

CISCO SIMULATOR

Manual

V 4.1

Group 8

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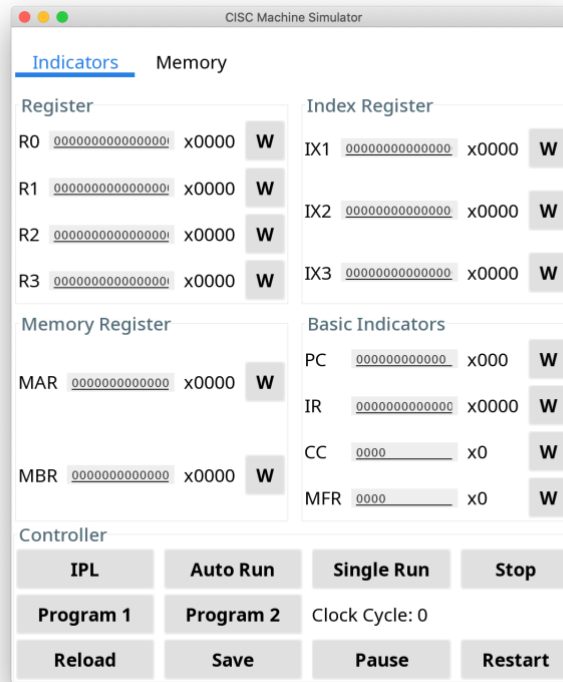
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1 Introduction

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

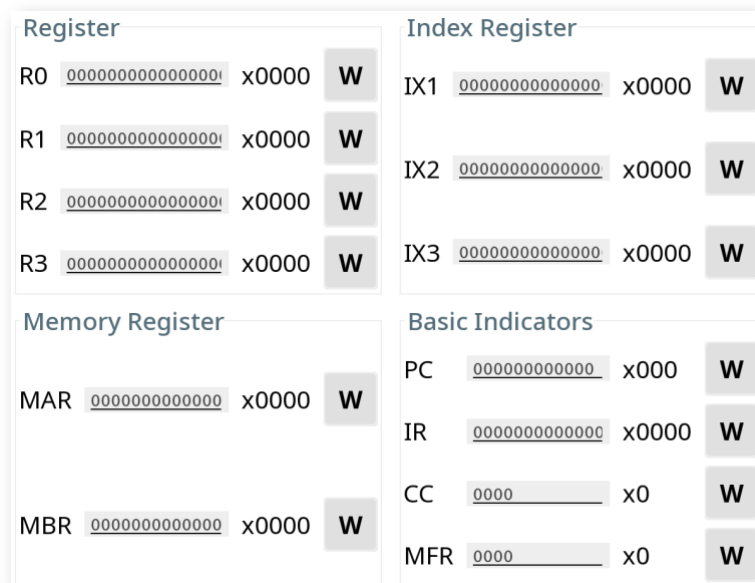
1.1 Debugging Panel

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

Indicators		Memory	
Address	Value	Hex Value	Assemble Code
x0000	0000000000000000	x0000	null
x0001	0000000001100100	x0064	null
x0002	0000000000000000	x0000	null
x0003	0000000000000000	x0000	null
x0004	0000000000100010	x0022	null
x0005	0000000000000000	x0000	null
x0006	0000000001100100	x0064	null
x0007	0000000000000000	x0000	null
x0008	0000010001000010	x0442	LDR 0,1,2
x0009	0000000000000000	x0000	null
x000A	0000000000000000	x0000	null
x000B	0000000001001101	x004D	null
x000C	0000000000000000	x0000	null
x000D	0000000000000000	x0000	null
x000E	0000000000000000	x0000	null
x000F	0000000000000000	x0000	null

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.

Controller			
IPL	Auto Run	Single Run	Stop
Program 1	Program 2	Clock Cycle: 0	
Reload	Save	Pause	Restart

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
Clock Cycle	Shows the clock cycle during program
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:

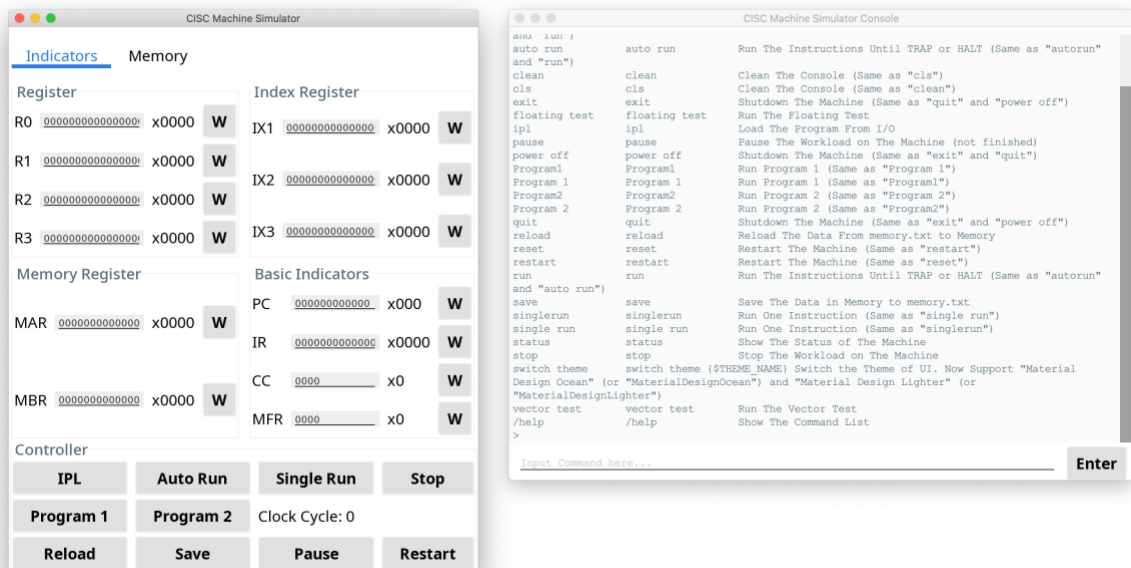
Command	Description
autorun	Run the instructions until TRAP or HALT (Same as 'auto run' and 'run')
auto run	Run the instructions Until TRAP or HALT (Same as 'autorun' and 'run')
clean	Clean the console (same as 'cls')
cls	Clean the console (same as 'clean')
exit	Shutdown the machine (same as 'quit' and 'power off')
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')
/help	Show the command list

1.3 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

CISC Machine Simulator

Indicators Memory

Register			
R0	0000000000000000	x0000	W
R1	0000000000000000	x0000	W
R2	0000000000000000	x0000	W
R3	0000000000000000	x0000	W

Index Register			
IX1	0000000000000000	x0000	W
IX2	0000000000000000	x0000	W
IX3	0000000000000000	x0000	W

Memory Register			
MAR	0000000000000000	x0000	W
MBR	0000000000000000	x0000	W

Basic Indicators			
PC	0000000000000000	x000	W
IR	0010010000100	x0484	W
CC	0000	x0	W
MFR	0010	x2	W

Controller

IPL	Auto Run	Single Run	Stop
Program 1	Program 2	Clock Cycle: 0	
Reload	Save	Pause	Restart

