DIRECTED ENERGY, INC.

GRX-1.5K-E

OPERATION MANUAL

SERIAL NUMBER:_____

DATE:_____

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********** **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 DEI GRX-1.5K-E grid driver is a high voltage solid state pulser designed to drive capacitive loads such as grids, deflection, reflection and acceleration plates.

The GRX-1.5K-E will generate an output voltage swing of 1500 volts, and output current of 16 amperes peak and .05 amperes continuous. It produces very flat voltage pulses to DC into a capacitive load.

The GRX-1.5K-E Pulser can generate single-ended output pulses from ground to +1500V or from ground to -1500V, and can also generate pulses originating from a voltage offset from ground. This offset can be from -1500V to +1500V, with a maximum power supply voltage differential ($V_{high} - V_{low}$) $\leq$1500V.

2.0 SPECIFICATIONS

INPUT PULSE VOLTAGE +V IN (V_{high})	
Source	External
Maximum Value	+1500 volts above -V IN level
Minimum Value	0 volts
Input Connector	Type SHV, Rear Panel (+V IN)
INPUT PULSE VOLTAGE -V IN(V_{low})	
Source	External
Maximum Value	-1500 volts below +V IN level
Minimum Value	0 volts
Input Connector	Type SHV, Rear Panel (-V IN)
OUTPUT PULSE VOLTAGE	
Maximum Value	±1500 volts (-V IN - +V IN)
Minimum Value	0 volts
Means of Adjustment	Controlled By Power Supply Input Voltages
Output Connector	Type SHV, Rear Panel (OUTPUT)
GATE	
Gate Source	External
Gate Input	+5V ±1V into 50Ω
Gate Rise Time	<20ns
Gate Input Connector	Type BNC, Front Panel
OUTPUT PULSE ELECTRICAL CHARACTERISTICS	
Pulse Rise Time	<25ns 1500V (10%-90%, 50pF load)
Pulse Fall Time	<25ns (10%-90%)
Pulse Width	<100ns to DC, controlled by input gate
Pulse Recurrence Frequency	Single Shot to 10KHz, controlled by input gate (into a 50pF load)
Droop	<1% into a capacitive load
Maximum Duty Cycle	Continuous
Maximum Average Output Power (CV^2F)	30 Watts

3.0 SAFETY

The high voltage 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 GRX-E.

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 GRX-E is designed to operate from a power source that will not apply more than 120 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 GRX-E is grounded through the grounding conductor of the AC power cord. **To avoid electrical shock, plug the GRX-E 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 GRX-E 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 pulser is in operation. Never short-circuit the output of the unit. 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 GRX-E 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 GRX-E is turned on, or dangerous voltage is present in the chassis, assume it is possible to get a pulse on the output connector.

3.2 Servicing Safety Summary

The GRX-E 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 GRX-E contains capacitors that are used as energy storage elements. When charged, these capacitors contain approximately 0.5 joules 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 3000VDC and 220VAC or greater. Dangerous voltages, floating ground planes and energy storage exist at several locations in the GRX-E. Touching connections and/or components could result in serious injury.

4.0 OPERATING CONSIDERATIONS

4.1 Output Cabling

The GRX-E is designed to drive capacitive loads with fast rise times. Since the current out of the GRX is limited, the lower the capacitance, the faster the risetime. Given fixed load characteristics, only the interconnecting cable type and length will vary the output capacitance.

The unit is supplied with an 8 foot length of RG-62 coaxial cable which has a capacitance of 13.5pF per foot. The unit is series terminated in the characteristic impedance of this cable, which is 93Ω. DEI recommends that the shortest length of cable possible be used to ensure the fastest possible rise times and best pulse fidelity.

4.2 Load Simulation

This unit was tested with a 50pF capacitive load connected to the output with 8 feet of RG-62 coaxial cable.

4.3 Trigger Input

An input trigger of +5V ±1V into 50Ω with a risetime of <20ns is required to gate on the GRX-E. 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 GRX-E trigger input. The input trigger amplitude should be set using a 50Ω load (e.g. a 50Ω scope input) before connecting it to the GRX-E. If the trigger input is greater than +5V into 50Ω, pulse stretching can occur.

