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Construction of a Variable Frequency High Voltage Power Supply for Dielectric Barrier Discharge

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Design of a Variable Frequency, High Voltage Power Supply for Dielectric Barrier Discharge

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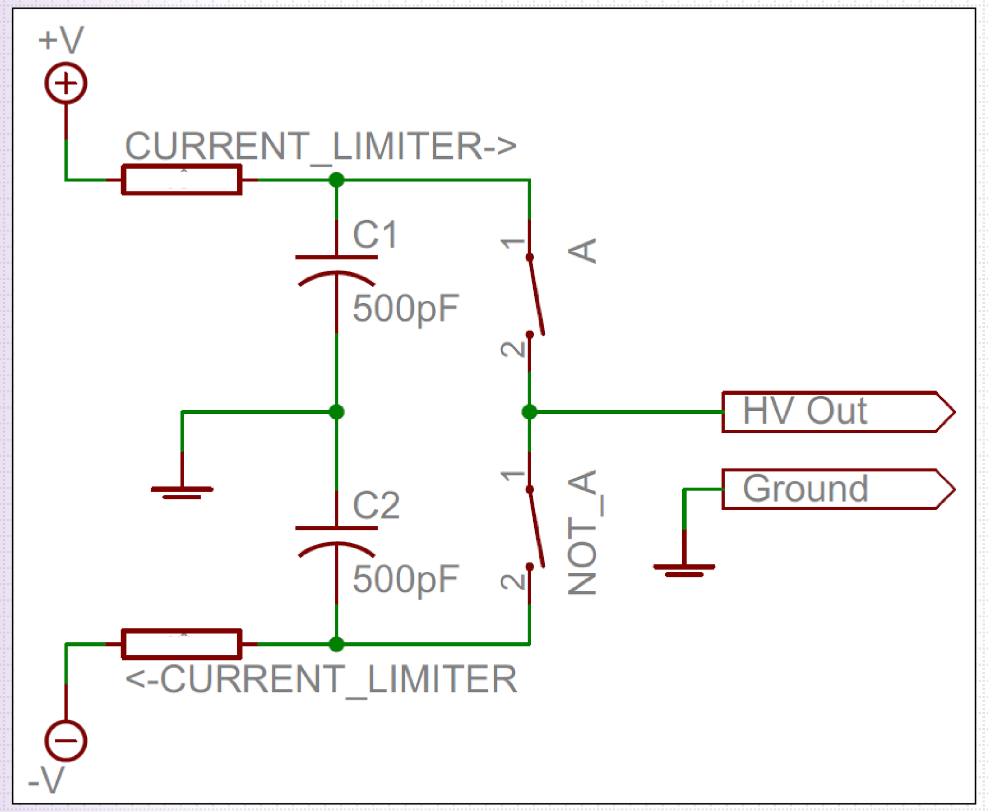
Abstract:

Here, we describe the design of a high voltage, variable frequency power supply for driving plasmas and testing the frequency responses of Dielectric Barrier Discharges (DBDs). DBDs are frequently used for surface treating, ozone production, and as UV sources. A DBD is an electrical discharge where the discharge path is blocked by an insulator. This results in a combination of glow and brush discharges between electrodes (plasma filaments are small, but numerous). However, before these can be studied, a high voltage DBD driver must be designed and implemented. Much strife may be had in designing such a driver with a respectable bandwidth when the available transistors (switches) can only handle a fraction of the desired output voltage. Here, we will consider the series connection of these transistors and the difficulties involved with the same. Once a reliable method of switching high voltages is found, the design of the power supply is rather straightforward.

Design Requirements:

- Square wave output 1Hz to 500kHz
- Adjustable Output Voltage envelope between ±0.5kV and ±4kV
- Short circuit current limited to 60mA
- Frequency and Voltage are independently adjustable

This suggests the following base design. The switches are controlled by square wave signals A and Not A.



