DIRECTED ENERGY, INC.

PVX-4450

HIGH VOLTAGE BIPOLAR PULSE GENERATOR

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.

1.0 Quick-Start Guide

This quick-start guide provides a step-by-step guide to manually operating the PVX-4450. Please refer to the appropriate sections of the manual for additional instructions and guidelines. The SAFETY warnings in the manual should be read and understood prior to operating the PVX-4450.

1.1 Operating The PVX-4450

1. Plug the AC power cord into the PVX-4450, and into an appropriate AC socket.

2. Install the mating rear panel DSUB connector supplied with the unit. This connector has pins 4 and 12 jumpered to satisfy the external interlock signal. **This connector must be installed in order to satisfy the interlock circuit. If it is not installed, the unit cannot be enabled.** In order to interface an external interlock, pins 4 and 12 may be wired to the contacts of a switch or relay. If the pin 4/pin 12 connection is opened, the interlock will not be completed, and the unit will generate an interlock fault.

3. Turn on the PVX-4450 by pressing the **POWER** button.

4. The front panel display will read **OUTPUT MENU** .

5. Use **up** and **down arrows** to scroll through the screen.

6. Scroll to the **FREQUENCY** option and use the encoder to change the frequency. Hitting **SELECT** confirms the value entered, and hitting **MENU** cancels the value entered and goes to the next menu. Hitting the **X10** button will multiply the frequency by 10x.

7. The next option is **PULSE CT**. This indicates the number of bursts output when the unit is triggered.

8. The next selection is **BURST CT**. If this is set to 3, the unit will output 3 positive pulses followed by three negative pulses continuously.

9. The next option displayed is **TRIGGER**. This sets the trigger source. Use the encoder to change the trigger source. **INTERNAL** means the unit will output continuously once the **OUTPUT** button is pressed, **EXTERNAL** means the unit will operate continuously when the **TRIGGER** input goes high, and **SING SHOT** will give a single positive pulse and a single negative pulse when the **OUTPUT** button is pressed. **BURST** and **COUNT** are disabled in **INTERNAL** mode. Press **MENU** to go to the next menu, **POSITIVE PULSE**.

10. **PHVS** sets the positive output voltage from 0-1750V.

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11. **DELAY** sets the delay after the positive pulse from 25ns to 950ms.

12. **WIDTH** sets the width of the positive pulse from 1us to 950ms.

13. **DUTY** sets the positive duty cycle from 1-95%. When this option is selected, the pulsewidth changes.

> **NOTE:** If the pulse width, delay, or duty cycle conflict with the repetition frequency setting, **LIMIT** will briefly appear to notify the user.

14. Press **MENU** again to access the next menu, **NEGATIVE PULSE**. These settings are the same as those used on the **POSITIVE PULSE**.

15. Pressing **MENU** again brings up the **USER SELECTION**.

Sync: Internal Preferences- Sync is off Frequency Signal

Negative- Sync is off negative pulse edge

Positive- Sync is off positive pulse edge

Off – no sync

Contrast: Sets the contrast of the display

GPIB ADD R: Sets current ADD R of unit. Saves in EEPROM.

Baud- Set RS232 Baud Rate

16. Pressing **MENU** again brings up the **MONITOR** menu. This screen displays the output voltage and current of the positive and negative high voltage power supplies.

17. Pressing **MENU** again brings up the **CONFIGS** menu. One can **LOAD** and **SAVE** configuration flies here in non-volatile memory.

18. Pressing **MENU** again brings up the **SYSTEMS MENU**. This displays the code versions.

19. Press **OUTPUT** to enable the output and generate output pulses. In continuous mode, press **OUTPUT** again to disable it. In pulse counting mode, the PVX-4450 automatically disables the output and turns off the **OUTPUT** LED when the count is reached, or a fault is detected. In **COUNT** mode, the count display is not updated during operation. It is updated only when the count value is reached or a fault occurs.

2.0 PVX-4450 DESCRIPTION

2.1 Conceptual Description

The PVX-4450 is a bi-polar pulse generator designed for pulsing high impedance, capacitive loads at voltages up to ±1,750V returning to ground between pulses. A microprocessor-controlled TTL pulse generator is incorporated into the system, along with high voltage DC power supplies. This provides a stand-alone test system that can be programmed to perform your device testing using either the front panel LCD control panel, RS-232 computer interface or GPIB.

Up to five user configurations may be stored in internal non-volatile memory, and recalled through the front panel or communications interface.

