Capacitors and Resistors at Nitrogen Temperatures and Operating Voltages

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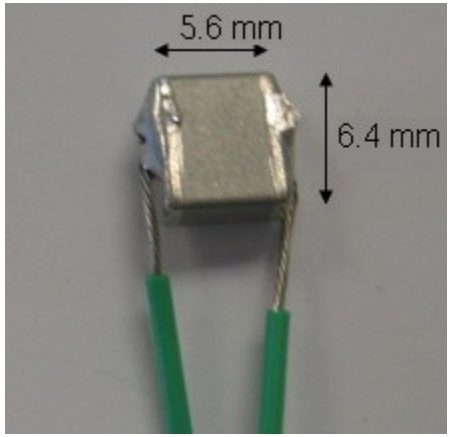
Objectives

1. To determine whether the capacitances and resistances of the PMT base components change at cold temperatures
2. To determine if the capacitors or resistors break at operating voltages

Purpose

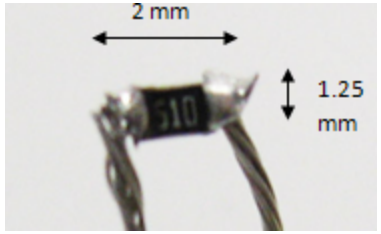
- PMT needs correct voltages across dynodes
- Dynode voltage determined by resisters and overall applied voltage
  - Resistance may be a function of temperature
  - 100 to 200 V across resistors (1000 V in one case)
- Capacitors provide charge for signals in base

Components



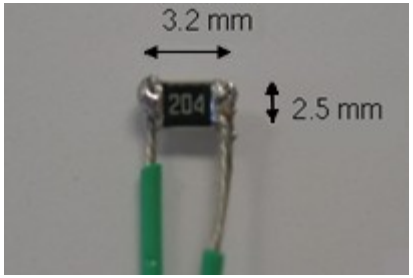
8.2 nF Capacitor

8.2 nF ceramic capacitor
22 nF ceramic capacitor
51 Ω, 0805 metal film resistor
150 kΩ, 1210 metal film resistor
200 kΩ, 1210 metal film resistor
270 kΩ, 0805 metal film resistor
470 kΩ, 1206 metal film resistor
560 kΩ, 0805 metal film resistor
620 kΩ, 1210 metal film resistor
500 MΩ, non-metal film, special HV resistor

