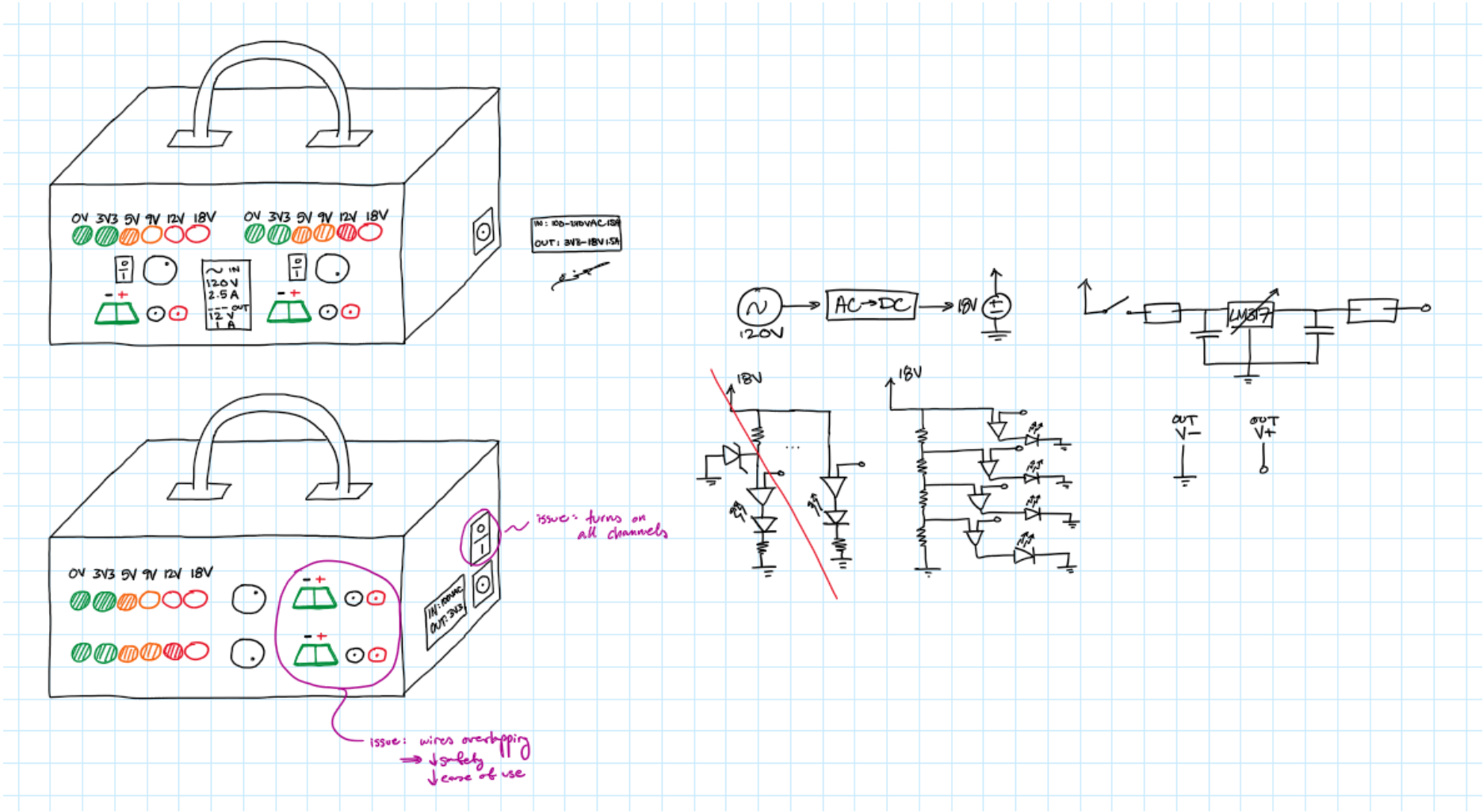
Design Requirements

Power Supply Requirements		Requirements language is to be interpreted as described in RFC 2119
Hamza Dugmag	Revision 1.4	2022-09-07
	Revision 1.3	2022-08-20
	Revision 1.2	2022-08-15
	Revision 1.0	2022-08-07
	Revision 0.1	2022-07-16

