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The Development of a Novel Electron Multiplier with an Onboard Integral High Voltage Power Supply for use in Mass Spectrometers

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Introduction

- A key component of a mass spectrometer is the electron multiplier, which serves to amplify the weak ion signal and provide information to the system electronics which identifies the unknown material.
- The gain of the multiplier is proportional to the high voltage applied which is historically provided external to the vacuum system.
- Bringing high voltage (3kv) into the vacuum system and outputting tiny signal currents has proven expensive and challenging for the instrument manufacturer.

Discussion

- Electron Multipliers produce very high gain and low noise signal amplification by a process of secondary electron emission. (Figure 1)

- In order to be effective, secondary electron emission must occur within a high electric field. Producing a high electric field in a vacuum system requires voltages, typically as high as 3kV.

- Electron Multipliers do not draw high current, typically less than 100 micro-amps.

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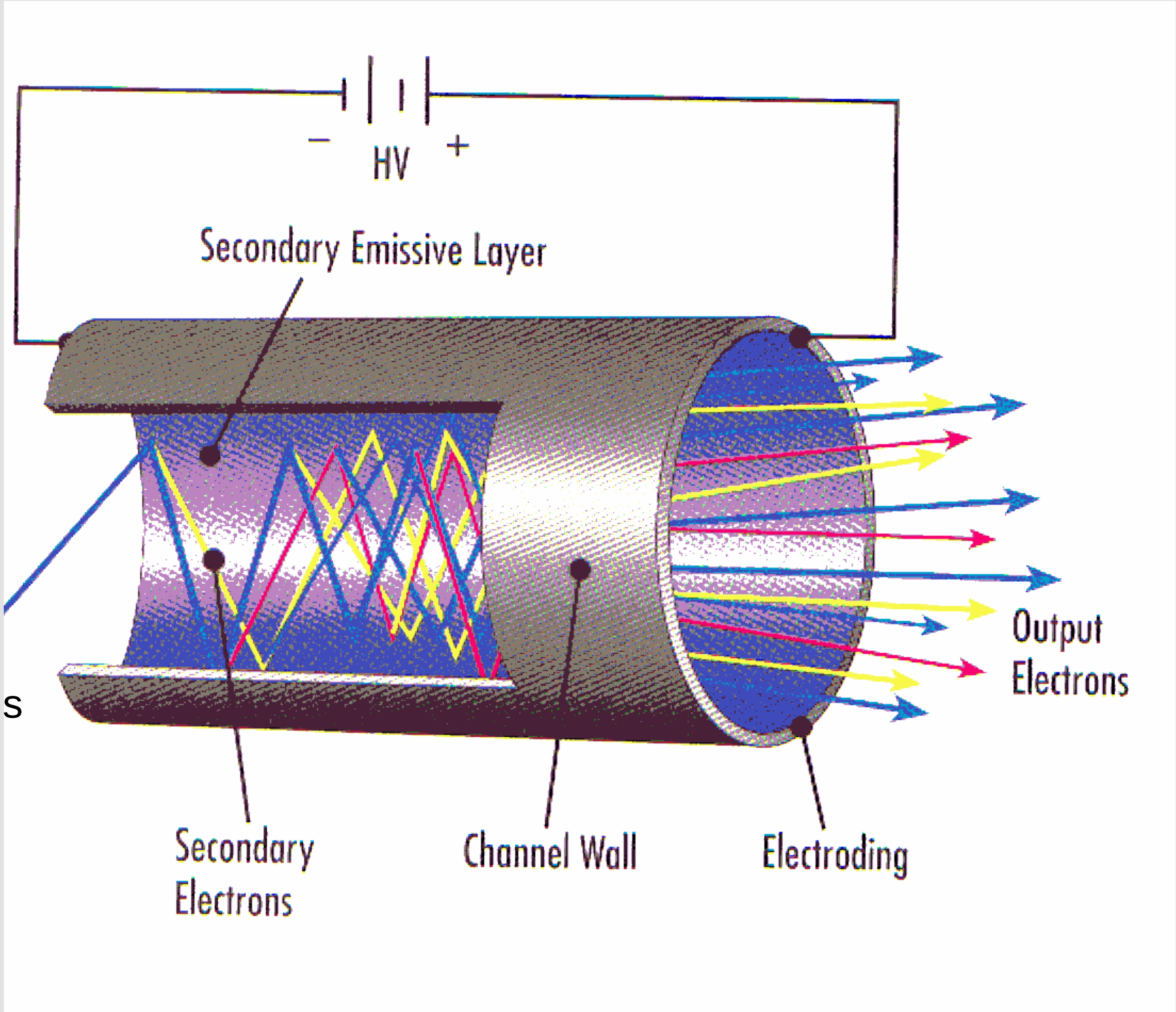
Single Channel Electron Multiplier Operation



Incident
Ions or photons

Figure 1

Discussion Continued

- Conventional rack mount high voltage power supplies typically measure 19x4x12 inches.
- In many instances rack mount supplies have more capability than is needed to operate an electron multiplier.
- Rack mount power supplies, are more costly, consume more power, take up more space and add more weight to the instrument than an equivalent miniature power supply.
- Running high voltage safely into the vacuum system involves expensive cabling and high vacuum feed-throughs which would be eliminated with point of use technology.