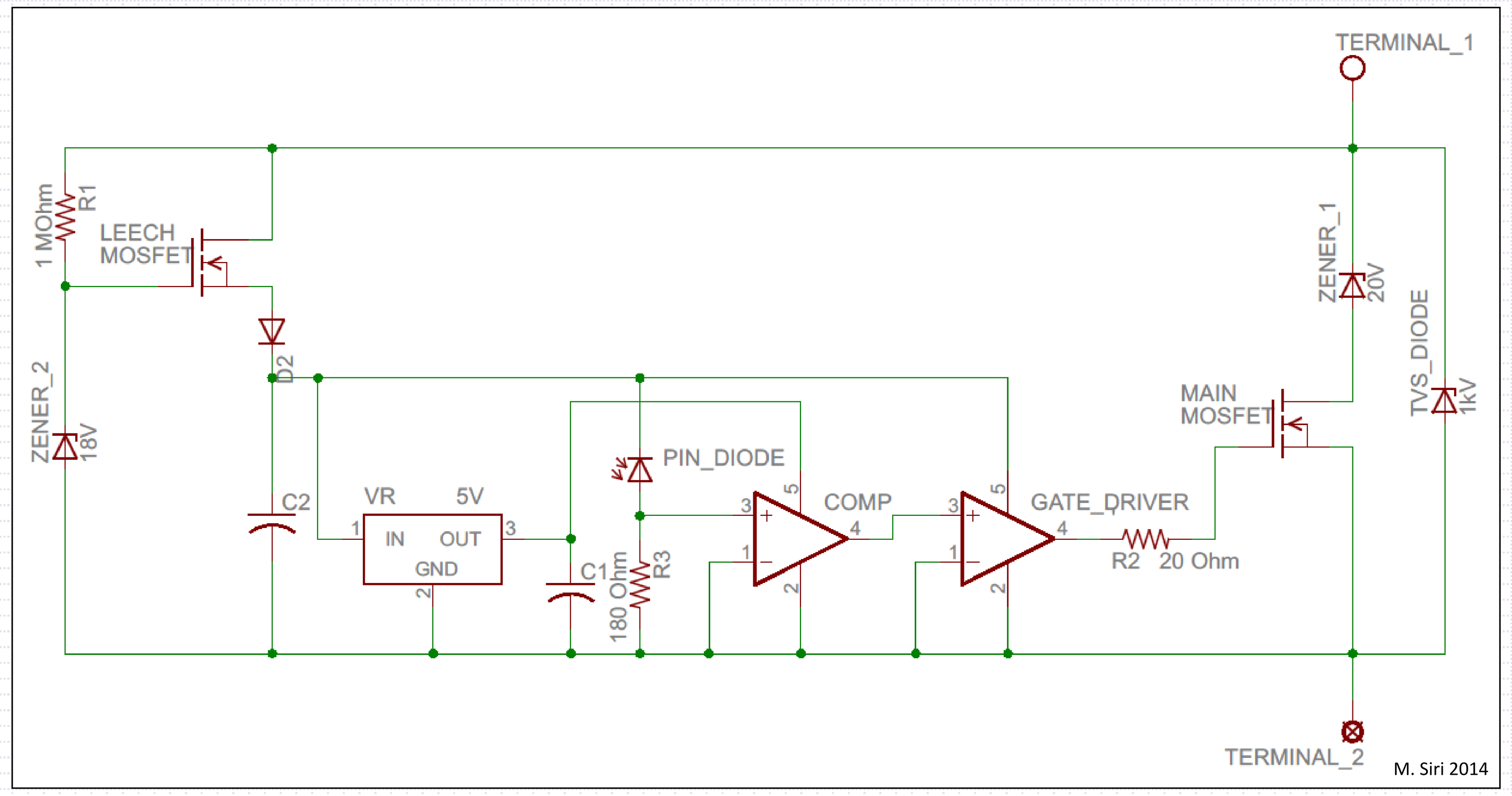
Basic (Conceptual) Schematic

High Voltage Switches:

Here, MOSFETs are to be used due to their speed, low cost, and availability. However, as high voltage switches (of several kV), they are very limited. Insulated-Gate Bipolar Transistors may also be used.

Problem	Solution
Cost effective MOSFETs can only switch 1200V each.	Several MOSFETs are to be connected in series each with a separate control circuit.
If one switch opens before the others in its string, the full output voltage will be placed across it.	A TVS diode string or another voltage limiting device is placed in parallel with each to protect the ambitious switch whilst the others catch up (150ns).
The signal source and receiver must be electrically isolated.	The signal to each switch is transmitted optically.
The optical receivers and other control electronics for each switch need power supplies.	An improved version of a leeching circuit by Nguyen et al. is employed.