CISC Machine Simulator Console

```
exit run /
clean          clean          Clean The Console (Same as "cls")
cls           cls           Clean The Console (Same as "clean")
exit          exit          Shutdown The Machine (Same as "quit" and "power off")
floating test floating test Run The Floating Test
ipl           ipl           Load The Program From I/O
pause        pause        Pause The Workload On The Machine (not finished)
power off    power off    Shutdown The Machine (Same as "exit" and "quit")
Program1     Program1     Run Program 1 (Same as "Program 1")
Program 1    Program 1    Run Program 1 (Same as "Program 1")
Program2     Program2     Run Program 2 (Same as "Program 2")
Program 2    Program 2    Run Program 2 (Same as "Program 2")
quit         quit         Shutdown The Machine (Same as "exit" and "power off")
reload       reload       Reload The Data From memory.txt to Memory
reset        reset        Restart The Machine (Same as "restart")
restart      restart      Restart The Machine (Same as "reset")
run          run          Run The Instructions Until TRAP or HALT (Same as "autorun"
and "auto run")
save         save         Save The Data in Memory to memory.txt
singlerun    singlerun    Run One Instruction (Same as "single run")
single run   single run   Run One Instruction (Same as "singlerun")
status       status       Show The Status of The Machine
stop         stop         Stop The Workload on The Machine
switch theme switch theme ($THEME_NAME) Switch the Theme of UI. Now Support "Material
Design Ocean" (or "MaterialDesignOcean") and "Material Design Lighter" (or
"MaterialDesignLighter")
vector test  vector test  Run The Vector Test
/help        /help        Show The Command List
> switch theme Material Design Ocean
Theme switch to Material Design Ocean
>

Input Command here... Enter
```

2 Design Notes

2.1 Packages

Source code is divided into following packages:

- common
- device
- instruction
- memory
- panel
- program
- register
- theme
- util

All the operations initialize by Main class. That class initializes class, which initializes CISCComputerClass. All the register, memory and essential variables get ready for running.

1) Common Package

This package contains the main CiscComputer class which contains all the register, memory, devices, clock cycle count.

Class display is used for displaying states of all the elements of CiscComputer.

Initializer Class used for initializing all the elements of CiscComputer.

2) Device Package

Device package contains CardReader, ConsoleKeyboard, ConsolePrinter.

All of these extended from abstract class Device and has unique DeviceType, which is enum.

3) Instruction Package

This package contains class for all the operations. ArithmeticLogicalInstructionProcessor, FloatingPointInstructionProcessor, InputOutputInstructionProcessor,

LoadStoreInstructionProcessor, MiscellaneousInstructionProcessor,

TransferInstructionProcessor implements interface Instruction to be called and perform any instruction. All of this class has unique enum InstructionType.

This package also contains Address decoder to decode the address for an instruction.

4) Memory Package

This package contains Address class, which is a combination of tag and offset for caching. The cache contains, CacheLine and each CacheLine contain 8 Words, that means contains 8 location of main memory. Memory class is the main memory which as a 16-bit boolean value.

5) Panel Package

This package contains classes for UI. Controller, DebugPanel and OptionPanel.

6) Register Package

This package contains all the registers which extend from abstract Register. All the register has a unique RegisterType.

7) Theme Package

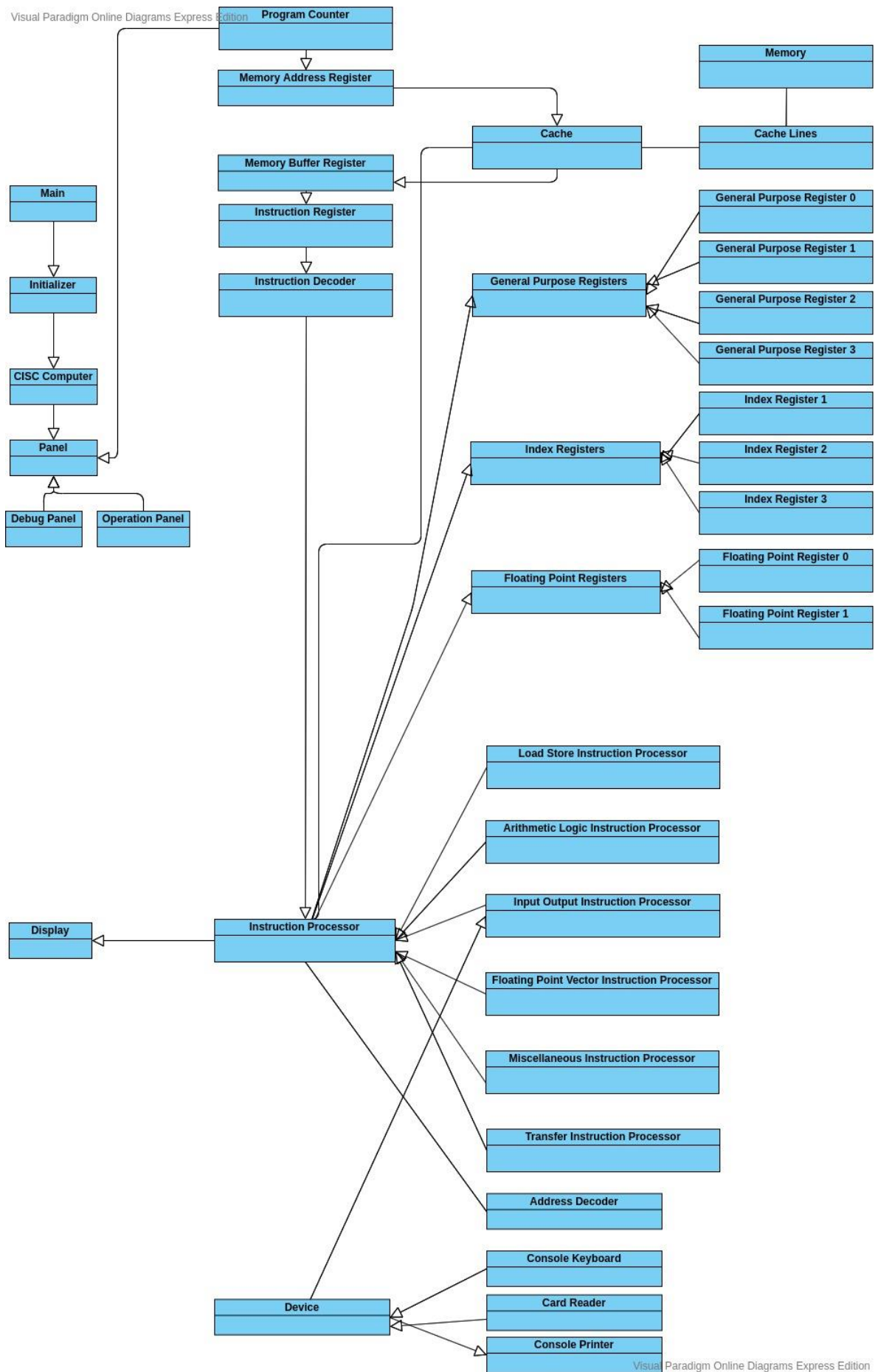
Contains class for UI looks.

8) Util Package

Common functions used all over the system kept here.

2.2 Interaction Logic

The interaction logic is shown as the image on the next page.

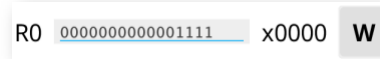


3 Basic Operations

3.1 Writing Values to Registers

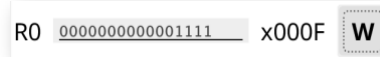
Following the steps below to write a value to a register.