- Micro-miniature high voltage power supplies have been used successfully in Space Exploration applications for many years.

- If it were possible to place a high voltage power supply at point of use and control it with low voltage DC signals, then a significant savings could be realized.

Objective

- The objective of this project was to determine if a micro-miniature high voltage power supply could be integrated on board an electron multiplier
- The resultant package would then be operated in vacuum from low voltage DC sources readily available within the instrument.
- Control signal voltages could be easily and cost effectively transmitted through low cost potted feed-throughs.

Experimental Design

- The 4822B Channeltron® was selected for the prototype because it is one of the most widely used electron multipliers in the mass spectrometry industry. This multiplier is capable of single ion detection at a gain of 100 million.
- The 4822B Channeltron® was then fitted to an Applied Kilovolts miniature high voltage power supply (model No MP003N).
- The hybrid multiplier and power supply was then loaded into a turbo pumped vacuum system.

- Performance of the multiplier was characterized using the on board high voltage supply to modulate the multiplier voltage.
- The multiplier was then removed from the onboard supply and characterized using the standard rack mount supply.

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Electron Multiplier Specification

PHYSICAL CHARACTERISTICS	SPECIFICATIONS
Mechanical Dimensions Defined by Drawing:	30118
Maximum Vacuum Bake Specification: (Not Operating)	8 Hours at 120°C at 1.0 x 1.0^{-5} Torr or Lower
Operating Temperature Range:	-50° to 120°C

ELECTRICAL CHARACTERISTICS	SPECIFICATIONS
Operation:	Pulse Counting
Maximum Operating Pressure:	5.0 x 10^{-6} Torr
Maximum Specified Operating Voltage:	3000 Volts
Bias Current @ 3,000 Volts:	25 to 45 Microamps
Resistance (For Reference Only):	66 to 120 Megohms
Minimum Gain @ 3,000 Volts:	1.0 x 10^{8}
Maximum Dark Count @ 3,000 Volts:	120 Counts in 60 Seconds
Maximum Linear Output Current:	10% of Bias Current (Typical)
Pulse Height Distribution (Maximum):	75% Full Width Half Maximum

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Power Supply Specification

Electrical Specification

UNIT TYPE	POLARITY	OUTPUT	RIPPLE AT FULL LOAD
MP003N	NEGATIVE	-125 volts to -3kV at 0.7mA	150mV peak to peak

INPUT VOLTAGE:	+24 volt d.c. ±10% at 0.25amp maximum.
CONTROL:	By 0 to +10V to give 0 to Full O/p Voltage ±5%
LINE REGULATION:	Better than 100ppm for 1V change in input voltage.
LOAD REGULATION:	Better than 100ppm for 0 to full load.
RIPPLE:	Better than 50ppm peak to peak (measured at maximum voltage and current).
TEMPERATURE CO EFFICIENT:	Typically <200ppm/ °C. Tighter versions available.
OPERATING TEMPERATURE:	0 °C to +50 °C
STORAGE TEMPERATURE:	-35 °C to +85 °C
R.F.I.:	Choke input filter

