EECE 143

Digital Design Laboratory

Laboratory Manual

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Laboratory 0: Digital Laboratory Introduction

<u>Purpose:</u>

1. Learn to use the Agilent 54622D Mixed Signal Oscilloscope functions
2. Learn to use the CADET II electronic training station
3. Experiment with digital ICs, Schmitt gates, and clock circuits.

<u>Preparation:</u>

1. Prepare your notebooks as described in Chapter 1 of the Class Notes.
2. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the tutorial sections for the logic analyzer and CADET board. The tutorials are found in Chapter 2 of the Class Notes.
3. Prepare the necessary data tables in your notebook for each Experiment Procedure.
4. You may wish to pre-build the Schmitt gate clock circuit in Figure 0.1.

<u>Experiment Procedure:</u>

1. Agilent 54622D Mixed Signal Oscilloscope Evaluation

This procedure requires the use of the Evaluation Card and the Mixed Signal Oscilloscope.

a. *Mixed Analog and Digital*

Plug in the demo board into the Agilent 54622D

Connect Channel 1 Probe to test point 1
Connect Channel 2 probe to test point 2
The scope may have been setup to another's application. Quickly return to factory setup by pressing **Save/Recall** on the front panel and **Default Setup** in the menu under the display.
Press **Autoscale**
Adjust **waveform intensity knob** to approximately 50%
With 2 scope channels and up to 16 logic channels you can view analog and digital signals simultaneously.

b. *Mega Zoom Deep Memory*

With 2 MB of Mega Zoom memory you can capture the big picture showing the 800 Hz ramp on channel 2 and every cycle of the PWM on channel 1 with 5ns resolution.
Press **Single**
Turn **Time/Div** knob clockwise to zoom in for a look at the details.

c. *High Definition Display*

Return to original setup:
Press **Autoscale**
Then Press **Single**
Adjust **waveform Inten;sity knob** to see bright spots on channel 1
Zoom in on the anamoly:
Center bright dot in middle of the screen using the **small Delay knob**
Zoom in using the **Time/Div knob**

d. *Flexible Triggering*

Press **Autoscale**
Press the **Pattern Key** to turn on Pattern triggering
Turn **entry knob** to:
Select D3: set to H (using the softkey under the display)
Select D2: set to H
Select D1: set to H
Select D0: set to L

e. Built-in Help

To get more information about a feature, use the built-in Quick Help.
Press and hold the **Pattern key** to view its built-in help

2. CADET function generator frequency measurement.

This procedure will will demonstrate how to take measurements with the Agilent 54622D Mixed Signal Oscilloscope Answer all questions in the spaces provided in the Laboratory 0 Data sheet.

a. Setup

Turn on the Agilent 54622D.
Connect a small wire to the TTL output of the CADET II function generator.
Set the function generator settings to give a signal of approximately 100kHz.
Connect the 54622D Channel 1 probe to the wire.
Turn on the CADET II training board.
Press **Autoscale**. You should see a waveform on the screen.
Adjust the frequency on the CADET board by turning the **01-1.0 Frequency knob**. What happens on the MSO screen? ____________
h. Set the Function generator to 100KHz again. Press **Autoscale** if necessary.

b. Taking measurements manually using markers

Press the *Cursors* button in the Measure portion of the control panel.
Notice the Softmenu appears on the display above the softkeys.
Verify the Check mark appears under **X**.
Press the **Softkey under X1** to highlite X1.
Turn the **entry knob** so that the marker is in line with the first negative edge of the waveform.
Press the **Softkey under X2** to highlight X2.
Turn the **entry knob** so the marker is in line with the next negative edge.
ΔX is the distance between X1 and X2. This is also the period,T, of the waveform. What is your measured value of ΔX? __________
The frequency of a waveform is f=1/T.
What is your measured frequency of the waveform? _______
Turn the **entry knob** so that X1 is now located at the positive edge immediately before X2.
ΔX is now the positve pulse width, measuring the time the signal is high.
What is your +pw? ______
Duty Cycle is defined as the percentage of time that a signal is spent at a high level.
DC= +pw/T *100
What is your measured value of DC for the signal? __________

Press the **softkey** so that Y is checked.
Press the **Softkey under Y1** to select the Y1 marker.
Turn the **entry knob** to adjust the Y1 marker so that it is in line with the lower level of the waveform. The value that appears under Y1 is the voltage of the waveform where it is crossed by the Y1 marker. What is your level 0 voltage? _____________
Press the **softkey under Y2** to select the Y2 marker.
Turn the **entry knob** to adjust the Y2 marker until it is at the upper level of the waveform. The value that appears below Y2 is the voltage of the waveform where it is crossed by the Y2 marker. What is your hi level voltage? ____________

c. Using Quick Measure

Press the **Quick Meas** button in the Measure section of the Control panel.
Notice that a softmenu a ppears. To measure the frequency, press the **Frequency** softkey. What is your Quick measured frequency? __________
Press the **Period softkey** to measure the period. What is your Quick measured period? ____
Press the **softkey with a right arrow** to see more menu items.
Press the **Maximum softkey** to display the maximum voltage. What is your hi voltage? _____
Press the **Minimum softkey** to display the minimum voltage.
What is your low level voltage? _____
Press the **Duty Cycle softkey**. What is your duty cycle? _________
Press the **right arrow softkey**. Press the **+ width softkey**. What is your + pulse width? _____

How did your quick measured values compare with your manually measured values for frequency, period, and duty cycle?

d. Printing Waveforms to disk
The following steps set the output for BMP files:
Press **Save/Recall button** under File.
Press **Formats softkey**. Press BMP softkey.
Press **QuickPrint button** to save image to disk.