2.2 Functional Description

The microprocessor-controlled pulse generator and front-panel interface provides individual control of each electronic function, while the backlit display provides immediate visual confirmation of all operating parameters. Parameters that can be varied through the front panel or RS-232 interface include:

- Positive Output voltage
- Negative Output voltage
- Trigger source (internal, external or single-shot)
- Pulse width for positive pulse
- Pulse width for negative pulse
- Delay interval between positive and negative pulses
- Repetition frequency
- Enable/Disable Output
- Show and clear all faults
- Load and save configurations

All error and fault messages are reported on the front panel display, you can retrieve them as well through the communications interface. Faults that are reported include positive and negative over current and interlock violation. Analog current and voltage monitors and a synchronization output are also provided for monitoring of the current and voltage to the load using an external oscilloscope or digitizer. In addition to stand-alone operation, the pulse generator can be externally triggered.

3.0 SPECIFICATIONS

All specifications are measured into a 1500pF load. The maximum load capacitance is 25nF.

OUTPUT PULSE CHARACTERISTICS	
Maximum Voltage	±1,750 volts bipolar
Means of Adjustment	Independent front panel control of both positive and negative output voltages, 1V resolution
Output Connector	SHV, Rear Panel (OUTPUT)
Pulse Rise Time (Leading edge of both +1750V and -1750V pulses)	≤200ns (10%-90%) measured into a 1500pF load
Pulse Fall Time (Falling edge of both +1750V and -1750V pulses)	≤200ns (10%-90%) measured into a 1500pF load
Pulse Width	1us to 950ms, controlled by front panel or RS-232 interface
Pulse Width Resolution	3 digits
Pulse Recurrence Frequency (1500pF load, 1.00us pulse widths, 25ns delays)	100mHz – 20 KHz Maximum frequency into higher load capacitances limited by DC power supply wattage. Lower load capacitances can be driven at higher frequencies. Pulser is limited to 20kHz maximum frequency. [1]
Pulse Recurrence Frequency Resolution	10 milliHertz at low end
Delay Between Positive And Negative Pulses	25ns to 950ms, controlled by front panel, RS-232 interface or external trigger input
Delay Resolution	25ns
Droop	<5%
Pulse Over/undershoot	<5%
Jitter (pulse-to-pulse)	<0.01% of pulse repetition period
Maximum Duty Cycle	95%
GATE	
Gate Source	Internal or External
Gate Input	TTL into 1KΩ
Gate Rise Time	<20ns
Gate Input Connector	BNC, Front Panel
POSITIVE DC POWER SUPPLY	
Voltage Source	Internal
Maximum Value	+1,750 volts
Minimum Value	~0 volts
Maximum Average Input Power	60 Watts
NEGATIVE DC POWER SUPPLY	
Voltage Source	Internal
Maximum Value	-1,750 volts
Minimum Value	~0 volts
Maximum Average Input Power	60 Watts
VOLTAGE MONITOR	
Monitor Scaling	1000V/V into 1 MegΩ
Monitor Connector	BNC, Front Panel

CURRENT MONITOR	
Monitor Scaling	20A/V into 1 MegΩ
Monitor Connector	BNC, Front Panel
GENERAL	
Support Power	90-260VAC, 50/60Hz
Size	5" H x 17" W x 20" D Rack-Mount Enclosure

Table 1: PVX-4450 Specifications

(1) The power dissipated when driving a capacitive load is defined by the formula CV^2F, where C is the total load capacitance, including the capacitance of the load, interconnect cable, and the internal capacitance of the pulse generator, V is the pulse voltage, and F is the pulse repetition frequency (or the total pulses per second). (For these calculations, the internal capacitance of the pulse generator is 120pF, and the output cable is about 21pf/foot.) Given the maximum available power of 60W each channel, the maximum load capacitance, frequency and/or voltage at which the pulse generator can operate can be approximated using this formula. For example, given a 1500pF load capacitance and a 11kHz frequency, the power required is 1746pF x 1750V^2 x 11kHz = 58.8W. Since the maximum power available is 60W, this approaches the maximum frequency that can be achieved when driving a 1500pF load.