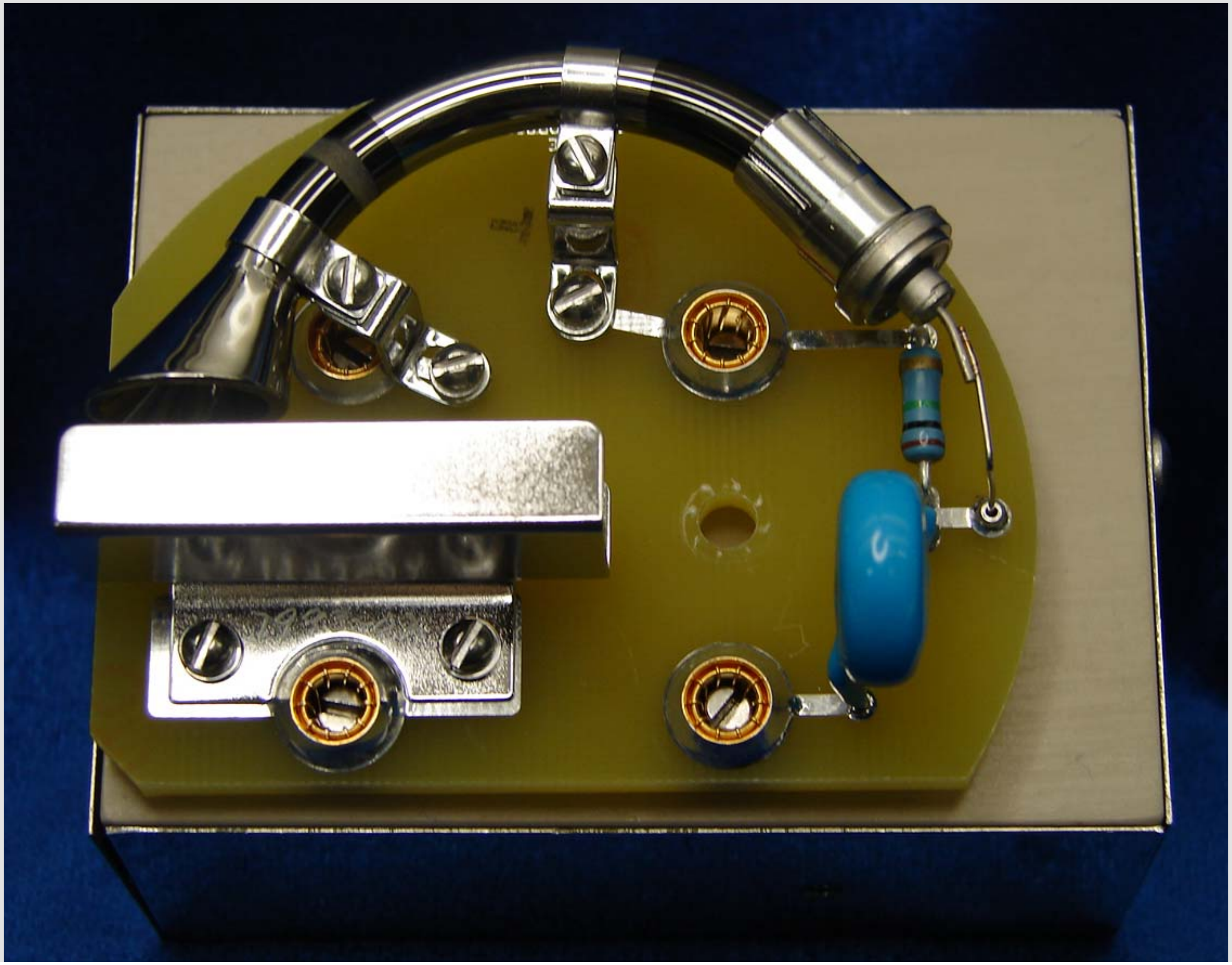
Mechanical Specification

SIZE:	80mm x 55mm x 20mm. - MP001 80mm x 60mm x 35mm. - MP2.5 & MP003
OUTPUT:	Pins for 1kV, o/p by flying lead for units >1kV.
ORDER CODE : series code MP	see below

o/p KV	Polarity	Options Code	Temp Co
001=1kV 2.5=2.5kV 003=3kV	P= +ve N= -ve	**AA** = No options **AV** = Voltage Monitor Fitted	200

eg. -1kV MP series with Voltage Monitor Option fitted : MP001NAV200

Prototype Electron Multiplier with Integrated High Voltage Power Supply



Multiplier is easily removed when replacement is required.