Use the Agilent 54622D Mixed Signal Oscilloscope to take measurements of the CADET function generator. Change the frequency, amplitude and signal type (TTL, square wave, sawtooth, sinusoid). Measure **Signal type, Frequency, Duty Cycle, Vhi, Vlo, and Vpp.** Use a total of 5 different waveforms.

Copy the screen image of each waveform to disk and print out your waveforms.

3. CADET bounceless push-buttons, logic switches, and LED indicators (LEDIs).

a) Connect a CADET board logic switch to a LED-Indicators (LEDIs).
Verify the voltage settings of the logic switches and LEDIs are set to +5V.
Connect scope channel 1 to one of the switches.
Set scope for single-edge trigger on CHANNEL 1 by pressing the **Single button** in the Run Control portion of the control panel.
Press the **Mode/Coupling button** in the Trigger portion of the Control Panel. Press the **Mode Softkey** and select **Normal**.

b) Flip the logic switch from 0 to 1 and 1 to 0. Notice when the logic analyzer display is triggered. Measure the logic 0 and logic 1 voltages using the Mixed Signal Oscilloscope using the Y markers as you learned in the previous excercise. Notice when the LEDIs are in the logic 0 or logic 1 position. Use the logic analyzer to check for “bouncing.”

c) Connect a 560 Ω pull-up resistor from the bounceless push-button switch located on the CADET board to +5 V. Connect the LEDI and logic analyzer scope probe to the button. Repeat voltage measurements and check for “bouncing.”

4. Schmitt gate digital clock.

A Schmitt gate clock is a simple clock circuit to build and will be discussed further in the Clock circuit section of the Class Notes. The output frequency is dependent on the resistor and capacitor values of the circuit. It is also dependent on the operating voltage of the Schmitt gate. For this experiment operating at a supply voltage (Vcc) of 5 volts, the equation for the frequency of a Schmitt gate digital clock is as follows:

$$f \approx \frac{1}{RC \ln 2.26}$$

Equation 0.1 Frequency of Schmitt Gate Clock

where: R is the value of the resistor and C is the value of the capacitor in the circuit

a) Assemble the circuit of Figure 0.1
b) Measure the output frequency, duty cycle, low voltage, high voltage and rise time using the Agilent 54622D Mixed Signal Oscilloscope.
c) Change C1 to five other values and repeat measurements. Change R1 to five other values and repeat measurements. Try to find the minimum and maximum frequencies.

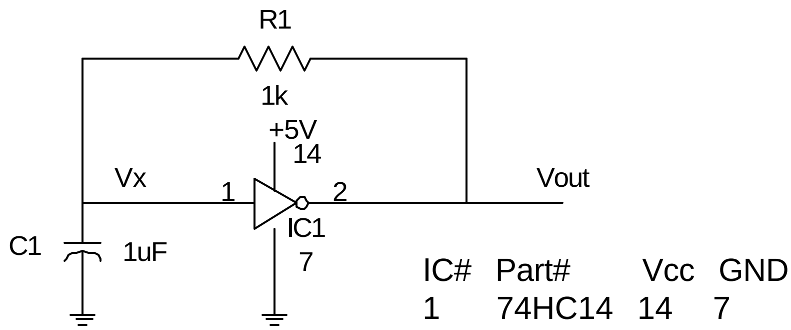

Figure 0.1 Schmitt gate digital clock

Laboratory 1: Boolean Implementations

Purpose:

1. Design circuits in specific combinational forms utilizing schematic diagrams.
2. Design circuits to minimize the number of ICs.
3. Gain experience in building and troubleshooting digital circuits.

A = wx+w'y	AND-OR
B = wx +w'y	NAND-NAND
C = (w+x)(x'+y')	NOR-NOR
D(w,x,y,z) = $\Sigma(1,4,7,12)$	Decoder-OR (Decoder*-NAND)
E(x,y,z) = $\Sigma(3,4,5)$	Multiplexer
F = x'y'z + xyz' + xyz	

Preparation:

1. Review digital logic functions and digital design techniques. You may need to refresh your knowledge with Digital Design texts.
2. Design a circuit for each of the given Boolean functions A, B, C, D, and E in the specific form. Prepare a COMPLETE schematic diagram for each design. Include all pin numbers and a completed IC table. Label all inputs and outputs. Use the minimum number of ICs for each function.
3. Complete the truth tables for each function by filling in the theoretical outputs section as part of Pre-Lab.
4. Design a circuit that implements functions D, E and F as one circuit with 3 outputs. Design to minimize the total number of ICs. Complete the truth table for this circuit.

Design Rules:

1. Use 74HC (or 74LS) series ICs in your designs.

Experiment Procedure:

1. Build each of your circuit designs.
   Keep circuits neat and organized. Use short wires.
   Use top and bottom lines if breadboard for power and ground rails.

2. Test each of your circuit designs. Record your measured values in your truth tables. Also record and troubleshooting tips in the troubleshooting section of your notebook.

