ECE2883 HP: Lab 2- nonSME

Introduction to project hardware

Using the oscilloscope, solenoids, audio transducers, motors

In the following exercises, you will use some of the project hardware devices, which will be on the table against the wall near where you enter they lab. Some of the devices have special customization (wires, test setups, etc.), so there will not be enough for everyone to do the same exercise at once. To get around this, it is fine to work in larger groups or to do exercises out of order.

Just as we did last week, 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, at least on Monday, August 31.

Oscilloscope revisited

Exercise 1

Figure 1. Connection of wire to function generator, as was done last week.

We'll start by picking up where we left off last week, with the oscilloscope. Turn on the PB-505 and the oscilloscope.

Connect a long wire to the TTL output of the function generator, as shown in Figure 1, just as you did last week. The figure shows a setting of 1 Hz, but change it to the 1K (1 KHz) scale, with the variable knob near 1.0. Connect the other end of this wire to the Channel 1 probe of the oscilloscope. Connect the ground clip of the oscilloscope to ground on the PB-505. A convenient spot is near the bottom left, as shown in Figure 2. On the oscilloscope, make sure that Channel 1 is on (press the yellow “1” until the yellow waveform appears, and if you like, press the blue “2” until the blue waveform vanishes) , press the Autoset button, and you should see the square wave of about 1 Khz.

This exercise isn’t anything new, but it sets up the oscilloscope for the next exercise.

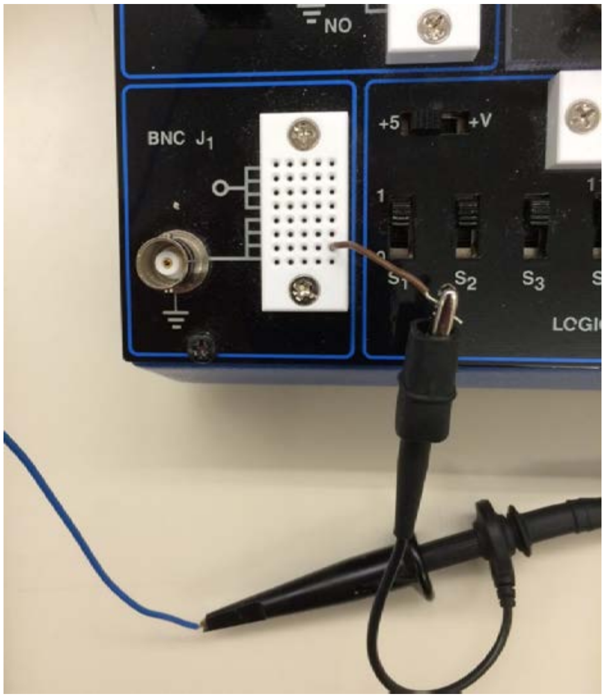

Figure 2. This connector on the PB-505, called a BNC, has an associated ground, with a wire connected here as an example.

Audio transducer

Exercise 2

Figure 3. Audio Transducer.

Find the audio transducer, which will look just like Figure 3, except that it is attached to a small audio amplifier, made from the components shown in shown in Figure 4. The audio amplifier is wrapped in tape to keep it from being accidentally short-circuited and thus damaged.

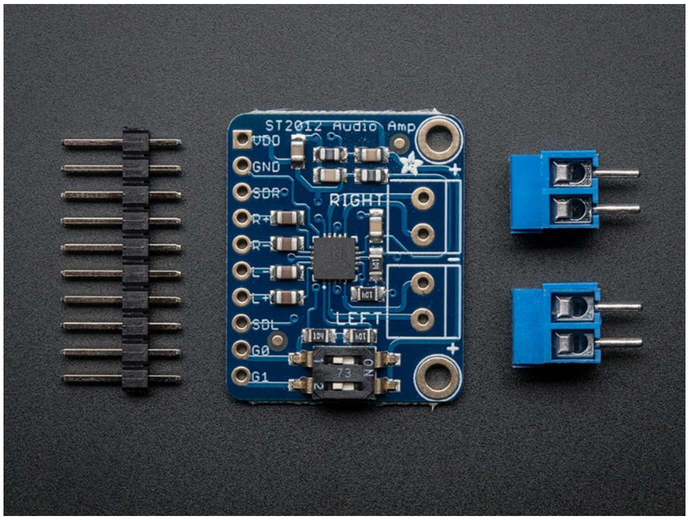

Figure 4. The transducer is connected to an audio amplifier, assembled from these parts. Power, ground, and two low-power signals (left and right audio) enter from the left, and two speakers (transducers in our case) can be driven on the right. Only the right channel is currently used.