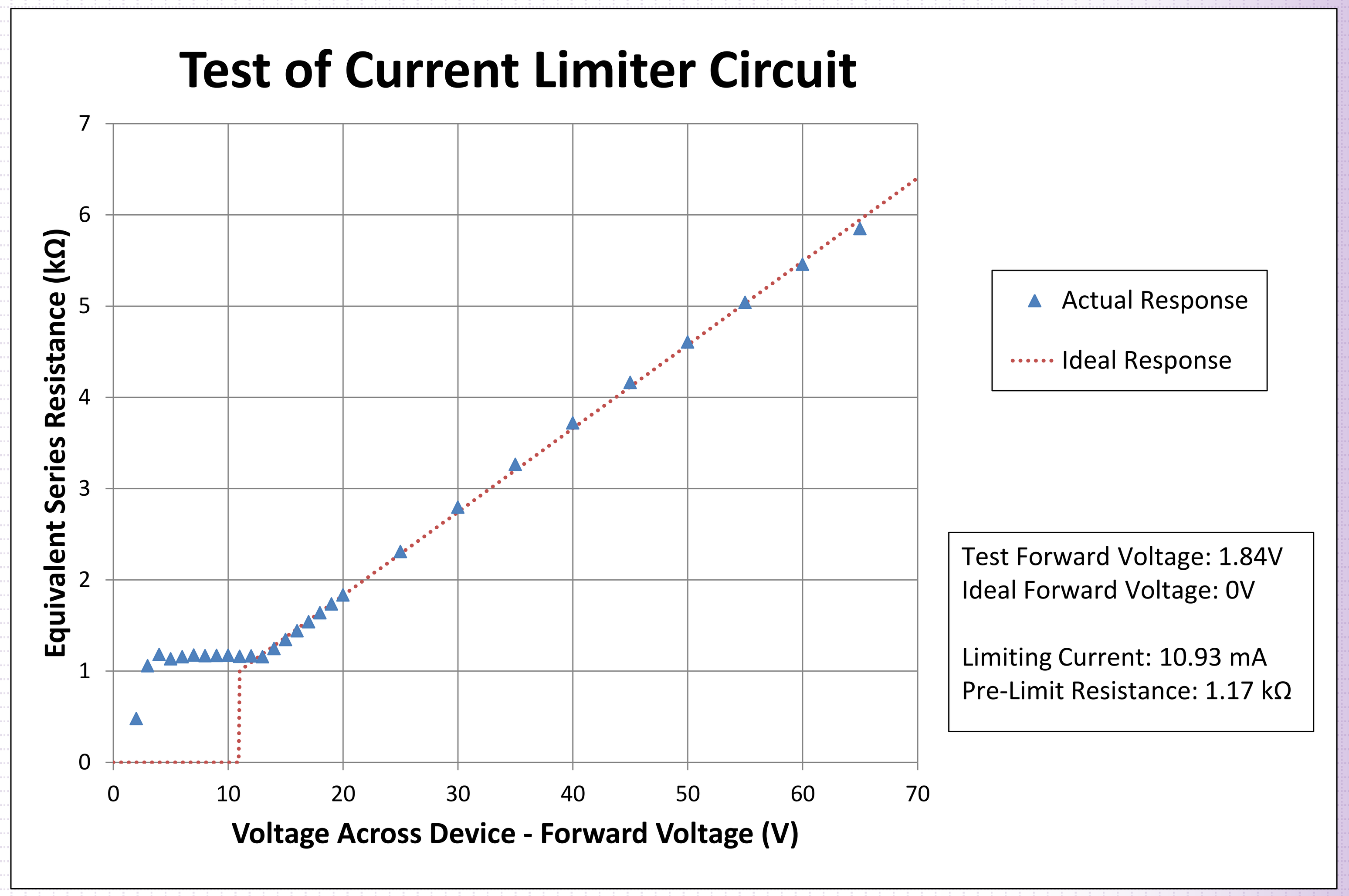
Each switch now becomes a module. In order to satisfy our design parameters, each switch in the base design must be represented by 8 modules in series.



Switching Module Schematic

Design of a Simple Current Limiter:

In order for this supply to reliably drive plasmas (and survive in a research lab), the output current must be limited. The ideal limiter would act as a voltage-controlled resistance where $R = \frac{V}{I_{limit}}$ (once the current limit is reached). Before this, the resistance of the device should be zero (the pre-limit resistance). The chosen design is an independent design consisting of just 4 components. The device has a small forward voltage (not a problem for this application). The pre-limit resistance and current limit are both adjustable. The response of a test circuit is shown below.



Continuing Work:

Component sourcing, prototype board layout, and preliminary testing is already underway (with promising results). The controller is currently being designed. Once the DBD driver is finished, research concerning the driving frequency dependence of DBD spectra will begin.

References:

1. Nguyen, T. V., Jeannin, P. O., Vagnon, E., Frey, D., & Crebier, J. C. (2010). Series Connection of IGBT. *APEC 2010, Palm Springs: United States*, 2238. http://hal.archives-ouvertes.fr