1 Technical Support Systems

Enter a technical support request in this system with a guaranteed response time of four hours at http://www.cypress.com/support/login.cfm

1.2.2 Product Upgrades

Cypress provides scheduled upgrades and version enhancements for PSoC software free of charge. You can order upgrades from your distributor on CD-ROM or download them directly from www.cypress.com under Software and Drivers. Critical updates to system documentation are also available on the Cypress web site.

1.3 Documentation Conventions

The following are easily identifiable conventions used throughout this guide.

Table 1-2. Documentation Conventions

Convention	Usage
`Courier New`	Displays file locations, user entered text, and source code: `C:\ ...cd\icc\`
Italics	Displays file names and reference documentation: Read about the *sourcefile.hex* file in the *PSoC Designer Guide*.
[**Bracketed, Bold**]	Displays keyboard commands in procedures: [**Enter**] or [**Ctrl**] [**C**]
File > Open	Represents menu paths: File > Open > New Project
Bold	Displays commands, menu paths, and icon names in procedures: Click the **File** icon and then click **Open**.
Text in gray boxes	Presents cautions or unique functionality of the product.

The following are acronyms used throughout this guide.

Table 1-3. Acronyms

Acronym	Description
A	CPU_A register (accumulator)
CF	carry flag
F	CPU_F register (flags ZF, CF, and others)
GIE	global enable interrupt
IDE	integrated development environment

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Table 1-3. Acronyms

Acronym	Description
NOP	no operation
PC	CPU_PC register (program counter)
POR	power-on-reset
RAM	random access memory
REG	register space
ROM	read only memory
SP	CPU_SP register (stack pointer)
SROM	supervisory read only memory
SSC	supervisory system call
WDR	watchdog timer reset
X	CPU_X register (index)
XRES	external reset
ZF	zero flag

1.4 Revision History

Table 1-4. Revision History

Revision	PDF Creation Date	Origin of Change	Description of Change
**	May 20, 2008	FSU	Put the original ImageCraft Assembly Guide in a new template and assigned a Spec Number.
*A	Sept 11, 2008	OGNE/ PYRS	Made changes in the Assembly instructions chapter, page 72.
*B	June 06, 2011	RAVG	Made changes in the Assembly Assembler Introduction. And added Note under section 3.1.1 - Labels

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2. M8C Microprocessor

This chapter covers internal M8C registers, address spaces, instruction summary and formats, and addressing modes for the M8C microprocessor. The M8C is a 4 MIPS 8-bit Harvard architecture microprocessor. Code selectable processor clock speeds from 93.7 kHz to 24 MHz allow the M8C to be tuned to a particular application's performance and power requirements. The M8C supports a rich instruction set which allows for efficient low-level language support. For a detailed description of all M8C instructions, refer to the M8C Instruction Set chapter on page 37.

2.1 Internal Registers

The M8C has five internal registers that are used in program execution:

- Accumulator (A)
- Index (X)
- Program Counter (PC)
- Stack Pointer (SP)
- Flags (F)

All of the internal M8C registers are 8 bits in width, except for the PC (CPU_PC register) which is 16 bits wide. Upon reset, A, X, PC, and SP are reset to 0x00. The Flag register CPU_F (F) is reset to 0x02 indicating that the Z flag is set.

With each stack operation, the SP is automatically incremented or decremented so that it always points at the next stack byte in Random Access Memory (RAM). If the last byte in the stack is at address 0xFF in RAM, the Stack Pointer (CPU_SP or SP) will wrap to RAM address 0x00. It is the firmware developer's responsibility to ensure that the stack does not overlap with user-defined variables in RAM.

As shown in Table 2-1, the Flag register has 6 of 8 bits defined. The PgMode and XIO bits are used to control the active register and RAM address spaces in the PSoC device. The C and Z bits are the Carry and Zero flags respectively. These flags are affected by arithmetic, logical, and shift operations provided in the M8C instruction. The GIE bit is the Global Interrupt Enable. When set, this bit allows the M8C to be interrupted by the PSoC device's interrupt controller.

Table 2-1. M8C Internal Flag (F) Register (CPU_F)

Bits	7	6	5	4	3	2	1	0
Name	PgMode[1:0]			XIO		C	Z	GIE

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With the exception of the CPU_F register, the M8C internal registers are not accessible via an explicit register address. PSoC parts in the CY8C25xxx and CY8C26xxx device family do not have a readable CPU_F register. The `OR F, expr` and `AND F, expr` instructions must be used to set and clear CPU_F register bits. The internal M8C registers are accessed using special instructions such as:

- `MOV A, expr`
- `MOV X, expr`
- `SWAP A, SP`
- `OR F, expr`
- `JMP`

The CPU_F register may be read by using address `0xF7` in any register bank, except in CY8C25xxx and CY8C26xxx devices.

2.2 Address Spaces

The M8C microcontroller has three address spaces: ROM, RAM, and registers. The Read Only Memory (ROM) address space is accessed via its own address and data bus. Figure 2-1 illustrates the arrangement of the PSoC device address spaces.

The ROM address space is composed of the Supervisory ROM and the on-chip Flash program store. Flash is organized into 64-byte blocks. The user need not be concerned with program store page boundaries, because the M8C automatically increments the 16-bit CPU_PC register (`PC`) on every instruction making the block boundaries invisible to user code. Instructions occurring on a 256-byte Flash page boundary (with the exception of jump instructions) incur an extra M8C clock cycle because the upper byte of the Program Counter (PC) is incremented.

The register address space is used to configure the PSoC device's programmable blocks. It consists of two banks of 256 bytes each. To switch between banks, the XIO bit in the Flag register is set or cleared (set for Bank1 = Configuration Space, cleared for Bank0 = User Space). The common convention is to leave the bank set to Bank0 (XIO cleared), switch to Bank1 as needed (set XIO), then switch back to Bank0.

RAM is broken into 256-byte pages. For PSoC devices with 256 bytes of RAM or less, the program stack is stored in RAM Page 0. For PSoC devices with 512 bytes of RAM or more, the stack is constrained to the last RAM page. For information on RAM configuration in a specific device, refer to the device-specific data sheet.

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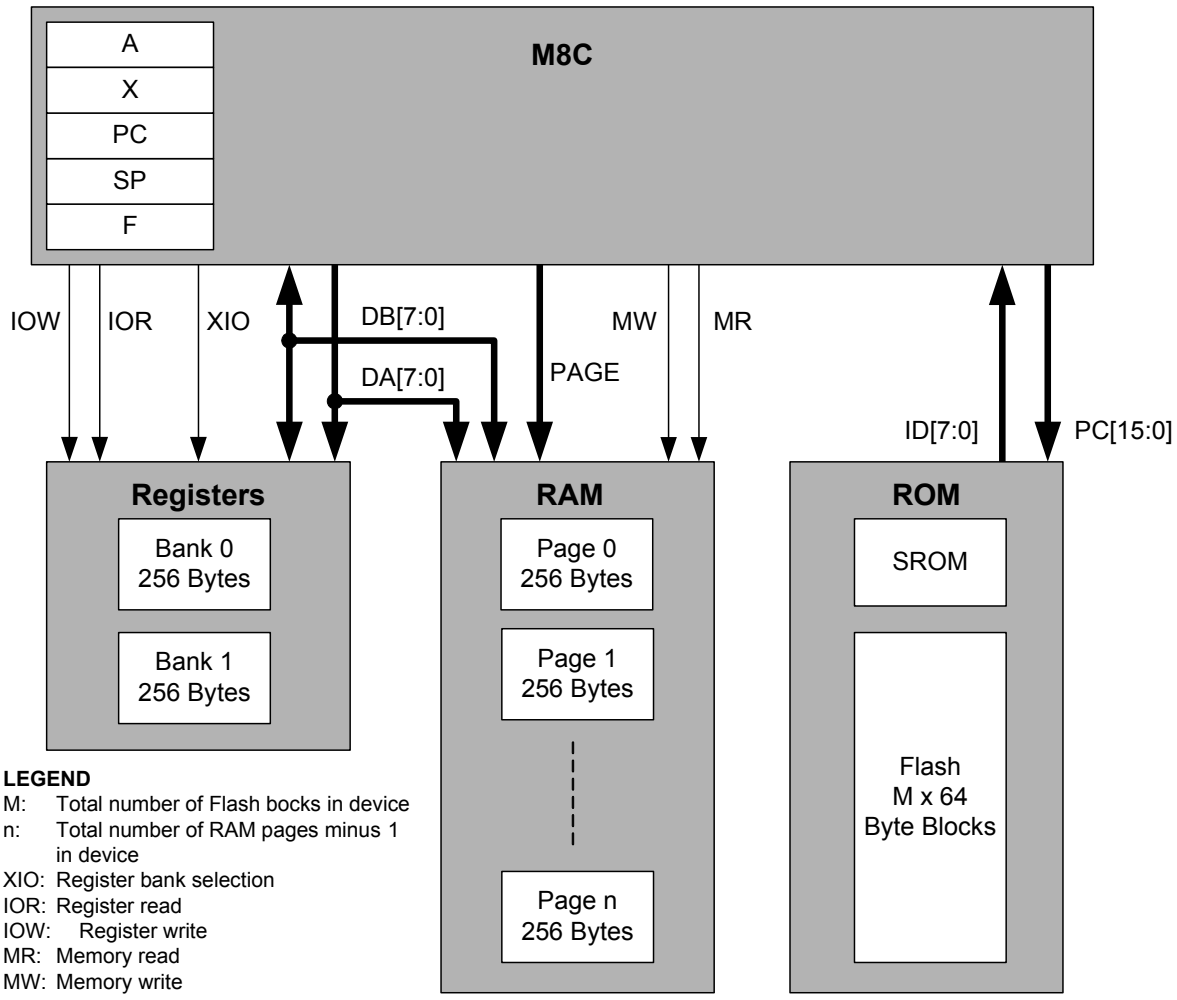


Figure 2-1. M8C Microcontroller Address Spaces

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2.3 Instruction Set Summary

The instruction set is summarized in both Table 2-2 and Table 2-3 (in numeric and mnemonic order, respectively), and serves as a quick reference.

Table 2-2. Instruction Set Summary Sorted Numerically by Opcode

Opcode Hex	Cycles	Bytes	Instruction Format	Flags	Opcode Hex	Cycles	Bytes	Instruction Format	Flags	Opcode Hex	Cycles	Bytes	Instruction Format	Flags
00	15	1	SSC		2D	8	2	OR [X+expr], A	Z	5A	5	2	MOV [expr], X	
01	4	2	ADD A, expr	C, Z	2E	9	3	OR [expr], expr	Z	5B	4	1	MOV A, X	Z
02	6	2	ADD A, [expr]	C, Z	2F	10	3	OR [X+expr], expr	Z	5C	4	1	MOV X, A	
03	7	2	ADD A, [X+expr]	C, Z	30	9	1	HALT		5D	6	2	MOV A, reg[expr]	Z
04	7	2	ADD [expr], A	C, Z	31	4	2	XOR A, expr	Z	5E	7	2	MOV A, reg[X+expr]	Z
05	8	2	ADD [X+expr], A	C, Z	32	6	2	XOR A, [expr]	Z	5F	10	3	MOV [expr], [expr]	
06	9	3	ADD [expr], expr	C, Z	33	7	2	XOR A, [X+expr]	Z	60	5	2	MOV reg[expr], A	
07	10	3	ADD [X+expr], expr	C, Z	34	7	2	XOR [expr], A	Z	61	6	2	MOV reg[X+expr], A	
08	4	1	PUSH A		35	8	2	XOR [X+expr], A	Z	62	8	3	MOV reg[expr], expr	
09	4	2	ADC A, expr	C, Z	36	9	3	XOR [expr], expr	Z	63	9	3	MOV reg[X+expr], expr	
0A	6	2	ADC A, [expr]	C, Z	37	10	3	XOR [X+expr], expr	Z	64	4	1	ASL A	C, Z
0B	7	2	ADC A, [X+expr]	C, Z	38	5	2	ADD SP, expr		65	7	2	ASL [expr]	C, Z
0C	7	2	ADC [expr], A	C, Z	39	5	2	CMP A, expr		66	8	2	ASL [X+expr]	C, Z
0D	8	2	ADC [X+expr], A	C, Z	3A	7	2	CMP A, [expr]		67	4	1	ASR A	C, Z
0E	9	3	ADC [expr], expr	C, Z	3B	8	2	CMP A, [X+expr]	if (A=B) Z=1 if (A<B) C=1	68	7	2	ASR [expr]	C, Z
0F	10	3	ADC [X+expr], expr	C, Z	3C	8	3	CMP [expr], expr		69	8	2	ASR [X+expr]	C, Z
10	4	1	PUSH X		3D	9	3	CMP [X+expr], expr		6A	4	1	RLC A	C, Z
11	4	2	SUB A, expr	C, Z	3E	10	2	MVI A, [[expr]++]	Z	6B	7	2	RLC [expr]	C, Z
12	6	2	SUB A, [expr]	C, Z	3F	10	2	MVI [[expr]++], A		6C	8	2	RLC [X+expr]	C, Z
13	7	2	SUB A, [X+expr]	C, Z	40	4	1	NOP		6D	4	1	RRC A	C, Z
14	7	2	SUB [expr], A	C, Z	41	9	3	AND reg[expr], expr	Z	6E	7	2	RRC [expr]	C, Z
15	8	2	SUB [X+expr], A	C, Z	42	10	3	AND reg[X+expr], expr	Z	6F	8	2	RRC [X+expr]	C, Z
16	9	3	SUB [expr], expr	C, Z	43	9	3	OR reg[expr], expr	Z	70	4	2	AND F, expr	C, Z
17	10	3	SUB [X+expr], expr	C, Z	44	10	3	OR reg[X+expr], expr	Z	71	4	2	OR F, expr	C, Z
18	5	1	POP A	Z	45	9	3	XOR reg[expr], expr	Z	72	4	2	XOR F, expr	C, Z
19	4	2	SBB A, expr	C, Z	46	10	3	XOR reg[X+expr], expr	Z	73	4	1	CPL A	Z
1A	6	2	SBB A, [expr]	C, Z	47	8	3	TST [expr], expr	Z	74	4	1	INC A	C, Z
1B	7	2	SBB A, [X+expr]	C, Z	48	9	3	TST [X+expr], expr	Z	75	4	1	INC X	C, Z
1C	7	2	SBB [expr], A	C, Z	49	9	3	TST reg[expr], expr	Z	76	7	2	INC [expr]	C, Z
1D	8	2	SBB [X+expr], A	C, Z	4A	10	3	TST reg[X+expr], expr	Z	77	8	2	INC [X+expr]	C, Z
1E	9	3	SBB [expr], expr	C, Z	4B	5	1	SWAP A, X	Z	78	4	1	DEC A	C, Z
1F	10	3	SBB [X+expr], expr	C, Z	4C	7	2	SWAP A, [expr]	Z	79	4	1	DEC X	C, Z
20	5	1	POP X		4D	7	2	SWAP X, [expr]		7A	7	2	DEC [expr]	C, Z
21	4	2	AND A, expr	Z	4E	5	1	SWAP A, SP	Z	7B	8	2	DEC [X+expr]	C, Z
22	6	2	AND A, [expr]	Z	4F	4	1	MOV X, SP		7C	13	3	LCALL	
23	7	2	AND A, [X+expr]	Z	50	4	2	MOV A, expr	Z	7D	7	3	LJMP	
24	7	2	AND [expr], A	Z	51	5	2	MOV A, [expr]	Z	7E	10	1	RETI	C, Z
25	8	2	AND [X+expr], A	Z	52	6	2	MOV A, [X+expr]	Z	7F	8	1	RET	
26	9	3	AND [expr], expr	Z	53	5	2	MOV [expr], A		8x	5	2	JMP	
27	10	3	AND [X+expr], expr	Z	54	6	2	MOV [X+expr], A		9x	11	2	CALL	
28	11	1	ROMX	Z	55	8	3	MOV [expr], expr		Ax	5	2	JZ	
29	4	2	OR A, expr	Z	56	9	3	MOV [X+expr], expr		Bx	5	2	JNZ	
2A	6	2	OR A, [expr]	Z	57	4	2	MOV X, expr		Cx	5	2	JC	
2B	7	2	OR A, [X+expr]	Z	58	6	2	MOV X, [expr]		Dx	5	2	JNC	
2C	7	2	OR [expr], A	Z	59	7	2	MOV X, [X+expr]		Ex	7	2	JACC	
										Fx	13	2	INDEX	Z

Note 1 Interrupt acknowledge to Interrupt Vector table = 13 cycles.

Note 2 The number of cycles required by an instruction is increased by one for instructions that span 256 byte page boundaries in the Flash memory space.

