

# IGBT Grid Switcher for the KEK/ISIS/LOI Amplifier

*Doug Horan  
APS RF Group*

***Argonne National Laboratory***



*A U.S. Department of Energy  
Office of Science Laboratory  
Operated by The University of Chicago*



## Selection of Method and Circuit

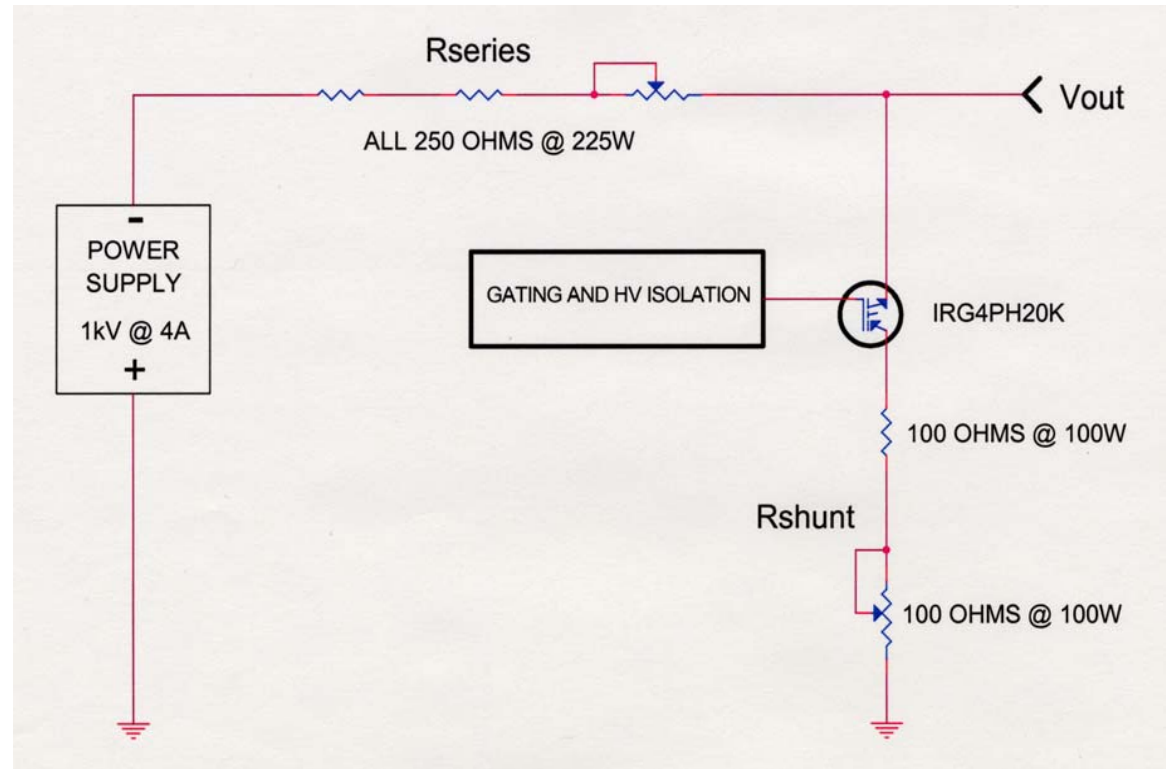
After discussing the use of several types of circuits for this application, the decision was made to proceed with the “*brute-force*” method, a simple resistive voltage divider with the shunt leg of the divider switched by an IGBT.

*This design was chosen because:*

- It is simple
- It would be the most effective in counteracting the effects of grid current
- No reverse-polarity problems with the IGBT
- Gate drive could be derived from the grid bias voltage