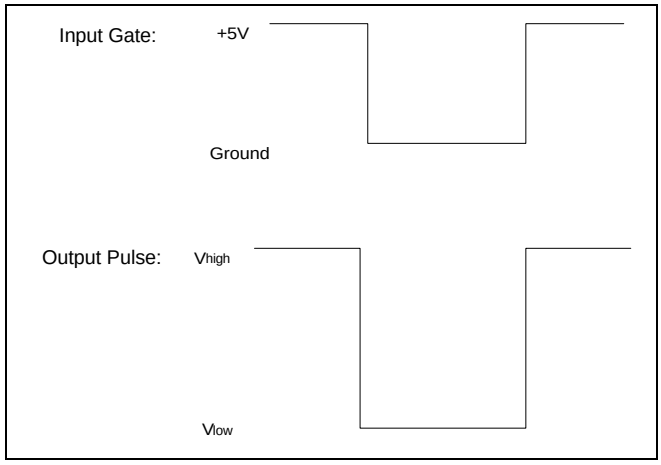
4.4 Pulse Voltages +V IN and -V IN

The GRX-E Pulser is rated at a maximum pulse output voltage of ±1500VDC. Proper precautions should be taken by the user to ensure that the maximum voltage is not exceeded.

4.5 Output Pulse Considerations

The GRX-E Pulser can generate single-ended output pulses from ground to +1500V or from ground to -1500V, and can also generate pulses originating from a voltage offset from ground. This offset can be from -1500V to +1500V, but the maximum power supply voltage differential (V_{high} - V_{low}) should never exceed 1500V. The V_{high} supply should always be equal to or greater than the V_{low} supply, but never greater than 1500V above the V_{low} supply. Therefore the V_{low} supply may be set to any voltage between -1500V and +1500V, and the V_{high} supply may be set to any voltage between -1500V and +1500V, but the voltage difference between V_{low} and V_{high} should never exceed +1500V. If the unit is operated with a single power supply (i.e. single-ended), the unused power supply input should be grounded.

When the input gate is high, the V_{high} supply is connected to the output. When the input gate is low, the V_{low} supply is connected to the output. Therefore the GRX-1.5K-E can be used to generate a negative-going pulse by logically inverting the input gate, so that the input gate is high until the unit is pulsed. When the input gate goes low, the V_{low} supply is connected to the output, thereby generating a negative going pulse (see the example in the figure below).



Generating a Negative Pulse With The GRX

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:
(970) 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 115 VAC input.

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

2. Connect the positive output power supply to the rear panel SHV connector labeled +V IN. Connect the negative output power supply to the rear panel SHV connector labeled -V IN. For +1500V single-ended output, -V IN must be connected to ground. The power supply input should be grounded if no power supply is connected. Ensure that both power supplies are turned off.

3. Plug the power cord into the AC power input and turn on the front panel Power switch. The "POWER" indicator LED should turn on, indicating that the GRX-E 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 pulse generator to the front panel BNC connector of the GRX-E labeled "GATE".

5. Connect an appropriate load to the rear panel SHV output connector.

6. Monitor the voltage at the output, by connecting an appropriate high voltage probe to the output load, utilizing an appropriate attenuator if necessary.

7. Slowly turn up the high voltage power supplies. The GRX-E should produce an output pulse, with a pulse width and pulse recurrence frequency following that of the incoming trigger.

8. If there is no output from the GRX-E, or the output is severely distorted, turn OFF the high voltage power supplies. Leave the GRX-E connected to the AC input without pulse 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 GRX-E. 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 GRX-E 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 pulse voltage output of the pulser. 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 GRX-E 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 GRX-E is turned on, or 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 GRX-E on an oscilloscope utilizing a high voltage probe connected to the output load, set the output amplitude of the GRX-E to the desired level by adjusting the output voltage of the high voltage power supplies.

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 GRX-E. The output pulse 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 controls of the high voltage power supplies to zero.

2. Turn off the high voltage power supplies.

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

4. Disconnect the AC power to the unit.

7.0 TROUBLESHOOTING

WARNING

The GRX-E contains capacitors that are used as energy storage elements. When charged, these capacitors contain approximately 0.5 joules 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 3000VDC and 220VAC or greater. Dangerous voltages, floating ground planes and energy storage exist at several locations in the GRX-E. Touching connections or components could result in serious injury.

