**EE283 Electrical Measurement Laboratory**
**Laboratory Exercise #7: Digital Counter**
**Supplement: What we will do in the Lab**

**Overview:**

The EE283 Laboratory Exercise #7 Instructions discuss the project to build a digital counter, which will be done over a period over a few weeks, as for the previous digital project. What is not described is just what we will do in the laboratory. This supplement is intended to address that. What we will do is build a simplified version of the overall project which will count up to 9, so that we can measure (to one digit of precision) frequencies of 10 Hz to 90 Hz. The circuit will be built incrementally starting with the timer and then extending to the counter.

**1. The Timer:**

The LM555 timer is described in the laboratory exercise instructions. We will be operating all of the circuitry for this exercise in the laboratory from 5 Volts, so you should start by connecting your breadboard to the lab power supply 5 Volt terminals, just as for the earlier digital project. Build your circuit for the 555 timer device. The design issue is to select resistors for "R1" and "R2" and capacitor C1 so that you get a waveform that is a square wave that is low for 0.1 seconds then high for about a second. By using a variable resistor (or "trimpot") as part of R2, you can adjust the circuit while observing the waveform on the oscilloscope so that you get the desired timing waveform. (See Figure 7.9 of the instructions, which shows the LM555 timer connected to the counter in its ultimate form.) Making R1 10K Ohms in series with a 10K trimpot, and having C1 as 10 uF, should allow you to get close to the .1 seconds high desired. The timing formulas are given in equations 7.1 and 7.2.

Power up your LM555 timer circuit and monitor the output with the oscilloscope and demonstrate that you have .1 seconds low and about 1 second high. The .1 seconds is the duration of time over which your counter is to count; the 1 second is how long it will hold the value until it counts again.

**2. The Gate Circuit:**

The purpose of the gate circuit is to control strings of pulses to the counter. We can use an "AND" gate to control the pulses going to the counter. The signal generator is the source of the pulses we will count. Think of the two terminals of the AND gate as the "signal" and the "control". If the "control" is 1, the "signal" passes through to the output. If the control is 0, the output stays at 0. The control will come from the LM555 timer. Since the .1 second phase of the timer output is low, we need an inverter to flip it over to give .1 seconds high. See figure below:

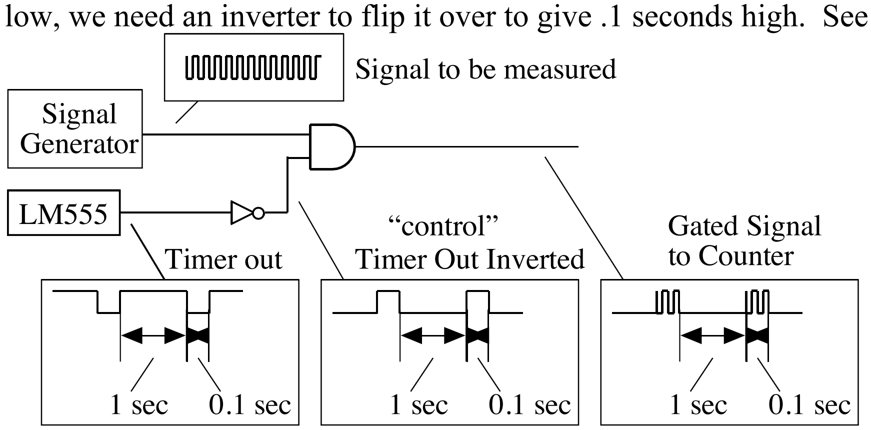


Figure 7s.1 The Counter Input Gating

It is inconvenient (and space consuming) to have to use two different logic devices to get both the inverting and AND functions. Instead, we can build the circuit using NAND gates. You can think of a NAND as an inverter with two inputs instead of one, both ANDed together. So, we can get an inverter just by tying the two inputs of the NAND gate together. We can get an AND gate by inverting the output of a NAND. Built with NAND gates, we get the circuit below:

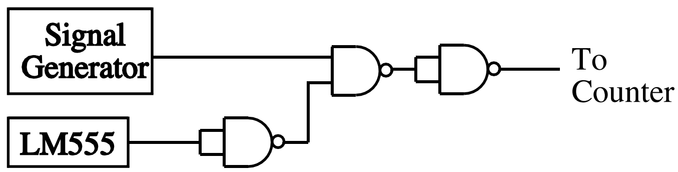


Figure 7s.2 Counter Input Gating using NAND gates

Build the gating circuit and connect it to the LM555 timer. Set the signal generator to give 2.5 Volts peak amplitude (so we get 5 Volts peak to peak) and add a 2.5 Volt DC "offset". We want a square wave (rather than sine) at the frequency 50 Hz. (It is important to include the DC offset so that the waveform does not go negative.) Check the waveform with Channel 1 of the oscilloscope. Now connect the LM555 and signal generator to the gate circuit as shown in the figure above, and observe the waveform. With a slow scan you should see the bursts of about 5 pulses spaced about 1 second apart. That's what we want to count.

