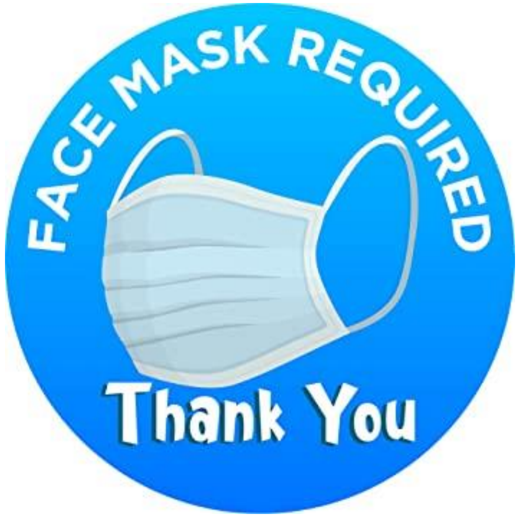
# CS 271
# Computer Architecture & Assembly Language

Lecture 4

First MASM Program and Conditionals

1/13/22, Thursday

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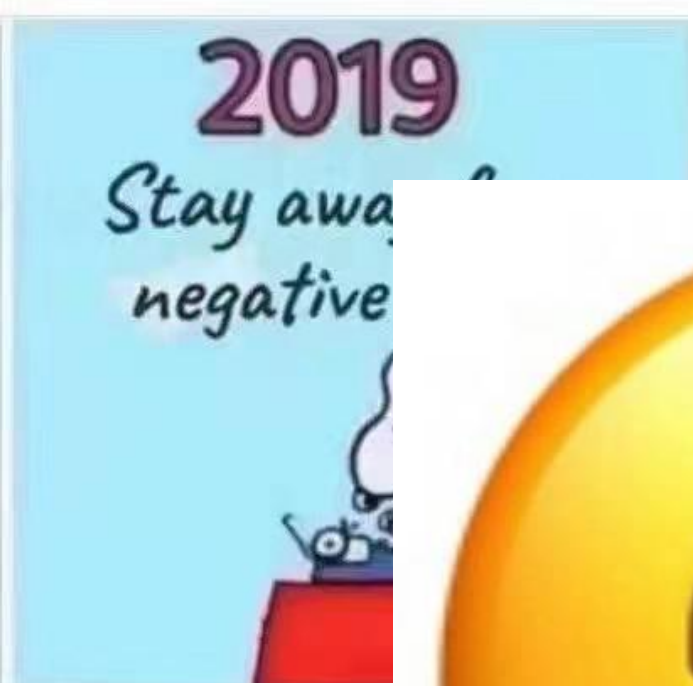
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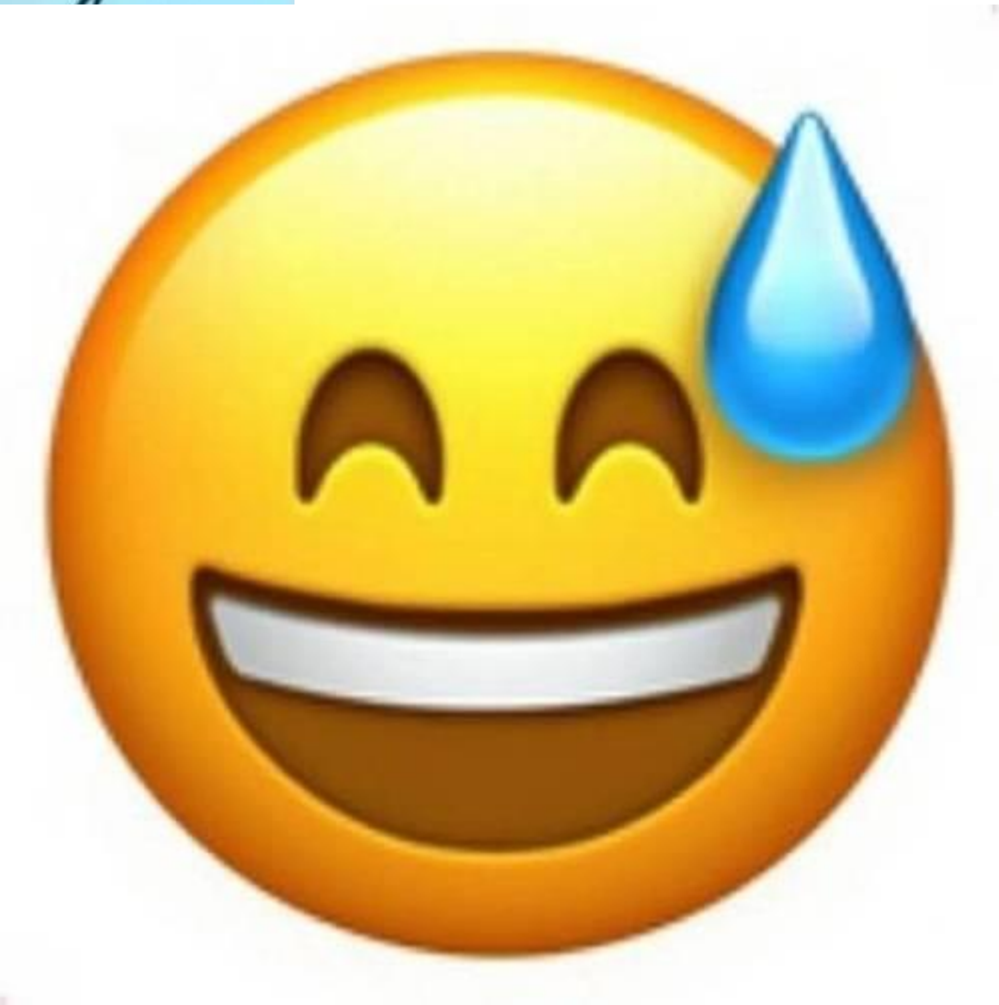

