UVU 4380 Instruction Set Architecture

Overview

Instruction Size: Fixed at 12 Bytes (96 bits)

4 Byte Instruction	4 Byte Operand 1	4 Byte Operand 2

Registers (22):

Name	Encoding	Description (all registers are 32 bits in size)
R0 – R15	0 - 15	General purpose registers, **initialized to 0 at startup**
PC	16	Program Counter, **initialized to the value of first integer in memory**
SL	17	Stack Lower limit (lowest legal address available to the stack)
SB	18	Stack Bottom (highest address)
SP	19	Stack Pointer (latest allocated byte on the stack, grows downward)
FP	20	Frame Pointer (points to the first word beneath the return address)
HP	21	Heap Pointer (initially set to SL, grows upward))

Memory: 32 bit address space; Byte addressable; Little-endian; 2^17 (131,072) Bytes of addressable memory

Instructions

Note: Several operands are marked as DC, meaning "Don't Care". This means that while the operand is required - its specific value doesn't matter to execution of the instruction.

Jump Instructions:

Value	Operator	Operand 1	Operand 2	Description
1	JMP	Address**	DC*	Jump to Address
2	JMR	RS	Don't Care	Update PC to value in RS
3	BNZ	RS	Address**	Update PC to Address if RS != 0
4	BGT	RS	Address**	Update PC to Address if RS > 0
5	BLT	RS	Address**	Update PC to Address if RS < 0
6	BRZ	RS	Address**	Update PC to Address if RS = 0

*This operand shall be omitted in 4380 assembly instructions but is required in 4380 bytecode.
**When represented in an assembly file the Address shall be represented as a label. Such labels MUST be associated with instructions.

Move Instructions:

Value	Operator	Operand 1	Operand 2	Description
7	MOV	RD	RS	Move contents of RS to RD
8	LDA	RD	Address**	Load address into RD
9	STR	RS	Address**	Store integer in RS at Address
10	LDR	RD	Address**	Load integer at Address to RD
11	STB	RS	Address**	Store least significant byte in RS at Address
12	LDB	RD	Address**	Load byte at Address to RD
22	ISTR	RS	RG	Store integer in RS at address in RG
23	ILDR	RD	RG	Load integer at address in RG into RD
24	ISTB	RS	RG	Store byte in RS at address in RG
25	ILDB	RD	RG	Load byte at address in RG into RD
31	MOVI	RD	Imm*	Move Imm value into RD

* When represented in an assembly file the Imm value shall be represented as a numeric or character literal.

**When represented in an assembly file the Address shall be represented as a label.

Arithmetic Operations:

Value	Operator	Operand 1	Operand 2	Description
13	ADD	RD	RS	Add RS to RD, store result in RD
14	ADDI	RD	Imm*	Add Imm to RD, store the result in RD
15	SUB	RD	RS	Subtract RS from RD, result in RD
16	MUL	RD	RS	Multiply RS by RD, result in RD
17	DIV	RD	RS	Perform unsigned integer division RD/RS. Store the result in RD. Division by zero shall result in an emulator error.
33	MULI	RD	Imm*	Multiply RD by Imm, store the result in RD
34	DIVI	RD	Imm*	Divide RD by Imm (signed), result in RD
38	SDIV	RD	RS	Store result of signed division RD / RS in RD

* When represented in an assembly file the Imm value shall be represented as a numeric literal.

Logical Instructions: (NOT BITWISE)

Value	Operator	Operand 1	Operand 2	Description
18	AND	RD	RS	Perform RD && RS, store result in RD
19	OR	RD	RS	Perform RD || RS, store result in RD

Compare Instructions:

Value	Operator	Operand 1	Operand 2	Description
20	CMP	RD	RS	Set RD = 0 if RD == RS | Set RD = 1 if RD > RS | Set RD = -1 if RD < RS
32	CMPI	RD	Imm*	Set RD = 0 if RD == Imm | Set RD = 1 if RD > Imm | Set RD = -1 if RD < Imm

* When represented in an assembly file the Imm value shall be represented as a numeric or character literal.

Traps/Interrupts:

Value	Operator	Operand 1*	Operand 2**	Description
21	TRP	#0	DC*	Executes the STOP/Exit routine
21	TRP	#1	DC*	Write int in R3 to stdout (console)
21	TRP	#2	DC*	Read an integer into R3 from stdin
21	TRP	#3	DC*	Write char in R3 to stdout
21	TRP	#4	DC*	Read a char into R3 from stdin
21	TRP	#5	DC*	Write the null-terminated Pascal-style string whose starting address is in R3 to stdout.
21	TRP	#6	DC*	Read a newline terminated string from stdin and store it in memory as a null-terminated Pascal-style string whose starting address is in R3. (Do not store the newline)
21	TRP	#98	DC*	Print all register contents to stdout

*Note: The leading '#' is required in 4380 assembly programs. Only the following numeric value is represented in 4380 bytecode.