7.1 Troubleshooting Procedures

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

The power MOSFETs utilized in the GRX-E are mounted on 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
"POWER" LED Does Not Illuminate	• AC power not plugged in. • Fuse(s) are blown. See fuse replacement instructions in Section 7.1.1
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 high voltage. Check power supplies • Output not connected correctly. Check all cables and connections. • Pulser is damaged. Contact DEI customer service.

7.1.1 Fuses

To avoid fire hazard or damage to the driver, use only the fuse types listed below. 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 3000VDC and 220VAC or greater.

FUSE LOCATION	FUSE VALUE
Printed Circuit Board	0.5A, Slow Blow (110VAC) 0.25A, Slow Blow (220VAC)

7.2 Factory Service

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

DIRECTED ENERGY, INC.
2401 RESEARCH BLVD SUITE 108
FORT COLLINS, CO 80526
(970) 493-1901
FAX (970) 493-1903

8.0 SYSTEM FAILURE MODES

The GRX-E 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 GRX-E. FAILURE TO DO SO VOIDS THE WARRANTY.

8.1 Over-Current Failure

When the output is shorted, the GRX-E can deliver in excess of 16A of current (depending on cabling, pulse 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 unit, load and/or associated cabling may result.

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

Supplemental Characterization Data

GRX-1.5K-E Data Sheet Supplement: Characterization Data

Directed Energy, Inc. • 2401 Research Blvd., Ste.108 • Ft. Collins CO 80526
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EMAIL: deiinfo@dirnrg.com • INTERNET: http://www.dirnrg.com

The information below is provided as supplemental data to the GRX-1.5K-E data sheet. Please contact DEI for the product data sheet, or for additional information.

The GRX-1.5K-E is designed to drive deflection plates, extraction grids, and other capacitive loads, using RG-62 interconnect cable. The data sheet specifies the performance of the pulser into a 50pF load with 8 feet of RG-62 cable connecting the pulser to the load. However the pulser can drive loads with a few picofarads to several hundred picofarads of capacitance. The information below is provided to assist the user of the GRX-1.5K-E to:

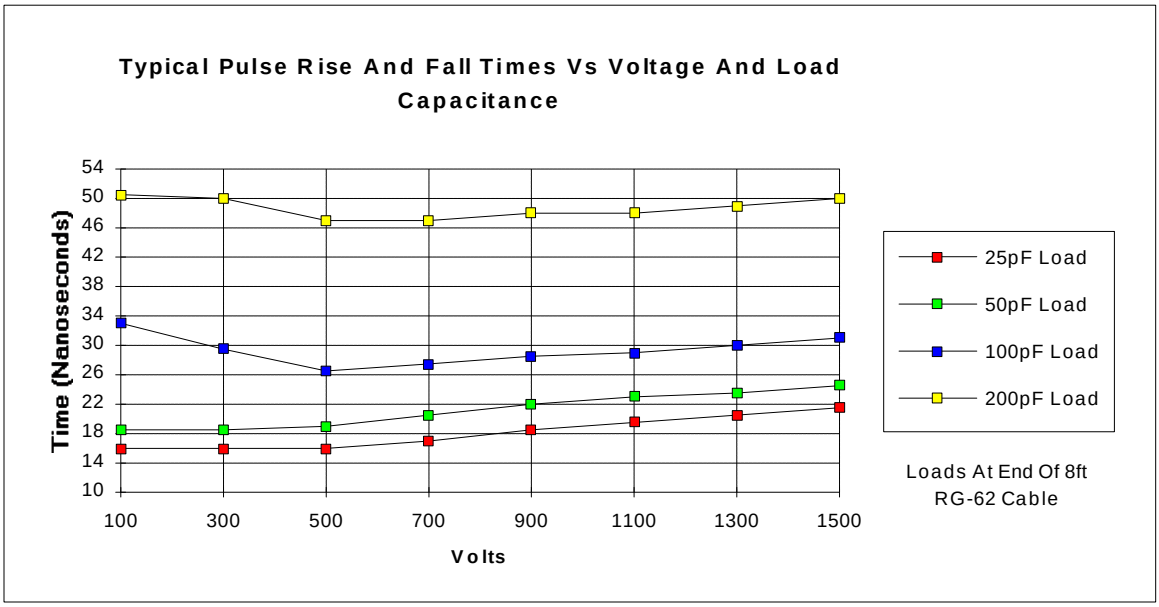
- Determine the operating characteristics of the pulser into loads other than 50pF;
- Determine the maximum operating frequency or voltage for a given load and power supply output power;
- Determine the power supply output power needed to operate the GRX-1.5K-E with a given load, input voltage and operating frequency.