The amplifier is needed for reasons similar to those mentioned in class regarding the solenoid: a TTL-level signal cannot drive the audio transducer, so it is amplified with a circuit similar to that in a phone or personal audio device. A time-varying voltage signal is sent to the right stereo channel of the amplifier, and the amplifier drives the audio transducer. But only a voltage that varies at audio frequencies will produce a response from the transducer that we can hear (~20 Hz to ~20 kHz, and probably not that entire range, either because of our hearing limitations or the range of the transducer).

Turn off the PB-505. The approximate layout on your desk is shown in Figure 5. You will end up with the amplifier resting above the DE2 board, getting power from the right and getting an input signal from your function generator. The details of connecting the power to the audio amplifier are shown in Figure 6, and the details of connecting the function generator are shown in Figure 7. This very temporary setup is only used to experiment with the function generator.

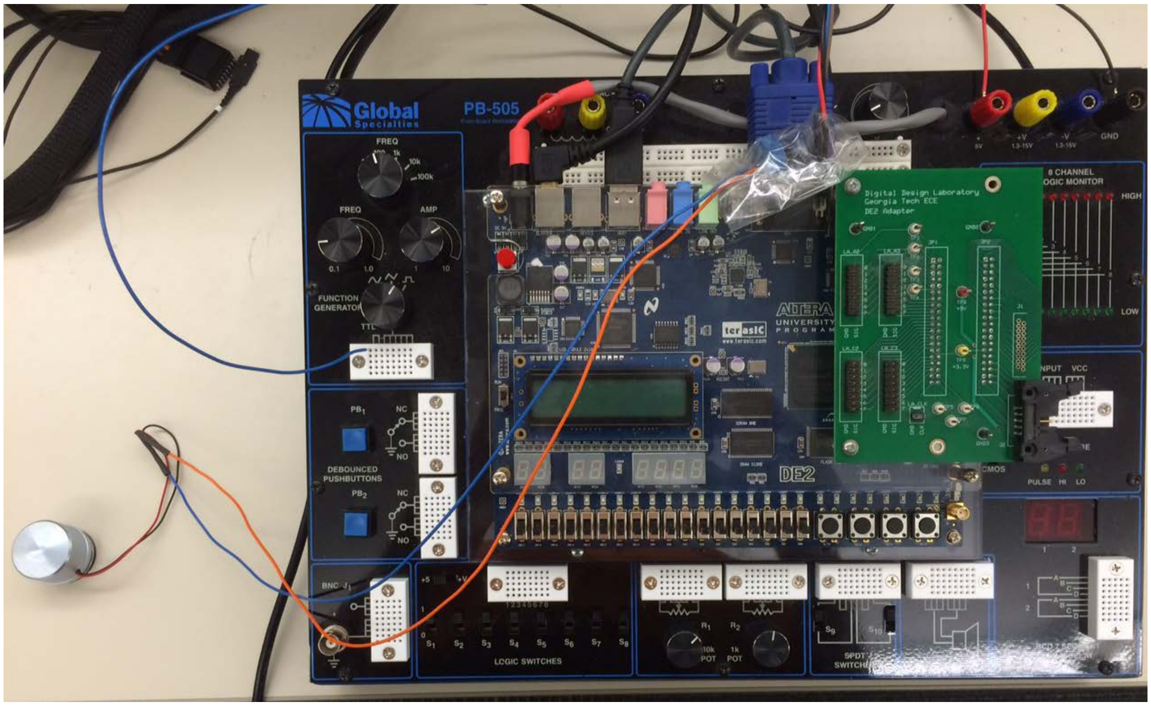

Figure 5.The next two pictures show connection details, but the end result is shown here. The audio amplifier is in the clear tape near top center.

