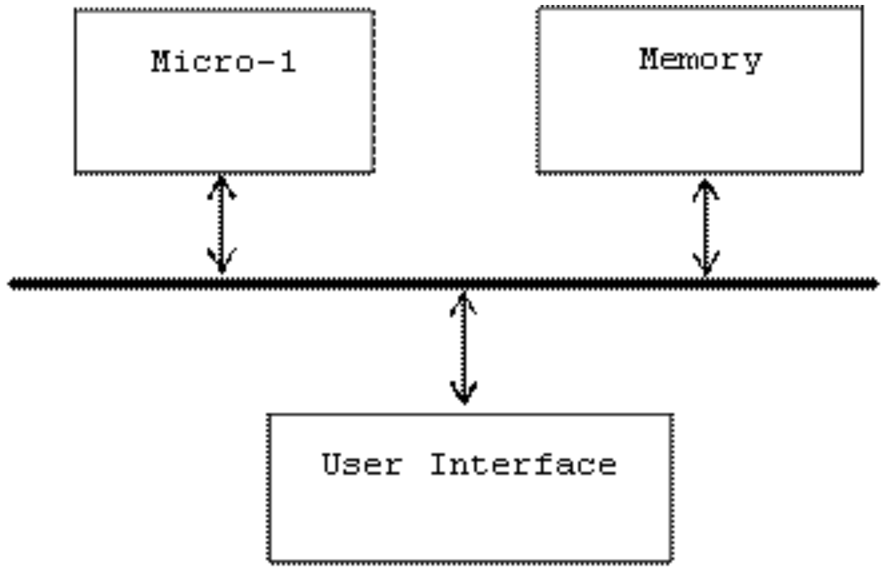
Group Project 1 The Micro-1 Processor Simulation

<Micro-1 Computer>

Here's the organization of a computer equipped with a Micro-1 processor

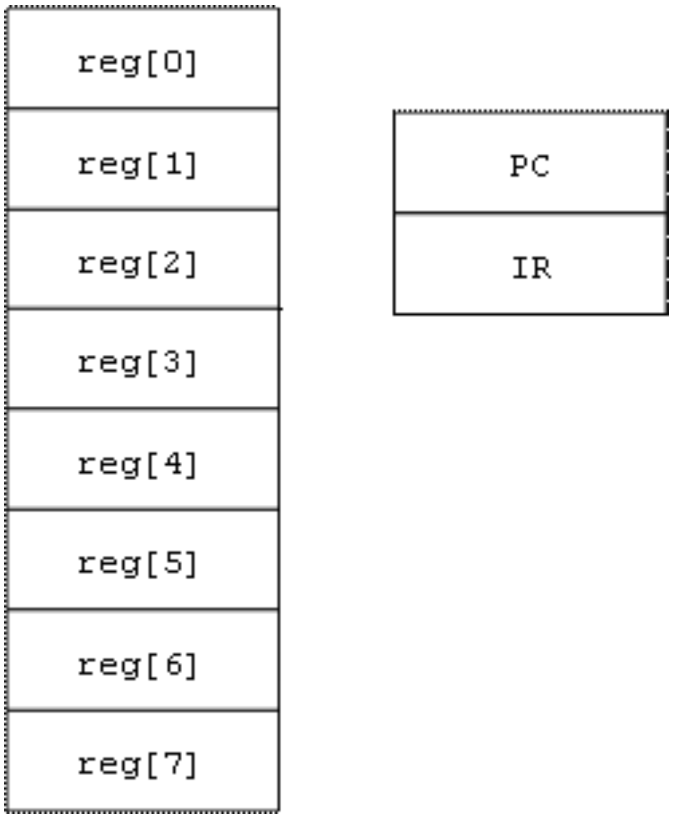


Memory contains an array of integer cells:

```
int cell[] = new int[CAP];
```

where CAP is the capacity of memory. Initially this is set to 256.

Internally, the Micro-1 processor is equipped with eight 32-bit data/address registers and two 32 bit control registers:



PC, the program counter, contains the address of the next instruction to execute.
IR, the instruction register, contains the hexadecimal representation of the current instruction being executed.

Here's a sketch of the Micro-1 fetch-execute cycle:

```
1. IR = cell[PC++]
2. if (IR == 0) halt
3. execute IR
4. goto 1
```

<Micro-1 Data Types>

The only Micro-1 data type is int, 32-bit integers. False is represented by 0 and true is represented by any non-zero integer.