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Table 2-3. Instruction Set Summary Sorted Alphabetically by Mnemonic

Opcode Hex	Cycles	Bytes	Instruction Format	Flags	Opcode Hex	Cycles	Bytes	Instruction Format	Flags	Opcode Hex	Cycles	Bytes	Instruction Format	Flags
09	4	2	ADC A, expr	C, Z	76	7	2	INC [expr]	C, Z	20	5	1	POP X	
0A	6	2	ADC A, [expr]	C, Z	77	8	2	INC [X+expr]	C, Z	18	5	1	POP A	Z
0B	7	2	ADC A, [X+expr]	C, Z	Fx	13	2	INDEX	Z	10	4	1	PUSH X	
0C	7	2	ADC [expr], A	C, Z	Ex	7	2	JACC		08	4	1	PUSH A	
0D	8	2	ADC [X+expr], A	C, Z	Cx	5	2	JC		7E	10	1	RETI	C, Z
0E	9	3	ADC [expr], expr	C, Z	8x	5	2	JMP		7F	8	1	RET	
0F	10	3	ADC [X+expr], expr	C, Z	Dx	5	2	JNC		6A	4	1	RLC A	C, Z
01	4	2	ADD A, expr	C, Z	Bx	5	2	JNZ		6B	7	2	RLC [expr]	C, Z
02	6	2	ADD A, [expr]	C, Z	Ax	5	2	JZ		6C	8	2	RLC [X+expr]	C, Z
03	7	2	ADD A, [X+expr]	C, Z	7C	13	3	LCALL		28	11	1	ROMX	Z
04	7	2	ADD [expr], A	C, Z	7D	7	3	LJMP		6D	4	1	RRC A	C, Z
05	8	2	ADD [X+expr], A	C, Z	4F	4	1	MOV X, SP		6E	7	2	RRC [expr]	C, Z
06	9	3	ADD [expr], expr	C, Z	50	4	2	MOV A, expr	Z	6F	8	2	RRC [X+expr]	C, Z
07	10	3	ADD [X+expr], expr	C, Z	51	5	2	MOV A, [expr]	Z	19	4	2	SBB A, expr	C, Z
38	5	2	ADD SP, expr		52	6	2	MOV A, [X+expr]	Z	1A	6	2	SBB A, [expr]	C, Z
21	4	2	AND A, expr	Z	53	5	2	MOV [expr], A		1B	7	2	SBB A, [X+expr]	C, Z
22	6	2	AND A, [expr]	Z	54	6	2	MOV [X+expr], A		1C	7	2	SBB [expr], A	C, Z
23	7	2	AND A, [X+expr]	Z	55	8	3	MOV [expr], expr		1D	8	2	SBB [X+expr], A	C, Z
24	7	2	AND [expr], A	Z	56	9	3	MOV [X+expr], expr		1E	9	3	SBB [expr], expr	C, Z
25	8	2	AND [X+expr], A	Z	57	4	2	MOV X, expr		1F	10	3	SBB [X+expr], expr	C, Z
26	9	3	AND [expr], expr	Z	58	6	2	MOV X, [expr]		00	15	1	SSC	
27	10	3	AND [X+expr], expr	Z	59	7	2	MOV X, [X+expr]		11	4	2	SUB A, expr	C, Z
70	4	2	AND F, expr	C, Z	5A	5	2	MOV [expr], X		12	6	2	SUB A, [expr]	C, Z
41	9	3	AND reg[expr], expr	Z	5B	4	1	MOV A, X	Z	13	7	2	SUB A, [X+expr]	C, Z
42	10	3	AND reg[X+expr], expr	Z	5C	4	1	MOV X, A		14	7	2	SUB [expr], A	C, Z
64	4	1	ASL A	C, Z	5D	6	2	MOV A, reg[expr]	Z	15	8	2	SUB [X+expr], A	C, Z
65	7	2	ASL [expr]	C, Z	5E	7	2	MOV A, reg[X+expr]	Z	16	9	3	SUB [expr], expr	C, Z
66	8	2	ASL [X+expr]	C, Z	5F	10	3	MOV [expr], [expr]		17	10	3	SUB [X+expr], expr	C, Z
67	4	1	ASR A	C, Z	60	5	2	MOV reg[expr], A		4B	5	1	SWAP A, X	Z
68	7	2	ASR [expr]	C, Z	61	6	2	MOV reg[X+expr], A		4C	7	2	SWAP A, [expr]	Z
69	8	2	ASR [X+expr]	C, Z	62	8	3	MOV reg[expr], expr		4D	7	2	SWAP X, [expr]	
9x	11	2	CALL		63	9	3	MOV reg[X+expr], expr		4E	5	1	SWAP A, SP	Z
39	5	2	CMP A, expr	if (A=B) Z=1 if (A<B) C=1	3E	10	2	MVI A, [[expr]++]	Z	47	8	3	TST [expr], expr	Z
3A	7	2	CMP A, [expr]		3F	10	2	MVI [[expr]++], A		48	9	3	TST [X+expr], expr	Z
3B	8	2	CMP A, [X+expr]		40	4	1	NOP		49	9	3	TST reg[expr], expr	Z
3C	8	3	CMP [expr], expr		29	4	2	OR A, expr	Z	4A	10	3	TST reg[X+expr], expr	Z
3D	9	3	CMP [X+expr], expr		2A	6	2	OR A, [expr]	Z	72	4	2	XOR F, expr	C, Z
73	4	1	CPL A	Z	2B	7	2	OR A, [X+expr]	Z	31	4	2	XOR A, expr	Z
78	4	1	DEC A	C, Z	2C	7	2	OR [expr], A	Z	32	6	2	XOR A, [expr]	Z
79	4	1	DEC X	C, Z	2D	8	2	OR [X+expr], A	Z	33	7	2	XOR A, [X+expr]	Z
7A	7	2	DEC [expr]	C, Z	2E	9	3	OR [expr], expr	Z	34	7	2	XOR [expr], A	Z
7B	8	2	DEC [X+expr]	C, Z	2F	10	3	OR [X+expr], expr	Z	35	8	2	XOR [X+expr], A	Z
30	9	1	HALT		43	9	3	OR reg[expr], expr	Z	36	9	3	XOR [expr], expr	Z
74	4	1	INC A	C, Z	44	10	3	OR reg[X+expr], expr	Z	37	10	3	XOR [X+expr], expr	Z
75	4	1	INC X	C, Z	71	4	2	OR F, expr	C, Z	45	9	3	XOR reg[expr], expr	Z
										46	10	3	XOR reg[X+expr], expr	Z

Note 1 Interrupt acknowledge to Interrupt Vector table = 13 cycles.

Note 2 The number of cycles required by an instruction is increased by one for instructions that span 256 byte page boundaries in the Flash memory space.

[+] Feedback

2.4 Instruction Formats

The M8C has a total of seven instruction formats which use instruction lengths of one, two, and three bytes. All instruction bytes are fetched from the program memory (Flash), using an address and data bus that are independent from the address and data buses used for register and RAM access.

While examples of instructions are given in this section, refer to the M8C Instruction Set chapter on page 37 for detailed information on individual instructions.

2.4.1 One-Byte Instruction

Many instructions, such as some of the MOV instructions, have single-byte forms, because they do not use an address or data as an operand. As shown in Table 2-4, one-byte instructions use an 8-bit opcode. The set of one-byte instructions can be divided into four categories, according to where their results are stored.

Table 2-4. One-Byte Instruction Format

Byte 0
8-Bit Opcode

The first category of one-byte instructions are those that do not update any registers or RAM. Only the one-byte no operation (NOP) and supervisory system call (SSC) instructions fit this category. While the program counter is incremented as these instructions execute, they do not cause any other internal M8C registers to be updated, nor do these instructions directly affect the register space or the RAM address space. The SSC instruction will cause SROM code to run, which will modify RAM and the M8C internal registers.

The second category has only the two PUSH instructions in it. The PUSH instructions are unique, because they are the only one-byte instructions that cause a RAM address to be modified. These instructions automatically increment the CPU_SP register (`SP`).

The third category has only the HALT instruction in it. The HALT instruction is unique, because it is the only one-byte instruction that causes a user register to be modified. The HALT instruction modifies user register space address FFh (CPU_SCR register).

The final category for one-byte instructions are those that cause updates of the internal M8C registers. This category holds the largest number of instructions: `ASL`, `ASR`, `CPL`, `DEC`, `INC`, `MOV`, `POP`, `RET`, `RETI`, `RLC`, `ROMX`, `RRC`, `SWAP`. These instructions can cause the CPU_A, CPU_X, and CPU_SP registers, or SRAM to update.

2.4.2 Two-Byte Instructions

The majority of M8C instructions are two bytes in length. While these instructions can be divided into categories identical to the one-byte instructions, this would not provide a useful distinction between the three two-byte instruction formats that the M8C uses.

Table 2-5. Two-Byte Instruction Formats

Byte 0	Byte 1
4-Bit Opcode	12-Bit Relative Address
8-Bit Opcode	8-Bit Data
8-Bit Opcode	8-Bit Address

[+] Feedback

The first two-byte instruction format, shown in the first row of Table 2-5, is used by short jumps and calls: `CALL`, `JMP`, `JACC`, `INDEX`, `JC`, `JNC`, `JNZ`, `JZ`. This instruction format uses only four bits for the instruction opcode, leaving 12 bits to store the relative destination address in a two's-complement form. These instructions can change program execution to an address relative to the current address by -2048 or +2047.

The second two-byte instruction format, shown in the second row of Table 2-5, is used by instructions that employ the Source Immediate addressing mode (see "Source Immediate" on page 18). The destination for these instructions is an internal M8C register, while the source is a constant value. An example of this type of instruction would be `ADD A, 7`.

The third two-byte instruction format, shown in the third row of Table 2-5, is used by a wide range of instructions and addressing modes. The following is a list of the addressing modes that use this third two-byte instruction format:

- Source Direct (`ADD A, [7]`)
- Source Indexed (`ADD A, [X+7]`)
- Destination Direct (`ADD [7], A`)
- Destination Indexed (`ADD [X+7], A`)
- Source Indirect Post Increment (`MVI A, [7]`)
- Destination Indirect Post Increment (`MVI [7], A`)

For more information on addressing modes see "Addressing Modes" on page 18.

2.4.3 Three-Byte Instructions

The three-byte instruction formats are the second most prevalent instruction formats. These instructions need three bytes because they either move data between two addresses in the user-accessible address space (registers and RAM) or they hold 16-bit absolute addresses as the destination of a long jump or long call.

Table 2-6. Three-Byte Instruction Formats

Byte 0	Byte 1	Byte 2
8-Bit Opcode	16-Bit Address (MSB, LSB)	
8-Bit Opcode	8-Bit Address	8-Bit Data
8-Bit Opcode	8-Bit Address	8-Bit Address

The first instruction format, shown in the first row of Table 2-6, is used by the LJMP and LCALL instructions. These instructions change program execution unconditionally to an absolute address. The instructions use an 8-bit opcode, leaving room for a 16-bit destination address.

The second three-byte instruction format, shown in the second row of Table 2-6, is used by the following two addressing modes:

- Destination Direct Source Immediate (`ADD [7], 5`)
- Destination Indexed Source Immediate (`ADD [X+7], 5`)

The third three-byte instruction format, shown in the third row of Table 2-6, is for the Destination Direct Source Direct addressing mode, which is used by only one instruction. This instruction format uses an 8-bit opcode followed by two 8-bit addresses. The first address is the destination address in RAM, while the second address is the source address in RAM. The following is an example of this instruction:

```
MOV [7], [5]
```


[+] Feedback

2.5 Addressing Modes

The M8C has ten addressing modes:

- “Source Immediate” on page 18.
- “Source Direct” on page 19.
- “Source Indexed” on page 19.
- “Destination Direct” on page 20.
- “Destination Indexed” on page 20.
- “Destination Direct Source Immediate” on page 21.
- “Destination Indexed Source Immediate” on page 21.
- “Destination Direct Source Direct” on page 22.
- “Source Indirect Post Increment” on page 22.
- “Destination Indirect Post Increment” on page 23.

2.5.1 Source Immediate

For these instructions, the source value is stored in operand 1 of the instruction. The result of these instructions is placed in either the M8C CPU_A, CPU_F, or CPU_X register as indicated by the instruction’s opcode. All instructions using the Source Immediate addressing mode are two bytes in length.

Table 2-7. Source Immediate

Opcode	Operand 1
Instruction	Immediate Value

Source Immediate Examples:

Source Code	Machine Code	Comments
`ADD A, 7`	`01 07`	The immediate value 7 is added to the Accumulator. The result is placed in the Accumulator.
`MOV X, 8`	`57 08`	The immediate value 8 is moved into the CPU_X register.
`AND F, 9`	`70 09`	The immediate value of 9 is logically AND’ed with the CPU_F register and the result is placed in the CPU_F register.

[+] Feedback

2.5.2 Source Direct

For these instructions, the source address is stored in operand 1 of the instruction. During instruction execution, the address will be used to retrieve the source value from RAM or register address space. The result of these instructions is placed in either the M8C CPU_A or CPU_X register as indicated by the instruction's opcode. All instructions using the Source Direct addressing mode are two bytes in length.

Table 2-8. Source Direct

Opcode	Operand 1
Instruction	Source Address

Source Direct Examples:

Source Code	Machine Code	Comments
`ADD A, [7]`	`02 07`	The value in memory at address 7 is added to the Accumulator and the result is placed into the Accumulator.
`MOV A, REG[8]`	`5D 08`	The value in the register space at address 8 is moved into the Accumulator.

2.5.3 Source Indexed

For these instructions, the source offset from the CPU_X register is stored in operand 1 of the instruction. During instruction execution, the current CPU_X register value is added to the signed offset, to determine the address of the source value in RAM or register address space. The result of these instructions is placed in either the M8C CPU_A or CPU_X register as indicated by the instruction's opcode. All instructions using the Source Indexed addressing mode are two bytes in length.

Table 2-9. Source Indexed

Opcode	Operand 1
Instruction	Source Index

Source Indexed Examples:

Source Code	Machine Code	Comments
`ADD A, [X+7]`	`03 07`	The value in memory at address X+7 is added to the Accumulator. The result is placed in the Accumulator.
`MOV X, [X+8]`	`59 08`	The value in RAM at address X+8 is moved into the CPU_X register.

[+] Feedback

2.5.4 Destination Direct

For these instructions, the destination address is stored in the machine code of the instruction. The source for the operation is either the M8C CPU_A or CPU_X register as indicated by the instruction's opcode. All instructions using the Destination Direct addressing mode are two bytes in length.

Table 2-10. Destination Direct

Opcode	Operand 1
Instruction	Destination Address

Destination Direct Examples:

Source Code	Machine Code	Comments
`ADD [7], A`	`04 07`	The value in the Accumulator is added to memory at address 7. The result is placed in memory at address 7. The Accumulator is unchanged.
`MOV REG[8], A`	`60 08`	The Accumulator value is moved to register space at address 8. The Accumulator is unchanged.

2.5.5 Destination Indexed

For these instructions, the destination offset from the CPU_X register is stored in the machine code for the instruction. The source for the operation is either the M8C CPU_A register or an immediate value as indicated by the instruction's opcode. All instructions using the Destination Indexed addressing mode are two bytes in length.

Table 2-11. Destination Indexed

Opcode	Operand 1
Instruction	Destination Index

Destination Indexed Example:

Source Code	Machine Code	Comments
`ADD [X+7], A`	`05 07`	The value in memory at address X+7 is added to the Accumulator. The result is placed in memory at address X+7. The Accumulator is unchanged.

[+] Feedback

2.5.6 Destination Direct Source Immediate

For these instructions, the destination address is stored in operand 1 of the instruction. The source value is stored in operand 2 of the instruction. All instructions using the Destination Direct Source Immediate addressing mode are three bytes in length.

Table 2-12. Destination Direct Source Immediate

Opcode	Operand 1	Operand 2
Instruction	Destination Address	Immediate Value

Destination Direct Source Immediate Examples:

Source Code	Machine Code	Comments
`ADD [7], 5`	`06 07 05`	The value in memory at address 7 is added to the immediate value 5. The result is placed in memory at address 7.
`MOV REG[8], 6`	`62 08 06`	The immediate value 6 is moved into register space at address 8.

2.5.7 Destination Indexed Source Immediate

For these instructions, the destination offset from the CPU_X register is stored in operand 1 of the instruction. The source value is stored in operand 2 of the instruction. All instructions using the Destination Indexed Source Immediate addressing mode are three bytes in length.

Table 2-13. Destination Indexed Source Immediate

Opcode	Operand 1	Operand 2
Instruction	Destination Index	Immediate Value

Destination Indexed Source Immediate Examples:

Source Code	Machine Code	Comments
`ADD [X+7], 5`	`07 07 05`	The value in memory at address X+7 is added to the immediate value 5. The result is placed in memory at address X+7.
`MOV REG[X+8], 6`	`63 08 06`	The immediate value 6 is moved into the register space at address X+8.

[+] Feedback

2.5.8 Destination Direct Source Direct

Only one instruction uses this addressing mode. The destination address is stored in operand 1 of the instruction. The source address is stored in operand 2 of the instruction. The instruction using the Destination Direct Source Direct addressing mode is three bytes in length.

Table 2-14. Destination Direct Source Direct

Opcode	Operand 1	Operand 2
Instruction	Destination Address	Source Address

Destination Direct Source Direct Example:

Source Code	Machine Code	Comments
`MOV [7], [8]`	`5F 07 08`	The value in memory at address 8 is moved to memory at address 7.

2.5.9 Source Indirect Post Increment

Only one instruction uses this addressing mode. The source address stored in operand 1 is actually the address of a pointer. During instruction execution, the pointer's current value is read to determine the address in RAM where the source value is found. The pointer's value is incremented after the source value is read. For PSoC microcontrollers with more than 256 bytes of RAM, the Data Page Read (MVR_PP) register is used to determine which RAM page to use with the source address. Therefore, values from pages other than the current page can be retrieved without changing the Current Page Pointer (CUR_PP). The pointer is always read from the current RAM page. For information on the MVR_PP and CUR_PP registers, see the Register Reference chapter in the *PSoC Technical Reference Manual*. The instruction using the Source Indirect Post Increment addressing mode is two bytes in length.

Table 2-15. Source Indirect Post Increment

Opcode	Operand 1
Instruction	Source Address Pointer

Source Indirect Post Increment Example:

Source Code	Machine Code	Comments
`MVI A, [8]`	`3E 08`	The value in memory at address 8 (the indirect address) points to a memory location in RAM. The value at the memory location, pointed to by the indirect address, is moved into the Accumulator. The indirect address, at address 8 in memory, is then incremented.

[+] Feedback

2.5.10 Destination Indirect Post Increment

Only one instruction uses this addressing mode. The destination address stored in operand 1 is actually the address of a pointer. During instruction execution, the pointer's current value is read to determine the destination address in RAM where the Accumulator's value is stored. The pointer's value is incremented, after the value is written to the destination address. For PSoC microcontrollers with more than 256 bytes of RAM, the Data Page Write (MVW_PP) register is used to determine which RAM page to use with the destination address. Therefore, values can be stored in pages other than the current page without changing the Current Page Pointer (CUR_PP). The pointer is always read from the current RAM page. For information on the MVR_PP and CUR_PP registers, see the Register Reference chapter in the *PSoC Technical Reference Manual*. The instruction using the Destination Indirect Post Increment addressing mode is two bytes in length.

Table 2-16. Destination Indirect Post Increment

Opcode	Operand 1
Instruction	Destination Address Pointer

Destination Indirect Post Increment Example:

Source Code	Machine Code	Comments
`MVI [8], A`	`3F 08`	The value in memory at address 8 (the indirect address) points to a memory location in RAM. The Accumulator value is moved into the memory location pointed to by the indirect address. The indirect address, at address 8 in memory, is then incremented.

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3. ImageCraft Assembler

This chapter details the information needed to use the ImageCraft Assembler. For information on command line usage of the ImageCraft Assembler, see the C Language Compiler User Guide (section 9.4 ImageCraft Assembler Arguments). For information on generating source code in PSoC Designer, see the PSoC Designer IDE Guide.

Assembly language is a low-level language. This means its structure is not like a human language. By comparison, 'C' is a high-level language with structures close to those used by human languages. Even though assembly is a low-level language, it is an abstraction created to make programming hardware easier for humans. Therefore, this abstraction must be eliminated before an input, in a form native to the microcontroller, can be generated. An assembler is used to convert the abstractions used in assembly language to machine code that the microcontroller can operate on directly.

3.1 Source File Format

Assembly language source files for the ImageCraft Assembler have five basic components as listed in Table 3-1. Each line of the source file may hold a single label, mnemonic, comment, or directive. Multiple operands or expressions may be used on a single source file line. The maximum length for a line is 2,048 characters (including spaces) and the maximum word length is 256 characters. A word is a string of characters surrounded by spaces.

Table 3-1. Five Basic Components of an Assembly Source File

Component	Description
Label	Symbolic name followed by a colon (`:`).
Mnemonic	Character string representing an M8C instruction.
Operand	Arguments to M8C instructions.
Comment	May follow operands or expressions and starts in any column if first non-space character is either a C++-style comment (`//`) or semi-colon (`;`).
Directive	A command, interpreted by the Assembler, to control the generation of machine code.

Avoid use of the following characters in path and file names (they are problematic): \ / : * ? " < > | & + , ; = [ ] % $ ` '.