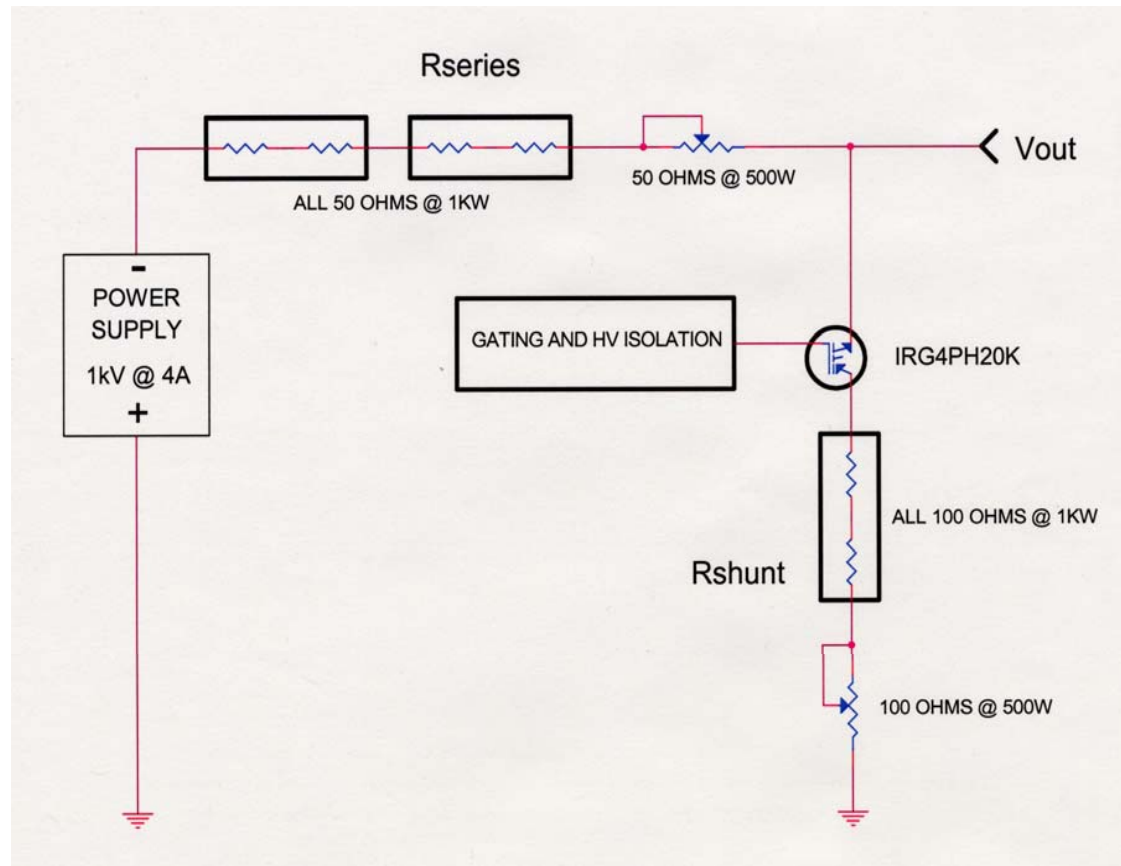
## The 1A Voltage Divider Circuit

- This circuit was the first version with 1A of current in the divider.
- Concern about the effects of grid current from the triode prompted a change in the design



## The 2A Voltage Divider Circuit

- The divider current was increased to  $\sim 2A$  to more dominate the effect of the triode grid current
- The increased power dissipation forced a design change to water-cooled resistors





# The IGBT Chosen For the Switch

- A discrete IGBT was chosen because of the circuit simplicity
- The device was chosen to operate at a nominal input voltage of 1kV

International Rectifier  
**IR** Rectifier

INSULATED GATE BIPOLAR TRANSISTOR

PD -91776  
**IRG4PH20K**  
Short Circuit Rated UltraFast IGBT

**Features**

- High short circuit rating optimized for motor control,  $t_{sc} = 10\mu s$ ,  $V_{CC} = 720V$ ,  $T_J = 125^\circ C$ ,  $V_{GE} = 15V$
- Combines low conduction losses with high switching speed
- Latest generation design provides tighter parameter distribution and higher efficiency than previous generations

**Benefits**

- As a Freewheeling Diode we recommend our HEXFRED™ ultrafast, ultrasoft recovery diodes for minimum EMI / Noise and switching losses in the Diode and IGBT
- Latest generation 4 IGBT's offer highest power density motor controls possible

**Absolute Maximum Ratings**

Parameter	Max.	Units
$V_{CES}$	1200	V
$I_C @ T_C = 25^\circ C$	11	A
$I_C @ T_C = 100^\circ C$	5.0	
$I_{CM}$	22	
$I_{LM}$	22	
$t_{sc}$	10	$\mu s$
$V_{GE}$	$\pm 20$	V
$E_{ARV}$	130	mJ
$P_D @ T_C = 25^\circ C$	60	W
$P_D @ T_C = 100^\circ C$	24	
$T_J$	-55 to +150	$^\circ C$
$T_{STG}$		
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)
	Mounting torque, 6-32 or M3 screw.	10 lb·in (1.1N·m)

**Thermal Resistance**

Parameter	Typ.	Max.	Units
$R_{\theta JC}$	—	2.1	$^\circ C/W$
$R_{\theta CS}$	0.24	—	
$R_{\theta JA}$	—	40	
$Wt$	6 (0.21)	—	g (oz)