**DC = "Don't Care". These operands shall be omitted in 4380 assembly instructions but are required in 4380 bytecode.

Heap Instructions:

Value	Operator	Operand 1	Operand 2	Description
35	ALCI	RD	Imm*	Allocate Imm bytes of space on the heap (and increment HP accordingly). The Imm value is a 4-byte unsigned integer. Store the initial heap pointer in RD.
36	ALLC	RD	Address**	Allocate a number of bytes on the heap according to the value of the 4-byte unsigned integer stored at Address (and increment HP accordingly). Store the initial heap pointer in RD.
37	IALLC	RD	RS	Indirectly allocate a number of bytes on the heap according to the value of the 4-byte unsigned integer at the memory address stored in RS (and increment HP accordingly). Store the initial heap pointer in RD.

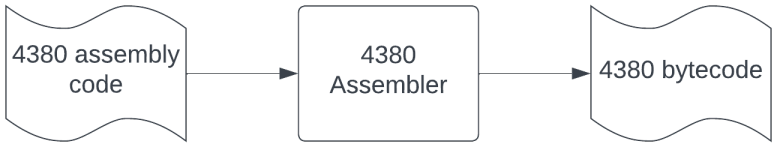
* When represented in an assembly file the Imm value shall be represented as a numeric literal.
** When represented in an assembly file the Address shall be represented as a label in the data section.

Procedure/Stack Instructions:

Value	Operator	Operand 1	Operand 2	Description
40	PSHR	RS	DC*	Set SP = SP - 4; Place the word in RS onto the stack
41	PSHB	RS	DC*	Set SP = SP - 1; Place the least significant byte in RS onto the stack
42	POPR	RD	DC*	Place the word on top of the stack into RD, update SP = SP + 4
43	POPB	RD	DC*	Place the byte on top of the stack into RD, update SP = SP + 1
44	CALL	Address**	DC*	Push PC onto stack, update PC to Address
45	RET	DC*	DC*	Pop stack into PC

*DC = "Don't Care". This operand shall be omitted in 4380 assembly instructions but is required in 4380 bytecode.
** When represented in an assembly file the Address shall be represented as a label.

4380 Assembly Language Programming



File Requirements

4380 assembly programs must be contained in text files with the '.asm' file extension (e.g. gradebook.asm). Each file is comprised of up to two sections - an optional Data Section (which contains the static and global variable definitions for the program), followed by a Code Section containing the program instructions. The Data Section (if present) must precede the Code Section. Both sections are described in greater detail below.

Line Format

Four valid line types may occur within a 4380 assembly file:

1. Blank lines: Containing only whitespace characters. These will be ignored by the assembler.
2. Comment lines: Containing zero or more whitespace characters followed by a valid comment. These will be ignored by the assembler.
3. Directive lines: Beginning with a label or whitespace character(s) followed by a valid directive.
4. Instruction lines: Beginning with a label or whitespace character(s) followed by a valid instruction.

Note that both directive and instruction lines begin with a label or whitespace, meaning that if a valid line begins with an alphanumeric character, that character is the beginning of a label.

Programmer Comments

4380 assembly files may contain programmer comments throughout the file. Comments begin with the ';' character and extend to the end of a line (much like C-style comments). All text following the ';' symbol shall be ignored by the 4380 Assembler.

```
;This example comment occupies an entire line.
A_LABEL     .BYT  #245;This comment occupies part of a line
```

Labels

Labels may be used to mark important locations within both the Data and Code sections of a 4380 assembly program (these sections are discussed below). Label definitions appear as the optional first elements of Directive Lines and Instruction Lines (they must not appear on a line by themselves). They must be left justified (no preceding whitespace characters). Label names must begin with an alphanumeric character and may contain alphanumeric characters and underscores. For example:

```
labelName9; This is a valid label
NUM_APPLES ; This is also a valid label
_bad ; This is an invalid label
```

Label names can be used as operands for instructions in the Code Section of a 4380 assembly.

Literal Data Representation

Both directives and instructions may make use of literal data within a 4380 assembly file. The supported numeric and character literals are as follows:

- Numeric: Signed integer value represented as a base 10 number preceded by the '#' character. Examples: #45, #2, #-67
- Character: Apostrophe delineated ascii character (including escape sequences for special characters), or a character's equivalent ascii code expressed as a decimal value. Examples: 't', 'Y', '6', '#', '\n', #83 (83 is the ascii code for the character 'S')

Data Section and Directives

The Data Section of a 4380 assembly contains assembler directives that define static and global variables. The Data Section implicitly begins with the first line of an assembly file and continues until the first line containing an assembly instruction.