Laboratory 2: Standard Combinational Circuits

Design with Standard Combinational ICs: Adders, Comparators, BCD to 7-Segment Display Converters, Drivers, Buffers

Purpose:

1. Learn to use standard combinational & sequential MSI ICs.
2. Gain more experience understanding data book specifications: Vih, Vil..
3. Gain more experience testing digital circuit functions.
4. Learn about simple switch inputs with pull-up or pull-down resistors.

Preparation:

1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections of the Class Notes pertaining to 7-segment displays.
2. Prepare data tables and COMPLETE schematic diagrams for each experiment section of this lab. Indicate a specific test plan for each experiment.
3. Design a decimal display circuit using 7-segment displays with the 74LS47 BCD-decimal display driver. Input numbers from a 4-position dipswitch or a BCD switch. You may wish to view the data sheet for the 74LS47 BCD-7Segmebt display driver.
4. Design an 8-bit adder using 74HC ICs. You will input two (2) 8-bit numbers using the logic switches and 8 position DIP switches. The output will be displayed on the LEDIs. You will take 6 different readings. Prepare a data table with a listing of your inputs and expected output.
5. Design an 8-bit magnitude comparator using 74HC ICs. You will input two (2) 8-bit numbers using the logic switches and 8 position DIP switches. The outputs will be connected to three (3) LEDIs to show A<B, A=B and A>B, where A and B are the input words. Prepare a data table for 6 different entries and include your expected outputs.
6. Read the DC Electrical Specifications section in the Class notes. Complete the schematic diagrams to test High-speed CMOS input voltage specs. The schematic diagrams are shown in the Class Notes. Compute values for load resistors as specified in the Experiment Procedure below.
7. You may wish to pre-build your circuits.

Design Rules:

1. Use the minimum number of ICs for each design.

Experiment Procedure:

1. 8-Bit Adder Circuit
   Build and test the circuit. Input two (2) 8-bit words from logic switches and DIP switches. Connect the output to the LEDIs. Repeat with different inputs until you have recorded 6 entries in your data table.

2. 8-Bit Magnitude Comparator
   Build and test the circuit. Input two (2) 8-bit words from logic switches and DIP switches. Connect the outputs to three (3) LEDIs. Repeat with different inputs until you have recorded 6 entries into your data table.

3. Vih and VIL measurements.

Set CADET LED indicator switch to CMOS.

High-Level Input (Vih) Test

Assemble the HC high-level input voltage (Vih) test circuit for a 74HC04.
Set Rload so that Iout equals data book Iol, when Vout equals data book Vol.
Adjust Rin so Vin is 5.0 V. Is the output logic 0? (Is the green LED indicator (LEDI-G) on?) ___
Measure Vout.
Adjust Rin until LEDI-G goes off, then re-adjust so that it just turns on.
Measure Vin. Vin is Vih.

Low-level Input Voltage (Vil) Test

Assemble the HC low-level input voltage (Vil) test circuit.
Set Rload so that Iout equals the databook Ioh, when Vout equals data book Voh.
Set Rin so Vin is 0.0 V. Is the output logic 1? (Is the red LED indicator (LEDI-R) on?) Measure Vout. Adjust Rin until LEDI-R goes off then readjust so that it turns on.
Measure Vin. Vin is Vil.

Laboratory 3: One Shots, Clocks and Counters

Purpose:

1. Learn about one-shot circuits as pulse generators.
2. Learn about crystal oscillators, counters and Mod-N counters.

Preparation:

1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections of the Class Notes pertaining to one-shots, clocks and counter circuits.
2. Prepare data tables and COMPLETE schematic diagrams for each experiment section of this lab. Indicate a specific test plan for each experiment.
3. Design a one-shot to produce an active low pulse from a positive-edge trigger. The pulse width should be the 4 msd's of your student ID as xxx.x ms. Suggestion Use the 74HC221 (or 74HC121) for one-shots.
4. Complete the schematic diagram for a crystal TTL oscillator. Refer to the crystal oscillator section in the Class Notes. Use a 4MHz crystal or other available crystal (<20MHz). In your data table include expected values for the following: Vhigh, Vlow, frequency and Duty Cycle.
5. Design an 8-bit synchronous counter. The counter should count from binary 00000000 – 11111111 then repeat.
6. Design a Mod-7 counter that counts the sequence: 1,2,3,4,5,6,7 repeat.

Experiment Procedure:

1. Build and test your one-shot circuit. Connect the trigger input to a CADET board push-button. Remember to use a pull-up resistor. Connect your output to LEDI. Use the Mixed Signal Oscilloscope to measure Vhigh, Vlow, pulse width and rise time. Look for ringing and noise.

2. Build and test your crystal oscillator circuit. Try to keep your connections as short as possible. Avoid "spaghetti wires." Measure: Vhigh, Vlow, frequency, Duty Cycle and rise time. Measure frequency using the oscilloscope. Look for ringing and noise. DO NOT disassemble your circuit until after finishing Experiment Procedure #4 below.

3. Build and test your 8-bit counter. Connect the output to the 8 LEDIs. First, use the CADET's TTL function generator for trigger input. Next use a logic switch as the trigger input. Then use the bounceless pushbutton with a pull-up resistor as the trigger input.

4. Connect the crystal oscillator output to the counter's trigger input. Measure the frequency at each counter output bit.

5. Build and test your Mod-7 counter. Connect the output to the BCD-7-segment display on the CADET board.

1.

Laboratory 4: Flip-Flops, Registers & Shift-Registers

Purpose:

1. Learn about preset and clear inputs on sequential circuits and their use in state analysis.
2. Gain experience design, assembly & test of sequential circuits.

