

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

EECS 150
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Lab 4
Using Test Equipment

4.1 Objective

The objective of this lab is familiarization with HW debugging instruments. These include the triple-output bench power supply, digital multimeter, pulse generator and a 100 MHz mixed signal oscilloscope.

4.2 Things to Remember

Always verify that your equipment is working before you use it.

- 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)

If you suspect faulty equipment, verify with your TA.

Before you leave the lab, please tidy up your station.

4.3 Pre-lab

Read this handout.

4.4 HP E3630A Triple-Output Power Supply

This lab will require more extensive use of the instrument than Lab 3. Each HP E3630A triple-output power supply has three outputs that generate 0-6V, 0-20V and -20-0V, marked accordingly, and a ground connection labeled COM. These outputs are current-limited for safety: they supply a maximum current, dropping the output voltage to prevent going over.

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 E3630A's analog meter can display the voltage of each output, selected by the buttons labeled +6, +18, and -18. This is useful for setting approximate voltages, but not as accurate as using a digital multimeter.

4.5 Fluke 8010A Digital Multimeter

This instrument may be used to measure AC/ DC voltage, current, resistance, or conductivity.

- To measure **voltage**:
Press the V button and select the range with one of the gray buttons. Connect the COMMON input

(black lead) to the circuit's ground, and connect the V/k Ω /S input (red lead) to the voltage.

- To measure **current**:
Press the "mA button" and select the scale of current to be measured by plugging the red lead into the "mA" (0-2000 mA) or "10A" (0-10A) input on the meter. Press one of the gray buttons corresponding to the range desired.
When measuring current, the meter must be inserted in series. Power down the circuit, break a connection, and connect the leads. With the red lead connected to the "more positive" voltage, the current flow will show on the meter as positive.
- To measure **resistance** or **conductance**:
Press the k Ω /S button. 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.

4.6 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 instance, as a digital system's clock.

To produce a square wave:

- Make sure the DISABLE button (lower right corner) is off (unlit).
- Set MODE to NORM by pressing the button beneath it (second to left).
- Set CTRL to disabled (nothing lit) (fourth to left).
- Press the button underneath PER until the PER lights, and set the period using the vernier buttons.
- 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.
- Press the button under HIL and set the high voltage using the vernier buttons.
- Press the button under LOL and set the low voltage using the vernier buttons.

4.7 HP 54645D 100 MHz Mixed Signal Oscilloscope

4.7.1 Oscilloscopes

An oscilloscope can be used to display very high-speed periodic events. Think of its screen as a graph of voltage vs. time. This particular model combines a digital storage oscilloscope with a logic analyzer in one chassis with extensive "mixed-signal" capabilities.

Conventional analog oscilloscopes work 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, as in the 54645D, solve this problem.

Starting the sweep at the right time is essential to obtain 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 - at some exact multiple of the period of the waveform - the traces superimpose to give a single, stable waveform, as in Figure 2b.

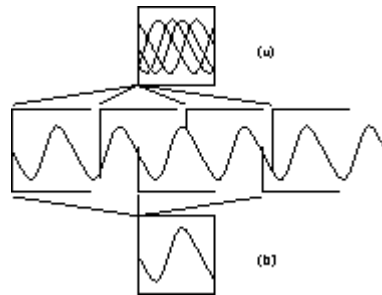


Figure 2: (a) Incorrect triggering. (b) Correct triggering.

Most oscilloscopes allow the user to set a voltage level and a slope (“rising” or “falling”) for the trigger. For example, in Figure 2b, 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.

4.7.2 Digital Storage Oscilloscopes

Digital storage oscilloscopes digitize their inputs, store them in memory, and recall them through a digital-to-analog converter. Using it 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.

4.7.3 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.