Figure 6. Connect the red and black wires to 5 V power and ground, respectively.

Figure 7. Connect your function generator output (blue wire on the left here) to the blue wire going to the audio amplifier. The other wire in that connector is not used.

With all of the connections made, turn on the P-505. If your function generator is set for 1 kHz, you will hear a sound. Place the transducer with the rubbery surface down on the desktop for the best sound. You should be able to monitor the signal on the oscilloscope.

Vary the frequency, changing both the left knob and the upper range knob. Watch the signal on the oscilloscope, changing the horizontal scale as needed to see it clearly. Even though this is a square wave, not a pure sine wave, it is still a reasonably clear tone. Although it would be tempting to compare it to a sine wave, using the other outputs of the function generator, it could damage the amplifier, so do not do that.

Some of the PB-505 stations in the lab may have broken function generators, especially on the variable amplitude sine and triangle waves, so if you do not hear anything, while the oscilloscope corroborates this with no apparent signal, you may have to move to another station. But note that the TTL output only works when the square wave function is set.

The function generator does not provide very much current, and the DE2 board used for the project can provide even less. So you will be using these small audio amplifiers for your project.

Solenoid

Exercise 3

Find a solenoid, similar to that shown in Figure 8, except that it will have some extension wires attached. The solenoid will work regardless of the polarity of the voltage that you apply, so you can disregard the color of the wires.

Connect either solenoid wire to the red 5 V terminal. The function generator, like a typical logic output, does not provide enough current to drive a solenoid. Eventually, when we build our projects, we will opt instead to connect the one wire of the solenoid to a power supply and use a DE2 board logic signal to operate a switch that selectively shorts the other wire to ground.

Let’s do that manually, without the help of a DE2. With the one wire connected to the red 5 V power terminal, carefully hold the other wire by the insulated portion and use the bare end to touch the internal brass portion of the black terminal. Touch it, remove it, touch it, remove it, and so on. This is what the DE2 daughterboard will effectively do, controlled by a digital output. The solenoid will move back and forth.

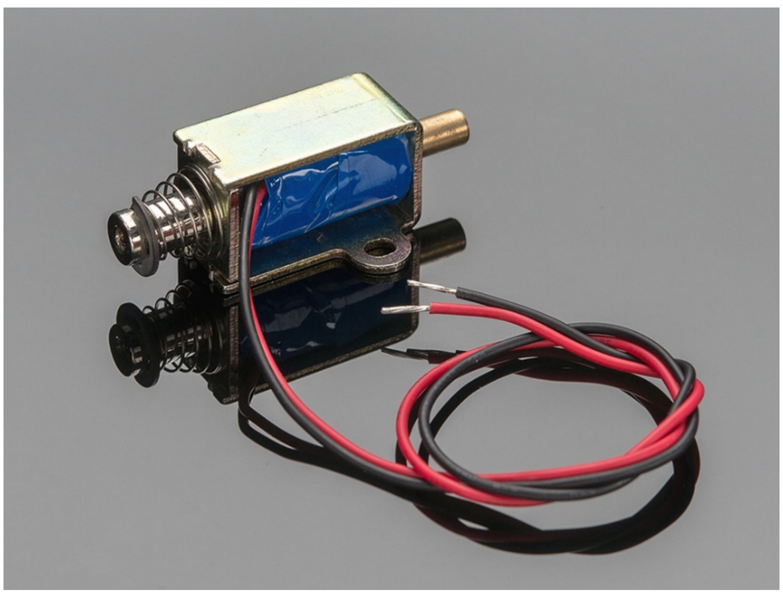

Figure 8. Small solenoid.

Before leaving this, use your free hand to shadow the area of the black terminal, and once again try touching and removing the wire. You should be able to see a small spark every time the connection is broken. This is exactly how a spark is generated on the spark plug of an automobile engine. The electrical part of a solenoid is simply a coil, which has large inductance. Inductance is to current like mass is to motion. The more inductance or mass that you have, the more “inertia” you have when something starts moving. Once the current starts moving through the solenoid, it does not “want” to stop (apologies for anthropomorphizing the inanimate solenoid) when you break the circuit, so it jumps the gap.