Preparation:

1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with data book entries pertaining to Flip-Flops, registers and shift registers.
2. Prepare data tables and COMPLETE schematic diagrams for each experiment section of this lab. Indicate a specific test plan for each experiment.
3. Design the sequential circuit for the given state diagram of Figure 4.1. Use 74HC74 or 74HC76 ICs for Flip-Flops.

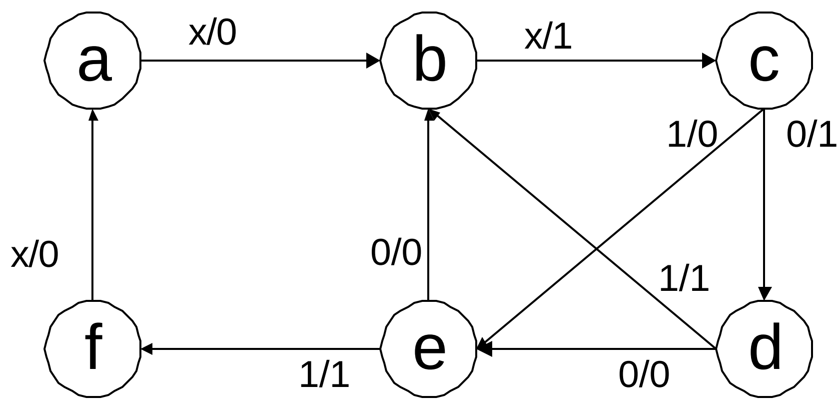

Figure 4.1

4. Design an 8-bit bi-directional serial shift register. Include hardware to prevent the shift register from being re-triggered less than 2 seconds after the last trigger. An 8-bit word will be parallel loaded when a load switch is enabled. Include a serial data input so that the data will then be shifted in the left or right directions based on a direction select input.

Experiment Procedure:

1. Build and test the sequential circuit. Complete a state table showing all state transitions.
2. Unused State Analysis: Force the sequential circuit of Figure 4.1 in each unused state and track transitions for each input combination.
3. Build and test the 8-bit shift register circuit. Connect the 8 logic switches to the 8 parallel load data input. Also use dip switches to control your serial load data input and serial shirft direction inputs. Test the shift register for parallel loading as well as shifting left and shifting right with the data in the data table.
4. Log your Building, Testing and Troubleshooting process.

Laboratory 5: Programmable Logic Devices 1

Programmable Logic Devices as replacements/improvements to standard logic ICs.

Purpose:

1. Learn to use programmable logic devices as MSI TTL & CMOS replacements.

Preparation:

1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections in the Class Notes pertaining to Programmable Logic Devices. Review the sample PLD files. Become familiar with the data sheets for the GAL16V8 and the GAL22V10.
2. Prepare data tables and COMPLETE schematic diagrams for each experiment section of this lab. Indicate a specific test plan for each experiment.
3. Create PAL source code that implements equations D, E &F from Laboratory #1.
4. Create PAL source code that implements the sequential circuit for the circuit of Figure 4.1 (state diagram) of Laboratory #4.
5. Use CUPL to compile all PAL source codes. Paste, tape or staple copies of your PLD files into your notebook. Bring source code listings (on paper) and floppy disk containing the files to lab. The files should be error free at the beginning of the lab period.

Design Rules:

GAL16V8 & GAL22V10s are recommended, but any other PAL may be used.

Experiment Procedure:

Program each PAL circuit as instructed by your TA. Test and make work each PAL circuit as instructed by your TA.

Laboratory 6: Programmable Logic Devices 2

Purpose:

1. Learn to use programmable logic devices as MSI TTL & CMOS replacements.

Preparation:

1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections in the Class Notes pertaining to Programmable Logic Devices. Review the sample PLD files. Become familiar with the data sheets for the GAL16V8 and the GAL22V10.
2. Create PAL source code that implements a MOD-N counter where N can be 6,10 or 12 depending on 2 or 3 select inputs. Include inputs that allow synchronous chaining of counters. When operating as a mod-6 counter, it should count through the sequence 0,1,2,3,4,5,0,… As a mod-10 it should count through the sequence 0,1,2,3,4,5,6,7,8,9,0,… As a mod-12 counter it should count through the sequence 1,2,3,4,5,6,7,8,9,10,11,1,… When the count enable input, Cin, is 0 the counter should stay in the same state regardless of the clock input. When the Cin input is 1 the counter should increment with each clock pulse. The chaining output, Cout, should ouput a 0 during all states except the final state. When the counter reaches the last state, it should output a 1 at Cout.
3. Create PAL source code that implements a HEX to 7-segment code converter. The outputs of the code converter should be able to drive two 7-segment displays to display Hex inputs from 00 to 0F as decimal values from 0 to 15.
4. Compile all PAL source codes. Paste, tape or staple copies of your PLD files into your notebook. Bring source code listings (on paper) and floppy disk containing the files to lab. The files should be error free at the beginning of the lab period.

Design Rules:

GAL16V8 & GAL22V10s are recommended, but any other PAL may be used.

Experiment Procedure:

Program each PAL circuit as instructed by your TA.
Test and demonstrate each PAL circuit as instructed by your TA.

Laboratory 7: Microprocessors #1- 68HC11 Introduction

Purpose:
1. Learn to use microprocessors and microcontrollers, particularly the Motorola 68HC11.
2. Learn to program in 68HC11 assembly language.
3. Become familiar with programming the M68HC11.

