

Introduction to laboratory tools

Getting acquainted with lab equipment

In addition to the computer sitting at every workstation in the lab, there are three main pieces of equipment:

- Protoboard design workstation
- Oscilloscope
- Logic Analyzer

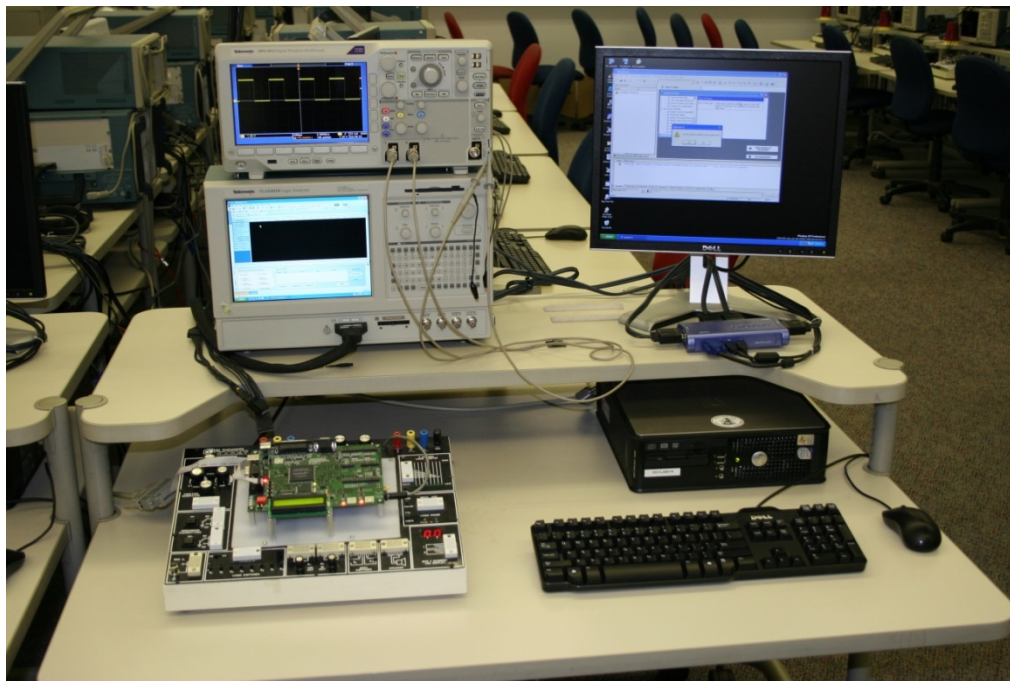


Figure 1. Typical lab workstation.

We will eventually use all three of them, with first two being used right away in this set of exercises. This week, you can probably do this alone in the lab (Van Leer E283), but we are trying to make sure that Dr. Collins or Kevin Johnson are in the lab at the times ECE2883 students are planning to attend, hopefully Monday, August 24.

Protoboard Design Workstation and DE2

First, we'll look at the main features of the area where we work on circuits. The Proto-board design workstation is the unit on the lower left in Figure 1. It is often referred to in the School of ECE as the

CADET, because that was the name of an earlier model, but this document will refer to it as the *PB-505*, the current model. A closer look is shown in Figure 2. An obscure detail is that the PB-505 comes with a large central area for plugging in integrated circuit chips and wires, but it has been modified for our use with an FPGA development board in the same location, the *DE-2*.