Step 1: Input a value into the box.



R0 0000000000001111 x0000 W

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

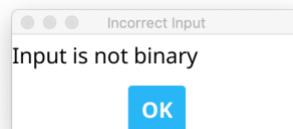


R0 0000000000001111 x000F W

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




3.2 Writing Values to Memory

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

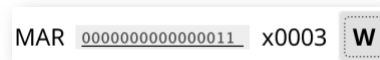
3.2.1 Using Memory Address Register and Memory Buffer Register

Step 1: Input a value into the MAR box.



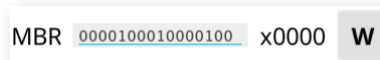
MAR 0000000000000011 x0003 W

Step 2: Click the ‘W’ button of MAR.



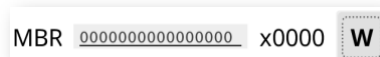
MAR 0000000000000011 x0003 W

Step 3: Input a value into the MBR box.



MBR 0000100010000100 x0000 W

Step 4: Click the ‘W’ button of MBR.



MBR 0000000000000000 x0000 W

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

MAR x0004 **W**

MBR x0000 **W**

Indicators Memory

Address	Value	Hex Value	Assemble Code
x0000	0000000000000000	x0000	null
x0001	0000000001100100	x0064	null
x0002	0000000000000000	x0000	null
x0003	0000100010000100	x0884	STR 0,2,4
x0004	0000000000100010	x0022	null

3.2.2 Modifying the Memory Area

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

Indicators Memory

Address	Value	Hex Value	Assemble Code
x0000	0000000000000000	x0000	null
x0001	0000000001100100	x0064	null
x0002	0000000000000000	x0000	null
x0003	0000100010000100	x0884	STR 0,2,4
x0004	0000000000100010	x0022	null
x0005	0000000000000000	x0000	null
x0006	0000000001100100	x0064	null
x0007	0000000000000000	x0000	null

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

Input

Input binary value

OK **Cancel**

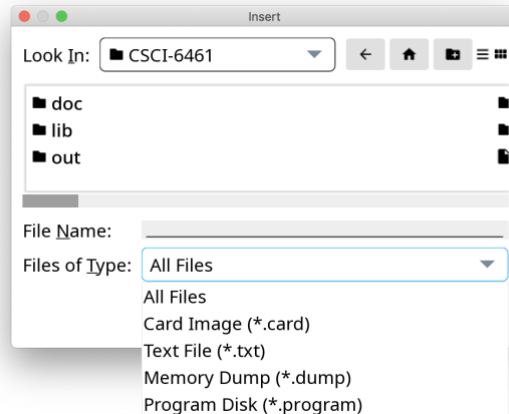
Step 3: Click the 'OK' button, and then the value will be written to the Memory.

Indicators Memory

Address	Value	Hex Value	Assemble Code
x0000	0000000000000000	x0000	null
x0001	0000000001100100	x0064	null
x0002	0000000000000000	x0000	null
x0003	0000100010000100	x0884	STR 0,2,4
x0004	0000000000100010	x0022	null
x0005	0000110101100011	x0D63	LDA 1,1,3,1
x0006	0000000001100100	x0064	null

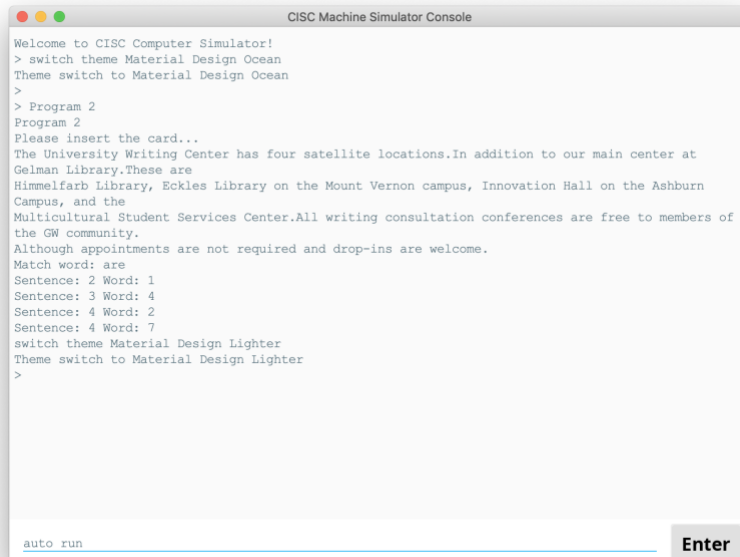
3.3 Inputting from the Outside

There are several ways for inputting from the Outside, form **Keyboard** or **IPL** files.



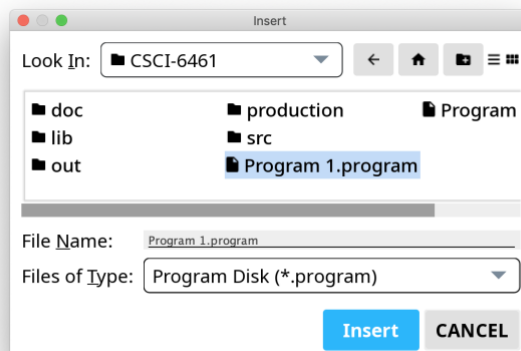
3.3.1 Inputting from Keyboard

Input words in the **Operation Panel (Console)** when the program asks for some keyboard inputs and then click the 'Enter' button.



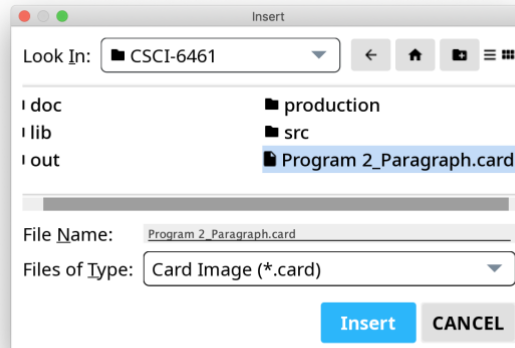
3.3.2 Inputting a Program

Input 'ipl' command to the **Operation Panel (Console)** or click the 'IPL' button in the **Debugging Panel**. Choose a '.program' file to be inserted into the machine. Then, the program will be loaded to Memory.



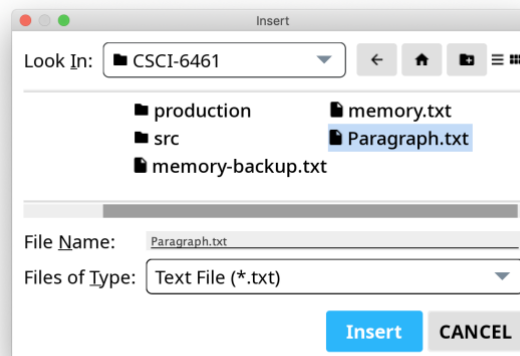
3.3.3 Inputting from Card Reader

Input 'ipl' command to the **Operation Panel (Console)** or click the 'IPL' button in the **Debugging Panel**. Choose a '.card' file to be inserted into the machine. Then, the card file will be loaded to Memory, using Card Reader as input device.



