Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

Lab 5: Design project, Part 3

6.117 Introduction to Electrical Engineering Lab Skills (IAP 2020)

Introduction

In this lab, you will finish construction of the design project and assemble the infrared (IR) transmitter. The goal of the IR transmitter circuit is to produce a signal that can be decoded by the IR receiver circuit you assembled in Lab 4 and used to remotely enable and disable the audio amplifier on the receiver PCB. The transmitter accomplishes this by using **amplitude-shift keying** (ASK) to transmit digital data. ASK is a **modulation** scheme that uses changes in amplitude to represent binary digits. Modulation is the process of encoding information in a (typically high-frequency) **carrier** wave. The modulation scheme used in this system is shown in Figure 1.

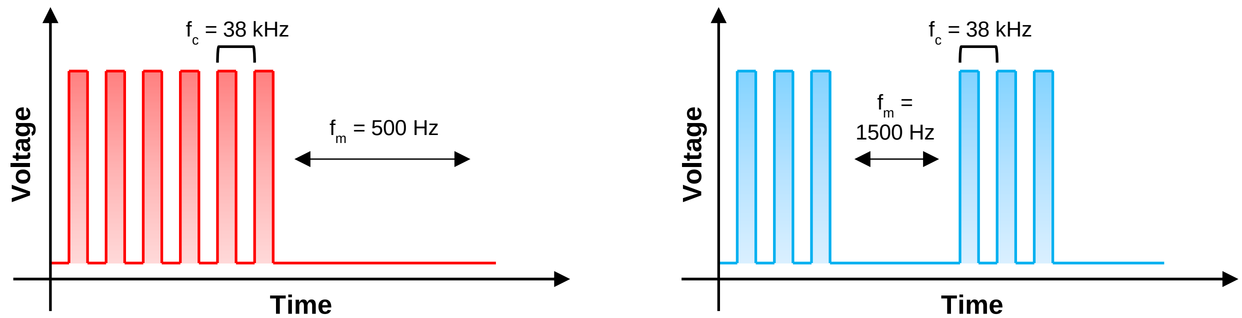

Figure 1: IR transmission scheme for 0 (left) and 1 (right)

To transmit a “0,” the transmitter uses a modulation frequency (f_m) of 500 Hz. To transmit a “1,” the transmitter uses f_m = 1500 Hz. The modulation frequencies were chosen to balance accuracy and selectivity. **Selectivity** is the ability of a receiver to distinguish between multiple incoming transmissions. Accuracy is the ability of the receiver to reliably distinguish between a “1” and a “0.” If the modulation frequencies for 1 and 0 are too far apart, the signal may be susceptible to interference. Conversely, if the modulation frequencies are too close together, it becomes difficult to distinguish between the two.

The transmitter PCB is designed to be powered by a single 9V battery. Timing for the transmitter is accomplished by three 555-type timers. The user input keys activate a timer configured for 500 Hz to transmit a 0, and 1500 Hz to transmit a 1. The outputs of these timers are logically multiplied together and used to modulate a 38 kHz carrier oscillator. A block diagram of the transmitter is shown in Figure 2.

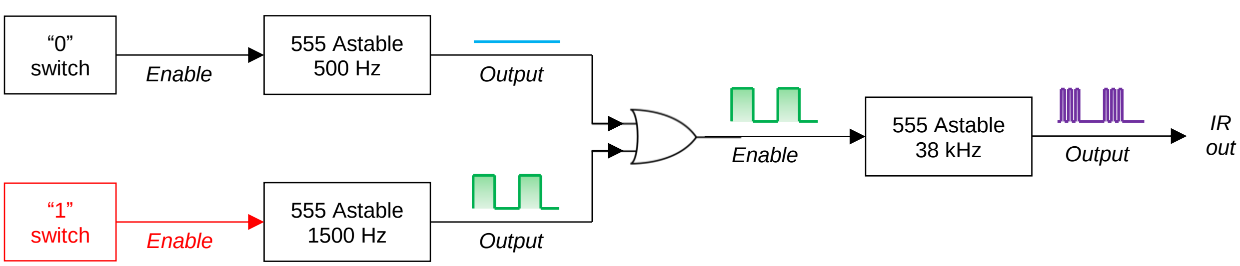

Figure 2: Transmitter block diagram

The low-frequency (500 Hz and 1500 Hz) timers are contained in a single package. The NE556 timer is a single IC that contains two circuits identical to 555 timers. The outputs of both of these timers are fed into a **diode-OR** circuit. The diode-OR circuit uses two diodes to perform a logical OR operation. The diode-OR circuit was used in the transmitter to eliminate the space required by a more complex logic gate (using either MOSFETs or an IC). When either timer output is high, current is allowed to flow through

R111, causing the voltage at the reset input of U102 to rise. When either timer output is low, no current is allowed to flow through that diode. When both outputs are low, no current flows through R111 and the voltage at the reset input falls to 0. The output of the diode-OR circuit enables and disables U102 by using its reset input. When the reset input is low, U102 is disabled and its output is forced to 0. By pulsing the reset input, we can generate ASK-modulated signals as described above.