Pulse Rise And Fall Time

As the load capacitance increases, the pulse rise and fall times will also increase. The following chart represents typical rise and fall times of the GRX-1.5K-E into loads of 25pF, 50pF, 100pF and 200pF, at voltages from 100V to 1500V. These four loads are connected to the GRX-1.5K-E with eight (8) feet of RG-62 cable, exhibiting a capacitance of 108pF (13.5pF/foot), and a nominal impedance of 93Ω. When determining the operating characteristics of the GRX-1.5K-E, the total load capacitance, including the length of the interconnect cable, must be taken into account.

For a given load, if a shorter length of RG-62 interconnect is used between the pulser and the load, the rise and fall times will improve, since the shorter cable length results in a lower total load capacitance. Conversely, a longer cable length will result in slower rise and fall times.

The rise and fall times are virtually the same, therefore one plot is shown that represents both rise and fall times at each load capacitance. These times are measured from the 10% to the 90% points of the slope.



Maximum Frequency And Power

The GRX-1.5K-E is limited to a maximum pulse recurrence frequency of 600kHz, a maximum output voltage of 1500V, and a maximum power dissipation of 30W. Within these absolute limits, the GRX-1.5K-E can operate at significantly higher frequencies than its rating in the data sheet.

The following four graphs present typical operation of the GRX-1.5K-E into 25pF, 50pF, 100pF and 200pF loads at the end of 8ft of RG-62 cable. Each data series shows the maximum operating frequency attainable at input voltages of 100V to 1500V for power supply outputs from 5W to 30W.

These graphs can be used in three ways. Referring to the first graph (25pF load) for the examples, one may:

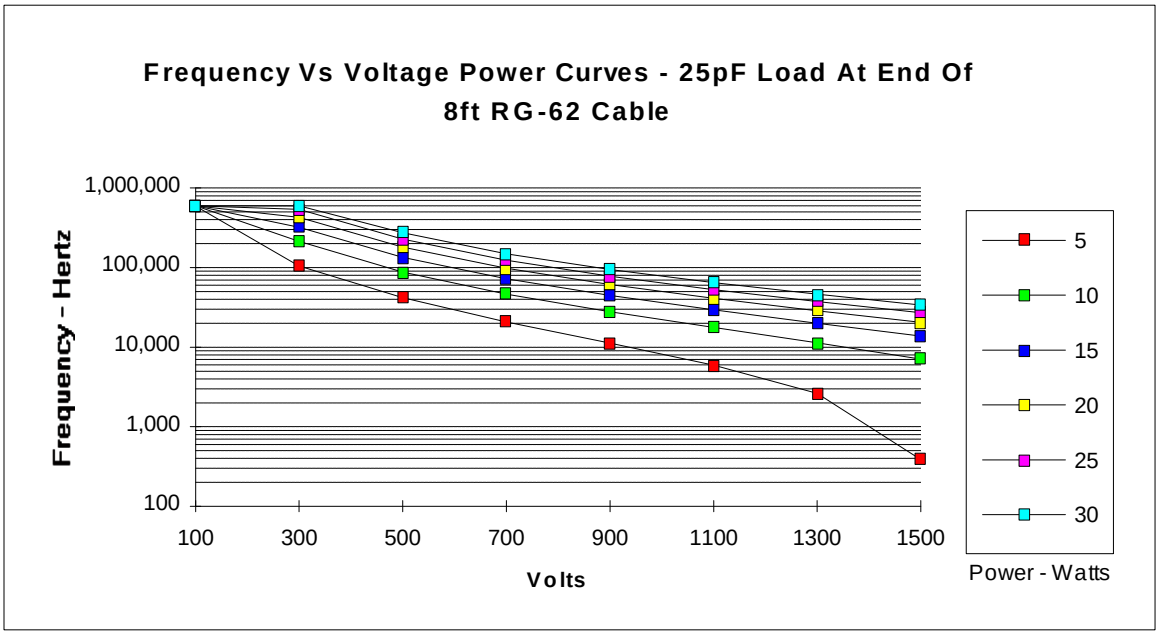
a) Determine the maximum operating frequency that can be attained at a given input voltage and power supply output power. For example, at 1500V output with a 5W power supply, the GRX-1.5K-E can operate at a maximum of approximately 400Hz.