www.irf.com

TO-247AC

E - RED  
C - BLACK (1/2")  
G - YELLOW

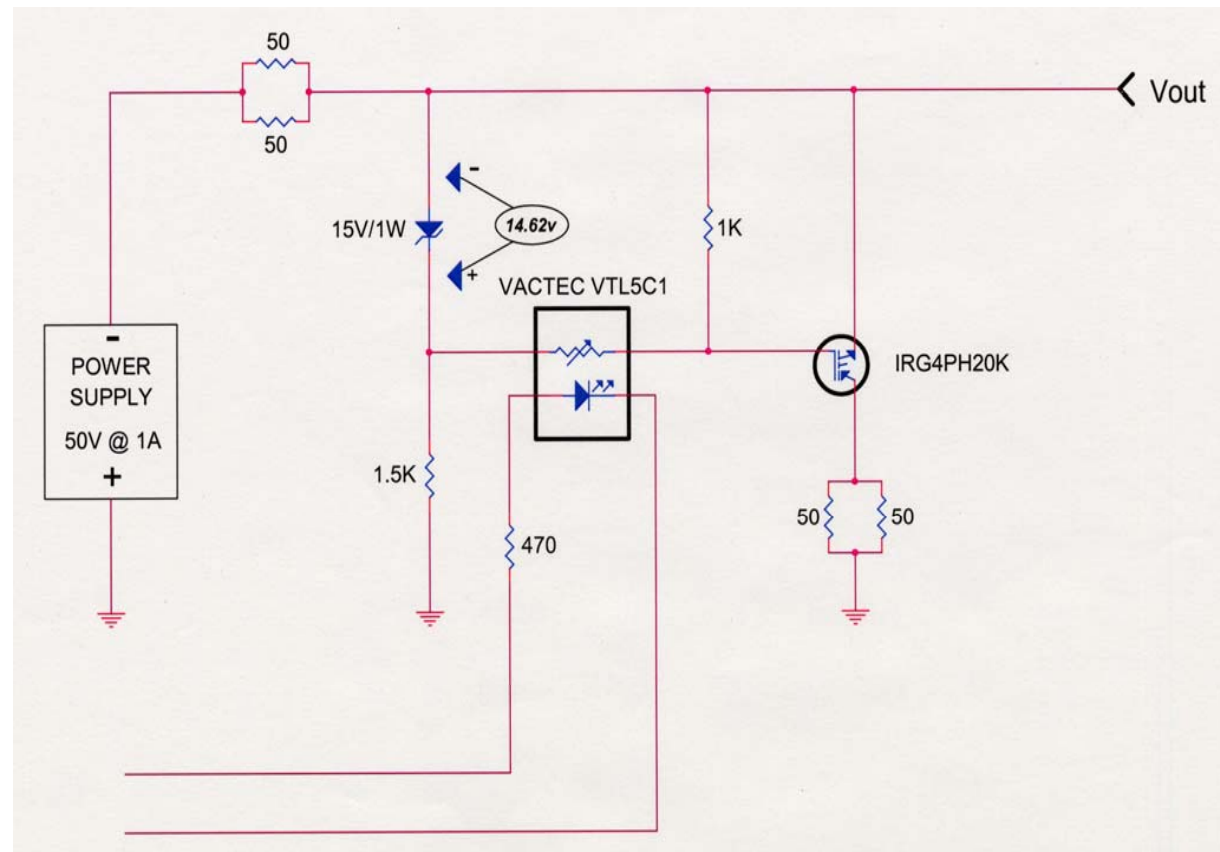
6/25/98





# IGBT Gating Circuits

- Gate voltage was to be derived from the applied voltage to insure isolation
- The first gate circuit utilized a “Vactec” opto-isolator

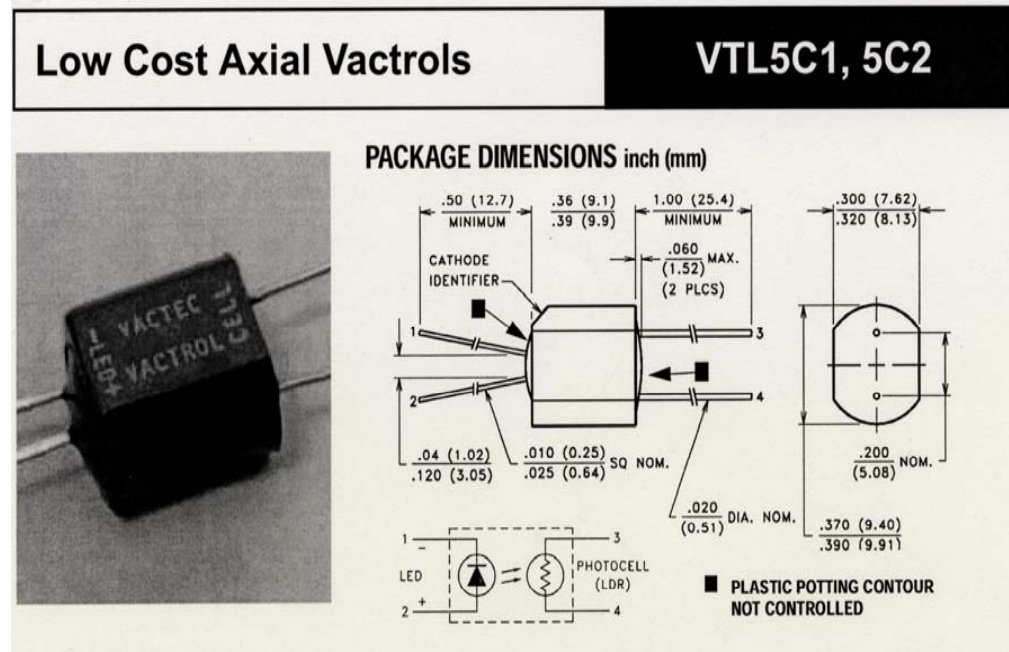


## The "Vactec" Opto-isolator

- Very reliable.....used in many applications in APS rf system for many years with no failures

HOWEVER.....