Even tiny sparks can cause damage over time. Although the details are beyond the scope of this course, even for the SMEs, there are some special components in our DE2 daughterboard that eliminate arcing inside the driver circuit.

The valve, shown in Figure 9, also incorporates a solenoid. We will not experiment with it now, because there is nothing visual associated with energizing it. Also, it requires 12 V for full operation.

Figure 9. Solenoid valve, not used in lab this week..

Servo motor

Exercise 4

The term *servo motor* can mean a lot of things. But in most cases, it refers to an electrical motor whose speed, position, or both can be precisely controlled. In our case, the servo motor of Figure 10 is a motor whose shaft rotates only about 180 degrees (let's call it from about -90 degrees to about +90 degrees), and it will reliably hold a commanded position in that range.

NOTE: The servo has a high gear ratio, and it should not be "back-driven," since that will strip gears. Do not attempt to rotate it manually for that reason. It is also possible to break an internal limit switch.

Servos like this were originally developed for hobby aircraft and other similar applications. A few similar standards were developed so that different servos would accept similar position commands. This particular servo responds to a signal on the yellow wire, relative to ground on the black wire. The red wire supplies 5 V power to the servo, and for this reason the signal on the yellow wire does not need to provide much current. It can be a "normal" TTL-level signal like the one from the function generator or from a pin on the DE2 board.

Put simply, this servo expects to see a logic high pulse about once every 20 ms (20 milliseconds). If that pulse is about 1 ms wide, it moves to -90 degrees. If it is 2 ms wide, it moves to +90 degrees. Any pulsewidth between 1 ms and 2 ms is an intermediate position. For example, halfway between 1 ms and 2 ms, or 1.5 ms, corresponds to halfway between -90 degrees and +90 degrees, or 0 degrees.

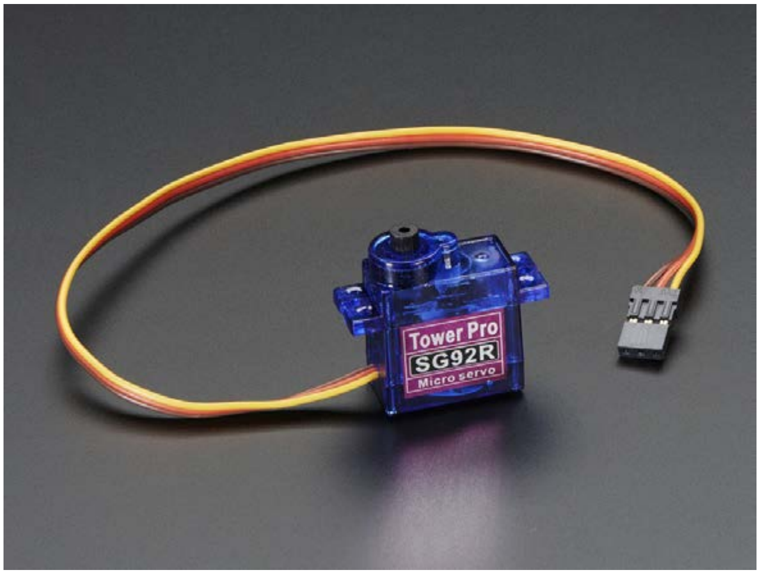

Figure 10. Servo motor.

The function generator on the PB-505 cannot produce pulses of varying width. So, to demonstrate operation of the servo, a specific digital design has been loaded into the DE2 board at station #14 in the lab. That station also has a servo plugged in, as shown in Figure 11. Details of the connection are shown in Figure 12. You probably wonder why the connection is made here. Suffice to say that the FPGA design is very flexible, and we simply chose a connection that was convenient. This connector had power and ground in the right place, so the signal adjacent to those pins was used in the design.

The signal being sent to the servo is duplicated on a small test point on the DE2 daughterboard, labelled TP1. Connect the oscilloscope Channel 1 probe to TP1, and connect the probe ground to any of the points on the daughterboard labelled GND. Turn on the PB-505, if it is not already on, and turn on the DE2 by pressing the red button on the upper left, if it is not already on. The special "servo PWM generator" device is already loaded and running. Turn on the oscilloscope, too.

