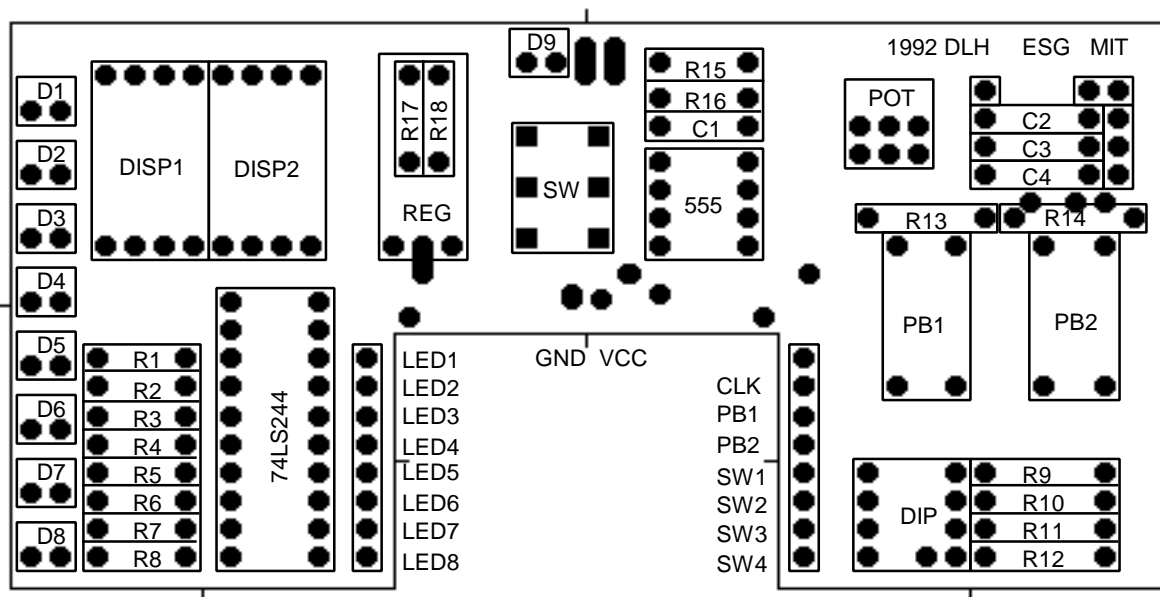


Digital electronics is one step removed from the real world in that it uses voltages to carry information while we humans cannot sense or create voltages directly. In order to use the circuits that we will be building for the rest of the semester, we need to be able to do three things: supply the correct power to operate digital circuits, be able to generate inputs, and be able to read outputs. Since we will use these capabilities in virtually every lab we build, it is most efficient to build them onto a printed circuit board that we will keep with the lab kits. The first part of these notes describe how to use the utility board and what features it supports. The second part contains more advanced information on how the utility board actually works.

The Utility Board

The illustration below shows the utility board that you will build in the first lab. At first it may appear somewhat intimidating, but it really can be broken up into a few systems that are easy to understand.



The board has 18 pins that protrude from the underside and go into holes in a breadboard. These are marked LED1-8, GND, VCC, CLK, PB1-2, and SW1-4.

The first system to understand is the power supply system. Digital circuits typically require two connections for power: 0 volts (called ground and labeled GND) and 5 volts (labeled VCC). A wall transformer brings 6-7 volts of unregulated DC voltage to the utility board. The power system is responsible for producing a steady 5 volt value from this input. When the power switch labeled SW is off, VCC is at 0 volts and no power is supplied to the circuit. When the power switch is turned on, the green light-emitting diode (LED) D9 turns on and VCC rises to 5 volts.

Next we will consider the six input switches: four DIP switches and two push-button switches. The DIP (Dual Inline Package) switches are all part of one box. Depending on their positions, they generate either a logic 1 (5 volts) or a logic 0 (0 volts) on the pins SW1-4. The two black push-button switches generate a logic 1 when pushed down on PB1-2 and a logic 0 when released.

The utility board has 8 LED outputs. These red lights are normally on when disconnected. If a voltage is applied at one of the LED pins (1-8), the corresponding light is off if the voltage is 0 and on if the voltage is 5 volts.

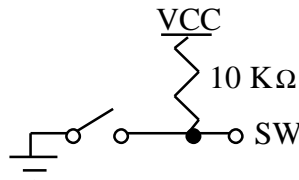
Finally, there is a clock generator. In digital electronics, the term clock refers to a square wave that oscillates between 0 and 5 volts at a constant frequency. Typically, clocks are used to control the action of a circuit; for instance, a typical flip-flop grabs and remembers its input every time the controlling clock rises from logic 0 to logic 1. The square wave is available at the CLK pin. The frequency of the square wave is controlled with two settings. There are four female header pins in the upper right corner of the board. The order of magnitude of the frequency is set by connecting the white wire to one of these header pins. The topmost pin is a user-defined range that is set by adding an additional capacitor between two additional header bins. The second, third, and fourth pins roughly correspond to frequencies in the range of 1, 10, and 100 hertz. Within these ranges, one can adjust the precise frequency by adjusting the gray potentiometer. As the knob turns from left to right, the frequency of the square wave increases.

In the upper left corner are spaces for two Hewlett-Packard hexadecimal displays. Unfortunately, the displays are far more expensive than originally expected so they were omitted.