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All user code is built from the components listed in Table 3-1 and complex conditional-assembly constraints can be placed on a collection of source files. The text below has an example of each of the six basic components that will be discussed in detail in the following subsections. Line 1 is a comment line as indicated by the "//" character string. Lines 5, 6, and 7 also have comments starting with the ";" character and continuing to the end of the line. Lines 2 and 3 are examples of assembler directives. The character strings before the ":" character in lines 3 and 4 are labels. Lines 5, 6, and 7 have instruction mnemonics and operands.

Source File Components:

```
1 // My Project Source Code
2 include "project.inc"
3 BASE: equ      0x10
4 _main:
5 mov reg[0x00], 0x34   ;write 0x34 to Port 0
6 mov A, reg[0x04]      ;read Port 1
7 and [BASE+2], A       ;store Port 1 value in RAM
```

3.1.1 Labels

A label is a case-sensitive string of alphanumeric characters and underscores (_) followed by a colon. A label is assigned the address of the current Program Counter by the Assembler, unless the label is defined on a line with an EQU directive. See "Equate Label EQU" on page 87 for more information. Labels can be placed on any line, including lines with source code as long as the label appears first. The Assembler supports three types of labels: local, global, and re-usable local.

Local Labels. These consist of a character string followed by a colon. Local labels cannot be referenced by other source files in the same project, they can only be used within the file in which they are defined. Local labels become global labels if they are "exported." The following example has a single local label named SubFun. Local labels are case sensitive.

Local Labels:

```
mov  X, 10

SubFun:
xor  reg[00h], FFh
dec  X
jnz  SubFun
```


[+] Feedback

Global Labels. These are defined by the `EXPORT` assembler directive or by ending the label with two colons "`::`" rather than one. Global labels may be referenced from any source file in a project. The following example has two global labels. The `EXPORT` directive is used to make the `SubFun` label global, while two colons are used to make the `MoreFun` label global. Global labels are case sensitive.

Global Labels:

```
EXPORT SubFun
mov  X, 10

SubFun:
xor  reg[00h], FFh
dec  X
jnz  SubFun
mov  X, 5

MoreFun::
xor  reg[00h], FFh
dec  X
jnz  MoreFun
```

Re-usable Local Labels. These have multiple independent definitions within a single source file. They are defined by preceding the label string with a period "`.`". The scope of a local label is bounded by the nearest local, or global label or the end of the source file. The following example has a single global label called `SubFun` and a re-usable local label called `.MoreFun`. Notice that while labels do not include the colon when referenced, re-usable local labels require that a period precede the label string for all instances. Re-usable local labels are case sensitive.

Re-usable Local Label:

```
EXPORT SubFun
mov  X, 10

SubFun:
xor  reg[00h], FFh
mov  A, 5

.MoreFun:
xor  reg[04h], FFh
dec  A
jnz  .MoreFun
dec  X
jnz  SubFun
```

Local labels with the same name but in different source files is not supported.

3.1.2 Mnemonics

An instruction mnemonic is a two to five letter string that represents one of the microcontroller instructions. All mnemonics are defined in the "Instruction Set Summary" on page 14. There can be 0 or 1 mnemonics per line of a source file. Mnemonics are not case sensitive.

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3.1.3 Operands

Operands are the arguments to instructions. The number of operands and the format they use are defined by the instruction being used. The operand format for each instruction is covered in the “Instruction Set Summary” on page 14.

Operands may take the form of constants, labels, dot operator, registers, RAM, or expressions.

Constants. These are operands bearing values explicitly stated in the source file. Constants may be stated in the source file using one of the radixes listed in Table 3-2.

Table 3-2. Constants Formats

Radix	Name	Formats	Example

127	ASCII Character	‘J’	`mov A, 'J' ;character constant`
			`mov A, '\'' ;use "\" to escape "'"`
			`mov A, '\\' ;use "\" to escape "\"`

16	Hexadecimal	0x4A
		4Ah
		$4A
			`mov A, 0x4A ;hex--"0x" prefix`
			`mov A, 4Ah ;hex--append "h"`
			`mov A, $4A ;hex--"$" prefix`

10	Decimal	74	`mov A, 74 ;decimal--no prefix`
8	Octal	0112	`mov A, 0112 ;octal--zero prefix`
2	Binary	0b01001010 %01001010	`mov A, 0b01001010 ;bin--"0b" prefix` `mov A, %01001010 ;bin--"%" prefix`

Labels. These may be used as an operand for an instruction, as described on page 26. Labels are most often used as the operands for `jump` and `call` instructions to specify the destination address. However, labels may be used as an argument for any instruction.

Dot Operator (.). This is used to indicate that the ROM address of the first byte of the instruction should be used as an argument to the instruction.

Example 1:
```
mov  A, <.      ; moves low byte of the PC to A
```
Example 2:
```
mov  A, >.      ; moves high byte of the PC to A
```
Example 3:
```
jmp  >.+3
nop
nop             ; jumped to this instruction
nop
```


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Registers. These have two forms in PSoC devices. The first type are those that exist in the two banks of user-accessible registers. The second type are those that exist in the microcontroller. Table 3-3 contains examples for all types of register operands.

Table 3-3. Register Formats

Type	Formats	Example
User-Accessible Registers	reg[expr]	`MOV A, reg[0x08] ;register at address 8` `MOV A reg[OU+8] ;address = label OU + 8`
M8C Registers	A	`MOV A, 8 ;move 8 into the accumulator`
	F	`OR F, 1 ;set bit 0 of the flags`
	SP	`MOV SP, 8 ;set the stack pointer to 8`
	X	`MOV X, 8 ;set the M8C's X reg to 8`

RAM. These references are made by enclosing the address or expression in square brackets. The Assembler will evaluate the expression to create the actual RAM address.

Table 3-4. RAM Format

Type	Formats	Example
Current RAM Page	[expr]	`MOV A, [0x08] ;RAM at address 8` `MOV A, [OU+8] ;address = label OU + 8`

Expressions. These may be constructed using any combination of labels, constants, the dot operator, and the arithmetic and logical operations defined in Table 3-5.

Table 3-5. Expressions

Precedence	Expression	Symbol	Form
1	Bitwise Complement	~	(~ a)
2	Multiplication Division Modulo	* / %	(a * b) (a / b) (a % b)
3	Addition Subtraction	+ -	(a + b) (a – b)
4	Bitwise AND	&	(a & b)
5	Bitwise XOR	^	(a ^ b)
6	Bitwise OR	|	(a | b)
7	High Byte of an Address	>	(>a)
8	Low Byte of an Address	<	(< a)

Only the Addition expression (+) may apply to a re-locatable symbol (i.e., an external symbol). All other expressions must be applied to constants or symbols resolvable by the Assembler (i.e., a symbol defined in the file).

3.1.4 Comments

A comment starts with a semicolon (`;`) or a double slash (`//`) and goes to the end of a line. It is usually used to explain the assembly code and may be placed anywhere in the source file. The Assembler ignores comments; however, they are written to the listing file for reference.

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3.1.5 Directives

An assembler directive is used to tell the ImageCraft Assembler to take some action during the assembly process. Directives are not understood by the M8C microcontroller. As such, directives allow the firmware writer to create code that is easier to maintain. See the Assembler Directives chapter on page 75 for more information on directives.

3.2 Listing File Format

A *<project name>.lst* file is created each time the ImageCraft Assembler completes without errors or warnings. The list file may be used to understand how the Assembler has converted the source code into machine code.

The two lines below represent typical lines found in a listing file. Lines that begin with a four-digit number in parentheses (“( )”) are source file lines. The number in parentheses is the source file line number. The text following the right parenthesis is the exact text from the source file. The second line in the example below begins with a four-digit number followed by a colon. This four-digit number indicates the ROM address for the first machine code byte that follows the colon. In this example, the two hexadecimal numbers that follow the colon are two bytes that form the `MOV A, 74` instruction. Notice that the ImageCraft Assembler converts the constants used in the source file to decimal values and that the machine code is always show in hexadecimal. In this case the source code expressed the constant as an octal value (0112), the Assembler represented the same value in decimal (74), and the machine code uses hexadecimal (4A).

Example LST File:
```
(0014)    mov    A,    0112    ; Octal constant
                  01AF: 50 4A     MOV    A,74
```

3.3 Map File Format

A <project name>.mp file is created each time the ImageCraft Assembler completes without errors or warnings.

The map file documents where the Assembler has placed areas defined by the AREA assembler directive and lists the values of global labels (also called global symbols).

The "__data_start" label shows the starting address of the RAM variables. InterruptRAM variables may overlap the "__data_start" label because "__data_start" is only used as a label by the compiler.

3.4 ROM File Format

A *<project name>.rom* file is created each time the ImageCraft Assembler completes without errors or warnings. This file is provided as an alternative to the Intel HEX file that is also created by the Assembler. The ROM file does not contain the user-defined protection settings for the Flash or the fill value used to initialize unused portions of Flash after the end of user code.

The ROM file is a simple text file with eight columns of data delimited by spaces. The example below is a complete ROM file for a 47-byte program. The ROM file does not contain any information about where the data should be located in Flash. By convention, the data in the ROM file starts at address

[+] Feedback

0x0000 in Flash. For the example below, only addresses 0x0000 through 0x002E of the Flash have assigned values according to the ROM file.

Example ROM File:

```
80 5B 00 00 7E 00 00 00
7E 00 00 00 7D 02 62 7E
7E 00 00 00 7D 01 EF 7E
91 73 90 FE 90 89 90 14
3D 7F 60 3A 5B 60 3E 7F
3F 00 3D FF 3E CC FF
```


[+] Feedback

3.5 Intel® HEX File Format

The Intel HEX file created by the ImageCraft Assembler is used as a platform-independent way of distributing all of the information needed to program a PSoC microcontroller. In addition to the user data created by the Assembler, the HEX file also contains the protection settings for the project that will be used by the programmer.

The basic building block of the Intel HEX file format is called a record. Every record consists of six fields as shown in Table 3-6. All fields, except for the start field, represent information as ASCII encoded hexadecimal. This means that every eight bits of information are encoded in two ASCII characters.

The start field is one byte in length and must always contain a colon (:). The length field is also one byte in length and indicates the number of bytes of data stored in the record. Because the length field is one byte in length, the maximum amount of data stored in a record is 255 bytes which would require 510 ASCII characters in the HEX file. The starting address field indicates the address of the first byte of information in the record. The address field is 16 bits in length (four ASCII characters) which allows room for 64 kilobytes of data per record.

Table 3-6. Intel HEX File Record Format

Field Number	Field Name	Length (bytes)	Description
1	start	1	The only valid value is the colon (:) character.
2	length	1	Indicates amount of data from 0 bytes to 255 bytes.
3	starting address	2	
4	type	1	“00”: data “01”: end of file “02”: extended segment address “03”: start segment address “04”: extended linear address “05”: start linear address record
5	data	Determined by length field	
6	checksum	1	

[+] Feedback

All HEX files created by the ImageCraft Assembler have the structure shown in Table 3-7. Each row in the table describes a record type used in the HEX file. Each record type conforms to the record definitions discussed previously.

Table 3-7. PSoC Microcontroller Intel HEX File Format

Record	Description
`<data record 1: flash data>`	This is the first of many data records in the HEX file that contain Flash data.
`<data record n: flash data>`	The nth record containing data for Flash (last record). The total number of data records for Flash data can be determined by dividing the available Flash space (in bytes) by 64. Therefore, a 16 KB part would have a HEX file with 256 Flash data records.
`:020000040010ea`	The first two characters (02) indicate that this record has a length of two bytes (4 ASCII characters). The next four characters (0000) specify the starting address. The next two characters (04) indicate that this is an extended linear address. The four characters following 04 are the data for this record. Because this is an extended linear address record, the four characters indicate the value for the upper 16 bits of a 32-bit address. Therefore, the value of 0x0010 is a 1 MB offset. For PSoC microcontroller HEX files, the extended linear address is used to offset Flash protection data from the Flash data. The Flash protection bits start at the 1 MB address.
`<data record 1: protection bits>`	For PSoC devices with 16 KB of Flash or less, this is the only data record for protection bits.
`<data record m: protection bits>`	For PSoC devices with more than 16 KB of Flash, there will be an additional data record with protection bits for each 16 KB of additional Flash.
`:020000040020da`	This is another extended linear address record. This record provides a 1 MB offset from the Flash protection bits (absolute address of 2 MB).
`<data record: checksum>`	This is a two-byte data record that stores a checksum for all of the Flash data stored in the HEX file. The record will always start with :0200000000 and end with the four characters that represent the two-byte checksum.
`:00000001ff`	This is the end-of-file record. The length and starting address fields are all zero. The type field has a value of 0x01 and the checksum value will always be 0xff.

[+] Feedback

The following is an example of a PSoC device HEX file for a very small program.

Example Code:

```
mov  A, reg[0x04]
inc  A
mov  reg[0x04], A
```

Example ROM File:

```
5D 04 74 60 04
```

Example HEX File:

```
:400000005d0474600430303030303030303030303030303030303030303
030303030303030303030303030303030303030303030303030303030303
030303030303030303030303030303077
:400040003030303030303030303030303030303030303030303030303
030303030303030303030303030303030303030303030303030303030303
030303030303030303030303030303080
```

Records removed to make example compact.

```
:403fc0003030303030303030303030303030303030303030303030303
030303030303030303030303030303030303030303030303030303030303
030303030303030303030303030303030c1
:020000040010ea
:40000000ffffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
ffffffffffffffffffffffffff00
:020000040020da
:020000000049b5
:00000001ff
```

3.6 Convention for Restoring Internal Registers

When calling PSoC user module APIs and library functions, it is the caller's responsibility to preserve the CPU_A and CPU_X registers. This means that if the current context of the code has a value in the CPU_X and/or CPU_A register that must be maintained after the API call, then the caller must save (`push` on the stack) and then restore (`pop` off the stack) them after the call has returned.

Even though some of the APIs do preserve the CPU_X and CPU_A register, Cypress reserves the right to modify the API in future releases in such a manner as to modify the contents of the CPU_X and CPU_A registers. Therefore, it is very important to observe the convention when calling from assembly. Note that the C compiler observes this convention.

3.7 Compiling a File into a Library Module

Each library module is simply an object file. Therefore, to create a library module, you need to compile a source file into an object file. There are several ways that you can create a library.

One method is to create a brand new project. Add all the necessary source files that you wish to be added to your custom library to this project. You then add a project-specific MAKE file action to add those project files to a custom library.

For example, a blank project is created for any type of part, since interest is only in using 'C' and/or assembly, the Application Editor, and the Debugger. The goal for creating a custom library is to centralize a set of common functions that can be shared between projects. These common functions, or primitives, have deterministic inputs and outputs. Another goal for creating this custom library is to be able to debug the primitives using a sequence of test instructions (e.g., a regression test) in a source file that should not be included in the library. No user modules are involved in this example.

[+] Feedback

PSoC Designer automatically generates a certain amount of code for each new project. In this example, use the generated `_main` source file to hold regression tests, but do not add this file to the custom library. Also, do not add the generated *boot.asm* source file to the library. Essentially, all the files under the "Source Files" branch of the project view source tree go into a custom library, except *main.asm* (or *main.c*) and *boot.asm*.

Create a file called *local.dep* in the root folder of the project. The *local.dep* file is included by the master *Makefile* (found in the ...`\PSoC Designer\tools` folder). The following shows how the *Makefile* includes *local.dep* (found at the bottom of *Makefile*).

```
#this include is the dependencies
-include project.dep
#if you like project.dep that is good!
-include local.dep
```

The nice thing about having *local.dep* included at the end of the master *Makefile* is that the rules used in the *Makefile* can be redefined (see the Help > Documentation `\Supporting Documents\make.pdf` for detailed information). In this example, it is used as an advantage.

The following shows information from example *local.dep*.

```
# ----- Cut/Paste to your local.dep File -----
define Add_To_MyCustomLib
$(CRLF)
$(LIBCMD) -a PSoCToolsLib.a $(library_file)
endif
obj/%.o : %.asm project.mk
ifeq ($(ECHO_COMMANDS),novice)
   echo $(call correct_path,$<)
endif
   $(ASMCMD) $(INCLUDEFLAGS) $(DEFAULTASMFLAGS) $(ASMFLAGS) -   $@ $(call
correct_path,$<)
   $(foreach library_file, $(filter-out obj/main.o, $@),
   $(Add_To_MyCustomLib))
obj/%.o : %.c project.mk
ifeq ($(ECHO_COMMANDS),novice)
   echo $(call correct_path,$<)
endif
   $(CCMD) $(CFLAGS) $(CDEFINES) $(INCLUDEFLAGS)
   $(DEFAULTCFLAGS) -o $@ $(call correct_path,$<)
   $(foreach library_file, $(filter-out obj/main.o, $@),
   $(Add_To_MyCustomLib))
# ------ End Cut -----
```


[+] Feedback

The rules (for example, `obj/%.o : %.asm project.mk` and `obj/%.o : %.c project.mk`) in the *local.dep* file shown above are the same rules found in the master *Makefile* with one addition each. The addition in the redefined rules is to add each object (target) to a library called *PSoC-ToolsLib.a*. For example:

```
$(foreach library_file, $(filter-out obj/main.o,
$@), $(Add_To_MyCustomLib))
```

The MAKE keyword `foreach` causes one piece of text (the first argument) to be used repeatedly, each time with a different substitution performed on it. The substitution list comes from the second `foreach` argument.

In this second argument, there is another MAKE keyword/function called `filter-out`. The `filter-out` function removes `obj/main.o` from the list of all targets being built (for example, `obj/%.o`). This was one of the goals for this example. You can filter out additional files by adding those files to the first argument of `filter-out` such as:

```
$(filter-out obj/main.o obj/excludeme.o, $@).
```

The MAKE symbol combination `$@` is a shortcut syntax that refers to the list of all the targets (for example, `obj/%.o`).

The third argument in the `foreach` function is expanded into a sequence of commands, for each substitution, to update or add the object file to the library. This *local.dep* example is prepared to handle both C and assembly source files and put them in the library, *PSoCToolsLib.a*. The library is created/updated in the project root folder in this example. However, you can provide a full path to another folder. For example:

```
$(LIBCMD) -a c:\temp\PSoCToolsLib.a $(library_file.
```

Another goal was to not include the *boot.asm* file in the library. This is easy given that the master *Makefile* contains a separate rule for the *boot.asm* source file, which is not redefined in *local.dep*.

You can cut and paste this example and place it in a *local.dep* file in the root folder of any project. To view messages in the Build tab of the Output Status window regarding the behavior of your custom process, go to Tools > Options > Builder tab and click a check at “Use verbose build messages.“

Use the Project > Settings > Linker tab fields to add the library modules/library path if you want other PSoC Designer projects to link in your custom library.

[+] Feedback

4. M8C Instruction Set

This chapter describes all M8C instructions in detail. The M8C supports a total of 256 instructions which are divided into 37 instruction types and arranged in alphabetical order according to the instruction types mnemonic.

