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Thyratron Driver Manual and Application Note

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Set the input 110/220 voltage switches before use

Place the boards in an area with air flow
at repetition rates above 200 Hz

If an ST board is ordered, fiber optic cables will not be included

Danger - High Voltage is produced by this board and High Voltage is used by thyratron circuits in general

This board is designed for use with grounded cathode tubes

THYRATRON DRIVER MANUAL AND APPLICATION NOTE

North Star Research Corporation has developed a set of thyratron drivers based on our experience with thyratron applications, our previous successful designs and the requirements of the modern marketplace. **The drivers are designed for grounded cathode ONLY unless otherwise specified. Floating operation requires power to be supplied by an appropriately connected isolation transformer. Grounded grid operation requires isolation of the voltage output of the driver. See addendum for notes on adaptation of drive circuits to grounded grid operation.**

1.0 Thyratron Trigger Requirement Overview

Modern thyratrons may have single or multiple trigger grids which have a variety of requirements. A thyratron is triggered by creating a plasma in the cathode/Grid (G2) space. This plasma is created by the action of a pulse applied to G2 which causes breakdown in the Grid/Cathode space.

Electrons from the G2/Cathode breakdown move into the Grid-Anode space leading to current multiplication and eventual triggering of the entire thyratron. The breakdown of the thyratron often involves a phase where the grid connects to the anode (high voltage) for up to 100 ns before current conduction occurs through the whole tube. G1 is often added to enhance or speed up this process by providing early ionization or "preionization If a tube requires only G2, the North Star TT-DC/G2 board is the recommended drive unit. G2 is often biased negative at times before and after triggering in order to prevent electrons from the G1 preionization circuit from entering the G2/Anode space. In most applications, more G2 voltage and current are not damaging, so a board with too much capability can be used in a smaller tube.

<u>The Role of G1</u>

The presence or absence of a G1 electrode is determined by application - G1 preionization may be provided for a variety of reasons. Preionization reduces jitter, and reduces wear on the tube by providing a population of electrons which is in the cathode-grid space before triggering. G2 is the main trigger electrode, and G1, (and G0 if present) are electrodes which provide the preionization in the tube. In order to prevent triggering of the main gap due to preionization, the G2 electrode must be negatively biased to a voltage which may be in the -50 - -200 V range depending on tube specification. G1 is operated in DC mode for most Triton, EG&G, and Litton tubes, and it may be operated in DC or pulsed mode for most EEV tubes. The manufacturer's specifications should be considered when determining these parameters. The tube manufacturer's specification supersedes this note. The voltage between G1 and the cathode will drop from it's original value as the tube heats up and fills with gas.

Pulsed G1

A pulsed G1 circiut supplies much higher peak current (up to 50 A) than a DC G1 electrode (tens of mA), leading to a higher electron density at the time of triggering. This method of triggering is recommended for many EEV tubes and some Triton and Litton tubes. G1 is triggered first followed by G2 after a fixed time interval. That interval is usually between 0.5 and 1.0 microseconds. The value of G1 current or dV/dt can be too large which will result in triggering of the whole tube when G1 is triggered and this condition should be avoided. In some cases, series resistance or shunt capacitance must be added to avoid spurious triggering. E2V has various notes on this point. Pretriggering of the tube by G1 should not be ignored - remember that if the tube tube triggers when G1 is triggered there is no preionization when the tube is fired and all the benefits of G1 are lost. DC priming of G1 is preferable to pulsed priming which prefires the tube.

2.0 North Star's Trigger System

North Star's series of Thyratron Drivers is based on a G2 module which derives its power from a 110 V or 220 V input bridge circuit. Our unit is an IGBT/transformer based generator capable of producing the G2 pulses required in order to trigger virtually all thyratrons. Our standard trigger method uses an on-board fiber optic input. A BNC/fiber transmitter plus a fiber transmitter are provided with each board so direct outputs from a signal generator or pulse generator can also be used to trigger the unit. Avago's versatile fiber optic link system is used but ST or SMA devices from Avago can also be provided as an option. This allows the user to isolate the trigger on the board from the low voltage trigger source. This is important in reducing system noise and reducing the likelihood of EMI problems and pre-triggering due to EMI. The only customer-based connections required are the trigger input (5V/20mA or fiber), AC voltage input, and G2 output (and G1 output if required).