The rise and fall times are specified into a 1500pF load. Driving a smaller load capacitance, the rise and fall times may be slightly faster. Driving a larger capacitance, the rise and fall times may be slower. The load capacitance must not exceed 25nF. The maximum output current is Vset / 75 Ohms, and the output impedance of the unit is approximately 75 Ohms. Therefore the rise time can be approximated using the greater of the results of the two formulas formula dt = 3RC, or dt = C(dv/I). In the former, R = 75 Ohms and C is the load capacitance, hence dt = 225C. In the latter, C is the load capacitance, dv is the output voltage, and dt is the rise time. For example, driving a 20nF load, the rise time will be approximately 4.5us (3 x 75 x 20nF).   The delay between the positive and negative pulses should be set to no less than three times the rise time as determined by the formula dt = 3RC.

The internal microprocessor-controlled pulse generator will allow pulse profiles as illustrated below. The width of the positive delay (A), the width of the positive pulse (B), the width of the negative delay (C), and the width of the negative pulse (D) are all adjustable individually.
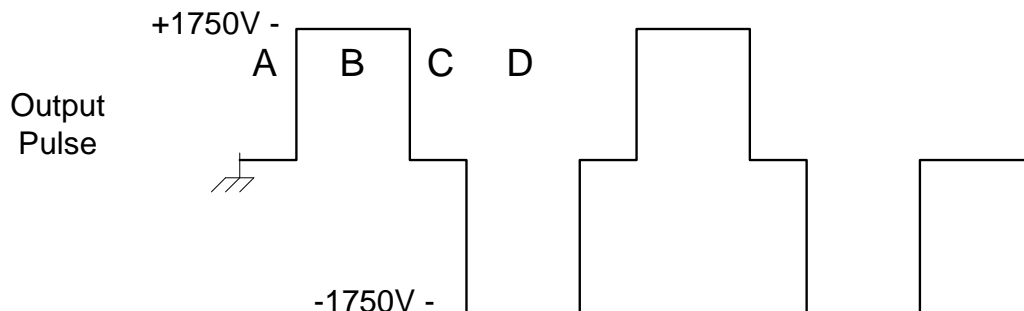
The output pulses may be programmed synchronously (so that the pulse widths and delay between pulses are the same for both positive and negative pulses), or asynchronously (so that the positive pulses may be a different width than the negative pulses, and the delays between the positive-to-negative transitions and the negative-to-positive transitions can be different periods). Therefore the voltage of the positive phase can be different than the voltage of the negative phase. For example, the positive phase can be set to 1000V, and the negative phase to 600V, approximating a 60% decay. Furthermore, by setting either the positive or negative output to zero, the unit can be operated as a monophasic pulse generator, providing an output pulse up to +1,750 or –1,750V.

4.0 SAFETY

Normal use of test equipment exposes the user to a certain amount of danger from electrical shock because testing may be performed with exposed voltages present, dictating 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 PVX-4450.

4.1 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.

4.1.1 Power Source

The PVX-4450 is designed to operate from a regulated power source. To assure proper system operation the input voltage should not vary by more than 10% from the recommended specification. The PVX-4450 accepts input voltages from 90VAC to 264VAC at 47Hz to 63Hz.

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

4.1.2 Grounding

The PVX-4450 is grounded through the grounding conductor of the AC power cord. **To avoid electrical shock, plug the PVX-4450 into a properly wired receptacle before making connection to any input or output connectors.** Use only a power cord that is in good condition. If the unit is not grounded properly, a failure may result.

4.1.3 Cover Removal

To avoid personal injury, do not remove the covers. **Do not operate the PVX-4450 while the covers are removed.** Operating the unit with the top cover removed voids any and all warranties associated with the PVX-4450.

4.1.4 General Operating Precautions

Do not open the unit while the system is in operation. Do not handle or remove the output cables while the unit is operating. Though the output voltage of the unit falls immediately to ground upon being shut off, your load may retain a charge. Turn off equipment when changing connections in high voltage or high current circuits. Discharge high voltage capacitors and/or capacitive loads after removing power.

4.2 Servicing Safety Summary

DEI strongly recommends that factory-qualified personnel perform all repairs and adjustments. DEI will not be responsible for personal injury or damage to the pulse generator that occurs during repair by any party other than the factory. Any repairs, adjustments or modifications made by anyone other than authorized DEI personnel voids the factory warranty.

5.0 PREPARATION FOR USE

5.1 General

After unpacking, initial inspection and electrical installation 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,

<div align="center">

Directed Energy, Inc. (DEI),
Fort Collins, Colorado.
Telephone: (970) 493-1901
FAX: (970) 493-1903

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5.2 Initial Inspection

Inspect unit for exterior mechanical damage.

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 90 - 264 VAC input.