Preparation:
1. Read the entire section of this laboratory exercise in this Laboratory Manual. Also read and familiarize yourself with the sections in the Class Notes pertaining to Microprocessors.
2. Prepare data for each experiment section of this lab. Indicate a specific test plan for each experiment.
3. Edit a text file containing the 68HC11 assembly language program: COUNT.A11.
4. Assembly the program using the AS11.EXE assembler. The as11.exe file can be downloaded from the course website. Save the file on your floppy disk. To use the assembler, you must open a command prompt window and type the following command. Your count.a11 file should be on the a:\ as well.

A:\AS11 COUNT.A11 -L CRE >COUNT.LST

5. Check COUNT.LST for errors. Correct any errors, and re-assemble.
6. Design a two digit (decimal) 7-segment display to connect to HC11-143 PortB connector.
7. Paste, tape or staple copies of your LST files into your notebook. Reminder: Bring to lab: a printout of COUNT.LST, a floppy disk containing your source file, COUNT.A11, and object code file, COUNT.S19. Also, be sure to have the class notes in order to use the MULT4BIT.LST.

Design Rules:
1. Use proper documentation when creating your source file.
2. Use flowcharts to develop your assembly code.

Experiment Procedure:
1. *68HC11 Start-Up and Test*

a) Measure the E clock frequency and duty cycle of the M68HC11EVB. (E == Pin 5, GND == Pin 1) If you are using the Port Access board the TA will show you where to find these pins.
b) Connect a RS-232 serial communication cable from the "TERMINAL" port of the EVB to the serial port of the PC. Establish a connection to the 68HC11EVB by using the Windows program Hyperterminal.
c) Press the reset button on the EVB. Note display on the terminal or PC monitor.

Simple Output:
Use the BUFFALO monitor's Memory Modify (MM) command to change an output port.
d) Measure output port B0 (on the Port Access Board or pin 42 on connector P1).
e) Enter the sequence of commands from the keyboard. Bold text is information you must enter. <CR> means to press the "RETURN" or "ENTER" key on the keyboard.

<u>Clear B0</u>
MM 1004
1004 ?? **00 <CR>**
Measure PortB bit 0 (B0)

Set B0
MM 1004
1004 00 **01 <CR>**
Measure PortB bit 0(B0)

Set entire port B to $05
MM 1004
1004 01 **05 <CR>**
Measure PortB bit 0, 1, 2 and 3(B0, B1, B2, and B3)

Simple Input:
Use the BUFFALO monitor's Memory Display (MD) display the binary value at an input port.

f) Connect input PortE bits 0, 1, 2 and 3 (E0, E1, E2, and E3) to switches on the CADET board. Connect ground from the CADET to GND on the EVB.
g) Set the switches to the specified values. Enter the sequence of commands from the keyboard. Bold text is information you must enter. <CR> means to press the "RETURN" or "ENTER" key on the keyboard. Write down the data value at address $100A after each command.

Switches E3 E2 E1 E0 = 0000
MD 1000 0 <CR>

Switches E3 E2 E1 E0 = 0110
MD 1000 0 <CR>

Switches E3 E2 E1 E0 = 1101
MD 1000 0 <CR>

2. On-Board Assembly -- Arithmetic: Multiplication using repeated addition.

a) Enter program MULT4BIT.A11 into the EVB's memory using the on-board assembler (ASM C000).
b) Connect PortE pins to logic switches. N is 4 lsbs. M is 4 msbs.
c) Run the program using the Go (**G C000**) command.
d) Use the Memory Display (MD) command to display the product at address $D001 (P).
e) Repeat steps b through d for 5 different values of M and N.

3. Uploading Programs -- Counter program.

Uploading programs from PC to EVB. (If PC is not available enter COUNT.A11 into the EVB using the on-board assembler.)

a) Turn off power to the EVB.
b) Connect PortE, bit 0 to a push-button on the CADET. (A pull-up resistor is needed.)
c) Connect your two-digit display to PortB of the EVB.
d) Turn on power to the EVB.
e) Run Hyperterminal program on PC connect to EVB using the COM port.
f) Press the Reset button on the EVB. Verify that BUFFALO is working.
g) Press **<CR>** on the keyboard.
h) Enter "**LOAD T**" command.
i) Select **Transfer** menu. Then select **Send Text File…**
j) Use the File browser window to select your COUNT.S19 file. Click **Open** to transfer.
k) Use MD command to verify your code has been transferred.
l) Run the program using the Go command (**G c000**).
m) Press the push-button on the CADET several times. Note display. Verify the counter program works.

Laboratory 8: Microprocessors #2 - Software

Purpose:

1. Practice assembly language programming of simple algorithms.

Preparation:

Create flowcharts and write code for the following:

1. Data Entry – Enter eight 4-bit numbers using a dipswitch (or BCD switch). Read the number when a button is pressed. Store the numbers in sequential memory locations starting at $D000. Display each number on a seven segment display via PortB as it is entered.
2. Data Sort —Sort eight 4-bit numbers in memory locations $D000-D007. (Largest to smallest)
3. Data Sum – Compute the sum of eight 4-bit numbers in memory locations $D000-D007. Display result in BCD on a dual 7-segment display via PortB
4. Combine Routines – Combine the functions of 1,2 and 3 into one program. Use 2 bits of PortA to specify which function to performData Entry, Data Sort, Data Sum or Exit (Jump to BUFFALO). The program should wait for an intial pushbutton to select which function to perform and after the function is performed, what for another pushbutton until Exit program is selected and the program ends.