This particular design reads the slide switches on the bottom of the DE2 board and sends a repeating pulse (every ~20 ms) based on those settings to the servo motor. In particular, it treats SW6, SW5, SW4, SW3, SW2, SW1, and SW0 like a binary number. If you raise the two rightmost switches (SW1 and SW0), that represents binary 0000011, or decimal 3. If all of the switches are down (decimal 0), the pulse width is 1 ms, and the motor is in its far clockwise position. As the number represented by the switches increases to 1, 2, 3, and so on, the pulse width increases by 20 µs (20 microseconds) each step. So the example of SW1 and SW0 being up (decimal 3) corresponds to an additional 3 × 20 µs, or 60 µs. This is added to the base of 1 ms (1000 µs), so the pulse width in that case is 1060 µs.

By this reasoning, the midway point of the servo at 1500 µs, or 1.5 ms, or 1.0 ms plus an additional 500 µs, is reached by setting the switches to the binary equivalent of 25 (500 µs /20 µs per "count" = 25). The far counterclockwise point (requiring a 2.0 ms pulse) is reached by setting the switches to the binary equivalent of 50. The servo calibration is not perfect, so you may get some additional movement with numbers larger than 50, but once the limit of motion is reached, larger numbers have no effect.

Press the Autoset button on the oscilloscope, and you should be able to see the pulse waveform. Set the switches for 25 and confirm that the pulse width is about 1.5 ns. Follow the steps described last week to save the screen to a memory stick. Do this again with switches set to 50. Turn in both of these images. You can do this as late as the seminar on Thursday, along with a couple short answers to questions below.

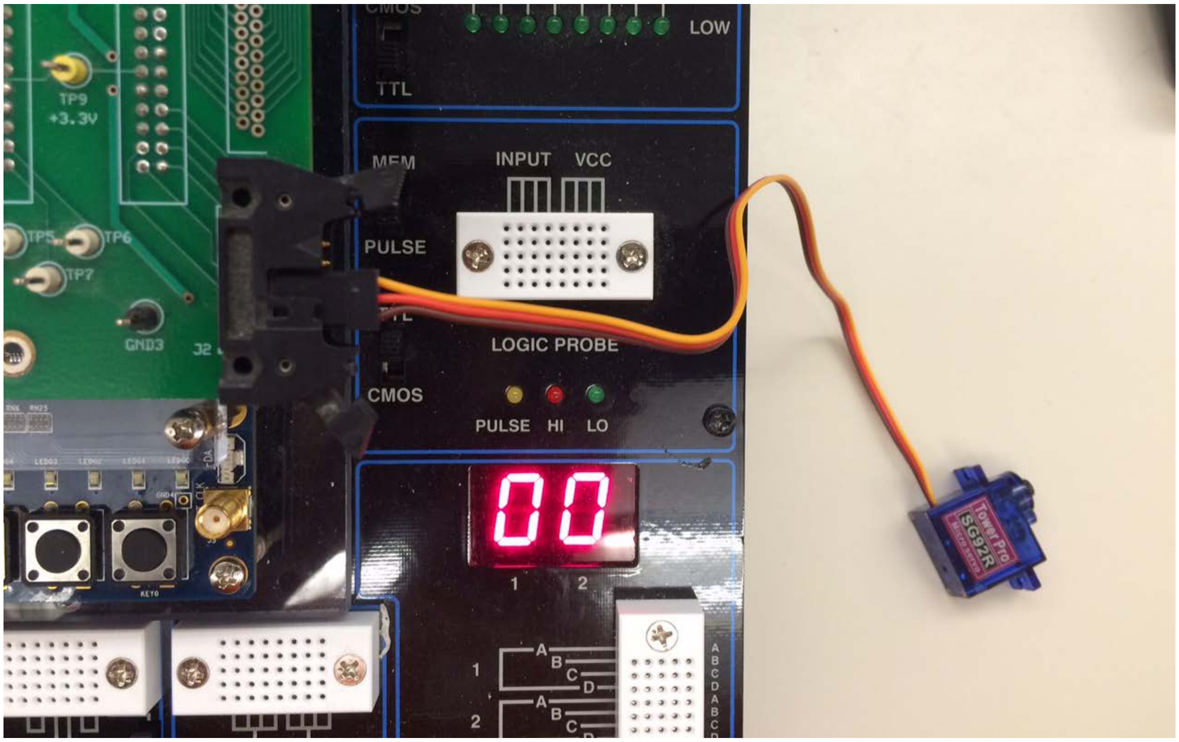

Figure 11. Servo plugged into the daughterboard on the right side of Station #14.