Requirement Number	Title	Description	Rationale, Comments	Verification Method
Functional Requirements				
SYS_F_001	Number of Channels	The design must have at least one channel	Primary functionality of a power supply	PCB review
SYS_F_002	Adjustable Channels	At least one channel must be voltage adjustable	Compatibility with a wide range of experiments and projects	PCB review
SYS_F_003	Constant Channels	There may be constant voltage channels	Ease of use when working with common voltages (e.g., 3.3V, 5V, 9V, 12V)	PCB review
SYS_F_004	Enclosure	The design must be enclosed in a 3D printed case	Permanent solution and aesthetics	CAD review
SYS_F_005	On/Off State	Each channel must be switched on and off individually using a rocker switch	Ease of use since there is no need to unplug/plug the AC-DC adapter each time	Experimental testing
SYS_F_006	LED Indicators	A row of LEDs per channel must indicate the on/off state and voltage level	Crude indicator to show the system is working properly; use a voltmeter for accurate reading	Experimental testing
SYS_F_007	LED Pattern	The LED voltage indicator colors and pattern may be arbitrary	E.g., green (>GND), green (>=3.3V), yellow (>=5V), yellow (>=9V), red (>=12V), red (>=18V)	CAD review
SYS_F_008	Number of Outputs	Each channel must have at least one output (any type of connection)	To power multiple circuits using the same voltage if desired	PCB review
SYS_F_009	Banana Plug Output	Each channel must contain banana plug outputs	To use alligator clips	PCB review
SYS_F_010	Voltage Adjust	All adjustable channels must be adjustable using physical interfaces	Ease of use; e.g. cylindrical knob	PCB review
SYS_F_011	Power Profile Sticker	The input and output voltage and current ranges must be indicated on the enclosure	Understandability, safety	CAD review
SYS_F_012	Financial Cost	The total cost of components must be less than C$50	Cheaper than off-the-shelf solutions	BOM review
SYS_F_013	Anti-Slip	The design may not slip on wooden surfaces	Stability and safety	Experimental testing
SYS_F_014	Handle	The design may have a handle	Ease of use and portability	Experimental testing
SYS_F_015	Continuous Adjustment	Adjustable voltage channels must adjust the voltage continuously	Wider range of values	Experimental testing
SYS_F_016	LED Brightness	The LED indicators must be of similar brightness	Consistency and aesthetics	Inspection
SYS_F_017	Main Switch	The power supply may have a main rocker switch	Added layer of safety	PCB review
SYS_F_018	Heatsink	Voltage regulators may be cooled using heatsinks	Maintain efficiency and a safe temperature	BOM review
Performance Requirements				
SYS_P_001	Component Power Rating	All components must be rated to handle at least 1A 12V power supply output	Factor of safety	BOM review, PCB review
SYS_P_002	Inrush Current Limiting	Current may be limited as switches are turned on	Surge protection	PCB review
SYS_P_003	Voltage Stability	Input and output voltages must be stabilized using capacitors	Reduce noise	PCB review
SYS_P_004	Maximum Current Output	The design must output a maximum, limited current of at least 1A	Many projects may need 1A	BOM review
SYS_P_005	Fuse Rating	Fuses must be rated for about the maximum output current	Over-current protection	PCB review
SYS_P_006	Minimum Voltage Output	The design must output a minimum voltage of at most 3.3V	Many digital circuits can be powered at 3.3V	Experimental testing
SYS_P_007	Maximum Voltage Output	The design must output a maximum voltage of at least 12V	Many projects may need 12V	Experimental testing
SYS_P_008	Minimum Input Voltage	The input voltage must be at least the maximum output voltage	Voltage regulators will step down voltage	BOM review
SYS_P_009	Schmitt Trigger	All comparator circuits should have hysterisis	Mitigate noisy input	PCB review
SYS_P_010	Barrel Jack Shielding	The power barrel jack may be shielded	Improve performance and safety	BOM review
SYS_P_011	Diode Protection	All voltage regulators must be diode protected	Safety against reverse current and capacitor discharge	PCB review
SYS_P_012	Mounting Type	All components must be soldered onto through-hole perfboards	Permanent solution with secure attatchment	PCB review
SYS_P_013	AC-DC Conversion	AC-DC conversion must occur within an AC-DC power adapter	Safety; avoid working with AC power	PCB review
SYS_P_014	Perfboard Isolation	All perfboards must be isolated from each other and the case	Safety and short prevention	CAD review
SYS_P_015	Perboard Stability	All perfboards must be secured to the inside of the case using standoffs	Safety, short prevention, and durability	CAD review
SYS_P_016	RoHS Compliance	All components must be RoHS compliant	Health and environmental safety	BOM review

Sketches


0V 3V3 5V 9V 12V 18V
0V 3V3 5V 9V 12V 18V
IN 120V 2.5A
12V 1A OUT
issue: turns on all channels
0V 3V3 5V 9V 12V 18V
issue: wires overlapping
⇒ safety
⇒ ease of use
120V
AC→DC
18V
18V
18V
LM317
OUT V-
OUT V+