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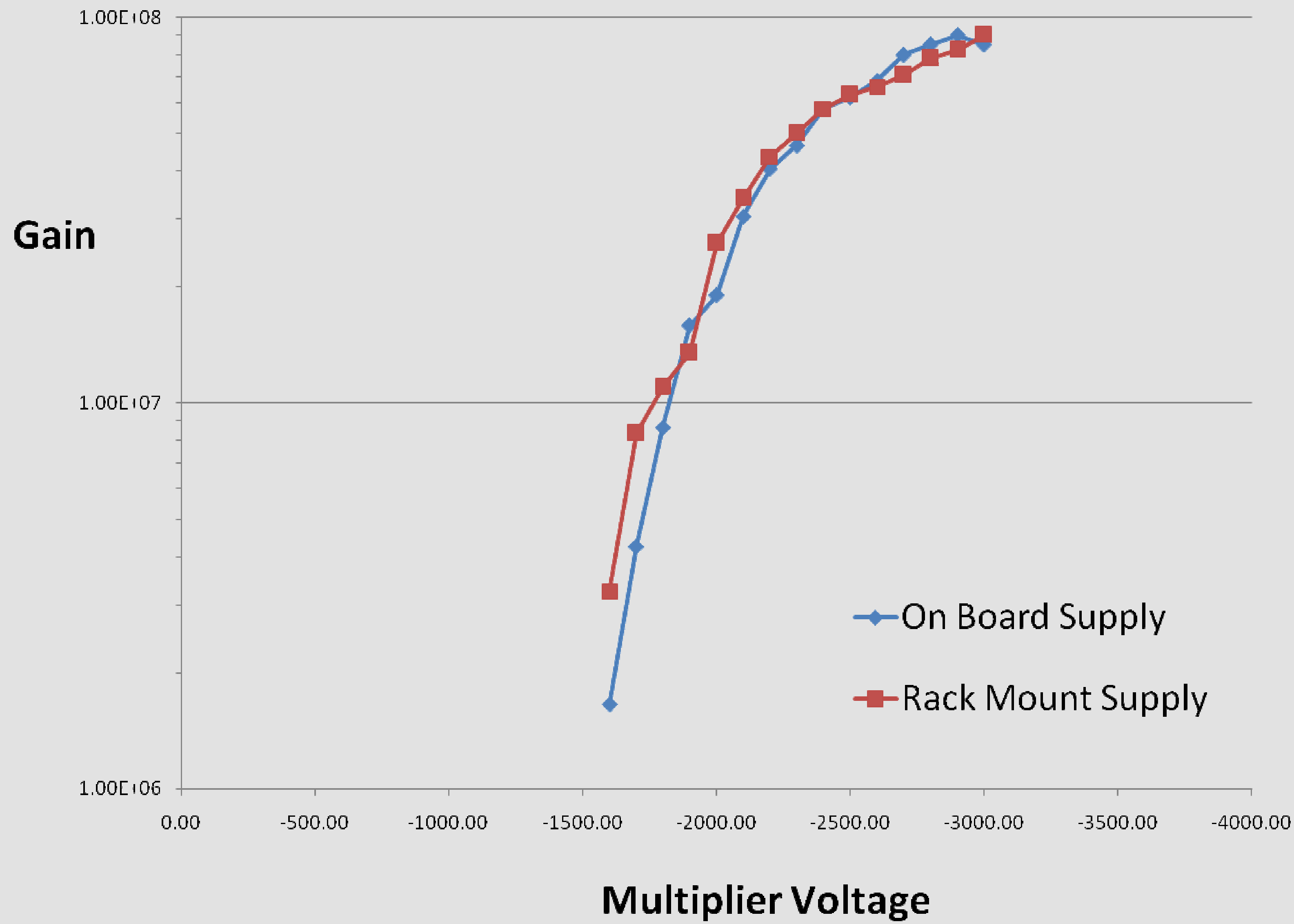
Gain Comparison