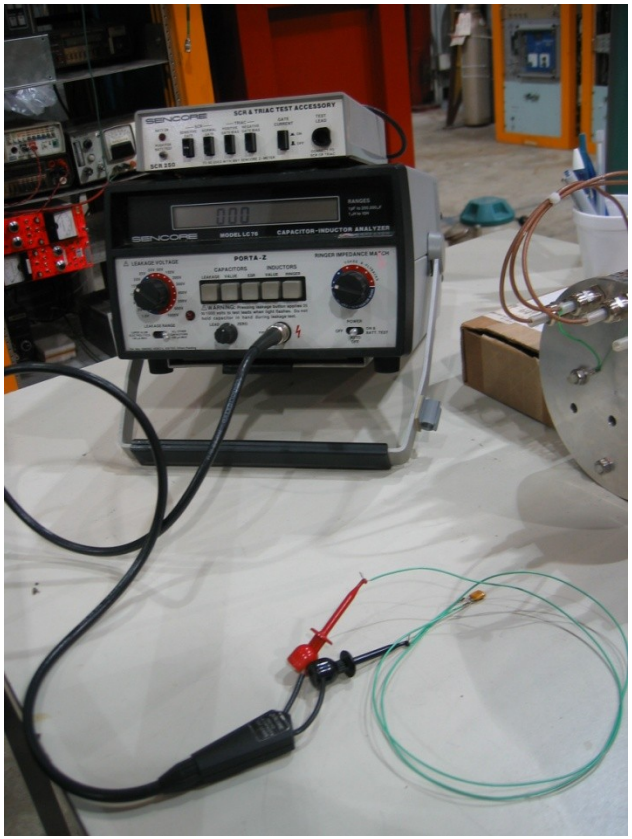


51 Ω resistor

200 kΩ resistor



Testing Capacitances



Capacitor-Inductor Analyzer

Capacitors in Liquid Nitrogen

Testing Voltages: Capacitor

High voltage supply

Testing Resistances

Hewlett Packard
Multimeter

Testing Voltages: Resistors

Based off PMT base design:
2000 V
4062 kΩ
0.5 mA

Reason for Fluke multimeter and not HV supply:
Internal 200 kΩ resistor in high voltage supply

Fluke multimeter

Results: Capacitors

Capacitances at Room Temperature and in Liquid Nitrogen

Capacitor #	Capacitance					
	Room Temperature (nF)	Nitrogen: Cycle 1 (nF)	Nitrogen: Cycle 2 (nF)	Nitrogen: Cycle 3 (nF)	Nitrogen: Cycle 4 (nF)	Nitrogen: Cycle 5 (nF)
1	8.37	8.31	8.38	8.36	8.33	8.35
2	8.17	8.12	8.17	8.16	8.14	8.16
3	22.6	22.8	22.8	22.8	22.8	22.8
4	23.1	23.2	23.2	23.2	23.2	23.2

Currents at Room Temperature and in Liquid Nitrogen

Capacitor #	Voltage (V)	Current at Room Temperature (mA)	Current in Liquid Nitrogen (mA)
1	2000	Undet.	Undet.
2	2000	Undet.	Undet.
3	500	Undet.	Undet.
4	500	Undet.	Undet.

Current undetectable to the sensitivity of the high voltage supply (1 nA)

Results: Capacitors

Capacitances at Room Temperature and in Liquid Nitrogen

Capacitor #		rogen: e 5 (nF)
1		8.35
2		8.16
3		22.8
4		23.2

No Change in Capacitances

Currents at Room Temperature and in Liquid Nitrogen

C		
4	500	Undet.	Undet.

Undetectable Currents

Current undetectable to the sensitivity of the high voltage supply (1 nA)

Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
3	150	150	150
4	150	150	150
5	200	200	200
6	200	200	200
7	270	270	271
8	270	270	271
9	470	470	470
10	470	471	471
11	560	560	562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
			150
			150
			200
			200
			271
			271
			470
			471
			562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

No Change in Resistances

Results: Resistors

Resistances at Room Temperature and in Liquid Nitrogen

Resistor #	Resistance		
	Claimed (kΩ)	Room Temperature (kΩ)	Liquid Nitrogen (kΩ)
1	51 Ω	51 Ω	51 Ω
2	51 Ω	51 Ω	51 Ω
3	150	150	150
4	150	150	150
5	200	200	200
6	200	200	200
7	270	270	271
8	270	270	271
9	470	470	470
10	470	471	471
11	560	560	562
12	560	560	562
13	620	620	620
14	620	620	620
15	500 MΩ	527 MΩ	575 MΩ

9.5% increase in resistance

Results: Resistors

Resistor #	Measured Voltage (V)				Calculated Resistance (kΩ)			
	0 mA	0.3 mA	0.6 mA	0.8 mA	0	0.3 mA	0.6 mA	0.8 mA
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	0	44.6	89.4	119.1	--	148.7	149.0	148.9
	0	44.6	89.4	119.1	--	148.7	149.0	148.9
4	0	44.7	89.4	119.1	--	149.0	149.2	149.0
	0	44.7	89.5	119.2	--	149.0	149.2	148.9
5	0	59.5	118.8	158.6	--	198.3	198.0	198.3
	0	59.3	119.0	158.5	--	197.7	198.3	198.1
6	0	59.3	119.1	158.7	--	197.7	198.5	198.4
	0	59.4	119.0	158.5	--	198.0	198.3	198.1
7	0	80.4	160.4	214.1	--	268.0	267.3	267.6
	0	80.3	161.0	213.9	--	267.7	268.3	267.4
8	0	79.8	160.0	213.7	--	266.0	266.7	267.1
	0	80.7	160.8	214.5	--	269.0	268.0	268.1