Circuit Calculations

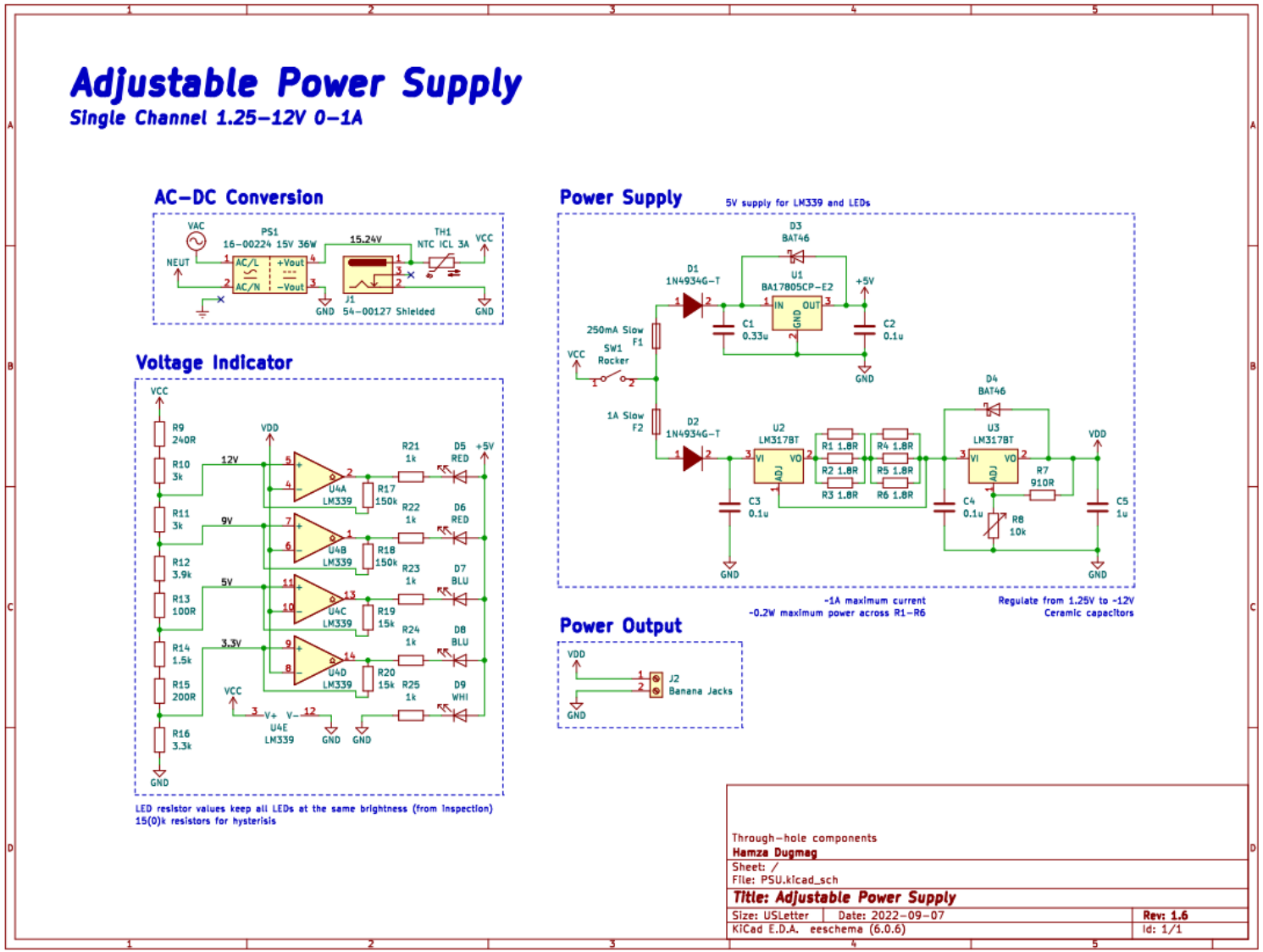
```python
def voltage_divider(vcc, resistances):
    """
    vcc: input voltage
    resistances: array of series resistor values
    return voltage at each node and current
    """
    assert len(resistances) > 0, "Short circuit!"

    # macro-analysis
    r_total = sum(resistances)
    current = vcc/r_total

    # array to return
    voltages = [vcc]

    v = vcc  # voltage of current node
    for r in resistances:
        v -= r*current  # count voltage drops
        voltages.append(v)

    voltages[-1] = 0  # fix floating point error

    return voltages, current


def resistor_ladder(voltages, current):
    """
    voltages: node voltages along voltage divider
    current: desired current
    return series resistor values that satisfy voltages and current inputs
    """
    assert len(voltages) > 1, "Short circuit!"

    # set ground to 0V
    for i in range(len(voltages)):
        voltages[i] -= voltages[-1]

    # array to return
    resistances = []

    # observe equivalent resistance past current node
    v = voltages[0]
    r_total = v/current

    # array to return
    resistances = []

    # observe equivalent resistance past current node
    v = voltages[0]
    r_total = v/current

    for i in range(1, len(voltages)):
        # split current equivalent resistance to two resistors
        r = r_total - r_total*voltages[i]/v  # r1 = r_total - r2
        resistances.append(r)

        # update current node voltage and equivalent resistance
        v = voltages[i]
        r_total = v/current

    return resistances


def LED_resistor(vcc, vf, current):
    vr = vcc - vf
    r = vr/current
    return r

def LED_current(vcc, vf, r):
    vr = vcc - vf
    current = vr/r
    return current

if __name__ == "__main__":
    # Voltage divider for LED circuit
    print(resistor_ladder(voltages=[15.24, 12, 9, 5, 3.3, 0], current=0.001))
    print(voltage_divider(15.24, [240, 3000, 3000, 4000, 1700, 3300]))

    # LED circuit current draw
    # LM339 maximum current is 20mA
    # Brightness is approx. prop. to current
    # print(LED_resistor(5, 1.8, 14/1000))  # red
    # print(LED_resistor(5, 2.15, 14/1000))  # yellow
    # print(LED_resistor(5, 2.95, 14/1000))  # green
```

