Signoff Request - 4/18 - Resistance Measurement

Sunday, April 17, 2022 9:48 PM

The original direction of the moisture probe circuit had to be changed because the normal resistance values of the wood being tested were much bigger than expected and had a much larger range going from about 460 kΩ to 22,400 MΩ [1]. This caused the current mirror to stop working effectively because even when the bias resistor had its value raised the range was too large and significant variations in current occurred. Analysis of this issue was performed in LT Spice and is found in figures 1 and 2.

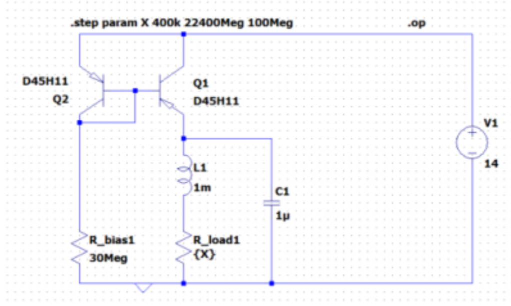

Figure 1: Current Mirror Schematic

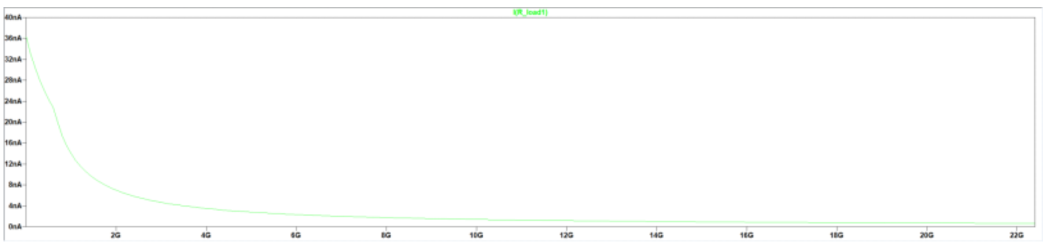

Figure 2: Current Mirror Step Analysis, Resistance (Ω) vs Current (Amps)

Multiple methods were experimented with to fix this issue with the first being a constant current IC to provide a known current value independent of the test resistor. However, this method was found to not work due to the wide range of resistance values. At a constant current which provides a reasonable voltage reading at the low resistance value, the high resistance value returns an excessively large current.

A second method was tested using a modified voltage divider and an MCU with an onboard voltmeter. Through a woodworking webpage, data was found showing a way to hook up a voltmeter with a known voltage, as seen in figure 3, and use some calculations with the internal resistance to solve for the probe resistance [2]. The equation is $R_{wood} = R_{meter} * \left(\frac{V_{Known}}{V_{meter}} - 1\right)$ which is obviously a rearranged version of the voltage divison equation. The plan was to preform this method with a multimeter board called a click. However, no multimeter of that form factor had the necessary resolution for this wide a range

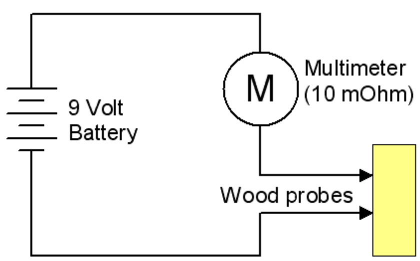

Figure 3: High-Level Circuit

MULTIMETER CLICK ELECTRICAL SPECIFICATIONS

Description	Min	Type	Max	Unit
Measurement resolution	-	$5e^{-4}$	-	V/bit
Current measurement range	0.001	-	1.024	A
Voltage measurement range	0.008	-	17.068	V
Resistance measurement range	0.25	-	20M	Ω
Capacitance measurement range	0.001	-	2.2	µF

Figure 4: Click Specs

All this research left the only option being an auto-ranging ohmmeter which uses a voltage divider. Although I was initially advised away from this option, opening a COTs wood moisture probe and inspecting revealed that this is how they approach that problem as well. The main issue that nomally arises with voltage divider measurements is that care has to be taken in choosing resistors for R1 that have a low tolerance value. However, in this case, we only need moisture content (MC) accuracy to the ones place and the corresponding resistance values are so far apart that it is not vital for resistance measurements to be overly precise. A semilog plot relating the resistance and MC is found in figure 4 which illustrates this.