Results: Resistors

Resistor #	Measured Voltage (V)				Calculated Resistance (kΩ)			
	0 mA	0.3 mA	0.6 mA	0.775 mA	0 mA	0.3 mA	0.6 mA	0.775 mA
9	0	139.9	278.7	359.9	--	466.3	464.5	464.4
	0	143.3	283.3	363.8	--	477.7	472.2	469.4
10	0	139.5	279.0	360.6	--	465.0	465.0	465.3
	0	143.6	284.5	365.6	--	465.0	465.0	47.2
11	0	166.0	332.1	428	--	553.3	553.5	570.3
	0	166.0	331.9	442	--	553.3	553.2	570.3
12	0	166.5	331.5	428	--	555.0	552.5	552.3
	0	166.2	332.4	429	--	554.0	554.0	553.5
13	0	183.5	367.8	478	--	611.7	613.0	616.8
	0	185.5	366.2	471	--	618.3	610.3	607.7
14	0	183.7	367.8	477	--	612.3	607.3	615.5
	0	184.8	364.4	470	--	612.3	613.0	615.5

Resistor #	Measured Current (mA)				Calculated Resistance (kΩ)			
	0 V	500 V	1000 V	1500 V	0	500 V	1000 V	1500 V
15	0	9.8e-4	1.91e-3	2.84e-3	--	508.2 MΩ	521.2 MΩ	526.2 MΩ
	0	9.8e-4	2.1e-3	3.13e-3	--	508.2 MΩ	474.2 MΩ	477.2 MΩ

Results: Resistors

Resistor #	Measured Voltage (V)				Calculated Resistance (kΩ)			
	0 mA	0.3 mA	0.6 mA	0.8 mA	0	0.3 mA	0.6 mA	0.8 mA
1	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--
3	0	44.6	89.4	119.1	--	148.7	149.0	148.9
							149.0	148.9
4							149.2	149.0
							149.2	148.9
5							198.0	198.3
							198.3	198.1
6							198.5	198.4
							198.3	198.1
7							267.3	267.6
	0	80.3	161.0	213.9	--	267.7	268.3	267.4
8	0	79.8	160.0	213.7	--	266.0	266.7	267.1
	0	80.7	160.8	214.5	--	269.0	268.0	268.1

No Change in Resistances

Results: Resistors

Resistor #	Measured Voltage (V)				Calculated Resistance (kΩ)			
	0 mA	0.3 mA	0.6 mA	0.775 mA	0 mA	0.3 mA	0.6 mA	0.775 mA
9	0						464.5	464.4
	0						472.2	469.4
10	0						465.0	465.3
	0						465.0	47.2
11	0						553.5	570.3
	0						553.2	570.3
12	0						552.5	552.3
	0						554.0	553.5
13	0						613.0	616.8
	0						610.3	607.7
14	0	183.7	367.8	477	--	612.3	607.3	615.5
	0	184.8	364.4	470	--	612.3	613.0	615.5

No Change in Resistances

Resistor #	Measured Current (mA)				Calculated Resistance (kΩ)			
	0 V	500 V	1000 V	1500 V	0	500 V	1000 V	1500 V
15	0	9.8e-4	1.91e-3	2.84e-3	--	508.2 MΩ	521.2 MΩ	526.2 MΩ
	0	9.8e-4	2.1e-3	3.13e-3	--	508.2 MΩ	474.2 MΩ	477.2 MΩ

Conclusion

These capacitors and resistors are suitable for MicroBooNE and Dark Matter Experiments