For each instruction the assembly code format will be illustrated as well as the operation performed by the instruction. The microprocessor cycles that are listed for each instruction are for instructions that are not on a ROM (Flash) page-boundary execution. If the instruction is located on a 256-byte ROM page boundary, an additional microprocessor clock cycle will be needed by the instruction. The `expr` string that is used to explain the assembly code format represents the use of assembler directives which tell the ImageCraft Assembler how to calculate the constant used in the final machine code. Note that in the operation equations the machine code constant is represented by `k`, k_1, and k_2.

While the instruction mnemonics are often shown in all capital letters, the ImageCraft Assembler ignores case for directives and instructions mnemonics. However, the Assembler does consider case for user-defined symbols (i.e., labels).

Note that information about individual M8C instructions is also available via *PSoC Designer Online Help*. Pressing the [F1] key will cause the online help system to search for the word at the current insertion point in a source file. If your insertion point is an instruction mnemonic, pressing [F1] will direct you to information about that instruction.

[+] Feedback

4.1 Add with Carry ADC

Computes the sum of the two operands plus the carry value from the Flag register. The first operand's value is replaced by the computed sum. If the sum is greater than 255, the Carry Flag is set in the Flag register. If the sum is zero, the Zero Flag is set in the Flag register.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
ADC	A, expr	$A \leftarrow A + k + CF$	0x09	4	2
ADC	A, [expr]	$A \leftarrow A + ram[k] + CF$	0x0A	6	2
ADC	A, [X+expr]	$A \leftarrow A + ram[X + k] + CF$	0x0B	7	2
ADC	[expr], A	$ram[k] \leftarrow ram[k] + A + CF$	0x0C	7	2
ADC	[X+expr], A	$ram[X + k] \leftarrow ram[X + k] + A + CF$	0x0D	8	2
ADC	[expr], expr	$ram[k_1] \leftarrow ram[k_1] + k_2 + CF$	0x0E	9	3
ADC	[X+expr], expr	$ram[X + k_1] \leftarrow ram[X + k_1] + k_2 + CF$	0x0F	10	3

Conditional Flags:
- CF — Set if the sum > 255; cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0          ;set accumulator to zero
or   F, 0x02       ;set carry flag
adc  A, 12         ;accumulator value is now 13
```

Example 2:

```
mov  [0x39], 0     ;initialize ram[0x39]=0x00
mov  [0x40], FFh   ;initialize ram[0x40]=0xFF
inc  [0x40]        ;ram[0x40]=0x00, CF=1, ZF=1
adc  [0x39], 0     ;ram[0x39]=0x01, CF=0, ZF=0
```


[+] Feedback

4.2 Add without Carry ADD

Computes the sum of the two operands. The first operand's value is replaced by the computed sum. If the sum is greater than 255, the Carry Flag is set in the Flag register. If the sum is zero, the Zero Flag is set in the Flag register. The `ADD SP, expr` instruction does not affect the flags in any way.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
ADD	A, expr	$A \leftarrow A + k$	0x01	4	2
ADD	A, [expr]	$A \leftarrow A + ram[k]$	0x02	6	2
ADD	A, [X+expr]	$A \leftarrow A + ram[X + k]$	0x03	7	2
ADD	[expr], A	$ram[k] \leftarrow ram[k] + A$	0x04	7	2
ADD	[X+expr], A	$ram[X + k] \leftarrow ram[X + k] + A$	0x05	8	2
ADD	[expr], expr	$ram[k_1] \leftarrow ram[k_1] + k_2$	0x06	9	3
ADD	[X+expr], expr	$ram[X + k_1] \leftarrow ram[X + k_1] + k_2$	0x07	10	3
ADD	SP, expr	$SP \leftarrow SP + k$	0x38	5	2

Conditional Flags:

CF — Set if the sum > 255; cleared otherwise.
`ADD SP, expr` does not affect the Carry Flag.

ZF — Set if the result is zero; cleared otherwise.
`ADD SP, expr` does not affect the Zero Flag.

Example 1:

```
mov  A, 10     ;initialize A to 10 (decimal)
add  A, 240    ;result is A=250 (decimal)
add  A, 6      ;result is A=0, CF=1, ZF=1
```

Example 2:

```
mov  A, 10     ;initialize A to 10 (decimal)
add  A, 240    ;result is A=250 (decimal)
add  A, 7      ;result is A=1, CF=1, ZF=0
add  A, 5      ;result is A=6, CF=0, ZF=0
```

Example 3:

```
mov  A, 10     ;initialize A to 10 (decimal)
swap A, SP     ;put 10 in SP
add  SP, 240   ;result is SP=250 (decimal)
add  SP, 6     ;SP=0, CF=unchanged, ZF=unchanged
```


[+] Feedback

4.3 Bitwise AND AND

Computes the logical AND for each bit position using both arguments. The result of the logical AND is placed in the corresponding bit position for the first argument.

The Carry Flag is only changed when the `AND F, expr` instruction is used. The CF will be set to the result of the logical AND of the CF at the beginning of instruction execution and the second argument's value at bit position 2 (i.e., F[2] and expr[2]).

For the `AND F, expr` instruction the ZF is handled the same as the CF in that it is changed as a result of the logical AND of the ZF's value at the beginning of instruction execution and the value of the second argument's value at bit position 1 (i.e., F[1] and expr[1]). However, for all other `AND` instructions the Zero Flag will be set or cleared based on the result of the logical AND operation. If the result of the AND is that all bits are zero, the Zero Flag will be set; otherwise, the Zero Flag Is cleared.

Note that AND (or OR or XOR, as appropriate) is a read-modify write instruction. When operating on a register, that register must be of the read-write type. Bitwise AND to a write only register will generate nonsense.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
AND	A, expr	$A \leftarrow A \ \& \ k$	0x21	4	2
AND	A, [expr]	$A \leftarrow A \ \& \ ram[k]$	0x22	6	2
AND	A, [X+expr]	$A \leftarrow A \ \& \ ram[X+k]$	0x23	7	2
AND	[expr], A	$ram[k] \leftarrow ram[k] \ \& \ A$	0x24	7	2
AND	[X+expr], A	$ram[X+k] \leftarrow ram[X+k] \ \& \ A$	0x25	8	2
AND	[expr], expr	$ram[k_1] \leftarrow ram[k_1] \ \& \ k_2$	0x26	9	3
AND	[X+expr], expr	$ram[X+k_1] \leftarrow ram[X+k_1] \ \& \ k_2$	0x27	10	3
AND	REG[expr], expr	$reg[k_1] \leftarrow reg[k_1] \ \& \ k_2$	0x41	9	3
AND	REG[X+expr], expr	$reg[X+k_1] \leftarrow reg[X+k_1] \ \& \ k_2$	0x42	10	3
AND	F, expr	$F \leftarrow F \ \& \ k$	0x70	4	2

Conditional Flags:

CF — Affected only by the `AND F, expr` instruction.

ZF — Set if the result is zero; cleared otherwise. `AND F, expr` will set this flag as a result of the AND operation.

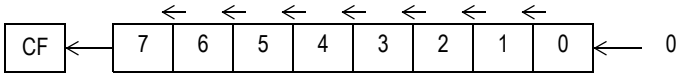
Example 1:
```
and  A, 0x00      ;A=0, CF=unchanged, ZF=1
```

Example 2:
```
and  F, 0x00      ;F=0 therefore CF=0, ZF=0
```


[+] Feedback

4.4 Arithmetic Shift Left ASL

Shifts all bits of the instruction's argument one bit to the left. Bit 7 is loaded into the Carry Flag and bit 0 is loaded with a zero.



Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
ASL	A	$A \leftarrow \begin{bmatrix} CF \leftarrow A{:}7 \\ A{:}7 \leftarrow A{:}6 \\ A{:}6 \leftarrow A{:}5 \\ A{:}5 \leftarrow A4 \\ A{:}4 \leftarrow A{:}3 \\ A{:}3 \leftarrow A{:}2 \\ A{:}2 \leftarrow A{:}1 \\ A{:}1 \leftarrow A{:}0 \\ A{:}0 \leftarrow 0 \end{bmatrix}$	0x64	4	1
ASL	[expr]	$ram[k] \leftarrow \begin{bmatrix} CF \leftarrow ram[k]{:}7 \\ ram[k]{:}7 \leftarrow ram[k]{:}6 \\ ram[k]{:}6 \leftarrow ram[k]{:}5 \\ ram[k]{:}5 \leftarrow ram[k]{:}4 \\ ram[k]{:}4 \leftarrow ram[k]{:}3 \\ ram[k]{:}3 \leftarrow ram[k]{:}2 \\ ram[k]{:}2 \leftarrow ram[k]{:}1 \\ ram[k]{:}1 \leftarrow ram[k]{:}0 \\ ram[k]{:}0 \leftarrow 0 \end{bmatrix}$	0x65	7	2
ASL	[X+expr]	$ram[X+k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(X+k)]{:}7 \\ ram[(X+k)]{:}7 \leftarrow ram[(X+k)]{:}6 \\ ram[(X+k)]{:}6 \leftarrow ram[(X+k)]{:}5 \\ ram[(X+k)]{:}5 \leftarrow ram[(X+k)]{:}4 \\ ram[(X+k)]{:}4 \leftarrow ram[(X+k)]{:}3 \\ ram[(X+k)]{:}3 \leftarrow ram[(X+k)]{:}2 \\ ram[(X+k)]{:}2 \leftarrow ram[(X+k)]{:}1 \\ ram[(X+k)]{:}1 \leftarrow ram[(X+k)]{:}0 \\ ram[(X+k)]{:}0 \leftarrow 0 \end{bmatrix}$	0x66	8	2

Conditional Flags:	CF	Set equal to the initial argument's bit 7 value.
	ZF	Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0x7F      ;initialize A with 127
asl  A            ;A=0xFE, CF=0, ZF=0
```

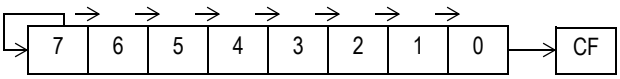
Example 2:

```
mov  0xEB], AA    ;initialize RAM @ 0xEB with 0
asl  0xEB]        ;ram[0xEB]=54, CF=1, ZF=0
```


[+] Feedback

4.5 Arithmetic Shift Right ASR

Shifts all bits of the instruction's argument one bit to the right. Bit 7 remains the same while bit 0 is shifted into the Carry Flag.



Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
ASR	A	$A \leftarrow \begin{bmatrix} CF \leftarrow A:0,\ A:0 \leftarrow A:1,\ A:1 \leftarrow A:2 \\ A:2 \leftarrow A:3,\ A:3 \leftarrow A:4,\ A:4 \leftarrow A:5 \\ A:5 \leftarrow A:6,\ A:6 \leftarrow A:7 \end{bmatrix}$	0x67	4	1
ASR	[expr]	$ram[k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(k)]:0 \\ ram[k]:0 \leftarrow ram[k]:1 \\ ram[k]:1 \leftarrow ram[k]:2 \\ ram[k]:2 \leftarrow ram[k]:3 \\ ram[k]:3 \leftarrow ram[k]:4 \\ ram[k]:4 \leftarrow ram[k]:5 \\ ram[k]:5 \leftarrow ram[k]:6 \\ ram[k]:6 \leftarrow ram[k]:7 \end{bmatrix}$	0x68	7	2
ASR	[X+expr]	$ram[X+k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(X+k)]:0 \\ ram[(X+k)]:0 \leftarrow ram[(X+k)]:1 \\ ram[(X+k)]:1 \leftarrow ram[(X+k)]:2 \\ ram[(X+k)]:2 \leftarrow ram[(X+k)]:3 \\ ram[(X+k)]:3 \leftarrow ram[(X+k)]:4 \\ ram[(X+k)]:4 \leftarrow ram[(X+k)]:5 \\ ram[(X+k)]:5 \leftarrow ram[(X+k)]:6 \\ ram[(X+k)]:6 \leftarrow ram[(X+k)]:7 \end{bmatrix}$	0x69	8	2

Conditional Flags:	CF	Set if LSB of the source was set before the shift, else cleared.
	ZF	Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0x00     ;initialize A to 0
and  F, 0x00     ;make sure all flags are cleared
asr  A           ;A=0, CF=0, ZF=1
```

Example 2:

```
mov  A, 0xFF     ;initialize A to 255
and  F, 0x00     ;make sure all flags are cleared
asr  A           ;A=0xFF, CF=1, ZF=0
```

Example 3:

```
mov  A, 0xAA     ;initialize A to 170
and  F, 0x00     ;make sure all flags are cleared
asr  A           ;A=0xD5, CF=0, ZF=0
```


[+] Feedback

4.6 Call Function CALL

Adds the signed argument to the current PC+2 value resulting in a new PC that determines the address of the first byte of the next instruction. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the next instruction.

Two pushes are used to store the Program Counter (PC+2) on the stack. First, the upper 8 bits of the PC (CPU_PC register) are placed on the stack followed by the lower 8 bits. The Stack Pointer is post-incremented for each push. For devices with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined in the device data sheet. The M8C automatically selects the stack page as the destination for the push during the CALL instruction. Therefore, a CALL instruction may be issued in any RAM page. After the CALL instruction has completed, user code will be operating from the same RAM page as before the CALL instruction was executed.

This instruction has a 12-bit two's-complement relative address that is added to the PC. The 12 bits are packed into the two-byte instruction format by using the lower nibble of the opcode and the second byte of the instruction format. Therefore, all opcodes with an upper nibble of 9 are CALL instructions. The "x" character is used in the table below to indicate that the first byte of a CALL instruction can have one of 16 values (i.e., 0x90, 0x91, 0x92,..., 0x9F).

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
CALL	expr	PC ← PC + 2 + k, (–2048 ≤ k ≤ 2047)	0x9x	11	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000            _main:
0000  40        nop
0001  90 E8     call SubFun
0003  40        nop
Note that the relative address for the CALL above is positive
(0xE8) and that the sum of that address and the PC value for
the first byte of the next instruction (0x0003) equals the
address of the SubFun label (0xE8 + 0x0003 = 0x00EB).

0004  9F FA     call _main
Note that the call to Main uses a negative address (0xFA).

0006
00EB            org 0x00EB
00EB            SubFun:
00EB  40        nop
00EC  7F        ret
```


[+] Feedback

4.7 Non-Destructive Compare CMP

Subtracts the second argument from the first. If the difference is less than zero the Carry Flag is set. If the difference is 0 the Zero Flag is set. Neither operand's value is destroyed by this instruction.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
CMP	A, expr	$A - k$	0x39	5	2
CMP	A, [expr]	$A - ram[k]$	0x3A	7	2
CMP	A, [X+expr]	$A - ram[X + k]$	0x3B	8	2
CMP	[expr], expr	$ram[k_1] - k_2$	0x3C	8	3
CMP	[X+expr], expr	$ram[X + k_1] - k_2$	0x3D	9	3

Conditional Flags:
- CF — Set if Operand 1 < Operand 2; cleared otherwise.
- ZF — Set if the operands are equal; cleared otherwise.

Example:

```
mov  A, 34     ;initialize the accumulator to 34
cmp  A, 33     ;A>=34 CF cleared, A != 33 ZF cleared
cmp  A, 34     ;A=34 CF cleared, ZF set
cmp  A, 35     ;A<35 CF set, A != 35 ZF cleared
```


[+] Feedback

4.8 Complement Accumulator CPL

Computes the bitwise complement of the Accumulator and stores the result in the Accumulator. The Carry Flag is not affected but the Zero Flag will be set, if the result of the complement is '0' (for example, the original value was 0xFF).

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
CPL	A	$A \leftarrow \overline{A}$	0x73	4	1

Conditional Flags:	CF	Unaffected.
	ZF	Set if the result is zero; cleared otherwise.

Example 1:
```
mov  A, 0xFF
cpl  A          ;A=0x00, ZF=1
```

Example 2:
```
mov  A, 0xA5
cpl  A          ;A=0x5A, ZF=0
```

Example 3:
```
mov  A, 0xFE
cpl  A          ;A=0x01, ZF=0
```


[+] Feedback

4.9 Decrement DEC

Subtracts one from the value of the argument and replaces the argument's original value with the result. If the result is '-1' (original value was zero) the Carry Flag is set. If the result is '0' (original value was one) the Zero Flag is set.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
DEC	A	$A \leftarrow A - 1$	0x78	4	1
DEC	X	$X \leftarrow X - 1$	0x79	4	1
DEC	[expr]	$ram[k] \leftarrow ram[k] - 1$	0x7A	7	2
DEC	[X+expr]	$ram[X + k] \leftarrow ram[X + k] - 1$	0x7B	8	2

Conditional Flags:
- CF — Set if the result is -1; cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example:

```
mov  [0xEB], 3
loop2:            ;The loop will be executed 3 times.
dec  [0xEB]
jnz  loop2        ;Jump will not be taken when ZF is set by
                  ;DEC (i.e., wait until the loop counter
                  ;(0xEB) is decremented to 0x00).
```


[+] Feedback

4.10 Halt HALT

Halts the execution of the processor. The processor will remain halted until a Power-On-Reset (POR), Watchdog Timer Reset (WDR), or external reset (XRES) event occurs. The POR, WDR, and XRES are all hardware resets that will cause a complete system reset, including the resetting of registers to their power-on state. Watchdog reset will not cause the Watchdog Timer to be disabled, while all other resets will disable the Watchdog Timer.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
HALT		reg[CPU_SCR] ← reg[CPU_SCR] + 1	0x30	9	1

Conditional Flags:	CF	Unaffected.
	ZF	Unaffected.

Example:
```
halt                ;sets STOP bit in CPU_SCR register
```


[+] Feedback

4.11 Increment INC

Adds one to the argument. The argument's original value is replaced by the new value. If the value after the increment is 0x00, the Carry Flag and the Zero Flag will be set (original value must have been 0xFF).

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
INC	A	$A \leftarrow A + 1$	0x74	4	1
INC	X	$X \leftarrow X + 1$	0x75	4	1
INC	[expr]	$ram[k] \leftarrow ram[k] + 1$	0x76	7	2
INC	[X+expr]	$ram[X + k] \leftarrow ram[X + k] + 1$	0x77	8	2

Conditional Flags:
- CF — Set if value after the increment is 0; cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0x00        ;initialize A to 0
or   F, 0x06        ;make sure CF and ZF are set (1)
inc  A              ;A=0x01, CF=0, ZF=0
```

Example 2:

```
mov  A, 0xFF        ;initialize A to 0
and  F, 0x00        ;make sure flags are all 0
inc  A              ;A=0x00, CF=1, ZF=1
```


[+] Feedback

4.12 Relative Table Read INDEX

Places the contents of ROM at the location indicated by the sum of the Accumulator, the argument, and the current PC+2 into the Accumulator. This instruction has a 12-bit, two's-complement offset address, relative to the current PC+2. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the instruction.

The `INDEX` instruction is used to retrieve information from a table to the Accumulator. The lower nibble of the first byte of the instruction is used as the upper 4 bits of the 12-bit address. Therefore, all instructions that begin with 0xF are `INDEX` instructions, so all of the following are `INDEX` opcodes: 0xF0, 0xF1, 0xF2,..., 0xFF.

The offset into the table is taken as the value of the Accumulator when the `INDEX` instruction is executed. The maximum readable table size is 256 bytes due to the Accumulator being 8 bits in length.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
INDEX	expr	$A \leftarrow rom[k + A + PC + 2], (-2048 \le k \le 2047)$	0xFx	13	2

Conditional Flags:
- CF — Unaffected.
- ZF — Set if the byte returned to `A` is zero.

Example:

```
0000              OUT_REG: equ 04h
0000  40          [04]  nop
0001  50 03       [04]  mov A, 3
0003  F0 E6       [13]  index ASCIInumbers
0005  60 04       [05]  mov reg[OUT_REG], A
```

Note that the 12-bit address for the `INDEX` instruction is positive and that the sum of the address (`0x0E6`) and the next instruction's address (`0x0005`) are equal to the first address of the ASCIInumbers table (`0x00EB`). Because the Accumulator has been set to 3 before executing the `INDEX` instruction, the fourth byte in the ASCIInumbers table will be returned to A. Therefore, A will be `0x33` at the end of the `INDEX` instruction.

