

# Testbed for Measurement and Control of Generator Power Oscillations



**Team name:** Shockwave

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**Sponsor:** The logo for Schweitzer Engineering Laboratories (SEL) is displayed. It consists of a dark blue rectangular background. On the left side, the letters 'SEL' are written in a white, bold, sans-serif font, enclosed within a white rounded rectangular border. To the right of this border, the words 'SCHWEITZER ENGINEERING LABORATORIES' are written in a smaller, white, all-caps, sans-serif font, stacked in three lines.

**Client:** Matchyaraju Alla

**Instructor:** Brian K. Johnson

**Mentor:** Hussain Beleed, Aljabrine Abdulwahab



# Objective

**Building on the data acquisition system designed by a 2018-2019 senior design team design a test bed and test plan for testing generator performance during power swings, especially those near boundary of pole slipping**

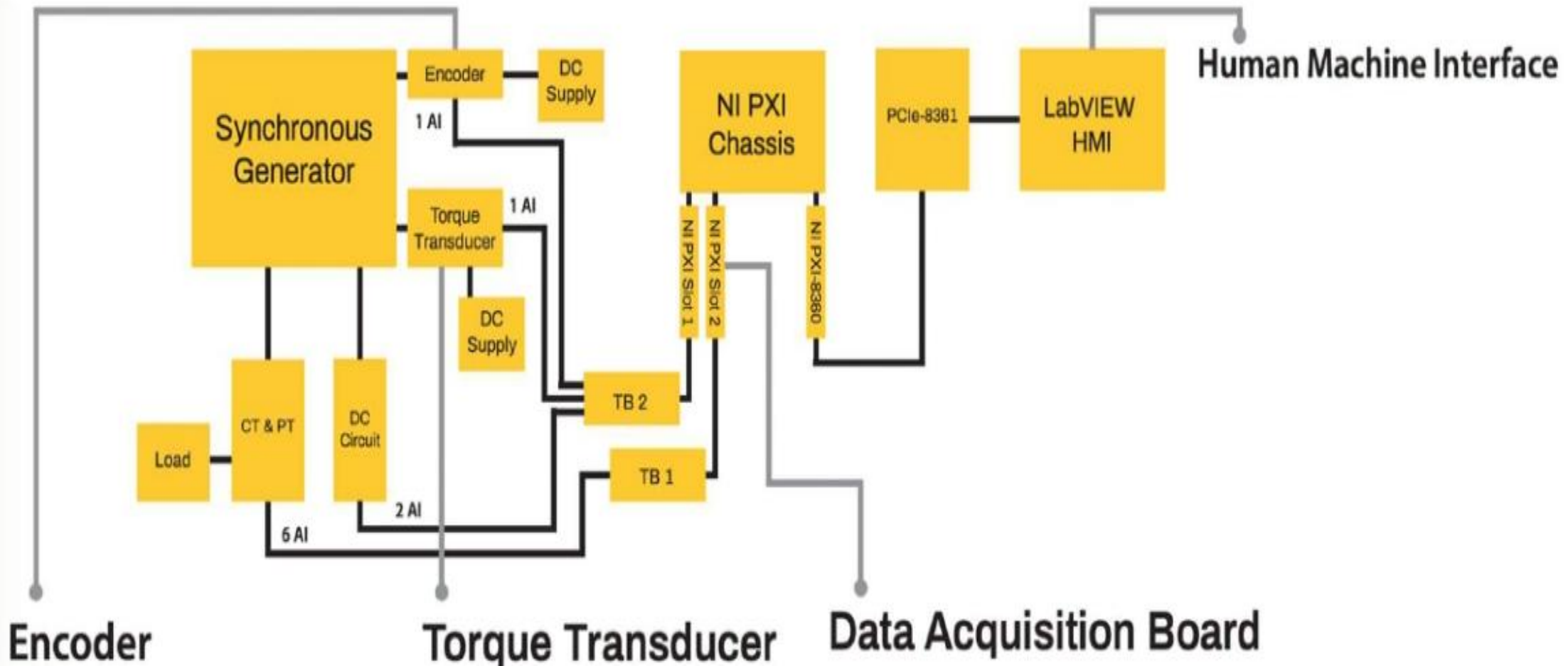


# Goals

1. Learn to use the present data acquisition system
2. Develop, test and implement test procedure for safely operating the generator
3. Integrate data from all measurement devices used in a time stamped and synchronized format for post process
4. Documentation.



# Measurement System Topology



# Design Considerations

Material of Testbed board

## Polyvinyl chloride

Pros:

- 1) Cheap
- 2) Non-conductive
- 3) Environmentally friendly
- 4) Easy to cut

Cons:

- 1) Low heat resistance



PVC (Polyvinyl Chloride) Sheet, Opaque White, Standard Tolerance, UL 94/ASTM D1784, 3/16" Thickness, 12" Width, 24" Length

by [Small Parts](#)

★★★★☆ 83 ratings | 40 answered questions

Best Deal

Price: \$16.10 & FREE Returns

W. Best price **W.+**

Item Thickness String: 1/2 Inches

1/2 Inches 1/4 Inches **3/16 Inches** 3/4 Inches 3/8 Inches

Item Width String: 12 Inches

Item Length String: 24 Inches

12 Inches **24 Inches**

Number of Items: 1

- PVC offers an excellent balance of strength and weight, and is typically resistant to acids, alkalis, and most other inorganic chemicals
- Color is opaque white
- Meets UL 94 and ASTM D1784 specifications
- Standard tolerance



