

University of California at Berkeley
College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 150

Spring 2000

Lab 4
Using Test Equipment

1 Objective

This lab will familiarize you with more hardware debugging instruments. Each station in 204B has a triple-output bench power supply, a digital multimeter, a pulse generator, and a 100 MHz mixed signal oscilloscope. You will use each of these in this lab.

Test equipment can be complex. The oscilloscope has more than forty knobs and switches. Unfortunately, missetting these can make the equipment appear broken.

If you suspect faulty equipment, verify it with your TA!

When you leave the lab, please tidy up around your station.

Always verify that your equipment is working before using it. Some specific items to check:

- Are the power supplies outputting correct voltage? (check using multimeter)
- Are the oscilloscope probes working? (check by connecting to power and ground)
- Is the pulse generator working? (check using oscilloscope)

2 Prelab

As usual, read through this lab. Most of this handout describes things to know, not things to do. And these should be easy if you know how to do them.

3 The HP E3630A Triple-Output Power Supply

Each station has an HP E3630A triple-output power supply, whose three outputs can generate 0-6V, 0-20V, and -20-0V, marked +6, +20 and -20 respectively. There is also a ground connection labeled COM.

The E3630A's outputs are current-limited for safety: they will supply some maximum amount of current, and will drop the output voltage to ensure it. In particular, if you short the outputs, instead of blowing fuses or becoming arc welders, these supplies peacefully supply the maximum current.

The E3630A's three knobs set the voltage on the +6 output, the voltage on the +20 output, and the ratio between the +20 and -20 outputs. Turn the ratio clockwise (to FIXED) until it clicks to set the ratio to 1.

The analog meter on the E3630A can display the voltage of each output, selected by the three buttons labeled +6, +18, and -18. This is useful for setting the voltages approximately, but it is not as accurate as measuring the output voltage with a digital multimeter.

4 The Fluke 8010A Digital Multimeter

Each station also has a Fluke 8010A digital multimeter, which can measure AC or DC voltage, current, resistance, or conductivity.

- Measuring Voltage

Press button marked V and select range with one of the grey buttons. Connect the COMMO input (a black lead) to the circuit's ground, and connect the V/k Ω /S input (a red lead) to the voltage to measure.

- Measuring Current

Press button marked mA.

Select the scale of current to be measured by plugging the red lead into either the "ma" (0-2000 ma) or "10A" (0-10A) input on the meter. Press a grey button corresponding to the range desired.

To measure current, the meter must be inserted in series. Power down the circuit, break a connection, and connect the red and black leads. With the red lead connected to the "more positive" voltage, the current flow will show on the meter as positive.

- Measuring Resistance or Conductance

Press button marked k Ω /S. With the circuit power off, connect the COMMON (black) and V/k Ω /S (red) leads across the resistive element. To do this accurately, the element usually has to be removed from the circuit, although simple continuity checking (determining if a wire is connected) can be done in-circuit.

5 The HP 8112A Pulse Generator

The pulse generator can generate single or periodic square waveforms with varying voltages, periods, duty cycles, pulse widths, and slew rates. These can be used, for example, as a digital system's clock.

The output of the pulse generator has a 50Ω output impedance, and expects to be driving a 50Ω load. Thus, with high-impedance inputs such as those on digital logic or a scope, **the voltage you observe will be twice as large as what you set**.

To produce a square wave,

1. Make sure the DISABLE button (in the lower right corner) is off (unlit).
2. Set MODE to NORM by pressing the button beneath it. (second to left)
3. Set CTRL to disabled (nothing lit). (fourth to left)
4. Press the button underneath PER until the PER lights, and set the period using the vernier buttons.
5. Press the button underneath DTY until the DTY lights, and set the duty cycle using the vernier buttons (the duty cycle is the percentage of the period for which the signal is high).

Or, set the pulse width (period x duty cycle) by pressing the same button until WID lights. Adjust using the vernier buttons.

6. Press the button under HIL and set the high voltage using the vernier buttons.
7. Press the button under LOL and set the low voltage using the vernier buttons.

6 The HP 54645D 100 MHz Mixed Signal Oscilloscope

6.1 Oscilloscopes

Oscilloscopes can display very high-speed periodic events. Think of the oscilloscope screen as a graph of voltage (x) versus time (y). The HP 54645D combines a digital storage oscilloscope with a logic analyzer in one chassis with extensive "mixed-signal" capabilities.