```
0007
00EB              org 0x00EB
00EB              ASCIInumbers:
00EB  30 31 ...           ds      "0123456789"
      32 33 34 35 36 37 38 39
```


[+] Feedback

4.13 Jump Accumulator JACC

Jump, unconditionally, to the address computed by the sum of the Accumulator, the 12-bit two's-compliment argument, and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JACC instruction.

The Accumulator is not affected by this instruction. The JACC instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JACC instruction: 0xE0, 0xE1, 0xE2,..., 0xEF.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JACC	expr	$PC \leftarrow (PC + 1) + k + A$	0xEx	7	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000              _main:
0000  50 03       mov A, 3          ;set A with jump offset
0002  E0 01       jacc SubFun
```

Program execution will jump to address 0x0007 (halt)

```
0004  SubFun:
0004  40          nop
0005  40          nop
0006  40          nop
0007  30          halt
```


[+] Feedback

4.14 Jump if Carry JC

If the Carry Flag is set, jump to the sum of the relative address argument and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JC instruction.

The JC instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JC instruction: 0xC0, 0xC1, 0xC2,..., 0xCF.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JC	expr	$PC \leftarrow (PC + 1) + k, (-2048 \leq k \leq 2047)$	0xCx	5	2

Conditional Flags:	CF	Unaffected.
	ZF	Unaffected.

Example:

```
0000                _main:
0000  55 3C 02      mov [3Ch], 2
0003  16 3C 03      sub [3Ch], 3     ;2-2=0 CF=1, ZF=0
0006  C0 02         jc SubFun        ;CF=1, jump to SubFun
0008  30            halt
0009
0009                SubFun:
0009  40            nop
```


[+] Feedback

4.15 Jump JMP

Jump, unconditionally, to the address indicated by the sum of the argument and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JMP instruction.

The JMP instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JMP instruction: 0x80, 0x81, 0x82,..., 0x8F.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JMP	expr	$PC \leftarrow (PC + 1) + k, (-2048 \leq k \leq 2047)$	0x8x	5	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000              _main:
0000  80 01       [05]  jmp SubFun
```

Jump is forward, relative to PC, therefore offset is positive (0x01).

```
0002              SubFun:
0002  8F FD       [05]  jmp _main
```

Jump is backwards, relative to PC, therefore, offset is negative (0xFD).

[+] Feedback

4.16 Jump if No Carry JNC

If the Carry Flag is not set, jump to the sum of the relative address argument and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JNC instruction.

The JNC instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JNC instruction: 0xD0, 0xD1, 0xD2,..., 0xDF.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JNC	expr	$PC \leftarrow (PC + 1) + k, (-2048 \leq k \leq 2047)$	0xDx	5	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000                _main:
0000  55 3C 02      [08]   mov [3Ch], 2
0003  16 3C 02      [09]   sub [3Ch], 2     ;2-2=0 CF=0, ZF=1
0006  D0 02         [05]   jnc SubFun       ;jump to SubFun
0008  30            [04]   halt
0009
0009                SubFun:
0009  40            [04]   nop
```


[+] Feedback

4.17 Jump if Not Zero JNZ

If the Zero Flag is not set, jump to the address indicated by the sum of the argument and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JNZ instruction.

The JNZ instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JNZ instruction: 0xB0, 0xB1, 0xB2,..., 0xBF.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JNZ	expr	PC ← (PC + 1) + k, (–2048 ≤ k ≤ 2047)	0xBx	5	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000                _main:
0000  55 3C 02      [08]   mov [3Ch], 2
0003  16 3C 01      [09]   sub [3Ch], 1     ;2-1=1 CF=0, ZF=0
0006  B0 02         [05]   jnz SubFun       ;jump to SubFun
0008  30            [04]   halt
0009
0009                SubFun:
0009  40            [04]   nop
```


[+] Feedback

4.18 Jump if Zero JZ

If the Zero Flag is set, jump to the address indicated by the sum of the argument and the current PC+1. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the JZ instruction.

The JZ instruction uses a two-byte instruction format where the lower nibble of the first byte is used for the upper 4 bits of the 12-bit relative address. This causes an effective 4-bit opcode. Therefore, the following are all valid opcode bytes for the JZ instruction: 0xA0, 0xA1, 0xA2,..., 0xAF.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
JZ	expr	PC ← (PC + 1) + k, (–2048 ≤ k ≤ 2047)	0xAx	5	2

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000              _main:
0000  55 3C 02    [08]   mov [3Ch], 2
0003  16 3C 02    [09]   sub [3Ch], 2      ;2-2=0 CF=0, ZF=1
0006  A0 02       [05]   jz SubFun         ;jump to SubFun
0008  30          [04]   halt
0009
0009              SubFun:
0009  40          [04]   nop
```


[+] Feedback

4.19 Long Call LCALL

Replaces the PC value with the LCALL instruction's argument. The new PC value determines the address of the first byte of the next instruction.

Two pushes are used to store the Program Counter (current PC+3) on the stack. The current PC value is defined as the PC value that corresponds to the ROM address of the first byte of the instruction.

First, the upper 8 bits of the PC+3 are placed on the stack followed by the lower 8 bits. The Stack Pointer is post-incremented for each push. For PSoC microcontrollers with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined in the device data sheet. The M8C automatically selects the stack page as the destination for the push during the LCALL instruction. Therefore, a LCALL instruction may be issued in any RAM page. After the LCALL instruction has completed, user code will be operating from the same RAM page as before the LCALL instruction was executed.

This instruction has a 16-bit unsigned address. A three-byte instruction format is used where the first byte is a full 8-bit opcode.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
LCALL	expr	ram[SP] ← (PC + 3)[15:8] SP ← SP + 1 ram[SP] ← (PC + 3)[7:0] SP ← SP + 1 PC ← k, (0 ≤ k ≤ 65535)	0x7C	13	3

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000                _main:
0000  7C 00 05      [13]    lcall SubFun
0003  8F FC         [05]    jmp _main
```

Although in this example a full 16-bit address is not needed for the call to SubFun, the listing above shows that the lcall instruction is using a three byte format which accommodates the 16-bit absolute jump address of 0x0005.

```
0005
0005                SubFun:
0005  7F            [08]    ret
```


[+] Feedback

4.20 Long Jump LJMP

Jump, unconditionally, to the unsigned address indicated by the instruction's argument. The `LJMP` instruction uses a three-byte instruction format to accommodate a full 16-bit argument. The first byte of the instruction is a full 8-bit opcode.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
LJMP	expr	$PC \leftarrow K, (0 \leq k \leq 65535)$	0x7D	7	3

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000             _main:
0000  7D 00 03 [07]   ljmp SubFun
```

Although in this example a full 16-bit address is not needed for the jump to `SubFun` the listing above shows that the `ljmp` instruction is using a three byte format which accommodates the 16-bit absolute jump address of `0x0003`.

```
0003
0003             SubFun:
0003  7D 00 00 [07]   ljmp _main
```

Note that this instruction is jumping backwards, relative to the current `PC` value, and the address in the instruction is a positive number (`0x0000`). This is because the `ljmp` instruction uses an absolute address.

[+] Feedback

4.21 Move MOV

Allows for a number of combinations of moves: immediate, direct, and indexed addressing are supported.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
MOV	X, SP	$X \leftarrow SP$	0x4F	4	1
MOV	A, expr	$A \leftarrow k$	0x50	4	2
MOV	A, [expr]	$A \leftarrow ram[k]$	0x51	5	2
MOV	A, [X+expr]	$A \leftarrow ram[X + k]$	0x52	6	2
MOV	[expr], A	$ram[k] \leftarrow A$	0x53	5	2
MOV	[X+expr], A	$ram[X + k] \leftarrow A$	0x54	6	2
MOV	[expr], expr	$ram[k_1] \leftarrow k_2$	0x55	8	3
MOV	[X+expr], expr	$ram[X + k_1] \leftarrow k_2$	0x56	9	3
MOV	X, expr	$X \leftarrow k$	0x57	4	2
MOV	X, [expr]	$X \leftarrow ram[k]$	0x58	6	2
MOV	X, [X+expr]	$X \leftarrow ram[X + k]$	0x59	7	2
MOV	[expr], X	$ram[k] \leftarrow X$	0x5A	5	2
MOV	A, X	$A \leftarrow X$	0x5B	4	1
MOV	X, A	$X \leftarrow A$	0x5C	4	1
MOV	A, reg[expr]	$A \leftarrow reg[k]$	0x5D	6	2
MOV	A, reg[X+expr]	$A \leftarrow reg[X + k]$	0x5E	7	2
MOV	[expr], [expr]	$ram[k_1] \leftarrow ram[k_2]$	0x5F	10	3
MOV	REG[expr], A	$reg[k] \leftarrow A$	0x60	5	2
MOV	REG[X+expr], A	$reg[X + k] \leftarrow A$	0x61	6	2
MOV	REG[expr], expr	$reg[k_1] \leftarrow k_2$	0x62	8	3
MOV	REG[X+expr], expr	$reg[X + k_1] \leftarrow k_2$	0x63	9	3

Conditional Flags:
- CF: Unaffected.
- ZF: Set if A is the destination and the result is zero.

Example:

```
mov  A, 0x01       ;accumulator will equal 1, ZF=0
mov  A, 0x00       ;accumulator will equal 0, ZF=1
```


[+] Feedback

4.22 Move Indirect, Post-Increment to Memory MVI

A data pointer in RAM is used to move data between another RAM address and the Accumulator. The data pointer is incremented after the data transfer has completed.

For PSoC microcontrollers with more than 256 bytes of RAM, special page pointers are used to allow the `MVI` instructions to access data in remote RAM pages. Two page pointers are available, one for MVI read (`MVI A, [[expr]++]`) and another for MVI write (`MVI [[expr]++], A`). The data pointer is always found in the current RAM page. The page pointers determine which RAM page the data pointer's address will use. At the end of an `MVI` instruction, user code will be operating from the same RAM page as before the `MVI` instruction was executed.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
MVI	A, [[expr]++]	A ← ram[ram[k]] ram[k] ← ram[k] + 1	0x3E	10	2
MVI	[[expr]++], A	ram[ram[k]] ← A ram[k] ← ram[k] + 1	0x3F	10	2

Conditional Flags:
- CF — Unaffected.
- ZF — Set if `A` is updated with zero.

Example 1:
```
mov  [10h], 4
mov  [11h], 3
mov  [EBh], 10h       ;initialize MVI read pointer to 10h
mvi  A, [EBh]         ;A=4, ram[EBh]=11h
mvi  A, [EBh]         ;A=3, ram[EBh]=12h
```

Example 2:
```
mov  [EBh], 10h       ;initialize MVI write pointer to 10h
mov  A, 8
mvi  [EBh], A         ;ram[10h]=8, ram[EBh]=11h
mov  A, 1
mvi  [EBh], A         ;ram[11h]=1, ram[EBh]=12h
```

Multi-Page Example 3:
```
mov  reg[CUR_PP], 2   ;set Current Page Pointer to 2
mov  [10h], 4         ;ram_2[10h]=4
mov  [11h], 3         ;ram_2[11h]=3
mov  reg[CUR_PP], 0   ;set Current Page Pointer back to 0
mov  reg[MVR_PP], 2   ;set MVI read RAM page pointer
mov  [EBh], 10h       ;initialize MVI read pointer to 10h
mvi  A, [EBh]         ;A=4, ram_0[EBh]=11h
mvi  A, [EBh]         ;A=3, ram_0[EBh]=12h
```

Multi-Page Example 4:
```
mov  reg[CUR_PP], 0   ;set Current Page Pointer to 0
mov  reg[MVW_PP], 3   ;set MVI write RAM page pointer
mov  [EBh], 10h       ;initialize MVI read pointer to 10h
mov  A, 8
mvi  [EBh], A         ;ram_3[10h]=8, ram_0[EBh]=11h
mov  A, 1
mvi  [EBh], A         ;ram_3[11h]=1, ram_0[EBh]=12h
```


[+] Feedback

4.23 No Operation NOP

Performs no operation but consumes 4 CPU clock cycles. This is a one-byte instruction.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
NOP		None	0x40	4	1

Conditional Flags:	CF	Unaffected.
	ZF	Unaffected.

[+] Feedback

4.24 Bitwise OR OR

Computes the logical OR for each bit position using both arguments. The result of the logical OR is placed in the corresponding bit position for the first argument.

The Carry Flag is only changed when the `OR F, expr` instruction is used. The Carry Flag will be set to the result of the logical OR of the Carry Flag at the beginning of instruction execution and the second argument's value at bit position 2 (i.e., F[2] and expr[2]).

For the `OR F, expr` instruction, the Zero Flag is handled the same as the Carry Flag in that it is changed as a result of the logical OR of the Zero Flag's value at the beginning of instruction execution, and the value of the second arguments value at bit position 1 (i.e., F[1] and expr[1]). However, for all other `OR` instructions the Zero Flag will be set or cleared based on the result of the logical OR operation. If the result of the `OR` instruction is that all bits are zero, the Zero Flag will be set; otherwise, the Zero Flag is cleared.

Note that OR (or AND or XOR, as appropriate) is a read-modify write instruction. When operating on a register, that register must be of the read/write type. Bitwise OR to a write only register will generate nonsense.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
OR	A, expr	$A \leftarrow A \mid k$	0x29	4	2
OR	A, [expr]	$A \leftarrow A \mid ram[k]$	0x2A	6	2
OR	A, [X+expr]	$A \leftarrow A \mid ram[X+k]$	0x2B	7	2
OR	[expr], A	$ram[k] \leftarrow ram[k] \mid A$	0x2C	7	2
OR	[X+expr], A	$ram[X+k] \leftarrow ram[X+k] \mid A$	0x2D	8	2
OR	[expr], expr	$ram[k_1] \leftarrow ram[k_1] \mid k_2$	0x2E	9	3
OR	[X+expr], expr	$ram[X+k_1] \leftarrow ram[X+k_1] \mid k_2$	0x2F	10	3
OR	REG[expr], expr	$reg[k_1] \leftarrow reg[k_1] \mid k_2$	0x43	9	3
OR	REG[X+expr], expr	$reg[X+k_1] \leftarrow reg[X+k_1] \mid k_2$	0x44	10	3
OR	F, expr	$F \leftarrow F \mid k$	0x71	4	2

Conditional Flags:
- CF — Unaffected (unless `F` is destination).
- ZF — Set if the result is zero; cleared otherwise (unless `F` is destination).

Example 1:
```
mov  A, 0x00
or   A, 0xAA     ;A=0xAA, CF=unchanged, ZF=0
```

Example 2:
```
and  F, 0x00
or   F, 0x01     ;F=1 therefore CF=0, ZF=0
```


[+] Feedback

4.25 Pop Stack into Register POP

Removes the last byte placed on the stack and put it in the specified M8C register. The Stack Pointer is automatically decremented. The Zero Flag is set if the popped value is zero; otherwise, the Zero Flag is cleared. The Carry Flag is not affected by this instruction.

For PSoC devices with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined by the value of the STK_PP Register. The M8C automatically selects the stack page as the source for the memory read during the `POP` instruction. Therefore, a `POP` instruction may be issued in any RAM page. After the `POP` instruction has completed, user code will be operating from the same RAM page as before the `POP` instruction was executed.

See the RAM Paging chapter of the *PSoC Technical Reference Manual (TRM)* for details.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
POP	A	$A \leftarrow ram[SP-1]$ $SP \leftarrow SP-1$	0x18	5	1
POP	X	$X \leftarrow ram[SP-1]$ $SP \leftarrow SP-1$	0x20	5	1

Conditional Flags:
- CF — Unaffected.
- ZF — Set if `A` is updated to zero.

Example 1:

```
mov  A, 34
push A          ;top value of stack is now 34, SP+1
mov  A, 0       ;clear the Accumulator
pop  A          ;A=34, SP-1
```

Example 2:

```
mov  A, 34
push A          ;top value of stack is now 34, SP+1
pop  X          ;X=34, SP-1
```


[+] Feedback

4.26 Push Register onto Stack PUSH

Transfers the value from the specified M8C register to the top of the stack, as indicated by the value of the CPU_SP register (SP) at the start of the instruction. After placing the value on the stack, the SP is incremented. The Zero Flag is set if the pushed value is zero, else the Zero Flag is cleared. The Carry Flag is not affected by this instruction.

For PSoC microcontrollers with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined by the value of the STK_PP Register. The M8C automatically selects the stack page as the source for the memory write during the PUSH instruction. Therefore, a PUSH instruction may be issued in any PUSH page. After the PUSH instruction has completed, user code will be operating from the same RAM page as before the PUSH instruction was executed.

See the RAM Paging chapter of the *PSoC Technical Reference Manual (TRM)* for details.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
PUSH	A	ram[SP] ← A SP ← SP + 1	0x08	4	1
PUSH	X	ram[SP] ← X SP ← SP + 1	0x10	4	1

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example 1:
```
mov  A, 0x3E
push A              ;top value of stack is now 0x3E, SP+1
```

Example 2:
```
mov  X, 0x3F
push X              ;top value of stack is now 0x3F, SP+1
```


[+] Feedback

4.27 Return RET

The last two bytes placed on the stack are used to change the PC (CPU_PC register). The lower 8 bits of the PC are popped off the stack first, followed by the SP being decremented by one. Next, the upper 8 bits of the PC are popped off the stack, followed by a decrement of the SP. Neither Carry or Zero Flag is affected by this instruction.

For PSoC devices with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined by the value of the STK_PP Register. The M8C automatically selects the stack page as the source for the pop during the `RET` instruction. Therefore, a `RET` instruction may be issued in any RAM page. After the `RET` instruction has completed, user code will be operating from the same RAM page as before the `RET` instruction was executed.