# Electronic wire





AWG	Diameter		Turns of wire, without insulation		Area		Copper wire							
							Resistance/length <sup>[7]</sup>		Ampacity, <sup>[8]</sup> at 20 °C insulation material temperature rating, or for single unbundled wires in equipment for 16 AWG and smaller <sup>[9]</sup>			Fusing current <sup>[10][11]</sup>		
	(in)	(mm)	(per in)	(per cm)	(kcmil)	(mm <sup>2</sup> )			(mΩ/m <sup>[a]</sup> )	(mΩ/ft <sup>[b]</sup> )	60 °C	75 °C	90 °C	Preece <sup>[12][13][14][15]</sup>
							(A)	(A)			(A)	~10 s	1 s	32 ms
16	0.0508	1.291	19.7	7.75	2.58	1.31	13.17	4.016			18	117 A	398 A	2.2 kA
17	0.0453	1.150	22.1	8.70	2.05	1.04	16.61	5.064				99 A	316 A	1.8 kA
18	0.0403	1.024	24.8	9.77	1.62	0.823	20.95	6.385	10	14	16	83 A	250 A	1.4 kA
19	0.0359	0.912	27.9	11.0	1.29	0.653	26.42	8.051	—	—	—	70 A	198 A	1.1 kA
20	0.0320	0.812	31.3	12.3	1.02	0.518	33.31	10.15	5	11	—	58.5 A	158 A	882 A
21	0.0285	0.723	35.1	13.8	0.810	0.410	42.00	12.80	—	—	—	49 A	125 A	700 A
22	0.0253	0.644	39.5	15.5	0.642	0.326	52.96	16.14	3	7	—	41 A	99 A	551 A

- Voltage Rating: 300 Volts ,Rated temperature: 0 C - 80 C
- Material : PVC , Tinning Copper;
- Wire Length:17 meter(55ft) each color
- Color:Red+Blue+Black



# Banana Plug

We use the same brand standard banana plug as the power lab for future replacement and use.

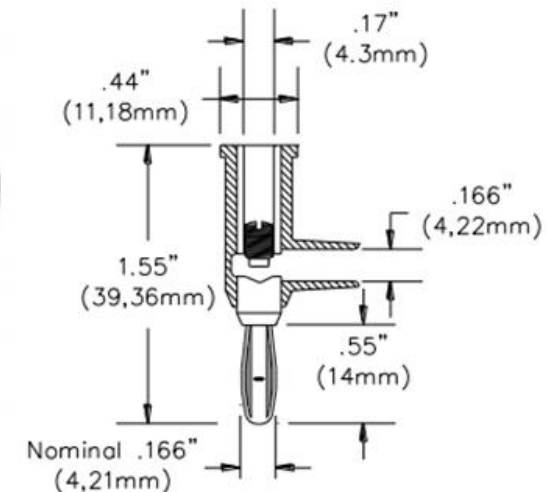
	<b>Technical Data Sheet</b>
	<b>Model 1825, 4897, 4899, 6545</b>  <b>Standard Banana Plug, Solderless and Stackable</b>

## Features

- Designed to fit on the end of any 22 AWG to 18 AWG wire.
- Cross hole wire entry fits wires up to .12" (3mm) diameter.
- Available with tarnish resistant nickel or gold plating for very low contact resistance.
- Model 4899 is rated to temperatures up to +302°F (+150°C).
- Set screw simplifies assembly of test leads and jumpers by using a flat blade screwdriver.
- Fits standard panel and binding post banana jacks .161" to .166" (4,0mm to 4,2mm) diameter.

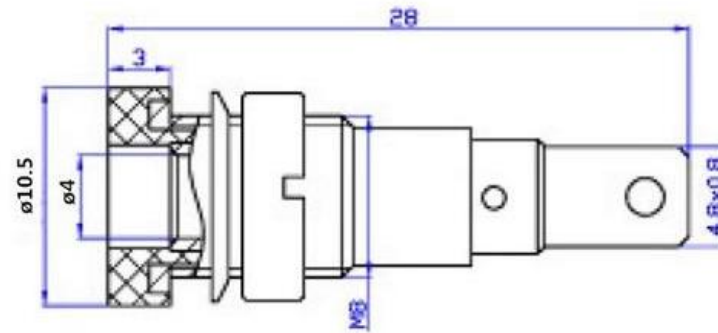
## Materials

Banana Jack: Zinc Die Cast, Nickel Plated (Model 4897 is Gold Plated)  
 Banana Plug: *Body* – Zinc Die Cast, Nickel Plated (Model 4897 is Gold Plated)  
*Spring* – Beryllium Copper, Nickel Plated (Model 4897 Gold Plated)  
 Insulation: Polypropylene (Model 4899 is Polyphenylene Sulfide)  
 Set Screw: Steel, Zinc Plated, 8-32 Single Slot





# Female Banana Plug



# Terminal Strip

- We use terminal strip to solve the wire clutter problem
- We use some jumpers to make series circuits easily.



# Connectors

## 1) Fork Connectors

**Red**

Wire range: 0.5~1.5mm<sup>2</sup>  
A.W.G.:22~16  
Max.current = 19A



# Connectors

## 2) Alligator Clips

Reasons that we do not use hook connectors

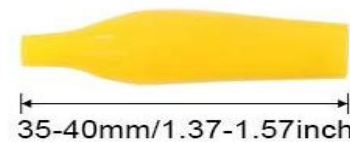
- 1) Its shape is difficult to fit a flat PVC board
- 2) More troublesome to install



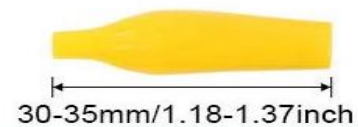
### ★ EASY TO INSTALL

Used as miniature clamps to hold parts together for gluing and wires together for soldering