Conventional analog oscilloscopes do best with periodically repeating waveforms which can trigger the 'scope and generate a stable display. Events that rarely or never repeat can also trigger the 'scope, but the resulting sweep is difficult to see with the naked eye. Digital storage oscilloscopes and logic analyzers, combined in the 54645D, solve this problem.

Starting the sweep at the right time is necessary for a stable image. Figure 2a shows the effect of choosing the wrong times: many segments of the waveform are superimposed, resulting in an unreadable mess. If these times are chosen correctly, i.e., at some exact multiple of the period of the waveform, the traces superimpose to give a single, stable waveform, as shown in Figure 2b.

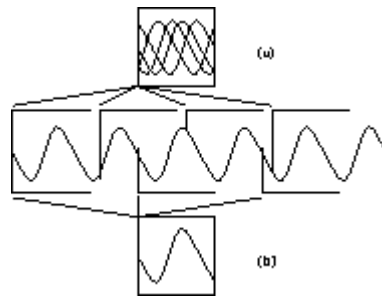


Figure 2: (a) Incorrect triggering. (b) Correct triggering.

Most oscilloscopes allow the user to set a voltage level and a slope ("rising" or "falling") for the trigger. For example, in Figure 2b (middle), the trigger is the voltage halfway between the two extremes, with a falling slope. Thus the waveform is displayed with its left-most point falling through that halfway voltage. For simple waveforms, this approach works well by itself. For more complex waveforms, the "variable holdoff" control can help. Variable holdoff sets the time between the end of a sweep and when the scope begins to look for the next trigger.

6.2 Digital Storage Oscilloscopes

DSOs, or digital storage oscilloscopes, digitize their inputs, store them in memory, and recall them through a digital-to-analog converter

Using a storage scope is much like using a non-storage scope: set the trigger to catch what you want and view the results. Instead of displaying the waveform for each trigger, however, a storage scope can await a single trigger, capture a short waveform, and display it until you store another.

6.3 Logic Analyzers

Although four-channel scopes exist, most digital circuits have far more than four interesting signals, and the “interesting” things on those signals are too complex for an oscilloscope’s simple trigger to find. Logic analyzers address these problems.

Logic analyzers are like many-channeled storage oscilloscopes with very sophisticated schemes for triggering. Some logic analyzers have hundreds of channels, and the triggers can be little programs consisting of comparisons, loops, and branches. Logic analyzers capture and store digital waveforms only (typically two voltage levels), and are typically not as fast as oscilloscopes. But for finding subtle, aperiodic bugs in digital hardware, they are unmatched.

The HP 54645D is both a Digital Storage Oscilloscope and a simple Logic Analyzer.

