# Computer Systems and Networks

ECPE 170 – Jeff Shafer – University of the Pacific

# MARIE Simulator

# Discussion

- What was easy about programming MARIE?
- What was hard about programming MARIE?
- What tips would you share to other beginning assembly programmers?

# MARIE Programming Tip

- Writing code in assembly can be intimidating at first
  - High-level languages are (much!) easier to use
- Treat the problem like a complier would
  - Think about how to code in another language, like C++
  - Convert each construct into a series of MARIE instructions
    - Variables first, then functions, loops, if statements, …

# SKIPCOND Operation

- **SKIPCOND 000**
  - if(AC < 0) skip next instruction
- **SKIPCOND 400**
  - if(AC == 0) skip next instruction
- **SKIPCOND 800**
  - if(AC > 0) skip next instruction
- SKIPCOND 800 = **1000 1000 0000 0000**

Upper 2 bits of "address" field determine which comparison SKIPCOND will use!

# Assembly Pitfall – Program Organization

- The assembler and CPU do exactly what we tell it.
  - However, that doesn’t always mean it does what we intend!
- You must be very explicit when organizing your program

# Assembly Pitfall – Program Organization

- **What did the programmer intend for this code to do?**
  - Z=X+Y
- **What does the program actually do?**
  - Our variable X (0006) gets interpreted as a JNS 6 instruction!

```
    LOAD X
    ADD  Y
X,  DEC  6
Y,  DEC  -3
Z,  DEC  0
    STORE  Z
    HALT
```

# Assembly Pitfall – Program Organization

- **Code should always jump around any data**
- Compilers did this for you in COMP 51
  - Automatically separate code and data

```
        LOAD X
        ADD  Y
        JMP  SKIP
X,      DEC  6
Y,      DEC  -3
Z       DEC  0
SKIP,   STORE  Z
        HALT
```

# Homework #9 Discussion

- Discuss algorithms for Problems 28 and 29…
- How many people submitted working .mas files that I can open in the simulator and run?
- Would you like an opportunity to re-submit a working program? (deadline: midnight?)
- Discuss schedule
  - Homework 10?
  - Quiz 3?

# Upcoming Schedule

- **Monday 20th – No class**
- **Wednesday 22nd**
  - MARIE assembly programming
  - **Homework #10 Due**
- **Friday 24th**
  - Start Chapter 5
  - **Quiz 3!**
    - Topic: Assembly programming!
    - *I will give you Table 4.7 from the book*

# Subroutines

# Subroutines

- `Result = addOne(input1);`
- **What do we need for a subroutine? (i.e. function)**
  - Arguments to the function (i.e. input data)
  - Return value from the function
  - A way to jump to the function
  - A way to return from the function when finished
- **Let's write a subroutine that increments a number by 1**

# Subroutine Example (Add One to Num)

```
        Load  Data      / get  value
        Store Arg1      / store value as argument
        Jns AddOne      / call subroutine
        Load Return     / load subroutine return data
        Output          / print it!
        Halt            / terminate
Data,  Dec 20           / original value
/ ** Subroutine **
AddOne,  Dec 0          / return address placed here
        Load  Arg1      / get argument
        Add   One       / increment it
        Store Return    / save return value
        JumpI AddOne    / return with value in a
Arg1,  Dec 0            / Empty: subroutine argument
Return, Dec 0           / Empty: subroutine return value
```

# Clever Tricks

# Clever Tricks – Memory Addresses

```
      ORG 100          / Example 4.1
      Load   Addr      /Load address of first number to be added
      Store  Next      /Store this address is our Next pointer
      Load   Num       /Load the number of items to be added
      Subt   One       /Decrement
      Store  Ctr       /Store this value in Ctr to control looping
Loop, Load   Sum       /Load the Sum into AC
      AddI   Next      /Add the value pointed to by location Next
      Store  Sum       /Store this sum
      Load   Next      /Load Next
      Add    One       /Increment by one to point to next address
      Store  Next      /Store in our pointer Next
      Load   Ctr       /Load the loop control variable
      Subt   One       /Subtract one from the loop control variable
      Store  Ctr       /Store this new value in loop control variable
      Skipcond 000     /If control variable < 0, skip next instruction
      Jump   Loop      /Otherwise, go to Loop
      Halt             /Terminate program
Addr, Hex    117       /Numbers to be summed start at location 117
Next, Hex    0         /A pointer to the next number to add
Num,  Dec    5         /The number of values to add
Sum,  Dec    0         /The sum
Ctr,  Hex    0         /The loop control variable
One,  Dec    1         /Used to increment and decrement by 1
      Dec    10        /The values to be added together
      Dec    15
      Dec    20
      Dec    25
      Dec    30
```

