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DOE Office of Science, Office of Nuclear Physics

Inexpensive Low Noise Fast Switching DC High Voltage Power Supply
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Minority Women Owned Small Business

Outline

- SBIR Topic Background and Need
- Phase II Technical Approach (Brief discussion)
- Specs for the Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies
- Some of the Protections for the Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies
- Some Phase II Examples and Results
- Summary
- Acknowledgements and Questions

Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies Background and Need

- There are needs for inexpensive, highly efficient, very low noise power supplies for magnetrons used in scientific experiments and explorations at USA national facilities and labs as well as other domestic and global applications and uses.
- For example, there is significant need at DOE facilities for a flexible, extremely efficient, modular, low noise family of magnetron power supplies and related electronics that are scalable in output power. These power supplies offer substantial cost reduction and efficiency boost as inexpensive, adaptable, ultra-efficient, compact form factor power supplies for the scientific community as well as numerous commercial, industrial and military applications.
- There is also a need for upgrades to the power supplies and related electronics for high power magnetron systems. This will also significantly increase the up-time, flexibility, innovation and reliability of the magnetron systems while reducing down time and maintenance costs. To address this need, we are investigating and implementing low noise, fast switching, highly efficient power supplies to replace existing power supplies with these state of the art switching power supplies with additional capabilities, features and functions. These switching power supply replacements must be flexible, intelligent and robust enough to meet current and expected future performance standards at National Labs and elsewhere.

Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies Phase II Tech Approach Brief discussion

- Magnetrons tend to wander, can be noisy and have power level fluctuations and performance non-optimization issues unless locked or synchronized. Synchronization typically requires sophisticated approaches which, if done properly, result in high performance, low cost and highly efficient operation.
- Power consumption and energy use in large national labs and facilities and other such facilities can be extremely high. Properly designed power supplies are needed to more fully take advantage of the capabilities of the magnetrons while dramatically reducing the power consumption, increasing the useable up time and significantly reducing maintenance costs and risks. These power supplies also include a number of safety features, functions, safeguards and protections.
- To address and meet these needs, we are researching, designing and implementing very low noise switching power supplies that cover the range of 1000s of watts to many hundreds of watts and include filament/heater and additional optional power supplies. The design approach for this DOE SBIR is highly scalable.
- The filament heater supply can be included/incorporated as part of the overall power supply. The filament heater supply can have a soft start. These improvements and enhancements advance the performance, flexibility and use of magnetrons including in fundamental, practical and commercial, industrial and defense applications.

Some of the Protections for the Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies

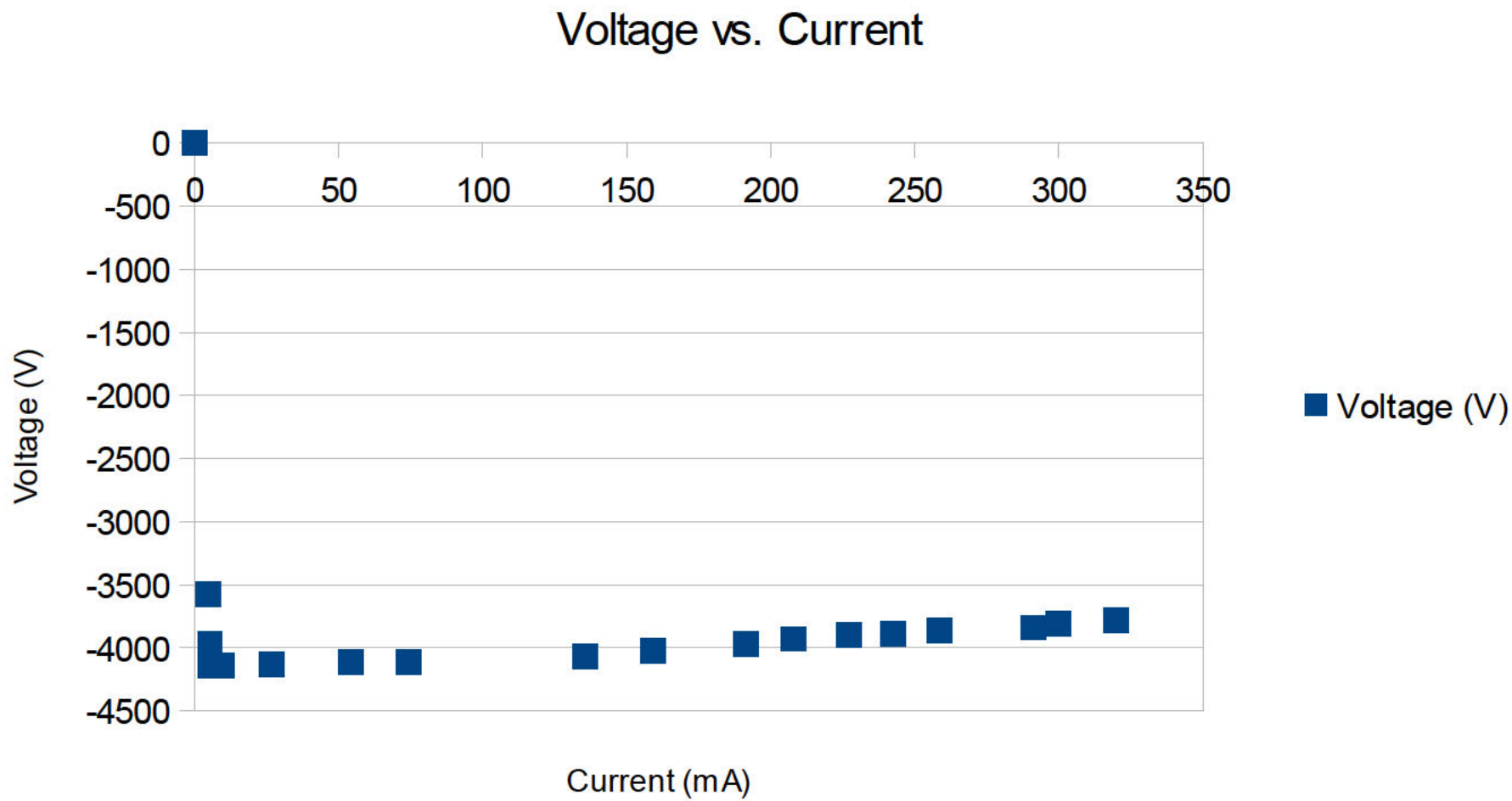
- The InnoSys power supplies have a number of protection and safety features and safeguards incorporated into the power supply which enable the protection of the power supply, itself, the magnetron, the system environment that the magnetron is in and, most importantly, humans who are interacting with, among other things, the high voltage and high power being used to generate and produce high power RF microwave energy.
- The power supplies are fully short circuit protected, over voltage, over current, over temperature protected and arc protected.
- The protections have been incorporated to detect issues with the performance of the magnetron and head off issues.
- The power supplies support both analog and digital monitoring and control. A number of options are available.
- The power supplies have isolated high voltage floating DC filament/heater power supplies. Both the magnetron current and the filament/heater current (or voltage) can be varied from 0 to 100%.