6.0 OPERATING CONSIDERATIONS

6.1 Local Mode Operation

This is the default operating mode that the unit assumes upon power up. It is designed for user front panel control. This allows the user to configure, test and operate the PVX-4450 without a host PC.

6.2 Remote Mode Operation

Through the RS-232 or GPIB interface, a host PC can remotely operate the PVX-4450. This feature allows the user to create system level control software to run standardized test procedures for research, test or manufacturing validation environments.

6.3 Front Panel Controls and Indicators

The PVX-4450 front panel consists of seven function buttons, an encoder wheel, and a display, facilitating stand-alone operation. Below is a brief description of the function supported by each front panel component.

6.3.1 Power Switch

The switch labeled **POWER** controls all AC power in the chassis.

6.3.2 Synchronous Pulse Monitor (**SYNC**)

This is a 5V TTL signal into 1 meg-Ohm or 2.5V signal into 50 Ohms that is synchronous with the frequency generator trigger. This is designed to assist the user in triggering when monitoring the output signals with an oscilloscope, or for use in triggering an external instrument. The rising edge of **SYNC** corresponds to the start of the positive delay, and the falling edge of **SYNC** corresponds to the start of the positive pulse.

6.3.3 External Trigger (**TRIGGER**)

This is an input signal into 1K Ohm used for external Pulse Repetition Frequency (PRF) triggering. It is designed to allow the user to trigger multiple PVX-4450 units from a single pulse generator. This allows the user to create synchronous waveforms from multiple units.

6.3.4 Current Monitor (**I MON**)

The BNC connector labeled **I MON** provides a 20A/V monitor of the output current. This monitor should be terminated into 1 MegΩ, such as the 1 MegΩ input of an oscilloscope.

6.3.5 Voltage Monitor (**V MON**)

The BNC connector labeled **V MON** provides a 1V/1000V monitor of the output pulse. This monitor should be terminated into 1MegΩ, such as the 1MegΩ input of an oscilloscope.

6.3.6 Menu Button (**MENU**)

This button goes to the next menu. If the value of a setting has changed but **SELECT** has not been pressed to confirm, **MENU** goes to the next menu and returns the present value of the parameter to its old value.

6.3.7 ENTER Button (**ENTER**)

Used for variables that will be permanently stored in the unit or require setup times internal to the PVX-4450 unit. When a question mark appears after the variable, the enter button will "confirm" or in some cases save that particular setting.

6.3.8 Up and down Arrows

The UP ARROW button allows the user to go up in any particular menu to change selections. If the user is at the top selection it will wrap back around to the bottom selection.

The DOWN ARROW button allow the user to go down in any particular menu to change selections. If the user is at the bottom selection it will wrap back around to the top selection.

6.3.9 Range Button (**X10**)

The **X10** button is used when varying parameters that have exponents that can change by a power of 10. By pressing the range button the user can increment the exponent within its acceptable range. This allows the user to quickly set the parameters, without having to excessively scroll the encoder wheel. The **X10** button functions with the following commands:

- Set Negative and Positive Pulse Widths
- Set Delay Interval
- Set Frequency
- Set Pulse Count
- Set Positive and Negative High Voltage

The **X10** button is effectively a 10X multiplier. For example, when setting frequency, the resolution of the encoder wheel is three digits (i.e. 1.00Hz, 10.0Hz, 100Hz). Therefore without adjusting the range, the encoder wheel must be turned many times to increase the frequency from 1Hz to 100Hz. However if the frequency is set to 1.00Hz, if the **X10** button is pressed once, it changes to 10.0Hz. If it is pressed

twice, it changes to 100Hz. Therefore from the power-up default of 1.00Hz, to set the output to 100Hz, press the **X10**button twice. Pressing it once will change it to 10.0Hz, and pressing it again will change it to 100Hz.

Setting the interval and pulse width is similar to setting frequency. For example, to set the interval to 300us, set the interval to 2.5us, press the**X10**button once to increment it to 250us, and then rotate the encoder wheel to increase it to 300us. At this point, pressing the **X10** button again would increase the interval to 3.00ms, pressing it again increments it to 30.0ms, etc.

6.3.10 Pulse On Button (**OUTPUT**)

This button enables and disables the output pulse. It has a corresponding LED that illuminates if the pulses are enabled. In pulse counting mode, the PVX-4450 automatically disables the output and turns off the **PULSE ON** LED when the count is reached, or a fault is detected.

6.3.11 Encoder Wheel

This is for varying the parameters such as Frequency, Pulse Width, Delay, Trigger Source, etc.