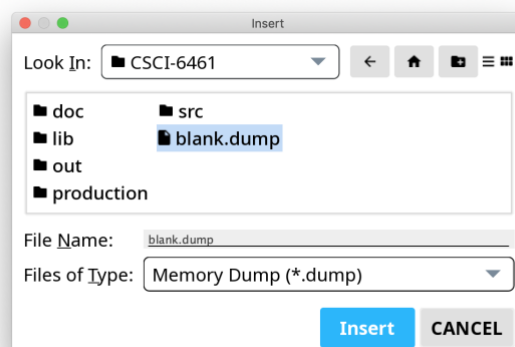
3.3.4 Inputting from Text File

Input 'ipl' command to the **Operation Panel (Console)** or click the 'IPL' button in the **Debugging Panel**. Choose a '.txt' file to be inserted into the machine. Then, the text file will be loaded to Memory.



3.3.5 Overwriting the Memory from Outside

Input 'ipl' command to the **Operation Panel (Console)** or click the 'IPL' button in the **Debugging Panel**. Choose a '.dump' file to be inserted into the machine. Then, the Memory will be overwritten by the memory file.



3.4 Executing Instructions

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

3.4.1 Executing Instructions Step-by-Step

Step 1: Store an instruction to the Memory.

Indicators <u>Memory</u>			
x0003	0000000000000000	x0000	null
x0004	0000000000000000	x0000	null
x0005	0000000000000000	x0000	null
x0006	0000010001000010	x0442	LDR 0,1,2
x0007	0000000000000000	x0000	null

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

PC x006

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.

Indicators <u>Memory</u>			
x0004	0000000000000000	x0000	null
x0005	0000000000000000	x0000	null
x0006	0000010001000010	x0442	LDR 0,1,2
x0007	0000000000000000	x0000	null
x0008	0000000000000000	x0000	null

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Indicators		Memory	
<div>Register</div> <div>R0 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>R1 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>R2 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>R3 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div>			
<div>Index Register</div> <div>IX1 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>IX2 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>IX3 <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div>			
<div>Memory Register</div> <div>MAR <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div> <div>MBR <input type="text" value="0000000000000000"/> x0000 <input type="button" value="W"/></div>		<div>Basic Indicators</div> <div>PC <input type="text" value="000000000111"/> x007 <input type="button" value="W"/></div> <div>IR <input type="text" value="0010001000010"/> x0442 <input type="button" value="W"/></div> <div>CC <input type="text" value="0000"/> x0 <input type="button" value="W"/></div> <div>MFR <input type="text" value="0010"/> x2 <input type="button" value="W"/></div>	
<div>Controller</div> <div> <input type="button" value="IPL"/> <input type="button" value="Auto Run"/> <input type="button" value="Single Run"/> <input type="button" value="Stop"/> </div> <div> <input type="button" value="Program 1"/> <input type="button" value="Program 2"/> <input type="button" value="Clock Cycle: 1"/> </div> <div> <input type="button" value="Reload"/> <input type="button" value="Save"/> <input type="button" value="Pause"/> <input type="button" value="Restart"/> </div>			

3.4.2 Executing Instructions Automatically

Step 1: Store instructions to the Memory.

Indicators		Memory	
x001A	0000000000000000	x0000	null
x001B	00000000001100100	x0064	HLT 0,1,4,1
x001C	1010010001010100	x0A454	LDX 1,20
x001D	1010010010010110	x0A496	LDX 2,22
x001E	1010010011111000	x0A4F8	LDX 3,24,1
x001F	0000011100001011	x070B	LDR 3,0,11
x0020	0000010000001011	x040B	LDR 0,0,11
x0021	0000010111001110	x05CE	LDR 1,3,14
x0022	0000011011101110	x06EE	LDR 2,3,14,1
x0023	0000101000011111	x0A1F	STR 2,0,31

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

PC x01C

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.

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Indicators Memory

Register		Index Register	
R0	<input type="text" value="000000000000010"/> x0005 <input type="button" value="W"/>	IX1	<input type="text" value="000000000000000"/> x0000 <input type="button" value="W"/>
R1	<input type="text" value="010011100100110"/> x4E4C <input type="button" value="W"/>	IX2	<input type="text" value="000000000000000"/> x0000 <input type="button" value="W"/>
R2	<input type="text" value="000000000000001"/> x0002 <input type="button" value="W"/>	IX3	<input type="text" value="00000000111001"/> x0064 <input type="button" value="W"/>
R3	<input type="text" value="000000000000001"/> x0002 <input type="button" value="W"/>		

Memory Register		Basic Indicators	
MAR	<input type="text" value="0000000000010"/> x0010 <input type="button" value="W"/>	PC	<input type="text" value="000000110001"/> x031 <input type="button" value="W"/>
MBR	<input type="text" value="0000000001100"/> x0064 <input type="button" value="W"/>	IR	<input type="text" value="0110000111000"/> x61C0 <input type="button" value="W"/>
		CC	<input type="text" value="0001"/> x1 <input type="button" value="W"/>
		MFR	<input type="text" value="0010"/> x2 <input type="button" value="W"/>

Controller

Clock Cycle: 49

Indicators				Memory	
x002E	0101110011000000	x5CC0	AND 0,3		
x002F	0110000111000000	x61C0	ORR 1,3		
x0030	0110011001000000	x6640	NOT 2		
x0031	0000000000000000	x0000	null		
x0032	0000000000000000	x0000	null		



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



4 Executing Programs

4.1 Executing Program 1

4.1.1 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.

4.1.2 Program 1 Files

Program 1.assemble 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 R0 != 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

```

Program 1.program is the program that has been translated to binary 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

```

4.1.3 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**.

program 1

Enter

Controller

IPL	Auto Run	Single Run	Stop
Program 1	Program 2	Clock Cycle: 49	
Reload	Save	Pause	Restart

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.

CISC Machine Simulator Console

```
Welcome to CISC Computer Simulator!
> program 1
Please input 20 numbers (using comma to split numbers):
13 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677)
11 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23)
9 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23,567,2)
4 data(s) need to input. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21)
All 20 data(s) got. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21,322,955,32,0)
Please input the number you want to compare:
```

Enter

Step 3: Input the number for comparing.

CISC Machine Simulator Console

```
Welcome to CISC Computer Simulator!
> program 1
Please input 20 numbers (using comma to split numbers):
13 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677)
11 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23)
9 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23,567,2)
4 data(s) need to input. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21)
All 20 data(s) got. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21,322,955,32,0)
Please input the number you want to compare:
```

1114

Enter

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

```

Welcome to CISC Computer Simulator!
> program 1
Please input 20 numbers (using comma to split numbers):
13 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677)
11 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23)
9 data(s) need to input. (Now we got: 123,4523,23,674,920,122,5677,982,23,567,2)
4 data(s) need to input. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21)
All 20 data(s) got. (Now we got:
123,4523,23,674,920,122,5677,982,23,567,2,111,093,2899,93,21,322,955,32,0)
Please input the number you want to compare:
All 1 data(s) got. (Now we got: 1114)
The closest number compare with 1114 is 982
>

```

4.2 Executing Program 2

4.2.1 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.

