

CS99S  
Laboratory 1

**Objectives:**

1. Become familiar with the breadboard
2. Build a logic power supply
3. Use switches to make 1s and 0s
4. Use LEDs to observe 1s and 0s
5. Make a simple oscillator
6. Use an inverter to convert 1s to 0s and vice-versa

**Part 1: Build a simple power supply**

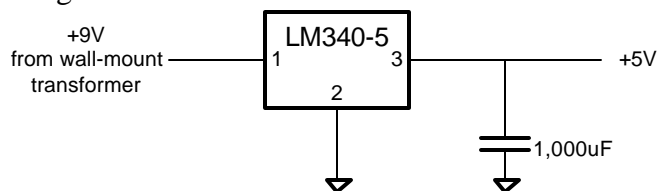
**Supplies:**

1. 3M solderless breadboard
2. 9V DC wall transformer (CUI)
3. LM340-5 5V regulator
4. 1000uF 10V electrolytic transformer
5. 22AWG solid-core hookup wire

We will be using a *solderless breadboard* to build circuits in this class. The breadboard connects together components and wire that are plugged into a common column of contacts. There are two large rows of contacts into which components can be plugged. At each position along these rows the five contacts above the row and the five contacts below the row are connected together. Any wires plugged into these five contacts are electrically connected together. To plug a wire into the breadboard you must first strip about 1/4" of insulation from the end of the wire. When wiring your breadboard, it pays to keep your wiring neat and flat against the board. This keeps wires from getting accidentally knocked out and makes it easier to debug your circuits.

Two small rows surround the main rows. These are used to distribute power (+5V DC), sometimes abbreviated  $V_{DD}$ , and ground (0V), which we will abbreviate GND. By convention, we will wire GND on the inside power row and +5V on the outside. Also by convention, GND is usually indicated with black wire and/or the black binding post.  $V_{DD}$  is usually indicated with red.

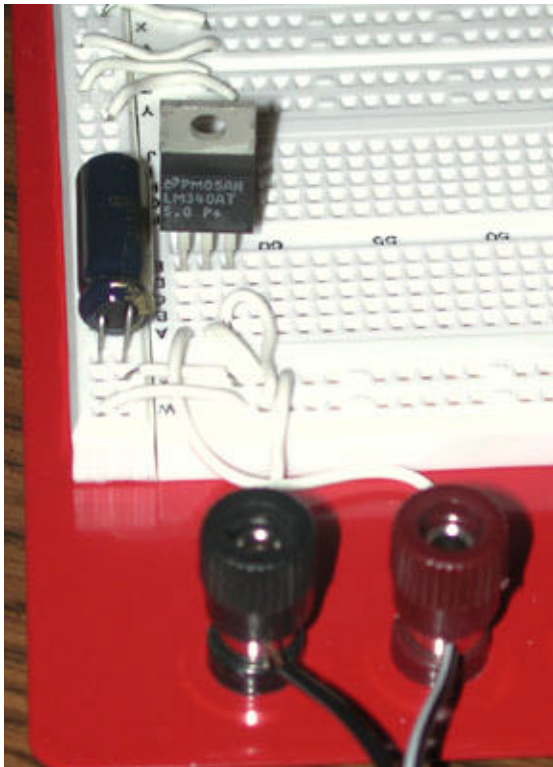
Your wall transformer, much like the one that probably powers your Discman, allegedly delivers +9V. Our first order of business is to create +5V from this +9V. To do this we will use a voltage regulator, an LM340-5 to reduce the voltage and a 1000uF capacitor to provide short term current and smooth transitions. We are going to build the following circuit – shown in schematic form:



To wire up your power supply, do the following:

1. Cut the connector off the cord attached to your wall transformer. Split the cord, strip about 3/8" of wire from each lead, and twist the ends. The lead with the white stripe is the positive lead.
2. Connect the positive lead of the wall transformer (+9V) to one of the red binding posts and the negative lead to the black binding post (GND).
3. Connect the black binding post to the GND row of the breadboard.
4. Place your LM340 in the last three columns of the breadboard nearest the binding posts (see photo below).
5. Connect the red binding post with the positive lead from the transformer to pin 1 of the LM340-5.
6. Connect pin 2 of the LM340-5 to GND
7. Connect pin 3 of the LM340-5 to the  $V_{DD}$  row of the breadboard
8. Connect the GND and  $V_{DD}$  rows of the breadboard together (not to each other though). Connect each horizontal row to the vertical row at one side. Also connect each horizontal row together across its midpoint – the circuit is otherwise broken here.
9. Connect your 1000uF capacitor across the power supply – DANGER – make sure to get the polarity right – the gold stripe must go to GND.
10. To verify that you have wired your power supply correctly, ask the professor or TA for a voltmeter and verify that you have 5V. (Also check the voltage coming out of the wall transformer – is it 9V?)