2.1 Description of Operation – DC/G2 Board

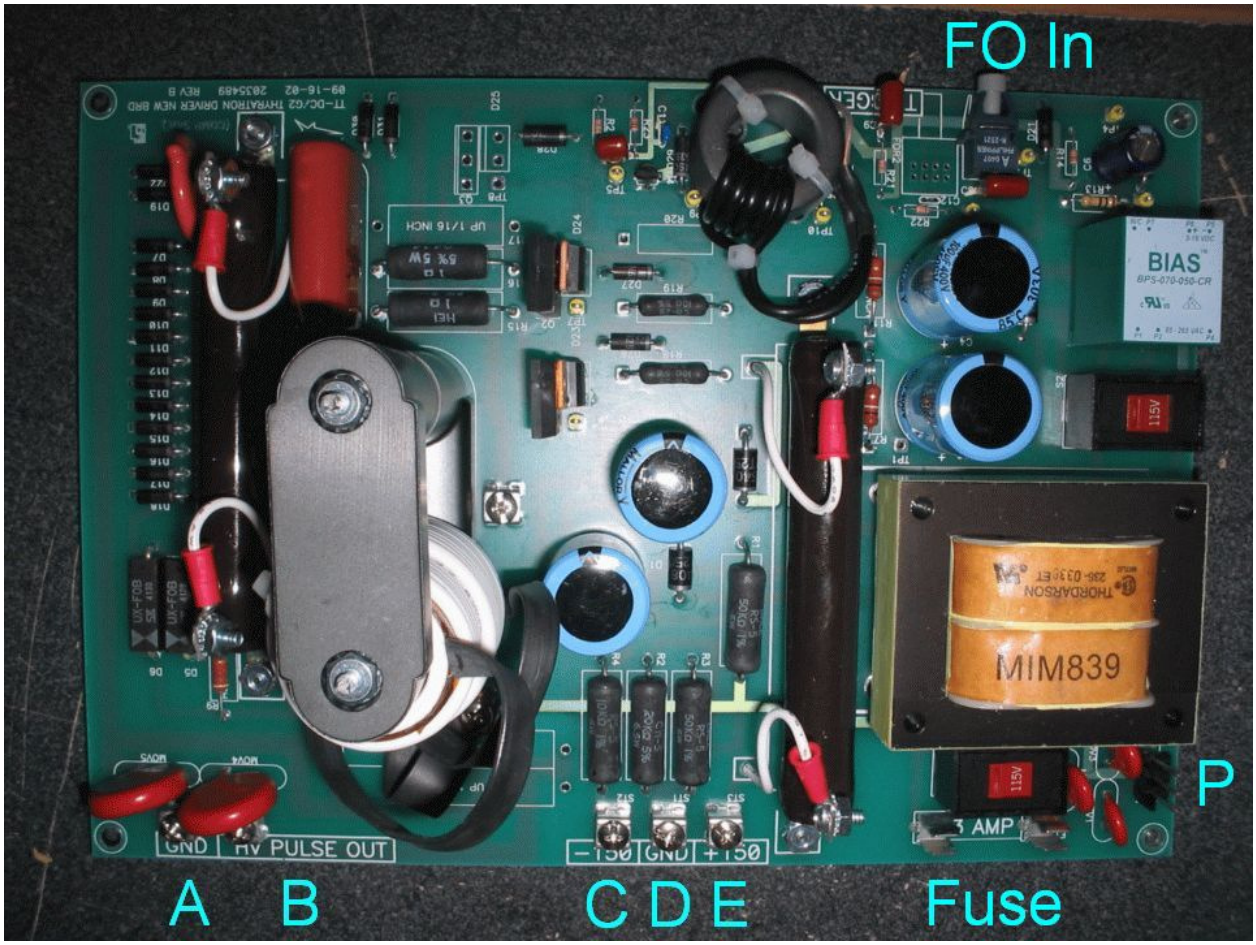


Figure 1 TT-DC/G2 Board. A is ground which is generally the cathode. B is the G2 pulse out. C is the negative bias for G2. D is the ground which is the same as A. E is the preionization connection which is equivalent to the G1 connection. P is power input and FO In is the location of the Fiber Optic Input.

Board Checkout

When you receive the board check for any obvious damage. Set the two switches (lower right and middle right of picture above) so the voltage is appropriate for your input – 110/120 or 200/240 depending on requirements. Plug the fiber optic in before power the board. Connected the BNC/FO adapter to a signal source. Pulses longer than a few hundred microseconds should be visible to the eye when looking at the fiber. The diodes are not laser diodes so you can look at the fiber safely. Connect one end of the fiber to the board and one end to the driver board.