Bill of Materials

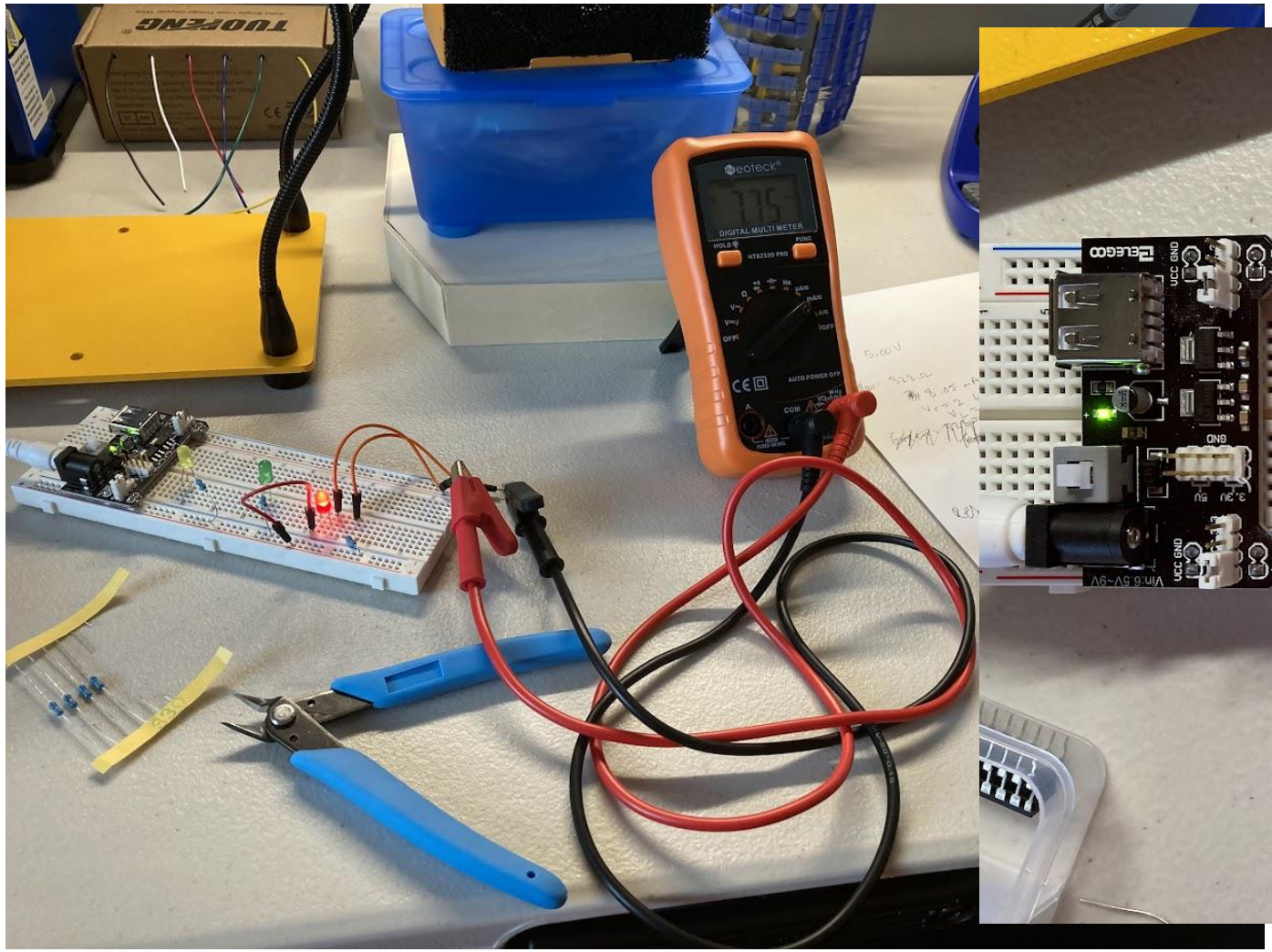
Power Supply BOM		Adjustable single channel
Hamza Dugmag	Revision 1.3	2022-09-07
	Revision 1.2	2022-08-20
	Revision 1.1	2022-08-15
	Revision 1.0	2022-08-13

