x86 and C refresher Lab

Background:
The x86 is a very widely used microprocessor, it is in Windows and Macintosh personal computers. It is important to be familiar with Intel Architecture, IA.

In this lab we will be come familiar with the Intel Architecture using debuggers, assemblers, un-assemblers, and hand assembly. These tools will allow us to enter programs, assemble, execute, debug, and modify programs.

Tools and techniques develop in this lab will prepare for using microcontrollers in later labs.

C programs in this lab are to refresh C programming knowledge and explore C programming used in microprocessors. Also, this x86 – C refresher Lab will be preparation for using the C programming language to program microcontrollers.

Objectives:

- To be come familiar with how microprocessors operate.
- To be come familiar with programming microprocessors using machine language, assembly language, and C language.
- To be come proficient in the use microprocessor debugging tools and techniques.
- To be come familiar with assemblers and their use in programming microprocessors.
- To understand how to hand assemble instructions for microprocessors.
- To understand the program development cycle (program-test-debug-modify-test-debug-repeat until done).
- To use tracing charts, break points, to verify and debug programs.
- To develop a program from a flow chart.
- To write documented code with flow chart and commented code.

X86 Lab Part 1: Introduction to Debug and C refresher

Intro to DEBUG: Debug Monitor, Machine Language, and Assembly Language, Machine Instructions: MOV, SUB, ADD, JGE, INT 20h, and Debug Commands: d, e, u, r, and t

Introduction:

In this section, you will begin familiarizing yourself with the laboratory equipment. You will load and run a program in the DEBUG environment. You will then describe in detail the nature of this program and write a laboratory report based on your findings. The procedure for this experiment is presented below.

1. Examine the Virtual Machine (link to file on Voyager to run on a computer outside of the lab: \\voyager\Lab\EEE-CPE\Lab_VMs). To get to DEBUG: Click on "**Start**". On the pull down menu select "**Programs**". On the next menu select "**MS-DOS Prompt**" or "**Command Prompt**". You should get the DOS prompt line "**C:\WINDOWS>**".

Type "**DEBUG**" on the DOS prompt line, and the Debug prompt "-" should appear. Type in a "**?**" for a listing of the DEBUG commands you can enter.

2. Use the DEBUG "**dump**" command ("**d**") to display the contents of the memory locations. Enter the following three commands noting their effect.
   a). d 0100
   b). d 0100 0110
   c). d 0100 0200

Describe and discuss the features of the display, such as the number of data blocks per row displayed for each of the above commands, the number system used, number of bits/byte, and the addressing scheme.

3. Use the DEBUG "**enter**" command ("**e**") to enter the assembly language program. Start at location "**CS:0100**". "CS" is the code segment and is determined by the operating system, and does not need to be set. Enter only the machine code (shown in **red** below).

An example of using the "e" command:

```
-e100
1390:0100  00.BA   00.20   00.01   00.A1   00.00   00.02   00.8B   00.1E
1390:0108  00.02   00.02   00.29   00.D8   00.7D   00.06   00.01   00.D0
1390:0110  00.7D   00.02   00.EB   00.FA   00.A3   00.00   00.02   00.CD
1390:0118  00.20
```

4. After you have entered in the program using the "**e**" command in step 3, use the DEBUG "**unassemble**" command ("**u**") to see the program you have just entered. Compare the output of this command with the program listing, note differences, and correct them.

Program Listing:

CS:IP	Machine Code	Mnemonics	
1390:0100	BA2001	MOV	DX,0120

```
-u100 118
1390:0100 BA2001        MOV     DX,0120
1390:0103 A10002        MOV     AX,[0200]
1390:0106 8B1E0202      MOV     BX,[0202]
1390:010A 29D8          SUB     AX,BX
1390:010C 7D06          JGE     0114
1390:010E 01D0          ADD     AX,DX
1390:0110 7D02          JGE     0114
1390:0112 EBFA          JMP     010E
1390:0114 A30002        MOV     [0200],AX
1390:0117 CD20          INT     20
```

5. Use the DEBUG "**register modify**" command ("**r**") to set the Instruction Pointer (IP) register to point to Location CS:0100 (the beginning of the program you have entered).

An example of using the "r" command:

```
-r
AX=0000  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0100   NV UP EI PL NZ NA PO NC
1390:0100 BA2001        MOV     DX,0120
```

6. Use the DEBUG "**trace**" command ("**t**") to trace through the program you have entered. Set the values in the memory locations first, before running or tracing the program (see below). Stop tracing the program at the "Int 20h" instruction. Determine the effect of the first several instructions. Try several values for variables (DX, and memory locations 200 and 202). Run the program several times recording the variables used and noting each time the behavior of the program. Repeat until you understand the program fully. Once you have done this, create a tracing chart for at least two runs of the program with multiple loops. On your tracing chart, record the changes observed during tracing. See attached sheet for chart format.