User input is provided by two momentary switches, S101 and S102. Each switch is accompanied by a simple RC **debounce** circuit that minimizes the chance of a single button press generating multiple electrical pulses. For example, when S101 is pressed, C101 charges through R103. When S101 is released, C101 discharges through R104. However, since R104 is much larger than R103, C101 discharges much slower than it was initially charged. If S101 is pressed again before C101 discharges, the voltage at the reset input of U101A rises again, and U101A is never disabled.

Assembly

This section makes extensive use of the transmitter schematic handout.

Assemble the transmitter PCB according to the same steps used to assemble the receiver PCB. In particular, recall all of the following steps:

1. Always **wear safety goggles** when soldering or clipping leads.
2. If using the tip cleaning sponge to clean the tip of your soldering iron, always **wet the sponge** before use to prevent damage to the tip cleaner.
3. Pay attention to the orientation of components. **Always check with a member of the course staff** if you are unsure about the orientation of a component.

The components you will need for the audio amplifier section are listed in Table 1. Components in *italics* are orientation-sensitive. If you have trouble locating the reference designators, see the assembly diagram provided in Figure 3 (at the end of this handout). As before,

DO NOT SOLDER ANY COMPONENTS WITHOUT APPROVAL.

Note that many of the components used in the transmitter PCB, while similar to those used in the receiver PCB, are sized differently. In particular, all resistors used in the transmitter (except R107) are ⅛-watt resistors, which are much smaller than those used in the receiver. R107 dissipates more than 0.125W, so it is a larger ¼-watt resistor. You must insert R107 vertically in order for it to fit properly. Additionally, C109 is shorter than the 100uF capacitors used on the receiver. The larger 100uF capacitors will not fit in this footprint.

Testing

In order to test the transmitter, you must first calibrate its onboard low-frequency oscillators. Calibrate the oscillators according to the following instructions:

1. Turn the transmitter on by sliding SW103 toward the top of the PCB. Connect the variable power supply to J101 (the positive connection is marked by a “+” on the PCB). Slowly increase the output to 9V and ensure the current **does not exceed 0.1A**.
2. Set the oscilloscope to a vertical scale of 2V/div and a horizontal scale of 500us/div. Add a frequency measurement to the channel you will use to measure the oscillators.
3. Press S101 and measure the voltage at pin 4 of U102. Adjust RV101 until the frequency is as close to 500 Hz as possible.
4. Press S102 and measure the voltage at pin 4 of U102. Adjust RV103 until the frequency is as close to 1500 Hz as possible.

Next, you must calibrate the high-frequency carrier oscillator. This will require the use of both the transmitter and the receiver PCBs. This section assumes you have already completed and tested the IR receiver section of the receiver PCB—**you must complete and test that section if you have not already done so**. Calibrate the oscillator according to the following instructions:

5. Turn the transmitter off by sliding SW103 toward the bottom of the PCB. Obtain a 9V battery connector from the back of the lab and attach it to J101. Connect the red wire to the positive connection and the black wire to the negative connection.
6. Obtain a power supply for the receiver from the back of the lab. **Make sure the receiver is not connected to the variable power supply or to any other power supply**. Plug the power supply into a wall socket and connect it to the barrel jack on the receiver. This will power up the receiver.
7. Point the transmitter at the receiver and press S101. Using the oscilloscope, measure the voltage at pin 8 of U301 on the receiver PCB.
8. Adjust RV102 on the transmitter until the voltage displayed on the oscilloscope is at its maximum amplitude.

Now, disconnect the oscilloscope from the receiver. Adjust RV301 on receiver so it is at the 0% position (completely counterclockwise). Aim the IR emitter on the transmitter at the photodiode on the transmitter. Enter your passcode using the transmitter and ensure the LEDs on the receiver change state.