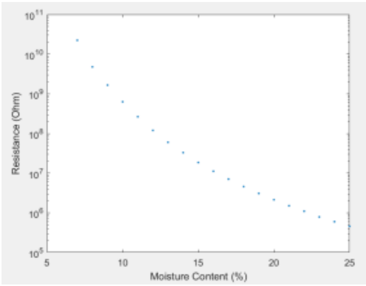

Figure 5: Resistance vs. MC

The circuit which will perform the measurements, as well as auto-ranging, is found in figure 6. Manual 5V and 0V nodes were used to simulate the control that the Arduino would perform. The specific mosfets were chosen because they are common, easily available PNPs with a base voltage of 5V. This voltage is consistent with the Arduino output and using a PNP allows for active low control. Each resistor is labeled with the minimum value it will be intended to help measure. Using this minimum value along with the next level up minimum, a middle resistance was calculated to use as R1 and then modified slightly to match standard manufactured resistance values.

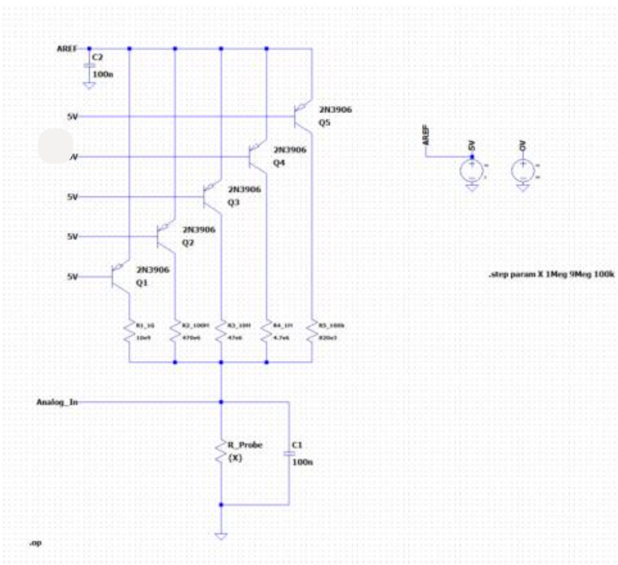

Figure 6: Auto-Ranging Ohmmeter Circuit

Arduino ADC returns a range of 0-1023 which corresponds to a resolution of 4.88mV. This means that if values are less than 4.88mV apart the Arduino will not be able to differentiate them. Figure 7 shows the voltage values that will be read by the Arduino for each 1% moisture content. Also included in the far right column is the difference between each moisture content's corresponding voltage. The different colors represent which resistor in the voltage divider will be set active. This will be set by the program which will test starting at the highest range and lower until it is getting values withing a .5-4 volt range. The edge cases are highlighted to show they will be tested in two ranges of the ohmmeter circuit in order to ensure there is no error. Looking at the right column of the table shows that all differences are well above the resolution of 0.00488 V which means the Arduino will be able to differentiate each 1% MC value from the next MC value. The value which the Arduino will read is also included

Active VD Resistor	MC%	R2 (MΩ)	Output Voltage (V)	Arduino Value	Voltage Difference between Resistances
R1	7	22400	3.4568	708	
R1	8	4780	1.6171	331	1.8397
R1	9	1660	0.7118	146	0.9053
R2	9	1660	3.8967	799	
R2	10	630	2.836	581	1.0607
R2	11	265	1.8027	369	1.0333
R2	12	120	1.0169	208	0.7858
R3	12	120	3.5928	736	
R3	13	60	2.8037	575	0.7891
R3	14	33	2.0625	423	0.7412
R3	15	18.6	1.4177	291	0.6448
R3	16	11.2	0.9622	197	0.4555
R4	16	11.2	3.522	722	
R4	17	7.1	3.0085	616	0.5135
R4	18	4.6	2.4731	507	0.5354
R4	19	3.09	1.9833	406	0.4898
R4	20	2.14	1.5643	321	0.419
R4	21	1.51	1.2158	249	0.3485
R4	22	1.1	0.9483	194	0.2675
R5	21	1.51	3.2403	664	
R5	22	1.1	2.8646	587	0.3757
R5	23	0.79	2.4534	503	0.4112
R5	24	0.6	2.1127	433	0.3407
R5	25	0.46	1.7969	368	0.3158

Figure 7: Voltage Resolution

A proximity sensor is also being included to tell the arm when to stop raising. The B5W-LA01 sensor was chosen for its range of 22.8 to 70 mm or 0.90 to 2.75 inches.

