DIRECTED ENERGY, INC.

TRX-2.5K
THYRATRON DRIVER

OPERATION MANUAL

SERIAL NUMBER:_____

DATE:_____

Directed Energy, Inc.
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TABLE OF CONTENTS

********** **WARNING** **********

SAFE OPERATING PROCEDURES AND PROPER USE OF THE EQUIPMENT ARE THE RESPONSIBILITY OF THE USER OF THIS SYSTEM.

Directed Energy, Inc (DEI) provides information on its products and associated hazards, but it assumes no responsibility for the after-sale operation and safety practices.

ALL PERSONNEL WHO WORK WITH OR ARE EXPOSED TO THIS EQUIPMENT MUST TAKE PRECAUTIONS TO PROTECT THEMSELVES AGAINST POSSIBLE SERIOUS AND/OR FATAL BODILY INJURY. DO NOT PERFORM INTERNAL REPAIR OR ADJUSTMENTS UNLESS ANOTHER PERSON CAPABLE OF RENDERING FIRST AID AND RESUSCITATION IS PRESENT.

1.0 GENERAL DESCRIPTION

The TRX Thyratron Driver is a high voltage thyratron driver designed to be operated into a load impedance of 50 TO 500 ohms.

The TRX requires an external high voltage DC supply (+650V maximum), an input trigger, and an optional negative bias supply (-800V maximum). All support power is derived from the AC input power.

1.1 Operational Overview

Referring to the schematic and PCB component outline in the appendix of this manual, the AC input is applied at P1. The input may either be 120VAC or 220VAC, depending on the jumper location of jumpers 1, 2 and 3. This AC input is stepped down by transformer T1, and rectified and regulated by the low voltage support power circuitry shown in the lower left corner of the schematic.

There are four (4) identical channels at the ground level that are used to drive the primaries of transformer T2. For purposes of this discussion, the top channel will be referenced, but the remaining three (3) channels function identically.

The input trigger enters the PCB at pin 2 of P2. The signal is clamped to both ground and the +5V rail and is conditioned so that the input pin 2 of the DS0026 CMOS Clock Driver at U2 provides a sufficient current level for proper drive. U2 performs a level translation from a TTL level to +15V for the gate input of Q1 and Q2.

Q1 and Q2 are a CMOS inverter, and provide the high current necessary to drive the gate of Q3. Q3 operates as a pulsed current source in saturated mode, until there is a short at the output of the pulse transformer. This technique provides automatic current limiting during heavy loads or short circuit conditions. During these conditions, most of the power output that would have been delivered to the load is delivered to the power MOSFETs themselves. If this power exceeds 80W, the power dissipation of the devices may be exceeded, and damage to the TRX could occur. Although it is protected against short circuits, sustained operation into a short circuit can damage the TRX.

The drain lead of Q3 is connected to the bottom end of the first primary of T2. The top end of the same primary is bypassed by 0.8uF of capacitance. The drain of Q3 is also clamped to ground via D12, and to the positive rail via D11. The Q3 devices are rated at 10A continuous current and 1000VDS. Under certain load conditions, transients can be created at the drain of Q3. It

is therefore very important to limit the DC power input at P3 to a maximum of 650V.

The pulse current applied to the primary of T2 provides approximately 600V step function that is multiplied across the transformer by an approximate factor of four, to provide an output pulse to the load circuit shown in Figure 1 of the Appendix of 2500V.

The bias input at P5 provides a negative bias voltage for the output pulse. In many thyratron applications it is desirable to bias the control grid of the thyratron at a negative potential prior to pulse arrival. This input provides for that bias.

2.0 SPECIFICATIONS

ALL MEASUREMENTS ARE WITH THE LOAD ILLUSTRATED IN FIGURE 1 OF THE APPENDIX.