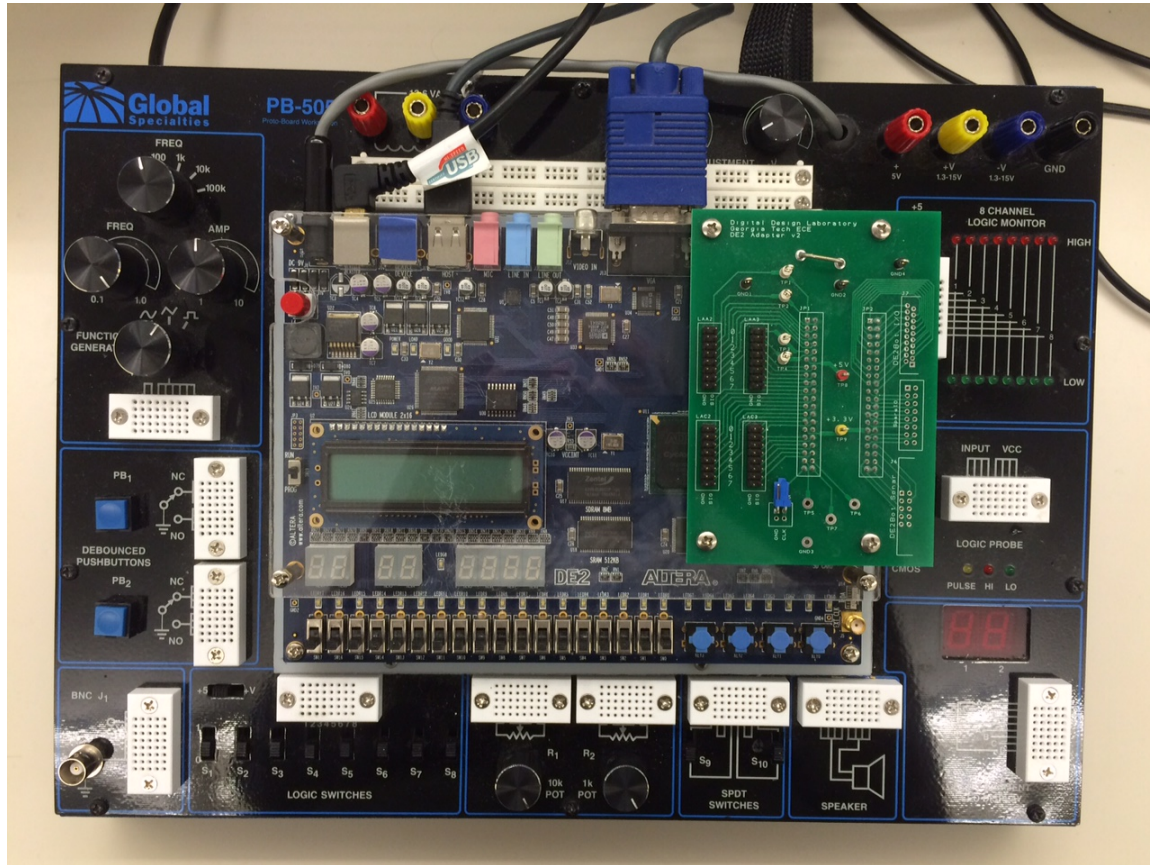


Figure 2. Protoboard Workstation.

The power switch of the PB-505 is located on the back side, near the power cord on the left, as you face it from your seat at the workstation. When you turn it on, the DE-2 may also come on, which does not matter either way until later in the semester, when we actually use it.

The upper left area of the PB-505, shown in Figure 3, provides a *function generator*, used to generate an electrical waveform that can either be a sine wave, a square wave, or a triangle wave. The frequency of the waveform is set to be in a broad range with the knob at the top, and the precise frequency is adjusted with the knob on the left.

The remaining two knobs select the type of waveform (square, sine, triangular) and the amplitude. These are relatively easy settings in our lab, because we always use square waves, and we avoid using the amplitude dial for reasons that will be clear shortly. In digital circuits, all values are either logical 0 or logical 1 (“false” or “true” or the binary digits 0/1), and for now let’s approximate that as being “clearly less than 1.5 volts (1.5 V)” or “clearly more than 1.5 volts (1.5 V).” So, the gradual

changes of a sine wave or triangular wave are analog phenomena that seldom concern us, and we would prefer that our signals switch from low to high as quickly as possible, like a square wave.



Figure 3. The function generator portion of the PB-505.

The white block at the bottom of Figure 3 contains many duplicate locations where a user can connect to the generated waveform. The six right columns are all identical, and they produce a waveform whose amplitude is controlled by the knob on the right, varying from negative voltage to positive voltage according to the specified amplitude. **We almost never use those columns, nor the amplitude knob.** The two left columns are also identical, and they produce a waveform that has a low level of about 0 V, and a high level of about 5 V. Signals that vary between 0 V and 5 V are commonly called *TTL-level* signals, a name that carries over from one of the most commonly used integrated circuit technologies, especially between the 1970s up to the present, but declining since around 2000.

There is no rule that dictates that **all** digital logic has to vary between 0 V and 5 V, with a dividing line at “about 1.5 V,” but it is definitely the approximate rule that we have with the electronics we will be using, and we call these devices *TTL-compatible*.

Before leaving the function generator, note that voltages are always measured relative to something. That reference is called *ground*, and there are numerous locations elsewhere on the PB-505 where the

user can connect to ground. All of the signals on the white block in Figure 3 are one of the two outputs from the function generator (TTL-level in the two left columns, variable-amplitude in the six right columns), and all of them must be referenced relative to a ground level. The symbol for digital ground is shown in Figure 4.

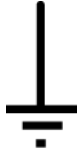


Figure 4. Symbol for digital ground, equivalent to 0 V or logical zero.

The lower left of the PB-505 is shown in Figure 5. Here, two pushbuttons and eight slide switches are located. For each of the eight slide switches, there is a column of connections where the switch output can be accessed. A down switch will produce a logical 0 (near 0 V) in the corresponding column, and an up switch will produce a logical 1 (near 5 V) in the corresponding column.

