Lab 12: Timing sequencer (Version 1.5)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Summary

In this lab, you will build a programmable time sequence of instructions. Timing is derived form a master oscillator, and each instruction is tied to this master oscillator with a programmable time sequence. In this lab, you will program a stop light as a toy model for more complex time control.

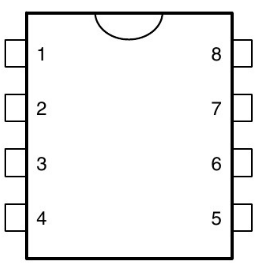
Sketch a timing diagram to help design the circuit. There are 4 traces on the timing diagram:
1) master oscillator,
2) green light,
3) yellow light, and
4) red light.

The master oscillator (~ 10 sec period) will be a rectangular wave. The green light turns on when the master oscillator waveform has a falling (negative) edge. The green lamp stays on for a selected time (3—4 seconds) that is independent of the master oscillator. When the green light turns off (falling edge), it triggers a second rectangular pulse to turn on and off the yellow light (~ 2 sec). When both green and yellow lights are off, the system defaults to red light on. It then waits for the next trigger pulse from the master oscillator and the cycle repeats.

Pinout diagrams

The connection diagrams for electronic components that are used in this lab are (from left to right) the 555 timer, 2N2222 transistor or 2N3904 transistor.

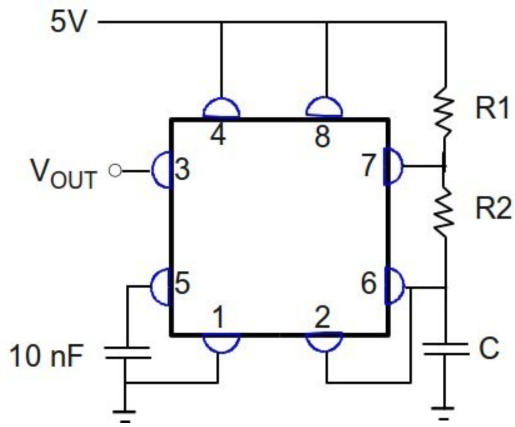
Pin connections
(top view)



This lab requires three 555 timers and two switching transistors.

Master oscillator

The master oscillator, or master clock, that runs the circuit is implemented with a 555 timer chip in the astable configuration; it generates a periodic rectangular wave. This circuit was built and analyzed in Lab 11 and is configured as shown in the following diagram:



Choose the values of R1 (> 1 kΩ), R2, and C to produce a sufficiently long period (8—10 sec) with frequency defined as follows:

$$f = \frac{1.44}{(R1 + 2R2)C}$$

and positive duty cycle calculated by:

$$\text{Duty cycle: } \frac{R1 + R2}{R1 + 2R2}$$

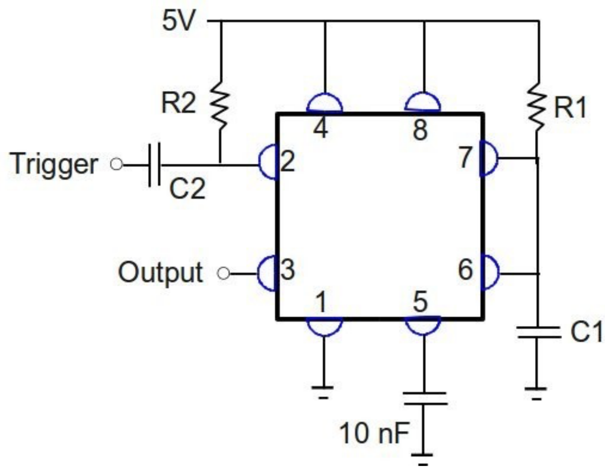
The duty cycle is not critical, but the circuit will be easier to troubleshoot if it is made much larger than 50%. When configuring 555 timers, it is convenient to run long jumper wires from pins 6 and 7 to an uncluttered area of the breadboard to allow easy component substitution. Confirm proper operation of the master oscillator with the oscilloscope.

Single square pulse generator

The 555 timer can be built in a monostable configuration in which it can be triggered to output a single square pulse. Two separate pulse generators (based on 555 timers) will be used to turn the green and yellow lights on and off. Referring to the following diagram, the pulse duration (green or yellow lamp "ON" time) is given by:

$$T = 1.1R1C1$$

The trigger signal for the green lamp pulser (*not* the yellow lamp) comes from the output of the master oscillator. The trigger point occurs on the negative slope of the oscillator waveform.