See the RAM Paging chapter of the *PSoC Technical Reference Manual (TRM)* for details.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
RET		SP ← SP – 1 PC[7:0] ← ram[SP] SP ← SP – 1 PC[15:8] ← ram[SP]	0x7F	8	1

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example:

```
0000              _main:
0000   90 02      [11]   call   SubFun
0002   40         [04]   nop
0003   30         [04]   halt
0004
0004              SubFun:
0004   40         [04]   nop
0005   7F         [08]   ret
```

The `RET` instruction will set the `PC` to `0x0002`, which is the starting address of the first instruction after the `CALL`.

[+] Feedback

4.28 Return from Interrupt RETI

When the M8C takes an interrupt, three bytes are pushed onto the stack. One for CPU_F and two for the PC. When a RETI is executed, the last three bytes placed on the stack are used to change the CPU_F register and the CPU_PC register. The first byte removed from the stack is used to restore the CPU_F register. The SP (CPU_SP register) is decremented after the first byte is removed. The lower 8 bits of the PC are popped off the stack next, followed by the SP being decremented by one again. Finally, the upper 8 bits of the PC are popped off the stack, followed by a last decrement of the SP. The Carry and Zero Flags are updated with the values from the first byte popped off the stack.

For PSoC devices with more than 256 bytes of RAM, the stack is confined to a single designated stack page defined by the value of the STK_PP Register. The M8C automatically selects the stack page as the source for the pop during the `RETI` instruction. Therefore, an `RETI` instruction may be issued in any RAM page. After the `RETI` instruction has completed, user code will be operating from the same RAM page as before the `RETI` instruction was executed.

See the RAM Paging chapter of the *PSoC Technical Reference Manual (TRM)* for details.

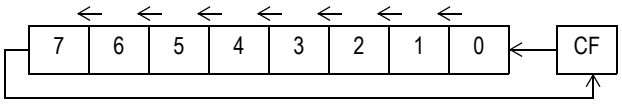
Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
RETI		SP ← SP – 1 F ← ram[SP] SP ← SP – 1 PC[7:0] ← ram[SP] SP ← SP – 1 PC[15:8] ← ram[SP]	0x7E	10	1

Conditional Flags:	CF	All Flag bits are restored to the value pushed during an interrupt call.
	ZF	All Flag bits are restored to the value pushed during an interrupt call.

[+] Feedback

4.29 Rotate Left through Carry RLC

Shifts all bits of the instruction's argument one bit to the left. Bit 0 is loaded with the Carry Flag. The most significant bit of the specified location is loaded into the Carry Flag.



.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
RLC	A	$A \leftarrow \begin{bmatrix} CF \leftarrow A:7 \\ A:7 \leftarrow A:6 \\ A:6 \leftarrow A:5 \\ A:5 \leftarrow A4 \\ A:4 \leftarrow A:3 \\ A:3 \leftarrow A:2 \\ A:2 \leftarrow A:1 \\ A:1 \leftarrow A:0 \\ A:0 \leftarrow CF \end{bmatrix}$	0x6A	4	1
RLC	[expr]	$ram[k] \leftarrow \begin{bmatrix} CF \leftarrow ram[k]:7 \\ ram[k]:7 \leftarrow ram[k]:6 \\ ram[k]:6 \leftarrow ram[k]:5 \\ ram[k]:5 \leftarrow ram[k]:4 \\ ram[k]:4 \leftarrow ram[k]:3 \\ ram[k]:3 \leftarrow ram[k]:2 \\ ram[k]:2 \leftarrow ram[k]:1 \\ ram[k]:1 \leftarrow ram[k]:0 \\ ram[k[0]] \leftarrow CF \end{bmatrix}$	0x6B	7	2
RLC	[X+expr]	$ram[X+k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(X+k)]:7 \\ ram[(X+k)]:7 \leftarrow ram[(X+k)]:6 \\ ram[(X+k)]:6 \leftarrow ram[(X+k)]:5 \\ ram[(X+k)]:5 \leftarrow ram[(X+k)]:4 \\ ram[(X+k)]:4 \leftarrow ram[(X+k)]:3 \\ ram[(X+k)]:3 \leftarrow ram[(X+k)]:2 \\ ram[(X+k)]:2 \leftarrow ram[(X+k)]:1 \\ ram[(X+k)]:1 \leftarrow ram[(X+k)]:0 \\ ram[(X+k)]:0 \leftarrow CF \end{bmatrix}$	0x6C	8	2

Conditional Flags:

- CF — Set if the MSB of the specified operand was set before the shift, cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example:

```
and  F, 0xFB        ;clear carry flag
mov  A, 0x7F        ;initialize A with 127
rlc  A              ;A=0xFE, CF=0, ZF=0
```


[+] Feedback

4.30 Absolute Table Read ROMX

Moves any byte from ROM (Flash) into the Accumulator. The address of the byte to be retrieved is determined by the 16-bit value formed by the concatenation of the CPU_A and CPU_X registers. The CPU_A register is the most significant byte and the CPU_X register is the least significant byte of the address. The Zero Flag is set if the retrieved byte is zero; otherwise, the Zero Flag is cleared. The Carry Flag is not affected by this instruction.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
ROMX		t1 ← PC[7:0] PC[7:0] ← X t2 ← PC[15:8] PC[15:8] ← A A ← rom[PC] PC[7:0] ← t1 PC[15:8] ← t2	0x28	11	1

Conditional Flags:

CF	Unaffected.
ZF	Set if A is zero; cleared otherwise.

Example:

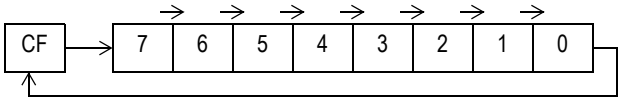
```
0000                _main:
0000   50 00        [04]    mov A, 00h
0002   57 08        [04]    mov X, 08h
0004   28           [11]    romx
0005   60 00        [05]    mov reg[00h], A
0007   40           [04]    nop
0008   30           [04]    halt
```

The ROMX instruction will read a byte from Flash at address 0x0008. The halt opcode is at address 0x0008; therefore, register 0x00 will receive the value 0x30.

[+] Feedback

4.31 Rotate Right through Carry RRC

Shifts all bits of the instruction's argument one bit to the right. The Carry Flag is loaded into the most significant bit of the argument. Bit 0 of the argument is loaded into the Carry Flag.



Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
RRC	A	$A \leftarrow \begin{bmatrix} CF \leftarrow A:0,\ A:0 \leftarrow A:1,\ A:1 \leftarrow A:2 \\ A:2 \leftarrow A:3,\ A:3 \leftarrow A:4,\ A:4 \leftarrow A:5 \\ A:5 \leftarrow A:6,\ A:6 \leftarrow A:7,\ A:7 \leftarrow CF \end{bmatrix}$	0x6D	4	1
RRC	[expr]	$ram[k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(k)]:0 \\ ram[k]:0 \leftarrow ram[k]:1 \\ ram[k]:1 \leftarrow ram[k]:2 \\ ram[k]:2 \leftarrow ram[k]:3 \\ ram[k]:3 \leftarrow ram[k]:4 \\ ram[k]:4 \leftarrow ram[k]:5 \\ ram[k]:5 \leftarrow ram[k]:6 \\ ram[k]:6 \leftarrow ram[k]:7 \\ ram[k]:7 \leftarrow CF \end{bmatrix}$	0x6E	7	2
RRC	[X+expr]	$ram[X+k] \leftarrow \begin{bmatrix} CF \leftarrow ram[(X+k)]:0 \\ ram[(X+k)]:0 \leftarrow ram[(X+k)]:1 \\ ram[(X+k)]:1 \leftarrow ram[(X+k)]:2 \\ ram[(X+k)]:2 \leftarrow ram[(X+k)]:3 \\ ram[(X+k)]:3 \leftarrow ram[(X+k)]:4 \\ ram[(X+k)]:4 \leftarrow ram[(X+k)]:5 \\ ram[(X+k)]:5 \leftarrow ram[(X+k)]:6 \\ ram[(X+k)]:6 \leftarrow ram[(X+k)]:7 \\ ram[(X+k)]:7 \leftarrow CF \end{bmatrix}$	0x6F	8	2

Conditional Flags:

- CF — Set if LSB of the specified operand was set before the shift; cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example 1:

```
or   F, 0x04        ;set carry flag
and  A, 0x00        ;clear the accumulator
rrc  A              ;A=0x80, CF=0, ZF=0
```

Example 2:

```
and  F, 0xFB        ;clear carry flag
mov  A, 0xFF        ;initialize A to 255
and  A, 0x00        ;make sure all flags are cleared
rrc  A              ;A=0x7F, CF=1, ZF=0
```

Example 3:

```
or   F, 0x04        ;set carry flag
mov  [0xEB], 0xAA   ;initialize A to 170
rrc  [0xEB]         ;ram[0xEB]=0xD5, CF=1, ZF=0
```


[+] Feedback

4.32 Subtract with Borrow SBB

Computes the difference of the two operands plus the carry value from the Flag register. The first operand's value is replaced by the computed difference. If the difference is less than '0' the Carry Flag is set in the Flag register. If the difference is zero, the Zero Flag is set in the Flag register; otherwise, the Zero Flag is cleared.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
SBB	A, expr	$A \leftarrow A - (K + CF)$	0x19	4	2
SBB	A, [expr]	$A \leftarrow A - (ram[k] + CF)$	0x1A	6	2
SBB	A, [X+expr]	$A \leftarrow A - (ram[X + k] + CF)$	0x1B	7	2
SBB	[expr], A	$ram[k] \leftarrow ram[k] - (A + CF)$	0x1C	7	2
SBB	[X+expr], A	$ram[X + k] \leftarrow ram[X + k] - (A + CF)$	0x1D	8	2
SBB	[expr], expr	$ram[k_1] \leftarrow ram[k_1] - (k_2 + CF)$	0x1E	9	3
SBB	[X+expr], expr	$ram[X + k_1] \leftarrow ram[X + k_1] - (k_2 + CF)$	0x1F	10	3

Conditional Flags:

CF Set if treating the numbers as unsigned, the difference < 0; cleared otherwise.

ZF Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0          ;set accumulator to zero
or   F, 0x02       ;set carry flag
sbb  A, 12         ;accumulator value is now 0xF3
```

Example 2:

```
mov  [0x39], 2     ;initialize ram[0x39]=0x02
mov  [0x40], FFh   ;initialize ram[0x40]=0xff
inc  [0x40]        ;ram[0x40]=0x00, CF=1
sbb  [0x39], 0     ;ram[0x39]=0x01
```


[+] Feedback

4.33 Subtract without Borrow SUB

Computes the difference of the two operands. The first operand's value is replaced by the computed difference. If the difference is less than zero, the Carry Flag is set in the Flag register. If the difference is zero, the Zero Flag is set in the Flag register; otherwise, the Zero Flag is cleared.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
SUB	A, expr	$A \leftarrow A - K$	0x11	4	2
SUB	A, [expr]	$A \leftarrow A - ram[k]$	0x12	6	2
SUB	A, [X+expr]	$A \leftarrow A - ram[X + k]$	0x13	7	2
SUB	[expr], A	$ram[k] \leftarrow ram[k] - A$	0x14	7	2
SUB	[X+expr], A	$ram[X + k] \leftarrow ram[X + k] - A$	0x15	8	2
SUB	[expr], expr	$ram[k_1] \leftarrow ram[k_1] - k_2$	0x16	9	3
SUB	[X+expr], expr	$ram[X + k_1] \leftarrow ram[X + k_1] - k_2$	0x17	10	3

Conditional Flags:
- CF — Set if treating the numbers as unsigned, the difference < 0; cleared otherwise.
- ZF — Set if the result is zero; cleared otherwise.

Example 1:

```
mov  A, 0          ;set accumulator to zero
or   F, 0x04       ;set carry flag
sub  A, 12         ;accumulator value is now 0xF4
```

Example 2:

```
mov  [0x39], 2     ;initialize ram[0x39]=0x02
mov  [0x40], FFh   ;initialize ram[0x40]=0xff
inc  [0x40]        ;ram[0x40]=0x00, CF=1
sub  [0x39], 0     ;ram[0x39]=0x02
```


[+] Feedback

4.34 Swap SWAP

Each argument is updated with the other argument's value. The Zero Flag is set if the Accumulator is updated with zero, else the Zero Flag is cleared. The `swap X, [expr]` instruction does not affect either the Carry or Zero Flags.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
SWAP	A, X	t ← X X ← A A ← t	0x4B	5	1
SWAP	A, [expr]	t ← ram[k] ram[k] ← A A ← t	0x4C	7	2
SWAP	X, [expr]	t ← ram[k] ram[k] ← X X ← t	0x4D	7	2
SWAP	A, SP	t ← SP SP ← A A ← t	0x4E	5	1

Conditional Flags:
- CF — Unaffected.
- ZF — Set if Accumulator is cleared.

Example:

```
mov  A, 0x30
swap A, SP          ;SP=0x30, A equals previous SP value
```


[+] Feedback

4.35 System Supervisor Call SSC

Provides the method for users to access pre-existing routines in the Supervisory ROM. The supervisory routines perform various system-related functions. The CPU_PC and CPU_F registers are pushed on the stack prior to the execution of the supervisory routine. All bits of the Flag register are cleared before any supervisory routine code is executed; therefore, interrupts and page mode are disabled.

All supervisory routines return using the `RETI` instruction, causing the CPU_PC and CPU_F register to be restored to their pre-supervisory routine state.

Supervisory routines are device specific. Reference the data sheet for the device you are using for detailed information on the available supervisory routines.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
SSC		ram[SP] ← PC[15:8] SP ← SP + 1 ram[SP] ← PC[7:0] SP ← SP + 1 ram[SP] ← F PC ← 0x0000 F ← 0x00	0x00	15	1

Conditional Flags:
CF Unaffected.
ZF Unaffected.

Example: The following example is one way to set up an SSC operation for the CY8C25xxx and CY8C26xxx PSoC devices. PSoC Designer uses the signature created by the following lines of code to recognize supervisory system calls and configures the In-Circuit Emulator for SSC debugging. It is recommended that users take advantage of the SSC Macro provided in PSoC Designer, to ensure that the debugger recognizes and therefore debugs supervisory operations correctly. See separate data sheets for complete device-specific options.

```
mov  X, SP            ;get stack pointers current value
mov  A, X             ;move SP to A
add  A, 3             ;add 3 to SP value
mov  [0xF9], A        ;store SP+3 value in ram[0xF9]=KEY2
mov  [0xF8], 0x3A     ;set ram[0xF9]=0x3A=KEY1
mov  A, 2             ;set supervisory function code = 2
SSC                   ;call supervisory function
```


[+] Feedback

4.36 Test for Mask TST

Calculates a bitwise AND with the value of argument one and argument two. Argument one's value is not affected by the `TST` instruction. If the result of the AND is zero, the Zero Flag is set; otherwise, the Zero Flag is cleared. The Carry Flag is not affected by the `TST` instruction.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
TST	[expr], expr	$ram[k_1] \ \& \ k_2$	0x47	8	3
TST	[X+expr], expr	$ram[X + k_1] \ \& \ k_2$	0x48	9	3
TST	REG[expr], expr	$reg[k_1] \ \& \ k_2$	0x49	9	3
TST	REG[X+expr], expr	$reg[X + k_1] \ \& \ k_2$	0x4A	10	3

Conditional Flags:

CF Unaffected.

ZF Set if the result of AND is zero; cleared otherwise.

Example:

```
mov  [0x00], 0x03
tst  [0x00], 0x02       ;CF=0, ZF=0 (i.e. bit 1 is 1)
tst  [0x00], 0x01       ;CF=0, ZF=0 (i.e. bit 0 is 1)
tst  [0x00], 0x03       ;CF=0, ZF=0 (i.e. bit 0 and 1 are 1)
tst  [0x00], 0x04       ;CF=0, ZF=1 (i.e. bit 2 is 0)
```


[+] Feedback

4.37 Bitwise XOR XOR

Computes the logical XOR for each bit position using both arguments. The result of the logical XOR is placed in the corresponding bit position for the argument.

The Carry Flag is only changed when the `XOR F, expr` instruction is used. The CF will be set to the result of the logical XOR of the CF at the beginning of instruction execution and the second argument's value at bit position 2 (i.e., F[2] and expr[2]).

For the `XOR F, expr` instruction, the Zero Flag is handled the same as the Carry Flag in that it is changed as a result of the logical XOR of the Zero Flag's value at the beginning of instruction execution, and the value of the second argument's value at bit position 1 (i.e., F[1] and expr[1]). However, for all other `XOR` instructions, the Zero Flag will be set or cleared based on the result of the logical XOR operation. If the result of the `XOR` instruction is that all bits are zero, the Zero Flag will be set; otherwise, the Zero Flag is cleared. The Carry Flag is not affected.

Note that XOR (or AND or OR, as appropriate) is a read-modify write instruction. When operating on a register, that register must be of the read/write type. Bitwise XOR to a write only register will generate nonsense.

Instructions		Operation	Opcode	Cycles	Bytes
Mnemonic	Argument				
XOR	A, expr	$A \leftarrow A \oplus k$	0x31	4	2
XOR	A, [expr]	$A \leftarrow A \oplus ram[k]$	0x32	6	2
XOR	A, [X+expr]	$A \leftarrow A \oplus ram[X + k]$	0x33	7	2
XOR	[expr], A	$ram[k] \leftarrow ram[k] \oplus A$	0x34	7	2
XOR	[X+expr], A	$ram[X + k] \leftarrow ram[X + k] \oplus A$	0x35	8	2
XOR	[expr], expr	$ram[k_1] \leftarrow ram[k_1] \oplus k_2$	0x36	9	3
XOR	[X+expr], expr	$ram[X + k_1] \leftarrow ram[X + k_1] \oplus k_2$	0x37	10	3
XOR	REG[expr], expr	$reg[k_1] \leftarrow reg[k_1] \oplus k_2$	0x45	9	3
XOR	REG[X+expr], expr	$reg[X + k_1] \leftarrow reg[X + k_1] \oplus k_2$	0x46	10	3
XOR	F, expr	$F \leftarrow F \oplus k$	0x72	4	2

Conditional Flags:	CF	Unaffected (unless `F` is destination).
	ZF	Set if the result is zero; cleared otherwise (unless `F` is destination).

Example 1:

```
mov  A, 0x00
xor  A, 0xAA      ;A=0xAA, CF=unchanged, ZF=0
```

Example 2:

```
and  F, 0x00      ;F=0
xor  F, 0x01      ;F=1 therefore CF=0, ZF=0
```

Example 3:

```
mov  A, 0x5A
xor  A, 0xAA      ;A=0xF0, CF=unchanged, ZF=0
```


[+] Feedback

5. Assembler Directives

This chapter covers all of the assembler directives currently supported by the ImageCraft Assembler. A description of each directive and its syntax will be given for each directive. ImageCraft Assembler directives are used to communicate with the ImageCraft Assembler and do not generate code. The directives allow a firmware developer to conditionally assemble source files, define symbolic equates for values, locate code or data at specific addresses, etc.

While the directives are often shown in all capital letters, the ImageCraft Assembler ignores case for directives and instructions mnemonics. However, the ImageCraft Assembler does consider case for user-defined symbols (i.e., labels). Table 5-1 presents a summary of the assembler directives.

Table 5-1. ImageCraft Assembler Directives Summary

Symbol	Directive
AREA	Area
ASCIZ	NULL Terminated ASCII String
BLK	RAM Byte Block
BLKW	RAM Word Block
DB	Define Byte
DF	Define Floating-point Number
DS	Define ASCII String
DSU	Define UNICODE String
DW	Define Word
DWL	Define Word With Little Endian Ordering
ELSE	Alternative Result of IF Directive
ENDIF	End Conditional Assembly
ENDM	End Macro
EQU	Equate Label to Variable Value
EXPORT	Export
IF	Start Conditional Assembly
INCLUDE	Include Source File
.LITERAL, .ENDLITERAL	Prevent Code Compression of Data
MACRO	Start Macro Definition
ORG	Area Origin
.SECTION, .ENDSECTION	Section for Dead-Code Elimination
Suspend - OR F,0 Resume - ADD SP,0	Suspend and Resume Code Compressor

[+] Feedback

5.1 Area AREA

Defines where code or data is located in Flash or RAM by the Linker. The Linker gathers all areas with the same name together from the source files, and either concatenates or overlays them, depending on the attributes specified. All areas with the same name must have the same attributes, even if they are used in different modules.

The following is a complete list of valid key words that can be used with the `AREA` directive:

RAM – Specifies that data is stored in RAM. Only used for variable storage. Commonly used with the `BLK` directive. Note that RAM AREAs are always overlay AREAs.

ROM – Specifies that code or data is stored in Flash.

ABS – Absolute, i.e., non-relocatable, location for code or data specified by the `ORG` directive. Default value of AREAs for type `ABS` or `REL` directives is not specified.

REL – Allows the Linker to relocate the code or data.

CON – Specifies that sequential AREAs follow each other in memory. Each AREA is allocated its own memory. The total size of the `AREA` directive is the sum of all AREA sizes. Default value of the AREAs for type `CON` or `OVR` directives is not specified.

OVR – Specifies that sequential AREAs start at the same address. This is a union of the AREAs. The total size of the `AREA` directive is the size of the largest area.

Directive	Arguments
AREA	<name> (< RAM | ROM >, [ABS | REL], [CON | OVR])

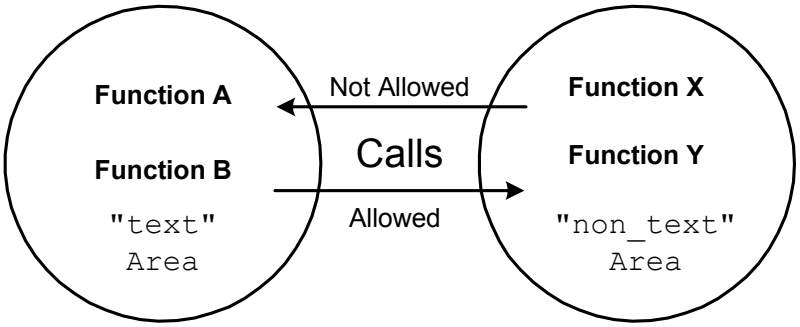
Example: A code area is defined at address 2000.

```
AREA MyArea(ROM,ABS,CON)
        ORG 2000h
_MyArea_start:
```


[+] Feedback

5.1.1 Code Compressor and the AREA Directive

The Code Compressor looks for duplicate code within the “text” Area. The text area is the default area in which all C code is placed.



The above diagram shows a scenario that is problematic. Code areas created with the `AREA` directive, using a name other than text, are not compressed or fixed up following compression. If Function Y calls Function B, there is the potential that the location of Function B will be changed by the Code Compressor. The call or jump generated in the code for Function Y will go to the wrong location.

It is allowable for Function A to call a function in a “non_text” Area. The location for Function B can change because it is in the text area. Calls and jumps are fixed up in the text area only. Following code compression, the call location to Function B from Function X in the non_text area will not be fixed up.

If Sublimation is on, there is another scenario that is problematic. Since Sublimation changes the UserModules Area, you cannot call routines in this area from a code area created with AREA directive, using a name other than “text”.

All normal user code that is to be compressed must be in the default text area. If you create code in other areas (for example, in a bootloader), then it must not call any functions in the text area. However, it is acceptable for a function in the text area to call functions in other areas. The exception is the TOP area where the interrupt vectors and the startup code can call functions in the text area. Addresses within the text area must be not used directly.

If you reference any text area function by address, then it must be done indirectly. Its address must be put in a word in the area "func_lit." At runtime, you must de-reference the content of this word to get the correct address of the function. Note that if you are using C to call a function indirectly, the compiler will take care of all these details for you. The information is useful if you are writing assembly code.

For further details on enabling and using code compression, see:

- *PSoC Designer C Language Compiler Guide*
- *PSoC Designer IDE Guide*

[+] Feedback

5.2 NULL Terminated ASCII String ASCIZ

Stores a string of characters as ASCII values and appends a terminating NULL (00h) character. The string must start and end with quotation marks ("").

The string is stored character by character in ASCII HEX format. The backslash character (\) is used in the string as an escape character. Non-printing characters, such as \n and \r, can be used. A quotation mark (") can be entered into a string using the backslash (\"), a single quote (‘) as (\’), and a backslash (\) as (\\).

Directive	Arguments
ASCIZ	< “character string“ >

Example: My"String\ is defined with a terminating NULL character.

```
MyString:
        ASCIZ "My\"String\\"
```


[+] Feedback

5.3 RAM Block in Bytes BLK

Reserves blocks of RAM in bytes. The argument is an expression, specifying the size of the block, in bytes, to reserve. The `AREA` directive must be used to ensure the block of bytes will reside in the correct memory location.

PSoC Designer requires that the `AREA bss` be used for RAM variables.

Directive	Arguments
BLK	< size >

Example: A 4-byte variable called MyVariable is allocated.

```
        AREA bss
MyVariable:
        BLK 4
```


[+] Feedback

5.4 RAM Block in Words BLKW

Reserves a block of RAM. The amount of RAM reserved is determined by the size argument to the directive. The units for the size argument is words (16 bits).

PSoC Designer requires that the `AREA bss` be used for RAM variables.

Directive	Arguments
BLKW	< size >

Example: A 4-byte variable called MyVariable is allocated.

```
        AREA bss
MyVariable:
        BLKW 2
```


[+] Feedback

5.5 Define Byte DB

Reserves bytes of ROM and assigns the specified values to the reserved bytes. This directive is useful for creating data tables in ROM.

Arguments may be constants or labels. The length of the source line limits the number of arguments in a `DB` directive.

Directive	Arguments
DB	< value1 > [, value2, ..., valuen]

Example: 3 bytes are defined starting at address 3000.

```
MyNum:  EQU 77h
        ORG 3000h
MyTable:
        DB 55h, 66h, MyNum
```


[+] Feedback

5.6 Define Floating-point Number DF

Reserves four-byte pairs of ROM and assigns the specified values to each reserved pair. The format used is the IEEE-754 Single Format stored in big-endian format. This directive is useful for creating data tables in ROM.

Arguments must be constants. Only the length of the source line limits the number of arguments in a `DF` directive.

Directive	Arguments
DF	< value1 > [, value2, ..., valuen]

Example:

```
MyTable:
        DF 1.2345, -1.07e-03f
```


[+] Feedback

5.7 Define ASCII String DS

Stores a string of characters as ASCII values. The string must start and end with quotation marks ("").

The string is stored character by character in ASCII HEX format. The backslash character (\) is used in the string as an escape character. Non-printing characters, such as \n and \r, can be used. A quotation mark (") can be entered into a string using the backslash (\"), a single quote (‘) as (\’), and a backslash (\) as (\\).

The string is not null terminated. To create a null terminated string; follow the `DS` directive with a DB 00h or use `ASCIZ` directive.

Directive	Arguments
DS	< “character string“ >

Example: My"String\ is defined:

```
MyString:
        DS "My\"String\\"
```


[+] Feedback

5.8 Define UNICODE String DSU

Stores a string of characters as UNICODE values with little ENDIAN byte order. The string must start and end with quotation marks ("").

The string is stored character by character in UNICODE format. Each character in the string is stored with the low byte followed by the high byte.

The backslash character (\) is used in the string as an escape character. Non-printing characters, such as \n and \r, can be used. A quotation mark (") can be entered into a string using the backslash (\"), a single quote (‘) as (\’), and a backslash (\) as (\\).

Directive	Arguments
DSU	< “character string“ >

Example: My"String\ is defined with little endian byte order.

```
MyString:
        DSU "My\"String\\"
```


[+] Feedback

5.9 Define Word, Big Endian Ordering DW

Reserves two-byte pairs of ROM and assigns the specified words to each reserved byte. This directive is useful for creating tables in ROM.

The arguments may be constants or labels. Only the length of the source line limits the number of arguments in a `DW` directive.

Directive	Arguments
DW	< value1 > [, value2, ..., valuen]

Example: 6 bytes are defined starting at address 2000.

```
MyNum:  EQU 3333h
        ORG 2000h
MyTable:
        DW 1111h, 2222h, MyNum
```


[+] Feedback

5.10 Define Word, Little Endian Ordering DWL

Reserves two-byte pairs of ROM and assigns the specified words to each reserved byte, swapping the order of the upper and lower bytes.

The arguments may be constants or labels. The length of the source line limits the number of arguments in a `DWL` directive.

Directive	Arguments
DWL	< value1 > [, value2, ..., valuen]

Example: 6 bytes are defined starting at address 2000.

```
MyNum:  EQU 6655h
        ORG 2000h
MyTable:
        DWL 2211h, 4433h, MyNum
```


[+] Feedback

5.11 Equate Label EQU

Assigns an integer value to a label. The label and operand are required for an `EQU` directive. The argument must be a constant or label or "." (the current PC). Each `EQU` directive may have only one argument and, if a label is defined more than once, an assembly error will occur.

To use the same equate in more than one assembly source file, place the equate in an .inc file and include that file in the referencing source files. Do not export equates from assembly source files, or the PSoC Designer Linker will resolve the directive in unpredictable ways.

Directive	Arguments
EQU	< label> EQU < value | address >

Example: BITMASK is equated to 1Fh.

```
BITMASK: EQU 1Fh
```


[+] Feedback

5.12 Export EXPORT

Designates that a label is global and can be referenced in another file. Otherwise, the label is not visible to another file. Another way to export a label is to end the label definition with two colons (::) instead of one.

Directive	Arguments
EXPORT	EXPORT < label >

Example:

```
Export MyVariable
        AREA bss
MyVariable:
        BLK 1
```


[+] Feedback

5.13 Conditional Source IF, ELSE, ENDIF

All source lines between the IF and ENDIF (or IF and ELSE) directives are assembled if the condition is true. These statements can be nested.

ELSE delineates a “not true” action for a previous IF directive.

ENDIF finishes a section of conditional assembly that began with an IF directive.

Directive	Arguments

IF
ELSE
ENDIF
	value

Example: Sections of the source code are conditional.

```
Cond1:  EQU 1
Cond2:  EQU 0
        ORG 1000h
        IF (Cond1)
        ADD A, 33h
        IF (Cond2)
        ADD A, FFh
        ENDIF ;Cond1
        NOP ;Cond1
        ELSE
        MOV A, FFh
        ENDIF ;Cond2
// The example creates the following code
        ADD A, 33h
        NOP
```


[+] Feedback

5.14 Include Source File INCLUDE

Used to add additional source files to the file being assembled. When an `INCLUDE` directive is encountered, the ImageCraft Assembler reads in the specified source file until either another `INCLUDE` directive is encountered or the end of file is reached. If additional `INCLUDE` directives are encountered, additional source files are read in. When an end of file is encountered, the Assembler resumes reading the previous file.

Specify the full (or relative) path to the file if the source file does not reside in the current directory.

Directive	Arguments
INCLUDE	< file name >

Example: Three files are included into the source code.

```
INCLUDE "MyInclude1.inc"
INCLUDE "MyIncludeFiles\MyInclude2.inc"
INCLUDE "C:\MyGlobalIncludeFiles\MyInclude3.inc"
```


[+] Feedback

5.15 Prevent Code Compression of Data .LITERAL, .ENDLITERAL

Used to avoid code compression of the data defined between the .LITERAL and .ENDLITERAL directives. For the code compressor to function, all data defined in ROM with the ASCIZ, DB, DS, DSU, DW, or DWL directives must use this directive. The .LITERAL directive must be followed by an exported global label. The .ENDLITERAL directive resumes code compression.

Directive	Arguments
.LITERAL .ENDLITERAL	< none >

Example: Code compression is suspended for the data table.

```
Export DataTable
.LITERAL
DataTable:
DB 01h, 02h, 03h
.ENDLITERAL
```


[+] Feedback

5.16 Macro Definition MACRO, ENDM

Used to specify the start and end of a macro definition. The lines of code defined between a MACRO directive and an ENDM directive are not directly assembled into the program. Instead, it forms a macro that can later be substituted into the code by a macro call. The following MACRO directive is used to call the macro as well as a list of parameters. Each time a parameter is used in the macro body of a macro call, it will be replaced by the corresponding value from the macro call.

Any assembly statement is allowed in a macro body except for another macro statement and labels that are referenced from outside the macro.

Labels in macros have to be local to each invocation of the macro, for example:

macro xyz

mov a,2

loop: mov a,x

jnz loop

endmacro

Within a macro body, the expression @digit, where digit is between 0 and 9, is replaced by the corresponding macro argument when the macro is invoked. You cannot define a macro name that conflicts with an instruction mnemonic or an assembly directive.

Directive	Arguments
MACRO ENDM	< name >< arguments >

Example: A MACRO is defined and used in the source code.

```
        MACRO MyMacro
        ADD A, 42h
        MOV X, 33h
        ENDM
// The Macro instructions are expanded at address 2400
        ORG 2400h
        MyMacro
```


[+] Feedback

5.17 Area Origin ORG

Allows the programmer to set the value of the Program/Data Counter during assembly. This is most often used to set the start of a table in conjunction with the define directives DB, DS, and DW. The ORG directive can only be used in areas with the ABS mode.

An operand is required for an ORG directive and may be an integer constant, a label, or "." (the current PC). The ImageCraft Assembler does not keep track of areas previously defined and will not flag overlapping areas in a single source file.

Directive	Arguments
ORG	< address >

Example: The bytes defined after the ORG directive are at address 1000.

```
ORG 1000h
DB 55h, 66h, 77h
```


[+] Feedback

5.18 Section for Dead-Code Elimination .SECTION, .ENDSECTION

Allows the removal of code specified between the .SECTION and .ENDSECTION directives. The .SECTION directive must be followed by an exported global label. If there is no call to the global label, the code will be eliminated and call offsets will be adjusted appropriately. The .ENDSECTION directive ends the dead-code section. Note that use of this directive is not limited to removing dead code.

PSoC Designer takes care of dead code. Check the “Enable Elimination of un-used User Modules (area) APIs” field under the Project > Settings > Compiler tab. If you check this field upon a build, the system will go in and remove all dead code from the APIs in an effort to free up space.

Directive	Arguments
.SECTION .ENDSECTION	< none >

Example: The section of code is designated as possible dead code.

```
Export Counter8_1_WriteCompareValue
.SECTION
Counter8_1_WriteCompareValue:
     MOV   reg[Counter8_1_COMPARE_REG], A
     RET
.ENDSECTION
```

5.19 Suspend/Resume Code Compressor OR F,0; ADD SP,0

Used to prevent code compression of the code between the OR F,0 and ADD SP,0 instructions. The code compressor may need to be suspended for timing loops and jump tables. If the JACC instruction is used to access fixed offset boundaries in a jump table, any LJMP and/or LCALL instruction entries in the table may be optimized to relative jumps or calls, changing the proper offset value for the JACC. A RET or RETI instruction will resume code compression if it is encountered before an ADD SP,0 instruction. These instructions are defined as the macros Suspend_CodeCompressor and Resume_CodeCompressor in the file *m8c.inc*.

Directive	Arguments
OR F,0 ADD SP,0	< none >

Example: Code compression is suspended for the jump table.

```
OR F,0
MOV A, [State]
JACC StateTable
StateTable:
LJMP State1
LJMP State2
LJMP State3
ADD SP,0
```


[+] Feedback

[+] Feedback

[+] Feedback

6. Builds and Error Messages

This chapter briefly describes the PSoC Designer assemble and build process, linker operations, and errors you might encounter with your code.

6.1 Assemble and Build

Once you have added and modified assembly language source files, you must assemble the files and build the project. This is done so PSoC Designer can generate a HEX file to be used to download to the ICE and debug the PSoC program. Each time you assemble files or build the project, the Output Status window is cleared and the current status is entered as the process occurs.



To compile the source files for the current project, click the Compile/Assemble icon in the toolbar.



To build the current project, click the Build icon in the toolbar.

When building is complete, you will see the number of errors. Zero errors signifies that the assemblage or build was successful. One or more errors indicate problems with one or more files. For more information on the PSoC Designer Output Status Window refer to the *PSoC Designer IDE Guide*.

6.2 Linker Operations

The main purpose of the Linker is to combine multiple object files into a single output file, suitable to be downloaded to the In-Circuit Emulator for debugging the code and programming the device. Linking takes place in PSoC Designer when a project build is executed. The linker can also take input from a library which is basically a file containing multiple object files. In producing the output file, the Linker resolves any references between the input files. In some detail, the linking steps involve:

1. Making the startup file (*boot.asm*) the first file to be linked. The startup file initializes the execution environment for the C program to run.
2. Appending any libraries that you explicitly request (or in most cases, as are requested by the IDE) to the list of files to be linked. Library modules that are directly or indirectly referenced will be linked. All user-specified object files (e.g., your program files) are linked.
3. Scanning the object files to find unresolved references. The linker marks the object file (possibly in the library) that satisfies the references and adds it to its list of unresolved references. It repeats the process until there are no outstanding unresolved references.
4. Combining all marked object files into an output file, and generating map and listing files as needed.

For additional information about the Linker and specifying Linker settings, refer to the *PSoC Designer IDE Guide*.

[+] Feedback

6.3 Code Compressor and Dead-Code Elimination Error Messages

Problem –

```
!X The compiler has failed an internal consistency check. This may be due
to incorrect input or an internal error. Please report the information
target == 0 || new_target at ..\optm8c.c(340) to "Cypress" at
www.cypress.com/support.