# Due Reminder

- Program #1
  - Due Sunday 11:59 pm on Canvas

- Weekly Summary Exercise 2
  - Due Sunday 11:59 pm on Canvas

# Lecture Topics:

- Finish our first MASM Program
- Introduction to conditions and control structures

# Example Problem Definition

Write a MASM program to perform the following tasks:

1. Introduce yourself to the user.
2. Get the user’s name and number of yards.
3. Greet the user, and report the yards in inches.
4. Say good-bye to the user.

Requirements:

1. The user’s name and yards must be entered by the user, and must be stored and accessed as data segment variables.
2. The “yard-to-inch factor” (36) must be defined as a constant.

# Program Design

- Decide what the program should do
- Define algorithm(s)
- Decide what the output should show
- Determine what variables/constants are required

# Implementing a MASM program

- Open project
- Start with template, “save as” <.asm file in the program directory>
    - This is the source code file
- Fill in identification block information
- Create comment outline for algorithms
- Define constants
    - Test/fix (syntax check, nothing happens)
- Declare variables (.data section)
    - Test/fix (syntax check, nothing happens)
- Enter the output code
    - Test/fix (no calculations, usually everything show 0)
- Enter the input code
    - Test/fix (no calculations, echo input)
- Enter the calculation code
    - Test/fix (logic check, verify)

*First try Debug, Start Without Debugging (more later on using the debug system)

# Writing a MASM program

- Demo

# Introduction to conditions and control structures

# Branching Execution

- Sometimes it is necessary to interrupt sequential instruction execution
- EIP is changed
  - But should not be changed directly
- Examples:
  - Skip ahead (e.g., skip the else block)
  - Jump backwards (e.g., repeat a section of code)
  - Call a procedure
- Conditional / Unconditional branching
- Label required

# MASM Labels

- Same rules as other identifiers
- May not be any previously defined identifier
- Label definition ends with colon :
  - Don’t use colon when referencing the label
- Specifies the memory address of the associated instruction
  - … just like a variable name
- Good practices:
  - Put labels on separate lines
  - Use meaningful label names
    - E.g., don’t use a label named label

# Unconditional branching

- Instruction format is **`jmp label`**
  - Meaning is "Set EIP to **`label`** and continue execution"
    - Remember: label is a name that has been set equivalent to a memory address. I.E., label is a constant
  - **`label`**: <u>should be inside the same procedure</u>
    - MASM allows jumps to labels in other procedures, but execution will almost certainly get lost in space
- Examples later

# Decision structures (alternation)

- We need a way to control branching by checking conditions
  - E.g., if a condition is true, do some task. Otherwise, do something else

- MASM provides a way to compare two operands. The result of the comparison is saved in the status register.

# Conditional branching

- Used for:
  - if structures (decisions, alternation)
  - loop structure (repetition, iteration)
- In general, MASM requires you to build your own control structures
- Note: MASM provides some “advanced” conditional directives (.repeat, .if, .else, … etc.) which we will NOT use in this course.
  - These directives don’t help you to understand how programs work.

# CMP Instruction

- Compares the destination operand to the source operand
  - Non-destructive subtraction: source – destination (*destination is not changed*)
  - Set specific bits in the status register
  - Status bits indicate how source compares to destination
    - <, >, =, <=, >=, etc.
    - Other information in status register:
      - Overflow, zero, error, etc.
    - Program can conditionally jump to a label, based on status bits.
- Syntax: **`CMP    destination, source`**

# The Status (Flag) Register

Each bit is 0 or 1 to indicate “off” or “on”, “false” or “true”, etc.

- Notes:
  - This is a partial list
  - We usually do not access these bits directly

| Bit abbreviation | Meaning |
|---|---|
| O | Overflow |
| D | Direction |
| I | Interrupt |
| T | Trap |
| S | Sign |
| Z | Zero |
| A | Auxiliary carry |
| P | Parity |
| C | Carry |

# *Jcond* Instruction

- A *conditional jump* instruction checks the status register and branches (or not) to label depending on status of specific flags.
  - … usually the next instruction after cmp
- Syntax: ***Jcond* label**
  - There are many *cond* forms that can be checked
  - label is defined by the programmer
- Example:

```
cmp     eax, 100
jle     notGreater      ; if eax <=100, go to notGreater
```

Meaning: if the value in *EAX* is less than or equal to 100, jump to the label *notGreater*.