- Very slow.....photo-resistor has millisecond response time

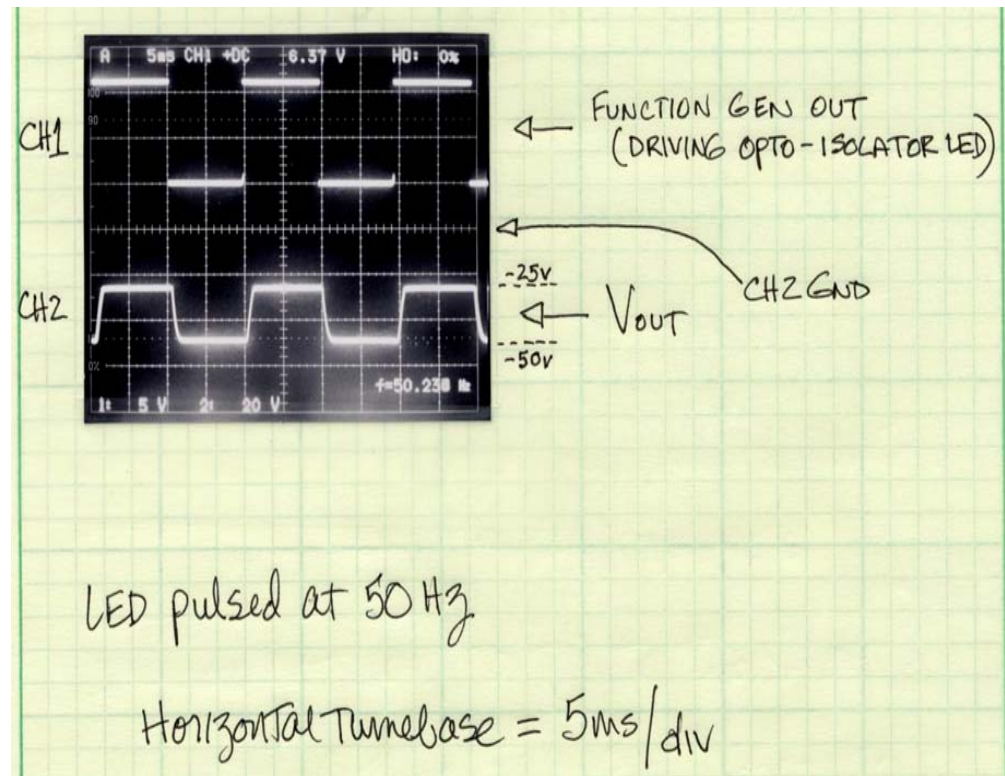




## 50V/1A Test of “Vactec” Gating Circuit

- Slow response of the “Vactec” isolator caused severe distortion in the output waveform.....