When you're done your power supply should look like this:



## Part 2: Hook up your switches and LEDs

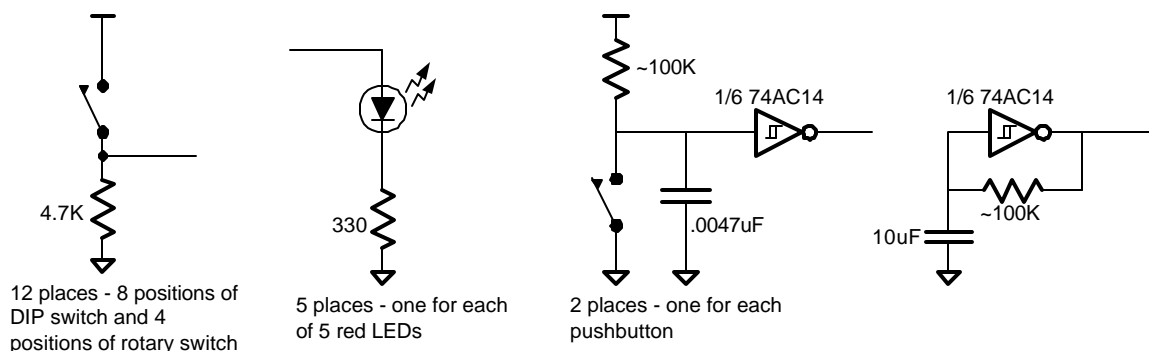
Supplies:

1. 8-position DIP switch
2. Hexadecimal rotary switch
3. (2) momentary pushbutton switches
4. 330-Ohm 10-pin resistor network
5. (2) 4.7K-Ohm 10-pin resistor network
6. (5) red light-emitting diodes (LEDs)
7. (3) resistors – values between 47K and 470K exact value not critical
8. 10uF tantalum capacitor
9. 74AC14 hex Schmidt trigger inverter (in a DIP package)

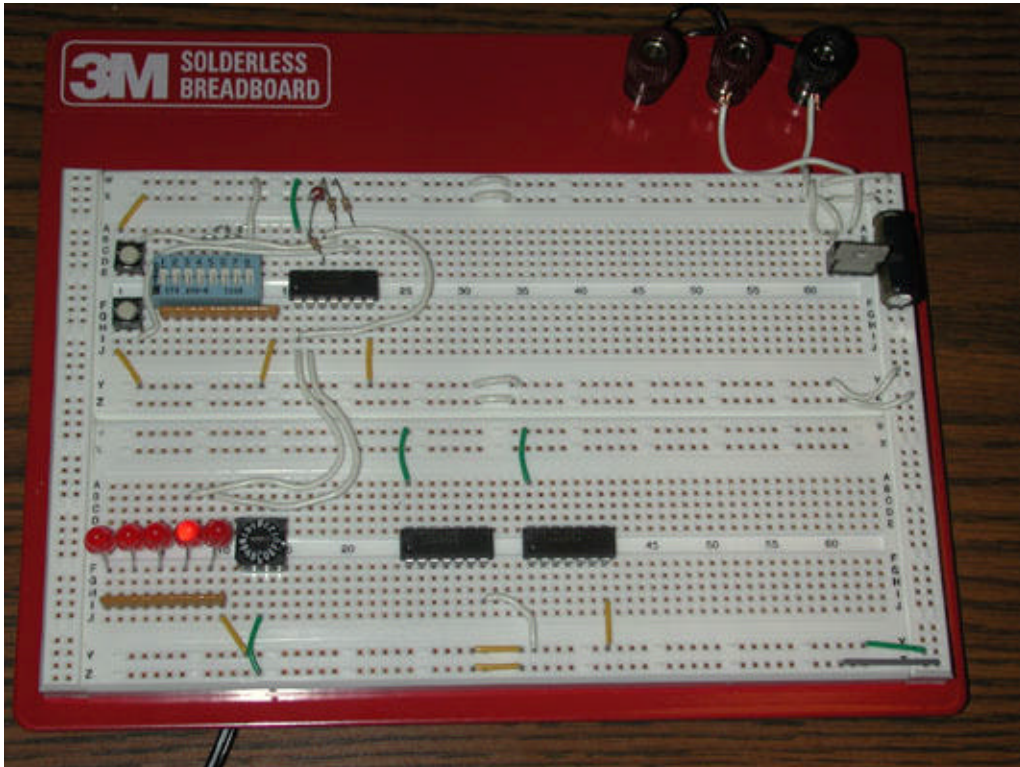
We are going to build *digital* circuits that use the *binary* number system encoded as voltages. That is, each wire will carry one of two symbols “1” or “0” we encode a “1” as +5V ( $V_{DD}$ ) and a “0” as 0V (GND). In this part of the lab we will use switches to make 1s and 0s and LEDs to observe them. The 74AC14 (see the data sheet) is a hex *inverter*, a logic circuit that inverts 1s to make 0s and 0s to make 1s. This particular type of inverter has an input with *hysteresis* (“a retardation of the effect when the forces acting upon a body are changed”). We are going to use the hysteresis of the 74AC14 to *debounce* the pushbutton switches and to make a simple relaxation oscillator. The oscillator generates an alternating source of 1s and 0s. This is useful to flash an LED, as a stimulus to observe the dynamics of circuits, and to *clock* sequential circuits.