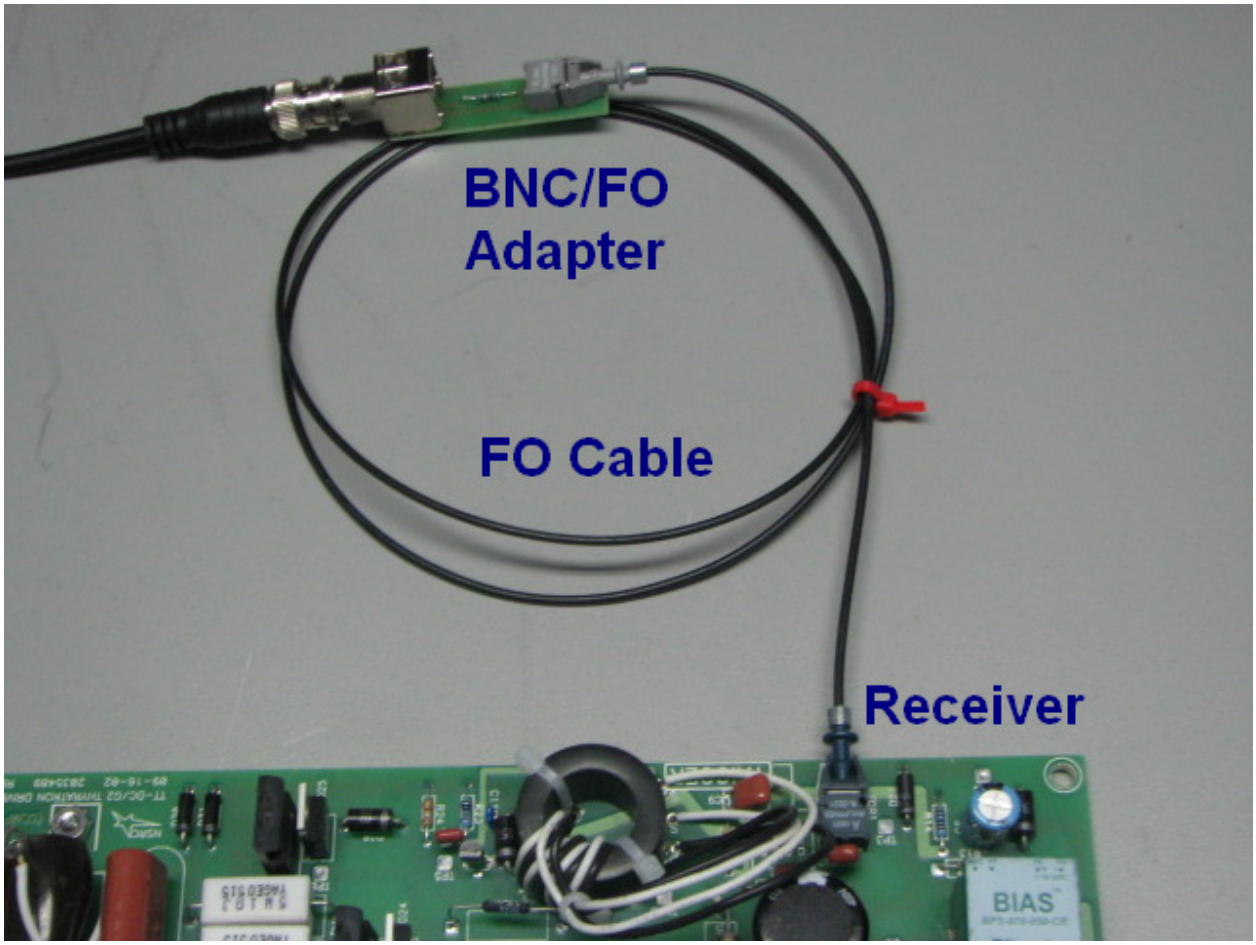


Figure 2 – FO Adapter board/Cable connection

Apply power to the board. With the tube disconnected, the +150 V output should be 140 – 180 V positive relative to ground. The open circuit voltage waveform is shown in Figure 3.

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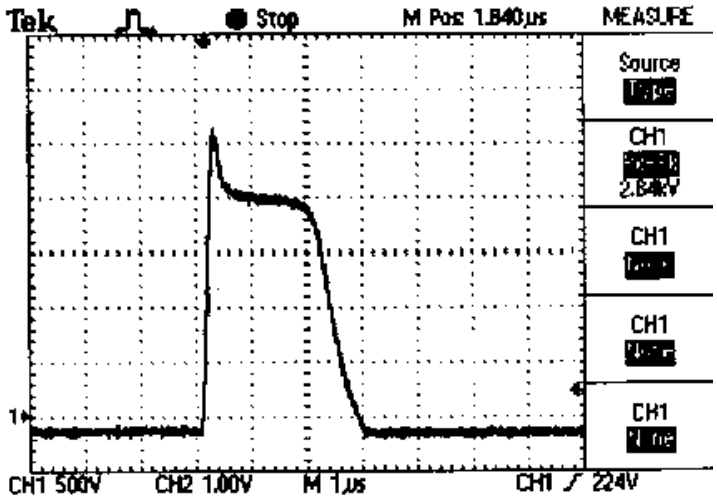


Figure 3 – Open Circuit voltage waveform of TT-DC/G2 board. Note negative bias.

