CISC SIMULATOR

Manual

V 3.3

Group 8

Md Shahjalal
Tianyou Bao
Xuzheng Lu

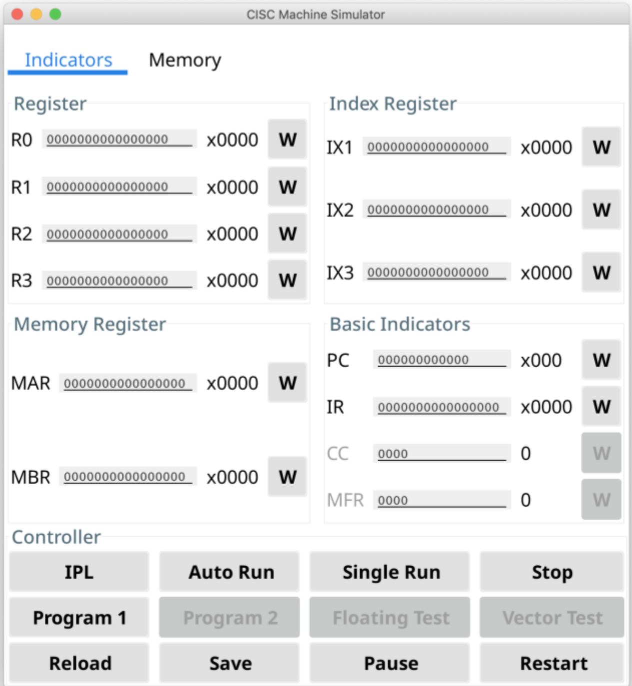
Contents

1 Introduction

This simulator is a simulation of a Complex Instruction Set Computer (CISC). Three panels are designed for the simulator, and two themes are supported.

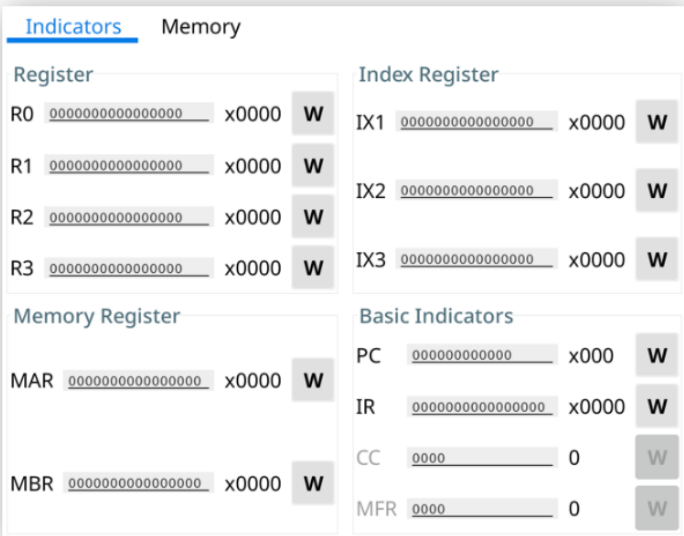
1.1 Debugging Panel

Debugging Panel displays all the information about the Registers, Indicators, and Memory in the computer and can be written manually.



The panel is divided into three parts:

1.1.1 Register Indicators Area

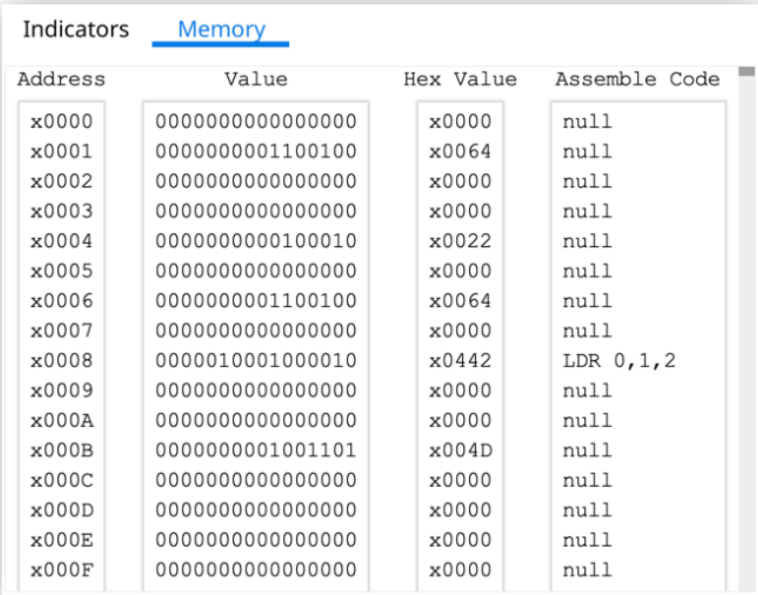


The Register Indicators display the values of all kinds of registers.

- Click the ‘W’ button to manually modify the value of a register.
- Hexadecimal values are shown on the right.

Type	Size(bits)	Number	Description
R0...R3	16	4	General-Purpose Register
IX1...IX3	16	3	Index Register
MAR	16	1	Memory Address Register
MBR	16	1	Memory Buffer Register
PC	12	1	Program Counter
IR	16	1	Instruction Register
CC	4	1	Condition Code
MFR	4	1	Machine Fault Register

1.1.2 Memory Area



The Memory Area shows the address, the value, the Hexadecimal value, and the Assemble Code of each line on memory.

- The memory address pointed by the Program Counter will be highlighted.
- Double click to manually modify the binary value of a memory row.

1.1.3 Controller Area

The Controller Area integrates all function buttons and the instruction input box.

Functions of the buttons in Controller Area:

Button	Function
IPL	Pre-load a program from I/O
Auto Run	Run the instructions until TRAP or HALT
Single Run	Run one instruction
Stop	Stop the workload on the machine
Program 1	Run Program 1
Program 2	Run Program 2
Floating Test	Test Floating Point Operations
Vector Test	Test Vector Operations
Reload	Reload the data from memory.txt to memory
Save	Save the data in memory to memory.txt
Pause	Pause the workload on the machine
Restart	Restart the machine

1.2 Operation Panel (Console)

Operation Panel is a console used for system operation through the command line.