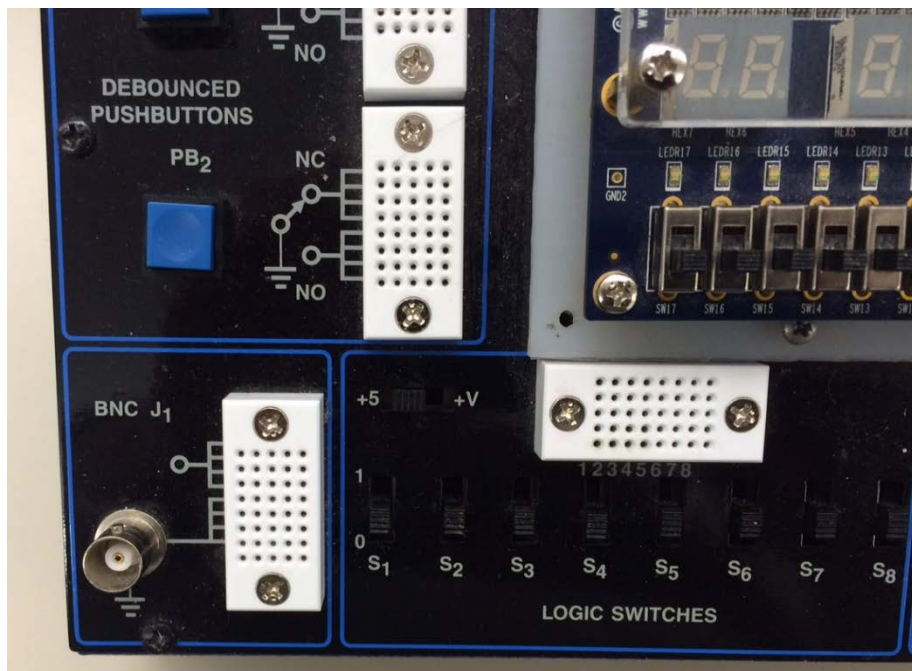


Figure 5. Area of PB-505 containing switches. One of the two pushbuttons is located just above the area shown here.

The pushbuttons, when closed, are connected to ground. The ground symbol is shown alongside the white block of connections. Half of the connection points (the upper ones) are normally-closed (NC), which means that when the button is not pressed (i. e., normal), those points go to ground. The lower half of the connection points are normally-open (NO), which means that they are only closed when the button is pressed. In either case, the points are *floating*, or not connected to anything, when they are not closed. As such, the voltage is unknown, unless there is some other connection made by the user, usually “pulling it up” to a logic high with a resistor. That “floating” phenomena may not be intuitive to you, but we will come back to it later when it matters.

Finally, consider the upper-right region of the PB-505, shown in Figure 6. At the top are locations where a user can connect to the 5 V power supply (red) and the ground reference (black), along with two other voltage levels that are not of interest to us with our digital circuits.

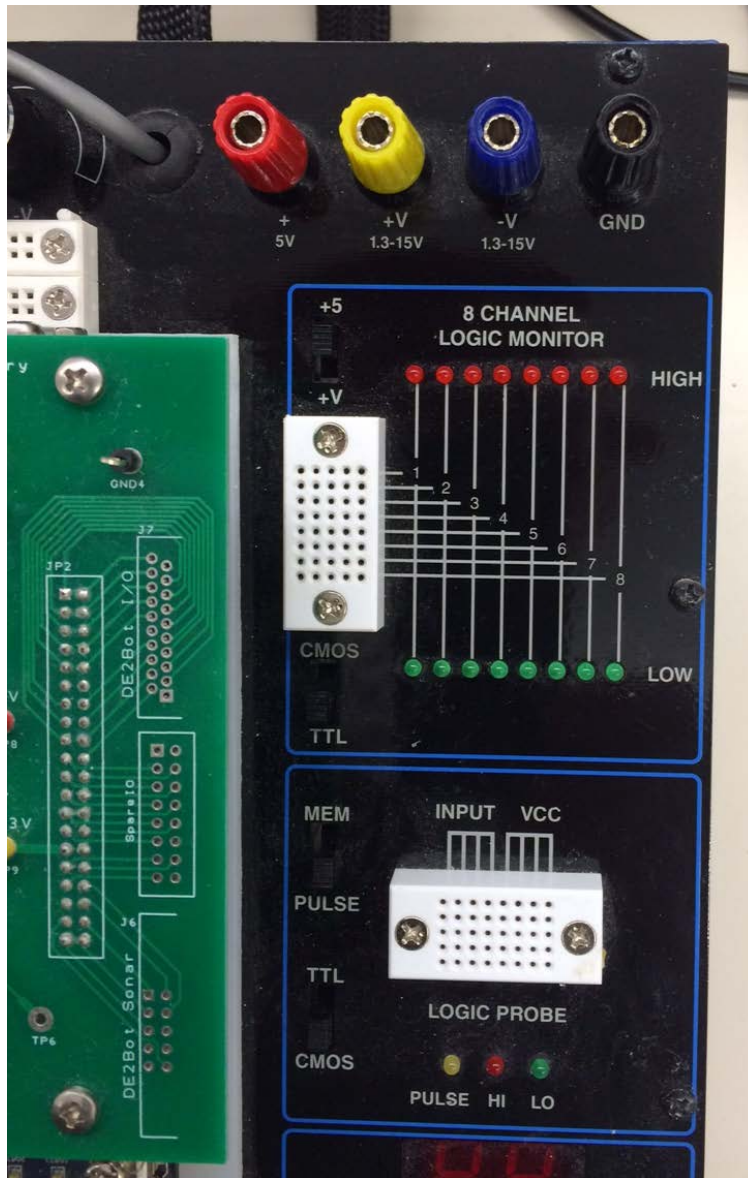


Figure 6. LED display and power connections on the PB-505.