4.2.2 Program 2 Files

Program 2.assemble is the program that was written in assembly language.

```

1001 IN 0, 2 // read from card reader (with default banner)
1002 STR 0, 0, 10 // Store #1500 to MEM[10] from R0
1003 LDX 2, 10 // Backup #1500 to IX0
1004 LDR 2, 0, 12 // Store #-1 to R2 from MEM[12]
1005 LDR 3, 0, 10, 1 // Get one character to R3
1006 TRR 3, 2 // Check if get the end
1007 JCC 3, 0, 20, 1 // jump out
1008 OUT 3, 1 // Print out
1009 AIR 0, 1 // R0++
1010 STR 0, 0, 10 // paragraph[i]++
1011 JMA 0, 21, 1 // jump to beginning
1012 STX 2, 10 // restore MEM[10]
1013 LDR 0, 0, 10 // Reset R0
1014 LDR 3, 0, 13 // load new line
1015 OUT 3, 1 // print new line
1016 LDR 3, 0, 17, 1 // 'M'
1017 OUT 3, 1 // print 'M'
1018 LDR 3, 0, 17
1019 AIR 3, 1
1020 STR 3, 0, 17 // move to next character
1021 LDR 3, 0, 17, 1 // 'a'
1022 OUT 3, 1 // print 'a'
1023 LDR 3, 0, 17
1024 AIR 3, 1

```

Program 2.program is the program that has been translated to binary machine codes.

```

Program 2.program x
11 000010111011100
12 0000011111010000
13 1111111111111111
14 0010111101101110
15 0000000000000000
16 0000000000000000
17 0000000000000000
18 0000000000100000
19 0000000000101110
20 0000000000100000
21 0000001111110011
22 0000001111101100
23 000010010111011

```

Program 2_Paragraph.card is the input card file, which contains the paragraph for program 2.

```

Program 2_Paragraph.card x
1 The University Writing Center has four satellite locations.In addition to our main center at Gelman Library.These are
2 Himmelfarb Library, Eckles Library on the Mount Vernon campus, Innovation Hall on the Ashburn Campus, and the
3 Multicultural Student Services Center.All writing consultation conferences are free to members of the GW community.
4 Although appointments are not required and drop-ins are welcome.

```

4.2.3 Running Program 2

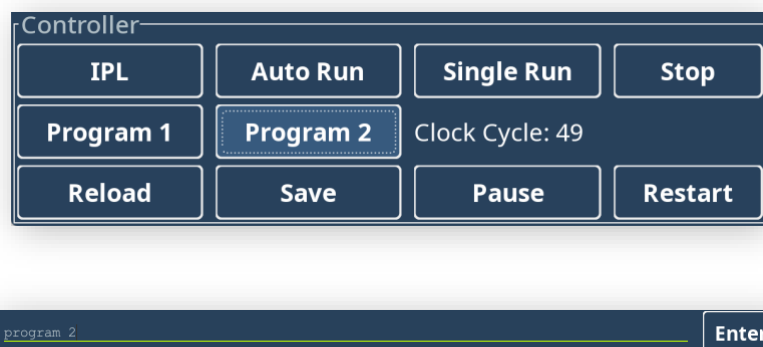
Step 1: Write a paragraph of 6 sentences into the card file ‘Program 2_Paragraph.card’.

```

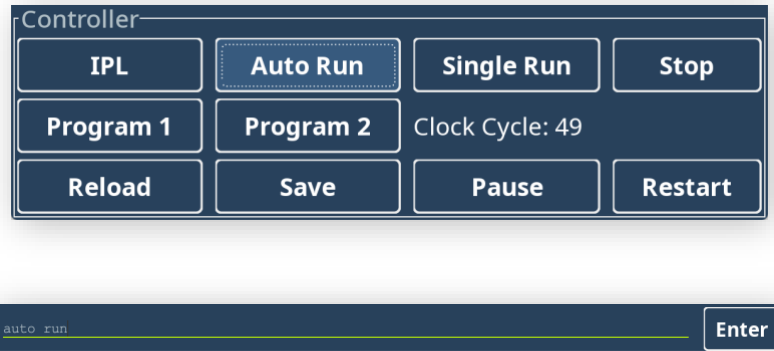
Program 2_Paragraph.card x
1 The University Writing Center has four satellite locations.In addition to our main center at Gelman Library.These are
2 Himmelfarb Library, Eckles Library on the Mount Vernon campus, Innovation Hall on the Ashburn Campus, and the
3 Multicultural Student Services Center.All writing consultation conferences are free to members of the GW community.
4 Although appointments are not required and drop-ins are welcome.

```

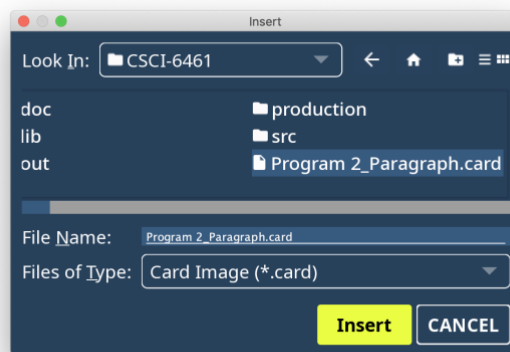
Step 2: Input ‘program 2’ or ‘program2’ in the **Operation Panel (Console)** and then click the ‘Enter’ button. Or click the ‘Program 2’ button in the **Debugging Panel**.



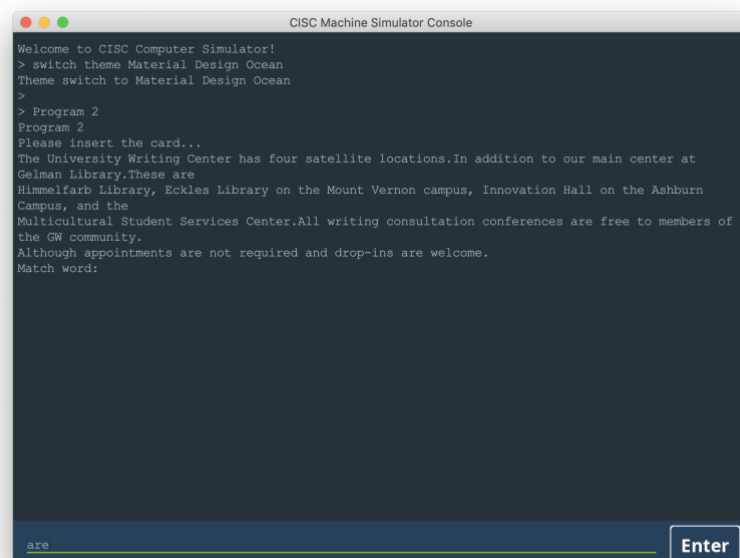
Step 3: The program 2 will be loaded from the program file ‘Program 2.program’ to Memory. Input ‘autorun’ or ‘auto run’ in the **Console** and then click the ‘Enter’ button. Or click the ‘Auto Run’ button in the **Debugging Panel**.