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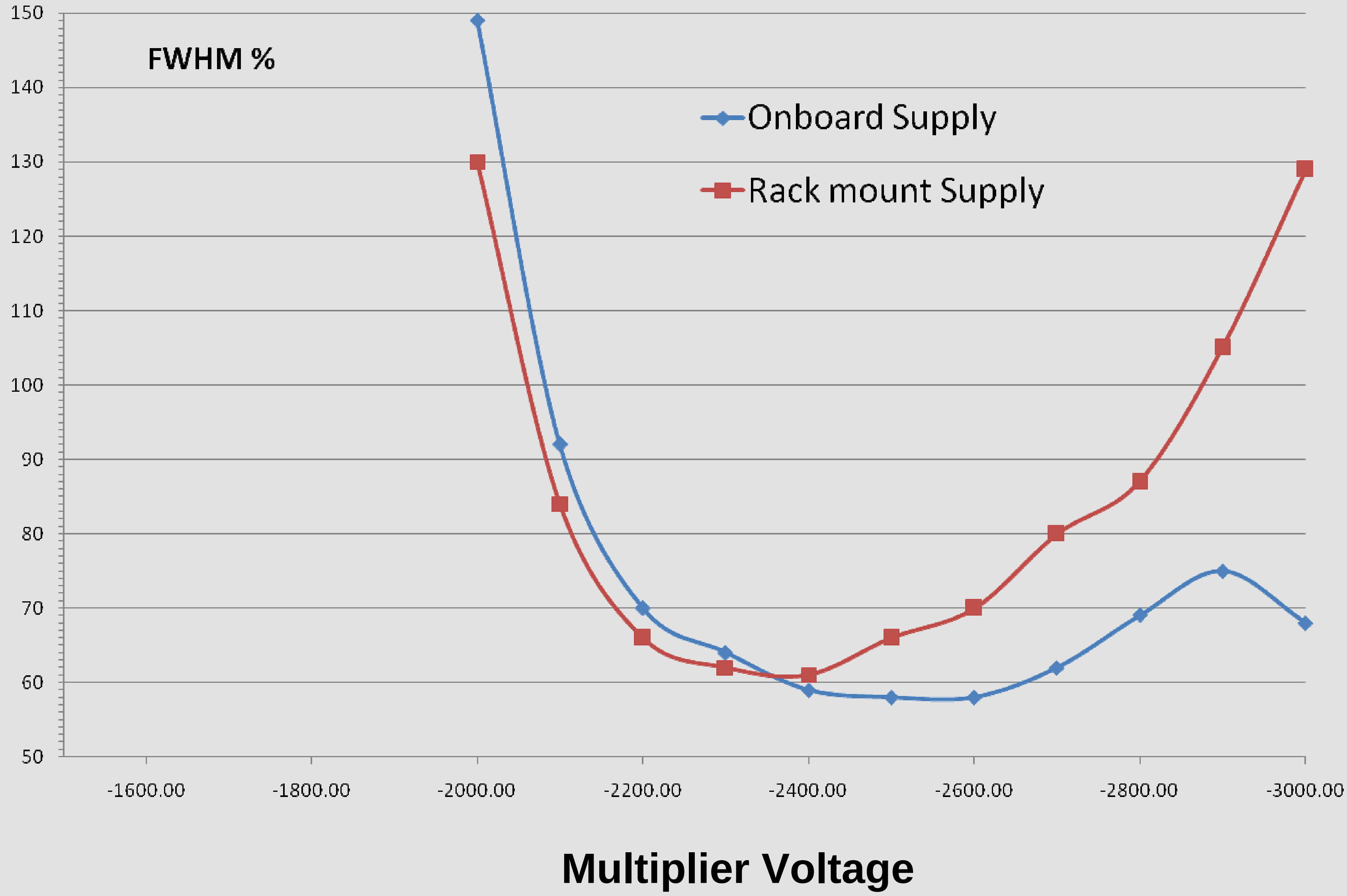
Pulse Height Resolution Comparison