Commands supported:

Command	Description
autorun	Run the instructions until TRAP or HALT (Same as ‘auto run’ and ‘run’)
auto run	Run the instructions Until TRAP or HALT (Same as ‘autorun’ and ‘run’)
clean	Clean the console (same as ‘cls’)
cls	Clean the console (same as ‘clean’)
exit	Shutdown the machine (same as ‘quit’ and ‘power off’)
floating test	Run the Floating Test
ipl	Load the program from I/O
pause	Pause the workload on the machine (not finished)
power off	Shutdown the machine (same as ‘exit’ and ‘quit’)
Program1	Run Program 1 (same as ‘Program 1’)

Program 1	Run Program 1 (same as ‘Program1’)
Program2	Run Program 1 (same as ‘Program 2’)
Program 2	Run Program 1 (same as ‘Program2’)
quit	Shutdown the machine (same as ‘exit’ and ‘power off’)
reload	Reload the data from memory.txt to memory
reset	Restart the machine (Same as ‘restart’)
restart	Restart the machine (Same as ‘reset’)
run	Run the instructions until TRAP or HALT (same as ‘autorun’ and ‘auto run’)
save	Save the data in memory to memory.txt
singlerun	Run one instruction (Same as ‘single run’)
single run	Run one instruction (Same as ‘singlerun’)
status	Show the status of the machine
stop	Stop the workload on the machine
switch theme	Switch the theme of UI Format: switch theme {$THEME_NAME} Now support ‘Material Design Ocean’ (or ‘MaterialDesignOcean’) and ‘Material Design Lighter’ (or ‘MaterialDesignLighter’)
vector test	Run the Vector Test
/help	Show the command list

1.3 Classic Panel

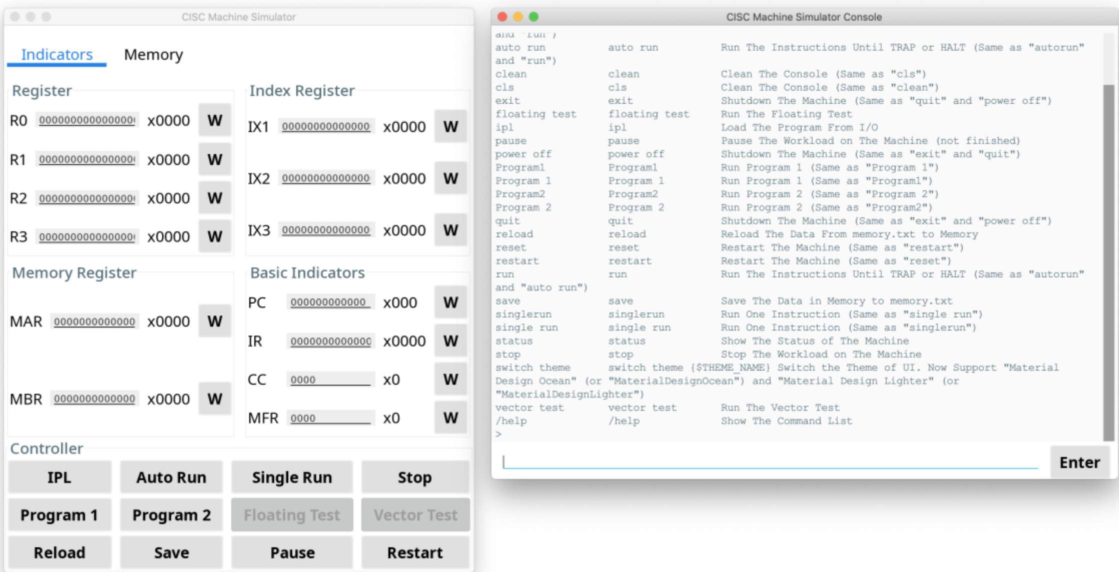
The appearance and operational logic of the **Classic Panel** emulate the PDP-8 computer. Users will use switches to input and lights for indication.

The **Classic Panel** has not been finished yet and will be released in the next version.

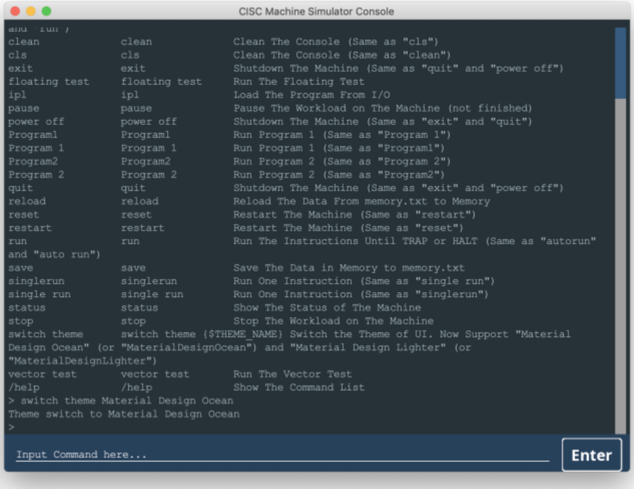
1.4 Themes

Two themes, Material Design Ocean and Material Design Lighter, are supported now.
To change the theme, input ‘switch theme {$THEME_NAME}’ in **Operation Panel**.

Material Design Lighter Theme (default)



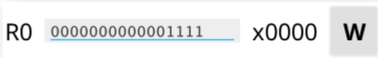
Material Design Ocean Theme



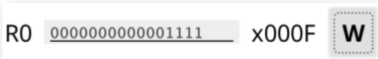
2 Basic Operations

2.1 Writing Values to Registers

Following the steps below to write a value to a register.
Step 1: Input a value into the box.

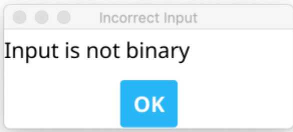


Step 2: Click the ‘W’ button at right to write the value to the register.



Step 3: Done! The value will be written to the Register.

Error handling:
- Input too long: Remove the excess bits from the left
- Input too short: Add zeros from the left
- Input is not binary: Pop up an Error window

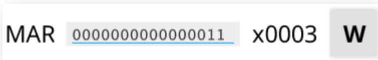


2.2 Writing Values to Memory

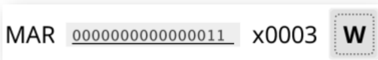
Two methods are acceptable to write a value to the Memory.

2.2.1 Using Memory Address Register and Memory Buffer Register

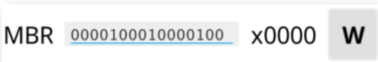
Step 1: Input a value into the MAR box.



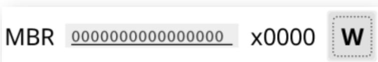
Step 2: Click the ‘W’ button of MAR.