Below the power jacks is a group of LEDs, in eight pairs of red and green. Each of the pairs has five connection points in the white block. When a signal is connected to an LED pair, the LEDs will indicate if it is high by illuminating the red LED, or low by illuminating the green LED. The switch below the white block should be in the TTL position, since that defines red and green in terms of the normal TTL logic levels that we use.

Below the eight pairs of LEDs is a *logic probe*. This is quite similar to the LED pairs above, but has additional features. When any one of the points labelled as INPUT is connected to a signal, the red LED

will indicate high, and the green LED will indicate low. If the signal is a square wave, changing slowly between high and low, then the red and green LEDs will alternate, just as any of the eight LED pairs above would alternate. But if the signal connected to the logic probe input alternates at a higher frequency, faster than the human eye would see it, or if it is usually at one logic level and only occasionally at the other (quick pulses), then the yellow LED will provide a visual indication. The logic probe also has a switch which should be set to the TTL position.

There are a few portable logic probes available in the lab that provide the same functionality, even when not physically near the PB-505.

Logic/voltage measurements

We will begin by generating some signals and making simple voltage measurements with the features built into the PB-505. We'll get some visual confirmation of logic levels being "near 0V" or "near 5V."

Exercise 1

Turn on the PB-505 (back-left side). Connect a wire between slide switch S1 and LED pair 1, as shown in Figure 7. Toggle S1 up and down and observe that the illuminated LEDs alternate between red and green.

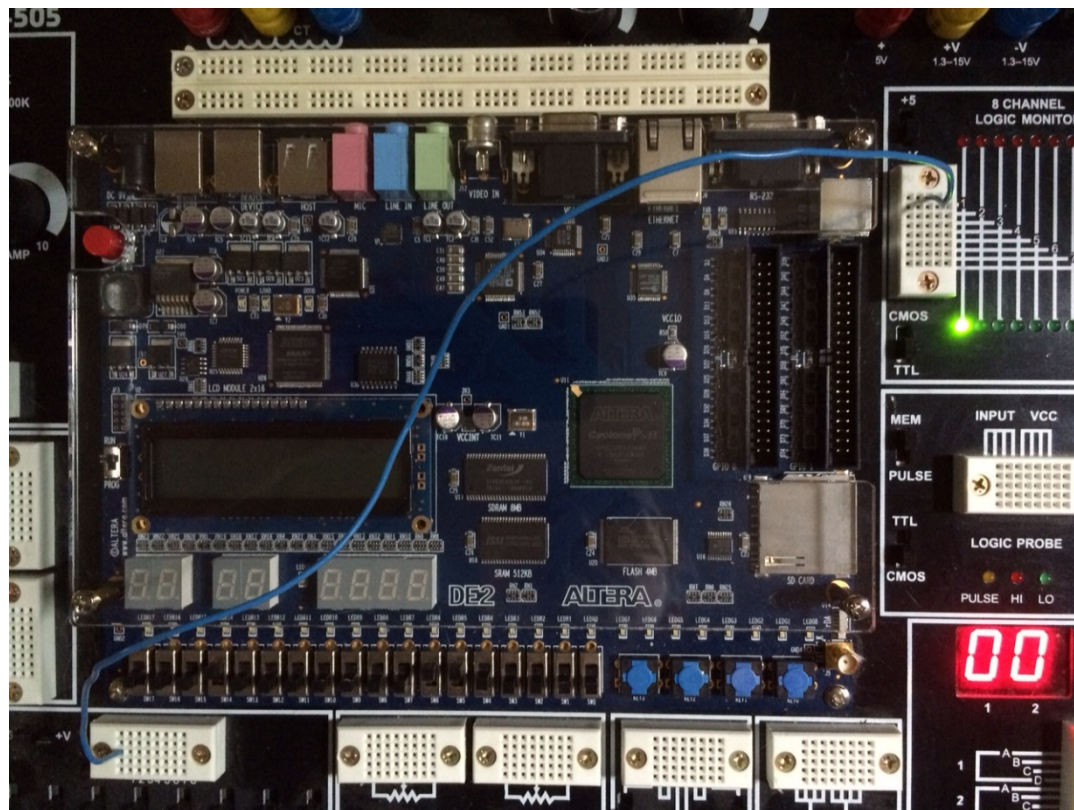


Figure 7. Make a connection S1 (the first slide switch) and the first LED pair in the "logic monitor" by pushing the bare ends of a wire into the corresponding locations in white blocks.