Setting values in memory:

```
-e200
1390:0200  00.20   00.01   00.50   00.02
```

Displaying memory values:

```
-d200 203
1390:0200  20 01 50 02                                          ..P.
```

An example of using the "t" command:

```
-t
AX=0000  BX=0000  CX=0000  DX=0110  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0103   NV UP EI PL NZ NA PO NC
1390:0103 A10002        MOV     AX,[0200]                  DS:0200=0120
-t
AX=0100  BX=0000  CX=0000  DX=0110  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0106   NV UP EI PL NZ NA PO NC
1390:0106 8B1E0202      MOV     BX,[0202]                  DS:0202=0250
```

7. Run the entire program using the DEBUG "**Go**" command ("**g**"). How does this program end? Also, explore the use of the "Go" command when specifying **breakpoints**. Command go, **G** [=address] [addresses]

An examples of using the "g" command:

```
-rip
IP 0106
:100
-g          ; using the go command when the IP has been set
-g=100      ; using the go command to start at memory location 100
An example of using the go command to set a breakpoint
-g=100 10E
AX=FF00  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=136C  ES=136C  SS=136C  CS=136C  IP=010E   NV UP EI NG NZ NA PE CY
136C:010E 01D0          ADD     AX,DX                            0
```

8. What is the function of the last instruction of this program (see program listing section 3)? Explain.

9. Demonstrate your ability to use the DEBUG Command Set to your instructor. Debug Commands: d, e, u, r, and t.

10. Prepare a laboratory report to address the work done in each of the above steps and in the same order in which they appear in this handout.

In your report include; a flow chart of the program, examples of program "runs" (capture Debug traces), and comment the code.

In the conclusions section of your report, be sure to address what you have learned in doing this lab. Also, address your understanding of the instructions and commands (Instructions: **MOV, SUB, ADD, JGE, INT 2Oh,** and Debug Commands: **d, e, u, r, g,** and **t**).

Be prepared to discuss in the lab demo and in your report:

What are the condition(s) under which the program will jump using the JGE instruction?

What is the program doing (your lab instructor may ask you to change part of the program and ask you questions about it)?

What does each of the instructions in the program do?

What do each of the Debug commands do, and how to use them?

C Programming Refresher

Write a "Hello" in **C** program

Write a program to add two numbers in **C**.

Write a program in **C** to perform the same function as the assembly language program used in **Debug**.

Information on C:
You can use any C compiler you like. Here are some links to information on C complier and tutorials:

Tiny C Compiler: http://bellard.org/tcc/

Tiny C Compiler Reference Documentation: http://bellard.org/tcc/tcc-doc.html

Programming in C: http://www.lysator.liu.se/c/

C Language Tutorial: http://www.physics.drexel.edu/students/courses/Comp_Phys/General/C_basics/

Demo Debug Introduction Lab:
Be prepared by addressing the following items:

1. Flow Charts (see Flow Chart symbol section) give an example application of the assembly program.
2. Commented Code (comments to reflect on the flow chart and program application.
3. Fill out tracing chart (Excel version) for 2 runs with different values for the assembly program
4. PreLab: Hand Assembly Lab Pre Lab Flow Chart of program and hand assembly
5. Show your results, running the programs at demo including your C programs
6. Example program run
   Be ready to answer questions on the program and Debug
   Break points?
7. Lab write up due after demo.

X86 Lab Part 2: Hand Assembly and C programming

Introduction:

In this Hand-Assembly Lab, you will develop an 8-bit version of the program from Debug Introduction Lab, using byte-size data and registers (Debug Introduction Lab uses word size, 16 bit registers and data). Your program must meet the following specifications:

1. Use the JGE instruction only once (only one conditional jump).
2. Make no use of register (obtain from the link EEE174_CpE185) _____, neither its low nor high byte.
3. Use consecutive memory locations for data starting at the address _____; you will obtain from your Lab Instructor.

Note: **Each person** will have a **unique register** to not use and an address for data. Also **DO NOT** use the **Assembler in DEBUG.** Refer to the hand-assembly examples.

4. After you have your program hand assembled and running, using the assemble command modify your program to display your name and title of your program (see the "Welcome to EEE174" program).
5. Modify your program to keep track of how many times the overdraft (or bail out) has been added to the account and display this amount.