Table 1: Components for IR transmitter

Resistors

Reference designator	Value
R101	100kΩ
R102	10kΩ
R103	1kΩ
R104	10kΩ
R105	100kΩ
R106	15kΩ
R107	15Ω
R108	100kΩ
R109	3.9kΩ
R110	1kΩ
R111	3.3kΩ
R112	10kΩ
R113	1kΩ

Connectors

Reference designator	Type
J101	Terminal block

Capacitors

Reference designator	Value
C101	100nF
C102	100nF
C103	10nF
C104	1nF
C105	10nF
C106	100nF
C107	100nF
C108	10nF
C109	*100uF*
C110	1uF

Diodes

Reference designator	Type
D101	*1N914*
D102	*IR emitter*
D103	*1N914*
D104	*RED*
D105	*1N914*

Switches

Reference designator	Type
S101	Push switch
S102	Push switch
SW103	*Slide switch*

Potentiometers

Reference designator	Type
RV101	10kΩ
RV102	10kΩ
RV103	2.2kΩ

ICs

Reference designator	Type
U101	*NE556*
U102	*NE555*

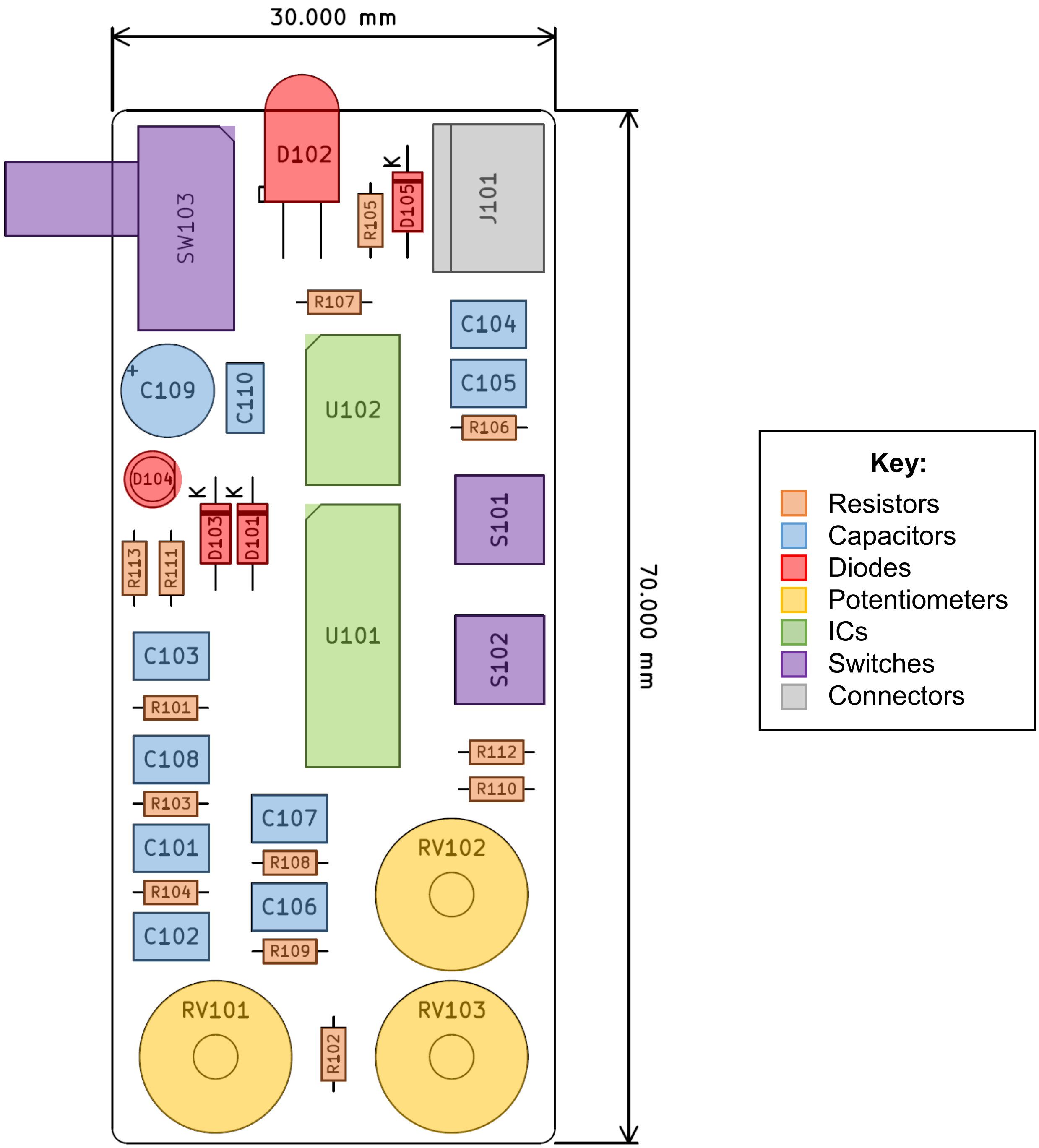

Figure 3: Transmitter PCB assembly diagram