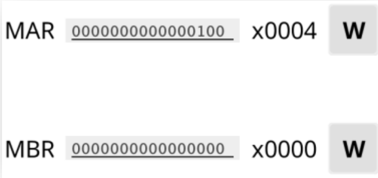
Step 3: Input a value into the MBR box.

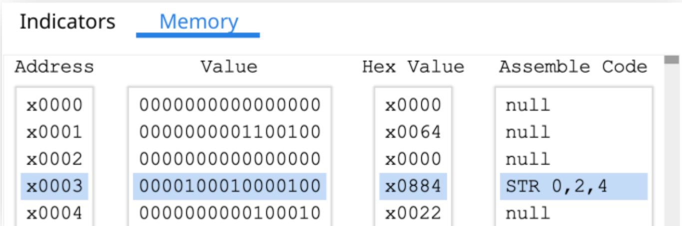


Step 4: Click the ‘W’ button of MBR.



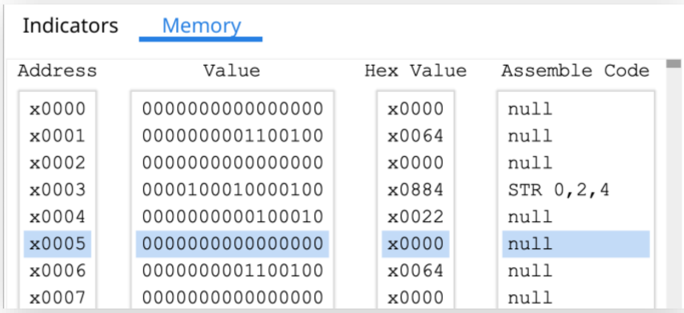
Step 5: Done! The value of MAR will be written to the Memory, and the MAR will automatically change to the next address.





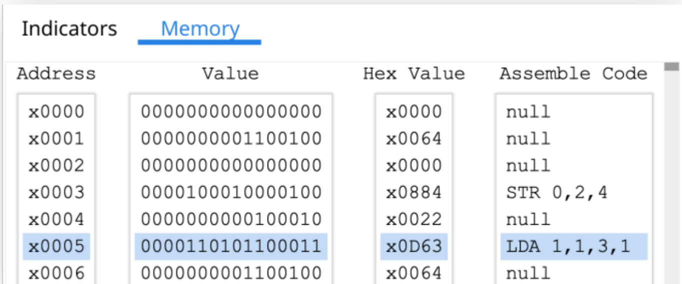
2.2.2 Modifying the Memory Area

Step 1: Double click the memory row that needs to modify.



Step 2: A window as the following will pop up. Input the value to be written to the memory.

Step 3: Click the 'OK' button, and then the value will be written to the Memory.

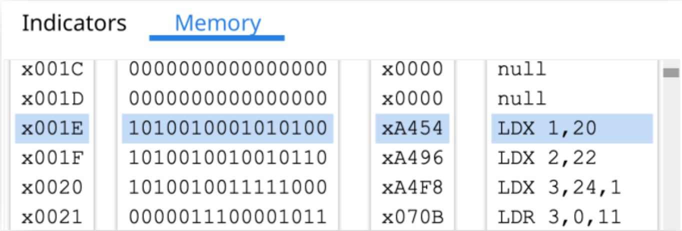


2.3 Executing Instructions

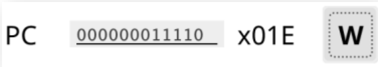
Instruction can be executed step-by-step or automatically.

2.3.1 Executing Instructions Step-by-Step

Step 1: Store an instruction to the Memory.

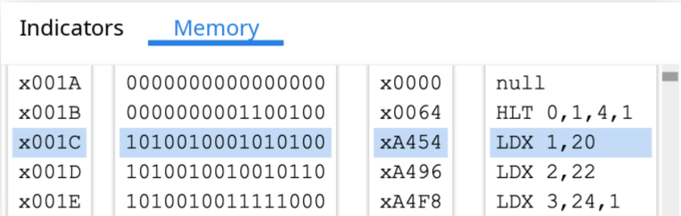


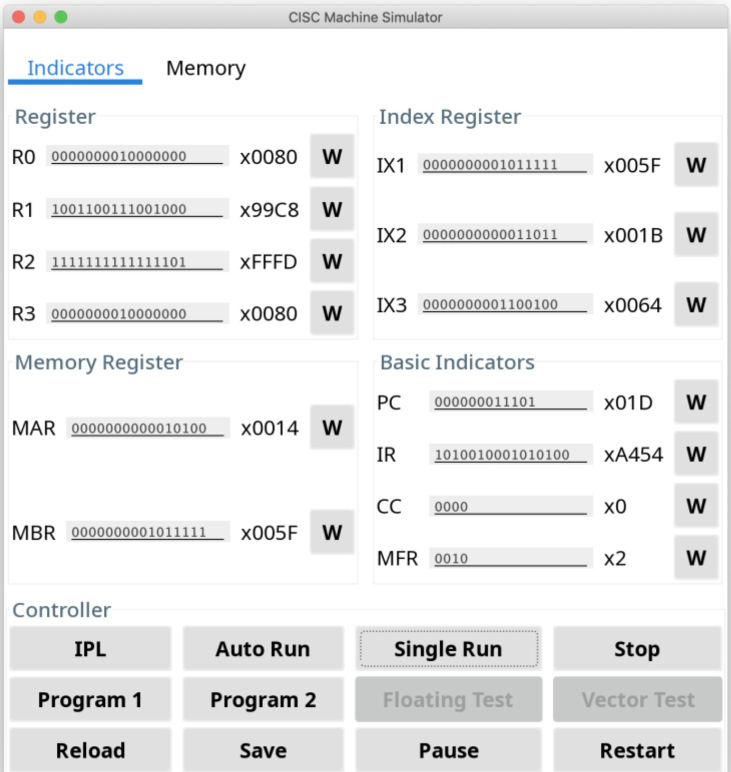
Step 2: Write the address of the instruction to the Program Counter (PC).



Step 3: Click the ‘Single Run’ button, and then the instruction will be executed.