Some of InnoSys' Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies

One version of the InnoSys Magnetron DC power supplies was designed to be an extremely low ripple AC in DC out constant current power supply.

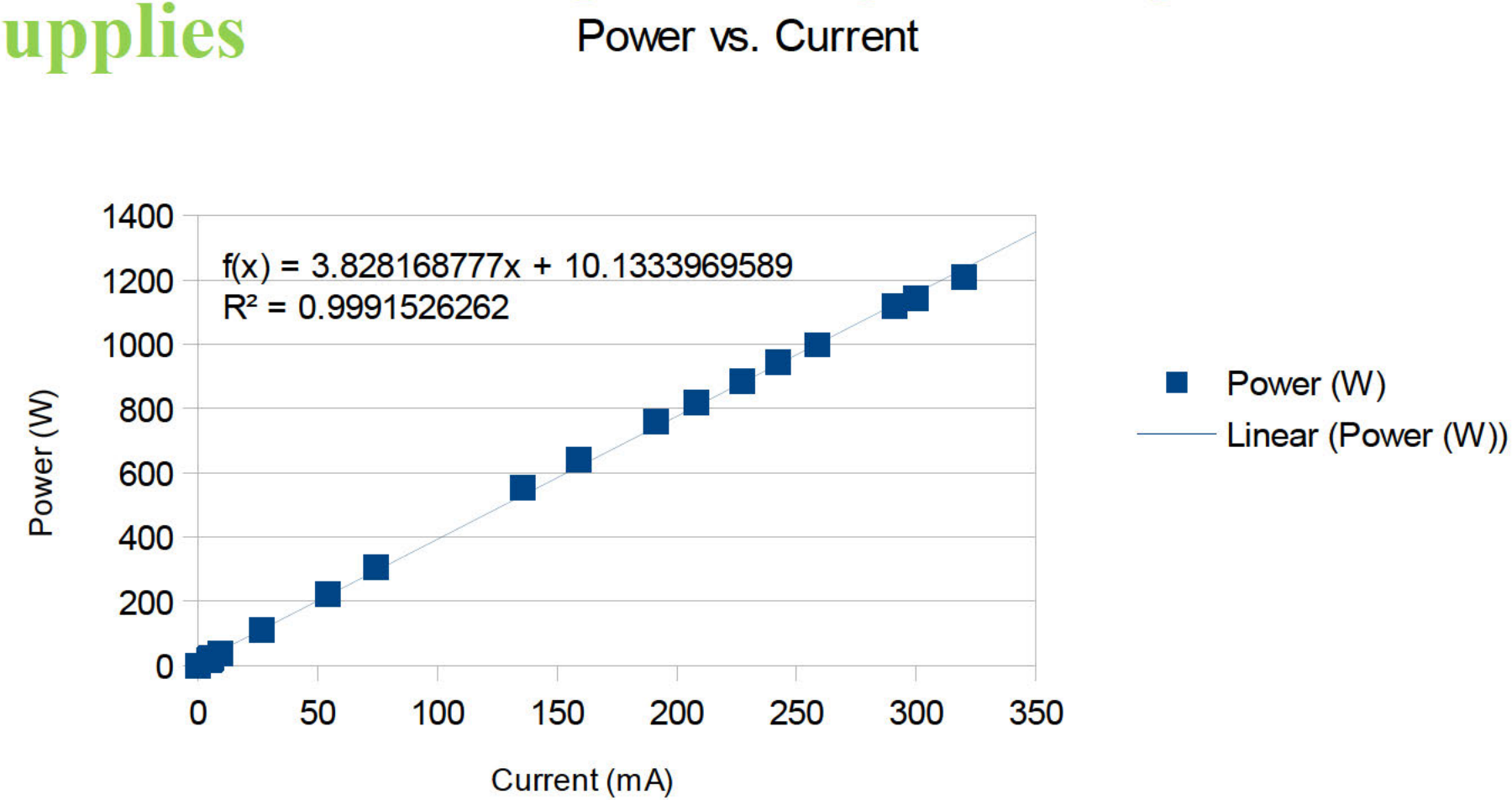
Another Version of the InnoSys Magnetron DC power supplies was designed to be an extremely low ripple DC in DC out constant current power supply.