Directives can only be used within the Data Section. The presence of one of these directives in the Code Section shall result in an assembler error. All directives begin with a period, making them easy to identify when parsing a 4380 assembly file. The supported directives for the Mark 1 assembler are as follows:

Directive	Operand	Examples	Behavior
.INT	Optional signed decimal value in the range -2147483648 to 2147483647 inclusive.	.INT #45 .INT #-12 .INT #2147483647	Allocates memory in place for a 4 byte integer and initializes it with the optional operand value. If no operand is provided the value is initialized to 0.
.BYT	Optional unsigned decimal value in the range 0 to 255 inclusive, OR apostrophe delineated ascii character (including escape sequences for special characters)	.BYT #45 .BYT 'a' .BYT '\n'	Allocates 1 byte of memory in place and initializes it with the optional decimal value or ascii code. If no operand is provided the value is initialized to 0.
.BTS	Required unsigned decimal value. This value is the number of bytes to be allocated.	.BTS #25 .BTS #5 a_label .BTS #20	Allocates the specified number of bytes in place and initializes them all to 0. If an optional label is present the label shall be associated with the address of the first byte allocated.
.STR	Required double quote delimited string OR a numeric literal. 255 shall be the maximum length of the string and the maximum value of the numeric literal.	.STR "Example!" name .STR "Fred" .STR #40 .STR #255	Allocates a number of bytes equal to the length of the string + 2. The first byte is initialized to the length of the string, and the last byte to 0 (null character). The remaining bytes (in the

			middle) are initialized to the ascii values for the characters in the string. **Note:** escape sequences such as \n must be properly handled. OR Allocates a number of bytes equal to the numeric literal + 2. The first byte is initialized to the value of the numeric literal and the remaining bytes are initialized to zeros. In both cases if an optional label is present the label shall be associated with the address of the first byte allocated.

Note that the assembler must treat directives as case INsensitive. For example ".int" and ".INT" must be treated the same by the assembler. The Data Section of an assembly may contain as many directives as desired (within the limitations of the emulator's memory) but shall be limited to one directive per line. Each directive may optionally be preceded by a label, which in this context serves as a variable or array name.

```
NUM_APPLES        .INT  #42; An integer variable initialized to 42
CURRENT_MONTH     .BYT ; An unsigned int variable initialized to 0
A_CHAR            .BYT  'A'; A char variable initialized to the
                           ; character 'A'
A_CHAR_ARRAY      .BYT  'H'; The first character of an array of
                           ; characters
                  .BYT  'e'
                  .BYT  'l'
                  .BYT  'l'
                  .BYT  'o'
```

Directive Format

Considering the preceding discussion the format of a 4380 directive can be summarized as follows:

```
[optional_label] <.directive> [optional_value][optional_comment]
```

Note the presence of required whitespace between the directive and the optional label and value. This whitespace must be comprised of space and/or tab characters.

Code Section

The Code Section of a 4380 assembly file implicitly begins with the first line containing an instruction, which must also be the following instruction:

```
    JMP   MAIN
```

Clearly this implies that a 4380 assembly file must contain a MAIN function/procedure that is properly marked with the label 'MAIN'. The absence of such a label and function shall result in an assembler error.

As with the Data Section and directives, the Code Section may contain as many instructions as are desired (within the limitations of the emulator's memory), but shall be limited to one instruction per line.

NOTE: Assembly directives and instructions cannot be interleaved. Directives are limited to the Data Section, and instructions must reside in the Code Section of a file.

Instruction Format

All 4380 Mark 1 instructions (including the additional instructions listed at the beginning of this document) shall be supported by the 4380 Mark 1 emulator. Instructions must be formatted as follows:

```
[optional_label] <operator> <operand_list> [optional_comment]
```

As with the format for directives, note the required whitespace (which can be comprised of spaces and/or tabs) separating the individual components of an instruction.

An instruction's `operator` is limited to one of the three-character representations of valid 4380 operators as listed in the instruction tables utilized in this course. For convenience we provide these tables again below. The assembler treats operators as case INsensitive. For example "aDd" and "ADD" should both be recognized/accepted by the assembler.

The `operand_list` is a comma separated list of the necessary operands for the operator being invoked. Valid operands include:

- Registers - indicated via the two or three-character register names listed in the register tables utilized in this course (again provided for convenience below). Note, the assembler shall treat register names as case INsensitive. R13 is considered the same as r13.
- Numeric constants - represented as literal values (e.g. #45).
- Labels - as defined in the assembly file and later resolved to addresses by the assembler. Labels are to be treated as case SENSITIVE by the assembler.