When the driver is connected to the tube and the tube is cold, the signals should be the same as when the tube is disconnected. When the tube is warm and properly set, the tube will have gas inside, and the G1 voltage will drop to 10 – 20 V.

The G2 voltage characteristic will rise to 500 – 1500 V and break down to zero when the reservoir voltage and heater voltage are properly set.

2.2 Troubleshooting

The schematic of the board is shown in Figure 4.

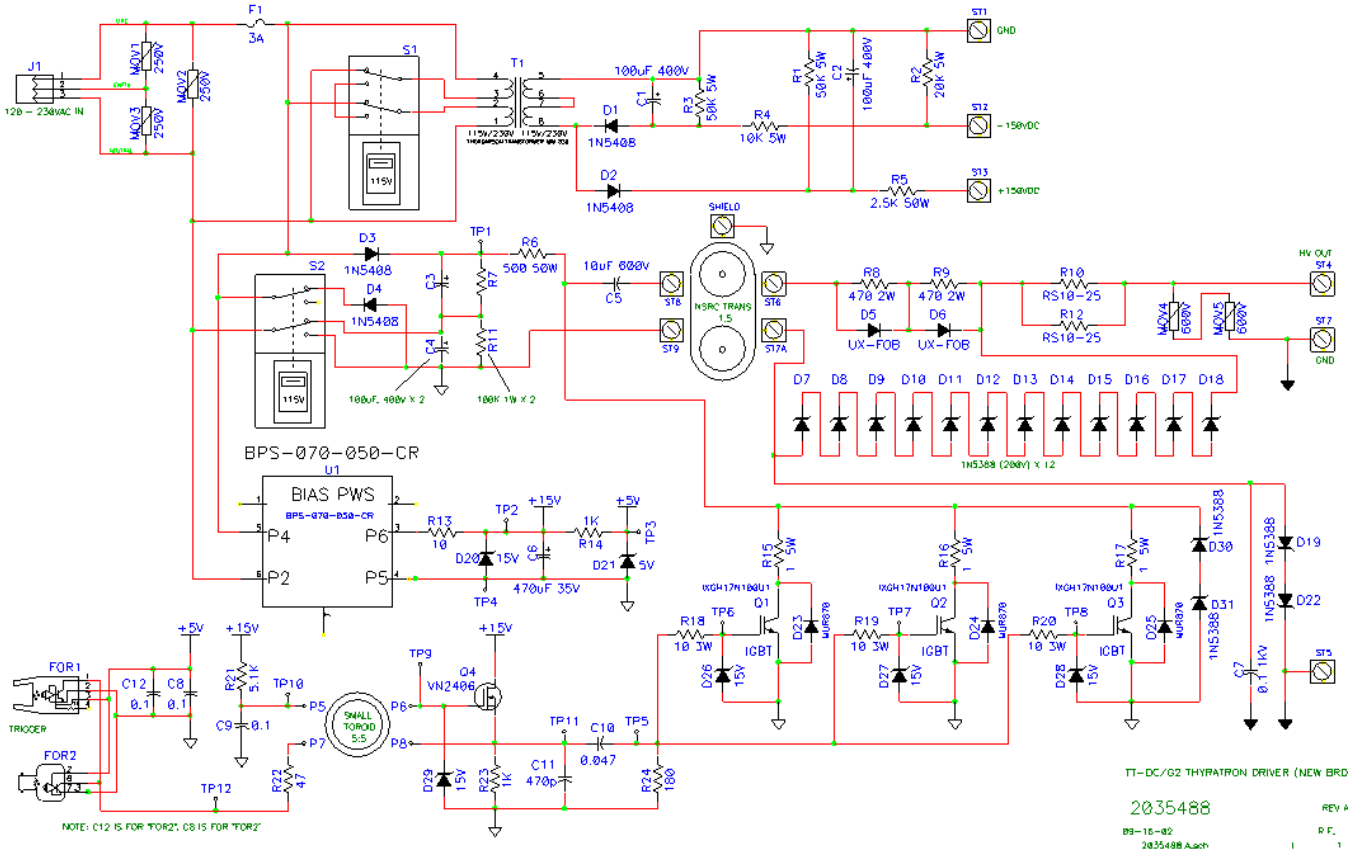


Figure 4 – Schematic of the TT-DC/G2 board.