INPUT HIGH VOLTAGE	
Maximum Value	650 volts DC
Minimum Value	0 volts DC
Input High Voltage Connector	Type BNC, Rear Panel
OUTPUT HIGH VOLTAGE	
Maximum Value	2500 volts DC
Minimum Value	0 volts DC
Maximum Current	>40 amperes
Means of Adjustment	Controlled By Input High Voltage
Output High Voltage Connector	Type SHV, Rear Panel
TRIGGER	
Trigger Source	External
Trigger Input	+5V ±1V into 50Ω
Trigger Rise Time	<20ns
Minimum Trigger Pulse Width	200ns
Maximum Trigger Pulse Width	2μs
Maximum Duty Cycle	0.002
Trigger Input Connector	Type BNC, Front Panel
BIAS	
Bias Source	External
Maximum Value	-750V
Minimum Value	0V
Bias Input Connector	Type BNC, Rear Panel
OUTPUT PULSE ELECTRICAL CHARACTERISTICS	
Pulse Rise Time	125ns 2500V (10%-90%)
Pulse Width	250ns to 2μs, controlled by input trigger
Pulse Recurrence Frequency	Single Shot to 500Hz, controlled by input trigger
Jitter	<100ps shot-to-shot
Delay Between Trigger and Output Pulse	<150ns
Pulse Droop	<20% at 1μs pulse width
GENERAI	
Input AC Power	110/220VAC, 50/50Hz, Cord provided
Dimensions	8.2"L x 5.4"W x 2.6"H
Weight	Approx. 4 lbs

3.0 SAFETY

The high voltage nature of this device dictates the use of caution when operating or servicing this equipment. The following is a summary of general safety precautions that must be observed during all phases of operation and repair of the TRX Thyratron Driver.

3.1 Operating Safety Summary

The safety information contained in this summary is for both operating and servicing personnel. Specific warnings may be found throughout this manual, but may not appear in this summary.

3.1.1 Power Source

The TRX is designed to operate from a power source that will not apply more than 220 volts between the supply conductors or between either supply conductor and ground.

A protective grounding connection by way of the grounding conductor in the AC power cord is essential.

3.1.2 Grounding

The TRX is grounded through the grounding conductor of the AC power cord. **To avoid electrical shock, plug the TRX into a properly wired receptacle before making connection to any input or output connectors.** Use only a power cord that is in good condition.

3.1.3 Cover Removal

To avoid personal injury, do not remove the covers. **Do not operate the TRX while the covers are removed.** The covers do not contain a safety interlock!

3.1.4 General Operating Precautions

Do not remove the input or output cables while the driver is in operation. Never short-circuit the high voltage output of the thyratron driver. Failure to observe these precautions can result in potential electric shock to personnel, arcing, and damage to the connectors and system.

The top cover of the TRX is not safety interlocked. Extreme caution should be exercised when removing the cover.

Any pulsed power system is capable of random triggering via transients. Therefore when the thyratron driver is turned on, or high voltage is present in

the chassis, assume it is possible to get a pulse on the output connector.

3.2 Servicing Safety Summary

The TRX contains dangerous voltages and stored energy. DEI strongly recommends that all repairs and adjustments be performed by factory qualified personnel. DEI will not be responsible for personal injury or damage to the driver that occurs during repair by any party other than the factory.

3.2.1 Servicing Procedure

Do not perform internal repair or adjustments unless another person capable of rendering first aid and resuscitation is present.

3.2.2 Internal Energy Storage

The TRX contains capacitors that are used as energy storage elements. When charged, these capacitors contain approximately 1 joule of stored energy. This is sufficient energy to cause serious injury. **Assure that the AC power cord is disconnected from the driver, and that the capacitor bank is fully discharged and a shorting strap installed before any repairs or adjustments are attempted.** Verify with a voltmeter that all circuits are de-energized before servicing. The voltmeter used to make these measurements must be certified for use at 1000VDC and 220VAC or greater. Dangerous voltages, floating ground planes and energy storage exist at several locations in the TRX. Touching connections and/or components could result in serious injury.

4.0 OPERATING CONSIDERATIONS

4.1 Output

The TRX is designed to operate into a load whose characteristic impedance is 50 to 500 ohms. An unterminated or improperly terminated output will cause excessive aberrations on the output waveform and could possibly damage the driver. To ensure this does not occur, observe the following precautions:

- Use good quality 50 ohm coaxial cable and connectors (e.g. RG-58 or equivalent);
- Make all external connections tight and as short as possible;
- Use terminators or impedance-matching devices to avoid reflections;
- Ensure that all external cables and hardware have adequate voltage and power ratings.