35MM SIZE

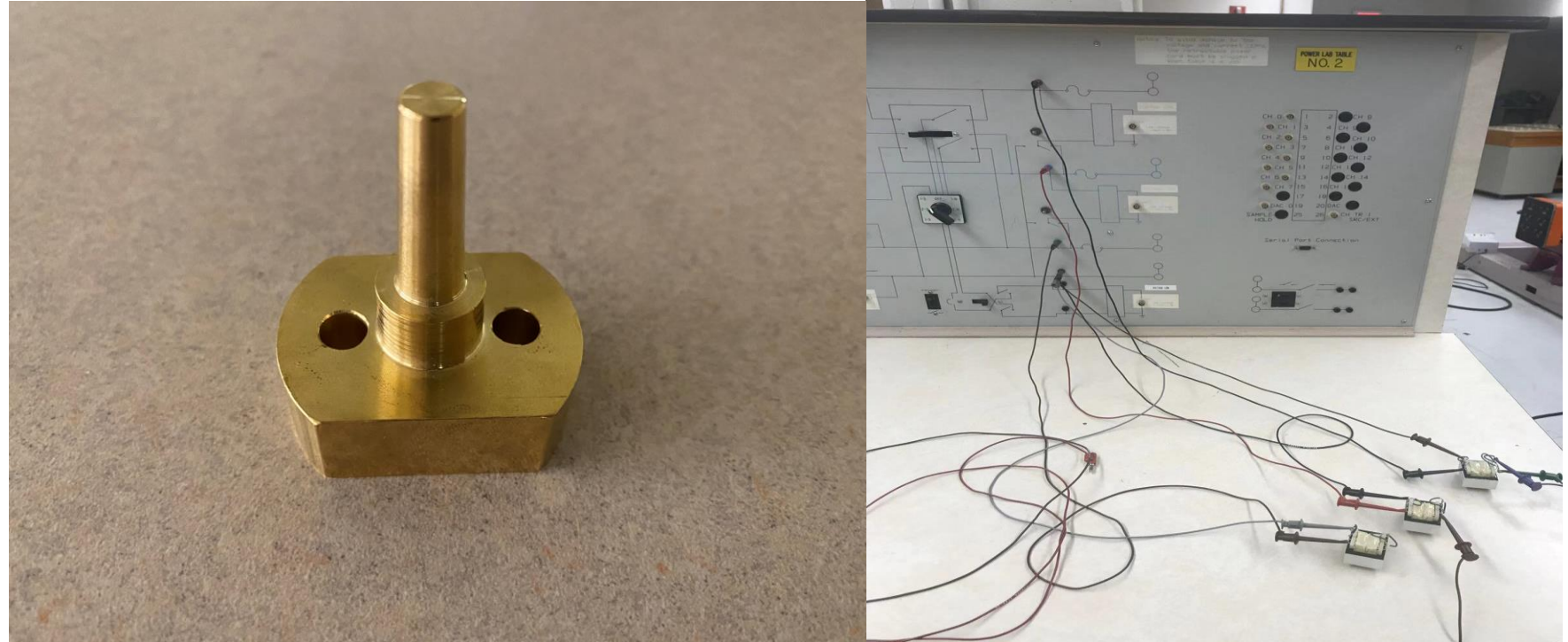


28MM SIZE



# Brass Adapter

- Replace the test table
- Convenience
- Lower security



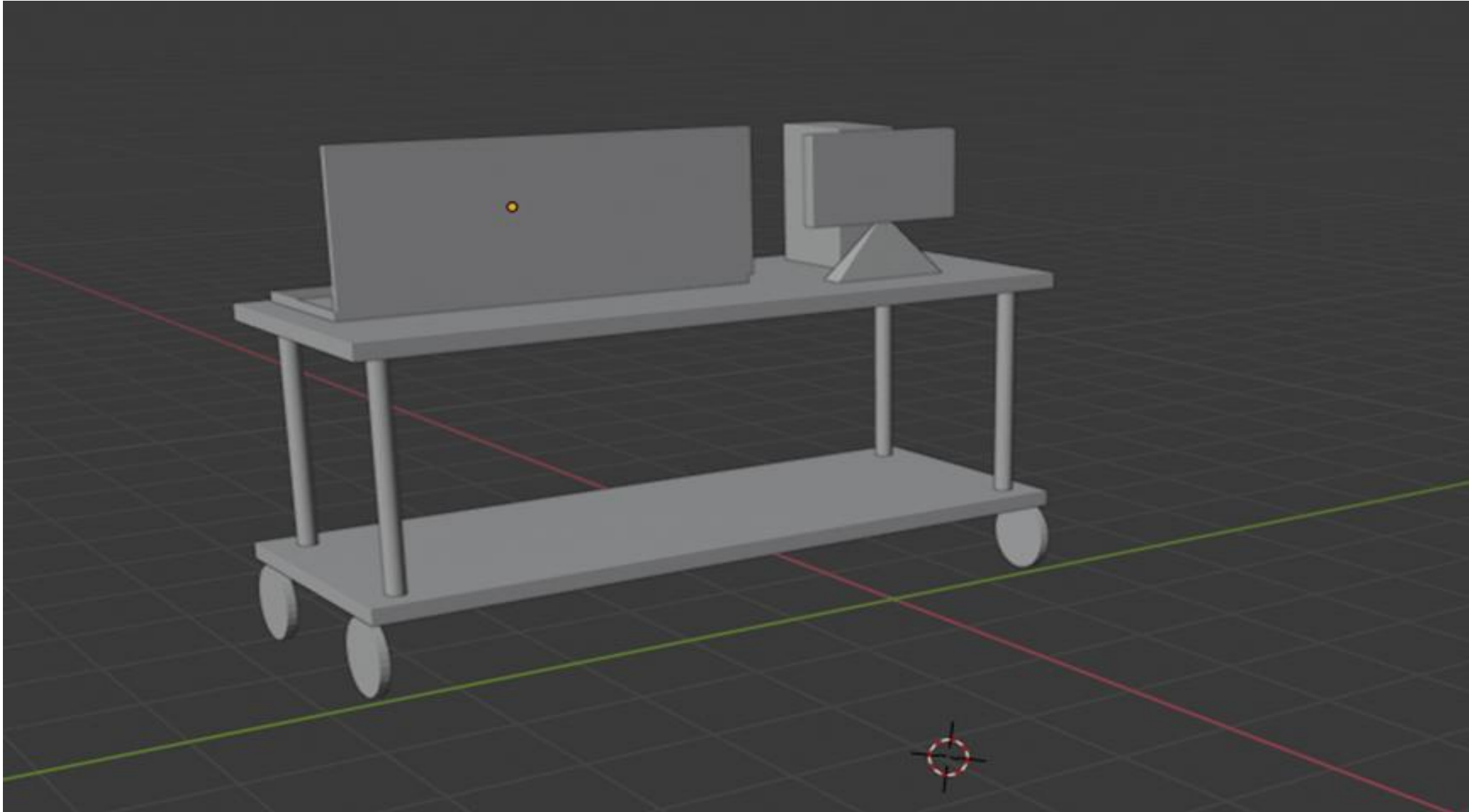
## Capstone Design

Combined BOM and Manufacturing Plan - Template

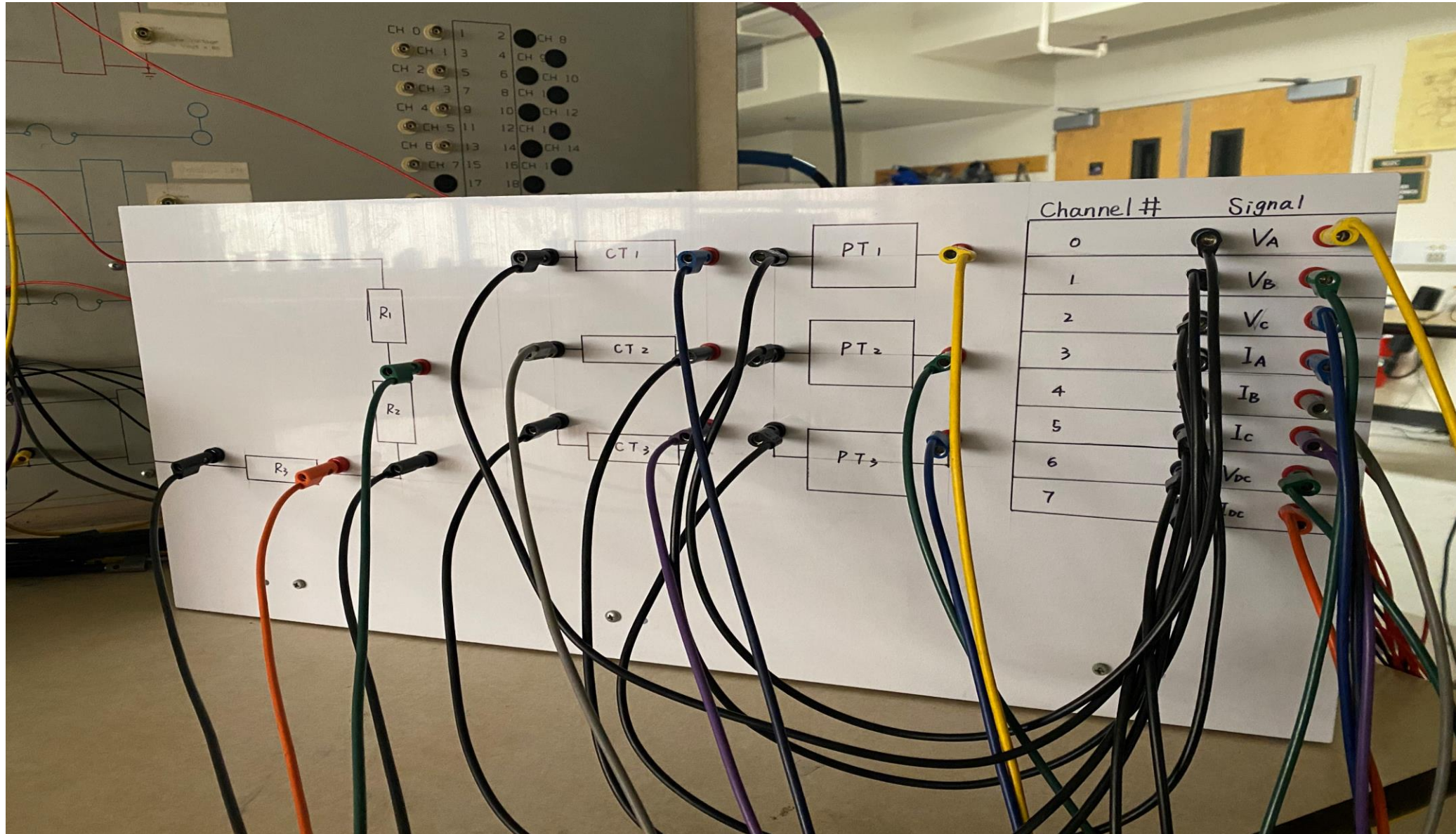
Indented Bill of Materials (BOM)			Manufacturing Plan							Cost	
Part No. or Assy No.	Description	Quantity	Make or Buy?	Source (or Fabrication Location)	Fabrication Technique (if appl.)	Is the Drawing Avail.?	Is the Material Avail.?	Who will lead (Name)?	Target Completion Date	Unit Cost (\$)	Extended Cost (\$)
<b>Full Assy 1</b>											\$ -
Part 1	C type adapter	2	make	ME Worksho		yes	Brass	Bill Magnie	12/03/2020	\$ 90.00	\$ 180.00
Part 2											\$ -