6.4 Rear Panel Connectors

6.4.1 RS-232

The male DB-9 connector labeled "RS-232" is the RS-232 interface for those units with the optional RS-232 interface. Its pin out is standard three wire RS-232. It should be connected to the control computer with a null modem cable.

Pin2	RxD	Receive
Pin3	TxD	Transmit
Pin5	GND	Ground

6.4.2 GPIB

The female GPIB connector labeled "GPIB" is the GPIB interface for controlling the unit in a manner similar to the RS-232 port.

6.4.2 INTERLOCK

The D/5 connector labeled INTERLOCK provides the IO for the external interlock. The interlock is on pins 4 and 12, with 4 being ground.

The INTERLOCK pin 12 must be jumpered to pin 4 in order to satisfy the PVX-4450's interlock circuit. If the INTERLOCK pin is not jumpered to pin 4, the user will not be able to enable the output.

6.4.3 AC Power Entry Module

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

The PVX-4450 accepts input voltages of 90-264VAC, 47-63Hz.

6.4.4 Output

The output connector is the high voltage pulse output. It is an SHV connector. The output of the PVX-4450 should be connected to the load using 75 Ohm coaxial cable.

7.0 HARDWARE OPERATING INSTRUCTIONS

This section provides basic operating instructions for the PVX-4450 hardware.

7.1 Power-Up Procedures

The unit should be powered up using the following procedures:

1. Connect the *Output* to an appropriate load using 75 Ohm coaxial cable.

2. Install the mating rear panel DSUB connector supplied with the unit. This connector has pins 4 and 12 jumpered to satisfy the external interlock signal. **This connector must be installed in order to satisfy the interlock circuit. If it is not installed, the unit cannot be enabled.** In order to interface an external interlock, pins 4 and 12 may be wired to the contacts of a switch or relay.

3. Plug the AC power cord into the PVX-4450, and into an appropriate AC socket.

4. Turn on the PVX-4450 by pressing the **POWER** button.

5. Configure the unit from either the front panel or RS-232 port GPIB. See the quick-start guide in Section 1.0 of this manual for specific operating instructions, and Sections 8 and 9 for detailed operation instructions.

8.0 LOCAL MODE OPERATING INSTRUCTIONS

8.1. OUTPUT menu

8.1.1 Setting Trigger

The **OUTPUT** menu allows the user to configure the parameters of trigger source, frequency, pulse count, and burst count. To change a parameter, use either the encoder or the **X10** button. To confirm a value, hit **SELECT**. Hitting **MENU** to access the next menu cancels a selection and returns the selected parameter to its previous value.

The user can choose from Internal Pulse Repetition Frequency (**INTERNAL**), **EXTERNAL**, or Single Shot (**SINGLE SHOT**)mode. In internal frequency generator mode, the repetition rate is internally generated based on a 24MHz crystal oscillator. External PRF allows the PVX-4450 to be triggered by an external pulse generator or control system. The Single Shot mode is for applications that need single pulses or frequencies less than 1.0 hertz.

In **INTERNAL PRF**, the pulse frequency is set through the *Set Frequency* controls.

In **EXTERNAL PRF**, the input trigger controls the pulse frequency. When a TTL trigger is received on the front panel **TRIGGER** input, output pulses are generated, with widths equal to the widths set in the appropriate width and delay menus.

In Single-Shot mode, when the **OUTPUT** front panel button is pressed, output pulses are generated, with widths and interval delays equal to the widths and delays set in the appropriate menu.

8.1.2 Setting Frequency

Available only when the trigger source is not in the Internal Single Shot (**SINGLE SHOT**) mode. Frequency can be varied by the encoder wheel and/or the range button for user convenience. The **X10** button selects the frequency exponent, and the encode wheel sets the number (see Section 6.3 above). The unit supports 1% resolution of frequencies and allows for user control to this level of accuracy.

8.1.3 Setting Pulse Count and Burst Count

Burst Count (**BURST**) and Pulse Count (**PULSE**) allow the user to output different sequences of pulses. When **BURST** and **PULSE** are set to 0, the unit operates normally, generating a positive pulse followed by a negative pulse continuously. When **BURST** is 0 and **PULSE** is set, the unit generates **PULSE CT** normal pulses then stops. When **BURST** is set and **PULSE** is 0, the unit continuously generates **BURST** positive pulses, then **BURST** negative pulses. When both **BURST** and **PULSE** are set, the unit generates **PULSE** bursts of **BURST** pulses, starting with a positive burst. This set of relationships is illustrated below.