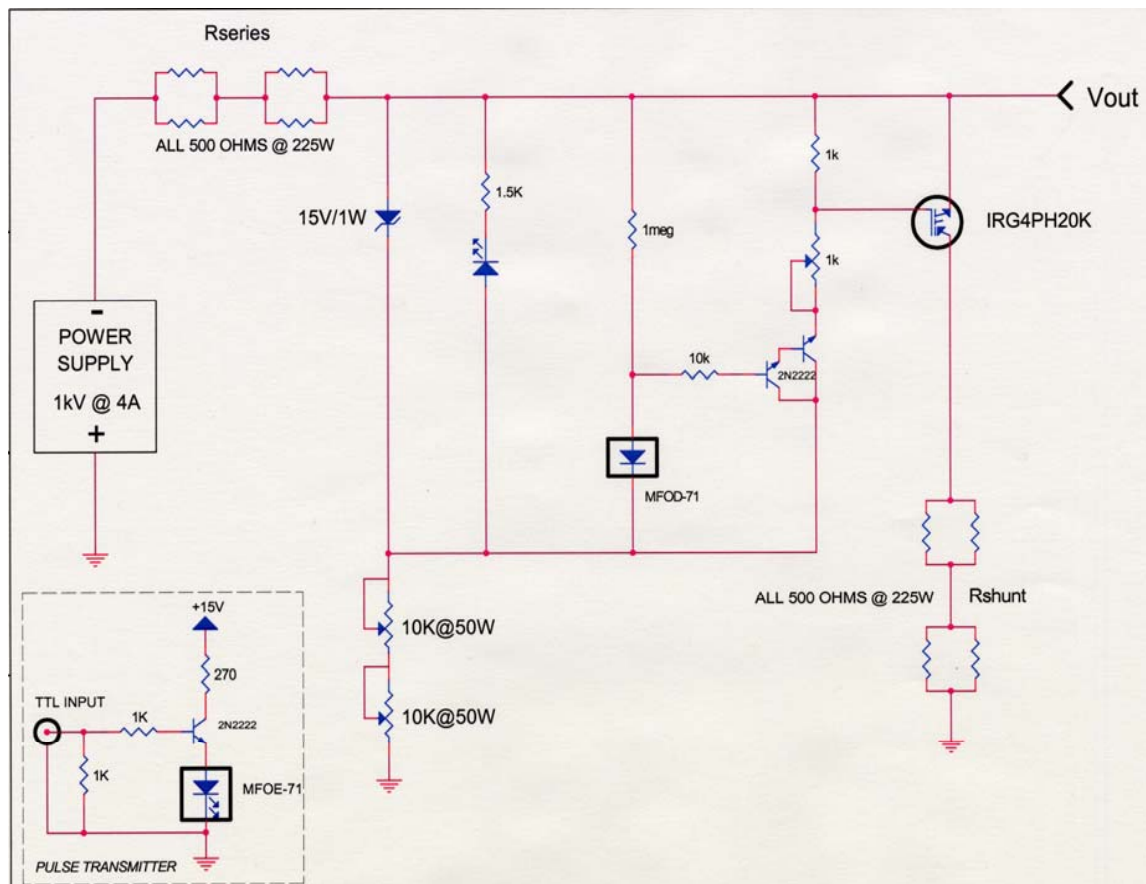
*Which most certainly would increase power dissipation in the IGBT, and also cause unwanted distortion in the output of the triode*





# Improved Gating Circuit with Fiber Optic Link

- This circuit uses Motorola fiber-optic link pair, providing absolute isolation from the bias voltage
- This circuit was tested to 1kV @ 1A, producing clean output waveforms with very little distortion
- Full saturation of the IGBT is achieved at ~ -300vdc input (when zener begins to clamp)





## Output Waveforms of Fiber Optic Gating Circuit at 1kV@1A

- Channel 1 (yellow) is function generator output driving fiber optic transmitter
- Channel 2 (green) is output of grid switcher:

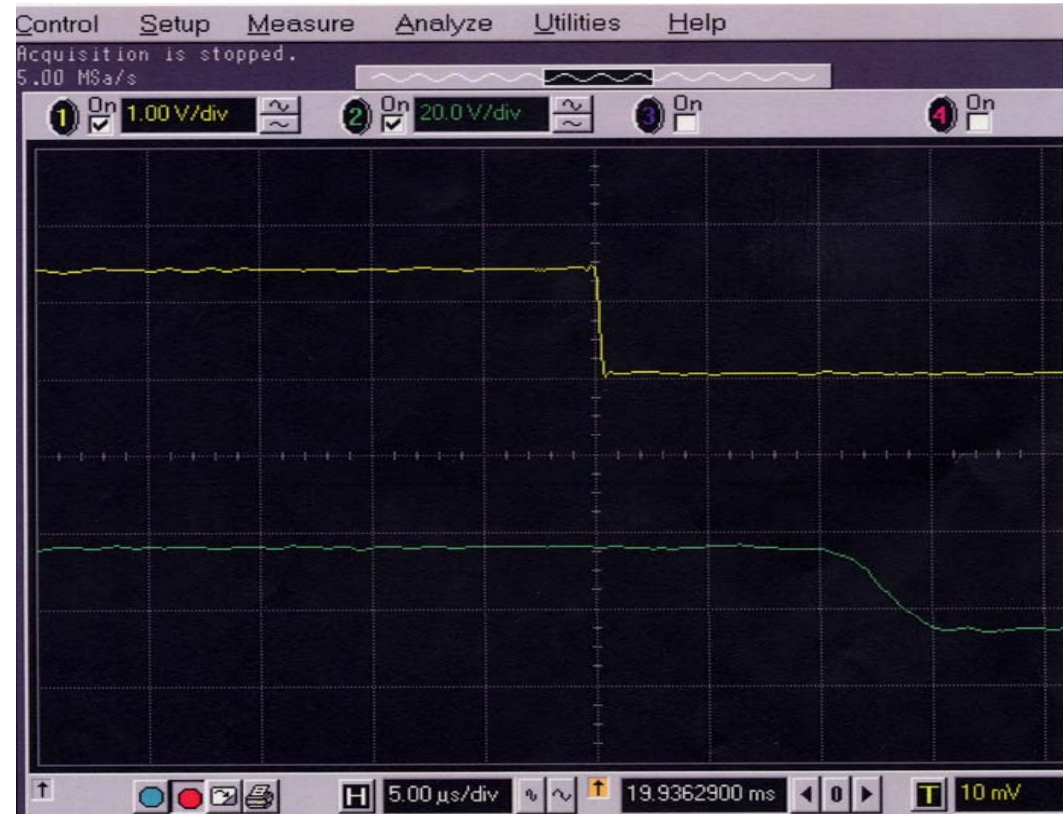
*1kV when TTL pulse is at 0v, 500V when TTL pulse goes positive*