Exercise 2

Move the wire between from LED pair 1, to the INPUT section of the logic probe, as shown in Figure 8. The logic probe requires 5 V power, so also make a connection between the VCC section of the logic probe and the red 5V terminal near the top of the PB-505. Note that the technique to connect to one of these terminals is to unscrew it (counterclockwise), then slide the bare end of a wire through a hole that will be barely visible in the brass screw (below the red plastic that you just unscrewed). Then, tighten the terminal by turning it clockwise (snug, not with much torque). It is common convention to refer to the power supply of a TTL logic circuit as “VCC.”

On the logic probe, there is a switch labeled MEM/PULSE. Set it to PULSE. Toggle S1 up and down and observe again that the illuminated LEDs alternate between red and green. You will also notice that the yellow LED pulses briefly each time it senses a change.

Change the MEM/PULSE setting to MEM. If you repeat the toggling of S1, you will see that the yellow LED stays lit. This is a feature that allows the user to detect when a quick pulse occurs and save it until it is deliberately cleared (by toggling MEM/PULSE).

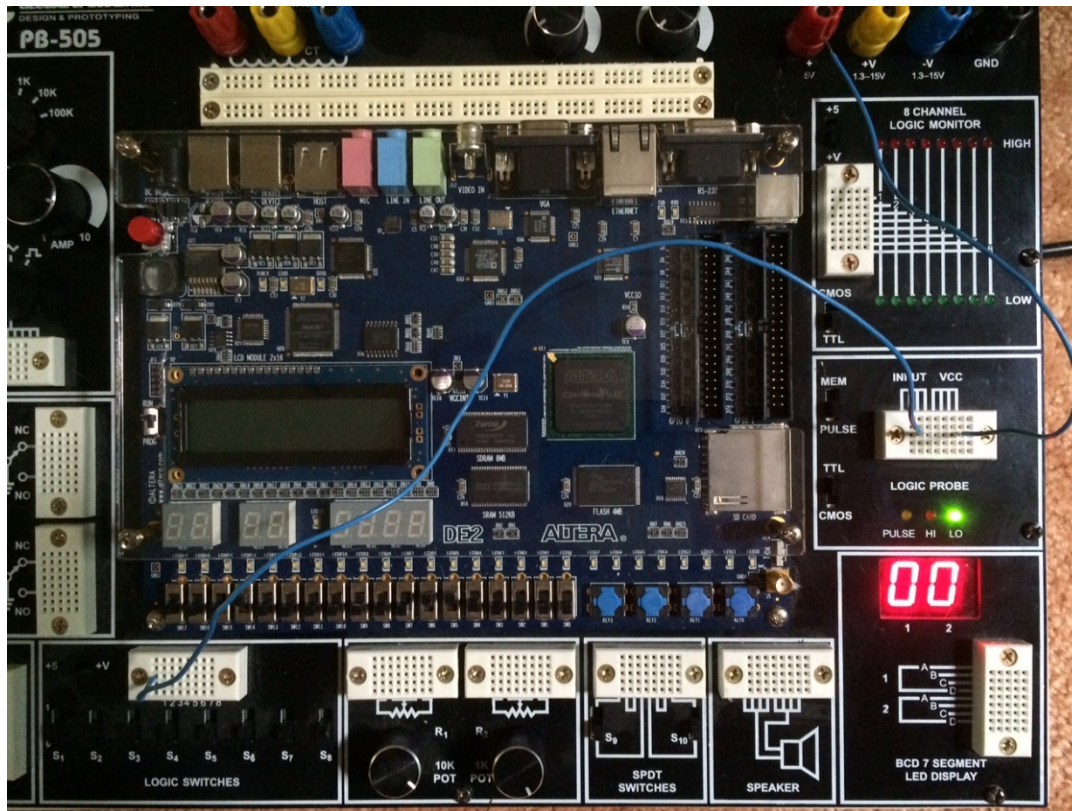


Figure 8. Connect the switch instead to the logic probe, and also connect power to the logic probe.

Exercise 3

Toggling a switch provides limited options. Keep the connection to the logic probe, but move the source of the signal from switch S1 to the function generator. Specifically, move it to one of the first two columns of the function generator, as shown in Figure 9. Refer back to Figure 3 for more detail about where the connection is made, noting that a wire is shown in that image. Also, note the knob settings in

Figure 3 and match them so that the frequency range (top knob) is “1” and the fine tuning of the frequency (left knob) is close to “1.0.” Finally, select the square wave on the bottom knob. (Reminder: as long as we use only the two leftmost (TTL) columns, it does not matter how the amplitude, or AMP, knob is set.)