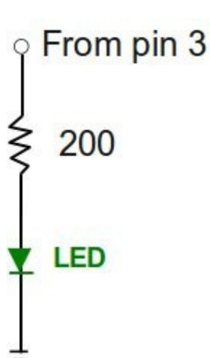


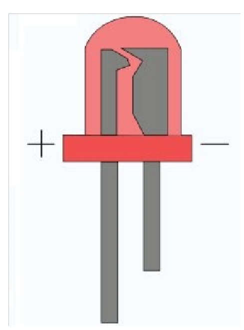
It is important that this trigger signal stays at ground for a time that is less than the pulse it is producing. Otherwise, the output pulse will just invert the trigger pulse. To make sure this stage operates correctly, the input pulse is differentiated with the highpass RC filter defined by R2 and C2. Pin 2 will see only the positive and negative edges of the input waveform on a 5V DC offset. The component values are not critical; R2 ~ 50 kΩ and C2 ≤100 nF should work well. Build the green lamp pulse generator and use the scope, on CH2 and DC coupling, to verify that the master oscillator triggers the green lamp correctly. Do not connect any of the LEDs until the circuit is completed and working.

The output of this pulse generator will do two things: 1) turn the green LED on and off and 2) trigger the second pulse generator for the yellow LED. When the green LED turns off, it will trigger the second pulse generator. For the second (yellow light) pulse generator, select values of R1 and C1 to get an on-time of about 2 seconds. Use values of R2 and C2 close to that used in the first pulse generator. Verify proper timing operation with the oscilloscope.

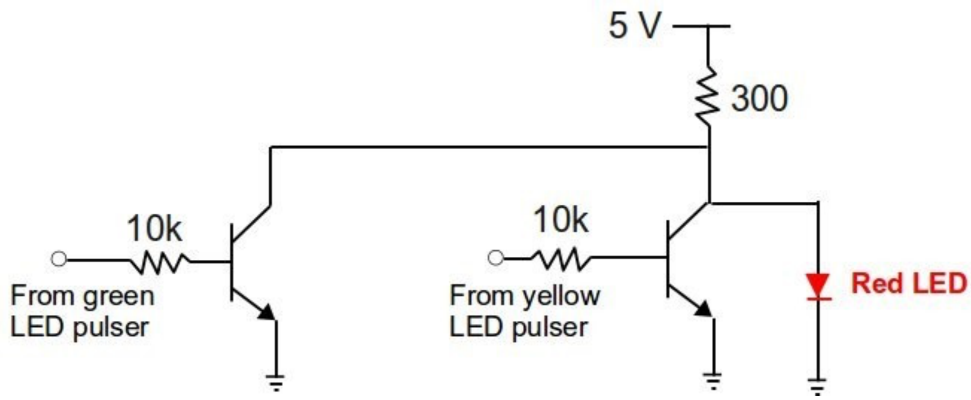
Arrange the R-Y-G LEDs in the pattern of a traffic light on the circuit breadboard. The current in each diode should be limited with a 100--200 Ω series resistor as shown in the diagram. Unlike a resistor, a diode cannot be placed in a circuit arbitrarily. The anode (+ terminal) should be connected to the resistor and the cathode (− terminal) to ground.

Proper orientation of the LED can be verified by connecting it through a resistor to the 5V supply. *Do not connect any LED to a voltage source without a current limiting resistor in place.*





The final step is to wire the logic for the red lamp. This can be done, in principle, with another 555 pulse generator. It is more straightforward and reliable to enable the red light with a logical NOR gate connected to the green and yellow lamp driver pulses. This is done using a transistor switching circuit as described and built in Lab 5.



Use the 2N2222 or 2N3904 NPN bipolar junction transistors (see pin diagrams above) to build the NOR gate. When you have a complete working circuit, have it evaluated by the instructor.

Cycle control

Design the traffic light but now with 5-10x faster clock rate. For that, you need to chose the proper combination of R's and C's controlling the duty cycle and frequency of the oscillators. This shows you have good control of timing for different processes. Compare your calculated times (duty cycles and rates) with the experimental observations.

Analysis

The analysis for this lab consists of the analysis of each component and their timing properties, including the master oscillator, the green/yellow-lamp oscillators, and logic gates. Comparison with theoretical timing are required. Include diagrams, waveforms, measure time comparisons with theory, and working principle of the traffic light based on timing control.

In addition, analyze the time response of the high pass circuit with bias (assuming infinite input impedance of the pin2 in the 555 timer), and compare with observations.