4.2 Pulse Risetime and Falltime

The physical and electrical characteristics of the cable transmitting the pulse determine the characteristic impedance, velocity of propagation and the amount of signal loss. Several feet of cable can attenuate high frequency components of the pulse. It is therefore important to keep these cables as short as is practical. For optimum performance, DEI recommends interconnecting cable lengths of 6' or less.

4.3 TRX To Load Interface

The circuit illustrated in Figure 2 of the Appendix is recommended by DEI for interfacing the TRX to the grid of a thyratron. The power dissipation capability of R1

through R3 and D1 and D2 should be consistent with the energy and frequency of the grid spike of the thyratron used.

4.4 Trigger Input

An input trigger of +5V ±1V into 50Ω with a risetime of <20ns is required to gate on the TRX. Departure from these values can result in a loss of performance. These trigger requirements are met by any high quality low voltage pulse generator. The trigger should be set to +5V ±1V into 50Ω before the trigger cable is attached to the TRX trigger input. The input trigger

amplitude should be set using a 50Ω load (e.g. a 50Ω scope input) before connecting it to the TRX. If the trigger input is greater than +5V into 50Ω, pulse stretching can occur.

4.5 High Voltage and Bias Inputs

The TRX is rated at a maximum input voltage of 750VDC, and a maximum bias voltage of -800VDC. Proper precautions should be taken by the user to ensure that the maximum voltage is not exceeded.

5.0 PREPARATION FOR USE

5.1 General

After unpacking, initial inspection and preliminary electrical check procedures should be performed to assure that the unit is in good working order. If it is determined that the unit is damaged, the carrier should be notified immediately. Repair problems should be directed to the service department, Directed Energy, Inc. (DEI), Fort Collins, Colorado. Telephone: (303) 493-1901.

5.2 Initial Inspection

1. Inspect unit for exterior mechanical damage.

2. Inspect power input cord and input power module for obvious signs of damage.

5.3 Electrical Installation

Standard units are shipped ready for use with a nominal 110 VAC input. The unit can be configured for 220VAC input by the factory.

5.3.1 Input Power Cord

The input power cord terminates externally in a three-prong polarized plug. The unit chassis is wired to the plug through the line cord, and therefore, the insertion of the plug into a compatible receptacle, hooked up to a grounded input, will automatically ground the unit. The unit should not be operated without a grounded AC input!

5.4 Electrical Check

Before proceeding, please review the precautions in Section 3.

5.4.1 Power-Up

The unit should be powered up using the following procedures:

1. Ensure that the high voltage power supply is turned off, and all controls set to zero volts.

2. Before connecting the pulse generator to the TRX, set up the pulse generator output to deliver a +5V pulse (±1V) into 50Ω, with a rep rate of approximately 500, and a pulse width of 500ns-1000μs.

3. Plug the power cord into the AC power input. The red "POWER" indicator light should turn on, indicating that the TRX is operational. If this does not occur, unplug the unit from the AC power, and refer to the Troubleshooting Section of this manual.

4. Connect the cable from the high voltage power supply to the BNC connector on the rear panel of the TRX labeled "+ INPUT".

5. Connect the pulse generator to the front panel BNC connector of the TRX labeled "TRIGGER".

6. Connect an appropriate load to the rear panel BNC connector of the TRX labeled "OUTPUT".

7. Connect the cable from the high voltage bias supply to the BNC connector on the rear panel of the TRX labeled "- BIAS".

8. Monitor the voltage across the load, utilizing an appropriate attenuator.

9. Turn ON the high voltage power supply. Slowly increase the power supply to 100VDC. The TRX should produce an output pulse of approximately 300V, with a pulse width and pulse recurrence frequency following that of the incoming trigger.

10. If there is no output from the TRX, or the output is severely distorted, set the output voltage of the high voltage power supply to zero and turn off the high voltage power supply. Leave the TRX connected to the AC input without high voltage and with all connectors in place for approximately five minutes to bleed off the stored energy, then disconnect the AC power to the unit and refer to the Troubleshooting Section of this manual.