#	Quantitity	Supplier	Manufacturer Part Number	Description	Comments	Unit Price (CAD)	Extended Price (CAD)
1	1	Digi-Key Canada	16-00224	AC/DC Wall Adapter 15V 36W	AC-DC Conversion	19.24	19.24
2	1	Digi-Key Canada	54-00127	Shielded Barrel Jack 5.5x2.1mm	AC-DC Conversion	1.13	1.13
3	3	Digi-Key Canada	EDZ250/2	Terminal Block 2 Positions	Power Input	2.61	7.83
4	1	Digi-Key Canada	MF72-005D9	Inrush Current Limiter 5R 3A	Both channels	0.55	0.55
5	1	Digi-Key Canada	SW-R3-1A-A-1-0	SPST Subminiature Rocker Switch	Main and channel switches	0.265	0.265
6	1	Digi-Key Canada	0697H0250-02	Fuse 250mA Slow Blow	5V linear regulator	0.51	0.51
7	1	Digi-Key Canada	0697W1000-02	Fuse 1A Slow Blow	Adjustable linear regulators	0.4	0.4
8	2	Digi-Key Canada	1N4934G-T	Diode 1A	Reverse current protection	0.434	0.868
9	2	Digi-Key Canada	BAT46	Schottky Diode 150mA	Capacitor discharge protection	0.69	1.38
10	1	Amazon Canada	Tn-19	Capacitor Ceramic 0.33u	5V linear regulator input	0.033	0.033
11	3	Amazon Canada	Tn-19	Capacitor Ceramic 0.1u	Linear regulator and LM339 inputs	0.033	0.099
12	1	Amazon Canada	Tn-19	Capacitor Ceramic 1u	CV linear regulator output	0.033	0.033
13	1	Digi-Key Canada	BA17805CP-E2	IC Linear Voltage Regulator 5V 1A TO220	LEDs and LM339	1.86	1.86
14	2	Digi-Key Canada	LM317BT	IC Linear Voltage Regulator Adjustable 1.5A TO220	Current limiter and voltage output	0.939	1.878
15	2	Digi-Key Canada	507302B00000G	Heatsink TO220 2.5W	Adjustable linear regulators	0.328	0.656
16	1	Digi-Key Canada	PTV09A-4225U-B103	Potentiometer 10k 1/20W Carbon Linear	Voltage adjustment	1.2	1.2
17	1	Digi-Key Canada	COM-10001	Knob Knurled Metal	Potentiometer aesthetic	2.37	2.37
18	6	Amazon Canada	An-resistor02	Resistor 1.8R 1% 1/4W	CC linear regulator output	0.0092	0.0552
19	1	Amazon Canada	An-resistor02	Resistor 910R 1% 1/4W	CV linear regulator adjust	0.0092	0.0092
20	1	Amazon Canada	An-resistor02	Resistor 240R 1% 1/4W	LM339 voltage divider	0.0092	0.0092
21	2	Amazon Canada	An-resistor02	Resistor 3k 1% 1/4W	LM339 voltage divider	0.0092	0.0184
22	1	Amazon Canada	An-resistor02	Resistor 3.9k 1% 1/4W	LM339 voltage divider	0.0092	0.0092
23	1	Amazon Canada	An-resistor02	Resistor 100R 1% 1/4W	LM339 voltage divider	0.0092	0.0092
24	1	Amazon Canada	An-resistor02	Resistor 1.5k 1% 1/4W	LM339 voltage divider	0.0092	0.0092
25	1	Amazon Canada	An-resistor02	Resistor 200R 1% 1/4W	LM339 voltage divider	0.0092	0.0092
26	1	Amazon Canada	An-resistor02	Resistor 3.3k 1% 1/4W	LM339 voltage divider	0.0092	0.0092
27	5	Amazon Canada	An-resistor02	Resistor 1k 1% 1/4W	LED resistors	0.0092	0.046
28	2	Amazon Canada	An-resistor02	Resistor 150k 1% 1/4W	LM339 Schmitt trigger (red LEDs)	0.0092	0.0184
29	2	Amazon Canada	An-resistor02	Resistor 15k 1% 1/4W	LM339 Schmitt trigger (blue LEDs)	0.0092	0.0184
30	1	Amazon Canada	LM339	IC Quad Differential Comparator	Voltage LED indicator	0.195	0.195
31	1	Amazon Canada	S1121	14 Pin DIP Socket	LM339 socket	0.195	0.195
32	1	Amazon Canada	n/a	White LED 5mm	Power Indicator	0	0
33	2	Amazon Canada	n/a	Blue LED 5mm	Low Voltage Indicator	0	0
34	2	Amazon Canada	n/a	Red LED 5mm	High Voltage Indicator	0	0
35	1	Digi-Key Canada	PRT-09739	Banana Binding Post Red	Power output	0.63	0.63
36	1	Digi-Key Canada	PRT-09740	Banana Binding Post Black	Ground output	0.63	0.63
Total	58						42.17