Pre-Lab Work:

1. **Identify the registers and memory locations** you want to use on the attached Register Template. Use descriptive words such as "old balance", "debit", "over-draft or bailout" to describe what numeric values are and how they relate to the program operation.
2. Cre ate a **Flow Chart** for your program (see handout on Flow Charting). Your instructor will want to see your flow chart at the beginning of the lab, make sure you instructor signs you off before you proceed with entering your program.
3. **Hand-assemble** the instructions using the hand-assembly template (see attached), you may need to use more than one page. Your instructor will want to see your Hand-assembly work.

Laboratory Work:

1. Use the DOS DEBUG command "e" to load the results of your hand-assembly work into memory starting at location CS: 0100 (use the "CS", Code Segment, value given by your computer). Use the DOS DEBUG command "u" to un-assemble your program to verify it was loaded correctly and is executing the instructions you programmed. Go back to your hand-assembly template to fix errors that you find.

2. When your program is working correctly, copy your program listing into a text editor and add commented code (a written comment on what the instruction does in context to the entire program), behind each machine language instruction. Use the tracing chart from the Debug Introduction Lab, and trace two runs of your program (at least one trace with the variables set to cause the program to loop more than once).

3. C Programming: Write and run a program in C to perform the same function as the assembly language program used in this lab. If you were to write a program in in-line assembly what would it look like? Try to write and run inline assembly program.
   - C reference information:
   - You can use any C compiler you like. Here are some links to information on C complier and tutorials:
   - Tiny C Compiler: **http://bellard.org/tcc/**
   - Tiny C Compiler Reference Documentation: **http://bellard.org/tcc/tcc-doc.html**
   - Programming in C: **http://www.lysator.liu.se/c/**
   - C Language Tutorial: **http://www.physics.drexel.edu/students/courses/Comp_Phys/General/C_basics/**

4. Hand Assembly Lab Demo Requirements:

I. **In the counter loop, suggestion would be to inc then add**
Example program with message and loop counter

II. **Hand Assembly filled out using Hand assembly template Excel file**

III. **Two Flow Charts: one for Hand assembly and one for the complete program with title and counter**

IV. **Commented Code Two listings, one for the hand assembly portion and one for the complete program with title and counter.**

V. **Fill out tracing chart Hand Assembled part Excel version for two runs of the hand assembly portion of the program.**

VI. **Show your results, run program demo**
Command Prompt
   A. **Be ready to answer questions on the program**
   B. **Show and run your C programs and answer questions on them**

VII. **Pre lab for Hello MASM**

X86 Lab Part 3: Microsoft's Assembly Language Development System (MASM)

Introduction:

This exercise will introduce you to the use of an assembler. The emphasis will be on gaining experience with the assembler syntax and pragmatics of the PWB (Programmer's Workbench) and Code View (Debugger). The x86 Virtual Machine is available on the ECS Lab Computers and/or network (link to file on Voyager to run on a computer outside of the lab: \\voyager\Lab\EEE-CPE\eee174).

MASM vs DOS DEBUG:

For this laboratory experiment, you will need to be able to store you files generated by the assembler (Flash drive, network access, etc.).

1. Use the PWB's editor to type a source file (see listing file attached). In PWB, set up a new project for DOS COM file and type in the program using "Save As" option from the PWB file menu and then type "X:\filename.asm" where "X" is the drive or path for storage, "filename" is the name you have chosen for your source file (for example, "Hello.ASM"). Make sure your file has the ".ASM" extension.
2. Investigate and compare the various options in PWB. A project ".MAK" file will keep track of your PWB settings. Use the menu "Options" – "Language Options" - "MASM Options" – "Set Debug Options" and set (click on) "Generate Listing File" to produce a MASM ".LST" file for viewing error/warnings.
3. Choose "Compile or Rebuild All" option from the PWB "Project" menu to compile your source file (be sure you have saved your ".ASM" file first). You will see a screen titled "Build Options … Complete … Errors/Warnings". You should expect to have a few errors initially. Use the generated listing file (your file with a ".LST" extension, for example "Hello.LST") to identify as many errors as you can.
   Once you have examined this file go back to your source file (your ".ASM" file) to correct the errors and make any other changes, and then compile the source again. Repeat this process until you can compile the file without any error/warnings. With a complete compile, you will see a ".COM" ("Hello.COM" for example) on working directory (or USB Flash Drive).
4. The behavior of DOS DEBUG and CodeView (accessed through PWB's "Run" menu – "Debug:") differ slightly when the program is run repeatedly. CodeView will want to reinitialize memory. Make at least two program runs in CodeView and DOS DEBUG (without restarting DEBUG in between. Use the machine code from the ".LST" (see attached) to enter into DOS DEBUG.
   Review your Listing file. How does the information in the symbol table relate to your experiences in hand assembly of other programs you have written? Include your response in your report.
   Why is the result of the second run (and repeated runs) different from the second run in CodeView? How would you alter the program so that when you ran it in CodeView or DOS DEBUG you would get the same result? Modify the program to fix the problem of multiple runs of the program and to print a title with your name in it, as part of the program initialization. Modify the program and include this in your demo (and report) to your lab instructor,
5. Write a program that will allow the user to specify how many times the program will loop and display the title of the program include your name in the title, print from in the loop a string and count. Example 0-19 format.
6. Write C programs for the Hello MASM 0-99 and for the user selectable loops.