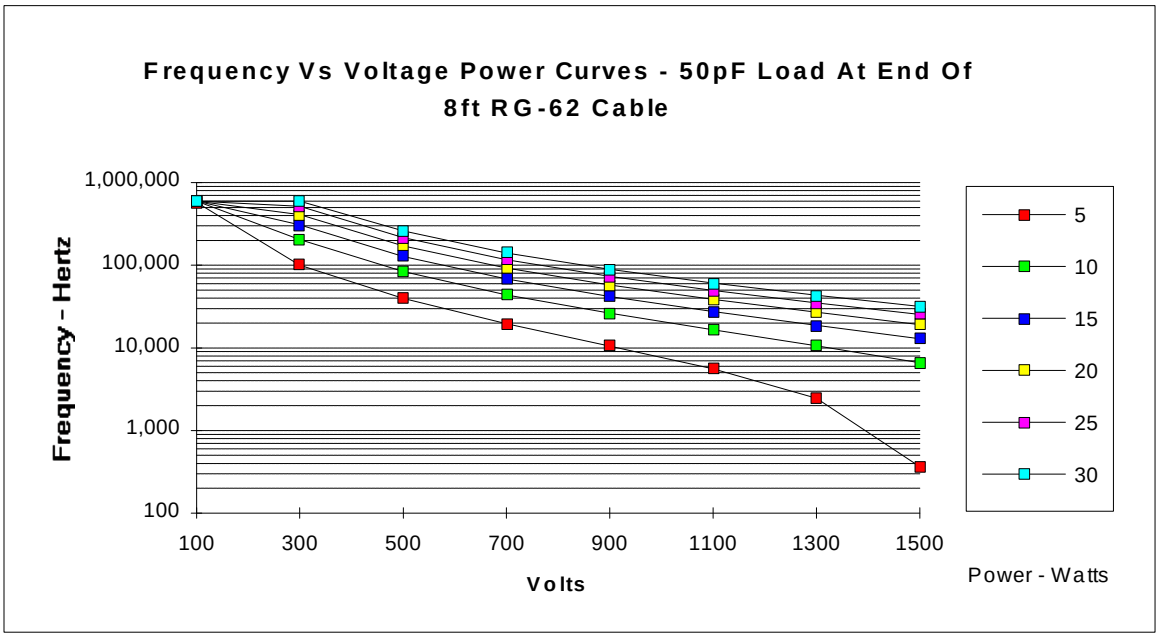
b) Determine the maximum output voltage for a given frequency and power supply level. For example, at a 30kHz pulse recurrence frequency and a 15W power supply, the maximum output voltage is approximately 1,100V.

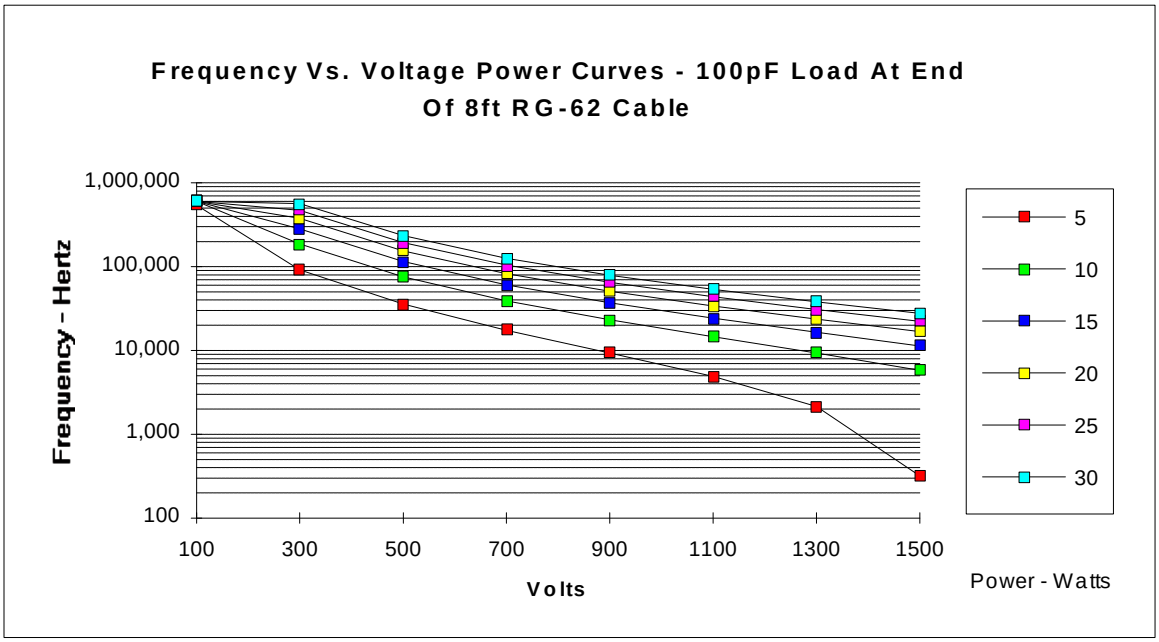
c) Determine the power supply requirements needed to operate at a given frequency and voltage. For example, to operate at 100kHz frequency and 500V output will require a power supply capable of delivering approximately 12W of power at 500V.

