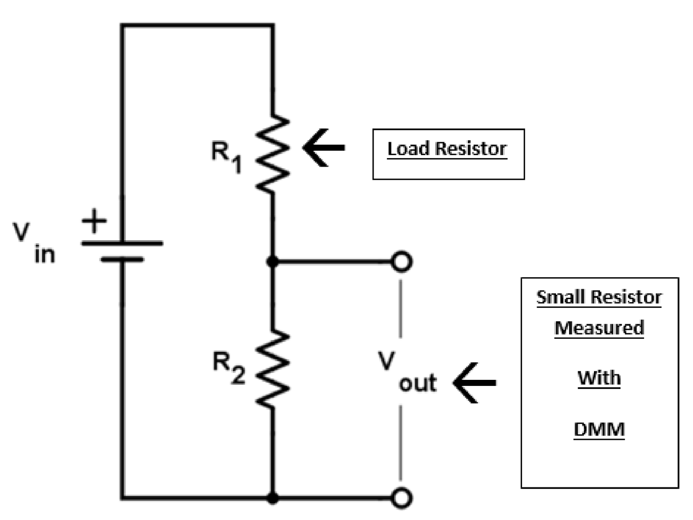
Characterization Of Low to High Voltage Converters for Cosmic Ray Muon Detectors

Abstract:

The EMCO G30 Low to High Voltage convert is a powerful tool with rated specifications that should meet our requirements to power the PMT's (Photomultiplier Tubes) inside our detectors. Since these converters are Load dependent, not load regulated, it is imperative that we characterize how they operate under different load impedances on the output end of the converters. By examining how these converters output voltage with variable loads, it can be concluded whether or not the converter will be able to sufficiently power a specific PMT based on its impedance. It was concluded that the converters operate most efficiently when the load resistance is of a relatively high value (i.e. Over 5 Mega Ohm). Studies were also conducted to see how potentially hazardous these converters can be while operating at different input voltages under different loads. It was concluded and proven that the EMCO G30 is power regulated and does not reach a potentially dangerous current output due to the current limitations that are in place when the unit is operating under a relatively small Load. (i.e. a Load < 4MΩ)

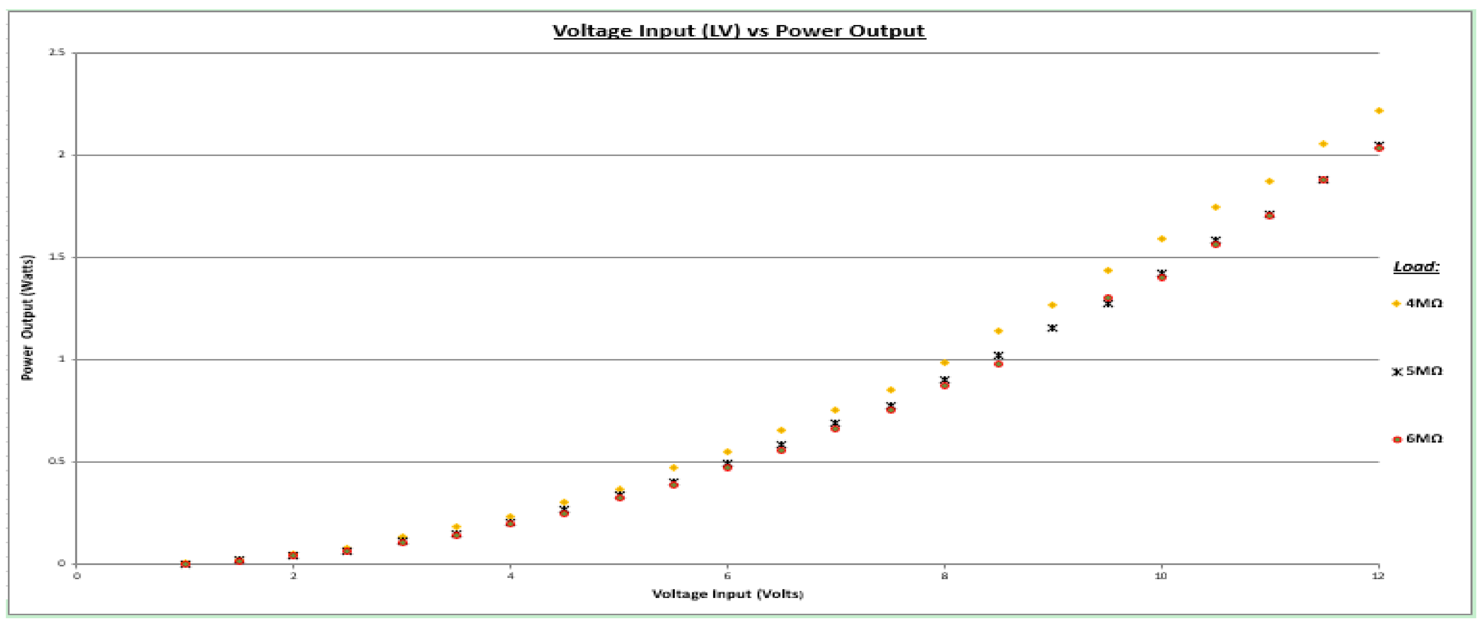
Voltage Divider Measurements:



$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

**V_{out}* Was the voltage Measured across the small Resistor ($R_{Measured}$) and V_{in} (The total voltage across the small resistor as well as the Load) was calculated using that measured value and the ratio of resistances based on a known load resistance and a known small resistor chosen to measure across.*

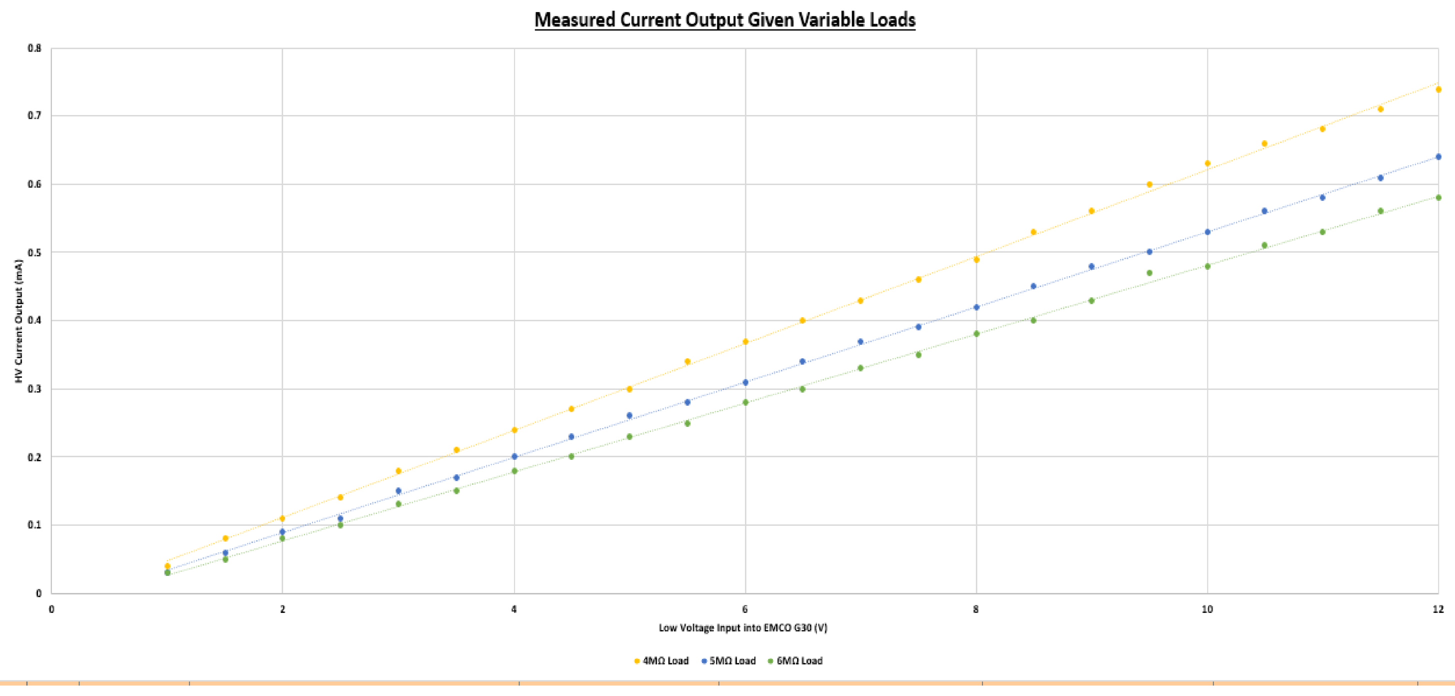
Proof of Power Regulation in EMCO G30:



****The Power was calculated using the formula:***

[P = V * I]

Where I is the output current measured from the EMCO G30 given different load resistances, and V is the High Voltage output calculated using Voltage Divider Measurements.