6.4 54645D Controls

Figure 2-2

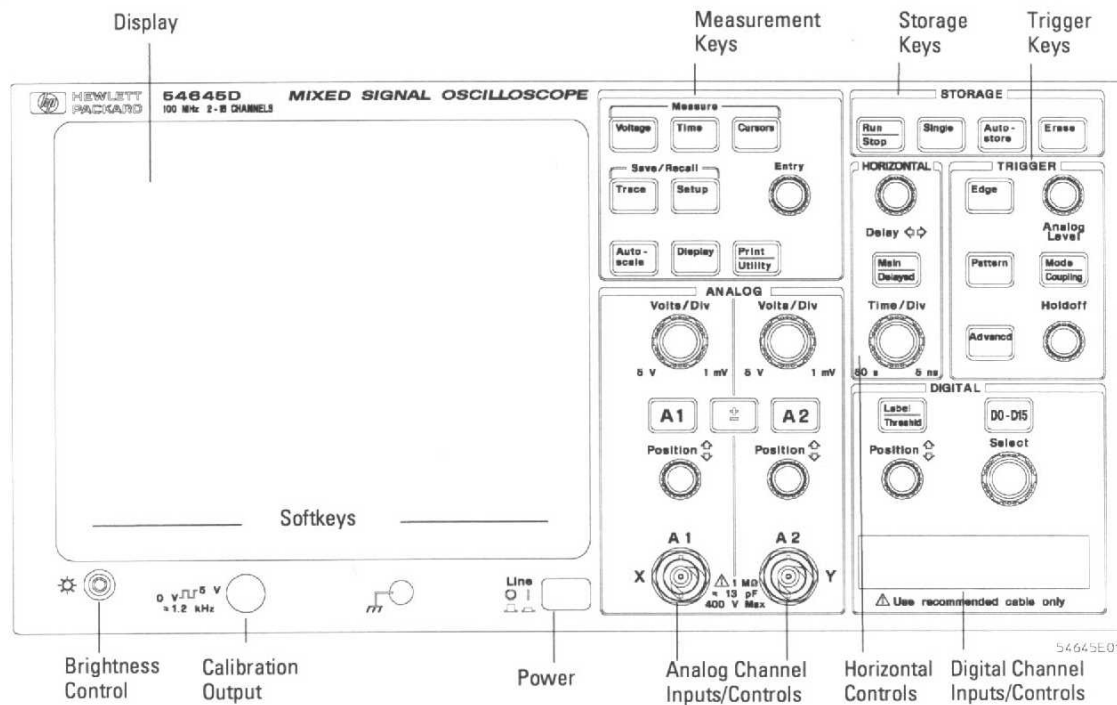


Figure 3: Groups of controls on the 54645D

The 54645D has some forty knobs, buttons, and switches. Even for this lab, you need to know most of them. Fortunately, using one oscilloscope is like using another, so learning one is worth your time.

Here is a list of controls that concern you for this lab, grouped as in Figure 3:

SOFTKEYS

The functions for these keys are displayed on the screen of each particular mode of operation

DISPLAY CONTROLS

Brightness control adjusts the intensity of the display.

If nothing appears on the screen, try adjusting the brightness control

Calibration Output

This hook is used to test probes. Whenever in doubt, attach a probe to the calibration output and hit AUTO-SCALE button in measurement section. It should display a nice 0-5V square wave at about 1.232kHz

AUTOSCALE

This button is located in the measurement section. Perhaps most frequently used button. Scope automatically searches for a signal, sets time and voltage ranges to place signal in middle of screen.

IF SIGNAL DISAPPEARS, TRY HITTING AUTOSCALE

MEASUREMENT CONTROLS

Consists of three buttons; VOLTAGE, TIME, and CURSORS. VOLTAGE and TIME will display options for types of measurements (V_{ave} , V_{p-p} , Freq, etc.) above softkeys. When selected, measurement will be displayed at bottom of screen. The SOURCE softkey should be set on correct analog source channel. The CURSORS button is used to display or clear time and voltage measurement cursors which are selected with and moved with ENTRY knob.

SAVE/RECALL

TRACE

Allows you to store waveforms in two memories. Save and recall signals with softkeys.

SETUP

Allows you to undo autoscaling, recover screens, and setup display defaults.

DISPLAY AND PRINT UTILITY

Softkeys set display and grid lines.

MAKE SURE MODE IS SET TO NORMAL WITH VECTORS ON.

ANALOG

VOLT/DIV

Increase gain at which signal is observed. Volts per grid block is given at top of screen.

A1, A2, and +-

A1 and A2 allow you to turn on and off each channel. High or low pass filtering with softkeys, AC or DC coupling can be used to get rid of excess noise. But note: Noise reduction decreases trigger sensitivity.

+ - allows you to do sums and differences of signals.

HORIZONTAL

DELAY knob moves time reference left or right.

Main Delayed

Horizontal mode should be set at normal with softkeys, the TIME REF softkey controls what reference to use when zooming in with TIME/DIV knob. VERNIER is used to minimize time steps in TIME/DIV knob.

TIME/DIV

Changes time per grid block in a 1-2-5 fashion. Values are displayed at the top of the screen. Try setting this to the smallest setting (~2ns) and zoom in on a signal. Hit the RUN/STOP button to freeze the screen and witness the degradation of smoothness in the signal. Can you explain this?

DIGITAL

Label/Threshold

Allows you to label one of the 16 probe leads of the logic analyzer. The threshold menu and softkeys let you choose what type of logic. MOS or TTL should work fine.