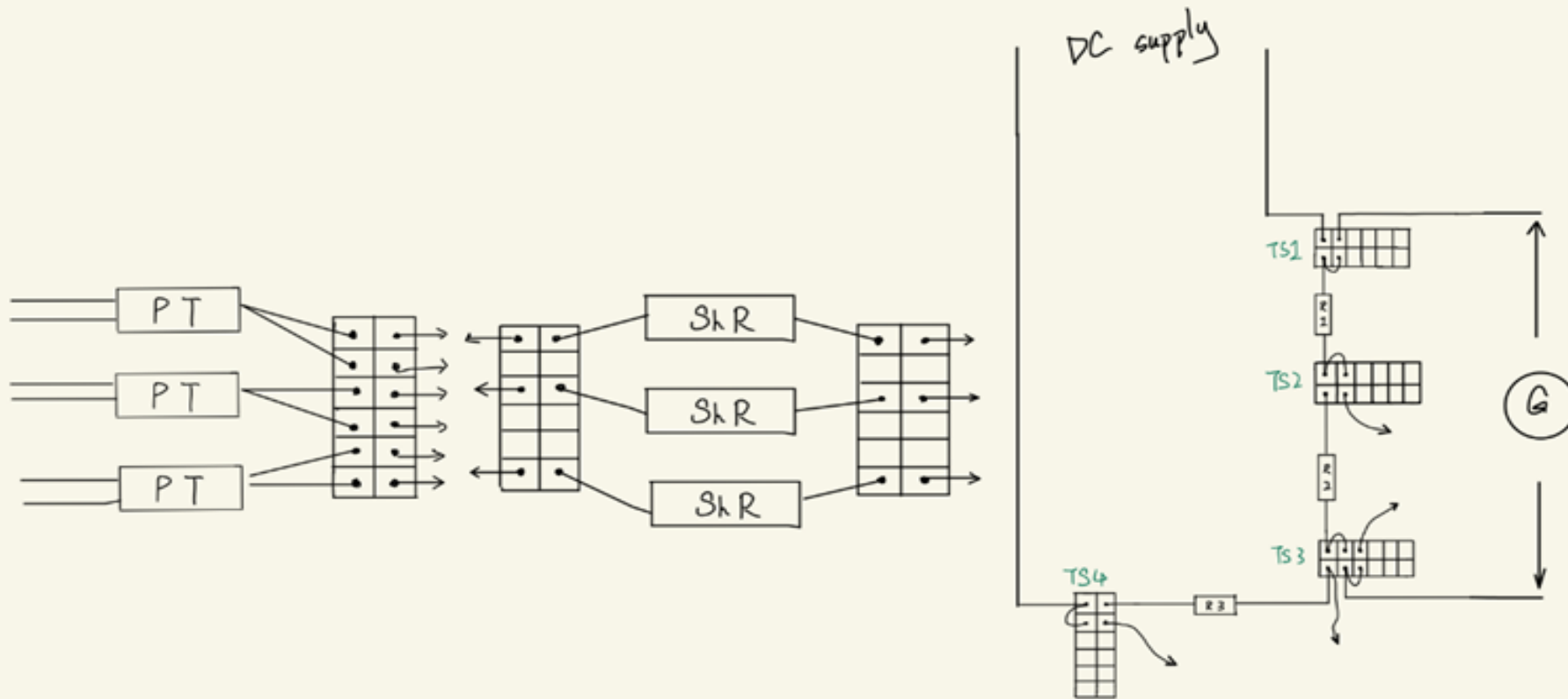
# Solid Model



# Testbed Front Panel



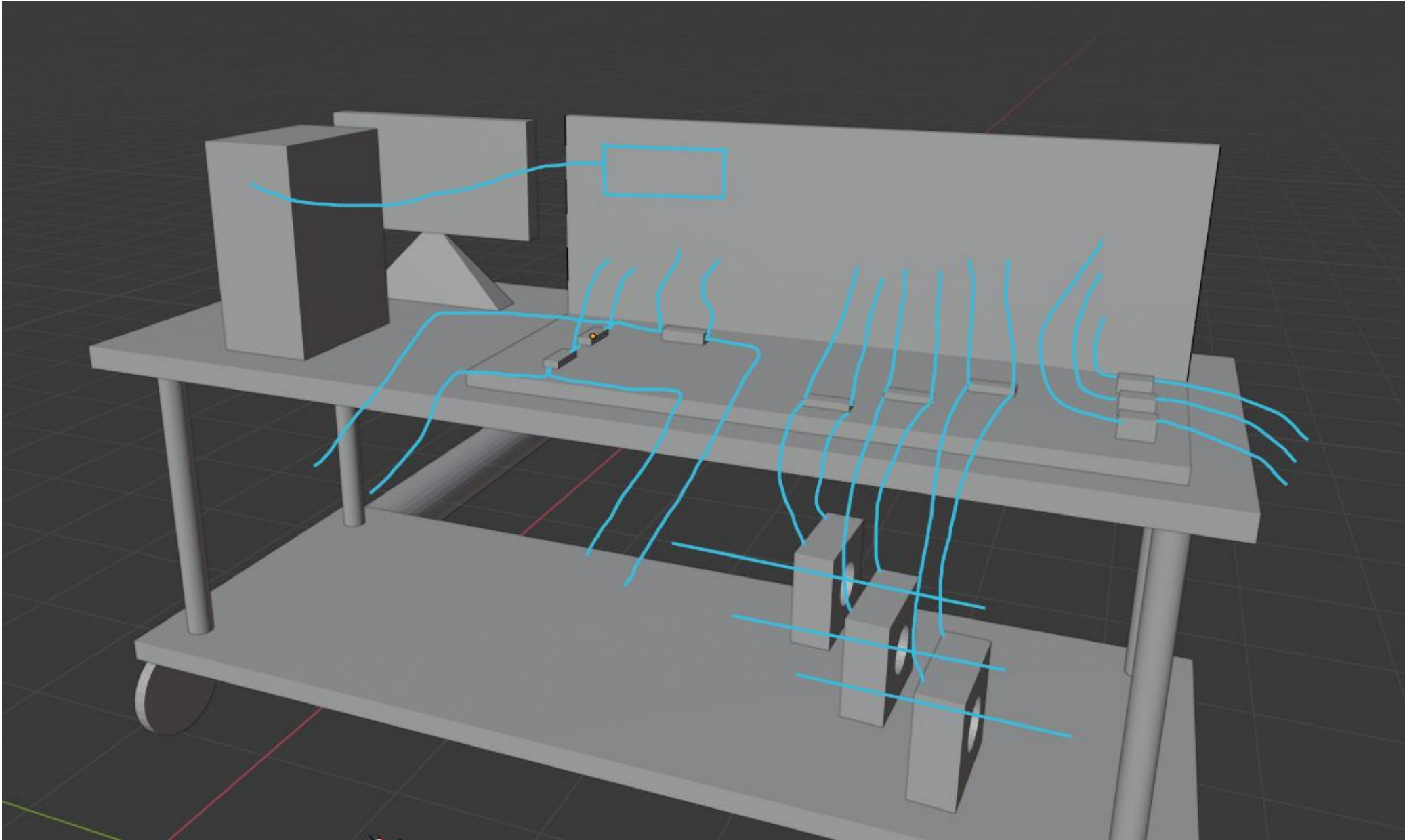
# Circuit Design



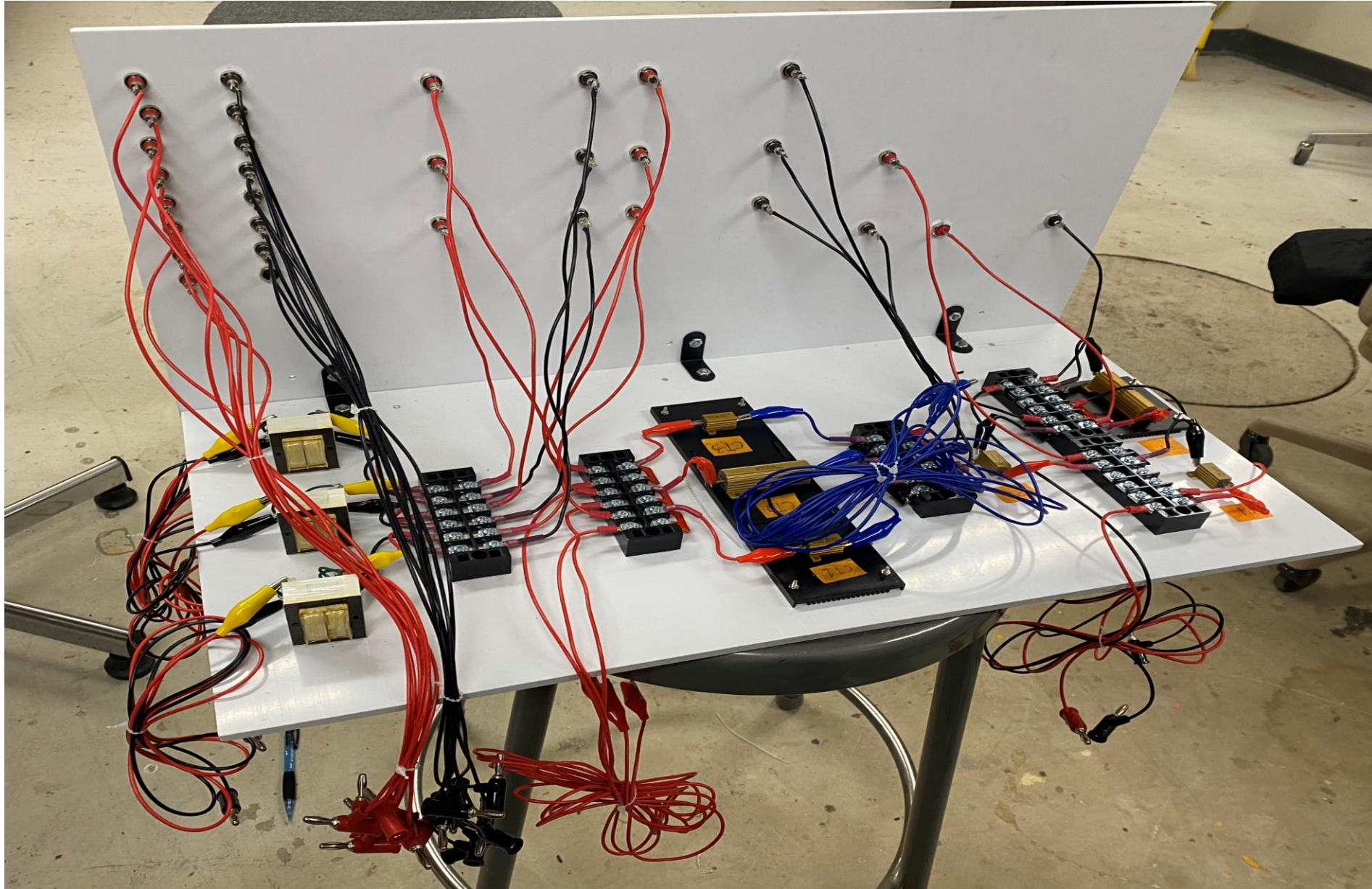




# Solid Model with Component Added

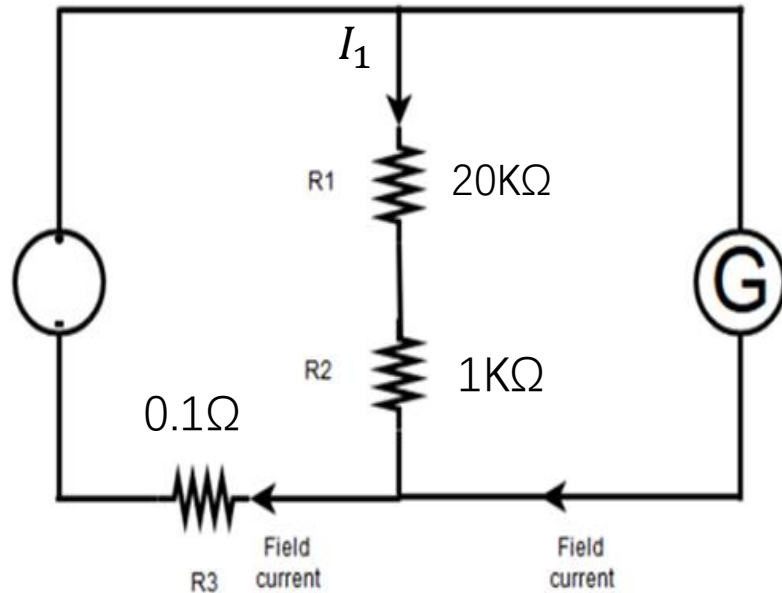


# Testbed



# Usability Test

## DC Circuit



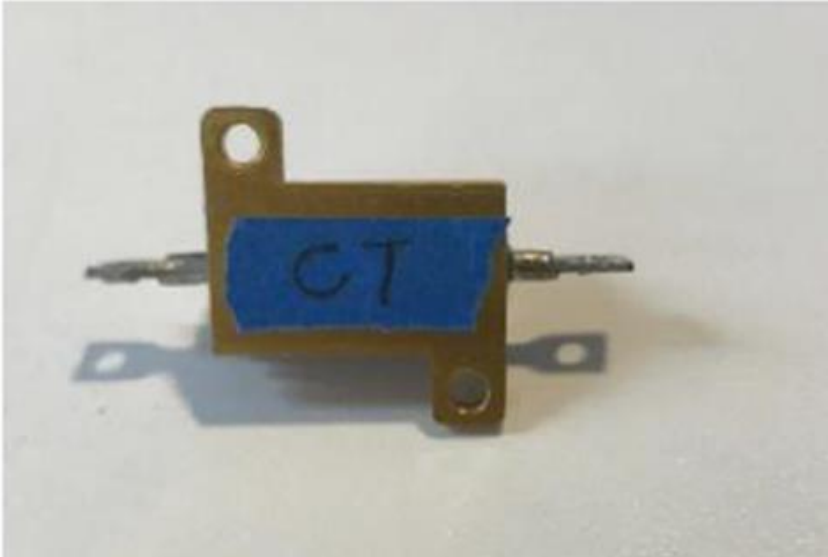
- $V_{R2}$  represent the terminal voltage, we set a ratio(21) in LabView which turns the scaled voltage to actual voltage
- The DAQ should not exceed 11V. So, we should set 10V is our max
- Calculate the ratio of DC power supply and multimeter reading by each test and get the average value of it.

**Conclusion:** The value of average ratio is 20.88 close to 21. This means the DC circuit part has the usability



# Usability Test

## CT Shunt Resistance



- CT shunt resistances are paralleled with current transformer