4.7.4 Controls

Figure 2-2

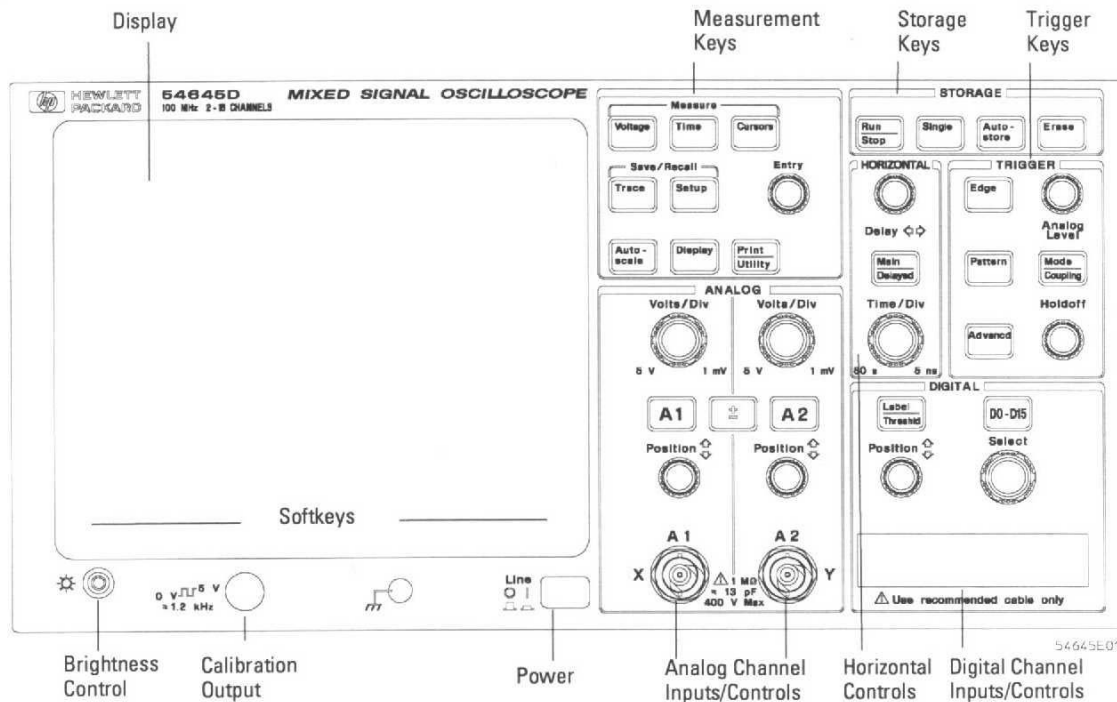


Figure 3: Groups of controls on the 54645D

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 is used to test probes. When in doubt, attach a probe to the calibration output and hit AUTOSCALE measurement key. It should display a 0-5V square wave at about 1.232kHz.

AUTOSCALE

This button, possibly the most frequently used, is located in the measurement section. The 'scope searches for a signal, sets time and voltage ranges to place signal in the middle of the screen.

IF SIGNAL DISAPPEARS, TRY HITTING AUTOSCALE

MEASUREMENT CONTROLS

VOLTAGE, TIME, and CURSORS are the three measurement control buttons.

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

SAVE/RECALL

TRACE allows the storage of waveforms in two memories. These are saved and recalled using softkeys. SETUP allows you to undo autoscaling, recover screens, and setup display defaults.

DISPLAY AND PRINT UTILITY

Soft keys set display and grid lines.
MODE MUST BE SET TO NORMAL WITH VECTORS ON.

ANALOG

VOLT/DIV increases the gain at which the signal is observed. The Volts/grid-block reading is on top of the screen.

A1 and A2 allow you to turn each channel on and off. High or low pass filtering with softkeys, AC or DC coupling can be used to get rid of excess noise. Note: Noise reduction decreases trigger sensitivity.
+- help to obtain the sums and differences of signals.

HORIZONTAL

DELAY 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 IME/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 allows you to select which logic analyzer probes will be displayed. Signals can be selected with SELECT knob and turned on or 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 the **SELECT** knob or 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 **SELECT** knob through each signal (D0-D15) and (A1 or A2), displayed above the **Source** softkey.

Press one of the softkeys to set the condition the 'scope 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

4.8 Lab Assignment

4.8.1 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 this to your TA.

4.8.2 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.

4.8.3 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 16-bit ROMs. Your task will be to use both channels of the 'scope to observe the outputs of ROM2 and ROM3 and deduce their contents, using the contents of ROM1 as a starting point.