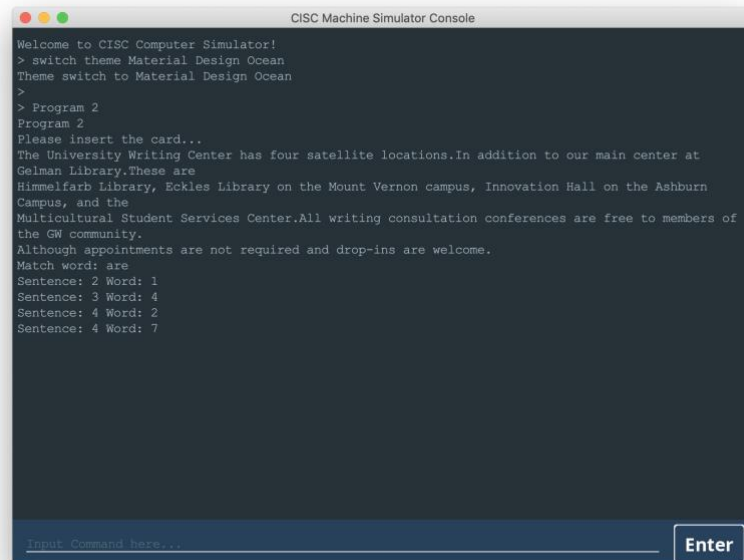
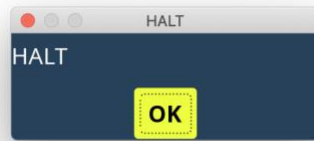
Step 4: A window will pop up, asking for inserting a card. Choose the card file 'Program 2_Paragraph.card' as the input card and insert it. Then, the paragraph will be loaded from the card file to the machine, using Card Reader as the input device, and will be displayed in the **Console**. Note that the reading process will last for a **few minutes**.



Step 4: Input the word to be matched to the paragraph in the **Console** and then click the 'Enter' button.



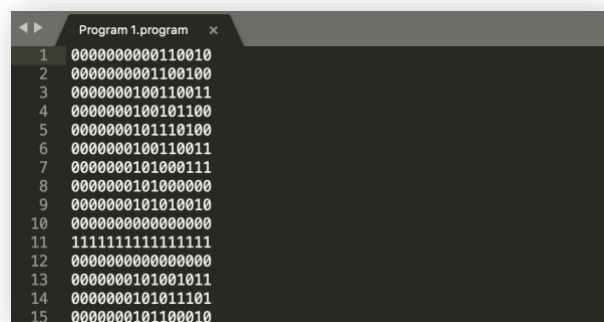
Step 5: The machine will start the calculation process, which will last for **a few minutes**. Then, the **Console** will print out the word, the sentence index in the paragraph, and the word index in the sentence. **Note that the index starts from 0 rather than 1.**



4.3 Executing a Custom Program Using IPL

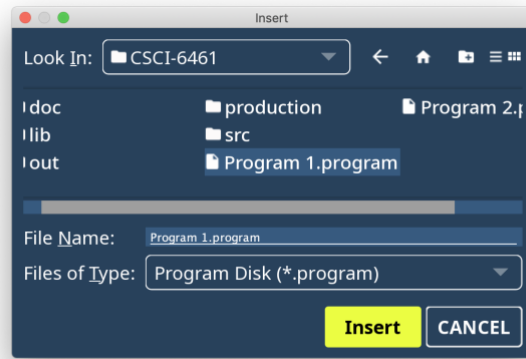
4.3.1 Using Operation Panel (Console)

Step 1: Write the custom program in a '.program' file, using binary machine code.



Step 2: Input 'ipl' command to the console to import the program to the memory.



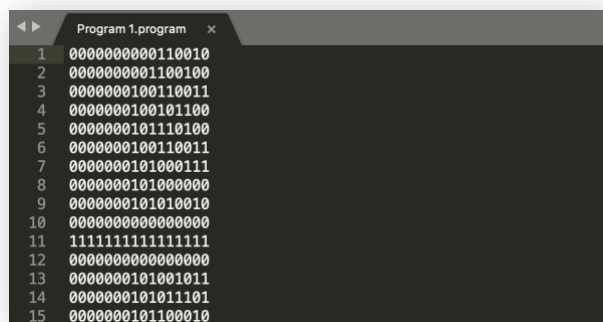


Step 4: Input 'auto run' or 'autorun' command to the console, and then the program will be executed. Or input 'single run' or 'singlerun' command to run the program step-by-step.

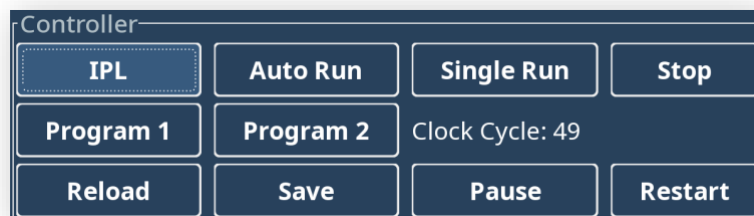


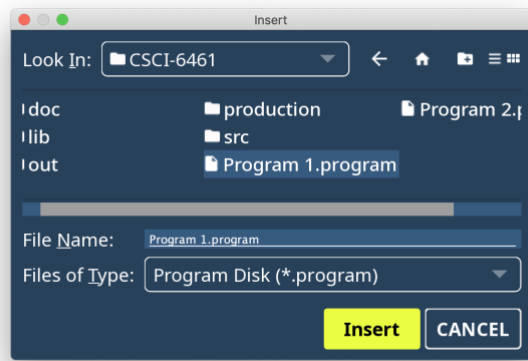
4.3.2 Using Debugging Panel

Step 1: Write the custom program in a '.program' file, using binary machine code.

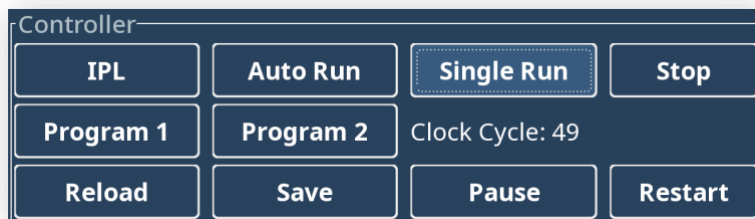
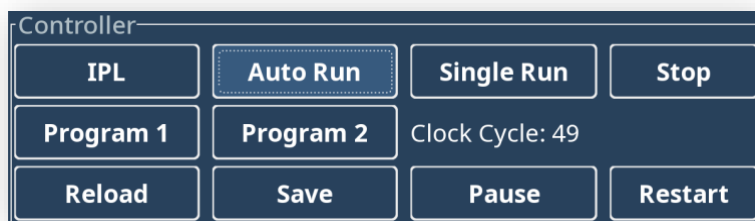


Step 2: Click the 'IPL' button to import the program to the memory.





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.



5 Instructions Reference

5.1 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	1 1	1 5
		0 1		

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

5.1.1 (01) LDR

000001	R	IX	I	Address
0 5	6 7	8 9	1 1	1 5
		0 1		

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

5.1.2 (02) STR

000010	R	IX	I	Address
0 5	6 7	8 9	1 1	1 5
		0 1		

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)

5.1.3 (03) LDA

000011	R	IX	I	Address
0 5	6 7	8 9	1 1	1
		0 1		5

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

5.1.4 (41) LDX

101001		IX	I	Address
0 5	6 7	8 9	1 1	1
		0 1		5

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

5.1.5 (42) STX

101010		IX	I	Address
0 5	6 7	8 9	1 1	1
		0 1		5

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

5.2 Arithmetic and Logical Instructions

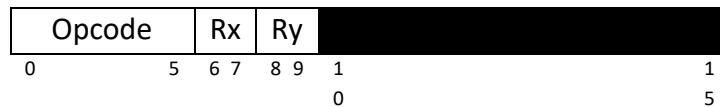
The instructions to perform most of the computational works in the machine.

