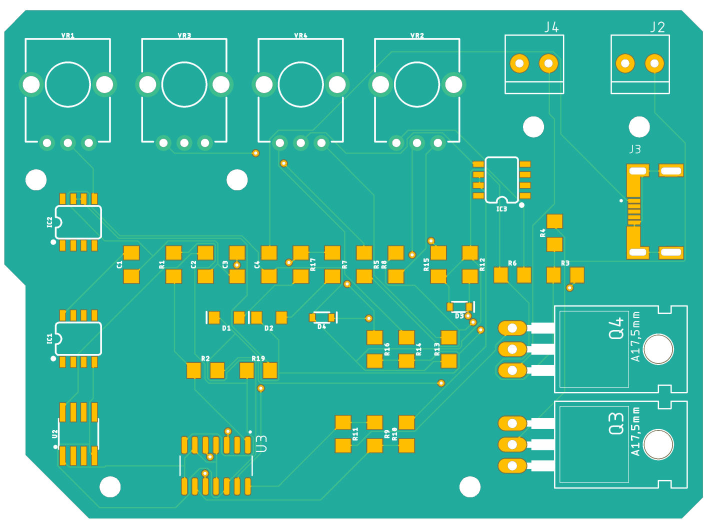
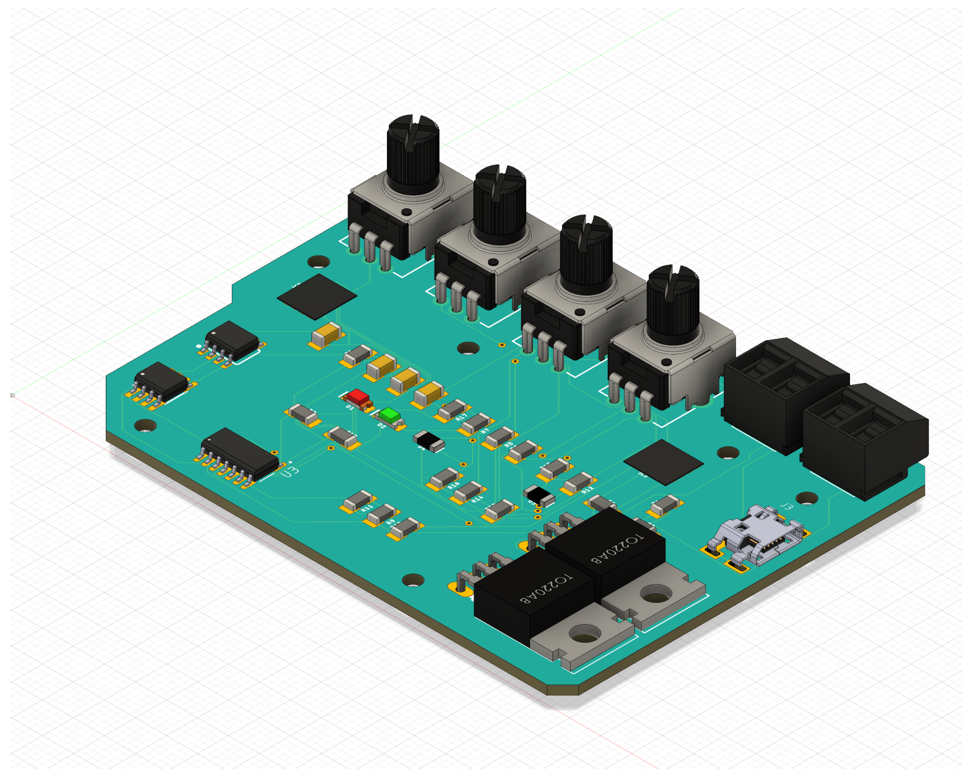
Tim Savas
Homework 11_v2

Homework 11

Doc	**Link**
Eagle Zip	Submitted into Canvas along with this file!
OshPark Quote	https://oshpark.com/shared_projects/wkmne1FM
Falstad Circuit	https://tinyurl.com/y3lsw8sx
BOM	attached here