Fire up the HW debugger and load the ROM circuit: `U: /CS150/LAB4ROM.BIT`. Once the design is downloaded, the clock will automatically be running (it uses the clock on the Xilinx board).

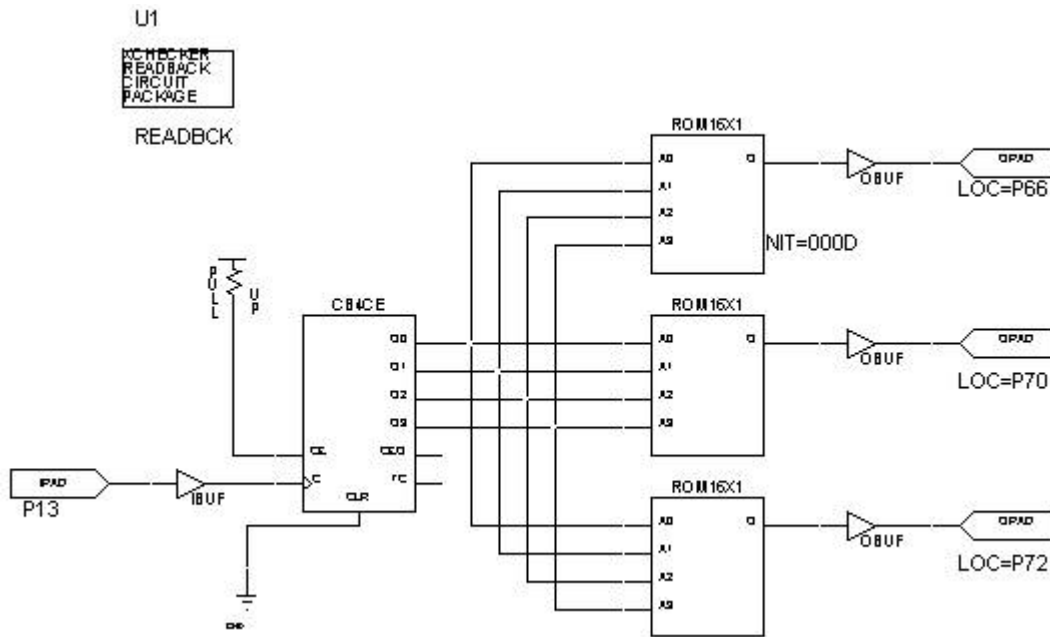


Figure 4: Three ROMs

The counter counts 0000, 0001, ..., 1111, and repeats. Address 0000 reads the least significant bit (LSB) of the four-digit hex number in the ROM, address 1111 the MSB. 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.

1. Connect the BNC ends of the oscilloscope probes to the 'scope's Channel 1 and Channel 2 inputs.
2. Carefully connect each probe's 'hook' to one of the wire-wrap pins connected to a Xilinx pin that is 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 'scope to the output of ROM1, whose contents are 000D, 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), then adjust the TIME/DIV knob so there are 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.

4.8.4 Measure Propagation Delay with the Logic Analyzer

We have entered and compiled the circuit in Figure 5, an 8-bit ripple adder summing the output of a 4-bit counter and four switches. Your task will be to measure the worst-case delay of the circuit.