Design Rules:

1. Use proper documentation when creating your source code.
2. M68HC11EVB I/O limitations: PortB, PortE, PortA (excluding PA7 and PA3)

Experiment Procedure:

1. Load your Data Entry routine. Test to verify it works.
2. Load your Data Sort routine. Test to verify it works.
3. Load your Data Sum routine. Test to verify it works.
4. Load your combined program. Test to verify it works.

Extra Credit:

1. Fastest executing sort code (2 points) Show Calculation.
2. Most compact summing code (2 points) Show calculation.

Laboratory 9: Microprocessors #3 - Count-Down Timer

Design of a microprocessor based timing application

Purpose:

1. Design a more complex application.
2. Compare similar applications based on PLDs versus microprocessors.
3. Consider I/O limitations.

Preparation:

Design a circuit to meet the following specs:

1. A two-digit BCD number will be entered.
2. Display the number on 7 segment displays as it counts down to zero @ 1.00 Hz.
3. Make an audible noise for the last 1 second before reaching zero. Use the function generator of the CADET board to supply a frequency in the audible range as an input to an AND gate. Use an output bit from the HC11EVB as the other input to the AND gate. Connect the output to the speaker of the CADET board. Be sure to ground the other speaker connection.
4. When the number reaches zero, drive a relay closed (Output an active high signal)
5. Use the 68HC11 as the primary controller.’
6. Use the minimum number of extra ICs.
7. The two-digit number will be entered using an 8-position dipswitch or two BCD-switches.

Pre-compile all source code. Bring source code listings (on paper) and floppy disk containing the files to lab. The files should be error free at the beginning of the lab period.

Create a test plan for each sub-system and the complete circuit.

Experiment Procedure:

Test each sub-system. Test the complete circuit. Show complete circuit to your TA.

Microprocessors #4 - Application Design

Purpose:

1. Develop an application using a microcontroller.

Preparation:

Design a vending machine control system for the given specifications.

- Use the M68HC11EVB with 143 extension.
- The vending machine dispenses: 4 varieties of soda pop: Coke®, Diet Coke®, Sprite®, and Mello Yello®.
- The coin entry mechanism accepts nickels, dimes, quarters, and dollar bills. The coin return mechanism gives only nickels, and dimes. Coin mechanisms produce or require positive level pulses on each coin.
- Display the amount entered or credit in the form: $0.00.

Design Rules:

1. Use proper documentation when creating your source file.
2. M68HC11EVB I/O limitations: PortB, PortE, PortA (excluding PA7).
3. Do not use LED Indicators on the CADET.

Experiment Procedure:

1. Test your vending machine controller.

Data Sheets

Group Names: ____
Lab Section Number: ____
Date: ____

Laboratory 0: Digital Laboratory Introduction
Data Sheets

2. CADET function generator frequency measurement.

a. *Setup*

Adjust the frequency on the CADET board by turning the **01-1.0 Frequency knob**. What happens on the MSO screen?

____

Set the Function generator to 100KHz again. Press **Autoscale** if necessary.

b. *Taking measurements manually using markers*

ΔX is the distance between X1 and X2. This is also the period,T, of the waveform. What is your measured value of ΔX? ________________

The frequency of a waveform is f=1/T.

What is your measured frequency of the waveform? __________

ΔX is now the positve pulse width, measuring the time the signal is high. What is your +pw? ______

Duty Cycle = +pw/T *100 What is your measured value of DC for the signal? __________

What is your level 0 voltage? ____________

What is your hi level voltage? ____________

c. *Using Quick Measure*

What is your Quick measured frequency? __________

What is your Quick measured period? __________

What is your hi voltage? _______

What is your low level voltage? __________

What is your duty cycle? _________

What is your + pulse width? _____

How did your quick measured values compare with your manually measured values for frequency, period, and duty cycle?

Table 0-1 CADET Function Generator Frequency Measurements

Signal	Signal Type	Frequency	Duty Cycle	Vhi	Vlo	Vpp
1						
2						
3						
4						
5						

Paste or tape your screen images of your waveforms in the space provided Attache an additional sheet if necessary.

Table 0-1 CADET Board Switch Voltage Measurements

Source	Logic 0 Voltage	Logic 1 Voltage	Bouncing?
Logic Switch			
Push Button w/ pull-up resistor			

Table 0-2 Sample Schmitt Gate Clock Measurements

Trial #	C1	R1	Frequency	DC	0 Voltage	1 Voltage	Rise Time
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 1: Boolean Implementation
Data Sheets

Table 1-1 Sample Truth Table for Function A(w,x,y) = wx+w'y , B = wx +w'y, C = (w+x)(x'+y'), D(w,x,y,z) = Σ(1,4,7,12), E(x,y,z) = Σ(3,4,5) Students fill-in the theoretical values for pre-lab work.

w	x	y	z	Th A	M A	Th B	M B	Th C	M C	Th D	M D	Th E	M E
0	0	0	0										
0	0	0	1										
0	0	1	0										
0	0	1	1										
0	1	0	0										
0	1	0	1										
0	1	1	0										
0	1	1	1										
1	0	0	0										
1	0	0	1										
1	0	1	0										
1	0	1	1										
1	1	0	0										
1	1	0	1										
1	1	1	0										
1	1	1	1										