BURST OFF
COUNT OFF

BURST OFF
COUNT 3

BURST 3
COUNT OFF

BURST 3
COUNT 3

START
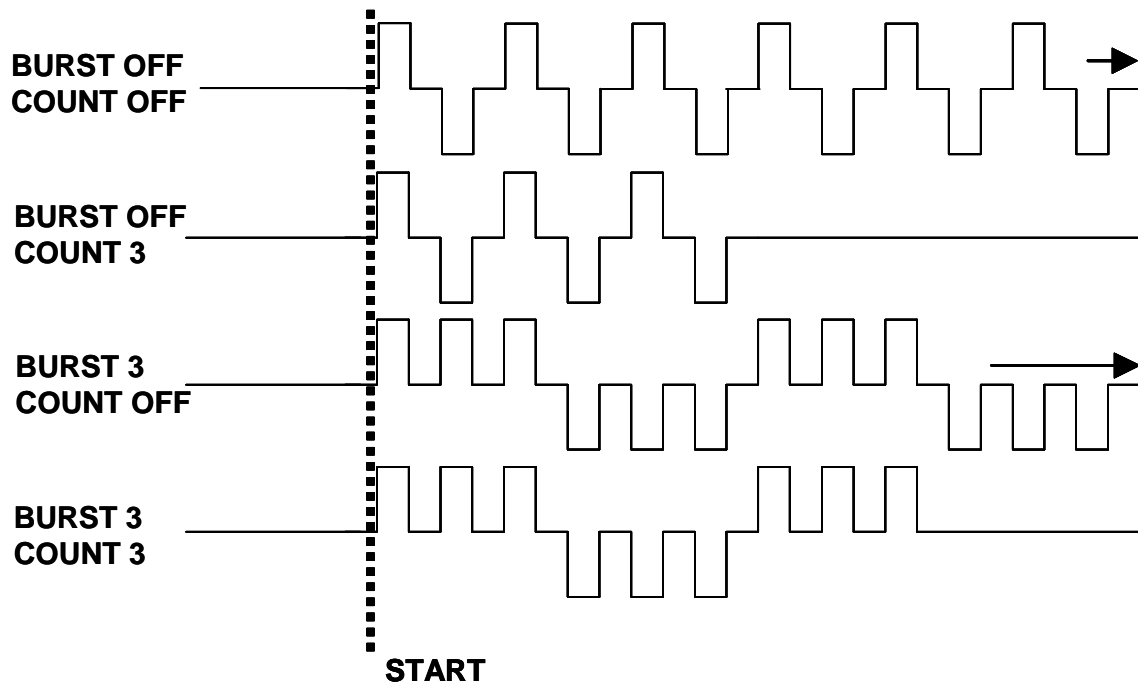
Here, the **X10** button is a 10X multiplier. For example, without adjusting the range, the encoder wheel must be turned many times to increase the count from 1 to 100. However if the count is set to 1, if the **X10** button is pressed once, it changes to 10. If it is pressed twice, it changes to 100. When pressed three times, it changes to 1,000.

8.2 SET POSITIVE OUTPUT and SET NEGATIVE OUTPUT menus

8.2.1 Pulse Widths and Delays

The pulse widths are independent variables for each polarity. The pulse width specifies the duration of the output pulses. The positive interval delay sets the period between the gate input pulse and the leading edge of the positive output pulse. The negative interval delay sets the period between the falling edge of the positive output pulse and the leading edge of the negative output pulse.

Because each of these variables are independent, the PVX-4450 can be configured to generate monophasic (either positive polarity or negative polarity) pulses. To generate only positive pulses, set the negative interval delay to its minimum (25ns), set the negative pulse width to 0, and set the negative voltage to 0. To generate only negative pulses, set the positive pulse width, positive interval delay to its minimum (25ns), and positive voltage to 0.

The **X10** button selects the pulse width or delay exponent, and the encoder wheel sets the number. Using the **X10** button and encoder wheel, select the pulse width

and delay (see Section 6.3 above). The PVX-4450 supports 1% accuracy, and the width and delay are displayed in engineering units.

8.2.2 Setting Positive and Negative High Voltage

The positive and negative high voltage amplitudes are set independently, facilitating asymmetric output pulses. Each high voltage may be set to any integer between 1V and 1750V. As with *Pulse Count*, the **X10** button can be used as a 10X multiplier in setting this value.