The most common problem is failure of one of the IGBTs Q1, Q2, or Q3. These can be replaced and the board will usually function. The diodes sometimes fail, and can be replaced by virtually any 500 V or higher diode.

The fiber optic receivers sometimes fail, and they can be “troubleshot” by putting +15 V across C6 (about 40 mA) without plugging in the unit. The TP12 to common voltage should be +5 V going to zero when a trigger is commanded. TP6 to common should be a 14 V positive pulse.

The DC G1 current drive has a capability of providing up to 70 mA. This can be measured with a DC ammeter.

Note that negative bias supply driving G2 should draw very low currents - probably < 5 mA, and usually < 1 mA. If the G2 draws large (>10 mA) negative currents, then the tube is probably damaged.

If the 2 kV G2 voltage does not break down the tube then either the heater or reservoir are improperly set, or the tube is broken in some other way. If the G2 voltage doesn't break down till the risetime is over the reservoir voltage is usually too low. A sign of tube end of life is gas clean-up – a condition where there is no longer gas in the envelope and all of it has been trapped in the walls.

2.3 TT-DC/G2 Mounting information

Board "Legs" are 2.54 cm high insulated standoffs. Do not use conducting standoffs.

Dimensions

Length	10.1" (256 mm)
Width	7.05" (178 mm)
Height (transformer)	4.6" (114 mm)
Mounting holes dimensions	9.68" X 6.64" (246 X 168 mm)
Mounting hole diameter	0.16" (4 mm)

3.0 TT-G1/G2 Board

The TT-G1/G2 board is shown in Figure 5.