Schematic Capture



LED Testing


TWOFENG
eoteck
DIGITAL MULTI METER
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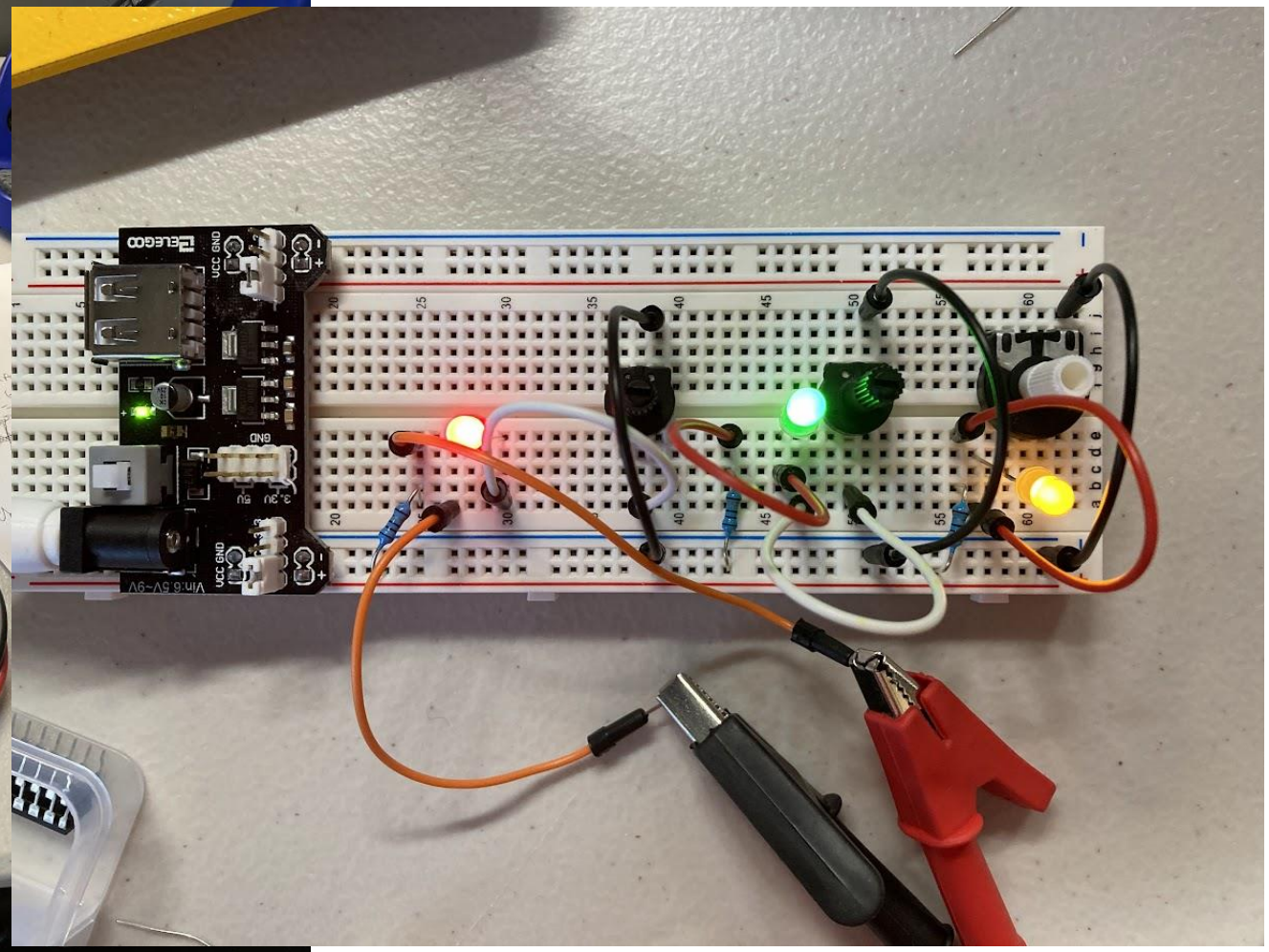