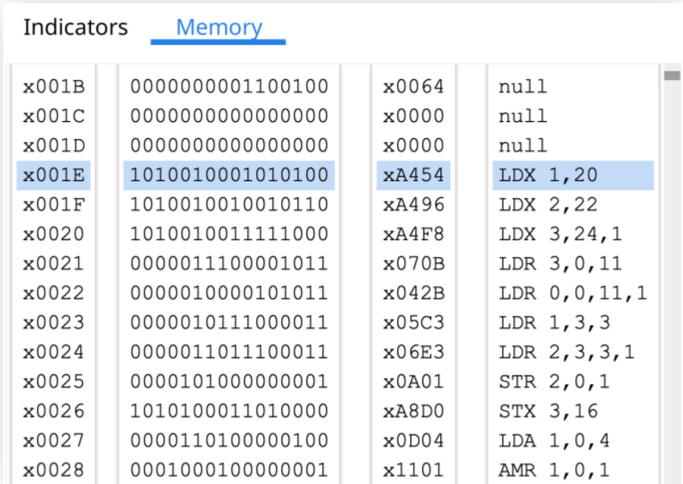
- The Program Counter will automatically point to the next address of Memory.
- The Instruction Register will store the last executed instruction.



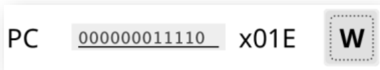


2.3.1 Executing Instructions Automatically

Step 1: Store instructions to the Memory.

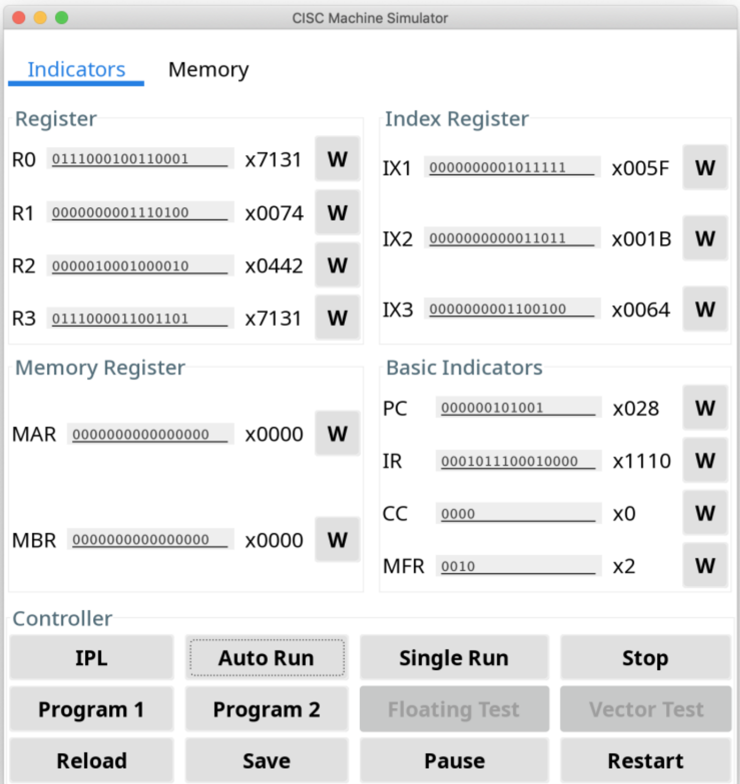


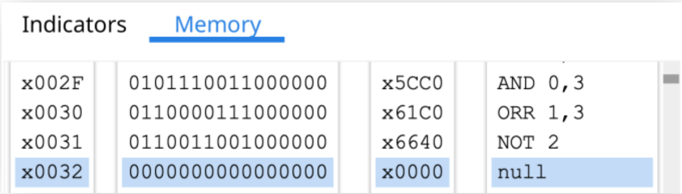
Step 2: Write the address of the **starting** instruction to the Program Counter (PC).



Step 3: Click the 'Auto Run' button, and then the instructions will be executed automatically.

- The Program Counter will automatically point to the next address of Memory after an instruction being executed.
- All the indicators will be continuously updated while the program is running.





Step 4: Click the ‘Pause’ button to pause the program or the ‘Stop’ button to stop the program.

3 Executing Programs

3.1 Executing Program 1

3.1.1 Program 1 Description

Program 1 is a program that reads 20 numbers (integers) from the keyboard, prints the numbers to the console printer, requests a number from the user, and searches the 20 numbers read in for the number closest to the number entered by the user. The numbers distributed over the range of 0 … 65535. Print the number entered by the user and the number closest to that number.

3.1.2 Program 1 Files

Program1.txt is the program that was written in assembly language.

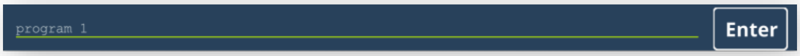
```
300  LDR 1, 0, 2, 1        // Print asking sentence              // Print 'Please input 20 numbers:\n'
301  JZ  1, 0, 3, 1        // Jump to the end if meet a blank line
302  OUT 1, 1              // Print a character
303  LDR 1, 0, 2
304  AIR 1, 1
305  STR 1, 0, 2           // MEM[2] ++
306  JMA 0, 4, 1           // Jump to start
307  LDA 0, 0, 0           // R0 = 0                             // Input 20 numbers
308  IN  1, 1              // read from input to R1
309  STR 1, 0, 1, 1        // Store R1 to MEM[MEM[1]]
310  LDR 1, 0, 1           // R1 = MEM[1]
311  AIR 1, 1              // R1 ++
312  STR 1, 0, 1           // MEM[1] ++
313  AIR 0, 1              // R0 ++
314  JMA 0, 5, 1           // Jump to print_2                    // Print received number
315  LDA 1, 0, 20          // R1 = 20
316  TRR 0, 1              // Test R0 == 20
317  JCC 3, 0, 6, 1        // Jump to start if RO != 20
318  LDR 1, 0, 26          // Initialize the pointer             // Print 'Please input the number you want to
     compare:\n'
319  STR 1, 0, 2           // MEM[2] = #138
320  LDR 1, 0, 2, 1        // Load a number
321  JZ  1, 0, 7, 1        // Jump to the end if meet a blank line
322  OUT 1, 1              // Print a character
323  LDR 1, 0, 2
324  AIR 1, 1
325  STR 1, 0, 2           // MEM[2] ++
326  JMA 0, 8, 1           // Jump to start
```

Program1.binary is the program that has been translated to machine codes.