The information in the remainder of these notes describes how each of the functions on the utility board is implemented. These details require a basic understanding of analog circuits and therefore are beyond the true scope of this class. If you have a strong background in electronics and are particularly curious how your utility board works, you may find the information useful; otherwise, feel free to ignore it.

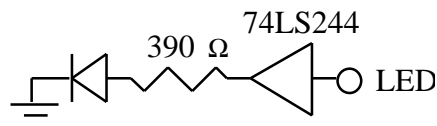
Switches

As noted before, there are two types of switches: pushbutton and DIP. The DIP switches happen to be wired as “Normally High” such that they default to 5 volts when open, but are pulled down to ground when closed. This is illustrated in the schematic below. The pushbutton switches are wired the other way (i.e. with GND & VCC reversed) so that they are normally false when not pressed, but pull up to true (5 volts) when pressed.



LEDs

There are a few concerns that must be addressed whenever using LEDs. One is that LEDs turn on when given about 5 mA of current and may burn up when given more than roughly 20 mA. Therefore, it is important to include a current-limiting resistor to prevent LEDs from burning out. A 390 Ω resistor does the job nicely, allowing $\frac{5 \text{ V}}{390 \Omega} \approx 12 \text{ mA}$ of current to flow. The second concern is that a standard 74LSxx logic chip usually cannot provide 13 mA to turn on an LED. This is solved by placing a buffer chip on the utility board to isolate the LED from any digital circuits being constructed. A 74LS244 chip contains eight buffers capable of providing the 12 mA of current. (Note that the 74LS244 also requires pins 1 and 19 to be connected to ground in order to enable the buffers). Schematics for one of the LEDs appears below:

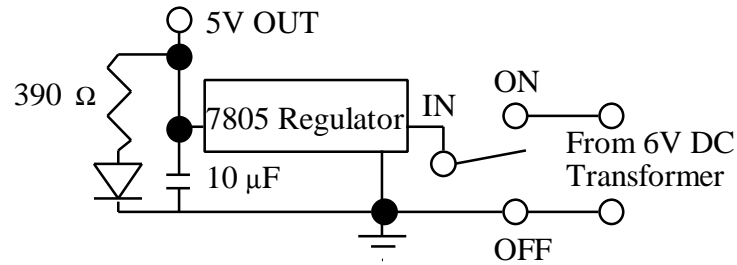


Note that since, when unconnected, the 74LS244 defaults to a high output, all of the LEDs default to being on when disconnected.

Power Supply

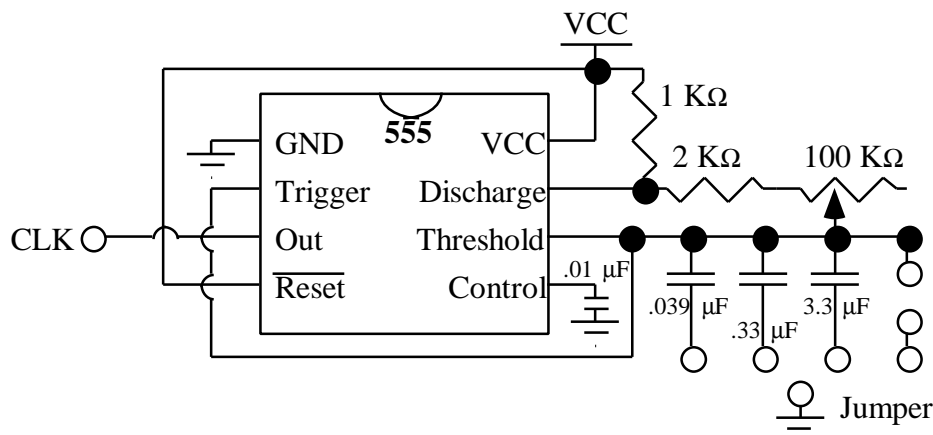
The power supply must generate a constant 5 volts given the 120 volts of AC power coming from the wall. Most of the effort is performed by the wall transformer, which produces a 6 or 7 volt signal with a small amount of ripple in it. The utility board contains a voltage regulator that produces the clean 5 volts from the output of the transformer. In addition, the utility board features an ON-OFF switch and a green LED (with a current-limiting resistor) to indicate that power is on. Finally, an external 10 μF capacitor provides a source of energy that prevents VCC from sagging when lots of current is drawn for a brief period of time. Warning: if a much larger bypass capacitor (say 100 μF) is used, the capacitor’s discharge may destroy the regulator in the event that 5 volts and

ground are accidentally shorted together. The schematic below shows the power supply circuitry on the utility board:



Clock Generator

The clock generator must produce a square wave of adjustable frequency. It is built around a 555 timer chip. A jumper wire selects the order of magnitude while a potentiometer allows the user to fine-tune the frequency. The schematic below illustrates the complete circuit:



The 555 timer alternately charges and discharges the selected capacitor. While charging, current flows to the capacitor through the three resistors. When discharging, the 1K resistor is bypassed. Using some algebra and basic analog electronics knowledge, we can find that the frequency of the oscillation is:

$$f = \frac{1.49}{(5K + 2 \cdot R) \cdot C}$$

where R is the setting of the variable resistor and C is the capacitance connected. For example, the lowest frequency is 2.2 Hz, available by setting the potentiometer to its full 100K and using the 3.3 μF capacitor. A high frequency like 8 KHz can be achieved by connecting a 0.0047 μF capacitor and tuning the resistor to about 17 K.