An Example of a Voltage-Current (I-V) Curve using one of InnoSys' Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies



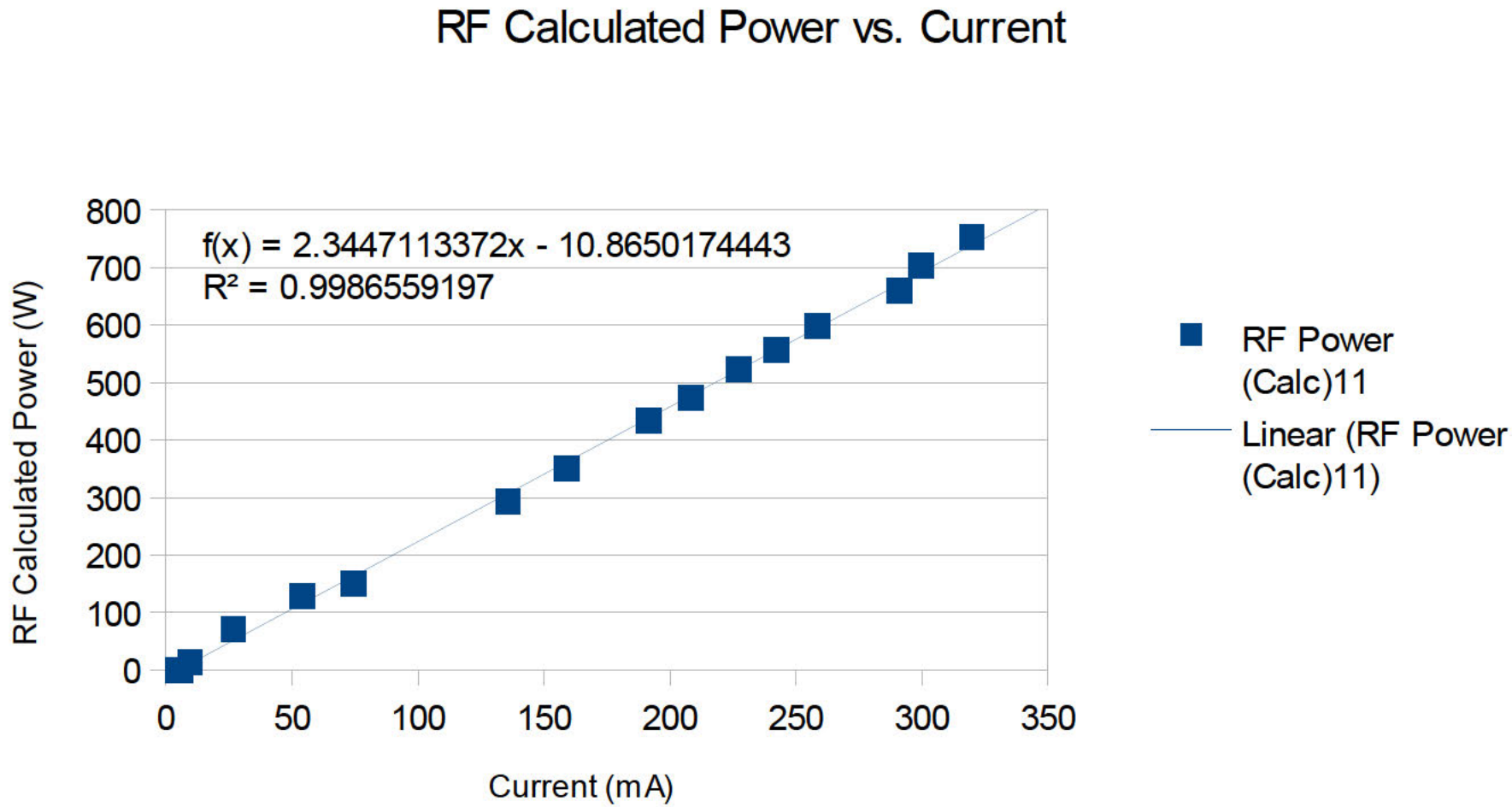
Voltage vs. Current (V-I) plot a 2.45 GHz magnetron using InnoSys' power supply.