6.0 OPERATING INSTRUCTIONS

This section provides basic operating instructions for the TRX. Additional application information may be found in Section 7.0.

WARNING

1. To avoid personal injury, do not remove the covers. Do not operate the TRX while the covers are removed. The covers do not contain safety interlocks!

2. Do not remove the input or output cables while the driver is in operation. Never short-circuit the high voltage output of the thyratron driver. Failure to observe these precautions can result in potential electric shock to

personnel, arcing, and damage to the connectors and system.

3. The covers of the thyratron driver are not safety interlocked. Extreme caution should be exercised when removing the covers.

4. Pulsed power systems are capable of random triggering via transients and therefore when the thyratron driver is turned on, or high voltage is present in the chassis, assume it is possible to get a pulse on the output connector.

6.1 Power-Up Procedures

The unit should be powered up using the procedures detailed in Section 5.3.1. When this is accomplished, the driver can be adjusted for the particular application through the following procedure:

1. Monitoring the output of the TRX on an oscilloscope utilizing an appropriate attenuator, set the output amplitude of the TRX to the desired level by adjusting the high voltage power supply.

2. Set the output pulse width and pulse recurrence frequency by varying the controls of the input pulse generator. The output pulse width should be set by monitoring the output of the TRX. The output high voltage will follow the input trigger, but will not replicate in time the exact duration of the input trigger due to the system propagation delay.

6.2 Power-Down Procedures

1. Set the output voltage of the high voltage power supply to zero and turn off the high voltage power supply.

2. Leave the TRX connected to the AC input without high voltage and with all connectors in place for approximately five minutes to bleed off the stored energy.

3. Disconnect the AC power to the unit.

7.0 TROUBLESHOOTING

WARNING

The TRX contains capacitors that are used as energy storage elements. When charged, these capacitors contain approximately 1 joule of stored energy. This is sufficient energy to cause serious injury. **Assure that the AC power cord is disconnected from the driver, and that the capacitor bank is fully discharged and a shorting strap installed before any repairs or adjustments are attempted.** Verify with a voltmeter that all circuits are de-energized before servicing. The voltmeter used to make these measurements must be certified for use at 1000VDC and 220VAC or greater. Dangerous voltages, floating ground planes and energy storage exist at several locations in the TRX. Touching connections or components could result in serious injury.

7.1 Troubleshooting Procedures

Before attempting to service or troubleshoot the TRX, review the servicing safety summary in Section 3.0.

The power MOSFETs utilized in the TRX are mounted underneath the printed circuit board. In the unlikely event that the MOSFETs need be replaced, it is highly recommended that the unit be returned to the factory for servicing.

The table below summarizes potential problems and their solutions. If these recommendations do not resolve the problem, DEI customer service can be contacted for further assistance.

SYMPTOM	SOLUTIONS
Red LED Does Not Illuminate	• AC power not plugged in. • Fuse(s) are blown. See fuse replacement instructions in Section 8.1.1
No Output Pulse	• No input trigger • Input trigger voltage too low • Input trigger pulse width too short. Increase width. • Input trigger frequency too high. Reduce frequency. • No input high voltage. Check HV supply and connections. • Output not connected correctly. Check all cables and connections.

- Driver is damaged. Contact DEI customer service.

7.1.1 Fuses

To avoid fire hazard or damage to the driver, use only ¾A fast blow fuses (Littelfuse #312.750 or equivalent). Fuse replacement should be performed by qualified personnel only. **Assure that the AC power cord is disconnected from the driver, and that the capacitor bank is fully discharged and a shorting strap installed before fuse replacement is attempted. Verify with a voltmeter that all circuits are de-energized before servicing.** The voltmeter used to make these measurements must be certified for use at 1000VDC and 220VAC or greater.

The fuses are located in the corner of the printed circuit board, adjacent to the power entry module.