Pre-Lab Work:

1. Create a flow chart for each program ("MASM Hello"). Create .ASM files for each program on a flash drive or directory (type the programs into a text editor program like "Notepad" or "TextPad" and save them with an ".ASM" extension). Review PWB Setup on how to set up a project to assemble.

Laboratory Work:

1. Demonstrate programs, have your updated pre-lab Flow Charts, Listing files, demonstrate the "fixed" MASM Hello program, discuss what causes the program to loop and what causes it to stop looping.

Hello MASM Lab Demo Requirements:

I. **Original Program**
   - **Flow Chart,**
   - **Commented code, and list file**
   - **Show program runs in DEBUG and MASM**

II. **Modified Hello program with fix so the program runs correctly with title (title to include student's name)**
   - **Flow Chart,**
   - **Commented code, and list file**
   - **Show program runs in DEBUG and MASM**

III. **Modified Hello program to display 0 to 19 and more (user selectable) with title (title to include student's name)**
   - **Flow Chart,**
   - **Commented code, and list file**
   - **Show program runs in MASM**

IV. **C programs for Hello MASM loops and user selectable Hello MASM.**
   1) Write, run, and demo C program to perform the same function as the assembly modified hello program to display 1 to 99 user selectable.
   2) Try to write and inline assembly program to perform the same function. Discuss the differences between C program and Inline assembly. What operations perform better in Inline assembly? Which perform better in C?

V. **Pre lab for next lab**

Lab Report Due: Week 6

IMPORTANT NOTE:
Throughout the semester, laboratory reports must be submitted to the laboratory instructor during the laboratory period in which they are due. Lab reports that are one week late will receive ½ credit. Reports later than two weeks will receive no credit.

```
C:\>debug
-e
^ Error
-rip
IP 0100
:100
-e100
1390:0100  00.BA   00.20   00.01   00.A1   00.00   00.02   00.8B   00.1E
1390:0108  00.02   00.02   00.29   00.D8   00.7D   00.06   00.01   00.D0
1390:0110  00.7D   00.02   00.EB   00.FA   00.A3   00.00   00.02   00.CD
1390:0118  00.20
-
-e200
1390:0200  00.50   00.01   00.50   00.20
-
-u100 118
1390:0100 BA2001        MOV     DX,0120
1390:0103 A10002        MOV     AX,[0200]
1390:0106 8B1E0202      MOV     BX,[0202]
1390:010A 29D8          SUB     AX,BX
1390:010C 7D06          JGE     0114
1390:010E 01D0          ADD     AX,DX
1390:0110 7D02          JGE     0114
1390:0112 EBFA          JMP     010E
1390:0114 A30002        MOV     [0200],AX
1390:0117 CD20          INT     20
-
-d200 203
1390:0200  D0 00 50 02                                        ..P.
-
```

Comments:

Examples of applications for a program like this could be a data acquisition system where Memory location 200, [200] value being moved into AX represents an output adjusted signal. Memory location [202] being moved into BX represents an input signal coming from a 16 bit Analog to Digital Converter, ADC. The value in DX represents an offset to be added to a negative value to bring the output to a positive value.

You may think of this little program as part of the software used by a bank to update your checking account, or this program may be part of a signal processing software to make sure the signal has a positive value. The word-size memory location **[0200] contains the balance of the checking account** or the current signal bias level. Memory location **[0202] contains the amount on a check**, which has just been presented for payment (or the level of an input signal).

You have an "Overdraft Protection Agreement" with the bank, which provides that **a fixed amount – the 0120 – "immediate data"** – will be transferred from your savings account into the checking account if the new balance is negative. Such a "bail-out" operation will be performed as many times as necessary to restore the checking balance to a non-negative value. In a signal processing example, this would be a step number level to bring the signal level to a positive value.