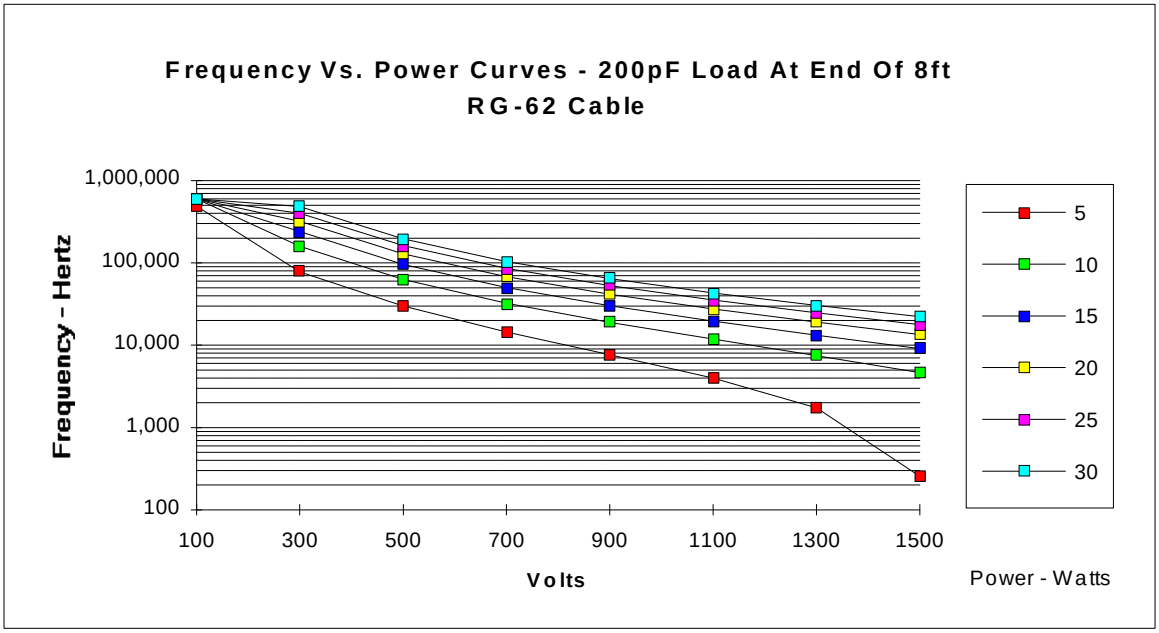
The data may be interpolated for load capacitances other than those listed.

As with the other measurements, these data were obtained with the loads connected to the GRX-1.5K-E by eight (8) feet of RG-62 cable, exhibiting a capacitance of 108pF. When determining the operating characteristics of the GRX-1.5K-E, the total load capacitance, including the length of interconnect cable, must be taken into account.






Frequency Vs. Voltage Power Curves - 100pF Load At End Of 8ft RG-62 Cable
Frequency - Hertz
1,000,000
100,000
10,000
1,000
100
100
300
500
700
900
1100
1300
1500
Volts
5
10
15
20
25
30
Power - Watts


Frequency Vs. Power Curves - 200pF Load At End Of 8ft RG-62 Cable
Frequency - Hertz
1,000,000
100,000
10,000
1,000
100
100
300
500
700
900
1100
1300
1500
Volts
5
10
15
20
25
30
Power - Watts