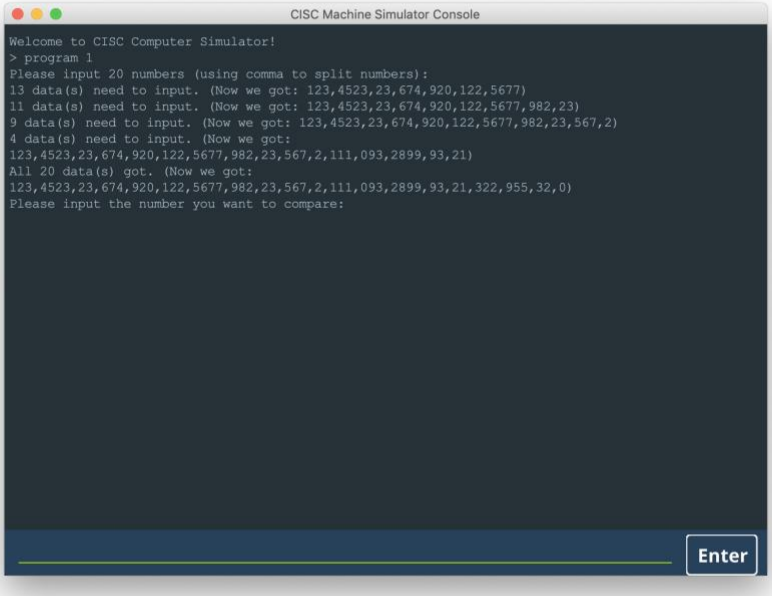
```
300  0000010100100010
301  0010100100100011
302  1111100100000001
303  0000010100000010
304  0001100100000001
305  0000100100000010
306  0011010000100100
307  0000110000000000
308  1111010100000001
309  0000100100100001
310  0000010100000001
311  0001100100000001
312  0000100100000001
313  0001100000000001
314  0011010000100101
315  0000110100010100
316  0101100001000000
317  0011001100100110
318  0000010100011010
319  0000100100000010
320  0000010100100010
321  0010100100100111
322  1111100100000001
323  0000010100000010
324  0001100100000001
325  0000100100000010
326  0011010000101000
```

3.1.3 Running Program 1

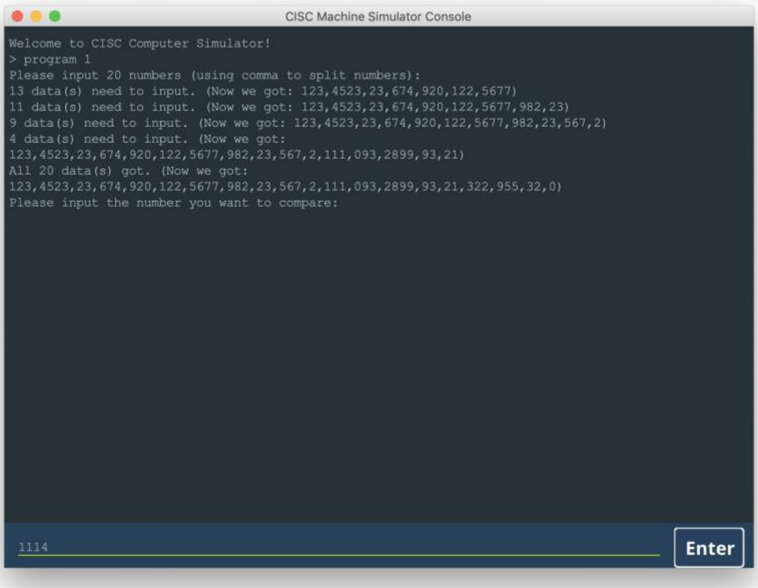
Step 1: Input ‘program 1’ or ‘program1’ in the **Operation Panel (Console)** and then click the ‘Enter’ button. Or click the ‘Program 1’ button in the **Debugging Panel**.



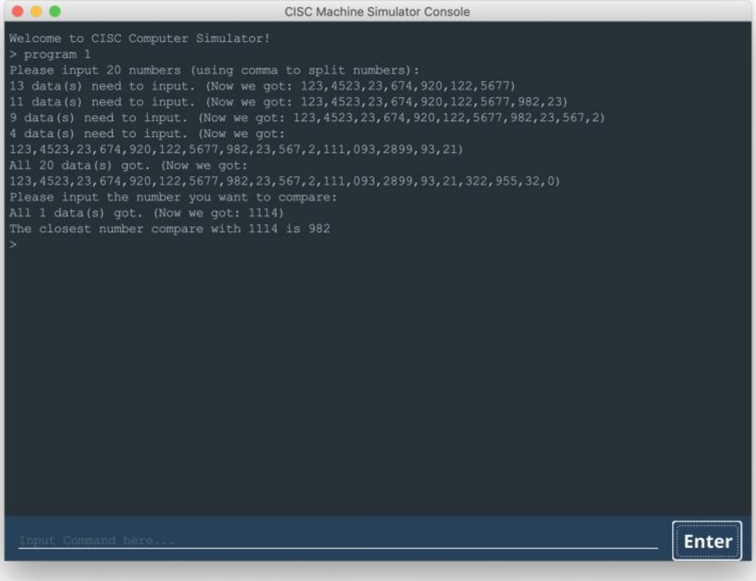
Step 2: Input numbers (use comma to split numbers) and then click the ‘Enter’ button. You can fill the numbers several times to input the required 20 numbers.



Step 3: Input the number for comparing.



Step 4: Done! The result of the calculation will be output to the **Console**.



3.2 Executing Program 2

3.1.1 Program 2 Description

Program 2 is a program that reads a set of a paragraph of 6 sentences from a file into memory. It prints the sentences on the console printer. It then asks the user for a word. It searches the paragraph to see if it contains the word. If so, it prints out the word, the sentence number, and the word number in the sentence.

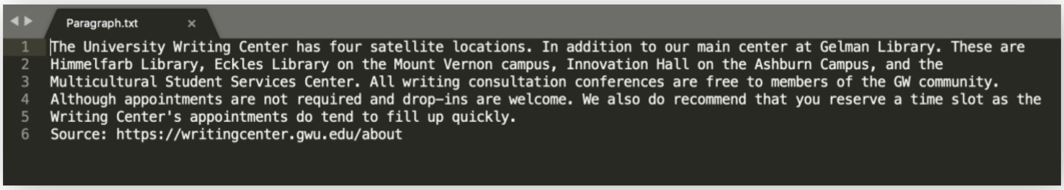
3.1.2 Program 2 Files

Program2.txt is the program that was written in assembly language.