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	1 1	1
		0 1		5

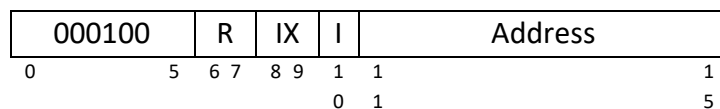
Opcode:	6 bits	Specifies the instruction
R:	2 bits	Specifies the General-Purpose Register
IX:	2 bits	Specifies the Index Register
I:	1 bit	Specifies Indirect Addressing
		If I =1, indirect addressing; otherwise, no indirect addressing.
Address:	5 bits	Specifies the location

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



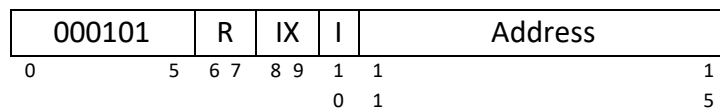
Opcode:	6 bits	Specifies the instruction
Rx:	2 bits	Specifies the General-Purpose Register x
Ry:	2 bits	Specifies the General-Purpose Register y

5.2.1 (04) AMR

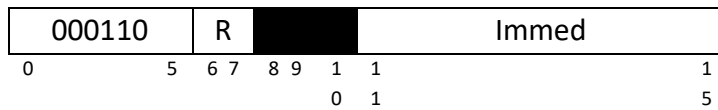


Instruction: AMR r, x, address[, I]
 Octal-Opcode: 04
 Binary-Opcode: 000100
 Function: Add Memory to Register
 Notes: $r = 0 \dots 3$
 $r \leftarrow c(r) + c(EA)$

5.2.2 (05) SMR



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

5.2.3 (06) AIR

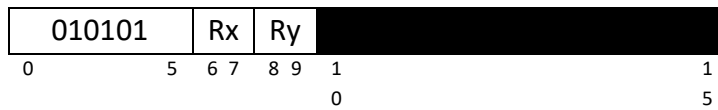
Instruction: AIR r, immed
 Octal-Opcode: 06
 Binary-Opcode: 000110
 Function: Add Immediate to Register
 Notes: $r = 0 \dots 3$
 $r \leftarrow c(r) + \text{Immed}$
 if Immed = 0, does nothing
 if $c(r) = 0$, loads r with Immed

5.2.4 (07) SIR

Instruction: SIR r, immed
 Octal-Opcode: 07
 Binary-Opcode: 000111
 Function: Subtract Immediate from Register
 Notes: $r = 0 \dots 3$
 $r \leftarrow c(r) - \text{Immed}$
 if Immed = 0, does nothing
 if $c(r) = 0$, loads R1 with $-(\text{Immed})$

5.2.5 (20) MLT

Instruction: MLT rx, ry
 Octal-Opcode: 20
 Binary-Opcode: 010100
 Function: Multiply Register by Register
 Notes: $rx, rx+1 \leftarrow c(rx) * c(ry)$
 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

5.2.6 (21) DVD

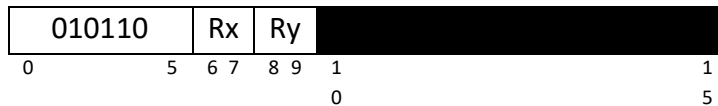
Instruction: DVD rx, ry

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)

5.2.7 (22) TRR

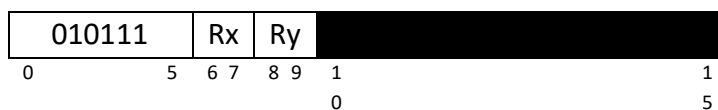
Instruction: TRR rx, ry

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

5.2.8 (23) AND

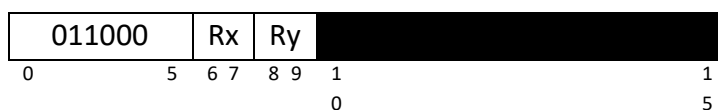
Instruction: AND rx, ry

Octal-Opcode: 23

Binary-Opcode: 010111

Function: Logical AND of Register and Register

Notes: c(rx) <- c(rx) AND c(ry)

5.2.9 (24) ORR

Instruction: ORR rx, ry
 Octal-Opcode: 24
 Binary-Opcode: 011000
 Function: Logical OR of Register and Register
 Notes: $c(rx) \leftarrow c(rx) \text{ OR } c(ry)$

5.2.10 (25) NOT

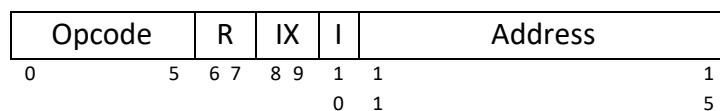


Instruction: NOT rx
 Octal-Opcode: 25
 Binary-Opcode: 011001
 Function: Logical NOT of Register to Register
 Notes: $C(rx) \leftarrow \text{NOT } c(rx)$

5.3 Transfer Instructions

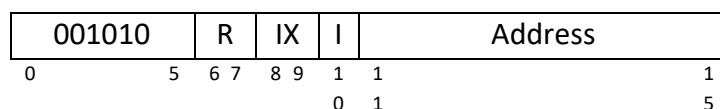
The instructions to check the value of a register and then change the control of program execution.

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



Opcode: 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

5.3.1 (10) JZ



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

Notes: $r = 0 \dots 3$
 If $c(r) = 0$, then $PC \leftarrow EA$; Else $PC \leftarrow PC + 1$

5.3.2 (11) JNE

001011	R	IX	I	Address
0	5	6 7	8 9	1 1
			0 1	1
				5

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

5.3.3 (12) JCC

001100	CC	IX	I	Address
0	5	6 7	8 9	1 1
			0 1	1
				5

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

5.3.4 (13) JMA

001101		IX	I	Address
0	5	6 7	8 9	1 1
			0 1	1
				5

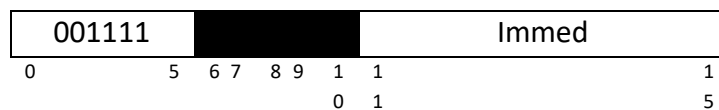
Instruction: JMA x, address[, I]
 Octal-Opcode: 13
 Binary-Opcode: 001101
 Function: Unconditional Jump to Address
 Notes: $PC \leftarrow EA$

5.3.5 (14) JSR

001110		IX	I	Address
0	5	6 7	8 9	1 1
			0 1	1
				5

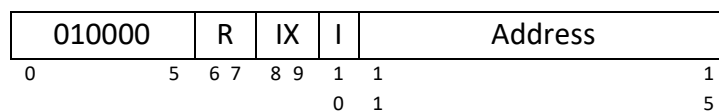
Instruction: JSR x, address[, I]
 Octal-Opcode: 14
 Binary-Opcode: 001110
 Function: Jump and Save Return Address
 Notes: $R3 \leftarrow PC+1$
 $PC \leftarrow EA$
 R0 should contain pointer to arguments
 Argument list should end with -1 (all 1s) value

5.3.6 (15) RFS



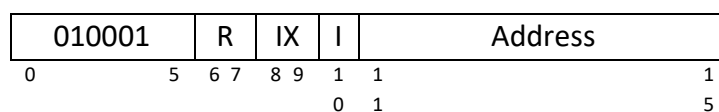
Instruction: RFS immed
 Octal-Opcode: 15
 Binary-Opcode: 001111
 Function: Return from Subroutine with Return Code as Immediate Portion (optional) Stored in the Instruction's Address Field
 Notes: $R0 \leftarrow \text{Immed}$
 $PC \leftarrow c(R3)$