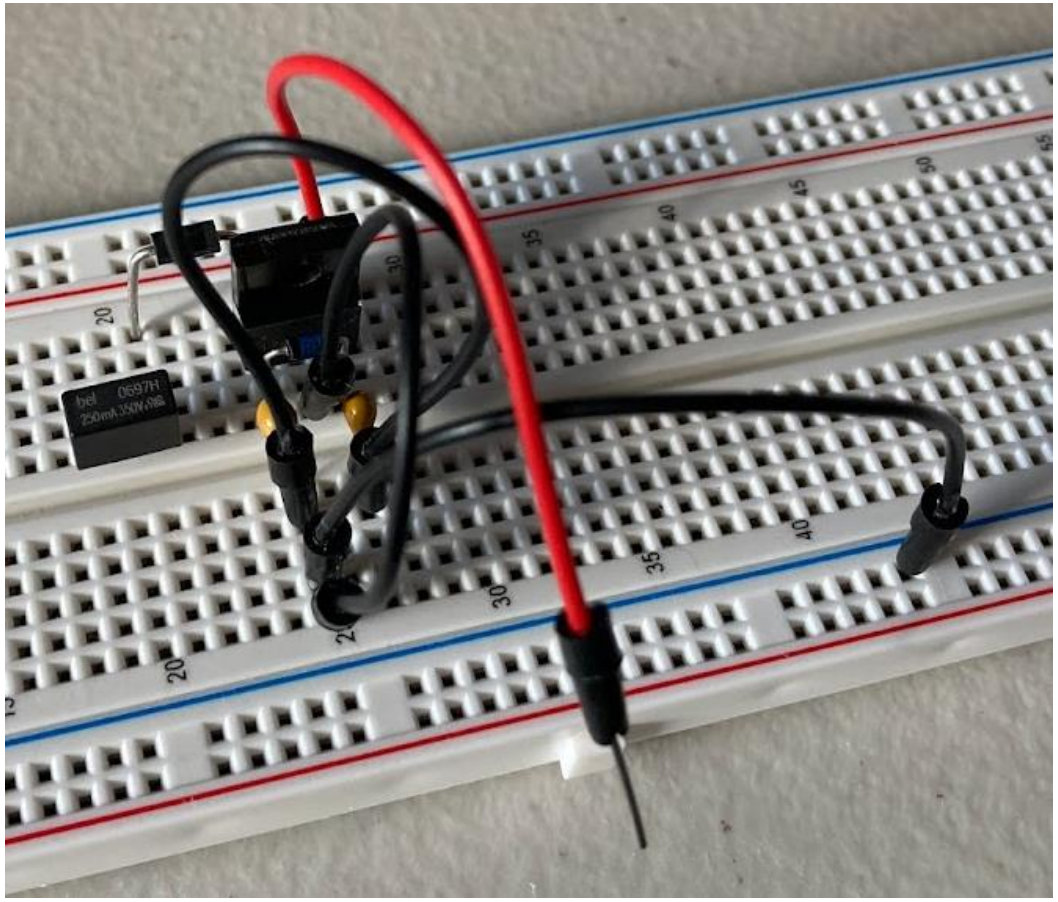
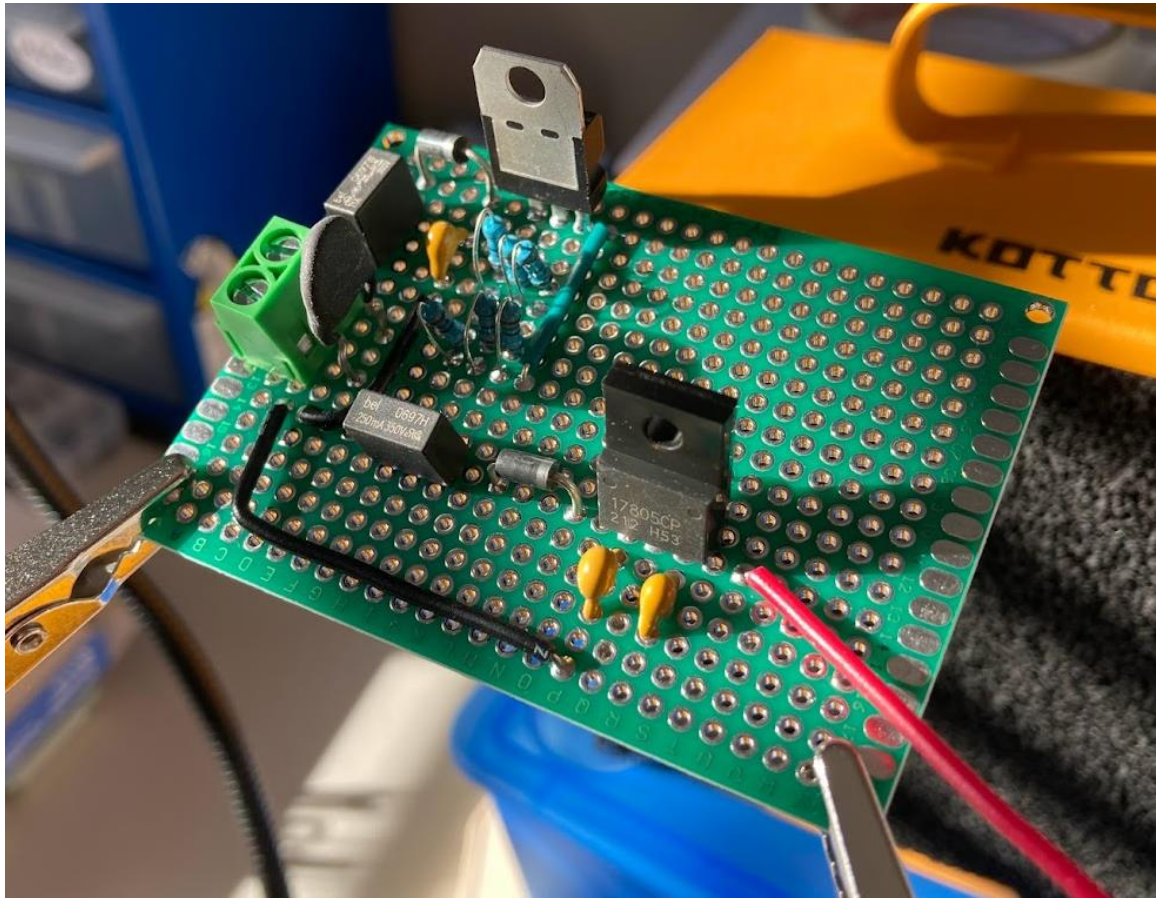
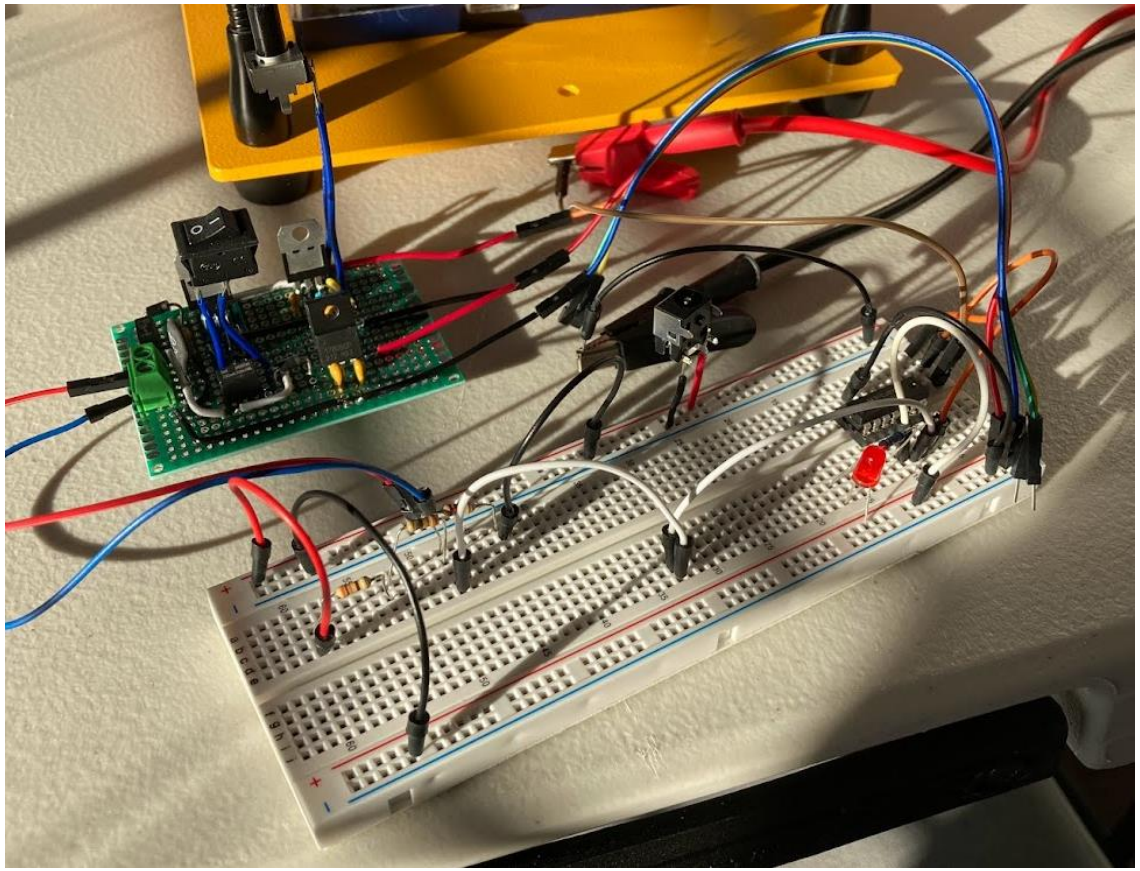