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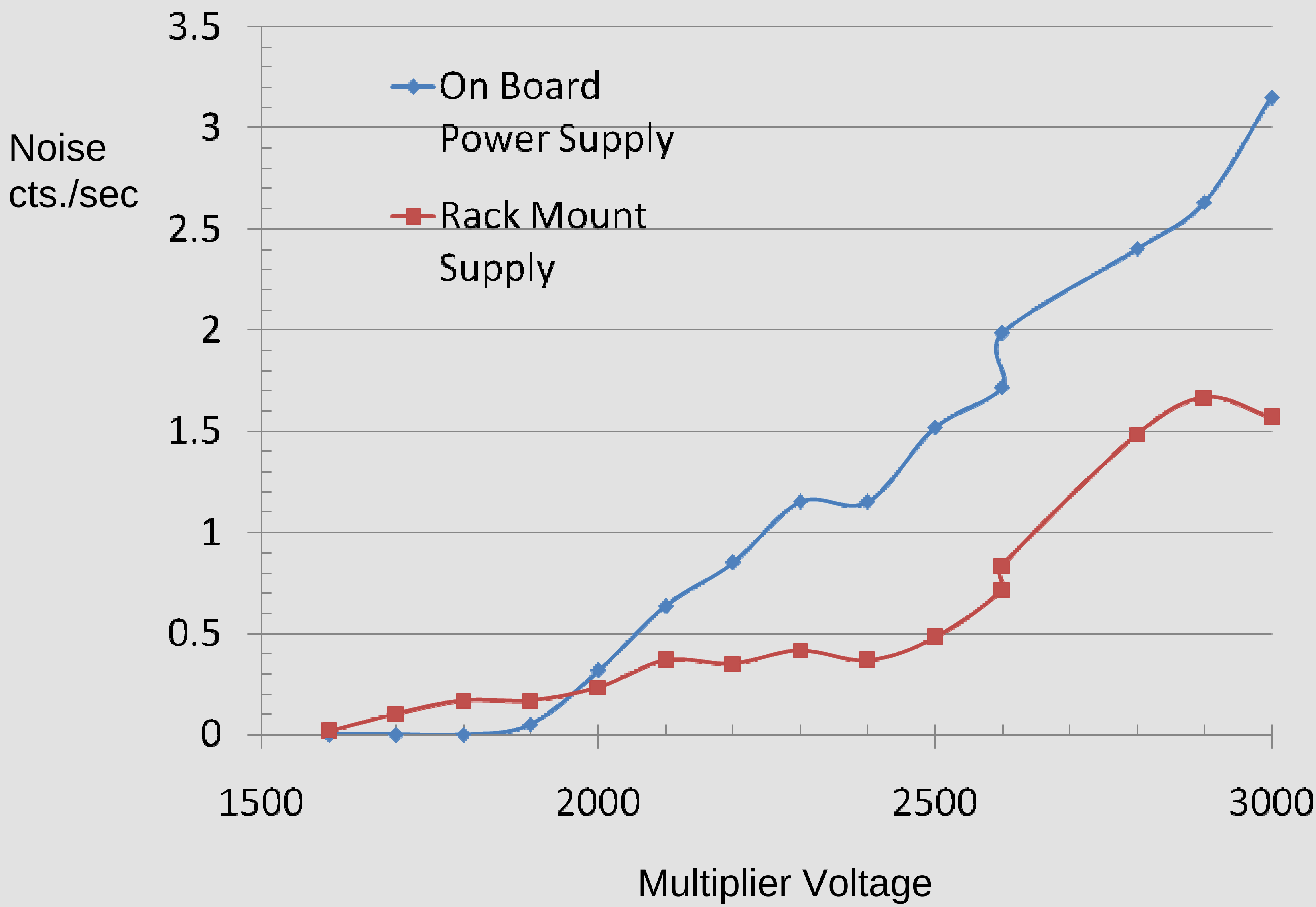
Noise