An Example of an Electrical Power vs. Current (P-V) Curve using one of InnoSys' Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies



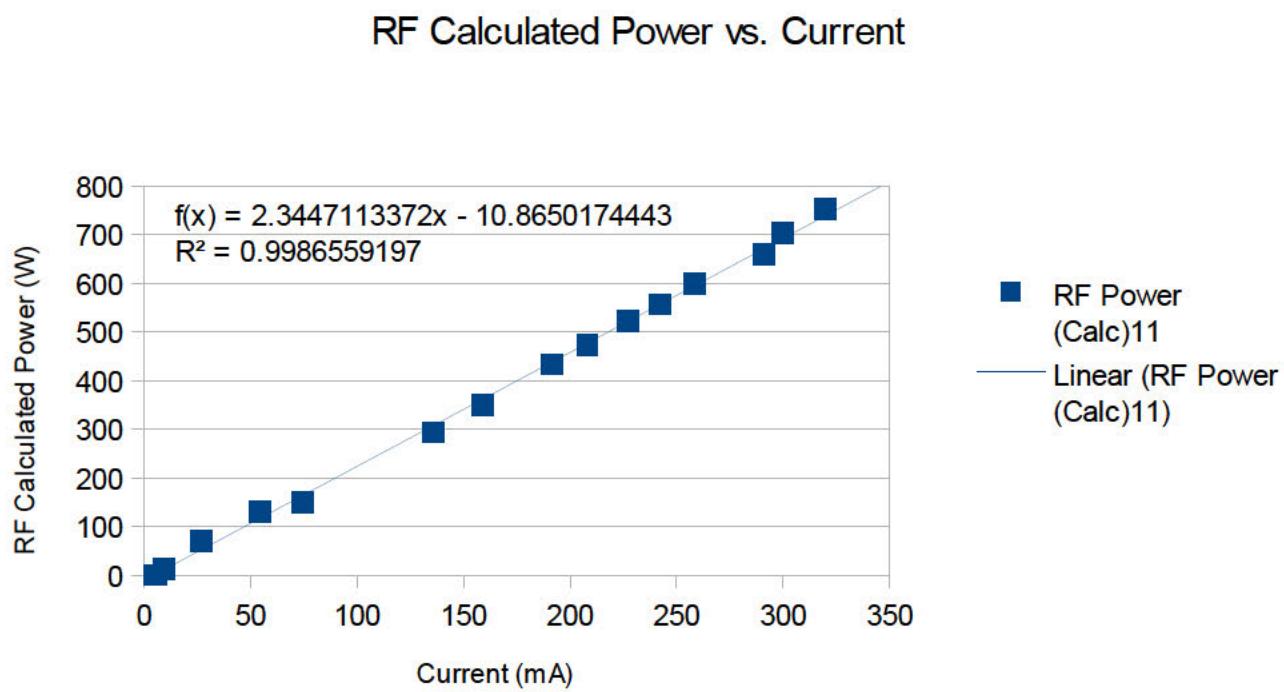
Electrical Power vs. Current (P-I) plot for the magnetron in the launcher using InnoSys' power supply.

An Example of an RF Power vs. Current Curve using one of InnoSys' Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies



Experimental RF calculated power vs. current for an attenuation factor of (negative) -64.3.

An Example of an RF Power vs. Current Curve using one of InnoSys' Inexpensive Low Noise Fast Switching DC High Voltage Power Supplies



This plot of the RF power supplied by the magnetron to a water cooled load vs. Current (RF-I) for the magnetron in the commercial unit/housing using an InnoSys power supply. Note the excellent linear fit (R^2 = ~0.99869) of the supplied power to current supplied to the magnetron as measured on an attenuation port for an attenuation factor of -64.3 dB.

A CAD rendering of the front view of the power supply enclosure for the InnoSys magnetron power supply.

A photo of an actual front view of the power supply enclosure for the InnoSys magnetron power supply.

A CAD rendering of the rear view of the power supply enclosure for the InnoSys magnetron power supply.

A CAD rendering of the side/rear view of the power supply enclosure for the InnoSys magnetron power supply.