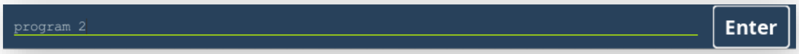
Program2.binary is the program that has been translated to machine codes.

3.1.3 Running Program 2

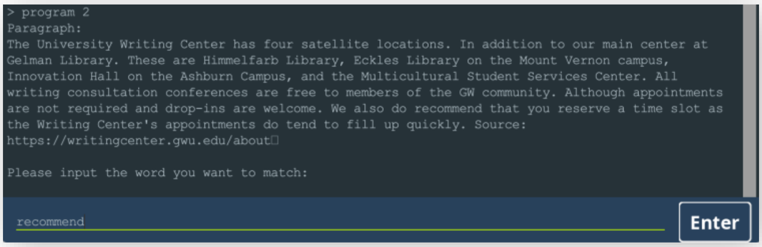
Step 1: Write a paragraph of 6 sentences into the text file ' Paragraph.txt'.



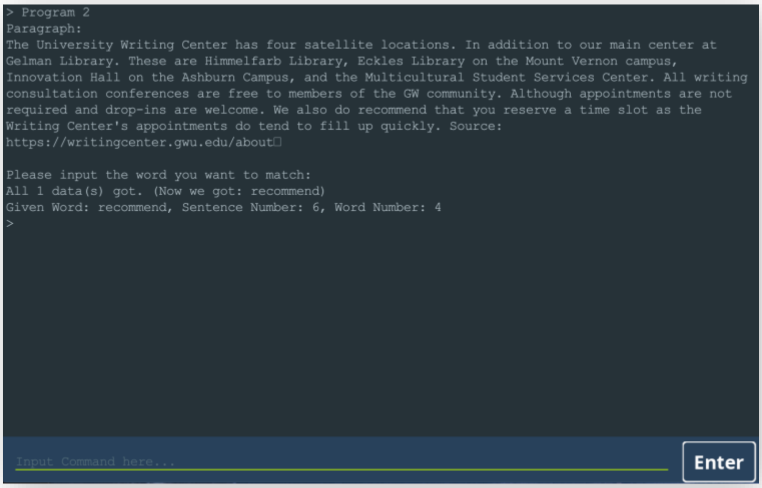
Step 2: Input ‘program 2’ or ‘program2’ in the **Operation Panel (Console)** and then click the ‘Enter’ button. Or click the ‘Program 2’ button in the **Debugging Panel**.



Step 3: The paragraph will be loaded from the text file to Memory and will be displayed in the **Operation Panel (Console)**. Then, input the word to be matched to the paragraph.



Step 4: Done! The **Operation Panel (Console)** will print out the word, the sentence number in the paragraph, and the word number in the sentence.



3.3 Executing a Custom Program Using IPL

3.3.1 Using Operation Panel (Console)

Step 1: Write the custom program in a text file.
Step 2: Input 'ipl' command to the console to import the program to the memory.
Step 4: Input 'auto run' or 'autorun' command to the console, and then the program will be executed. Or input 'single run' or 'singlerun' command to run the program step-by-step.

3.3.2 Using Debugging Panel

Step 1: Write the custom program in a text file.
Step 2: Click the 'IPL' button to import the program to the memory.
Step 3: Click the 'Auto Run' button, and then the program will be executed. Or click the 'Single Run' button to run the program step-by-step.

4 Instructions Reference

4.1 Load/Store Instructions

The instructions to load/store values from/to Registers or Memory.

The binary instruction code format of Load/Store Instructions is as follows:

Opcode	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Opcode:	6 bits	Specifies the instruction
R:	2 bits	Specifies the General-Purpose Register
IX:	2 bits	Specifies the Index Register
I:	1 bit	Specifies Indirect Addressing If I =1, indirect addressing; otherwise, no indirect addressing.
Address:	5 bits	Specifies the location

4.1.1 (01) LDR

000001	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	LDR r, x, address[, I]
Octal-Opcode:	01
Binary-Opcode:	000001
Function:	Loads Register from Memory
Notes:	r = 0...3 r <- c(EA) r <- c(c(EA)), if I bit set

4.1.2 (02) STR

000010	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	STR r, x, address[, I]
Octal-Opcode:	02
Binary-Opcode:	000010
Function:	Stores Register to Memory
Notes:	r = 0...3 Memory(EA) <- c(r)

4.1.3 (03) LDA

000011	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: LDA r, x, address[, I]
Octal-Opcode: 03
Binary-Opcode: 000011
Function: Loads Register with Address
Notes: r = 0...3
r <- EA

4.1.4 (41) LDX

101001		IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: LDX x, address[, I]
Octal-Opcode: 41
Binary-Opcode: 101001
Function: Loads Index Register from Memory
Notes: Xx <- c(EA)

4.1.5 (42) STX

101010		IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: STX x, address[, I]
Octal-Opcode: 42
Binary-Opcode: 101010
Function: Stores Index Register to Memory
Notes: Memory(EA) <- c(Xx)

4.2 Arithmetic and Logical Instructions

The instructions to perform most of the computational works in the machine.

The binary instruction code format of basic Arithmetic and Logical Instructions is as follows:

Opcode	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Opcode:	6 bits	Specifies the instruction
R:	2 bits	Specifies the General-Purpose Register
IX:	2 bits	Specifies the Index Register
I:	1 bit	Specifies Indirect Addressing If I =1, indirect addressing; otherwise, no indirect addressing.
Address:	5 bits	Specifies the location

The binary instruction code format of register-to-register Arithmetic and Logical Instructions is as follows:

Opcode	Rx	Ry	
0 5	6 7	8 9	10 15

Opcode:	6 bits	Specifies the instruction
Rx:	2 bits	Specifies the General-Purpose Register x
Ry:	2 bits	Specifies the General-Purpose Register y

4.2.1 (04) AMR

000100	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	AMR r, x, address[, I]
Octal-Opcode:	04
Binary-Opcode:	000100
Function:	Add Memory to Register
Notes:	r = 0...3
	r <- c(r) + c(EA)

4.2.2 (05) SMR

000101	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	SMR r, x, address[, I]
Octal-Opcode:	05
Binary-Opcode:	000101
Function:	Subtract Memory from Register
Notes:	r = 0...3
	r <- c(r) - c(EA)