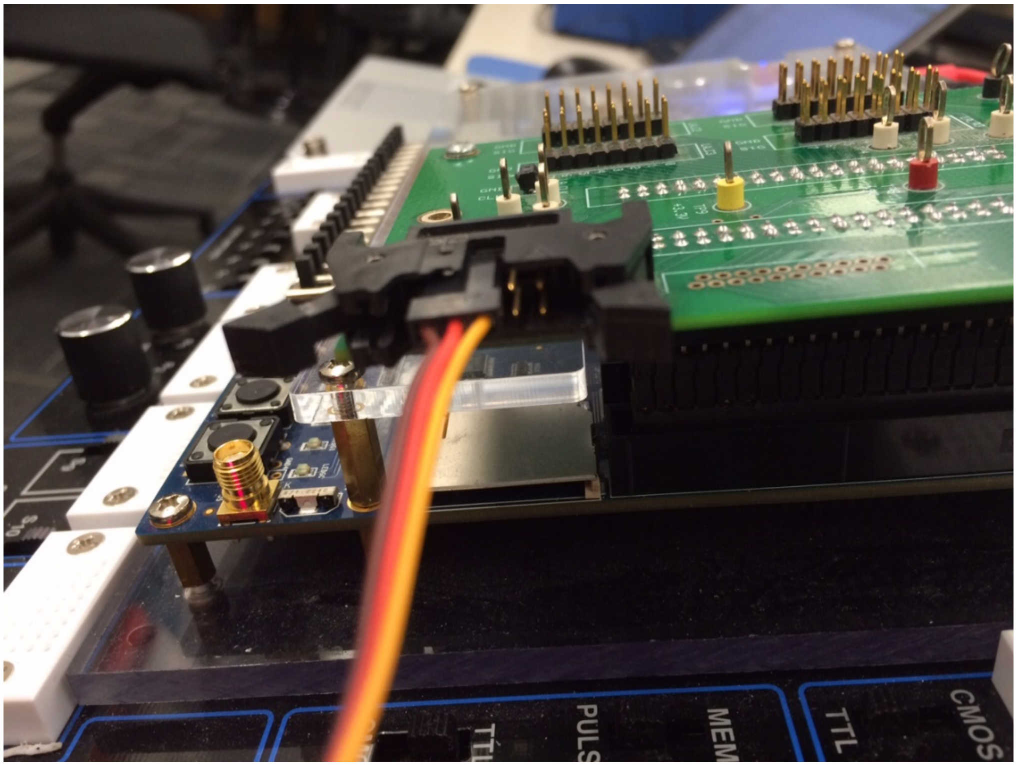

Figure 12. Detail of the connection. Leave it plugged in, but if it is ever necessary to reconnect, note that it plugs into the upper left three pins, with the yellow wire on the right.

Coming up in lab

Our favorite day in the lab, Monday, is a holiday next week. Thus, it will be a good week for an activity that does not have to take place in lab. You will have a self-paced learning module in basic combinational logic, bringing you up to speed with the essentials of what the SMEs would have learned in the first couple weeks of their previous logic course.

Results to turn in

Turn in the two oscilloscope screen captures. You can incorporate them into a document using your favorite word processing application. Then, in the same document, answer the following short questions. One or two sentences for each answer is fine.

1. Is the audio transducer loud enough for anything you might imagine in your project?
2. Is the limitation of a square wave tone too severe?
3. Is the servo fast enough to be useful?
4. Suppose that you wanted the servo to move much slower. How would you accomplish this with the same servo and something driving it with pulses in much the same way as you saw here?

You may bring the printed document to our seminar on August 3, or we may have something set up for electronic submittal before then.