ELEGOO
VCC GND
GND
3.3V 5V
Vin:6.5V~9V

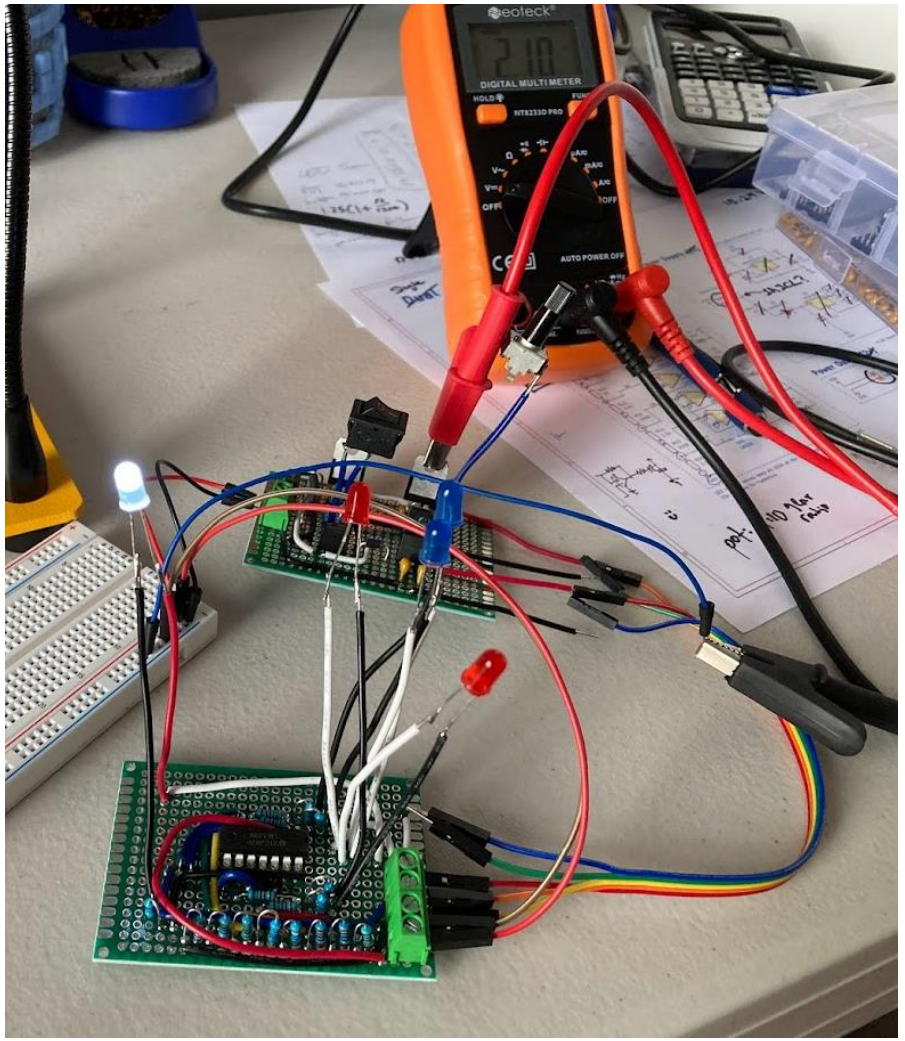
Power Supply: Breadboarding & Soldering





Voltage Indicator: Breadboarding & Soldering





System Testing