The logic probe LEDs should be pulsing at 1 Hz, about 0.5 seconds high and 0.5 seconds low. If the MEM/PULSE setting is PULSE, it will register a pulse at every transition.

Increase the frequency by turning the top knob one step clockwise, to the “10” position. Since the left knob is still set for 1.0, the function generator is now producing a square wave at 10×1.0 Hz, or 10 Hz. Visually, you can still see some red/green alternation, and the yellow pulse indicator becomes virtually constant. You can decrease the frequency gradually back to about 1 Hz by turning the left knob counterclockwise, and you can also increase the frequency in steps by using the top knob. But clearly, there’s not much you can see with LEDs at higher frequencies.

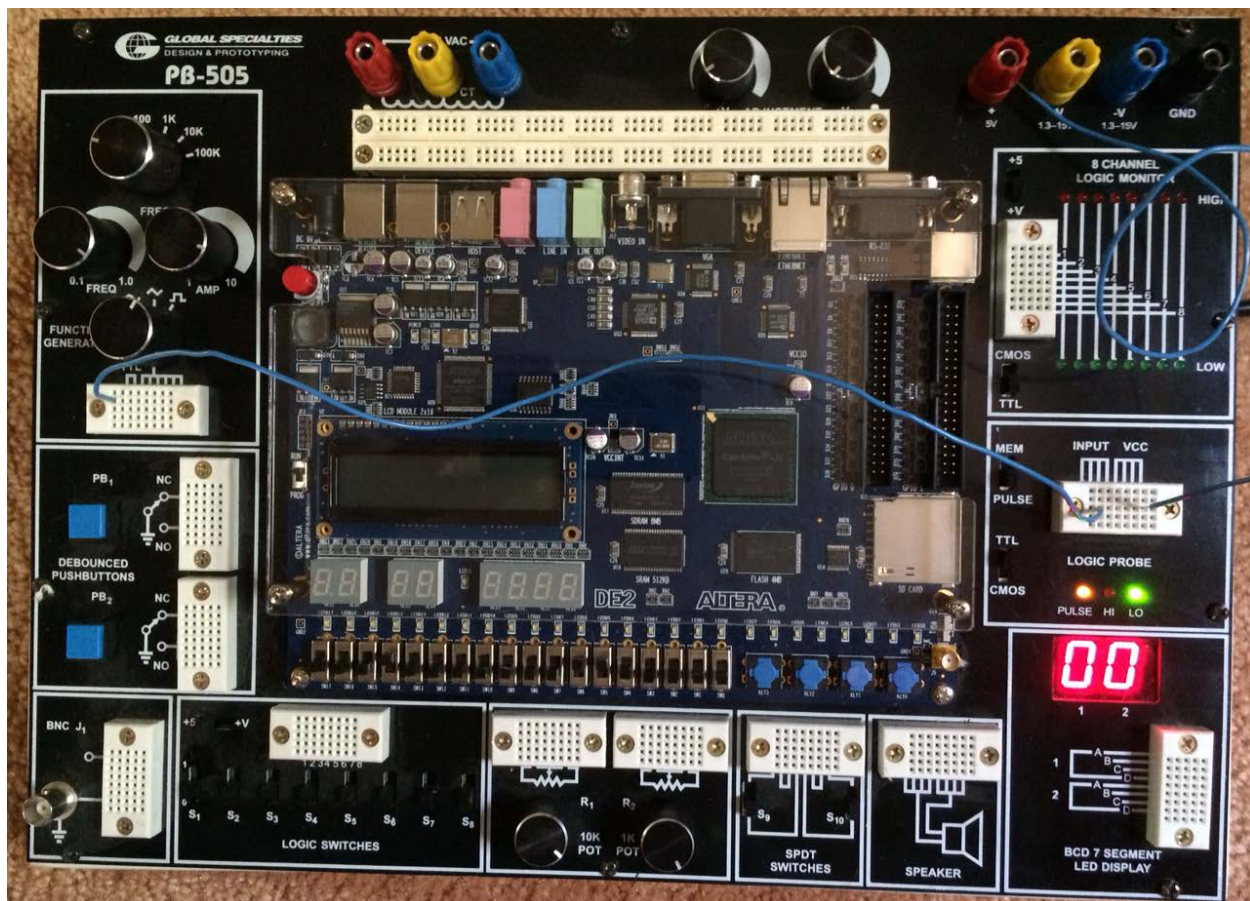


Figure 9. The function generator is used to drive the logic probe with a signal that changes faster than the switch can easily do. The actual placement of the wire is shown more clearly in Figure 3.

Exercise 4

Low frequencies will be of interest in the audio/visual/tactile aspects of 2883 projects. Events happening on this scale, the scale of human perception, will be very important. What may not be quite as obvious at this point is that higher frequencies are of interest, too. Light intensity, motor speed, and

other properties can be controlled by turning a digital signal on and off at a frequency higher than we perceive, where the average voltage, not the high/low voltages, determines the perceived property.