D0-D15

This button allows you to select which logic analyzer probes will be displayed. Signals can be selected with SELECT knob and turned on/off with softkeys

Position

Lets you reorder signals

TRIGGER

Edge

Lets you pick trigger source and select rising or falling edges.

Pattern

Allows you to trigger on a pattern of signals. Used with SELECT with digital signals and softkeys.

Analog level & Holdoff

Lets you select voltage level to trigger at. It should be used with analog signals. Holdoff controls amount of time to wait before new screen is drawn. Should be set to minimum value

STORAGE

RUN/STOP

Starts and stops refresh on display and can be used with TRIGGER to start automatically. TIME/DIV also determines how much signal will be stored on screen.

SINGLE

Takes a single frame rather than looping like RUN.

AUTOSTORE

Superimposes previous traces.

ERASE

Erases stored or stopped signals, measurements should be restarted with RUN button.

TIPS ON TRIGGERING FOR THE LAB

To trigger off a signal edge:

Hit **EDGE**

Select a channel as the trigger source using either the **SELECT** knob or by pressing a **Trigger Source** softkey.

Press one of the **Edge** softkeys to choose whether the trigger will occur on the rising or falling edge.

To define a pattern trigger

Press **PATTERN**

Rotate the **SELEC** knob through each signal (D0-D15) and (A1 or A2), which is displayed above the **Source** softkey.

Then, press one of the softkeys to set the condition the oscilloscope will recognize as part of the pattern for that channel:

L for logic low

H for logic high

X to ignore this channel

Rising or falling edge

7 Lab Assignments

7.1 Use the Multimeter to Measure the Power Supply's Voltage

1. Use banana leads to connect the output of the power supply to the input of the multimeter. Use black for common, red for power.
2. Adjust the supply to simultaneously generate +12V, -12V, and +5V, and measure this with the multimeter. Show your TA this.

7.2 Observe the Pulse Generator's Output with the Scope

1. Connect the output of the HP 8112A Pulse Generator to Channel 1 of the scope using a coaxial cable with BNC ends.
2. Set the pulse generator to generate a 10 kHz, 45% duty cycle, 4 volt peak-to-peak, zero volt offset (i.e., peaks at ± 2 V) square wave.
3. Display this square wave using the STORE mode of the scope. In the STORE mode, use the cursors to verify the pulse width, frequency, and voltages. Show your TA this.
4. Set the pulse generator to generate a 10 MHz, 0-5V square wave with a 40ns pulse width.
5. Again, store the display, and verify the pulse width, frequency and voltages. Show your TA this.

7.3 Read the Contents of a Xilinx Design with the Oscilloscope

We have entered and compiled the circuit in Figure 4, a four-bit counter driving the addresses of three sixteen-bit ROMs. Your task will be to use both channels of the oscilloscope to observe the outputs of ROM2 and ROM3 and deduce their contents, using the contents of ROM1 as a starting point.

Fire up Hwdebugr and load the ROM circuit: U: /WVLIB/CS150/LAB4ROM.BIT. Open the Control Panel from the View menu and start the clock. If all goes well, the fourth LED will light (the output of ROM1).