Table 1-2 Sample Truth Table for Implementation of Functions D, E, F (F = x'y'z + xyz' + xyz)

				Th	M	Th	M	Th	M
W	x	y	z	D	D	E	E	F	F
0	0	0	0						
0	0	0	1						
0	0	1	0						
0	0	1	1						
0	1	0	0						
0	1	0	1						
0	1	1	0						
0	1	1	1						
1	0	0	0						
1	0	0	1						
1	0	1	0						
1	0	1	1						
1	1	0	0						
1	1	0	1						
1	1	1	0						
1	1	1	1						

Group Names: ____________________
Lab Section Number: ____________________
Date: ____________________

Laboratory 2: Standard Combinational Circuits Data Sheets

Table 2-1 Sample Truth Table for 7 segment Display Circuit

	Inputs			Theoretical Output	Actual Output
w	x	y	z		
0	0	0	0		
0	0	0	1		
0	0	1	0		
0	0	1	1		
0	1	0	0		
0	1	0	1		
0	1	1	0		
0	1	1	1		
1	0	0	0		
1	0	0	1		
1	0	1	0		
1	0	1	1		
1	1	0	0		
1	1	0	1		
1	1	1	0		
1	1	1	1		

Table 2-2 Sample Truth Table for 8-bit adder Circuit

Input A	Input B	Theoretical Output w/CO	Measured Output w/CO
0000 0000	0000 0001		
1111 1111	0000 0001		
1010 1010	0101 0101		
1010 1011	0101 0101		
0101 1101	1101 0011		

Table 2-3 Sample Truth Table for 8-bit Magnitude Comparator Circuit

		Theor.			Meas.		
Input A	Input B	A<B	A=B	A>B	A<B	A=B	A>B
0000 0000	0000 0000						
1000 0000	0000 1000						
1111 0000	1111 1111						
1010 1010	0101 0101						
1110 0111	1110 0111						
0000 0001	1000 0000						
1111 1111	1111 1111						

1. Vih and VIL measurements.

High-Level Input (Vih) Test

Set Rload so that Iout equals data book Iol, when Vout equals data book Vol.
Adjust Rin so Vin is 5.0 V. Is the output logic 0? ________

Rload = (5-Vol) / Iol =_________
Measured Vout = ____________
Measured Vin = Vih = ________

Low-level Input Voltage (Vil) Test

Set Rload so that Iout equals the databook Ioh, when Vout equals data book Voh.
Set Rin so Vin is 0.0 V. Is the output logic 1? __________
Adjust Rin until LEDI-R goes off then readjust so that it turns on.

Rload = Voh / Ioh = _________
Measured Vout = ___________
Measured Vin = Vil = ________

Group Names: ______________________________

Lab Section Number: ______________________________

Date: ______________________________

Laboratory 3: One Shots, Clocks and Counters
Data Sheets

Table 3-1 One-shot Circuit Measurements

Vhigh	
Vlow	
Pulsewidth	
Rise time	

Table 3-2 Crystal Oscillator Circuit Measurements

Vhigh	
Vlow	
Frequency	
Duty Cycle	
Rise time	
Witnessed Ringing(Y/N)	

DO NOT disassemble your circuit until after finishing Experiment Procedure #4 below.

Table 3-3 8-bit Counter Circuit Measurements

	Theoretical Output	**Measured Output**
Startup	0000 0000	
1st clock pulse		
2nd clock pulse		
3rd clock pulse		
4th clock pulse		
5th clock pulse		
6th clock pulse		
7th clock pulse		
8th clock pulse		

Table 3-4 8-bit counter-Crystal Oscillator Circuit Measurements

Signal	**Measured Frequency**
Clock input	
Bit 0 (Least Significant Bit)	
Bit 1	
Bit 2	
Bit 3	
Bit 4	
Bit 5	
Bit 6	
Bit 7 (Most Significant Bit)	

Table 3-5 Mod-7 counter Circuit Measurements

	Theoretical Output	**Measured Output**
Startup	0	
1st clock pulse		
2nd clock pulse		
3rd clock pulse		
4th clock pulse		
5th clock pulse		
6th clock pulse		
7th clock pulse		
8th clock pulse		

Group Names: ______________________________

Lab Section Number: ______________________________

Date: ______________________________

Laboratory 4: Flip-Flops, Registers & Shift-Registers Data Sheets

Table 4-1 Sequential Design

Present State	Input X	Theoretical Next State	Theoretical Output	Measured Next State	Measured Output
000	0				
000	1				
001	0				
001	1				
010	0				
010	1				
011	0				
011	1				
100	0				
100	1				
101	0				
101	1				
110	0				
110	1				
111	0				
111	1				

Table 4-2 8-bit Shift Register Design

Parallel Load Input	Serial Data Input	Mode Select	Theoretical Output	Measured Output
0000 0101	0	Parallel		
	1	Shift Left		
	1	Shift Left		
	0	Shift Left		
	1	Shift Right		
	0	Shift Right		
0110 0011	0	Parallel		
1001 1100	1	Parallel		
	0	Shift Right		
	0	Shift Right		
	0	Shift Right		
	1	Shift Left		

Group Names: ____________________

Lab Section Number: ____________________

Date: ____________________

Laboratory 5: Programmable Logic Devices 1
Data Sheets

Table 5-1 Truth Table for Implementation of Functions D, E, F (F = x'y'z + xyz' + xyz)