The bookkeeping for the savings account is not part of the code shown here. In the above software the bank know you as a valued customer and a person of infinite means, so that bailout operations can always be performed without checking the savings balance first. In the near future the bank will probably discover that it has overestimated your financial strength and that the program needs to include the activity on the savings account. By the time they discover that, we should be able to write an improved program for them. We should expect that they would also want to level a service charge for each bail- out operation performed.

Finally note that the present version of the program handles your money in the form of hexadecimal integers, which is not very practical and may have to be changed.

Program trace

```
-r
AX=0000  BX=0000  CX=0000  DX=0000  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0100   NV UP EI PL NZ NA PO NC
1390:0100 BA2001        MOV     DX,0120
-t
AX=0000  BX=0000  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0103   NV UP EI PL NZ NA PO NC
1390:0103 A10002        MOV     AX,[0200]                    DS:0200=0120
-t
AX=0120  BX=0000  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0106   NV UP EI PL NZ NA PO NC
1390:0106 8B1E0202      MOV     BX,[0202]                    DS:0202=0250
-t
AX=0120  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=010A   NV UP EI PL NZ NA PO NC
1390:010A 29D8          SUB     AX,BX
-t
AX=FEB0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=010C   NV UP EI NG NZ NA PO CY
1390:010C 7D06          JGE     0114
-t
AX=FEB0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=010E   NV UP EI NG NZ NA PO CY
1390:010E 01D0          ADD     AX,DX
-t
AX=FFC0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0110   NV UP EI NG NZ NA PE NC
1390:0110 7D02          JGE     0114
-t
AX=FFC0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0112   NV UP EI NG NZ NA PE NC
1390:0112 EBFA          JMP     010E
-t
AX=FFC0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=010E   NV UP EI NG NZ NA PE NC
1390:010E 01D0          ADD     AX,DX
-t
AX=00D0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0110   NV UP EI PL NZ NA PO CY
1390:0110 7D02          JGE     0114
-t
AX=00D0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0114   NV UP EI PL NZ NA PO CY
1390:0114 A30002        MOV     [0200],AX
DS:0200=0100
-t
AX=00D0  BX=0250  CX=0000  DX=0120  SP=FFEE  BP=0000  SI=0000  DI=0000
DS=1390  ES=1390  SS=1390  CS=1390  IP=0117   NV UP EI PL NZ NA PO CY
1390:0117 CD20          INT     20
-p
Program terminated normally
-
-d200 203
1390:0200  D0 00 50 02                                         ..P.
```

Commented Code

Flow Chart

```
-
a100
MOV DX,0120        ; move hex value 0120 into register DX
MOV AX,[0200]      ; move 2 bytes from memory location 0200 into reg AX
MOV BX,[0202]      ; move 2 bytes from memory location 0200 into reg BX
SUB AX,BX          ; subtract reg BX from AX and store in AX
JGE 0114           ; jump to location 114 if the result is ≥ 0
ADD AX,DX          ; add reg DX to AX and store in AX
JGE 0114           ; jump to location 114 if the result is ≥ 0
JMP 010E           ; jump unconditionally to location 010E
MOV [0200],AX      ; move the contents of AX to memory location 0200
INT 20             ; BIOS service interrupt 20, end program

a200
db 20 01 50 02

e100
BA 20 01 A1 00 02 8B 1E 02 02 29 D8 7D 06 01 D0 7D 02 EB FA A3 00 02 CD
20

e200
20 01 50 20

-e100
1390:0100  00.BA   00.20   00.01   00.A1   00.00   00.02   00.8B   00.1E
1390:0108  00.02   00.02   00.29   00.D8   00.7D   00.06   00.01   00.D0
1390:0110  00.7D   00.02   00.EB   00.FA   00.A3   00.00   00.02   00.CD
1390:0118  00.20
-
-e200
1390:0200  00.20   00.01   00.50   00.20
-
-d100 118
1390:0100  BA 20 01 A1 00 02 8B 1E-02 02 29 D8 7D 06 01 D0
..........).}...
1390:0110  7D 02 EB FA A3 00 02 CD-20                         }.......
-
-d200 203
1390:0200  D0 00 50 02                                        ..P.
-
-u100 118
1390:0100 BA2001        MOV     DX,0120
1390:0103 A10002        MOV     AX,[0200]
1390:0106 8B1E0202      MOV     BX,[0202]
1390:010A 29D8          SUB     AX,BX
1390:010C 7D06          JGE     0114
1390:010E 01D0          ADD     AX,DX
1390:0110 7D02          JGE     0114
1390:0112 EBFA          JMP     010E
1390:0114 A30002        MOV     [0200],AX
1390:0117 CD20          INT     20
-

-u200 203
1390:0200 0001          ADD     [BX+DI],AL
1390:0202 50            PUSH    AX
1390:0203 2000          AND     [BX+SI],AL
```