- Simply use the law of resistance to measure the value of resistance
- Compare the value shown by the power supply machine and the multimeter reading

**Conclusion:** The value of CT2 and CT3 has changed by unknow reason. The ratio of voltage to current is an exponential function, not a proportional relationship. CT1 has usability.



# Future Work

- ❑ Test the usability of I\_R3 and three PTs
- ❑ Change CT2 and CT3 into new shunt resistance( 1ohm, 50W)
- ❑ Change the heat sink which more suitable for resistances or add a fan
- ❑ Integrate data from all measuring devices in timestamp and synchronized format for post-processing



Questions?



Thank you very much







# Test Data

DC Circuit V<sub>DC</sub>

# Test <sup>o</sup>	DC Power Supply (V) <sup>o</sup>	Multimeter (V) <sup>o</sup>	Ratio <sup>o</sup>
1 <sup>o</sup>	9.6 <sup>o</sup>	0.459 <sup>o</sup>	20.915 <sup>o</sup>
2 <sup>o</sup>	18.8 <sup>o</sup>	0.901 <sup>o</sup>	20.866 <sup>o</sup>
3 <sup>o</sup>	29.2 <sup>o</sup>	1.399 <sup>o</sup>	20.872 <sup>o</sup>
4 <sup>o</sup>	39.7 <sup>o</sup>	1.900 <sup>o</sup>	20.895 <sup>o</sup>
5 <sup>o</sup>	48.7 <sup>o</sup>	2.332 <sup>o</sup>	20.883 <sup>o</sup>
6 <sup>o</sup>	52.9 <sup>o</sup>	2.536 <sup>o</sup>	20.860 <sup>o</sup>
7 <sup>o</sup>	65.7 <sup>o</sup>	3.147 <sup>o</sup>	20.877 <sup>o</sup>
8 <sup>o</sup>	72.1 <sup>o</sup>	3.451 <sup>o</sup>	20.892 <sup>o</sup>
9 <sup>o</sup>	84.0 <sup>o</sup>	4.022 <sup>o</sup>	20.885 <sup>o</sup>
10 <sup>o</sup>	92.7 <sup>o</sup>	4.44 <sup>o</sup>	20.878 <sup>o</sup>
11 <sup>o</sup>	105.5 <sup>o</sup>	5.05 <sup>o</sup>	20.891 <sup>o</sup>
12 <sup>o</sup>	110.0 <sup>o</sup>	5.27 <sup>o</sup>	20.873 <sup>o</sup>
13 <sup>o</sup>	114.1 <sup>o</sup>	5.46 <sup>o</sup>	20.897 <sup>o</sup>