<Micro-1 Instruction Set>

Micro-1 Assembly Language
Assume a and b are register indices. This means $0 \leq a, b < 8$.

Data Control
```
1. load a b  // reg[a] = cell[reg[b]]
```

```
2. loadc a // reg[a] = cell[PC++]
3. store a b // cell[reg[a]] = reg[b]
```

Arithmetic

```
4. add a b // reg[a] = reg[a] + reg[b]
5. mul a b // reg[a] = reg[a] * reg[b]
6. sub a b // reg[a] = reg[a] - reg[b]
7. div a b // reg[a] = reg[a] / reg[b], error if reg[b] == 0
```

Logic

```
8. and a b  // if (reg[a]!= 0&&reg[b]!=0) reg[a]=1 else reg[a]=0
9. or a b  // if (reg[a]!=0||reg[b]!=0) reg[a]=1 else reg[a]=0
10. not a b // if (reg[b]!=0) reg[a]=0 else reg[a]=1
```

Bitwise

```
11. lshift a b // reg[a] = reg[b] << 1
12. rshift a b // reg[a] = reg[b] >> 1
13. bwc a b // reg[a] = reg[a] & reg[b]
14. bwd a b // reg[a] = reg[a] | reg[b]
```

Sequence Control

```
15. if a b // if (reg[a] != 0) pc = reg[b]
0. halt // stop fetch-execute cycle
```

Micro-1 Machine Language

Micro-1 machine language instructions are just the hexadecimal representation of Micro-1 assembly language instructions.

The number of each instruction shown above is its opcode (i.e. operational code), p, where $0 \le p < 16$.

The format of Micro-1 machine language instructions is the hexadecimal number:

`0x00000pab`

where

```
p = the 4-bit opcode
a = argument 1 = the 4 bit index of some register
b = argument 2 = the 4 bit index of some register
```

<Sample Program 1>

The following program implements:

```
cell[23] = cell[20] + cell[21] + cell[22]
```

We begin by loading constants into the first three registers:

```
loadc 0
0x14
loadc 1
0x0
loadc 2
0x1
```

Register 0 will be our address register. It holds address 20 (0x14), where our first summand is stored.

Register 1 will be our accumulator. This is where the sum will be stored. Initially it holds 0.

Register 2 holds the constant 1, which will be repeatedly added to the address.

Here are the hexadecimal representations of these instructions:

```
0x00000200 // loadc 0
0x00000014 // 0x14 = 20 -> reg[0] = 20
0x00000210 // loadc 1
0x00000000 // 0 -> reg[1] = 0
0x00000220 // loadc 2
0x00000001 // 1
```

Register 3 will hold the next number to add to the accumulator.

```
load 3 0 // reg[3] = cell[reg[0]] = cell[20]
```

Now we add register 3 to the accumulator, then increment the address register:

```
add 1 3 // reg[1] += reg[3]
add 0 2 // reg[0] += reg[2]
```

Here's the hexadecimal for these three instructions:

```
0x00000130 // load 3 0 -> reg[3] = reg[0]
0x00000413 // add 1 3 -> reg[1] += reg[3]
0x00000402 // add 0 2 -> reg[0] += reg[2]
```

We repeat these three instructions two more times:

```
load 3 0 // reg[3] = cell[reg[0]] = cell[21]
add 1 3 // reg[1] += reg[3]
add 0 2 // reg[0] += reg[2]
load 3 0 // reg[3] = cell[reg[0]] = cell[22]
add 1 3 // reg[1] += reg[3]
add 0 2 // reg[0] += reg[2]
```

Now we are ready to write the accumulator back to memory location 23, then halt:

```
store 0 1 // cell[reg[0]] = reg[1]
halt
```

Here's the hexadecimal:

```
0x00000301 // store 0 2 -> mem[reg[0]] = reg[1]
0x00000000 // halt
```

Here's a test harness

To test this program we make the following assignments:

```
cell[20] = 100
cell[21] = 200
cell[22] = 300
```

The entire program can be found in **program1.m1**.