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Laboratory Exercise #1

Name: ______________________________

Program Tracing Chart

			Registers:									
	AX:	BX:	CX:	DX:	OF:	ZF:	SF:	CS:	IP:	DS:200	DS:202	Next Instruction:
Value:--->												

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Laboratory Exercise #1

Name: Example

Program Tracing Chart

Registers:

	AX:	**BX:**	**CX:**	**DX:**	**OF:**	**ZF:**	**SF:**	**CS:**	**IP:**	**DS:200**	**DS:202**	**Next Instruction:**
Value:--->	0000	0000	0000	0000	NV (0)	NZ (0)	PL (0)	1390	0100	0150	0250	Mov DX, 120
	0000	0000	0000	0120	NV (0)	NZ (0)	PL (0)	1390	0103	0150	0250	Mov AX [0200]
	0150	0000	0000	0120	NV (0)	NZ (0)	PL (0)	1390	0106	0150	0250	Mov BX [0202]

Flowcharting

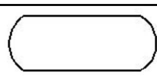
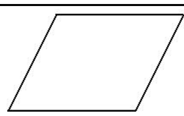
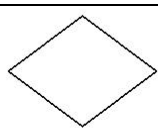
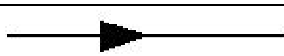
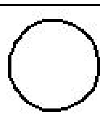
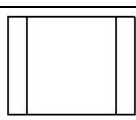
A flowchart is a detailed graphic representation illustrating the nature and sequencing of an operation on a step-by-step basis. A flowchart may be made of an everyday task such as driving to the store. How many steps are involved in this simple task? How many decisions are made in getting to the store? A formalized operation such as baking cookies can be flowcharted, whether on a small-scale process in your kitchen or on a very large scale in a commercial bakery. And, of course, a flowchart also may be made of the steps and decisions necessary for a computer or microcontroller to carry out a task.

A relatively simple process is usually easy to understand and flows logically from start to finish. In the case of baking cookies, the steps involved are fairly easy. A recipe typically requires mixing the required ingredients, forming the cookies and properly baking them. There are several decisions to make: Are the ingredients mixed enough? Is the oven pre-heated? Have the cookies baked for the recommended time?

As processes become more complex, however, it is equally more difficult to chart the order of events needed to reach a successful conclusion. A program may have several dozen steps and possibly a number of `if - then` branches. It can be difficult to grasp the flow of the program simply by reading the code.

A flowchart is made up of a series of unique graphic symbols representing actions, functions, and equipment used to bring about a desired result. Table 1 summarizes the symbols and their uses.

Table 1: Flowchart Symbols

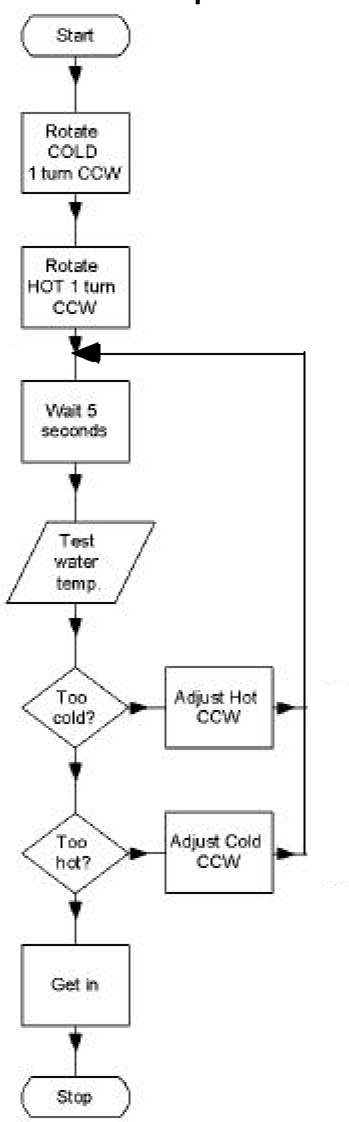
	**Start/Stop** box indicates the beginning and end of a program or process.
	**Process** box indicates a step that needs to be accomplished.
	**Input/Output** box indicates the process requires an input or provides an output.
	**Decision** box indicates the process has a choice of taking different directions based on a condition. Typically, it is in the form of a yes-no question.
	**Flowline** is used to show direction of flow between symbols.
	**Connector** box is used to show a connection between points of a single flowchart, or different flowcharts.
	**Sub-routine or sub-process** box indicates the use of a defined routine or process.