## Fall-time of the Fiber Optic Gating Circuit

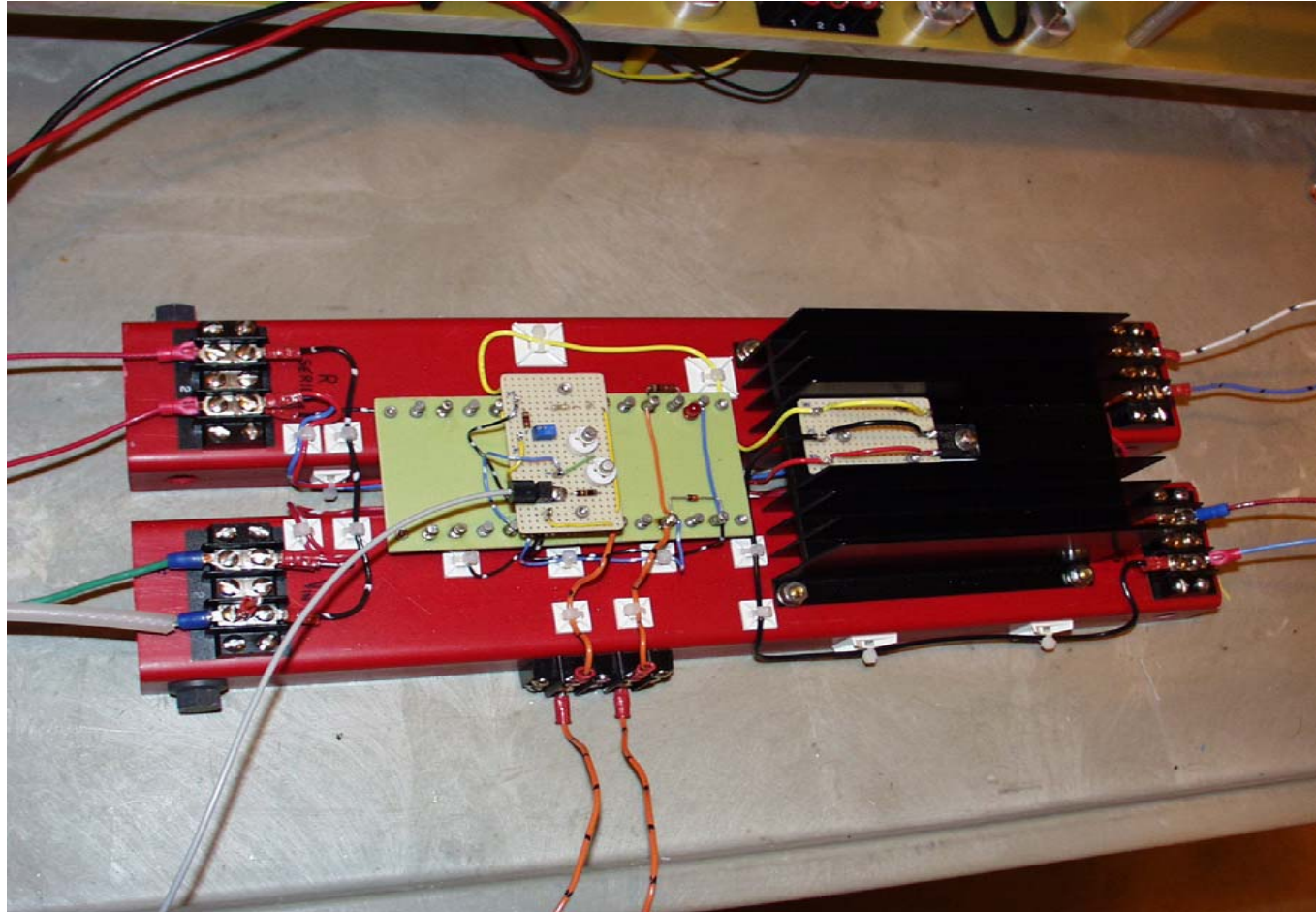
- Characteristic of IGBT's, turn-off time is longest, measured here at ~ 13 microseconds