8.2 FAULTS Menu

This menu only appears when a fault is detected. From this menu, any faults encountered during operation can be displayed and cleared. If a fault is encountered, it must be cleared through this menu prior to resuming operation.

Possible faults are:

INTERLOCK: Indicates the interlock circuit has been broken through the external interlock on the rear panel.

OVERCURRENT_FAULT: Indicates an over current fault has occurred on the positive or negative channel.

8.5 CONFIGS menu

8.5.1 Saving a Setup

For user convenience the PVX-4450 has the ability to save up to five different configurations. Numbered from 1-5, the user can keep their most used configurations in a fast access state. By selecting one of the five configurations and saving from this menu option the user can later recall their favorite system setups. Located in non-volatile RAM, the setups will be intact even when system power is off.

Parameters saved are: configuration name, trigger source, frequency, positive pulse width, negative pulse width, positive delay, negative delay, pulse count, burst count, positive high voltage, and negative high voltage.

8.5.2 Loading A System Setup

To access an existing setup the user can select 1-5 using the **ENCODER**, hit **SELECT**, and then let the PVX-4450 load the different parameters associated with the configuration.

8.6 OUTPUT MONITOR Menu

This menu displays the values of the voltage and current monitors for both channels.

9.0 REMOTE MODE OPERATION

The remote host instructions are sent using an ASCII string of characters to manipulate the PVX-4450 settings. The command set is based upon the SCPI (Standard Commands for Programmable Instruments) protocol. It has been optimized for use in DEI's equipment for application ease and device efficiency. Each command includes a string of words and if necessary, data or a keyword. The interface is not case sensitive.

In between each word in the string there must be a colon with no empty spaces and there should be nothing after the string (the interface will not ignore any new line or return characters and this will cause a parsing error). However for commands with a data parameter there must be at least one space between the command string and the data. After a set command, the unit will return a pound sign and an error code. A #0 represents no error. To query the PVX-4450 on a parameter setting or system status, the same string is used except there is no data or keyword following the string, instead the string is terminated with a question mark. Please note there should be no empty spaces between the string and the question mark.

9.1 Remote Host Command Overview

9.1.1 SCPI Based Command Set

Here is the complete list of all SCPI commands supported by the PVX-4450. These commands can be used on either the GPIB or RS-232 interfaces.

CHAN:FREQ data	Set frequency
CHAN:FREQ?	Read frequency
CHAN:PULS:BCTR data	Set burst count
CHAN:PULS:BCTR?	Read burst counter
CHAN:PULS:PCTR data	Set pulse count
CHAN:PULS:PCTR?	Read pulse counter
CHAN:TRIG:(EXTL,INTL,SING)	Set trigger
CHAN:TRIG?	Read trigger status

CHN1:PULS:DCYC	Set positive duty cycle
CHN1:PULS:DCYC?	Read positive duty cycle
CHN1:PULS:DLAY	Set positive delay
CHN1:PULS:DLAY?	Read positive pulse delay
CHN1:PULS:WIDT	Set positive pulsewidth
CHN1:PULS:WIDT?	Read positive pulse width
CHN2:PULS:DCYC	Set negative duty cycle
CHN2:PULS:DCYC?	Read negative duty cycle
CHN2:PULS:DLAY	Set negative delay

CHN2:PULS:DLAY?	Read negative pulse delay
CHN2:PULS:WIDT	Set negative pulse width
CHN2:PULS:WIDT?	Read negative pulse width

NHVS:IMON?	Read negative current monitor
NHVS:SETV data	Set negative setpoint
NHVS:SETV?	Read negative voltage setpoint
NHVS:VMON?	Read negative voltage monitor
PHVS:IMON?	Read positive current monitor
PHVS:SETV data	Set positive setpoint
PHVS:SETV?	Read positive voltage setpoint
PHVS:VMON?	Read positive voltage monitor

OUTP:STAT:(DSBL,ENBL)	Enable/disable output
OUTP:STAT?	Read output status

CONF:ACTV?	Read active configuration
FALT RSET	Reset faults
FALT:LIST?	Read faults
FIRM:PROG:(DSBL,ENBL)	Enable firmware upgrade
GPIB:ADDR	Set GPIB address
GPIB:ADDR?	Read gpib address
MMEM:LOAD:CONX(1-5)	Load configuration #
MMEM:SAVE:CONX(1-5)	Save configuration #

NOTE: These should only be used at the manufacturing facility.