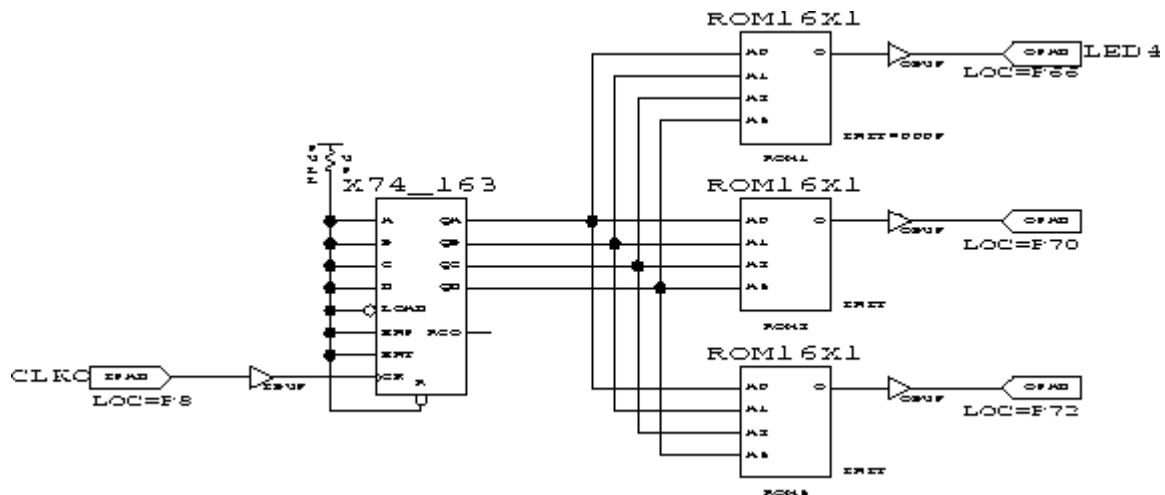


Figure 4: Three ROMs

The counter counts 0000, 0001, ..., 1111, and repeats.. Address 0000 reads the least significant bit of the four-digit hex number in the ROM, address 1111 the most. For example, if one of the ROMs contained a zero in address 0000 and ones in addresses 0001 through 1111, the ROM contents would be FFFE. See the ROM16X1 page in your reader for more information.

1. Connect the BNC ends of the oscilloscope probes to the oscilloscope's Channel 1 and Channel 2 inputs. These are 10x probes, so the volts/div reading on the oscilloscope's display will be a tenth of the circuit's voltages.
2. Carefully connect each probe's "hook" to one of the wire-wrap pins connected to a Xilinx pin connected to a ROM's output. **Be careful not to short together two pins, and don't let the probe bend the pin.** Connect Channel 1 of the oscilloscope to the output of ROM1, whose contents are 000D (ignore the label INIT=000F in Figure 4), and connect Channel 2 to the output of one of the others.
3. Connect **both** probes' alligator clips to a ground reference in the prototyping area of the board.
4. Set the oscilloscope to trigger on Channel 1 (the output of ROM1), and display both channels.
5. Turn on the vernier mode on the oscilloscope (MAIN/DELAYED), and then adjust the TIME/DIV knob so that there is exactly two bits per division - adjust it so eight divisions occur between rising edges in the output of ROM1.
6. Read off the bits from each ROM, moving the Channel 2 probe between pins to view the contents of the two ROMs, and translate each into a four-digit hex number. Record these on the checkoff sheet and show your TA.

7.4 Measure Propagation Delay with the Logic Analyzer

We have entered and compiled the circuit in Figure 5, a eight-bit ripple adder summing the output of a four-bit counter and four switches. Your task will be to measure the worst-case delay of the circuit.