As an example of this, you may have noticed in the previous exercise that when the red and green LEDs were alternating slowly, they were clearly bright or clearly off. But at high frequencies, when they were illuminated on the average about half the time, they showed an intermediate brightness, because the human eye does not perceive the rapid change, but only the average value. (If it does not appear to be half of full brightness, that is because of some nonlinear aspects of LEDs and human visual sensitivity.)

So, we are going to have a need to observe these high frequencies, if nothing else than to debug signals that we are creating for projects. The primary tool for this is the *oscilloscope*, the instrument on the top left of each workstation.



Figure 10. Oscilloscope, with two probes attached.

The next few steps are what we will call a “scope checkout.” This is introduced here just so that you’ll have a feel for the oscilloscope before you watch a video about it in next week’s prelab. You should do a scope checkout each time you use an oscilloscope in the lab.

- A. Make sure the oscilloscope is turned off and that two probes are attached to it, as shown in Figure 10.
- B. Connect both oscilloscope probes to the test point labelled “probe comp.” on the oscilloscope, as shown in Figure 11. Connect the ground leads of the probes to the provided ground just above that. This provides a convenient source of a square wave signal with a known frequency and amplitude.
- C. Turn on the oscilloscope, wait for it to finish booting (after the introductory screen goes away), and reset it to its factory default state by pressing the front-panel Default Setup button. Confirm

selection if necessary. This eliminates a number of possible situations that could cause problems when making a measurement, since you never know how it was left by the previous user.



Figure 11. Proper connection of two probes (bottom right) and their grounds (immediately above).

- D. At this point, Channel 1 is turned on (by default), but Channel 2 probably is not. Turn it on by pressing the Channel 2 button or “2” button.
- E. Perform an “autoset” by pressing the Autoset button. This is a quick way to select settings that may be appropriate for some measurements. It does not always work this well, depending on the nature of the signals being probed.
- F. Place blank storage media (usually, a memory stick) in the oscilloscope.
- G. To produce a better, more readable output, before saving the screen, press the Menu button (under Save/Recall, below the screen), then select Save Screen Image, and finally turn the Ink Saver option On. (It is probably already “On,” but it does not hurt to check.) This prints black or colors on a white background, which keeps your narrow waveform and grid lines from being lost in the toner.
- H. To produce a cleaner screen to capture for hardcopy, press the “Menu Off” key that turns the menus off. (If there are menus along both the top and the side, you will have to press it twice to eliminate both.) Press the Save button to actually save your waveform. If at any time (now, or later when using the oscilloscope for measurements) the Save button does NOT save a normal dark-on-white image to your USB device, then someone may have changed the assignment of the Save button to something other than Save Image. That can be restored in the same menu where you set the Ink Saver feature. Remove the storage media and place it in a computer long enough to verify that you have acquired a valid graphic file (e.g., open it in an image viewer. Don’t forget to take your memory stick with you!

- I. As your final step in the lab, move the Channel 1 scope probe from the calibration signal to the output of the function generator, which should still be connected to the logic probe. Connect the probe ground to a ground on the PF-505, too. Using another short wire in the logic probe block is the easiest way, since the ground connection terminal is nearby, as shown in Figure 12. Set the function generator frequency to be about 1000 Hz (1 kHz), and the display on Channel 1 should be quite similar to what it was before, since that was also a 1 kHz square wave. Since the new signal is about 5 V in amplitude, and the calibration signal was about 2 V, you should turn the vertical scale knob (under the “1” button) one step counterclockwise to make the signal fit on the screen vertically. But since the signal on Channel 2 (the original calibration input) is not exactly the same in frequency, nor is it synchronized, you will see a “rolling” display. You may be able to minimize this by carefully adjusting the frequency dial of the function generator (Figure 13), but it does not matter. It simply illustrates that when using an oscilloscope, it is necessary to lock the display relative to some event on some signal of interest. This is called *triggering*, and in the default case resulting from the “autoset” you did earlier, it is triggering on the rising edge of Channel 1, and events on Channel 2 are displayed wherever they happen to occur relative to Channel 1.