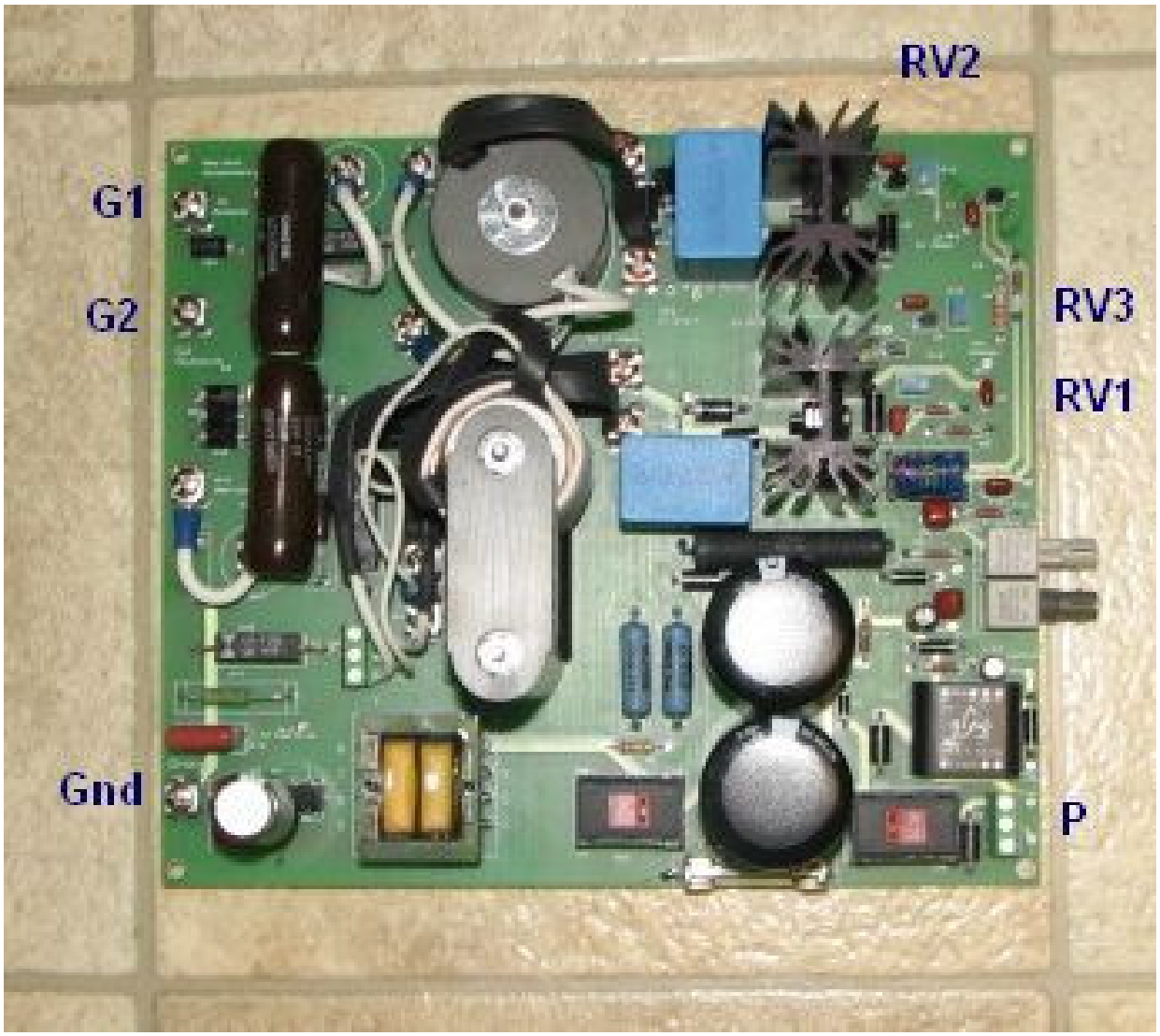


Figure 5 – Connect Ground/Cathode to Gnd, G2 to G2 and G1 to G1. The delay between drivers is adjusted by RV1. The G2 pulse duration is controlled by RV3. The G1 pulse width is controlled by RV2. This is the ST connector version of the board.

The waveforms into an open circuit for G1 and G2 are shown in Figure 6.

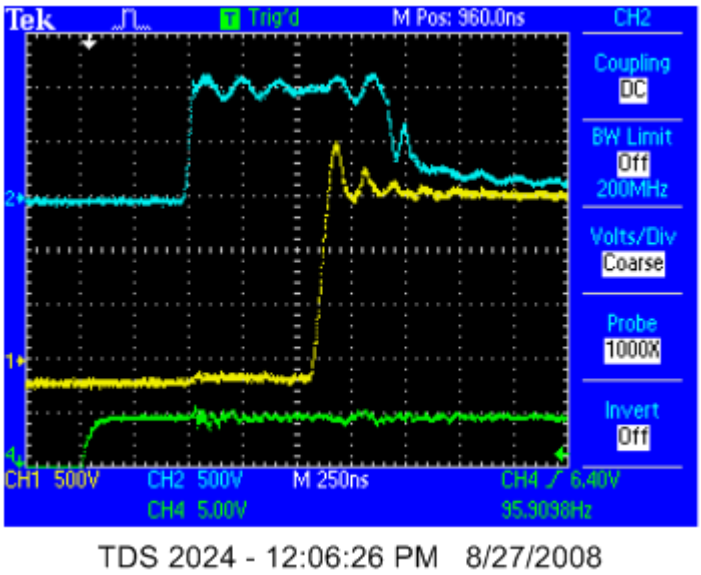


Figure 6 – Blue is G1, Yellow is G2 and Green is the input trigger.

2 kV is achieved on G2 only during the overshoot as shown. In general with a G1/G2 board, the G2 will break down at voltages below 1000 V.

The currents from G1 and G2 are shown in Figure 7.

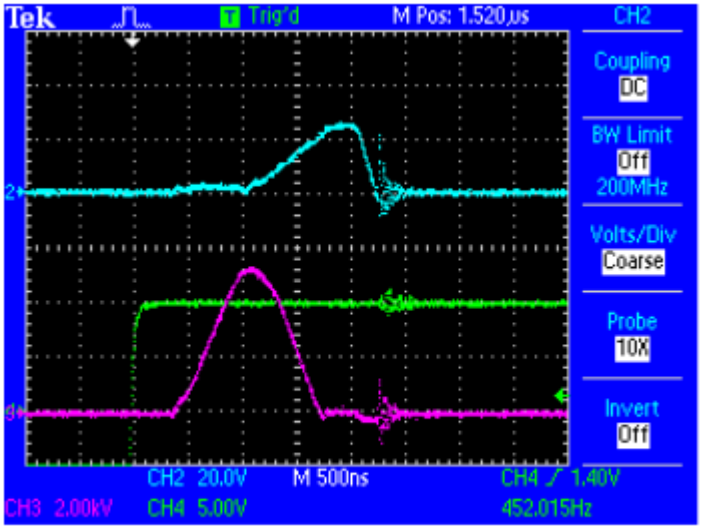


Figure 7 – Magenta is G1 current at 20 A/division. Light blue is G2 current at 20 A/division.

When the board is connected to the tube and the tube is hot, the G1 and G2 will come up to a few hundred volts and then break down. When the tube is cold or disconnected, waveforms are as in Figure 6. For checkout procedures follow the same procedure as in section 2.1.