*This is location 117*

- Think back to first MARIE program (Example 4.1)
- ADDR variable holds the address of the element to be added
  - It's a pointer
  - Value = 0x117

# Clever Tricks – Memory Addresses

- **What happens if the program changes?**
  - Say, we add a few instructions

- We would have to find the *new* starting address of the data, save its value in our assembly code, and re-run the assembler
  - **Annoying!**

```
ADDR, HEX 125
```

# Clever Tricks – Memory Addresses

- Perfect world: The assembler lets us use a label and fills in the address from the symbol table on pass 2
  - Unfortunately we don't live in this perfect world!
  - Assembler doesn't do this directly, but we can fool it into doing something similarly useful
- Solution takes advantage of the fact that the instruction format always uses the lower 12 bits of each instruction for the address
  - i.e. this solution works for MARIE, but not necessarily other assembly languages

# Clever Tricks – Memory Addresses

- **What happens when these changes are made to the example program?**

```
100                 Load    Addr
101                 Store   Next
…
106     Addi        Next
…
111     Addr,       JnS     List
112     Next,       Hex     0
…
116     One,        Dec     1
117     List,       Dec     10
```

# Clever Tricks – Memory Addresses

- Recall the RTL for the ADDI instruction:

```
MAR ← X
MBR ← M[MAR]
MAR ← MBR
MBR ← M[MAR]
AC  ← AC + MBR
```

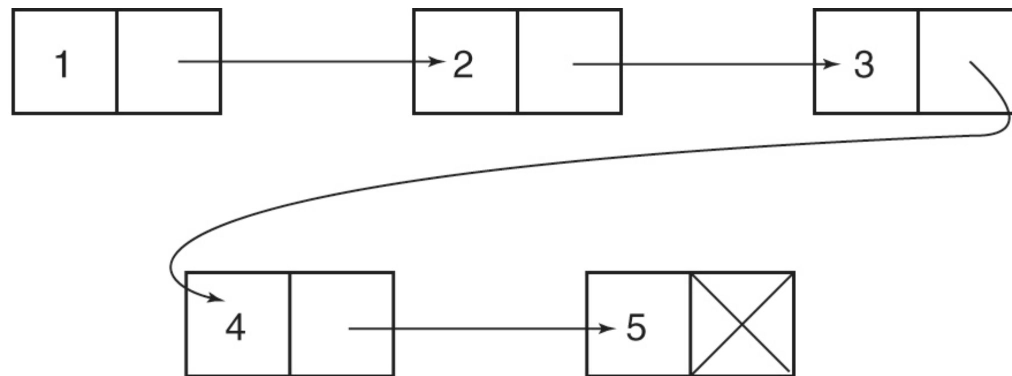
- The third operation truncates the opcode
  - MBR = 16 bits, but MAR = 12 bits
- Result: MAR ends up with only the address of LIST

# Clever Tricks – Memory Addresses

- This trick works with all instructions
  - `JnS` is safest since its opcode is 0
  - The resulting value placed in memory is **only** the 12-bit address

# Homework 4.33 Tips

- Either use the JNS trick just shown, *or* write your program in two passes
  - Pass 1: Write the code the traverses the linked list
  - Run the assembler and look at memory addresses where it placed your program
  - Pass 2: Update the linked list memory addresses based on the assembler listing file produced



# Today's Lab

- **Any or all of the following items:**
  - Fix your Homework #9 and resubmit
  - Start Homework #10
  - Assist your friends / neighbors