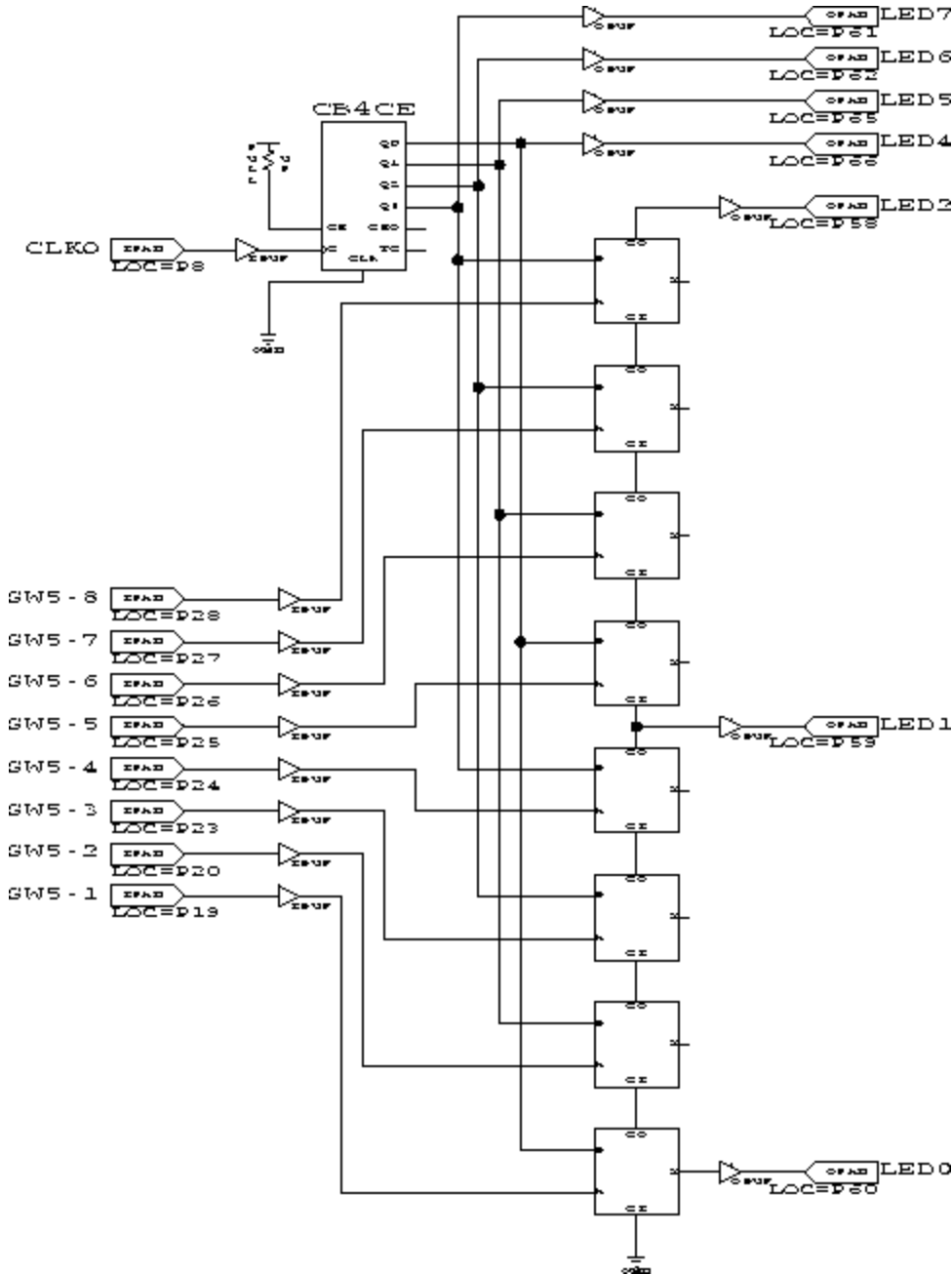


Figure 5: An eight-bit adder

The worst-case delay occurs when a carry must ripple through each stage, such as when 11111111 and 00000001 are added. To find this, set the switches to 00000001, and set the logic analyzer (Probes on DIGITAL section) to trigger when the counter hits 1111.

1. Fire up Hwdebugr and load the adder: U:/WVLIB/CS150/ADD.BIT.

Since the outputs all go to LEDs, this circuit is an excellent one to single-step with the clock. From the Readback Control Panel, set the clock steps to 1 and use APPLY to step the counter. The adder will still work even when the clock is stopped. Remember that the LEDs light when their output is low.

2. Connect the logic analyzer's pod's black ground lead to a ground reference (e.g., one of the ground pins on the Xilinx), and connect seven of the eight inputs to the four counter outputs and three adder outputs.

Be careful when connecting the probe leads. They are delicate and expensive, even more so than the wire-wrap posts.

3. Set the switches so 00000001 is one of the addends. (See Figure. 5 to determine which switch should be least significant)
4. Set the trigger on the logic analyzer to when the counter reaches 1111. Make sure that TRIGGER MODE is set to NORMAL.
5. Measure the delay from when the counter output changes to when the final carry-out changes, and record this on the checkoff sheet. Show your TA this.

8 Acknowledgments

Original lab by J. Wawrzynek, Fall 1994. Modifications by P. Kim, D. Chinnery, R. Fearing, T. Tuan, J. Beck and E. Caspi.

Name: _____ Name: _____

Lab Section: _____

9 Checkoffs

1. Power Supply and Multimeter. TA: _____ (10%)

2. Pulse Generator and Oscilloscope

- 10kHz. TA: _____ (15%)

- 10MHz. TA: _____ (15%)

3. ROMs

- ROM1 ___000D___

- ROM2 _____ TA: _____ (20%)

- ROM3 _____ TA: _____ (20%)

4. Logic Analyzer Delay. TA: _____ (30%)

5. Turned in on time. TA: _____ (x100%)

6. Turned in wk late. TA: _____ (x50%)