High Voltage Output -- Single 2.45 GHz Power Supply into a Resistor Dummy Load

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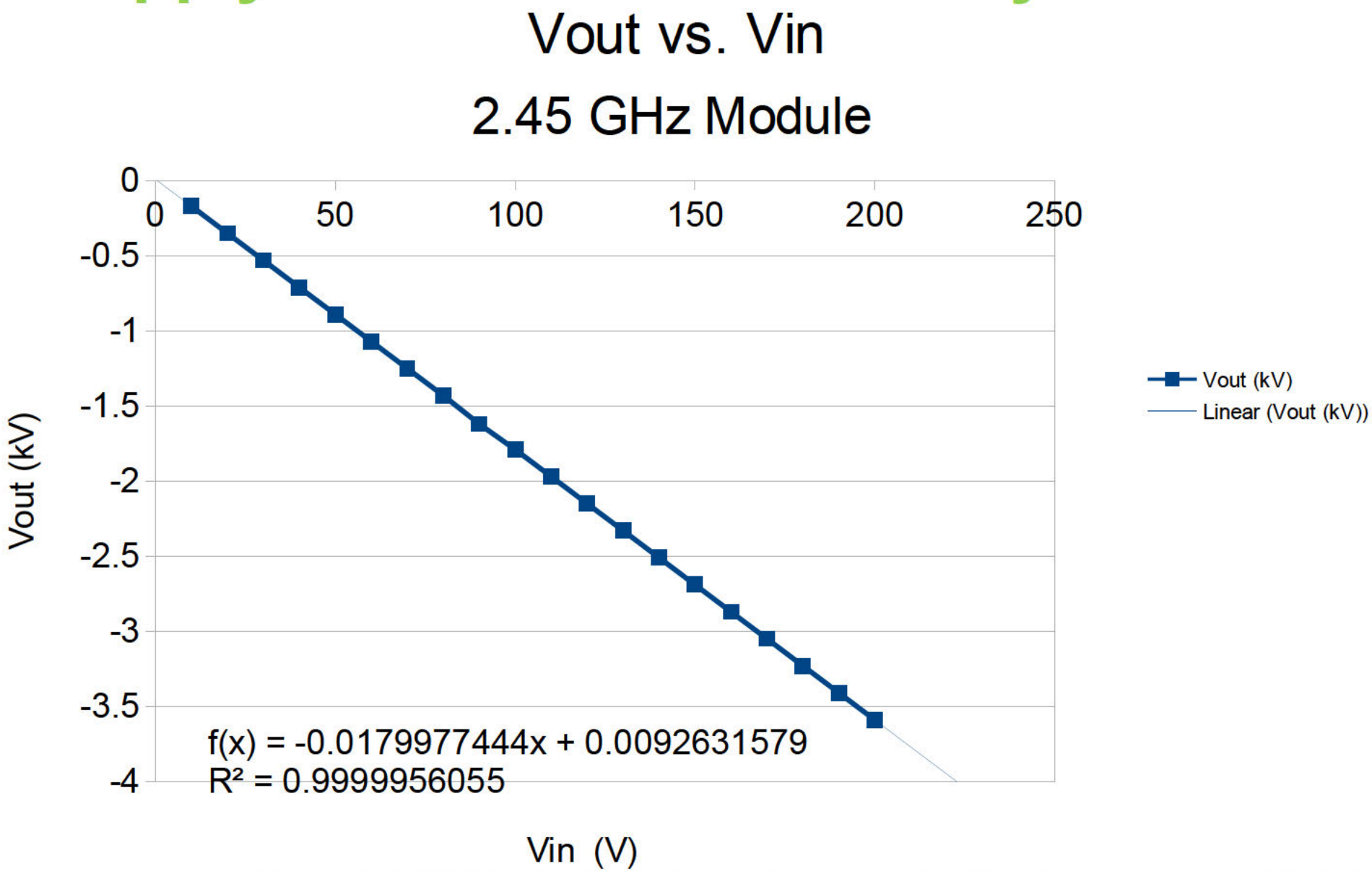
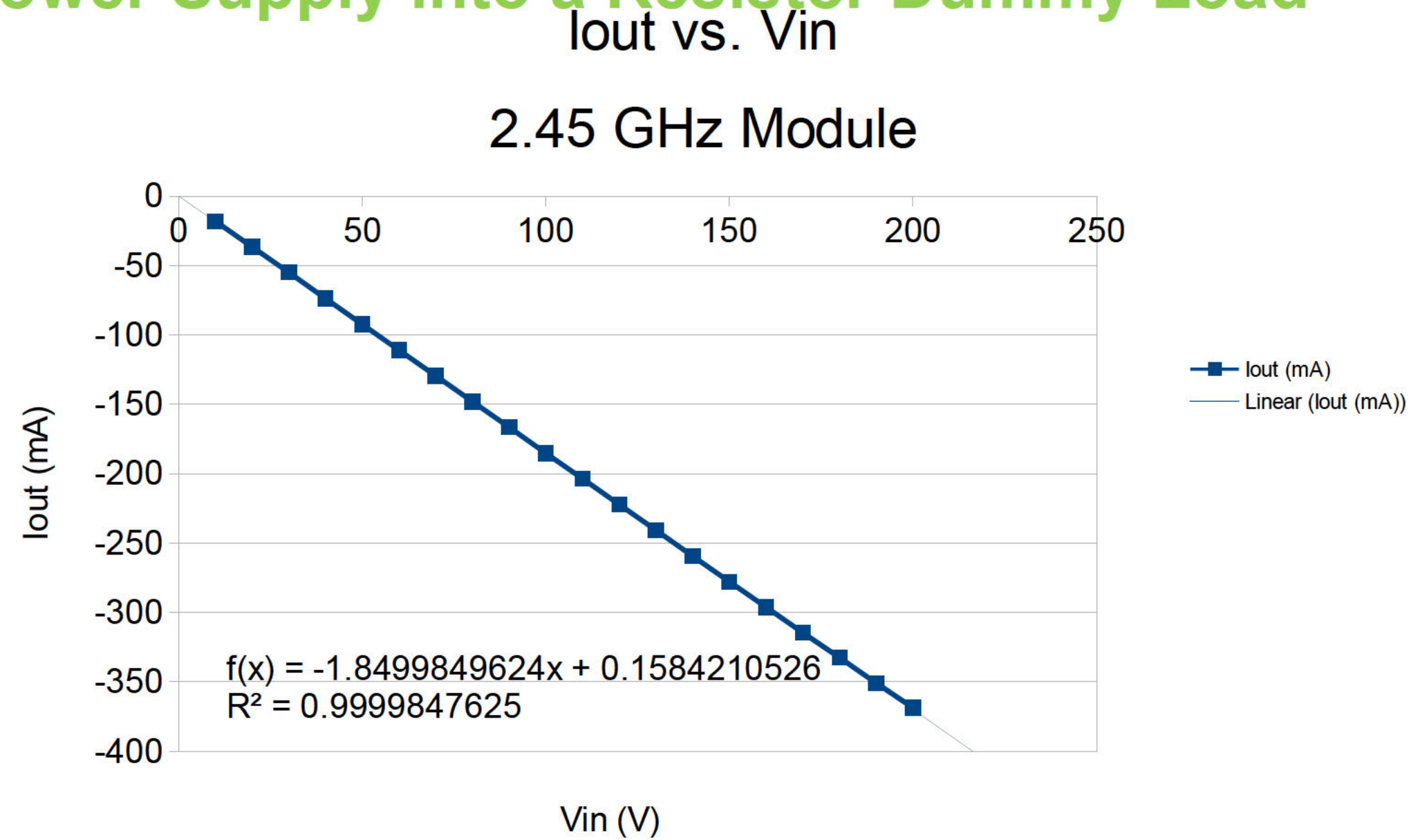