Because the linear actuator chosen in the mechanical signoff has a stroke of 100 mm this is right in the desired range for the stop signal. The proximity sensor will work better than a distance sensor because it will simply give an on when it hits its range which means an analog voltage value won't have to be read or filtered. The final schematic including this part and the motors picked in the mechanical section is found in figure 8.

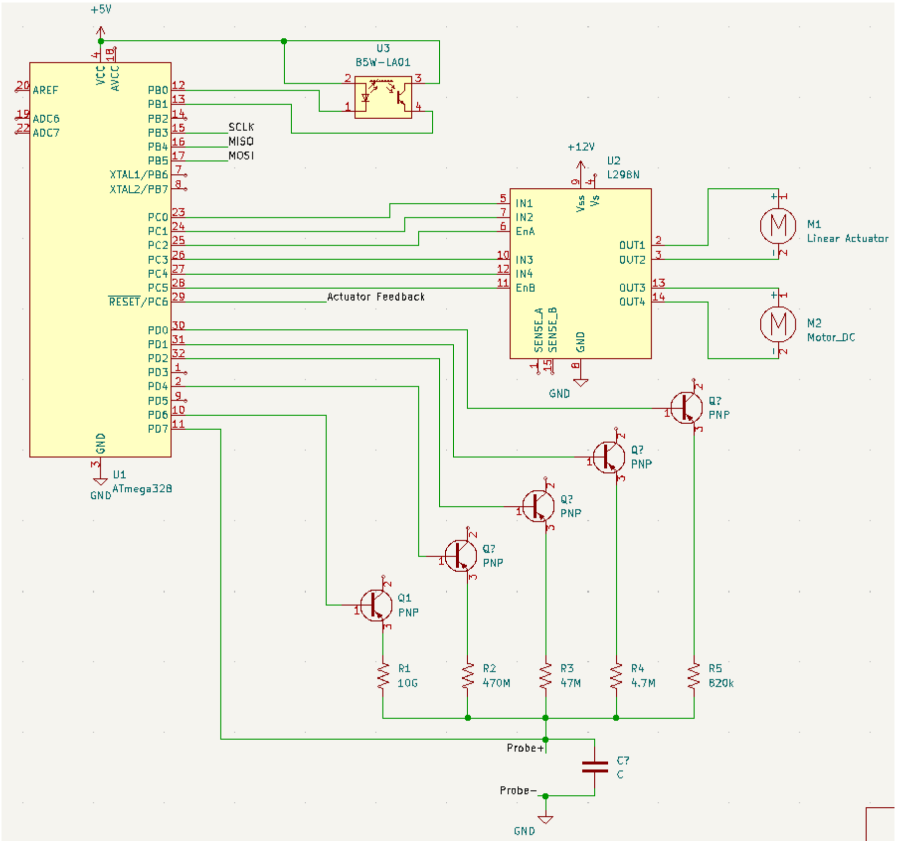

Figure 8: Final Schematic

Finally, in the table below a list of part numbers is included for this signoff. It is likely a PCB will be necessary for this circuit but that will be designed once the circuit design has been approved.

Part Number	Price	QTY	Description	Value	Supplier
2N3906	$0.05	5	MOSFET	PNP	Mouser
C1206F104K5RACAUTO	$0.49	2	Capacitor	100nF	Mouser
RH73X2B10GKTN	$4.57	1	Resistor	10G	Mouser
CRCW1206470MJPEAHR	$0.69	1	Resistor	470M	Mouser
CRCW120647M0JPEAHR	$0.69	1	Resistor	47M	Mouser
CR1206-FW-4704ELF	$0.10	1	Resistor	4.7M	Mouser
CR1206-FX-8203ELF	$0.10	1	Resistor	820k	Mouser
B5W-LA01	7.45	1	Proximity Sensor	22.8mm - 70mm	Mouser
L298N	6.99	1	Motor Driver		Amazon

[1] William L. James. Electric Moisture Meters for Wood. USDA. https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr06.pdf. (Accessed April 16, 2022).
[2] Matthias Swandel. Wood Mositure Meter. WoodGear.Ca. https://woodgears.ca/lumber/moisture_meter.html. (Accessed April 16, 2022).
[3] Multimeter Click. Mikroe. https://www.mikroe.com/multimeter-click. (Accessed April 16, 2022)
[4] Arduino Based Auto-Ranging Ohmeter. Simple Projects. https://simple-circuit.com/arduino-auto-ranging-ohmmeter-lcd/ (Accessed April 27, 2022).