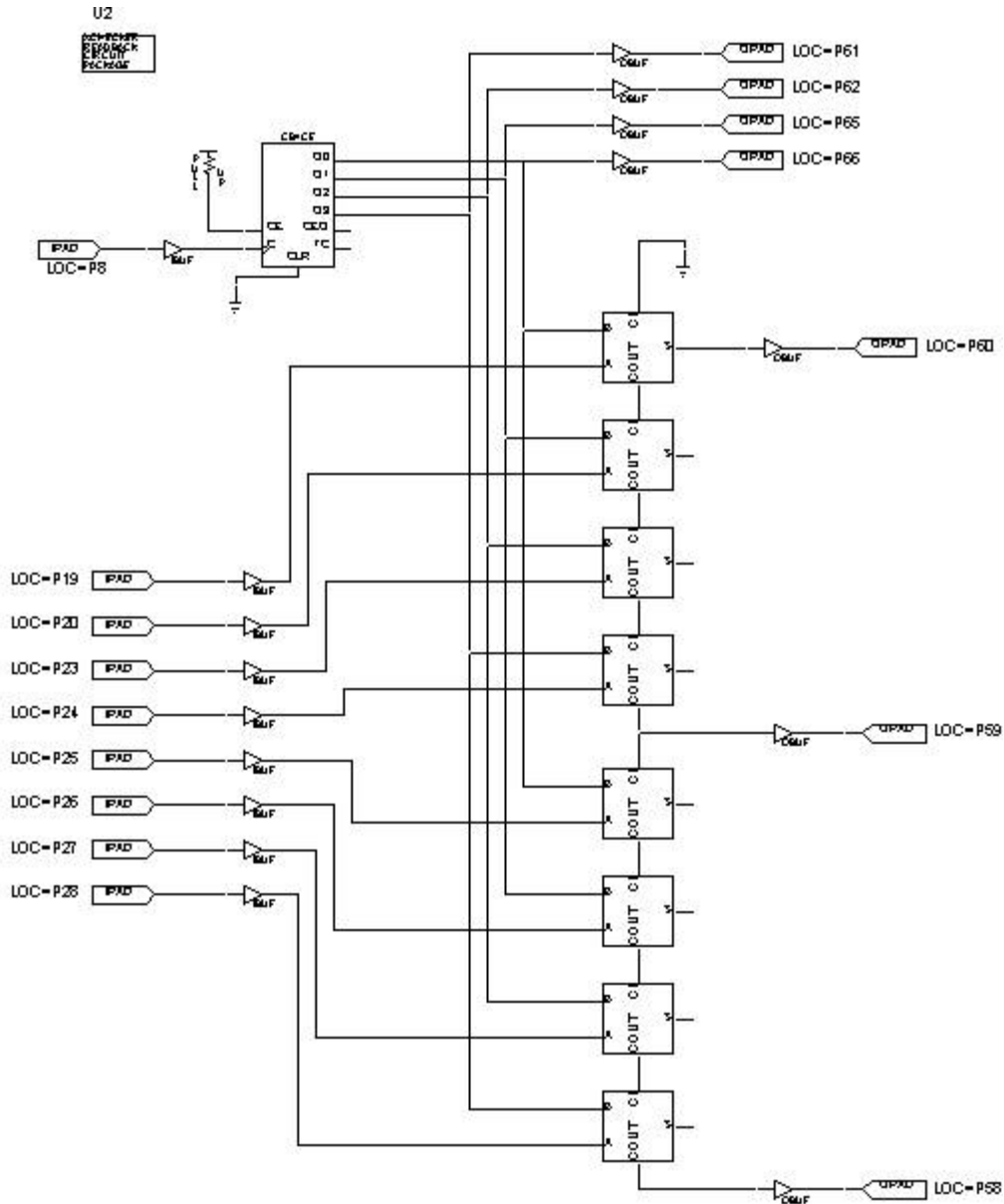


Figure 5: An eight-bit adder

The worst-case delay occurs when a carry must ripple through each stage, such as when 1111111 and 0000001 are added. To find this, set the switches to 0000001, and set the logic analyzer (Probes on DIGITAL section) to trigger when the counter makes a transition from 1110 to 1111.

1. Fire up the HW debugger and load the adder: U:/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 when the counter reads 1110. Make sure that TRIGGER MODE is set to NORMAL.
5. Step the clock one cycle so that the counter reaches 1111. Measure the delay from when the counter output changes to when the final carry-out changes, and record this on the checkoff sheet. Show this to your TA for your final check-off.

4.9 Acknowledgments

Original lab by J. Wawrzynek, Fall '94. Modifications by P. Kim, D. Chinnery, R. Fearing, T. Tuan, J. Beck, E. Caspi, P. Yan and N. Kumar.

Name _____ Name _____

Lab Section _____

4.10 Check-offs

1. Power Supply and Multimeter _____ (10%)

2. Pulse Generator and Oscilloscope

- 10kHz. _____ (15%)
- 10MHz. _____ (15%)

3. ROMs

- ROM1 ____000D____
- ROM2 _____ (20%)
- ROM3 _____ (20%)

4. Logic Analyzer Delay _____ (30%)

On Time _____ (x100%)

Turned in a week late _____ (x50%)