3.2 Adjusting the Delay and Pulse Duration

The G1/G2 board has two pulses and the timing relationship between the two is important. When setting up the tube and driver the timing of the tube closure should be monitored (with some high voltage applied). The tube closure should occur shortly after the initiation of the G2 pulse. The tube should not break down a long time after initiation of G2. Tube breakdown should occur <100 ns after the G2 pulse is initiated. Tube breakdown should not occur before the G2 pulse is initiated. If the G2 pulse takes a long time to break down, increase the delay, and increase the G1 pulse duration. Increasing the reservoir voltage may also be required. G1 and G2 must overlap for about 500 ns. If G1 initiates tube breakdown, use a capacitor in parallel with G1 to slow the voltage risetime as shown in Figure 8.

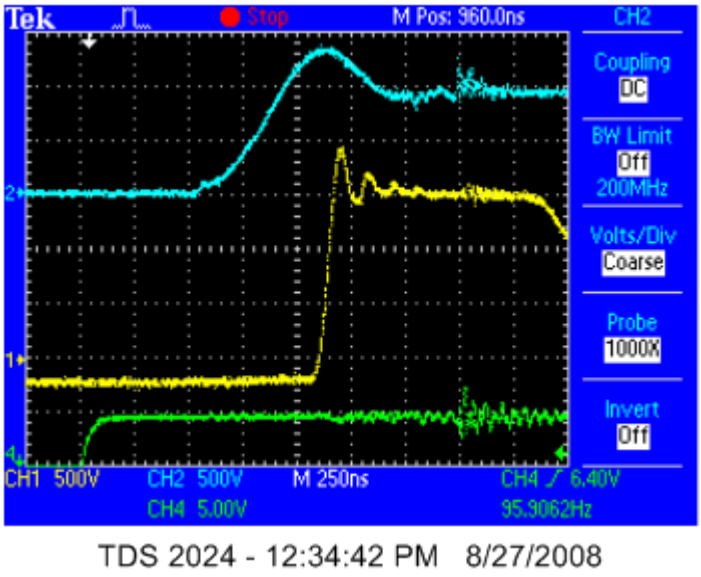


Figure 8 - G1 slowed with a 5000 pf capacitor in parallel with G1 (light blule).

3.3 Troubleshooting

See section 2.3. Beyond the recommendations of section 2.3, it may be possible to set the pulse durations or delays such that no pulse is produced. So adjustments should be made while watching the effect of the adjustment.

The schematic of the board is shown in Figure 9.