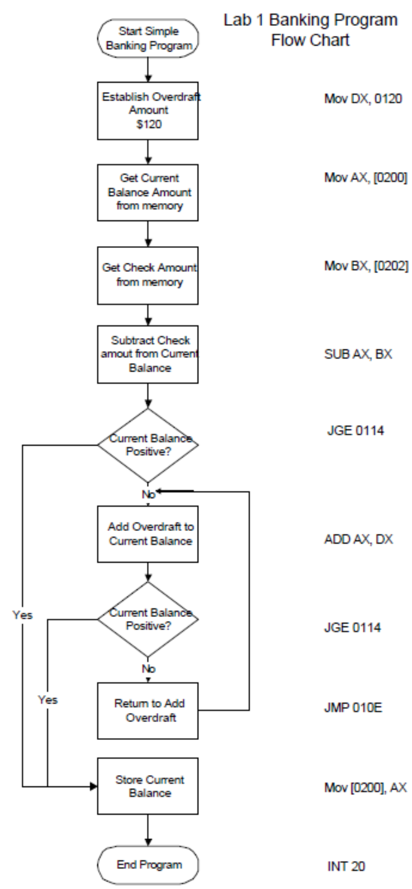
Flowchart Example

Let's take an example flowchart of an everyday task: adjusting the temperature for a shower. The process of adjusting the water temperature has several steps involved. The water valves are initially opened, we wait a while for the temperature to stabilize, test it, and make some decisions for adjustments accordingly. If the water temperature is too cold, the hot valve is opened more and we go back to test it again. If the water is too hot, the cold valve is opened more. Once we make this adjustment, we go back to the point where we wait for a few seconds before testing again. Of course this doesn't take into account whether the valves are fully opened. Steps may be inserted during the temperature adjustment procedure to correct for this condition. Figure 1 shows a flowchart of this process.

This example demonstrates a process that may be used in adjusting the temperature, but could it also be the steps in a microcontroller program? Sure! The valves may be adjusted by servos, and the water temperature determined with a sensor. In most cases, a simple process we go through can be quite complex for a microcontroller. Take the example of turning a corner in a car. Can you list all the various inputs we process in making the turn?

Figure 1:
Shower Temperature Example





Registers Used:

AX

AH	AL
BH	BL
CH	CL
DH	DL

DX

Memory Locations:

Address:				
Label:				
Contents:				

```

;-------------------------------------------------------------;
;                                                             ;
;       This is an example Hello program (in x86 code)        ;
;       for use in DOS Debug                                  ;
;                                                             ;
;       Written by Dennis Dahlquist 7/30/16                   ;
;                                                             ;
;                                                             ;
;-------------------------------------------------------------;

debug
A 100
        Mov     DX, 200                 ; load DX with the value of location of the message
        mov     AH, 09                  ; set the BIOS service to display the message
        int     21                      ; DOS interupt to display message
        int     20                      ; terminate program and return to DOS

E 200  "Hello, Welcome to EEE174-CpE185" 0d 0a "$"
                                        ; Message Data, 0d & 0a - cr and lf, $ - end of string



Results:

-u100 108
290D:0100 BA0002        MOV     DX,0200
290D:0103 B409          MOV     AH,09
290D:0105 CD21          INT     21
290D:0107 CD20          INT     20
-

-d200 21a
290D:0200  48 65 6C 6C 6F 2C 20 57-65 6C 63 6F 6D 65 20 74   Hello, Welcome t
290D:0210  6F 20 45 45 45 31 37 34-0D 0A 24                  o EEE174-CpE185..$
-

-g=100
Hello, Welcome to EEE174-CpE185

Program terminated normally
-


C:\WINDOWS>debug
-?
assemble     A [address]
compare      C range address
dump         D [range]
enter        E address [list]
fill         F range list
go           G [=address] [addresses]
hex          H value1 value2
input        I port
load         L [address] [drive] [firstsector] [number]
move         M range address
name         N [pathname] [arglist]
output       O port byte
proceed      P [=address] [number]
quit         Q
register     R [register]
search       S range list
trace        T [=address] [value]
unassemble   U [range]
write        W [address] [drive] [firstsector] [number]
allocate expanded memory        XA [#pages]
deallocate expanded memory      XD [handle]
map expanded memory pages       XM [Lpage] [Ppage] [handle]
display expanded memory status  XS
-

```

EEE 174
Laboratory Hand-Assembly Template
Dahlquist/Stoffers/Schultz

Instruction:

Address: CS : 100 Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

Instruction:

Address: CS : Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

Instruction:

Address: CS : Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

Instruction:

Address: CS : Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

Instruction:

Address: CS : Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

Instruction:

Address: CS : Operation: Dest.: Source:

Instruction Format

Binary:

Hex:

EEE 174
Laboratory Hand-Assembly Template
Dahlquist/Stoffers/Schultz

Example

Instruction: Mov DL, 25

Address: CS : **0100** Operation: Mov Dest.: DL Source: **25**

immediate to register (alternate encoding)

Instruction Format: 1011 w reg : immediate data

w=0 reg DL=010 data=0010 0101

Binary:	1011	0010	0010	0101
	B	2	2	5

Hex: B2 25

Instruction: Mov BL, [0200]

Address: CS : **0102** Operation: Mov Dest.: BL Source: **[0200]**

memory to reg

Instruction Format: 1000 101w : mod reg r/m : memory address

mod=00 reg BL=011 r/m=110 memory address = 0002

Binary:	1000	1010	0001	1110	0000	0000	0000	0010
	9	A	1	E	0	0	0	2

Hex: 8A 1E 00 02

Instruction: ADD BL, DL

Address: CS : **0106** Operation: ADD Dest.: BL Source: **DL, BL**

register2 to register1

Instruction Format: 0000 001w : 11 reg1 reg2

w=0 reg1=BL=011 reg2=DL=010

Binary:	0000	0010	1101	1010
	0	2	D	A

Hex: 02 DA

Instruction: INT 20

Address: CS : **0108** Operation: INT Dest.: 20 Source:

INT n – Interrupt Type

Instruction Format: 1100 1101 : type

n=20 or 0010 0000

Binary:	1100	1101	0010	0000

Hex: CD 20

Instruction JMP 110

Address: CS : **0114** Operation: JMP Dest.: 110 Source:

JMP –Unconditional Jump (to same segment)

Instruction Format short 1110 1011 : 8-bit displacement

Binary: 1110 1011 1111 1010

Hex: EB FA

Instruction JGE 11A

Address: CS : **112** Operation: Dest.: Source:

Jcc –Jump if Condition is Met

Instruction Format 8-bit displacement 0111 tttn : 8-bit displacement

JGE => tttn = 1101 displacement = 06 or

Binary: 0111 1101 0000 0110

Hex: 7D 06

```
Microsoft (R) Macro Assembler Version 6.14.8444          08/03/16 20:51:49
MASMLab                                                  Page 1 - 1
                                 Page 58,132
                                 Title MASMLab
                             ;************************
                             ;*                      *
                             ;* MASM Hello           *
                             ;*                      *
                             ;************************
 0000                        cseg segment 'code'
                             assume cs:cseg, ds:cseg, ss:cseg, es:cseg

                                     org 100h

 0100  B9 000A               start:  mov cx,10
 0103  B4 09                         mov ah,9

 0105  BA 0200 R             again:  mov dx, offset Hello
 0108  CD 21                         int 21h
 010A  BA 020E R                     mov dx, offset Num_msg
 010D  CD 21                         int 21h
 010F  FE 06 020E R                  inc byte ptr Num_msg
 0113  E0 F0                         loopne again

 0115  B4 4C                 done:   mov ah, 4ch
 0117  CD 21                         int 21h

                                     org 200h

 0200 48 65 6C 6C 6F 20      Hello   db "Hello World", 20h, 20h, "$"
       57 6F 72 6C 64 20
       20 24

 020E 30 0D 0A 24            Num_msg db 30h,13,10, 36

 0212                        cseg ends
                             end start
```

For MASM Hello.asm

IP Machine Code

For Debug

In Debug use "CD 20" to keep the OS from closing Debug.

```
Microsoft (R) Macro Assembler Version 6.14.8444          08/03/16 10:41:46
MASMLab                                                  Symbols 2 - 1
Segments and Groups:
                N a m e                 Size     Length   Align   Combine
                Class
cseg . . . . . . . . . . . . . .        16 Bit   0212     Para    Private
'CODE'
Microsoft (R) Macro Assembler Version 6.14.8444          08/03/16 10:41:46
MASMLab                                                  Symbols 3 - 1

Symbols:
                N a m e                 Type     Value    Attr
Hello  . . . . . . . . . . . . .        Byte     0200     cseg
Num_msg  . . . . . . . . . . . .        Byte     020E     cseg
again  . . . . . . . . . . . . .        L Near   0105     cseg
done . . . . . . . . . . . . . .        L Near   0115     cseg
start  . . . . . . . . . . . . .        L Near   0100     cseg
```