The CMPE 118 Mini-Beacon Board
Dept. of Computer Engineering, UCSC

Background:
The CMPE118 Mini-Beacon board is a small PCB designed with only through hole parts in order to learn to solder, as well as to give you a functioning piece of test equipment for later labs and designs.

The Mini-Beacon board is based on an LM555 timer chip, set to oscillate at 1.5-2.5KHz (set by resistors R1 and R2, see below), at 50% duty cycle. As you will be building analog filters to detect 2KHz IR beacons later in the quarter, this board will allow you to have a test source for your filter, as well as having two off peak signals that your filter should reject.

The power input is reverse polarity protected using a single silicon diode. The data sheet for the LM555 is available at the class website at: https://classes.soe.ucsc.edu/cmpe118/Fall15/Datasheets/LM555.pdf.

Theory of Operation:
The LM555 Timer chip is a very ubiquitous chip used in myriad circuits to generate various signals and decode them. It is a highly stable timing source, does not vary with either input voltage or temperature, and can be used for such applications as: precision timing, pulse generation, time delay, PWM, frequency division, and a host of others. It is capable of sourcing or sinking up to 200mA, which allows you to directly drive moderate loads.

For this specific application, we have set up the 555 as an astable 50% duty cycle oscillator, and will use the output to drive two LEDs (visible and IR) in a sourcing configuration. Note that the traditional astable oscillator circuit (Fig. 4 in the data sheet) cannot achieve a 50% duty cycle. The way this works is by feeding back the reset pin into a charge and discharge RC circuit such that the output toggles between on and off.

However, there is a variation on this design (Fig. 14 in the data sheet) that is better able to achieve 50% duty cycle. This modifies the previous circuit by moving the resistor (RB) in between the trigger and the threshold pin. In effect, you have a push-pull circuit to create a better charge/discharge ramp.

For the 50% duty cycle oscillator, the initial charge time is given by: $t_1 = 0.693 R_A C$. The output low time is: $t_2 = \left(\frac{R_A R_B}{R_A + R_B}\right) C \ln \left(\frac{R_B - 2R_A}{2R_B - R_A}\right)$, and lastly the frequency is given as: $f = 1/(t_1 + t_2)$, and the corresponding duty cycle is: $\%DC = t_1/(t_1 + t_2)$.

In order to have a 2KHz frequency, and a 50% duty cycle, the capacitor is set at 0.027uF, $R_A$ is 13KΩ, and $R_B$ is 5.6KΩ. This results in $t_1 = 0.243ms$ and $t_2 = 0.256ms$, resulting in a frequency of 2.00KHz, and a duty cycle of 48.67%.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>$R_1$ ($R_A$)</th>
<th>$R_2$ ($R_B$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5KHz</td>
<td>18kΩ</td>
<td>7.5kΩ</td>
</tr>
<tr>
<td>2.0KHz</td>
<td>13kΩ</td>
<td>5.6kΩ</td>
</tr>
<tr>
<td>2.5KHz</td>
<td>12kΩ</td>
<td>4.7kΩ</td>
</tr>
</tbody>
</table>
In order to set the frequency of the beacon, there are three matched resistors for \( R_A \) and \( R_B \) (\( R_1 \) and \( R_2 \) on the schematic and silkscreen). Note that on the back of the board has this same table with the resistors for all three frequencies (1.5, 2.0, 2.5KHz).

**Using the CMPE118 Mini-Beacon:**

In order to make use of the CMPE118 MiniBeacon, you will need to apply power to the power connector (J1), with between 4.5 – 12V on the + terminal, and ground on the other. The beacon will start up and deliver the square wave to the LEDs immediately, the visible LED can be seen with the naked eye, and the IR LED is visible through most cellphone cameras.

**Assembling the CMPE118 Mini-Beacon Board:**

The CMPE118 Mini-Beacon boards come unassembled. That is, you will be soldering all of the components onto the board and verifying that it is functional afterwards. There are a few tips and tricks to assembling a PCB, but mostly it comes down to planning what you are going to do first, and then executing your plan.

![PCB Diagram](image)

In the case of this board, there are several components that need to be inserted into the board and soldered down. We have provided a “diode bender” that will aid in getting the leads of the resistors and diodes into the right shape for insertion. There are two capacitors that need to be inserted with different values: \( C_1 \) is a 0.027uF, and \( C_2 \) is 0.01uF. Make sure you put the right one in the right place.

Both of the caps, \( C_1 \) and \( C_2 \), look like yellow gumdrops. \( C_1 \) is labeled “273” and \( C_2 \) is labeled “103.” Double check that you have them in the right place BEFORE you solder them down.

The diode, \( D_1 \), is there to prevent reversing power and ground, and it is important to match the line on the diode to the line on the board. This ensures proper current flow. Lastly, there are three different values of resistors on the board, \( R_1 \), \( R_2 \), and \( R_3=R_4 \). \( R_1 \) and \( R_2 \) are set by the table on the back of the board, and you should make sure you have a matched pair for \( R_1 \), \( R_2 \) before you solder them down. Resistor values can be confirmed using the color codes (and also by measuring them with a multimeter).

The LM555 chip has a dot on the chip next to pin 1, make sure to position that dot next to the semi-circular cutout on the silkscreen (next to \( C_1 \)). The green visible LED has a flat part of the circle, match that up to the image on the silkscreen. The IR LED has a bump sticking out of one side, make sure that points outwards on the board.

The power connector needs to be pressed against the side of the board and held there while soldering in order to make a good mechanical as well as electrical connection. All components of this board are on the top side (with the CMPE-118/L MINI-BEACON V1.0 label), therefore all of your soldering will be on the bottom side. Make sure the components are well seated and don’t move while you solder them.
If you have done everything correctly, the assembled board will look like this:

The tutors/TAs will inspect your board for good soldering, and test it to make sure it is functional. You might want to take a Sharpie and write down which frequency it’s on. Keep this board in your lab kit, as you will need it in further labs to come.

**CMPE118 Mini-Beacon Board Schematic:**