Lab II:
From Specifications to Prototype

By Kyle Thomson

The point of this lab is to introduce you the concepts of going from your sponsor’s specifications to a final working prototype. You will be introduced to the process of design, using data sheets, and meeting sponsor specifications. Parts A through C must be done by the end of your lab period during the second week of lab. Your final prototype is due at the BEGINNING of the third week of lab.

A. Introduction

Your sponsor has requested that you build a circuit that generates a square wave pulse. By strange coincidence, the frequency requested is equal to 100xA Hz, where A is the last digit of your PID. (If your last digit is 0, A = 10). Additionally, the Duty Cycle of the circuit must be at 70%. This lab will take you through the process of design.

A-1. First, you must understand the concepts of this lab. The sponsor requested that the circuit have a duty cycle of 70%. In your own words, fill in your lab report what duty cycle means.

A-2. Your sponsor is a reasonable person, and has given you a margin for error. Your actual frequency may be within ±5% of the requested frequency. (For full credit on this lab, your circuit must perform in this region, no exceptions) You must also know what your target period is, as well as $t_h$ and $t_l$. Fill all of these in on your lab report. (REMEMBER UNITS!)

A-3. Your facilitator has suggested that you use a National Semiconductor LM555 timer. Coincidently, you happen to already have 2 in your lab kit! You need to obtain the data sheet online. Fill in the box with the web address were the data sheet is available.

A-4. The data sheet gives 6 possible figures for circuit layouts. Determine which figure you will use to layout the circuit. Also, determine what circuit type this is. Fill this information in on your lab report.
B. Design & Decisions

B-1. Now that you have your plan, your layout, and all your relevant information, you can move to the design phase. The data sheet gives you 2 equations, and 3 unknowns. How do you solve this? (Hint: Look at the title of the section)

B-2. You need to solve for your unknowns. Use the area provided on your lab report. Note that the duty cycle equation is wrong in the data sheet. Here is the correct equation: (Additionally, you may want to use other available equations, since they make the design process easier)

\[ D = \frac{R_A + R_B}{R_A + 2R_B} \]

B-3. Fill in your calculated resistances and capacitance on your lab report.

B-4. The values you calculated may be close to actual available resistances and capacitances, or they may not. You have three options:
   A. Build and test the circuit, and see if the frequency falls within the target range (May require rebuilding the circuit)
   B. Use multiple resistors and capacitors to get closer to the desired values. (More soldering, more cost)
   C. Return to your equations, and see if you can change something to get closer to actual values. (May be pointless, as your estimation may be close enough)

Determine which approach you will use, and fill this in on your lab report. Then, after you are set, fill in the final values as well.

B-5. Build your circuit on your protoboard. Use Red for VDD, and Black for GND. It makes it easier on your TA to look at your circuit. Ignore RL when building the circuit.

B-6. Turn on the power supply. Set the power supply to 5V, and turn it off. Attach the banana-to-grabber to your protoboard. Turn the power supply on.

WARNING!
If a yellow light comes on under OVERLOAD, or your amps go past 0.25, turn off the power supply IMMEDIATELY and ask your TA for help. You can burn out your timer chip very easily!
B-5. You now need to test your circuit. Turn on the oscilloscope, and hook it to your output. Press AUTO SET, noted by green.

B-6. Look at the screen. If there is no text, as shown below, press DIGITAL MEMORY, noted by the red circle.

B-7 You should see your waveform. You can obtain the calculations by pressing CURSOR, CALC, TIME, and then desired value. These buttons may be hidden from your view. They are shown below, circled in purple.

B-8. If you get an f=Error, you need more time per waveform. Press the blue circled button above to get more time per screen.

B-9. Record your frequency, period and width. Note that the width the scope selects may be $t_h$ or $t_l$. Determine which it is, and fill in the values on your lab report. Calculate your Duty cycle.

B-10. Have your TA check off that part B is working.
**C. Sponsor Update**

C-1. You have a meeting with your sponsor, showing your fine work. Impressed, your sponsor asks you for an additional part to be added. You need to add a frequency divider to the circuit, with $F = f/3$. Going back to the data sheet, determine the figure of the circuit you will use. Record this in your lab report. Also label this circuit.