4.2.3 (06) AIR

000110	R			Immed
0 5	6 7	8 9	10	11 15

Instruction: AIR r, immed
Octal-Opcode: 06
Binary-Opcode: 000110
Function: Add Immediate to Register
Notes: r = 0...3
r <- c(r) + Immed
if Immed = 0, does nothing
if c(r) = 0, loads r with Immed

4.2.4 (07) SIR

000111	R			Immed
0 5	6 7	8 9	10	11 15

Instruction: SIR r, immed
Octal-Opcode: 07
Binary-Opcode: 000111
Function: Subtract Immediate from Register
Notes: r = 0...3
r <- c(r) - Immed
if Immed = 0, does nothing
if c(r) = 0, loads R1 with -(Immed)

4.2.5 (20) MLT

010100	Rx	Ry	
0 5	6 7	8 9	10 15

Instruction: MLT rx, ry
Octal-Opcode: 20
Binary-Opcode: 010100
Function: Multiply Register by Register
Notes: rx, rx+1 <- c(rx) * c(ry)
rx, ry must be 0 or 2
rx contains the high order bits
rx+1 contains the low order bits of the result
Set OVERFLOW flag, if overflow

4.2.6 (21) DVD

010101	Rx	Ry	
0 5	6 7	8 9	10 15

Instruction: DVD rx, ry
Octal-Opcode: 21
Binary-Opcode: 010101
Function: Divide Register by Register
Notes: rx, rx+1 <- c(rx) / c(ry)
rx, ry must be 0 or 2
rx contains the quotient; rx+1 contains the remainder
If c(ry) = 0, set cc(3) to 1 (set DIVZERO flag)

4.2.7 (22) TRR

010110	Rx	Ry	
0 5	6 7	8 9	10 15

Instruction: TRR rx, ry
Octal-Opcode: 22
Binary-Opcode: 010110
Function: Test the Equality of Register and Register
Notes: If c(rx) = c(ry), set cc(4) <- 1;
Else, cc(4) <- 0

4.2.8 (23) AND

010111	Rx	Ry	
0 5	6 7	8 9	10 15

Instruction: AND rx, ry
Octal-Opcode: 23
Binary-Opcode: 010111
Function: Logical AND of Register and Register
Notes: c(rx) <- c(rx) AND c(ry)

4.2.9 (24) ORR

011000	Rx	Ry	
0 5	6 7	8 9	10 15

Instruction: ORR rx, ry
Octal-Opcode: 24
Binary-Opcode: 011000
Function: Logical OR of Register and Register
Notes: c(rx) <- c(rx) OR c(ry)

4.2.10 (25) NOT

011001	Rx	
0 5	6 7	8 15

Instruction: NOT rx
Octal-Opcode: 25
Binary-Opcode: 011001
Function: Logical NOT of Register to Register
Notes: C(rx) <- NOT c(rx)

4.3 Transfer Instructions

The instructions to check the value of a register and then change the control of program execution.

The binary instruction code format of Transfer Instructions is as follows:

Opcode	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Opcode:	6 bits	Specifies the instruction
R:	2 bits	Specifies the General-Purpose Register
IX:	2 bits	Specifies the Index Register
I:	1 bit	Specifies Indirect Addressing If I =1, indirect addressing; otherwise, no indirect addressing.
Address:	5 bits	Specifies the location

4.3.1 (10) JZ

001010	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: JZ r, x, address[, I]
Octal-Opcode: 10
Binary-Opcode: 001010
Function: Jump if Zero

Notes: r = 0...3
If c(r) = 0, then PC <- EA; Else PC <- PC+1

4.3.2 (11) JNE

001011	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: JNE r, x, address[, I]
Octal-Opcode: 11
Binary-Opcode: 001011
Function: Jump if Not Equal
Notes: r = 0...3
If c(r) != 0, then PC <- EA;
Else PC <- PC + 1

4.3.3 (12) JCC

001100	CC	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: JCC cc, x, address[, I]
Octal-Opcode: 12
Binary-Opcode: 001100
Function: Jump if Condition Code
Notes: cc = 0...3, specifies the bit in the Condition Code Register to check
If cc = 1, PC <- EA; Else PC <- PC + 1

4.3.4 (13) JMA

001101		IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: JMA x, address[, I]
Octal-Opcode: 13
Binary-Opcode: 001101
Function: Unconditional Jump to Address
Notes: PC <- EA

4.3.5 (14) JSR

001110		IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	JSR x, address[, I]
Octal-Opcode:	14
Binary-Opcode:	001110
Function:	Jump and Save Return Address
Notes:	R3 <- PC+1
	PC <- EA
	R0 should contain pointer to arguments
	Argument list should end with -1 (all 1s) value

4.3.6 (15) RFS

001111			Immed
0 … 5	6 7	8 9	10	11 … 15

Instruction:	RFS immed
Octal-Opcode:	15
Binary-Opcode:	001111
Function:	Return from Subroutine with Return Code as Immediate Portion (optional) Stored in the Instruction’s Address Field
Notes:	R0 <- Immed
	PC <- c(R3)

4.3.7 (16) SOB

010000	R	IX	I	Address
0 … 5	6 7	8 9	10	11 … 15

Instruction:	SOB r, x, address[, I]
Octal-Opcode:	16
Binary-Opcode:	010000
Function:	Subtract One and Branch
Notes:	r = 0...3
	r <- c(r) - 1
	If c(r) > 0, PC <- EA;
	Else PC <- PC + 1

4.3.8 (17) JGE

010001	R	IX	I	Address
0 … 5	6 7	8 9	10	11 … 15

Instruction:	JGE r, x, address[, I]
Octal-Opcode:	17

Binary-Opcode: 010001
Function: Jump Greater than or Equal to
Notes: If c(r) >= 0, then PC <- EA; Else PC <- PC + 1

4.4 Shift/Rotate Instructions

The instructions to manipulate a datum in a register.