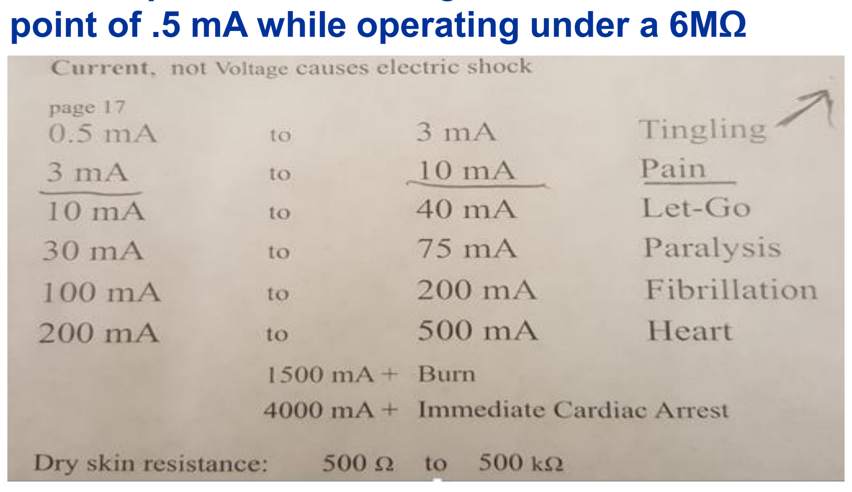


****The EMCO model G30 Low to High voltage converters max current output at its maximum voltage output was expected to be no more than .5mA as stated in the models spec sheets. It is important to understand how the output current may increase given variable load resistances. By testing the units in a circuit where variable load resistances were applied, it was measured that the output current on the high voltage end of the converter can actually exceed .5mA when the load is below 6MΩ.***

Testing Current to Observe Potential Saturation Point:

The EMCO model G30 Low to High Voltage converter is capable of achieving a maximum voltage output of 3kV with a supposed current saturation point of .5 mA while operating under a 6MΩ Load (Calculated using ohms law below).

In this case using Ohm's law, we can determine that the R_{Load} Value should be about 6 MΩ.



Current,	not Voltage causes electric shock		
0.5 mA	to	3 mA	Tingling
3 mA	to	10 mA	Pain
10 mA	to	40 mA	Let-Go
30 mA	to	75 mA	Paralysis
100 mA	to	200 mA	Fibrillation
200 mA	to	500 mA	Heart
		1500 mA +	Burn
		4000 mA +	Immediate Cardiac Arrest
Dry skin resistance:	500 Ω	to	500 kΩ

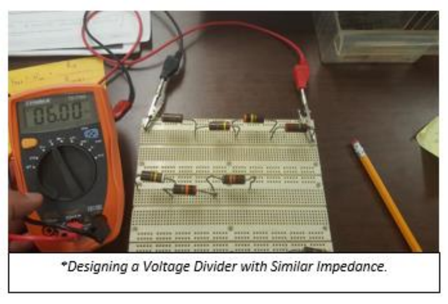
Since $[V = IR] \rightarrow [R_{Load} = \frac{V_{out}}{I_{out}}]$

We can calculate the value of the rated Load Resistor (R_{Load}) by using the maximum values provided by the spec sheet (i.e. 3kV and .5mA).

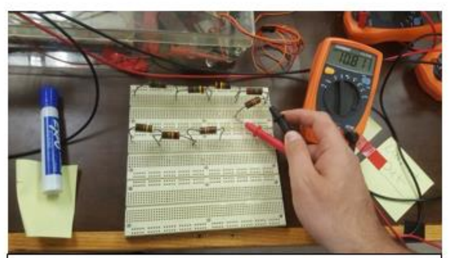
So…

$[R_{Load} = \frac{V}{I}] \rightarrow [R_{Load} = \frac{3{,}000V}{.005A}] \rightarrow [R_{Load} = 6M\Omega]$

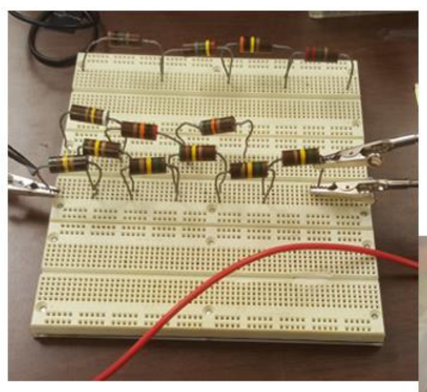
**Measuring the Photo Multiplier Tubes (PMT's) Impedance (Resistance).*