C-2. You have problems understanding the data sheet for the circuit you are using. Your facilitator explains to you how it works:

“your time delay, $t_d$, must be between two and three periods.”

Write the equation for time delay, replacing $t_d$ with $2 \times p$ and $3 \times p$ using greater than and less than signs on C-2 in your lab report.

C-3. Using the space on the lab report, calculate the resistance and capacitance you will be using. Fill in the calculated values.

C-4. Once again, you won’t have exact resistors and capacitors. Fill in the resistor and capacitor you used.

C-5. Add your new circuit to your protoboard.

C-6. Turn on the power supply.

**WARNING!**

If a yellow light comes on under OVERLOAD, or your amps go past 0.25, turn off the power supply IMMEDIATELY and ask your TA for help. You can burn out your timer chip very easily!

C-7. Check your frequency. If it is not $1/3$ of your target frequency ($\pm 5\%$) from A-2, you must go back to C-3 and try new values. If your frequency is correct, fill in the frequency and period on your lab report.
D. Final Prototype

D-1. Design day approaches, and you need to have a deliverable circuit to your sponsor. A protoboard just won’t cut it. You do not want to be *that* team. Weighing your options, you don’t have time to send out for a PCB. You will need to solder using a project board. (Coincidently also included in your parts kit!) You need to move parts B and C from your proto-board to the project board. Start by soldering your chips in first, as shown to the right. VDD and GND are the 2 lines that run through the middle of the board. For additional soldering instruction, consult your TA.

The board works as such: anywhere there is white connecting 2 or more holes, when you solder to the bottom, those holes will be electrically connected. (The copper on the bottom connects the holes) This means you have 2 holes per pin of the chip. Additionally, the left and right sides of the board have 2 holes to connect things. It is extremely difficult to solder over non-copper parts of the board. This is intentional, so you don’t accidentally *bridge* a connection. (A bridge is anywhere solder connects without copper underneath it.)

Note that soldering takes 1-3 hours, depending on your skill. This project is due at the **BEGINNING** of lab week 4, so you must come in and solder on your own time!

D-2. Demonstrate your working project to your TA. He/she will fill in the box on your lab report! Do not do this yourself!

D-3. Draw a schematic of your circuit. Note that the use of the schematics from the data sheet will result in **IMMEDIATE FAILURE** of the lab.

D-4. Staple the schematic to your lab report, and hand it in.
Lab Report

Lab II – From Specifications to Prototype

Name: .................................................................

Date: .................................................................

Lab Section Number .............................................

Code of Ethics Declaration

All of the attached work was performed by me as listed above. I did not obtain any information or data from any other student in this lab or any other lab.

Signature ............................................................
Target Frequency: _________  Max Frequency: ____________

Minimum Frequency: ___________

Period: ______________  \( t_h: \) ______________  \( t_i: \) __________

Figure: _____  Circuit Type: _________________________________
B-2 WORK AREA

B-3

RA: ___________ RB: ___________ C: ___________

B-4

Approach: ___________

RA: ___________ RB: ___________ C: ___________

B-9

Measured Frequency: ___________

Measured Period: ___________

Measured Width: ___________

Calculated Duty Cycle: ___________

B-10 I, _____________ (Lab instructor’s initials) verify that part C is working correctly.
C-1

Figure: _____  Circuit Type: _________________________________

C-2 Equation

__________________________________________________________________

C-3 WORK AREA

C-3: Estimated:

R:___________ C: ________________

C-4: Actual:

R:___________ C: ________________

C-7

Frequency:______________   Period: __________________

C-8 I, _________________ (Lab instructor’s initials) verify that part C is working correctly.
FREQ: ________________

PERIOD: ________________

WIDTH: ________________

I, ________________ (Lab instructor’s signature) verify that part D is working correctly.

Make sure to mark the circuit with a sharpie as it is turned in, so it does not get turned in twice by unscrupulous students.