Output Load Current-- Single 2.45 GHz Power Supply into a Resistor Dummy Load



Output Load Power -- 2.45 GHz Magnetron Power Supply into a Resistor Dummy Load

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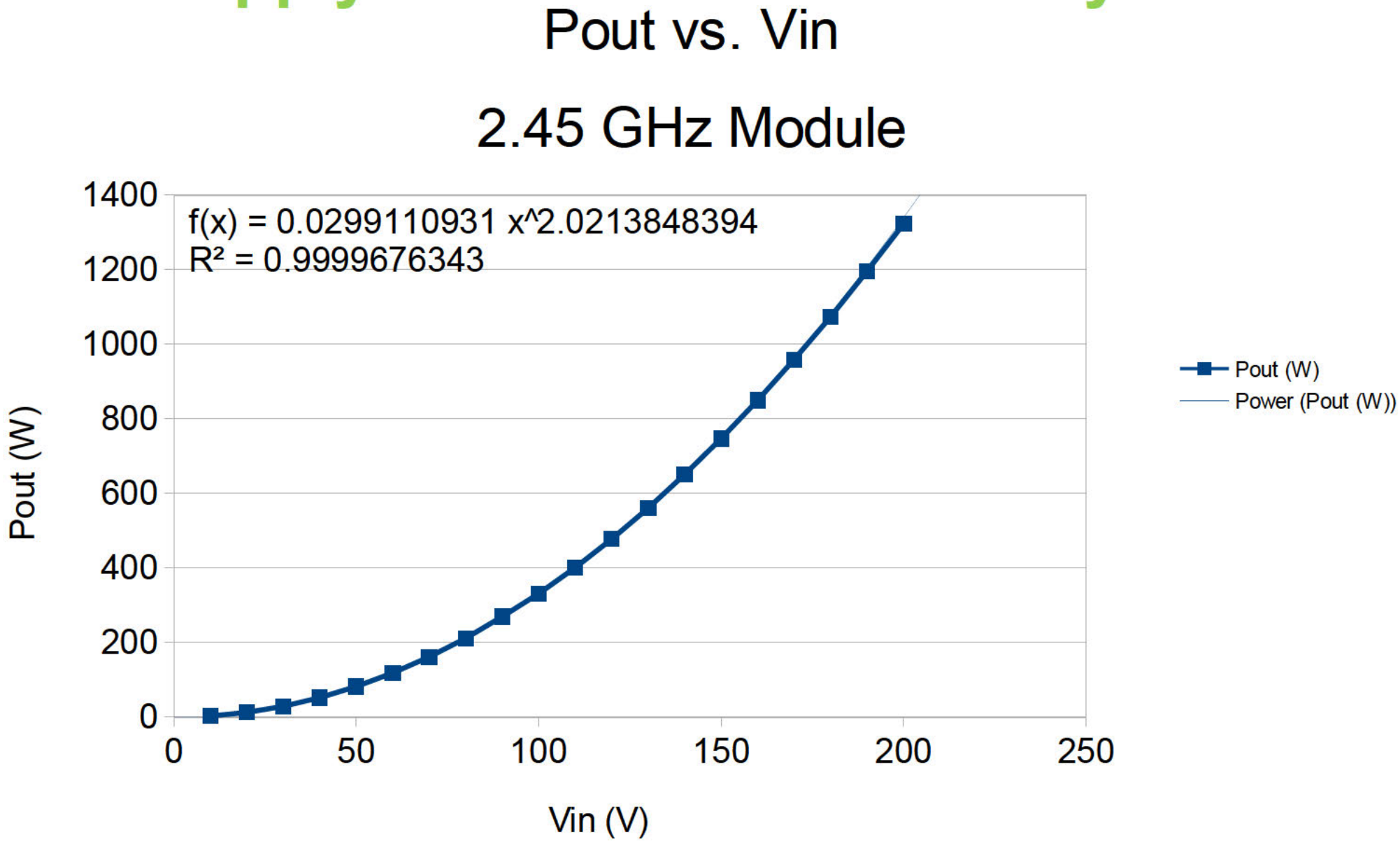
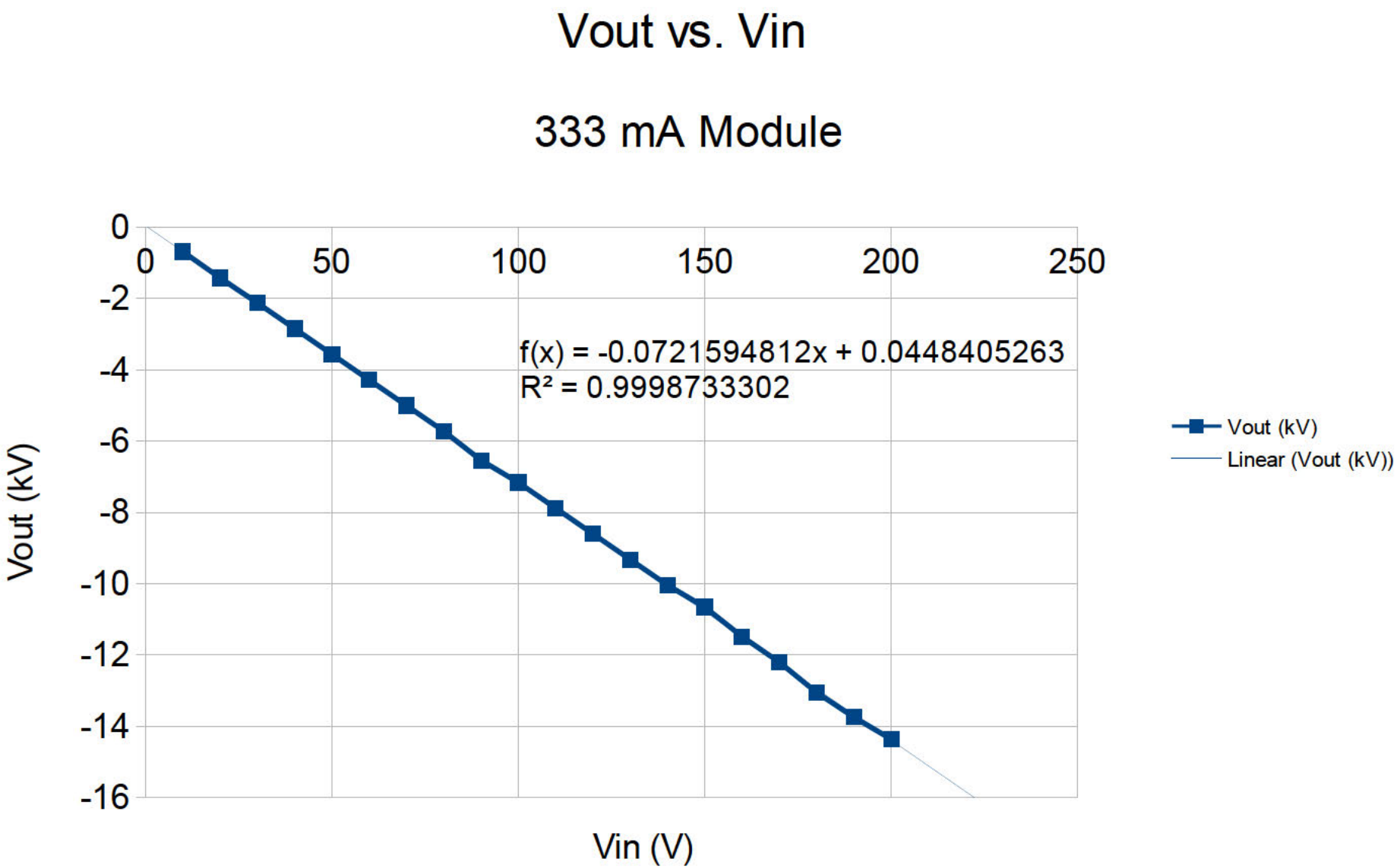
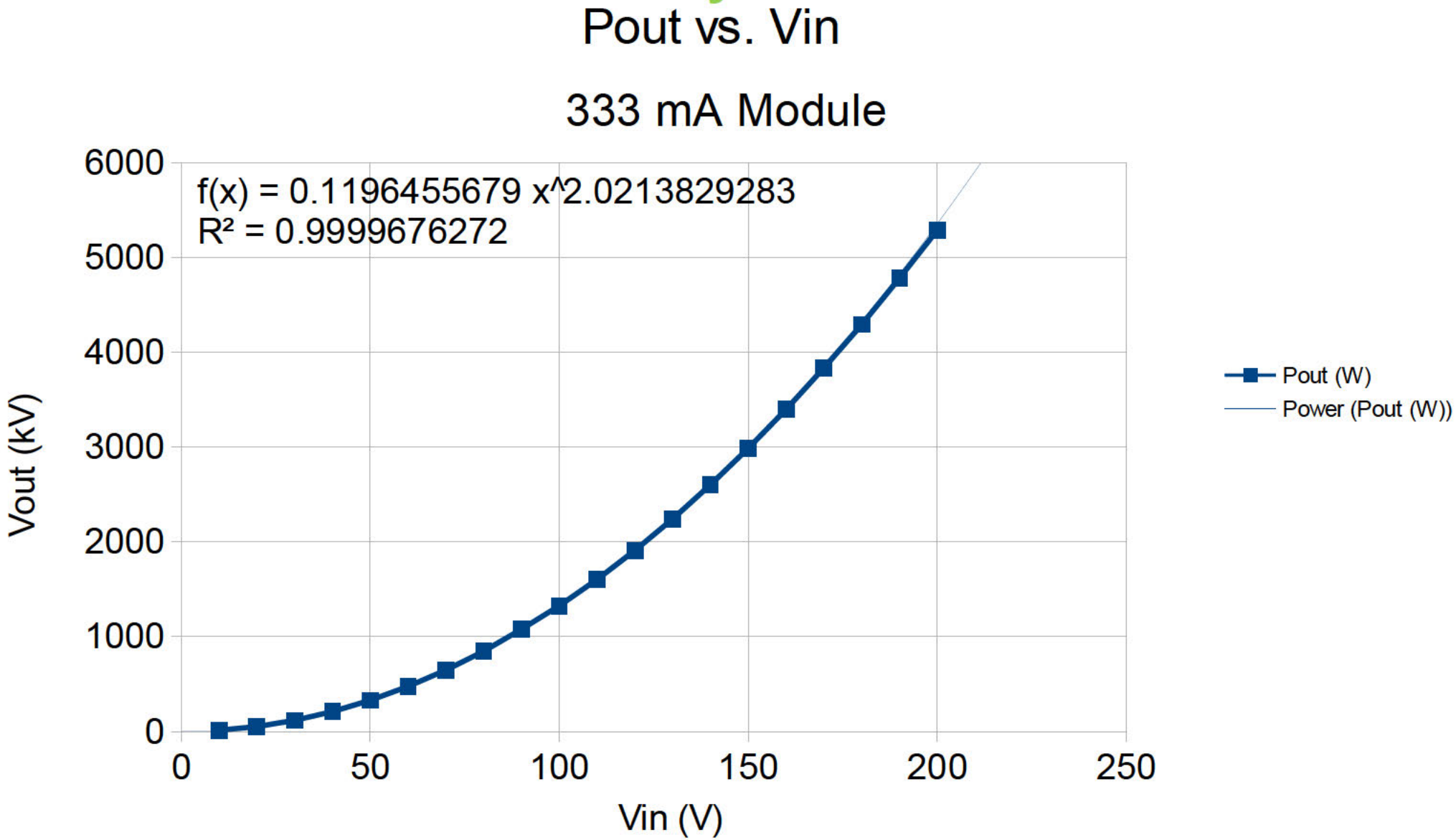