The switches make a connection in one direction – toward  $V_{DD}$  for the DIP switch and toward GND for the pushbutton. To pull the signal in the other direction when the switch is open (unconnected) we use a resistor. We also use resistors (of lower value) to limit the current through the LEDs. The resistor networks each have 9 resistors with one terminal of each resistor wired to the pin near the dot on the package – this saves a lot of wiring.

Rather than give you step-by-step directions, here are the circuits you are to wire up. Refer to the photo below for suggested component positions. Try to keep your wiring neat.



When you're done it should look like this – less the two 4007 chips already in place for lab 2.



You will need to provide a connection to  $V_{DD}$  and GND for each of your DIP chips. By convention, the top left of each DIP has a little dot on it. The pin next to the dot is pin 1. The pins are numbered from pin 1 down the left side of the chip to the bottom, then move over to the right side of the chip at the bottom and keep numbering until you reach the top. On most, but not all DIP chips, the bottom left pin is GND (so connect it to GND) and the top right to  $V_{DD}$  (so connect it to  $V_{DD}$ ). On a 14-pin DIP, GND is pin 7,  $V_{DD}$  is pin 14.

Once you have it wired, try the following to verify your circuit and familiarize yourself with its operation:

1. Connect the four outputs of the rotary switch to four LEDs. Rotate the switch and observe the LEDs.
2. Connect the output of your oscillator to one LED. Also connect the output to the input of one of the unused inverters on the 74AC14 and connect the output to a second LED.
3. Observe the output of the pushbuttons – both before and after the 74AC14 inverter on the LEDs. Explain what you observe.

## Terms and Explanations (or An Idiot's Guide to Electronics).

- Voltage. The voltage between two points is a potential difference between them. It is measured in volts (V). The simplest difference is DC (direct current) voltage, where the difference between the two leads (as in out of your wall transformer) is constant. AC (alternating current) voltage indicates that the difference varies with time – this is what you see out of a AC outlet in the wall. You will note in this lab (as in most digital systems) you are dealing with DC. One AA battery (for instance) gives you 1.5V DC. Most digital electronics today run between 1.5V and 5V DC.
- Current. Current is measured as charge per time, as in how much charge is moving through a wire per second. It is measured in amps (A). In our circuits we will deal with currents on the order of milliamps ( $10^{-3}$  amps).
- Resistance (Ohms or  $\Omega$ ). Defined as voltage over current. Higher resistance indicates less current for a given voltage. Resistors usually range from 10s of ohms to 100k ohms or so.
- Capacitance (Farads, abbreviated F). A capacitor stores charge. Capacitance is defined as charge over voltage, so a device that can store a lot of charge across a given voltage has more capacitance than a device that can only store a little. A farad is a huge amount of capacitance; most capacitors are pF (picofarad,  $10^{-12}$ ) to  $\mu$ F or  $\mu$ F (microfarad,  $10^{-6}$ ). In this lab we use capacitors to smooth out the power supply. Consider what happens when a lot of devices suddenly switch states and demand charge from  $V_{DD}$ . If the power supply is not able to suddenly deliver all that charge, its voltage will instead drop, which will make the devices behave incorrectly. But if a capacitor is charged across the power supply, when more charge is suddenly needed, it is storing that charge and can deliver it instead.
- DIP chips. DIP stands for Dual Inline Package; it looks like a little spider with two rows of pins for legs. It's a handy way of putting several components in a single chip.
- LED. Light Emitting Diode – it's a little light-bulb-looking device. LEDs, like all diodes, have a special property: they only conduct current (and light up) when current is flowing through it in one direction. (This is in contrast to a light bulb, which will light up if current flows in either direction through it.) It is important to always place a resistor in series with a LED. (In other words, don't ever let there be a path between  $V_{DD}$  and GND through a LED without also passing through a resistor.) The reason is because current through an LED with 5 V across it is not physically possible (it has an exponential dependence on voltage) so instead your LED will burn out. The LEDs we are using in the lab have flat spot on the same side as their negative terminal or anode.