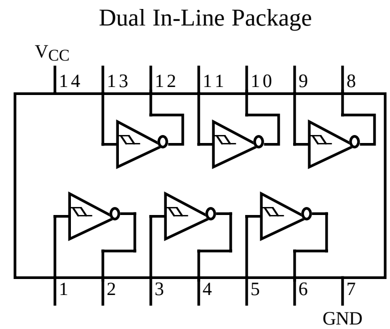
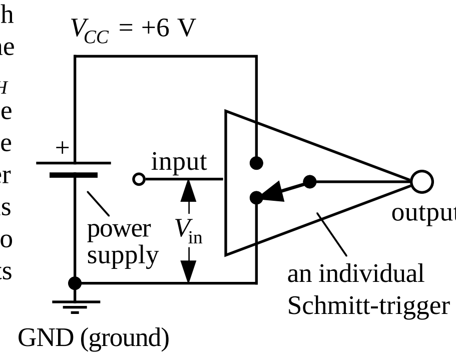
EXPERIMENTAL GOAL

Your goal in this laboratory is to design and build an LED blinker circuit using an integrated circuit called a “hex Schmitt-trigger inverter.”

THEORETICAL BACKGROUND



The integrated circuit contains six (hence the “hex”) separate Schmitt-trigger inverters, each with one input and one output, and two pins labeled V_{CC} and GND that should be connected to the terminals to the positive and negative terminals (respectively) of a 6-V power supply. We will define the potential at GND to be 0 V, meaning that V_{CC} = +6 V. The pin connection diagram to the right shows how the integrated circuit components are connected to the metal pins. Each Schmitt trigger is represented by a triangle; the line going into broad side of the triangle represents the input while the line coming out of the circle at the triangle’s point represents the output.



When the integrated circuit is connected to the power supply, each individual Schmitt-trigger inverter can be modeled as a voltage-controlled switch with the following characteristics. If the voltage difference V_{in} between the Schmitt-trigger’s input and ground *rises* past a threshold voltage V_H (usually about 3.2 V), the output will act as if it has been connected to the negative end of the power supply (that is, the switch in the diagram to the right gets set to the lower position). If V_{in} subsequently falls below a lower threshold voltage V_L (usually about 2.2 V), the output will act as if it has been connected the positive end of the power supply (the switch gets set to the upper position). The input has almost infinite resistance, so it conducts a negligible amount of current to ground from whatever it is connected to.

PROCEDURAL SUGGESTIONS AND NOTES

Given this information about the Schmitt trigger, you should be able to design a circuit using one Schmitt-trigger inverter, a capacitor, and a resistor of your choice that will cause the Schmitt trigger’s output to switch back and forth with a frequency of very roughly 50 cycles per second. Note that whether you are charging or discharging a capacitor, the *difference* $|V(t) - V_\infty|$ between the voltage $V(t)$ across the capacitor’s terminals at time t and the voltage V_∞ that the capacitor would reach as $t \to \infty$ decays exponentially toward zero as follows:

$$|V(t) - V_\infty| = |V_0 - V_\infty| e^{-t/RC}$$

Using this, you should be able to estimate the frequency of your oscillator pretty accurately for a given resistance.

Once you have designed your circuit and think that you can predict the frequency, check with your helper, who after checking your circuit will give you permission to construct it. (Don’t play with the equipment until *after* you have checked with the helper, because it is really easy to destroy the integrated circuit by connecting it to incorrect voltages.) After constructing your circuit, use the oscilloscope to display waveforms at both the input and output ends of your Schmitt trigger, and measure, V_L, V_H, and the frequency of the oscillation, and make *sure* that it is consistent with your theoretical measurement.

Now change the resistor in your oscillator circuit so that it will oscillate at 1 Hz to 2 Hz instead of at 50 Hz. You can connect the output of your oscillator to a second Schmitt-trigger-based circuit (that you will design) to create an LED blinker that will make the LED blink (i.e. turn it on and off) at 1 to 2 Hz. Remind yourself of the current limitations involving an LED and its other characteristics by looking at your notebook entry from Lab 2. Again, do not actually connect your circuit until you have checked your design with your helper.

YOUR CHECKOUT INTERVIEW

During your checkout interview, you should be able to (1) thoroughly explain how your complete LED blinker circuit works, and (2) predict how changing the various resistances or the capacitance in your circuit will modify its behavior. Your Recorder should also have clear diagrams of both your circuits, sketches of the waveforms on the oscilloscope and measured data (V_L, V_H, and frequency) from those displays, and a comparison of your predicted frequency with your chosen resistor for the 50-Hz case with your actually measured frequency for that resistor.

THEORETICAL BACKGROUND

A Schmitt-trigger inverter can be modeled as a voltage-controlled switch with an input and output that operates as follows. The ST-inverter is connected to a power supply with a voltge V_s. If the voltage at the input of the ST-inverter is below V_{in} ª , then the voltage at its output V_{out} will be equal to V_s (logic “high”). If V_{in} = V_s (high), V_{out} = 0V (low). What differentiates an ST-inverter from a regular inverter is that V_{out} exhibits “hysteresis,” i.e. V_{out} depends on the history of V_{in}. The value of V_{out} swtiches from V_s to 0V when the value of V_{in} <u>increases</u> above a particular threshold voltage V_H, and V_{out} swtiches from 0V to V_s when the value of V_{in} <u>decreases</u> below a particular threshold voltage V_L.

Armed with this knowledge of the ST-inverter, explain what the circuit in Fig. 1 does qualitatively and quantitatively. In particular, sketch and describe how V_{out} varies with time quantitatively. You should express quantities in terms of V_s, V_H, V_L, R and C.

In deriving the behavior of the above circuit, you may find the following information helpful:
If the voltage across a capacitor with capcitance C is initally V_i, and if it is connected to a battery V_s via a resistor with resistance R at t = 0, then the voltage across the capcitor
$V(t) = V_s (1 - e^{-t/RC}) + V_i \; e^{-t/RC}$

PROCEDURAL SUGGESTIONS AND NOTES

Once you understand how the circuit Fig. 1 works, build it with a ª 1 µF capacitor and a resistor of your choice to measure V_H and V_L, and verify your predictions.
(Are we spelling things out too much here by telling them what to measure?)