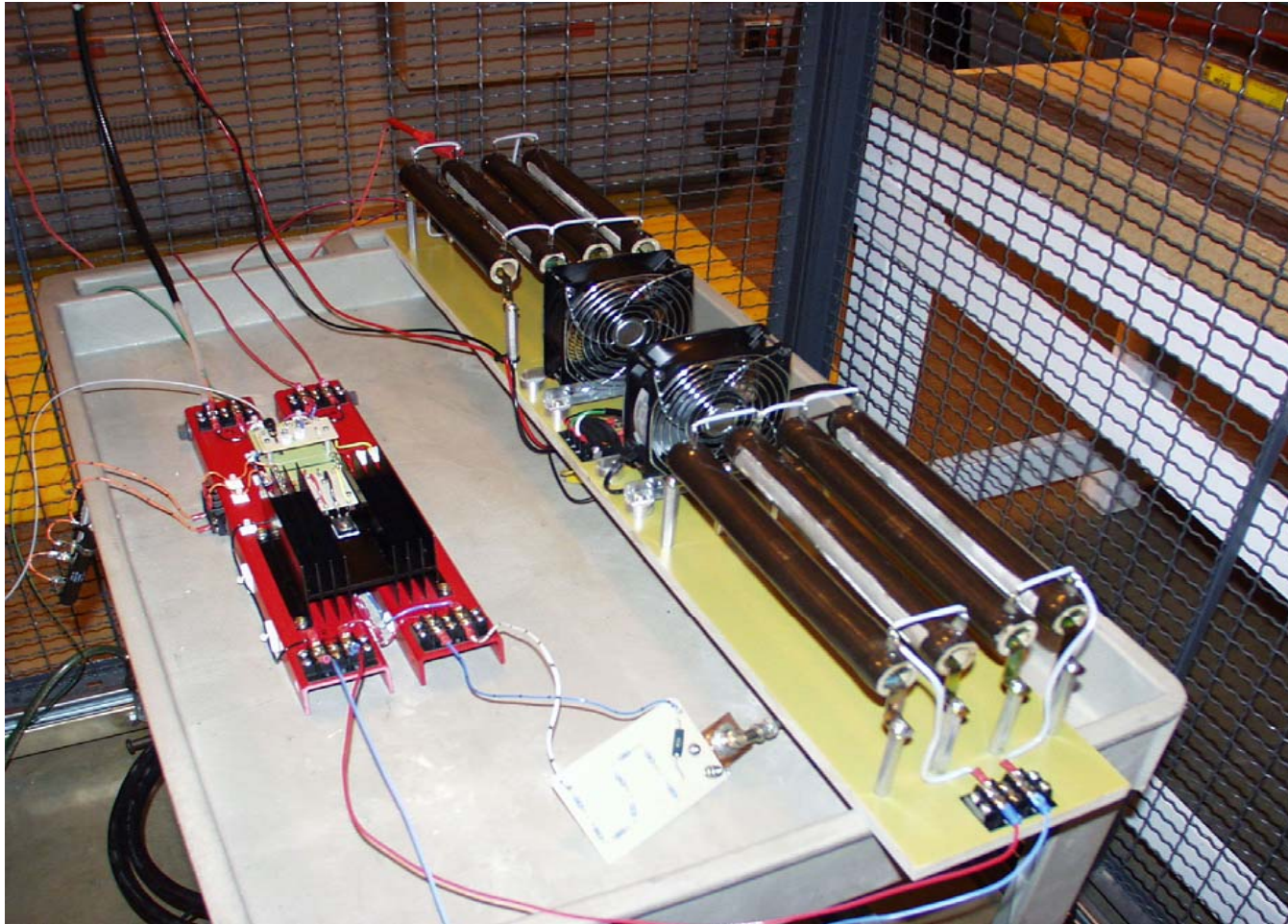




# Photo of Grid Switcher Chassis

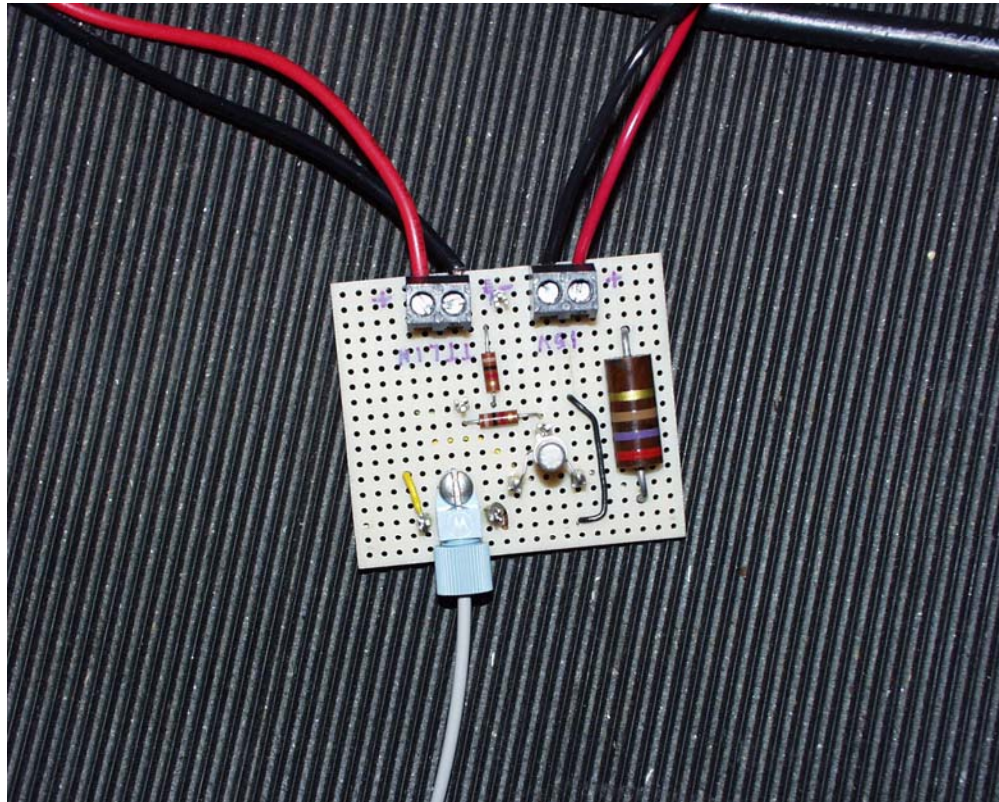


# Photo of Grid Switcher Test Setup



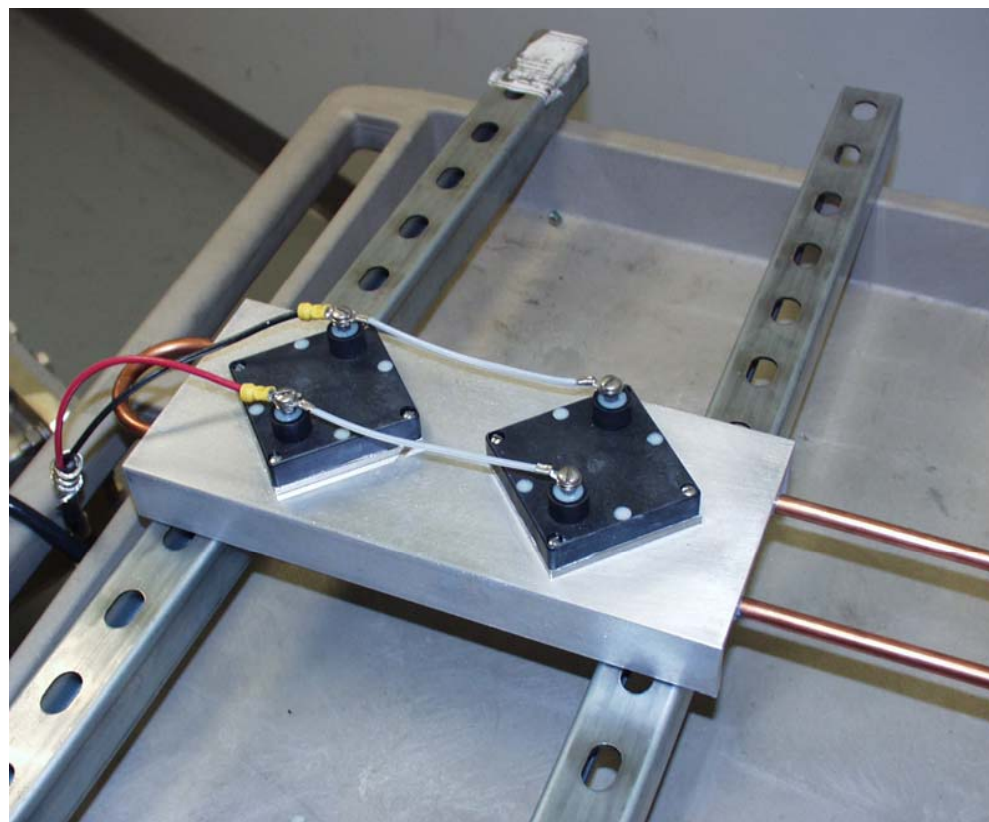


## Photo of Fiber Optic Transmitter



## Power Test of Water-Cooled Resistors

- Tested to 900 watts with ~ 3GPM of cooling water:
  - *heat sink temp reached 37.3° C*
  - *resistor case reached 42° C*
- Packaging these water-cooled resistor assemblies should not pose a thermal problem



## Present Status of Grid Switcher Project

- 1kV/1A tests completed – *no problems noted with device or gating*
- Power test on water-cooled resistors completed – *no problems noted*
- Preparing for 1kV/2A test with water-cooled resistors
- Working on packaging design for entire unit
- Unit can be completed and ready to ship by mid-July

## Remaining Issues and Questions

- Adequate adjustment range on series and shunt resistors?
- Suggestions on final physical design of system?

*Design change to 1kV/2A requiring the use of water-cooled resistors forced an increase in size over original estimate*

- *Multiple rack chassis will probably be required*
- *Connections between chassis made by RG-8 and N connectors*