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Name	SubName	Supplier	Supplier Part Number	Quant	Cost Per Unit	Total Cost	Files Source	Spec Sheet
2134441-2	USB port	Digikey	A118104TR-ND	1	$1.77	$1.77	link	
lm358	op-amp	Digikey	LM358DR2GOSTR-ND	1	$0.44	$0.44	link	link
heating pad	10cm x 5cm	Adafruit	1481	1	$3.95	$3.95	custom	link, link
G4020S	40mm fan	Digikey	1570-1614-ND	1	$15.37	$15.37	custom	link
screw terminal	2-position	Sparkfun	PRT-08432	2	$0.95	$1.90	link	link
lm34	temp sensor	Digikey	LM34DMX/NOPBTR-ND	1	$3.45	$3.45	link	link
LED, 1206	blue	Digikey	160-1643-2-ND	1	$0.36	$0.36	link	link
LED, 1206	red	Digikey	160-1167-2-ND	1	$0.33	$0.33	link	link
TLC372	comparator	Digikey	2156-TLC374ID-ND	1	$0.78	$0.78	link	link
1K potentiometer	trimmer	Digikey		4	$2.71	$10.84	link	link
33K resistor	1206 package	Digikey	CR1206-JW-333ELFTR-ND	4	$0.10	$0.40	custom	link
6.8K resistor	1206 package	Digikey	CR1206-FX-6801ELFTR-ND	2	$0.10	$0.20	custom	link
8.2K resistor	1206 package	Digikey	118-CR1206-FX-8201ELFTR-ND	2	$0.10	$0.20	custom	link
220 resistor	1206 package	Digikey	CR1206-FX-2200ELFTR-ND	2	$0.10	$0.20	custom	link
DDZ9689T-7	diode	Digikey	DDZ9689T-7DITR-ND	2	$0.43	$0.86	custom	link
TIP100	NPN darlington tran	Digikey	2368-TIP100-ND	2	$1.04	$2.08	link	link

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Circuit Design

Here I explain the circuit a bit. Overall this is a classic temperature sensor circuit problem brought to a PCB. We are dealing with familiar components and problems like comparators, positive and negative feedback in op-amps, hysteresis, voltage dividers, and transistors as switches. I go through my thinking here.

Conversion

First off, what a convenient temperature sensor. It reads out degrees-F in mV, and zero F is at zero V. Pretty neat! So here I do a basic conversion on what kind of mV readings we want to be working with.

Temp, F	Vout, mV 10mV/F	Description
0	0	Sensor conveniently has no offset.
92	920	Minimum temperature. When the temp sensor outputs 920mV, the heater should turn on and light the indicator LED.
104	1040	Maximum temperature. When the temp sensor outputs 1040mV, the fan should turn on and light the indicator LED.

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Hysteresis Design

You'll see four comparators in the circuit. Two for the actuators and two for the LED indicators. The LEDs need no hysteresis, that's why they are split out on their own. And for the actuators, the hysteresis is designed in a way that I think accommodates the function of the circuit well. Allow me to speak to how it works:

Temperature	Actuation
92	At any temp below 92 the blue LED is ON. If it was off, the heating pad also turns ON.
96	As temperature rises from 92 or below, the heating pad does not turn OFF until 96F. So there is a 4º buffer for the actuator!
104	At any temp above 104 the red LED is ON. If it was off, the cooling fan also turns ON.
100	As temperature falls from 104 or above, the cooling fan does not turn OFF until 100. So there is a 4º buffer for the actuator!
96-100	This is the happy range. No indicators or actuators on. It's where we want to be.

So there is some nice asymmetric hysteresis going on here. I created this by altering the voltage at the foot of the feedback divider. So why are there potentiometers? Well there aren't perfectly precise standard R values for our given set points, and so the voltage at the foot—which helps control our desired set points/hysteresis—are therefore controlled by some potentiometers I installed. They allow the circuit to be precision tuned. Of course there is a follower to hide any RThev of that second divider from altering the hysteresis.

Actuators

The actuators' comparators output high or low into the base of respective transistors. These are just acting as switches that turn on or off the actuators. I've installed two diodes to prevent voltage backlash when when they're turned off. Darlington pairs are good here. Remember that the idea here is to saturate the transistor, so we use a 10x rule for the currents between collector and current. This just makes "on" really mean "on" and same for "off". The switch is sure of itself. Lastly I use one NPN and one PNP resistor for the two actuators, because we really want an inverse relationship between their threshold breaches. NPN and PNP together are super handy for that.

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LEDs

We want indicator LEDs for the thresholds, but I think it's important that these don't have any hysteresis. These should just be reading out true values to the humans who may need to be reading them and coming to an egg's rescue. This reminds me of the hysteresis in a car gas tank indicator light that may say "empty" when in fact it has a few gallons left to go. With lives on the line, we don't want this imprecision—we want to know exactly what is going on inside of the box. For this reason I've isolated the LEDs with their own comparators without positive feedback or hysteresis.

Mechanical Design

Some notes on my mechanical design. I've gone with 1206 packages for my passive components where possible. From lecture, these seam small enough to look cool and big enough to be able to work with in-hand and with my soldering skills. I've also gone with surface mounted components for my ICs, because those seem like the coolest.

I used Fusion 360 to do some rendering in 3D. To do this, I tied a 3D model to each one of my components in Eagle. Some were from online libraries and others I designed. Then I rendered the board in Fusion 360. clever how these things are tied together.

I punched out some through-holes so I can mount the board in some kind of enclosure. I'll see if I can whip up a simple enclosure by end of semester.

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