Designer\tools\make: *** [output/drc_test.rom] Error 1
```

Note To obtain support go to http://www.cypress.com/support/login.cfm or www.cypress.com and click on Technical and Support KnowledgeBase at the bottom of the page.

Possible Causes –

1. The label in a `.LITERAL` or `.SECTION` segment of code has not been made global using the `EXPORT` directive or a double colon.
2. A `.LITERAL` segment has only a label and no defined data.
   a. `.SECTION` was not followed by a label.
   b. `.LITERAL` was not followed by a label.
   c. `.ENDSECTION` has no matching `.SECTION`.
   d. `.ENDLITERAL` has no matching `.LITERAL`.
   e. `.SECTION` has no `.ENDSECTION`.
   f. Unmatched `.LITERAL` directive.
   g. Directive creating data may not be compatible with Code Compression and other advanced technologies.
3. Data defined in ROM does not have the `.LITERAL` and `.ENDLITERAL` directives.

[+] Feedback

A. Reference Tables Appendix

The tables in this appendix are intended to serve as a quick reference to the M8C assembler directives. The tables are also found in the body of this guide. For detailed information on the instruction set and the assembler directives, refer to the Instruction Set Summary on page 14 and the Assembler Directives chapter on page 75.

A.1 Assembly Syntax Expressions

Table A-1. Assembly Syntax Expressions

Precedence	Expression	Symbol	Form
1	Bitwise Complement	~	(~a)
2	Multiplication/Division/Modulo	*, /, %	(a*b), (a/b), (a%b)
3	Addition / Subtraction	+, -	(a+b), (a-b)
4	Bitwise AND	&	(a&b)
5	Bitwise XOR	^	(a^b)
6	Bitwise OR	|	(a|b)
7	High Byte of an Address	>	(>a)
8	Low Byte of an Address	<	(<a)

A.2 Operand Constant Formats.

Table A-2. Constants Formats

Radix	Name	Formats	Example

127	ASCII Character	'J'	`mov A, 'J' ;character constant`
			`mov A, '\'' ;use "\" to escape "'"`
			`mov A, '\\' ;use "\" to escape "\"`

16	Hexadecimal	0x4A
		4Ah
		$4A
			`mov A, 0x4A ;hex--"0x" prefix`
			`mov A, 4Ah ;hex--append "h"`
			`mov A, $4A ;hex--"$" prefix`

10	Decimal	74	`mov A, 74 ;decimal--no prefix`
8	Octal	0112	`mov A, 0112 ;octal--zero prefix`
2	Binary	0b01001010 %01001010	`mov A, 0b01001010 ;bin--"0b" prefix` `mov A, %01001010 ;bin--"%" prefix`

[+] Feedback

A.3 Assembler Directives Summary

Table A-3. Assembler Directives Summary

Symbol	Directive
AREA	Area
ASCIZ	NULL Terminated ASCII String
BLK	RAM Byte Block
BLKW	RAM Word Block
DB	Define Byte
DS	Define ASCII String
DSU	Define UNICODE String
DW	Define Word
DWL	Define Word With Little Endian Ordering
ELSE	Alternative Result of IF Directive
ENDIF	End Conditional Assembly
ENDM	End Macro
EQU	Equate Label to Variable Value
EXPORT	Export
IF	Start Conditional Assembly
INCLUDE	Include Source File
.LITERAL, .ENDLITERAL	Prevent Code Compression of Data
MACRO	Start Macro Definition
ORG	Area Origin
.SECTION, .ENDSECTION	Section for Dead-Code Elimination
Suspend - OR F,0 Resume - ADD SP,0	Suspend and Resume Code Compressor

A.4 ASCII Code Table

Table A-4. ASCII Code Table

Dec	HEX	Oct	Char	Dec	HEX	Oct	Char	Dec	HEX	Oct	Char	Dec	HEX	Oct	Char
0	00	000	NULL	32	20	040	space	64	40	100	@	96	60	140	‘
1	01	001	SOH	33	21	041	!	65	41	101	A	97	61	141	a
2	02	002	STX	34	22	042	“	66	42	102	B	98	62	142	b
3	03	003	ETX	35	23	043	#	67	43	103	C	99	63	143	c
4	04	004	EOT	36	24	044	$	68	44	104	D	100	64	144	d
5	05	005	ENQ	37	25	045	%	69	45	105	E	101	65	145	e
6	06	006	ACK	38	26	046	&	70	46	106	F	102	66	146	f
7	07	007	BEL	39	27	047	‘	71	47	107	G	103	67	147	g
8	08	010	BS	40	28	050	(	72	48	110	H	104	68	150	h
9	09	011	HT	41	29	051	)	73	49	111	I	105	69	151	i
10	0A	012	LF	42	2A	052	*	74	4A	112	J	106	6A	152	j
11	0B	013	VT	43	2B	053	+	75	4B	113	K	107	6B	153	k
12	0C	014	FF	44	2C	054	,	76	4C	114	L	108	6C	154	l
13	0D	015	CR	45	2D	055	-	77	4D	115	M	109	6D	155	m
14	0E	016	SO	46	2E	056	.	78	4E	116	N	110	6E	156	n
15	0F	017	SI	47	2F	057	/	79	4F	117	O	111	6F	157	o
16	10	020	DLE	48	30	060	0	80	50	120	P	112	70	160	p
17	11	021	DC1	49	31	061	1	81	51	121	Q	113	71	161	q
18	12	022	DC2	50	32	062	2	82	52	122	R	114	72	162	r
19	13	023	DC3	51	33	063	3	83	53	123	S	115	73	163	s
20	14	024	DC4	52	34	064	4	84	54	124	T	116	74	164	t
21	15	025	NAK	53	35	065	5	85	55	125	U	117	75	165	u
22	16	026	SYN	54	36	066	6	86	56	126	V	118	76	166	v
23	17	027	ETB	55	37	067	7	87	57	127	W	119	77	167	w
24	18	030	CAN	56	38	070	8	88	58	130	X	120	78	170	x
25	19	031	EM	57	39	071	9	89	59	131	Y	121	79	171	y
26	1A	032	SUB	58	3A	072	:	90	5A	132	Z	122	7A	172	z
27	1B	033	ESC	59	3B	073	;	91	5B	133	[	123	7B	173	{
28	1C	034	FS	60	3C	074	<	92	5C	134	\	124	7C	174	|
29	1D	035	GS	61	3D	075	=	93	5D	135	]	125	7D	175	}
30	1E	036	RS	62	3E	076	>	94	5E	136	^	126	7E	176	~
31	1F	037	US	63	3F	077	?	95	5F	137	_	127	7F	177	DEL

[+] Feedback

A.5 Instruction Set Summary

Table A-5. Instruction Set Summary Sorted Numerically by Opcode

Opcode HEX	Cycles	Bytes	Instruction Format	Flags	Opcode HEX	Cycles	Bytes	Instruction Format	Flags	Opcode HEX	Cycles	Bytes	Instruction Format	Flags
00	15	1	SSC		2D	8	2	OR [X+expr], A	Z	5A	5	2	MOV [expr], X	
01	4	2	ADD A, expr	C, Z	2E	9	3	OR [expr], expr	Z	5B	4	1	MOV A, X	Z
02	6	2	ADD A, [expr]	C, Z	2F	10	3	OR [X+expr], expr	Z	5C	4	1	MOV X, A	
03	7	2	ADD A, [X+expr]	C, Z	30	9	1	HALT		5D	6	2	MOV A, reg[expr]	Z
04	7	2	ADD [expr], A	C, Z	31	4	2	XOR A, expr	Z	5E	7	2	MOV A, reg[X+expr]	Z
05	8	2	ADD [X+expr], A	C, Z	32	6	2	XOR A, [expr]	Z	5F	10	3	MOV [expr], [expr]	
06	9	3	ADD [expr], expr	C, Z	33	7	2	XOR A, [X+expr]	Z	60	5	2	MOV reg[expr], A	
07	10	3	ADD [X+expr], expr	C, Z	34	7	2	XOR [expr], A	Z	61	6	2	MOV reg[X+expr], A	
08	4	1	PUSH A		35	8	2	XOR [X+expr], A	Z	62	8	3	MOV reg[expr], expr	
09	4	2	ADC A, expr	C, Z	36	9	3	XOR [expr], expr	Z	63	9	3	MOV reg[X+expr], expr	
0A	6	2	ADC A, [expr]	C, Z	37	10	3	XOR [X+expr], expr	Z	64	4	1	ASL A	C, Z
0B	7	2	ADC A, [X+expr]	C, Z	38	5	2	ADD SP, expr		65	7	2	ASL [expr]	C, Z
0C	7	2	ADC [expr], A	C, Z	39	5	2	CMP A, expr		66	8	2	ASL [X+expr]	C, Z
0D	8	2	ADC [X+expr], A	C, Z	3A	7	2	CMP A, [expr]	if (A=B) Z=1	67	4	1	ASR A	C, Z
0E	9	3	ADC [expr], expr	C, Z	3B	8	2	CMP A, [X+expr]	if (A<B) C=1	68	7	2	ASR [expr]	C, Z
0F	10	3	ADC [X+expr], expr	C, Z	3C	8	3	CMP [expr], expr		69	8	2	ASR [X+expr]	C, Z
10	4	1	PUSH X		3D	9	3	CMP [X+expr], expr		6A	4	1	RLC A	C, Z
11	4	2	SUB A, expr	C, Z	3E	10	2	MVI A, [[expr]++]	Z	6B	7	2	RLC [expr]	C, Z
12	6	2	SUB A, [expr]	C, Z	3F	10	2	MVI [[expr]++], A		6C	8	2	RLC [X+expr]	C, Z
13	7	2	SUB A, [X+expr]	C, Z	40	4	1	NOP		6D	4	1	RRC A	C, Z
14	7	2	SUB [expr], A	C, Z	41	9	3	AND reg[expr], expr	Z	6E	7	2	RRC [expr]	C, Z
15	8	2	SUB [X+expr], A	C, Z	42	10	3	AND reg[X+expr], expr	Z	6F	8	2	RRC [X+expr]	C, Z
16	9	3	SUB [expr], expr	C, Z	43	9	3	OR reg[expr], expr	Z	70	4	2	AND F, expr	C, Z
17	10	3	SUB [X+expr], expr	C, Z	44	10	3	OR reg[X+expr], expr	Z	71	4	2	OR F, expr	C, Z
18	5	1	POP A	Z	45	9	3	XOR reg[expr], expr	Z	72	4	2	XOR F, expr	C, Z
19	4	2	SBB A, expr	C, Z	46	10	3	XOR reg[X+expr], expr	Z	73	4	1	CPL A	Z
1A	6	2	SBB A, [expr]	C, Z	47	8	3	TST [expr], expr	Z	74	4	1	INC A	C, Z
1B	7	2	SBB A, [X+expr]	C, Z	48	9	3	TST [X+expr], expr	Z	75	4	1	INC X	C, Z
1C	7	2	SBB [expr], A	C, Z	49	9	3	TST reg[expr], expr	Z	76	7	2	INC [expr]	C, Z
1D	8	2	SBB [X+expr], A	C, Z	4A	10	3	TST reg[X+expr], expr	Z	77	8	2	INC [X+expr]	C, Z
1E	9	3	SBB [expr], expr	C, Z	4B	5	1	SWAP A, X	Z	78	4	1	DEC A	C, Z
1F	10	3	SBB [X+expr], expr	C, Z	4C	7	2	SWAP A, [expr]	Z	79	4	1	DEC X	C, Z
20	5	1	POP X		4D	7	2	SWAP X, [expr]		7A	7	2	DEC [expr]	C, Z
21	4	2	AND A, expr	Z	4E	5	1	SWAP A, SP	Z	7B	8	2	DEC [X+expr]	C, Z
22	6	2	AND A, [expr]	Z	4F	4	1	MOV X, SP		7C	13	3	LCALL	
23	7	2	AND A, [X+expr]	Z	50	4	2	MOV A, expr	Z	7D	7	3	LJMP	
24	7	2	AND [expr], A	Z	51	5	2	MOV A, [expr]	Z	7E	10	1	RETI	C, Z
25	8	2	AND [X+expr], A	Z	52	6	2	MOV A, [X+expr]	Z	7F	8	1	RET	
26	9	3	AND [expr], expr	Z	53	5	2	MOV [expr], A		8x	5	2	JMP	
27	10	3	AND [X+expr], expr	Z	54	6	2	MOV [X+expr], A		9x	11	2	CALL	
28	11	1	ROMX	Z	55	8	3	MOV [expr], expr		Ax	5	2	JZ	
29	4	2	OR A, expr	Z	56	9	3	MOV [X+expr], expr		Bx	5	2	JNZ	
2A	6	2	OR A, [expr]	Z	57	4	2	MOV X, expr		Cx	5	2	JC	
2B	7	2	OR A, [X+expr]	Z	58	6	2	MOV X, [expr]		Dx	5	2	JNC	
2C	7	2	OR [expr], A	Z	59	7	2	MOV X, [X+expr]		Ex	7	2	JACC	
										Fx	13	2	INDEX	Z

Note 1 Interrupt acknowledge to Interrupt Vector table = 13 cycles.

Note 2 The number of cycles required by an instruction is increased by one for instructions that span 256 byte page boundaries in the Flash memory space.

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Table A-6. Instruction Set Summary Sorted Alphabetically by Mnemonic

Opcode HEX	Cycles	Bytes	Instruction Format	Flags	Opcode HEX	Cycles	Bytes	Instruction Format	Flags	Opcode HEX	Cycles	Bytes	Instruction Format	Flags
09	4	2	ADC A, expr	C, Z	76	7	2	INC [expr]	C, Z	20	5	1	POP X	
0A	6	2	ADC A, [expr]	C, Z	77	8	2	INC [X+expr]	C, Z	18	5	1	POP A	Z
0B	7	2	ADC A, [X+expr]	C, Z	Fx	13	2	INDEX	Z	10	4	1	PUSH X	
0C	7	2	ADC [expr], A	C, Z	Ex	7	2	JACC		08	4	1	PUSH A	
0D	8	2	ADC [X+expr], A	C, Z	Cx	5	2	JC		7E	10	1	RETI	C, Z
0E	9	3	ADC [expr], expr	C, Z	8x	5	2	JMP		7F	8	1	RET	
0F	10	3	ADC [X+expr], expr	C, Z	Dx	5	2	JNC		6A	4	1	RLC A	C, Z
01	4	2	ADD A, expr	C, Z	Bx	5	2	JNZ		6B	7	2	RLC [expr]	C, Z
02	6	2	ADD A, [expr]	C, Z	Ax	5	2	JZ		6C	8	2	RLC [X+expr]	C, Z
03	7	2	ADD A, [X+expr]	C, Z	7C	13	3	LCALL		28	11	1	ROMX	Z
04	7	2	ADD [expr], A	C, Z	7D	7	3	LJMP		6D	4	1	RRC A	C, Z
05	8	2	ADD [X+expr], A	C, Z	4F	4	1	MOV X, SP		6E	7	2	RRC [expr]	C, Z
06	9	3	ADD [expr], expr	C, Z	50	4	2	MOV A, expr	Z	6F	8	2	RRC [X+expr]	C, Z
07	10	3	ADD [X+expr], expr	C, Z	51	5	2	MOV A, [expr]	Z	19	4	2	SBB A, expr	C, Z
38	5	2	ADD SP, expr		52	6	2	MOV A, [X+expr]	Z	1A	6	2	SBB A, [expr]	C, Z
21	4	2	AND A, expr	Z	53	5	2	MOV [expr], A		1B	7	2	SBB A, [X+expr]	C, Z
22	6	2	AND A, [expr]	Z	54	6	2	MOV [X+expr], A		1C	7	2	SBB [expr], A	C, Z
23	7	2	AND A, [X+expr]	Z	55	8	3	MOV [expr], expr		1D	8	2	SBB [X+expr], A	C, Z
24	7	2	AND [expr], A	Z	56	9	3	MOV [X+expr], expr		1E	9	3	SBB [expr], expr	C, Z
25	8	2	AND [X+expr], A	Z	57	4	2	MOV X, expr		1F	10	3	SBB [X+expr], expr	C, Z
26	9	3	AND [expr], expr	Z	58	6	2	MOV X, [expr]		00	15	1	SSC	
27	10	3	AND [X+expr], expr	Z	59	7	2	MOV X, [X+expr]		11	4	2	SUB A, expr	C, Z
70	4	2	AND F, expr	C, Z	5A	5	2	MOV [expr], X		12	6	2	SUB A, [expr]	C, Z
41	9	3	AND reg[expr], expr	Z	5B	4	1	MOV A, X	Z	13	7	2	SUB A, [X+expr]	C, Z
42	10	3	AND reg[X+expr], expr	Z	5C	4	1	MOV X, A		14	7	2	SUB [expr], A	C, Z
64	4	1	ASL A	C, Z	5D	6	2	MOV A, reg[expr]	Z	15	8	2	SUB [X+expr], A	C, Z
65	7	2	ASL [expr]	C, Z	5E	7	2	MOV A, reg[X+expr]	Z	16	9	3	SUB [expr], expr	C, Z
66	8	2	ASL [X+expr]	C, Z	5F	10	3	MOV [expr], [expr]		17	10	3	SUB [X+expr], expr	C, Z
67	4	1	ASR A	C, Z	60	5	2	MOV reg[expr], A		4B	5	1	SWAP A, X	Z
68	7	2	ASR [expr]	C, Z	61	6	2	MOV reg[X+expr], A		4C	7	2	SWAP A, [expr]	Z
69	8	2	ASR [X+expr]	C, Z	62	8	3	MOV reg[expr], expr		4D	7	2	SWAP X, [expr]	
9x	11	2	CALL		63	9	3	MOV reg[X+expr], expr		4E	5	1	SWAP A, SP	Z
39	5	2	CMP A, expr	if (A=B) Z=1 if (A<B) C=1	3E	10	2	MVI A, [[expr]++]	Z	47	8	3	TST [expr], expr	Z
3A	7	2	CMP A, [expr]		3F	10	2	MVI [[expr]++], A		48	9	3	TST [X+expr], expr	Z
3B	8	2	CMP A, [X+expr]		40	4	1	NOP		49	9	3	TST reg[expr], expr	Z
3C	8	3	CMP [expr], expr		29	4	2	OR A, expr	Z	4A	10	3	TST reg[X+expr], expr	Z
3D	9	3	CMP [X+expr], expr		2A	6	2	OR A, [expr]	Z	72	4	2	XOR F, expr	C, Z
73	4	1	CPL A	Z	2B	7	2	OR A, [X+expr]	Z	31	4	2	XOR A, expr	Z
78	4	1	DEC A	C, Z	2C	7	2	OR [expr], A	Z	32	6	2	XOR A, [expr]	Z
79	4	1	DEC X	C, Z	2D	8	2	OR [X+expr], A	Z	33	7	2	XOR A, [X+expr]	Z
7A	7	2	DEC [expr]	C, Z	2E	9	3	OR [expr], expr	Z	34	7	2	XOR [expr], A	Z
7B	8	2	DEC [X+expr]	C, Z	2F	10	3	OR [X+expr], expr	Z	35	8	2	XOR [X+expr], A	Z
30	9	1	HALT		43	9	3	OR reg[expr], expr	Z	36	9	3	XOR [expr], expr	Z
74	4	1	INC A	C, Z	44	10	3	OR reg[X+expr], expr	Z	37	10	3	XOR [X+expr], expr	Z
75	4	1	INC X	C, Z	71	4	2	OR F, expr	C, Z	45	9	3	XOR reg[expr], expr	Z
										46	10	3	XOR reg[X+expr], expr	Z

Note 1 Interrupt acknowledge to Interrupt Vector table = 13 cycles.

Note 2 The number of cycles required by an instruction is increased by one for instructions that span 256 byte page boundaries in the Flash memory space.

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