Output Voltage – One module of the power supply into a Resistor Dummy Load



Output Power – One module of the power supply into a Resistor Dummy Load



Some Electrical Considerations of the 30kW 2A Magnetron Power Supply.

- These Magnetron Power Supplies can come with an AC (i.e., 208 VAC 50/60 Hz; 240 VAC, 50/60 Hz; 480 50/60 Hz, etc. power factor corrected) to DC front end conversion stage.
- Heater/Filament floats at cathode potential and can be connected as such.
- The Heater/Filament can be varied from 0 to 100% in either constant current or constant voltage mode.

Summary

- We have been researching and developing high voltage/current power supplies for nuclear physics and other applications.
- We have encountered challenges with supply chains especially in electronic parts. We have been able to work past these supply chain issues.
- We have successfully built several versions of the power supplies.
- The power supplies work at full power (and also at lower powers) for both with air cooled and water cooled 2.45 GHz magnetrons.
- We have implemented extensive safety, protection and safeguards.
- We have implemented both 0 to 100% full scale for both the magnetron and the filament/heater current controls.
- We have designed, developed and implemented a module approach for higher power.
- We appreciate your questions, input and feedback – Thank you.

Thank you for your time and attention today

Acknowledgements and Appreciation to
Dr. Michelle Shinn and the DOE NP Program

Questions?