**Designing a Voltage Divider with Similar Impedance.*

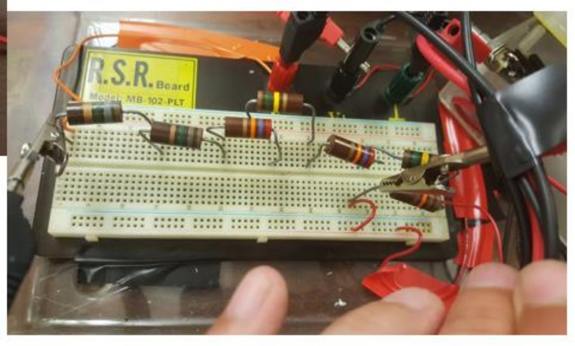


**Measuring the resistance of the small Resistor. (This is the Resistor that will be probed for a Low Voltage Value. That Value will then be used to calculate the total output voltage out of the EMCO G30)*



← Design

Enclosure →

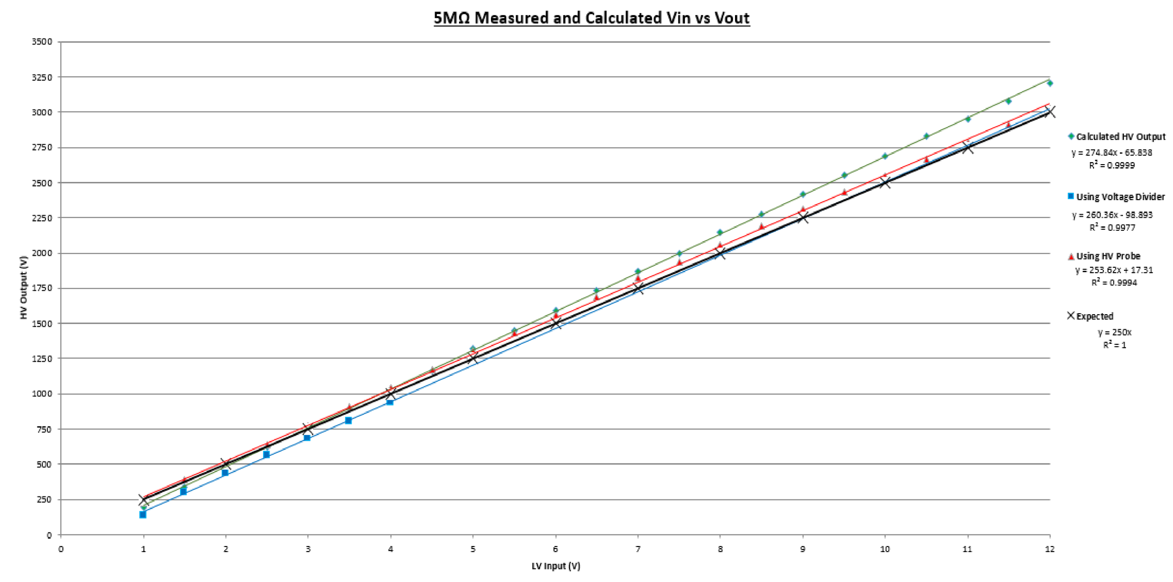


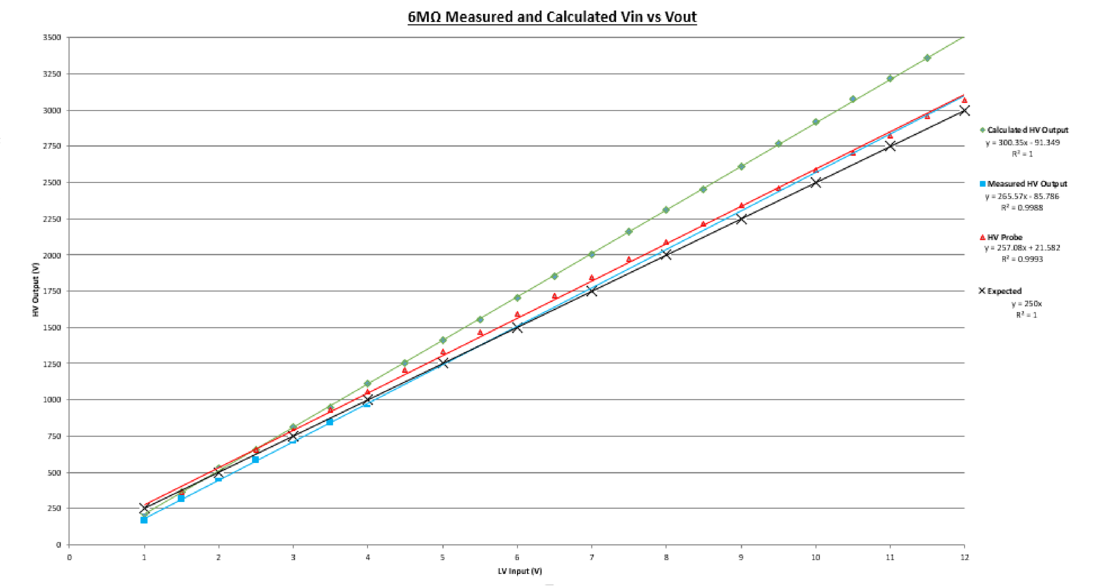
**The Voltage divider was designed and then placed in an enclosure such that if there is a live current running through any of the wires, it won't be possible to touch it by mistake.*

