Eclectronics Mini-Project 1

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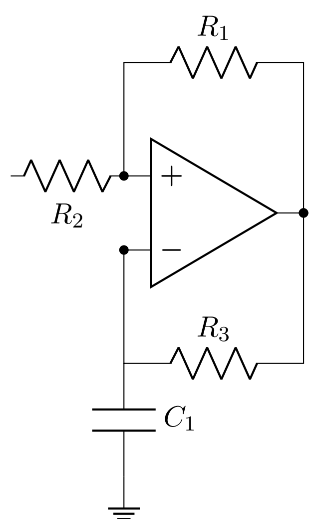
1 Introduction

In this project, I used LTspice and KiCad6 to design a USB-powered LED flasher circuit on a small two-layer printed circuit board (PCB) using surface-mount components. The circuit will flash an LED with a period of within ±10% of 1 s.

2 Design Decisions

2.1 Choosing Values

To create this circuit, also known as a hysteretic oscillator, 4 main components needed to be selected, 3 resistors and 1 capacitor. The unknown resistors and capacitors are labeled R_1, R_2, R_3, and C_1 respectively below.



In order to find these values, I used an equation from "Another Book On Circuits" which can be seen in Equation 1. In this case, I had T as 1 second as that was the period we were designing for.

$$T = \tau log(\frac{V_{dd} - \alpha(V_{dd} - V_{ref})}{\alpha(V_{dd} - V_{ref})}\frac{V_{dd} - \alpha V_{ref}}{\alpha V_{ref}}) \tag{1}$$

While choosing values for this equation, I also kept in mind the tolerances of each component, as it was important to keep my tolerance within 10%. All the resistors had the same tolerance of 1%, while the capacitors had a range of tolerances. I first focused on finding the values of the capacitor and the R_3, which are related by $\tau = R_3 * C_1$. This is because R_1 and R_2 are tightly related due to $\alpha = R_1/(R_1 + R_2)$, which means $0 \leq \alpha \leq 1$. After plugging in a few various values of R_3 and C_1 (using values from the list of usable parts) into Equation 1, I found a value for R_3 and C_1 that resulted in an α value that was between 0 and 1. These values were $2M\Omega$ and $0.1\mu F$. With those values as R_3 and C_1, α is equal to 0.15171. Using the equation for alpha and testing various resistor values, I found that when $R_1 = 2000$ (equivalent to a $2K\Omega$ resistor), $R_2 \approx 11183$, a value similar to a $11K\Omega$ resistor.

To confirm that using a $11K\Omega$ resistor still keeps the period to about one second, I recalculated Equation 1 with the chosen values of R_1, R_2, R_3, and C_1, and found that $T \approx 0.9939$, which was close enough to 1 to pursue worst-case analysis with these values.

2.2 Worst-Case Analysis

To do the worst-case analysis, I created a simulation in LTSpice, to test that the circuit would be within the $\pm 10\%$ requirement for the period. In the simulation, I created the hysteretic oscillator with the resistors and capacitors, each with their tolerance calculations. I then ran 64 simulations to look at all combinations for all of the edge cases. Then, I took the results of this simulation and ran them through a MATLAB script to find the average period and check that they are all within 0.1 seconds of a second period. The results of this script can be found in the Appendix.

3 Schematic

The complete schematic of the circuit, which can be found in the Appendix, includes bypass capacitors (matching the datasheet of the Linear Regulator and OpAmp) a voltage divider, and an LED that will blink.

4 Bill of Materials

The Bill of Materials is available in the appendix attached in a zip file, titled MP1_BOM.csv.

5 Appendix

The Appendix includes:

- All the KiCad files in the MP1-OJB-KiCad.zip file.
- The Library of the Footprints is acquired in MP1-OJB-Library.zip, MP1-OJB-2KLib.zip, and MP1-OJB-2MLib.zip.
- The Bill of Materials can be found in the MP1_BOM.csv.
- The LTSpice files can be found in MP1-OJB-LTSpice.zip
- The Matlab script and files can be found in MP1-OJB-MATLAB.zip

In my Eclectronics Github Repo here (long link https://github.com/oliviajobradley/EclectronicsMP1$_{B}link$)

The data from the MATLAB script is below.

Run	Avg. Period
1	0.963441771325839
2	0.963441771325839
3	0.956531958112577
4	0.956531958112577
5	0.969803721599082
6	0.969803721599082
7	0.962875261670039
8	0.962875261670039
9	0.982862393374078
10	0.982862393374078
11	0.975839310917226
12	0.975839310917226
13	0.989202849663465
14	0.989202849663465
15	0.981004268677794
16	0.981004268677794
17	1.06482171114216
18	1.06482171114216
19	1.05718077480107
20	1.05718077480107
21	1.07186132410044
22	1.07186132410044
23	1.06421363809685
24	1.06421363809685
25	1.08633172573497
26	1.08633172573497
27	1.07853597603408
28	1.07853597603408
29	1.09356683773003
30	1.09356683773003
31	1.08568737619174
32	1.08568737619174
33	0.963750719994608
34	0.963750719994608
35	0.956843944798884
36	0.956843944798884
37	0.969781938295991
38	0.969781938295991
39	0.963189406002255
40	0.963189406002255
41	0.983201187065619
42	0.983201187065619
43	0.976156965537296
44	0.976156965537296
45	0.989309790092411

46	0.989309790092411
47	0.982619404443258
48	0.982619404443258
49	1.06513845866522
50	1.06513845866522
51	1.05750924385977
52	1.05750924385977
53	1.07218964931615
54	1.07218964931615
55	1.06430301014787
56	1.06430301014787
57	1.08663144873041
58	1.08663144873041
59	1.07888592802036
60	1.07888592802036
61	1.09357082837057
62	1.09357082837057
63	1.08605650830813
64	1.08605650830813