7.2 Factory Service

If the procedures above fail to resolve an operational problem, please contact the factory for further assistance:

DIRECTED ENERGY, INC.
2301 RESEARCH BLVD SUITE 105
FORT COLLINS, CO 80526
(303) 493-1901
FAX (303) 493-1903

8.0 SYSTEM FAILURE MODES

The TRX thyratron driver is capable of generating large amplitude current pulses with very fast rise and fall times. There is limited over-current or over-voltage protection circuitry, and it is the user's responsibility to assure that the interconnect cables and load do not create transients, over-current or over-voltage conditions that could damage the thyratron driver. FAILURE TO DO SO VOIDS THE WARRANTY.

8.1 Over-Current Failure

When the output is shorted, the TRX can deliver in excess of 50A of current (depending on cabling, HV power supply setting, etc.). A current pulse of this magnitude is in excess of the driver's specifications. If allowed to operate into a short for an extended period of time, damage to the thyratron driver, load and/or associated cabling may result.

8.2 Over-Voltage Failure

Input voltages in excess of 650V will damage the TRX. It is the user's responsibility to ensure that this maximum input is never exceeded.

9.0 WARRANTY

Directed Energy, Inc. (DEI) warrants all parts of equipment of its manufacture to be free from defects caused by faulty material or poor workmanship. Directed Energy, Inc's obligation is limited under the warranty to repair or replacement of products in kind. Returns must be accompanied by a Directed Energy, Inc. return authorization number and conform to standard conditions for adjustment. The aforesaid warranty shall expire twelve (12) months following the day of shipment from Directed Energy, Inc's plant. The foregoing states the entire warranty extended by Directed Energy, Inc. No other warranty, expressed or implied, is made and, specifically, Directed Energy, Inc. makes no warranty of merchantability or fitness for any purpose. In no case shall Directed Energy, Inc. be liable for any special or consequential damages. Authorization must be obtained prior to return of defective items.

APPENDIX

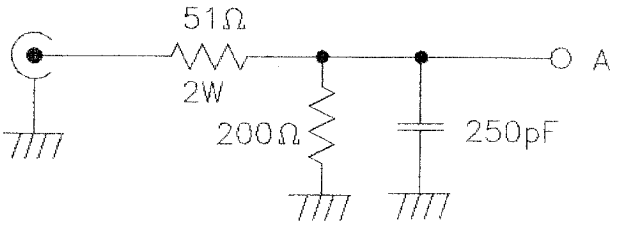
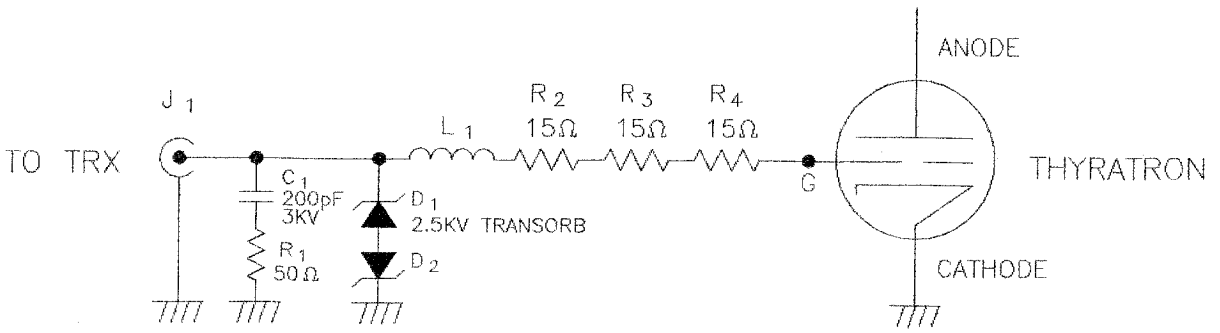


FIGURE 1.
DUMMY LOAD FOR
ALL SPECIFICATIONS



L_1 = 5 TURNS #14 WIRE ON 0.5 INCH DIAMETER.

D_1 = 10 EACH 1.5KE250 IN SERIES.

R_1 THRU R_4 : SIZE WATTAGE FOR APPLICATION.

D_2 USED IF NEGATIVE BIAS IS REQUIRED. USE AS MANY 1.5KE250 250V TRANSORBS IN SERIES AS REQUIRED TO ALLOW NEGATIVE BIAS.

FIGURE 2.
THYRATRON INTERFACE
CIRCUIT

DEI
DWG 9030-0010 R A3