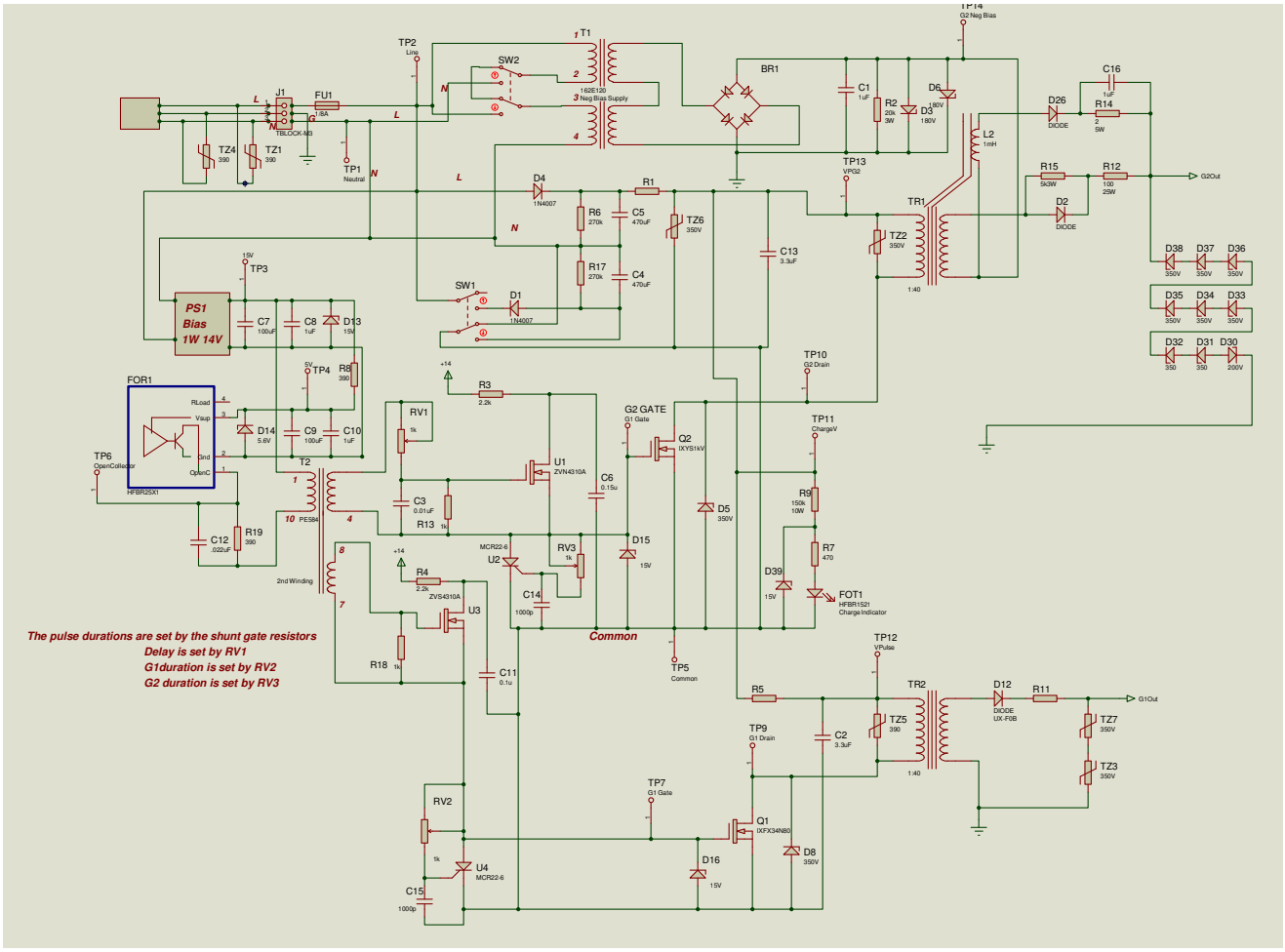


Figure 9 – TT-G1/G2 schematic.

3.4 TT-G1/G2 Mounting Information

8.55” x 7.35” total board dimensions
8.25” x 7.05” hole dimensions
0.15” hole diameter

Nominal Specifications - G2 on TT-DC/G2

Open Circuit Output Voltage	2.2 kV
Short Circuit Current	30 A
Voltage pulse Duration (FWHM)	1.5 - 2.0 us.
Current Pulse Duration (Short Circuit)	1.5 us.
Maximum Repetition Rate	500 Hz. Nominal
Max Rep in still air	200 Hz
Delay Trigger to 10 % current including fiber	300 ns.
Voltage input (200 ohm source impedance)	5 V
Fuse Value	2 A (1000 Hz.)
Nominal Power Required at 1000 Hz.	120V/1 A
Dimensions	10" X 7" X 4" High
Output G2 Voltage Bias	-180 V

DC G1 Specification

Current (negative) max	20 mA
Output Voltage G1, Open Ckt. V_{oc}	+180 V
Current Out	70 mA Typical

Note: Higher currents or rep rates (up to 8 kHz) can be provided in special order units

Nominal Specifications - G2 on TT-G1/G2

Open Circuit Output Voltage	2.0 kV
Short Circuit Current	30 A
Voltage pulse Duration (FWHM)	1.5 us.
Current Pulse Duration (Short Circuit)	1.5 us.
Maximum Repetition Rate	1000 Hz. Nominal
Max Rep in still air	200 Hz
Delay Trigger to 10 % current including fiber	1100 ns.
Voltage input (200 ohm source impedance)	5 V
Fuse Value	2 A (1000 Hz.)
Nominal Power Required at 1000 Hz.	120V/1 A
Dimensions	8.55” x 7.35” x 4.5” high

Pulsed G1 Spec

Open Circuit Output Voltage	950 V
Short Circuit Current	45 A
Voltage pulse Duration (FWHM)	1.5 us.
Current Pulse Duration (Short Circuit)	1.5 us.
Delay Trigger to 10 % current including fiber	600 ns
Delay from G1 to G2	200 – 800 ns adjustable.

Note: Higher currents or rep rates (up to 8 kHz) can be provided in special order units

Addendum: Grounded Grid Tubes

A grounded grid thyratron is a device which has similarities to a spark gap and a thyratron. It is a thyratron with a low gas fill. It is triggered like a thyratron but it conducts without cathode electron emission in a manner similar to a spark gap (the grounded grid tube has electrode erosion). The device triggering differs from a common thyratron primarily because the grid rather than the cathode is grounded. The voltage relationship between the cathode and grid is unchaged – the grid must be more positive than the cathode to trigger. If the grid is grounded, and the grid must be more positive than the cathode, then the cathode pulse must be negative with respect to ground.

Our board must be modified because it has a connection between safety ground (the usual 3rd wire) and cathode flange ground on the board.