# Common Jcond instructions

- JE — jump if destination = source
- JL — jump if destination < source
- JG — jump if destination > source
- JLE — jump if destination <= source
- JGE — jump if destination >= source
- JNE — jump if destination not = source

- NOTE: These conditions are for signed integers
  - OK to compare negative to non-negative, etc.
  - More later on this

# Block-structured IF statements

- You can create assembly language control structures that are equivalent to statements written in C++/Java/etc…
- Example:

```
if( op1 == op2 )
   x = 1;
else
   x = 2;
```

```
    mov  eax,op1
    cmp  eax,op2
    jne  L1
    mov  x,1
    jmp  L2
L1:
    mov  x,2
L2:
```

# Assembly Language Control Structures

- Extend the concept to create your own:
  - If-then
  - If-then-else
  - If-then-elseif-else
  - Compound conditions
  - While loop
  - Do-while loop
  - For loop
  - Nested structures, switch structures, etc.

# If-then

- Check condition using CMP
- If condition is false, jump to endThen
  - code for TRUE block
- endThen

```
if (a==b)
    b = 3;

L1 → // ....
```

```
mov eax, a
cmp eax, b
jne L1
mov b, 3

L1:
  ....
```

# If-then-else (Method 1)

- Check condition using CMP
- If condition is false, jump to falseBlock
  - Code for TRUE block
  - Jump to endFalse
- falseBlock:
  - Code for FALSE block
- endFalse:

# Convert pseudo-code to MASM

```
if( op1 == op2 )
   x = 1;
else
   x = 2;
```

```
    mov eax,op1
    cmp eax,op2         ;test condition
    jne fBlock          ;if op1 ≠ op2, jump to false block
    mov x,1             ;true block
    jmp done            ;skip over false block
fBlock:
    mov x,2             ;false block
done:                   ;end of decision structure
```

# If-then-else (Method 2)

- Check condition using CMP
- If condition is true, jump to trueBlock
  - Code for FALSE block
  - Jump to endTrue
- trueBlock:
  - Code for TRUE block
- endTrue:

```
if(op1 == op2)
    x = 1;
else
    x = 2;
```

```
    mov  eax, op1
    cmp  eax, op2
    je   trueB
    mov  x, 2
    jmp  Done
trueB:
    mov  x, 1
Done:
```

```
if(op1 != op2)
    x = 2;
else
    x = 1
```

# If-then-elseif-else

- Check condition1 using CMP
- If condition1 is true, jump to trueBlock1
- Check condition2 using CMP
- If condition2 is true, jump to trueBlock1
    - Code for FALSE block
    - Jump to endBlock
- trueBlock1:
    - Code for TRUE block1
    - Jump to endBlock
- trueBlock2:
    - Code for TRUE block2
- endBlock:

```
if (op1 == op2)
    x = 1;
elseif (op1 == op3)
    x = 2;
else
    x = 3;

mov  eax, op1
cmp  eax, op2
je   true1
cmp  eax, op3
je   true2
mov  x, 3
jmp  endB
true1:
mov  x, 1
jmp  endB

true2:
    mov  x,2
endB:
```

# Compound conditions (AND)

- Check condition1 using CMP
- If condition1 is false, jump to falseBlock
- Check condition2 using CMP
- If condition2 is false, jump to falseBlock
    - Code for TRUE block
    - Jump to endBlock
- falseBlock:
    - Code for FALSE block
- endBlock:

- Note: this structure implements short-circuit evaluation

```
if (op1 == op2 && op2 == op3)
    x = 1
else
    ...

    mov  eax, op1
    cmp  eax, op2
    jne  false
    cmp  eax, op3
    jne  false
    mov  x, 1
    jmp  done

false:
    ...

done:
```

# Compound conditions (OR)

- Check condition1 using CMP
- If condition1 is true, jump to trueBlock
- Check condition2 using CMP
- If condition2 is true, jump to trueBlock
    - Code for FALSE block
    - Jump to endBlock
- trueBlock:
    - Code for TRUE block
- endBlock:

- Note: this structure implements short-circuit evaluation

```
if (op1==op2 || op1 == op3)
    x = 1
else
    ...
```

```
    mov eax, op1
    cmp eax, op2
    je  true
    cmp eax, op3
    je  true
    ....
    jmp done
true:
    mov x, 1
done:
    ....
```

# … and so on, and on …

- Of course there is no end to the variety of decision structures in software systems
- Things can get complicated. As you construct your decision structures in MASM, be sure to
  - Jump to the correct block based on the result of the comparison
  - Jump over the other blocks when you are finished with the selected block