Here's a snapshot just before halt is executed:

```
-> registers
Registers:
reg[0] = 17
reg[1] = 258
reg[2] = 1
reg[3] = 12c
reg[4] = 0
reg[5] = 0
reg[6] = 0
reg[7] = 0
PC = 10
IR = 301

-> memory
cell[0] = 200
cell[1] = 14
cell[2] = 210
cell[3] = 0
cell[4] = 220
cell[5] = 1
cell[6] = 130
cell[7] = 413
cell[8] = 402
cell[9] = 130
cell[a] = 413
cell[b] = 402
cell[c] = 130
cell[d] = 413
cell[e] = 402
cell[f] = 301
cell[10] = 0
cell[11] = 0
cell[12] = 0
cell[13] = 0
cell[14] = 64
cell[15] = c8
cell[16] = 12c
```

```
cell[17] = 258
etc.
```

Note that all values are in hexadecimal (base 16), so

```
cell[17] = 258
```

translates in decimal to:

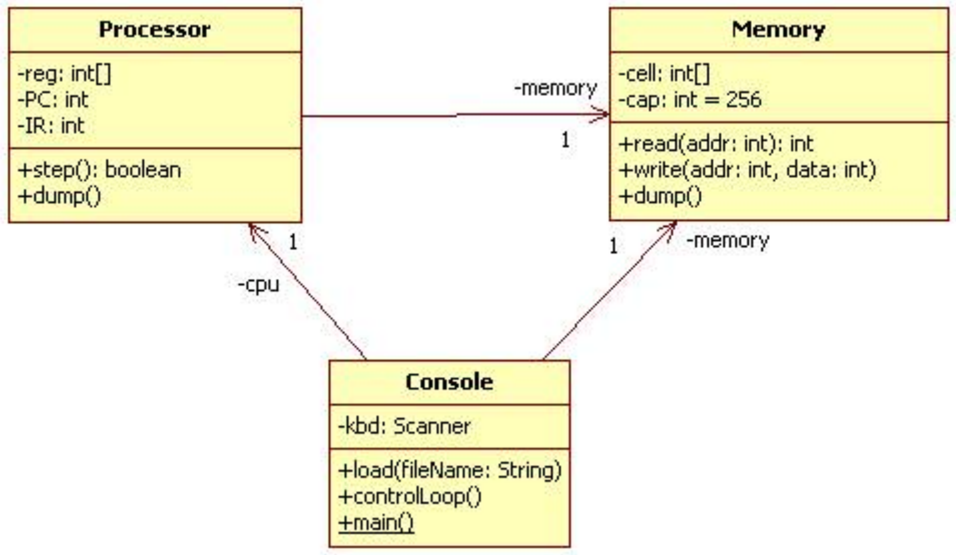
```
cell[23] = 600
```

<Project>

Create and test a simulator for a computer equipped with a Micro-1 processor.

Design

The Micro-1 simulator consists of three classes:



Recall that in a UML class diagram arrows and attributes translate into fields.
Warning: additional fields and methods may be needed.

Hints

Console.java has been implemented for you, including a **javadoc** page.

To get started, determine which methods Memory and Processor need. This can be determined from studying Console.java and the UML class diagram. Quickly create Memory and Processor classes with these methods. Don't worry about how the methods should work. The only important thing is that the program compiles and runs. Next, replace the implementation of the Memory methods with ones that work. This should be easy, but may involve adding fields to the class. Then replace the implementation of the Processor methods with ones that work. This may also involve adding fields to the Processor class. Finally, test your program on **program1.m1**.

Processor.java will need to make use of Java's right shift (>>) and bitwise conjunction (&) to mask out and shift fields of IR representing opcodes and arguments.

Testing

Test your implementation by writing and running the following Micro-1 programs:

```
1. cell[103] = 3 * cell[100] + 2 * cell[101] + cell[102]
```

2. `cell[101] =` $2^{\texttt{cell[100]}}$ `// hint: use left shift`

```
3. cell[101] = cell[100] + cell[100]>>1 + cell[100]>>2 + ... + 1
```

Note: these numbers are in base 10.

Extra Credit

Add an assembler

Modify the load method in the Console class so that it reads a file containing Micro-1 assembly language instructions instead of hexadecimal machine language instructions. The translation should be easy. For example:

```
add a b translates into the hexadecimal number 4ab
```

Interpret everything in the file after the halt instruction as a hexadecimal constant.

Add a GUI

Replace Console.java with Micro1Viewer.java. The viewer contains a control panel (JPanel) with text fields (JTextField) showing the current content of each register, and buttons (JButton) for the Console commands: step, load, memory (dumps to the command console), and registers (updates the text fields.)