The binary instruction code format of Shift and Rotate Instructions is as follows:

Opcode	R	A/L	L/R		Count
0 5	6 7	8	9	10 11	12 15

Opcode:	6 bits	Specifies the instruction
R:	2 bits	Specifies the General-Purpose Register
A/L:	2 bits	Arithmetic Shift (A/L = 0); Logical Shift (A/L = 1)
L/R:	2 bits	Logical Rotate (L/R = 1)
Count:	4 bits	Specifies the Count for Operation

4.4.1 (31) SRC

Opcode	R	A/L	L/R		Count
0 5	6 7	8	9	10 11	12 15

Instruction: SRC r, count, L/R, A/L
Octal-Opcode: 31
Binary-Opcode: 011111
Function: Shift Register by Count
Notes: c(r) is shifted left (L/R =1) or right (L/R = 0) either logically (A/L = 1) or arithmetically (A/L = 0)
Count = 0...15; If Count = 0, no shift occurs

4.4.2 (32) RRC

Opcode	R	A/L	L/R		Count
0 5	6 7	8	9	10 11	12 15

Instruction: RRC r, count, L/R, A/L
Octal-Opcode: 32
Binary-Opcode: 100000
Function: Rotate Register by Count
Notes: c(r) is rotated left (L/R = 1) or right (L/R =0) either logically (A/L =1)
Count = 0...15

4.5 Floating Point and Vector Instructions

The instructions for calculation of floating points and vectors.

The binary instruction code format of Floating Point and Vector Instructions is as follows:

Opcode	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Opcode:	6 bits	Specifies the instruction
FR:	2 bis	Specifies the Floating Point Register
IX:	2 bits	Specifies the Index Register
I:	1 bit	Specifies Indirect Addressing If I =1, indirect addressing; otherwise, no indirect addressing.
Address:	5 bits	Specifies the location

Floating Point numbers are 16 bits in length, and the format of the Floating Point number is as follows:

S	Exponent	Mantissa
0	1 7	8 15

S:	1 bit	The sign of the Floating Point number
Exponent:	7 bits	Specifies the Exponent
Mantissa:	8 bits	Specifies the Mantissa

4.5.1 (33) FADD

100001	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	FADD fr, x, address[, I]
Octal-Opcode:	33
Binary-Opcode:	100001
Function:	Floating Point Add Memory to Floating Point Register
Notes:	c(fr) <- c(fr) + c(EA) c(fr) <- c(fr) + c(c(EA)), if I bit set fr must be 0 or 1.

4.5.2 (34) FSUB

100010	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: FSUB fr, x, address[, I]
Octal-Opcode: 34
Binary-Opcode: 100010
Function: Floating Point Subtract Memory from Floating Point Register
Notes: c(fr) <- c(fr) - c(EA)
c(fr) <- c(fr) - c(c(EA)), if I bit set
fr must be 0 or 1
UNDERFLOW may be set

4.5.3 (35) VADD

100011	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: VADD fr, x, address[, I]
Octal-Opcode: 35
Binary-Opcode: 100011
Function: Vector Add Memory to Floating Point Register
Notes: fr contains the length of the vectors
c(EA) or c(c(EA)), if I bit set, is address of first vector
c(EA+1) or c(c(EA+1)), if I bit set, is address of the second vector
Let V1 be vector at address; Let V2 be vector at address+1
Then, V1[i] = V1[i]+ V2[i], i = 1, c(fr).

4.5.4 (36) VSUB

100100	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction: VSUB fr, x, address[, I]
Octal-Opcode: 36
Binary-Opcode: 100100
Function: Vector Subtract Memory to Floating Point Register
Notes: fr contains the length of the vectors
c(EA) or c(c(EA)), if I bit set is address of first vector
c(EA+1) or c(c(EA+1)), if I bit set is address of the second vector
Let V1 be vector at address; Let V2 be vector at address+1
Then, V1[i] = V1[i] - V2[i], i = 1, c(fr)

4.5.5 (37) CNVRT

100101	R	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	CNVRT r, x, address[, I]
Octal-Opcode:	37
Binary-Opcode:	100101
Function:	Convert to Fixed/Floating Point
Notes:	If F = 0, convert c(EA) to a Fixed Point number and store in r If F = 1, convert c(EA) to a Floating Point number and store in FR0 The r register contains the value of F before the instruction is executed

4.5.6 (50) LDFR

110010	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	LDFR fr, x, address [, I]
Octal-Opcode:	50
Binary-Opcode:	110010
Function:	Load Floating Point Register from Memory
Notes:	fr <- c(EA), c(EA+1) fr <- c(c(EA), c(EA)+1), if I bit set

4.5.7 (51) STFR

110011	FR	IX	I	Address
0 5	6 7	8 9	10	11 15

Instruction:	STFR fr, x, address [, I]
Octal-Opcode:	51
Binary-Opcode:	110011
Function:	Store Floating Point Register to Memory
Notes:	EA, EA+1 <- c(fr) c(EA), c(EA)+1 <- c(fr), if I-bit set

4.6 I/O Instructions

The instructions to communicate with the peripherals attached to the computer system.

The binary instruction code format of I/O Instructions is as follows:

Opcode	R		DevID
0 5	6 7	8 10	11 15

Opcode:	6 bits	Specifies the instruction	
R:	2 bits	Specifies the General-Purpose Register	
DevID:	5 bits	Device ID:	
		0	Console Keyboard
		1	Console Printer
		2	Card Reader
		3-31	Console Registers, Switches, etc.

4.6.1 (61) IN

111101	R		DevID
0 … 5	6 7	8 … 10	11 … 15

Instruction: IN r, devid
Octal-Opcode: 61
Binary-Opcode: 111101
Function: Input Character to Register from Device
Notes: r = 0...3

4.6.2 (62) OUT

111110	R		DevID
0 … 5	6 7	8 … 10	11 … 15

Instruction: OUT r, devid
Octal-Opcode: 62
Binary-Opcode: 111110
Function: Output Character to Device from Register
Notes: r = 0...3

4.6.3 (63) CHK

111111	R		DevID
0 … 5	6 7	8 … 10	11 … 15

Instruction: CHK r, devid
Octal-Opcode: 63
Binary-Opcode: 111111
Function: Check Device Status to Register
Notes: r = 0...3
c(r) <- device status

4.7 Other Instructions

4.7.1 (00) HALT

Instruction: HALT
Octal-Opcode: 00
Binary-Opcode: 000000
Function: Stop the machine

4.7.2 (30) TRAP

Instruction: TRAP code
Octal-Opcode: 30
Binary-Opcode: 011110
Function: Traps to memory address 0, which contains the address of a table in memory. Stores the PC+1 in memory location 2.
Notes: The table can have a maximum of 16 entries representing 16 routines for user-specified instructions stored elsewhere in memory. Trap code contains an index into the table, e.g. it takes values 0 – 15.
When a TRAP instruction is executed, it goes to the routine whose address is in memory location 0, executes those instructions, and returns to the instruction stored in memory location 2. The PC+1 of the TRAP instruction is stored in memory location 2.