14 <sup>o</sup>	123.2 <sup>o</sup>	5.90 <sup>o</sup>	20.881 <sup>o</sup>
15 <sup>o</sup>	134.4 <sup>o</sup>	6.44 <sup>o</sup>	20.870 <sup>o</sup>
16 <sup>o</sup>	143.2 <sup>o</sup>	6.86 <sup>o</sup>	20.875 <sup>o</sup>
17 <sup>o</sup>	147.7 <sup>o</sup>	7.07 <sup>o</sup>	20.891 <sup>o</sup>
18 <sup>o</sup>	150.2 <sup>o</sup>	7.19 <sup>o</sup>	20.890 <sup>o</sup>
19 <sup>o</sup>	154.7 <sup>o</sup>	7.41 <sup>o</sup>	20.877 <sup>o</sup>
20 <sup>o</sup>	155.1 <sup>o</sup>	7.43 <sup>o</sup>	20.875 <sup>o</sup>

Average Ratio= 20.88215<sup>o</sup>



# Test Data

## CT Shunt Resistance

a) CT1, 1 $\Omega$ , 10W $\leftrightarrow$

# TEST $\leftrightarrow$	Supply Voltage(V) $\leftrightarrow$	Supply Current (A) $\leftrightarrow$	Multimeter(A) $\leftrightarrow$
1 $\leftrightarrow$	0.4 $\leftrightarrow$	0.3 $\leftrightarrow$	0.307 $\leftrightarrow$
2 $\leftrightarrow$	1.2 $\leftrightarrow$	0.99 $\leftrightarrow$	1.011 $\leftrightarrow$
3 $\leftrightarrow$	1.6 $\leftrightarrow$	1.32 $\leftrightarrow$	1.35 $\leftrightarrow$
4 $\leftrightarrow$	2.3 $\leftrightarrow$	1.91 $\leftrightarrow$	1.954 $\leftrightarrow$
5 $\leftrightarrow$	3.1 $\leftrightarrow$	2.62 $\leftrightarrow$	2.678 $\leftrightarrow$

b) CT2, 1 $\Omega$ , 50W $\leftrightarrow$

# TEST $\leftrightarrow$	Supply Voltage(V) $\leftrightarrow$	Supply Current (A) $\leftrightarrow$	Multimeter(A) $\leftrightarrow$
1 $\leftrightarrow$	0.4 $\leftrightarrow$	0.3 $\leftrightarrow$	0.307 $\leftrightarrow$
2 $\leftrightarrow$	1.2 $\leftrightarrow$	0.99 $\leftrightarrow$	1.011 $\leftrightarrow$
3 $\leftrightarrow$	1.6 $\leftrightarrow$	1.32 $\leftrightarrow$	1.35 $\leftrightarrow$
4 $\leftrightarrow$	2.3 $\leftrightarrow$	1.91 $\leftrightarrow$	1.954 $\leftrightarrow$
5 $\leftrightarrow$	3.1 $\leftrightarrow$	2.62 $\leftrightarrow$	2.678 $\leftrightarrow$
6 $\leftrightarrow$	3.9 $\leftrightarrow$	3.23 $\leftrightarrow$	3.301 $\leftrightarrow$
7 $\leftrightarrow$	4.4 $\leftrightarrow$	3.70 $\leftrightarrow$	3.782 $\leftrightarrow$



# Test Data

## CT Shunt Resistance

8 <sup>o</sup>	5.1 <sup>o</sup>	4.26 <sup>o</sup>	4.35 <sup>o</sup>
9 <sup>o</sup>	5.9 <sup>o</sup>	4.91 <sup>o</sup>	5.02 <sup>o</sup>
10 <sup>o</sup>	6.7 <sup>o</sup>	5.63 <sup>o</sup>	5.75 <sup>o</sup>
11 <sup>o</sup>	7.2 <sup>o</sup>	6.02 <sup>o</sup>	6.16 <sup>o</sup>
12 <sup>o</sup>	8.0 <sup>o</sup>	6.66 <sup>o</sup>	6.81 <sup>o</sup>

c) CT3, 1 $\Omega$ , 10W<sup>o</sup>

# TEST <sup>o</sup>	Supply Voltage(V) <sup>o</sup>	Supply Current (A) <sup>o</sup>	Multimeter(A) <sup>o</sup>
1 <sup>o</sup>	0.7 <sup>o</sup>	0.63 <sup>o</sup>	0.647 <sup>o</sup>
2 <sup>o</sup>	1.3 <sup>o</sup>	1.09 <sup>o</sup>	1.084 <sup>o</sup>
3 <sup>o</sup>	2.1 <sup>o</sup>	1.77 <sup>o</sup>	1.765 <sup>o</sup>
4 <sup>o</sup>	2.8 <sup>o</sup>	2.41 <sup>o</sup>	2.421 <sup>o</sup>
5 <sup>o</sup>	3.3 <sup>o</sup>	2.99 <sup>o</sup>	3.006 <sup>o</sup>