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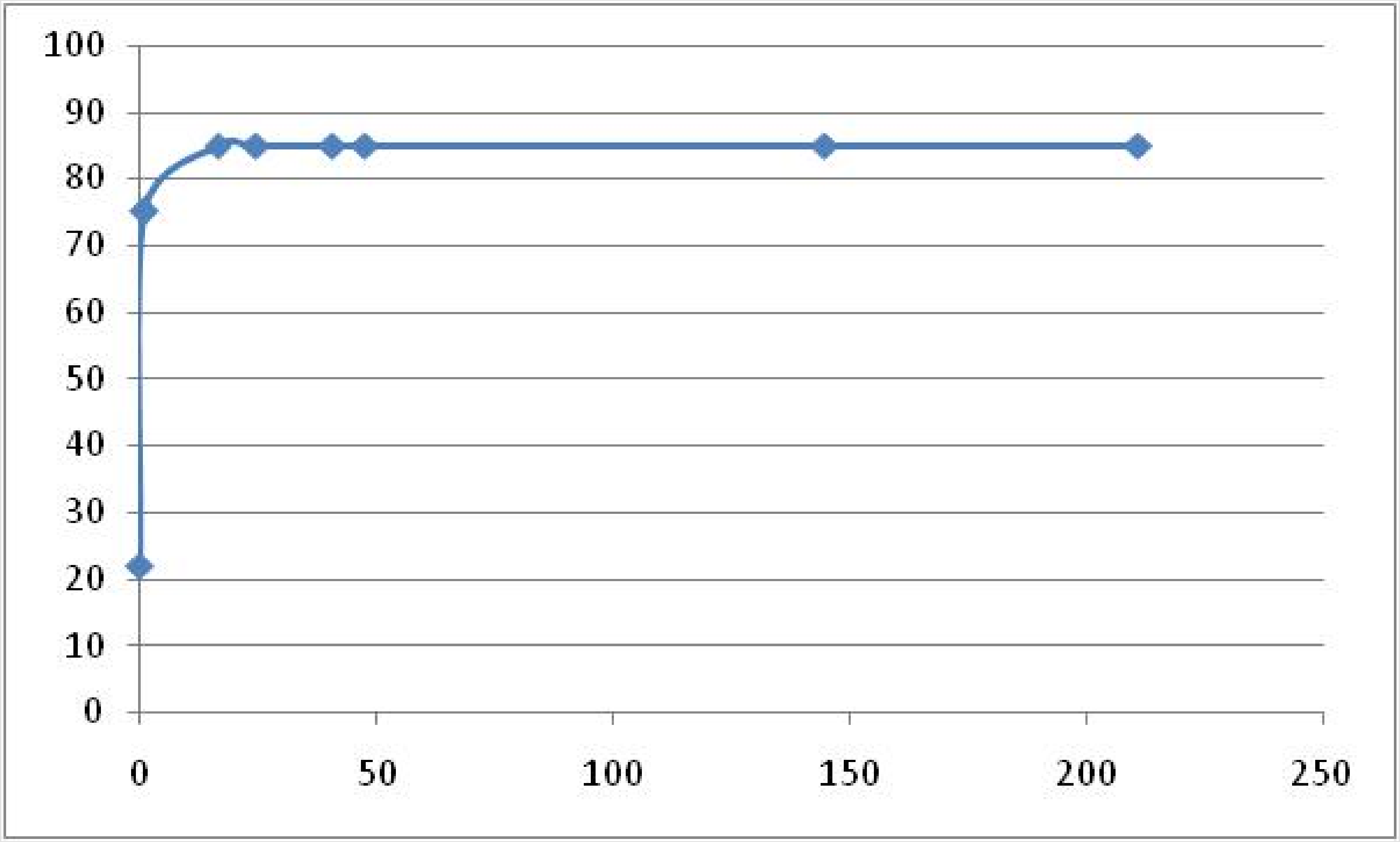
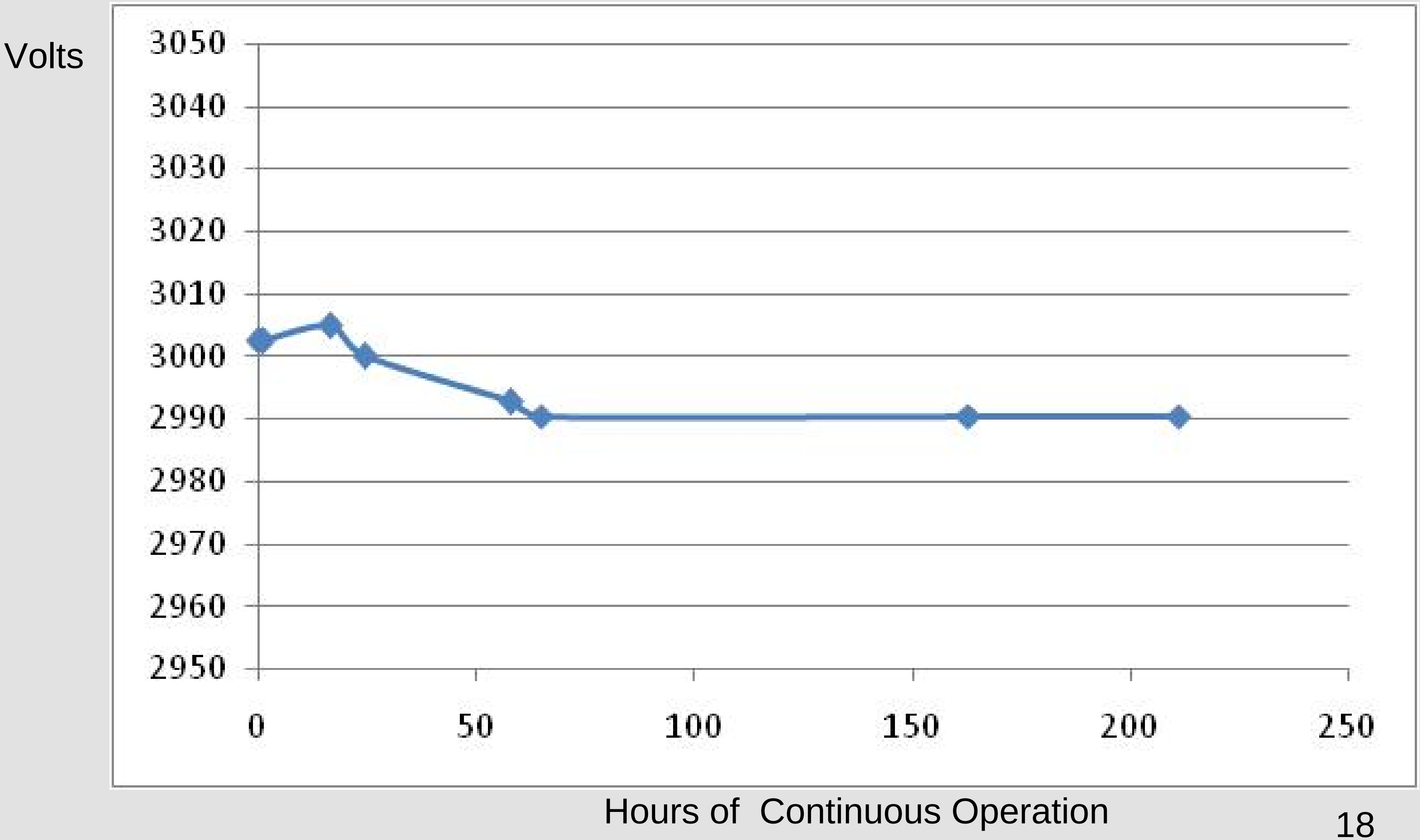
Thermal Stability