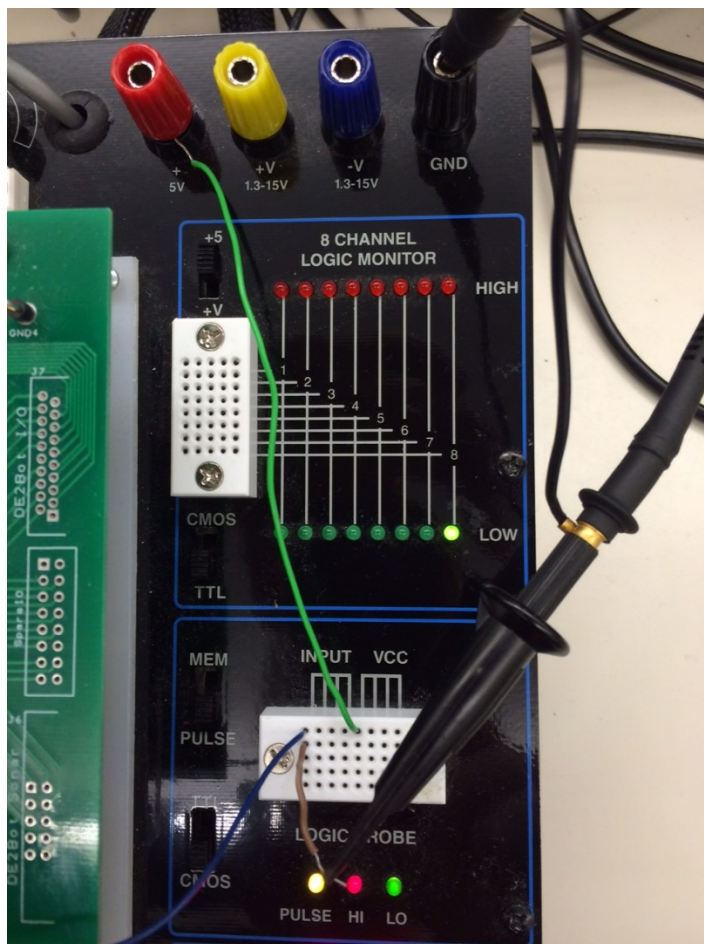


Figure 12. Connection of probe to the same signal already connected to the logic probe, along with a probe ground connection to the black terminal.

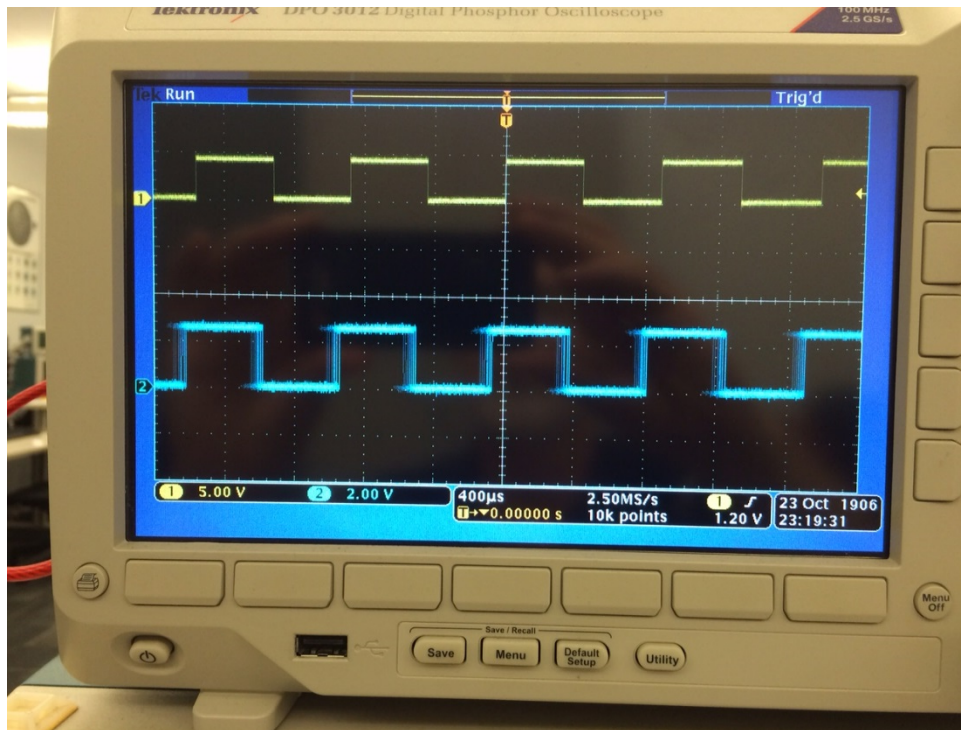


Figure 13. Result of connecting function generator to Channel 1 at 5 V per vertical division, with the calibration signal still connected to Channel 2 at 2 V per vertical division. Some adjustment of the function generator frequency is necessary to get it this close to the 1 kHz calibration signal.

Coming up in lab

Next week, as we divide the class up into digital logic subject-matter experts (SMEs) and non-SMEs, the SMEs will begin to look at generating signals on the DE2 board, something that the non-SMEs will catch up to in just a couple weeks. Meanwhile, the SMEs will use the function generator to drive devices that are more interesting than single LEDs, something that they will eventually share with the SMEs. The non-SMEs will also get an earlier look at more examples of using the oscilloscope.

Results to turn in

There is nothing to turn in for this set of exercises. In the future, you will be asked to turn in brief results of certain exercises, possibly including data like the oscilloscope screen capture that you saved this week. This will only occur for about a month, and beyond that you will be asked to provide some specific updates about your project ideas and eventually your project progress.