5.3.7 (16) SOB



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

5.3.8 (17) JGE



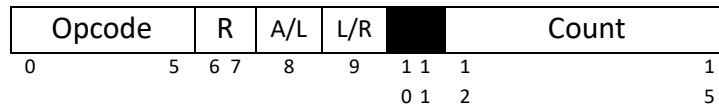
Instruction: JGE r, x, address[, I]
 Octal-Opcode: 17

Binary-Opcode: 010001
 Function: Jump Greater than or Equal to
 Notes: If $c(r) \geq 0$, then $PC \leftarrow EA$; Else $PC \leftarrow PC + 1$

5.4 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:



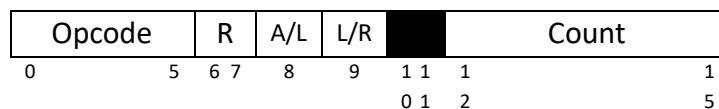
Opcode: 6 bits Specifies the instruction
R: 2 bits Specifies the General-Purpose Register
A/L: 2 bits Arithmetic Shift (A/L = 0); Logical Shift (A/L = 1)
L/R: 2 bits Logical Rotate (L/R = 1)
Count: 4 bits Specifies the Count for Operation

5.4.1 (31) SRC



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

5.4.2 (32) RRC

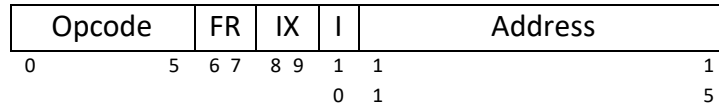


Instruction: RRC r, count, L/R, A/L
 Octal-Opcode: 32
 Binary-Opcode: 100000
 Function: Rotate Register by Count
 Notes: $c(r)$ is rotated left (L/R = 1) or right (L/R = 0) either logically (A/L = 1)
 Count = 0...15

5.5 Floating Point and Vector Instructions

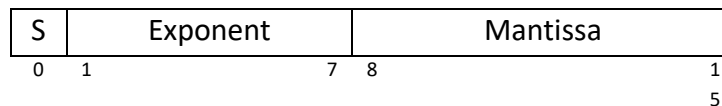
The instructions for calculation of floating points and vectors.

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



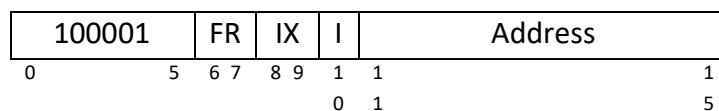
- Opcode:** 6 bits Specifies the instruction
FR: 2 bits Specifies the Floating Point Register
IX: 2 bits Specifies the Index Register
I: 1 bit Specifies Indirect Addressing
 If I = 1, indirect addressing; otherwise, no indirect addressing.
Address: 5 bits Specifies the location

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



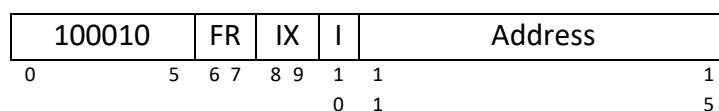
- S:** 1 bit The sign of the Floating Point number
Exponent: 7 bits Specifies the Exponent
Mantissa: 8 bits Specifies the Mantissa

5.5.1 (33) FADD



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

5.5.2 (34) FSUB



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

5.5.3 (35) VADD

100011	FR	IX	I	Address
0	5	6 7	8 9	1 1
			0 1	5

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, $V1[i] = V1[i] + V2[i]$, $i = 1, c(fr)$.

5.5.4 (36) VSUB

100100	FR	IX	I	Address
0	5	6 7	8 9	1 1
			0 1	5

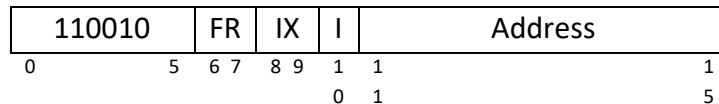
Instruction: VSUB fr, x, address[, I]
 Octal-Opcode: 36
 Binary-Opcode: 100100
 Function: Vector Subtract Memory to Floating Point Register
 Notes: fr contains the length of the vectors
 $c(EA)$ or $c(c(EA))$, if I bit set is address of first vector
 $c(EA+1)$ or $c(c(EA+1))$, if I bit set is address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

5.5.5 (37) CNVRT

100101	R	IX	I	Address
0	5	6 7	8 9	1 1
			0 1	5

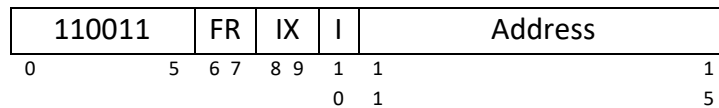
Instruction: CNVRT r, x, address[, I]
 Octal-Opcode: 37
 Binary-Opcode: 100101
 Function: Convert to Fixed/Floating Point
 Notes: If F = 0, convert c(EA) to a Fixed Point number and store in r
 If F = 1, convert c(EA) to a Floating Point number and store in FR0
 The r register contains the value of F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

5.5.6 (50) LDFR



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

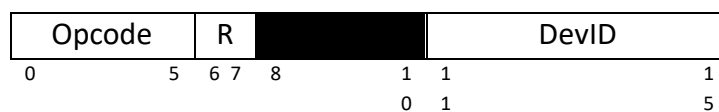


Instruction: STFR fr, x, address [, I]
 Octal-Opcode: 51
 Binary-Opcode: 110011
 Function: Store Floating Point Register to Memory
 Notes: EA, EA+1 <- c(fr)
 c(EA), c(EA)+1 <- c(fr), if I-bit set

5.6 I/O Instructions

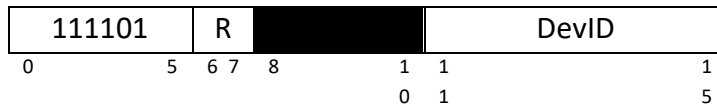
The instructions to communicate with the peripherals attached to the computer system.

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



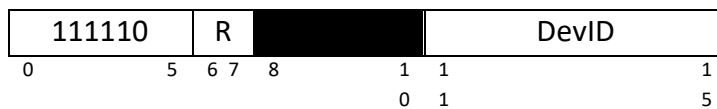
Opcode: 6 bits Specifies the instruction
R: 2 bits Specifies the General-Purpose Register
DevID: 5 bits Device ID:
 0 Console Keyboard
 1 Console Printer
 2 Card Reader
 3-31 Console Registers, Switches, etc.

5.6.1 (61) IN



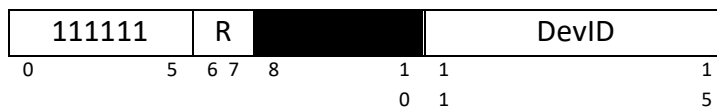
Instruction: IN r, devid
 Octal-Opcode: 61
 Binary-Opcode: 111101
 Function: Input Character to Register from Device
 Notes: r = 0...3

5.6.2 (62) OUT



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

5.6.3 (63) CHK



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

5.7 Other Instructions

5.7.1 (00) HALT



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

5.7.2 (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.