				Th	M	Th	M	Th	M
W	x	y	z	D	D	E	E	F	F
0	0	0	0						
0	0	0	1						
0	0	1	0						
0	0	1	1						
0	1	0	0						
0	1	0	1						
0	1	1	0						
0	1	1	1						
1	0	0	0						
1	0	0	1						
1	0	1	0						
1	0	1	1						
1	1	0	0						
1	1	0	1						
1	1	1	0						
1	1	1	1						

Table 5-2 Sequential Design

Present State	Input X	Theoretical Next State	Theoretical Output	Measured Next State	Measured Output
000	0				
000	1				
001	0				
001	1				
010	0				
010	1				
011	0				
011	1				
100	0				
100	1				
101	0				
101	1				
110	0				
110	1				
111	0				
111	1				

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 6: Programmable Logic Devices 2
Data Sheets

Table 6-1 MOD-6,10,12 Counter

Mod-Select	Theoretical	Measured Display
Mod-6	0,1,2,3,4,5,0,…	
Mod-10	0,1,2,3,4,5,6,7,8,9,0,…	
Mod-12	1,2,3,4,5,6,7,8,9,10,11,1,…	
Cin	0=No count 1= Count	
Cout	Outputs as necessary	

Table 6-2 Hex-Dual 7-segment Display

Input	Theoretical Display	Measured Display
0000		
0001		
0010		
0011		
0100		
0101		
0110		
0111		
1000		
1001		
1010		
1011		
1100		
1101		
1110		
1111		

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 7: Microprocessors #1- 68HC11 Introduction Data Sheets

Table 7-1 68HC11 Start-Up and Test

E clock Frequency	
Duty Cycle	

Press the reset button on the EVB. Note display on the terminal or PC monitor.

____

Table 7-2 Simple Output

Command Entered	**Theoretical**	**PortB bit 0 Measurement**
Initial measurement		
MM 1004 00		
MM 1004 01		
		PortB B3, B2, B1, B0 Measurement
MM 1004 05		

Table 7-3 Simple Input

Input Switch (E3 E2 E1 E0)	**Expected Contents of Port E in Memory ($100A)**	**PortE Measurement**
0000		
0110		
1101		
		PortB B3, B2, B1, B0 Measurement
MM 1004 05		

Table 7-4 MULT4BIT.A11 Results

M (4MSBs)	N (4 LSBs)	Theoretical ($D001)	Measured ($D001)
0010	1001		
1011	0011		
0100	1111		
0111	0011		
1111	1111		

Table 7-5 8-bit Count.a11 Measurements

	Theoretical Output	Measured Output
Startup		
1st clock pulse		
2nd clock pulse		
3rd clock pulse		
4th clock pulse		
5th clock pulse		
6th clock pulse		
7th clock pulse		
8th clock pulse		

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 8: Microprocessors #2- Software Data Sheets

Table 8-1 Data Entry Routine

Port E Input	Theoretical Contents of Memory	Measured Contents of Memory
03	$D000 -	$D000 -
05	$D001 -	$D001 -
03	$D002 -	$D002 -
01	$D003 -	$D003 -
02	$D004 -	$D004 -
07	$D005 -	$D005 -
08	$D006 -	$D006 -
04	$D007 -	$D007 -

Table 8-2 Data Sort Routine

Initial Contents	Theoretical Contents of Memory	Measured Contents of Memory
03	$D000 -	$D000 -
05	$D001 -	$D001 -
03	$D002 -	$D002 -
01	$D003 -	$D003 -
02	$D004 -	$D004 -
07	$D005 -	$D005 -
08	$D006 -	$D006 -
04	$D007 -	$D007 -

Table 8-3 Data Sum Routine

Initial Contents $D000-D007	Theoretical Sum	Measured Sum
03,05,03,01,02,07,08,04		
00,01,02,03,04,05,06,07		
01,01,01,01,01,01,01,01		
00,00,00,00,00,00,00,00		
05,05,05,05,05,05,05,05		

Combined Routine

(Use the same data as above)
Data Entry routine functions properly when selected? ________
Data Sort routine functions properly when selected? ________
Data Sum routine functions properly when selected? ________
Program Exits when selected? _______

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 9: Microprocessors #3- Countdown Timer Data Sheets

	Trial 1	Trial 2	Trial 3	Trial 4
Program Clears				
Number Entered				
Timer Counts down and displays				
Buzzer Sounds at 1 second				
Buzzer Shuts off at 0 seconds				
Signal goes hi at 0 seconds				

Group Names: ______________________________
Lab Section Number: ______________________________
Date: ______________________________

Laboratory 10: Microprocessors #4- Application Design Data Sheets

	Trial 1	Trial 2	Trial 3	Trial 4
Program Clears				
Number Entered				
Timer Counts down and displays				
Buzzer Sounds at 1 second				
Buzzer Shuts off at 0 seconds				
Signal goes hi at 0 seconds				

The vending machine dispenses: 4 varieties of soda pop:
Coke®, Diet Coke®, Sprite®, and Mello Yello®.
Each input selection works correctly: ______
Each output works correctly: _____

The coin entry mechanism accepts nickels, dimes, quarters, and dollar bills.
Each input selection works correctly: ______

The coin return mechanism gives only nickels, and dimes.
Each output works correctly: _____

Coin mechanisms produce or require positive level pulses on each coin.

Display the amount entered or credit in the form: $0.00.
This is done correctly: _______