Temperature
Deg. C

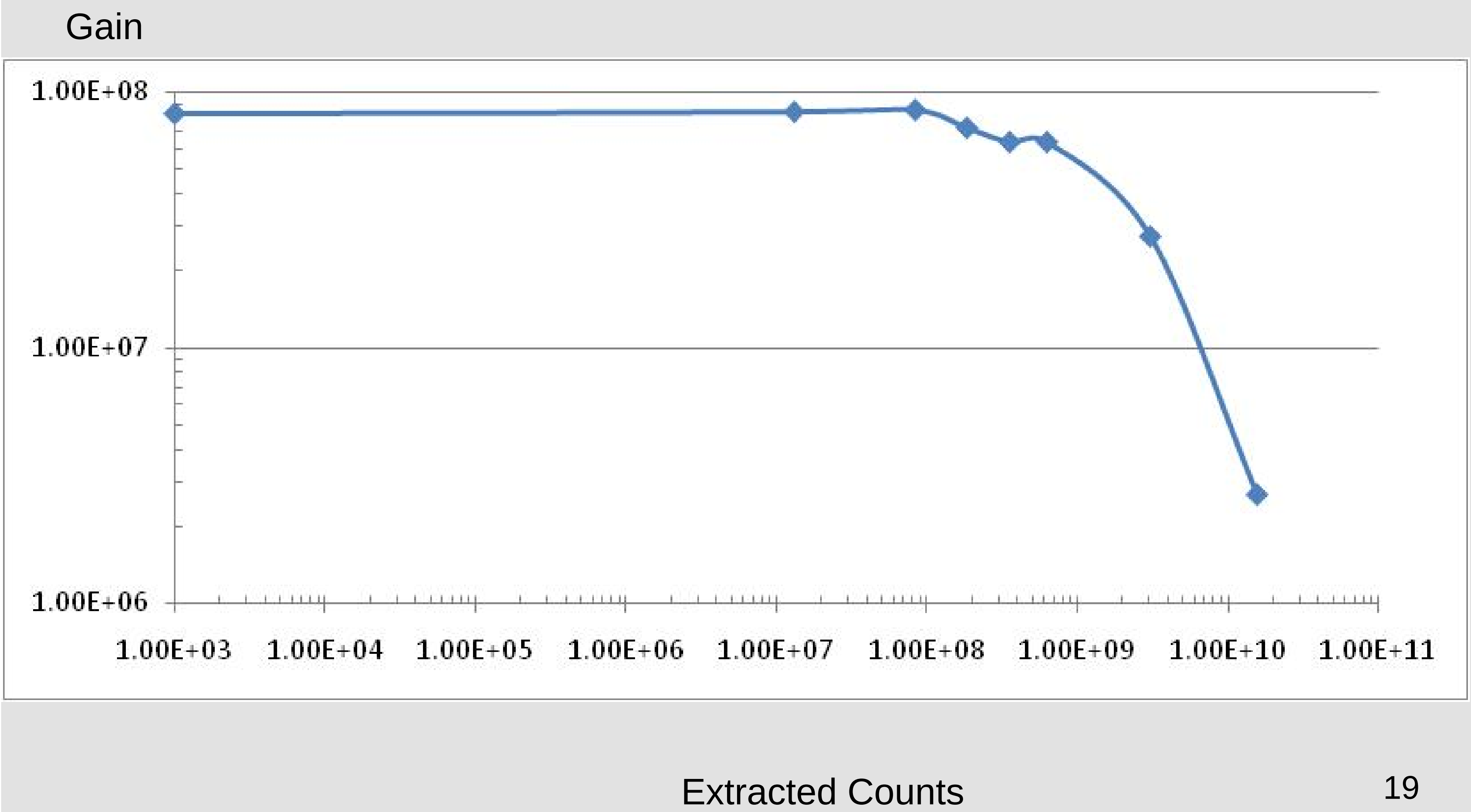


Hours of Continuous Operation (Hours)

Voltage Stability



Gain Stability



Summary

- A hybrid electron multiplier with an integral power supply has been successfully operated in vacuum for hundreds of hours.
- This ion detector was operated using low voltage (<24 volts) DC only.
- The prototype power supply generated a significant amount of heat, stabilizing at 85°C in the free standing configuration.

- Electron multiplier performance comparisons with standard lab supplies produced similar results.
- The supply voltage varied 0.4% during the initial 60 hours of operation.
- The power supply voltage remained constant for the final 150 hours of operation.

Future Work

- The operating temperature of the miniature supply will be addressed. Power management, heat sinking, and circuit design can all be explored.
- The out gassing characteristics of the supply will be determined. Using a Residual Gas Analyzer (RGA), the composition of the out gassed material will be determined.
- The hybrid multiplier will be mounted behind a quadrupole mass filter inside a Mass Spectrometer for dynamic testing.