**Voltage Measurements were taken across the small resistor, and the total voltage coming out of the EMCO G30 was calculated using the formula:*

$\rightarrow \quad [V_{in} = V_{out} \times \frac{R_{Total}}{R_{Measured}}]$.

**The Current input and output were also measured using two Digital Multi-meters configured to measure in Milliamps. This was conducted for Load Resistances ranging from 1MΩ to 6MΩ where the input voltage being put into the EMCO from the power supply is increased from 0V – 12V. The values for the output voltage coming out of the EMCO vary with varying Load resistances; this can be inferred by looking at the data tables and graphs that follow.*





***The Green Plot was calculated using voltage divider measurements and the formula depicted above:**

$[V_{out} = V_{in} \times \frac{R_{Measuring}}{R_{Total}}]$

Using the value measured across the resistor, this formula can be manipulated to calculate the total voltage output of the EMCO G30:

i.e. $[V_{in} = V_{out} \times \frac{R_{Total}}{R_{Measuring}}]$

***The Red Plot is composed of measurements taken using a HV Probe.**

***The Blue Plot was the output voltage physically being measured using a Digital Multi-Meter with a maximum Voltage range up to 1kV (1,000V).**

***The Black plot represents 1Vin yielding the expected 250Vout**

Conclusions:

EMCO G30 Output Current:

The EMCO model G30 Low to High Voltage converter is capable of achieving a maximum voltage output of 3kV with a supposed current saturation point of .5 mA while operating under a 6MΩ Load; as stated by the proved spec sheets by EMCO. Essentially, the units have the potential in theory to output a higher current on the high voltage side of the converters. It was measured that given lower impedances in the circuit, the EMCO model G30's were able to output a current higher than the .5mA stated on the spec sheets when given a load less than the 6MΩ required to achieve maximum voltage output. Since these converters are load dependent, not load regulated, the maximum output voltage varies given different impedances however, maximizes at approximately .5mA when the load resistance in the circuit is above 6MΩ.

i.e.

$([V = IR] \rightarrow [R = \frac{V}{I}] \rightarrow [R = \frac{3kV}{.5mA} = 6M\Omega])$

Vin vs Vout (5MΩ, 6MΩ):

It was concluded that if the impedance of a specific Photo-Multiplier Tube is imperative to measure in order to be able to conclude if the EMCO G30 can power that specific Photo tube. Since the EMCO G30 is Load dependent, the output voltage of the converter is dependent on the impedance of the circuit. If the impedance is low and the Photo Tube requires upwards of 3kV to power it, it will not properly power the photo tube. i.e. in order to achieve the maximum voltage output of 3kV, the Load impedance of the photo tube must be at least 4MΩ. If the Load Impedance is below 4MΩ than you can't achieve the maximum voltage output of 3kV. As far as calibrating the PMT's such that they achieve a maximum gain of 10^6, the output voltages measured should be configured to output a voltage within 10% of what can be inferred from the above data. In doing this one can achieve a maximum gain relative to a photomultiplier tube that has an impedance at or between 5MΩ and 6MΩ.

Power Regulation (4MΩ,5MΩ, 6MΩ):

The EMCO G30 models Load regulation was concluded to coincide with power regulation. This was proven using the measurements in the plot above labeled "LV vs Power Output." For each different load, it is clear that the power outputs are within acceptable range of one another and can be concluded to be the limiting factor in these converters. It was also concluded that these converters are specified to run at a maximum of 1.5 Watts however, they have the potential to output more power than specified and may be damaged if not considered. Future trials will be run with the EMCO G30's running for extended periods of time with different output powers. This will determine if a specific output power will cause damage to this unit.

Acknowledgements:

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References:

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