**3. The counter**

We are using the 74LS160 "decimal counter" to count the pulses coming out of the gate circuit. See the lab instructions for details of the counter (page 2). For now, we will use LED's to observe the counter outputs. The figure below shows this. The counter actually counts in binary, but when it gets to 9 it rolls over to 0 on the next count, so it is called a "decimal" counter because it counts in 10's. Cascading three such counters we can count 0 to 999. The output is in binary, at QD, QC, QB, and QA. So, when it counts up to 5, you would see the pattern 0101 displayed on the LED's.

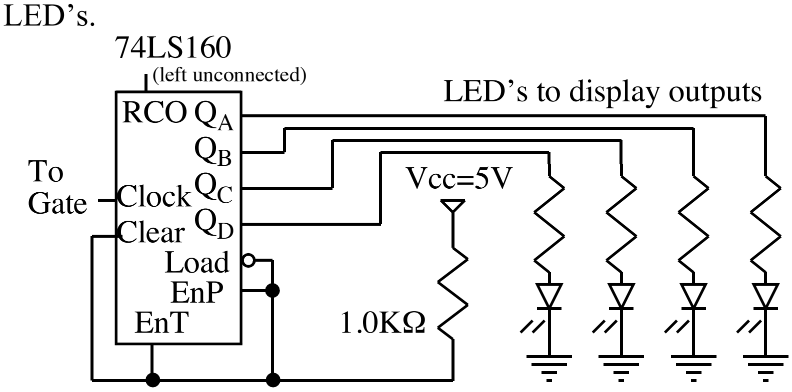


Figure 7s.3 Decimal Counter Circuit

Add a 74LS160 counter to your breadboard, and connect it to power. (Bring both the Vcc and Ground power connections to the same breadboard bus strip and put a 4.7 uF tantalum capacitor across the power supply there. This is called "bypassing" the power supply. It short circuits high frequency noise that appears on the power supply to ground.) Notice that unused (inactive) inputs need to be pulled up to a good "1" input with a resistor to power. One 1K Ohm resistor can do this for several of these signals, as shown. Unused outputs are left unconnected.

Now once the counter is connected to the gating circuit, we should see the counter count up in groups of 5 or 6 (depending on the phasing of the timer and the signal generator). When it counts above 9, it will roll over to 0 and keep going. The problem is that we would like to see it start over at zero whenever it counts.

Before connecting the gate circuit (or after), you might want to see if you can give the circuit just one pulse at a time manually. See the lab instructions about that.

**4. Clear Signal Reset**

This refinement of the one digit counter sends a "clear" to the counter as it begins to count each burst of pulses coming through the gate. We can do this with a high pass filter. The negative going pulse edge from the LM555 timer is transmitted to the Clear pin of the 74LS160 counter through a small capacitor. A 1K Ohm resistor pulls the Clear signal back up to a good "1" so that the "active low" clear signal is very brief, enough to zero out the counter, but so brief that the counting of pulses is not suppressed for any significant time. The diode protects the 74LS160 from overvoltage at the positive going output edge of the LM555 timer; the positive peak is shunted to power.

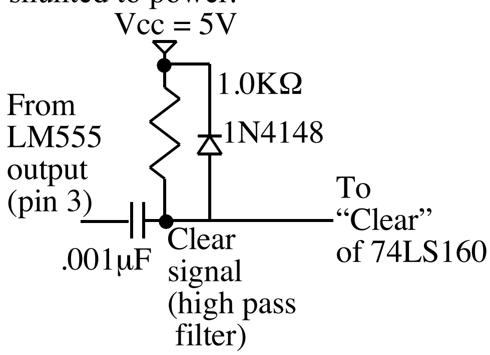


Figure 7s.4 Clear Circuitry

With this circuit added, you should see the counter count to about 5 consistently. (Note: you need to disconnect Clear from the other signals being pulled up by the 1K Ohm resistor shown in Figure 7s.3.)

**5. Seven Segment Display**

If you have time, you could have the counter drive a 74LS47 seven segment decoder device, and have that drive a seven-segment display. However, that's a lot of wiring. Maybe that can be saved for when you do all this on your own breadboard for the project.

**Conclusion:**

This supplement should help you with getting the project started. The remaining steps are mostly building this out to handle 3 digits rather than one. The small breadboards will be a bit crowded, so good "floor planning" is needed. Think about where you need connections. Orienting the devices to minimize wiring lengths and crossing over other signals will help.