CALB:IMON:NHVS	Decrement/increment negative current offset
CALB:IMON:NHVS?	Query negative current offset
CALB:IMON:PHVS (0,1)	Decrement/increment positive current offset
CALB:IMON:PHVS?	Query positive current offset
CALB:VMON:NHVS?	Decrement/increment negative voltage offset
CALB:VMON:PHVS	Query negative voltage offset
CALB:VMON:PHVS?	Decrement/increment positive voltage offset
CALB:VMUL:NHVS	Query positive voltage offset
CALB:VMUL:NHVS?	Set negative voltage ADC multiplier
CALB:VMUL:PHVS	Read negative voltage ADC multiplier
CALB:VMUL:PHVS?	Set positive voltage ADC multiplier
	Read positive voltage ADC multiplier

- Before any data leave only one space (0x20) between the last word and the first number.

- Data in engineering format is X.XXE+XX or X.XXE-XX.

- Integer data format is any number 0 - 32332 (depending on data range of instruction).

- When using GPIB, only terminate with EOI, make sure there is no terminating characters such as new line or null characters. With a serial packet (RS232) make sure to terminate the packet with a '/r' character.

- The GPIB bus returns a #0 in the output buffer when a command executes successfully, when a command fails the output buffer is loaded with the error code (and a pound sign before it) and the SRQ byte is loaded with the error code for applications that support asynchronous notification.

- External communication will automatically put unit into remote mode and lock out front panel for safety reasons. The **FAULT**, **INTERLOCK**, and **ENABLED** lights will still function.

9.1.3 Sample Commands

Frequency:
Setting the frequency to 15kHz is as follows.
Setting Examples: CHAN:FREQ 1.50E+04
Reading Examples: CHAN:FREQ?

Pulse Width:
Setting the pulse width to 150us is as follows.
Setting Examples -> CHAN:PULS:WIDT 1.50E-04
Reading Examples -> CHAN:PULS:WIDT?

Duty Cycle:
Acceptable values for this parameter are from 1 to 95, representing the duty cycle values from 1% to 95%. Please note that the PVX-4450 does not compute non whole number values of duty cycle. This means if the duty cycle is 20.3% the PVX-4450 will not respond. Setting the duty cycle to 25% is as follows.
Setting Examples -> CHAN:PULS:DCYC 25
Reading Examples -> CHAN:PULS:DCYC?

Trigger Source:
There are three acceptable keywords for this instruction. Setting and reading the trigger source in short form is as follows.

Setting Examples -> CHAN:TRIG:INTL or CHAN:TRIG:EXTL or CHAN:TRIG:SING
Reading Examples -> CHAN:TRIG?

9.2 RS-232 Serial Operation

This RS-232 serial port allows a user another way to connect a personal computer as the remote host to the DEI PVX-4450. Utilizing a standard three wire interface and DEI's defined communication protocol the user can write a custom control program for their particular testing needs. This interface has the advantage of being less expensive than the GPIB interface, but is limited that each PVX-4450 would need its own serial port on the host PC. Multipoint addressing is not supported by the PVX-4450's serial interface. The end of packet characters is an ascii return ('/r') and the PVX-4450 expects to receive this terminating character before executing this command. After seeing the '/r' the PVX-4450 assumes the whole data packet is received and processes the command immediately.

9.2.1 Serial Parameters

The standard communication parameters for the PVX-4450 over a serial port are 115200 baud (default), 8 data bits, no parity, 1 stop bit, and no flow control.

9.3.2 Serial Data Packets

The serial data packets are identical to the GPIB data packets. The same SCPI command structure outlined in Section 9.1 is used. The end of packet character is an ascii return character ('/r'). After seeing the termination character, the unit assumes the whole data packet is received and processes the command immediately.

9.3.3 Serial Programming Features and Limitations

The PVX-4450 will accept remote commands in Local mode. Please note that if the remote host elects to operate in this mode using the RS-232 interface it becomes the remote host's responsibility to poll for any parameter status change. The PVX-4450 does not notify the remote host when parameters change over the RS-232 bus, only on the GPIB bus.

9.3 GPIB Operation

This remote control port allows a user to connect a personal computer as the remote host to the DEI PVX-4450. Since GPIB supports multiple targets the GPIB port is ideal for applications that require multiple instruments to be controlled by one remote host. This interface uses the SCPI command set covered in Section 9.1. It also supports asynchronous notification of fault events, removing the burden of status polling from the remote host. This is covered in Section 9.3.1. The GPIB bus loads the output buffer with a #0 when a command executes successfully and the error code when there is unsuccessful execution. Section 9.4 covers the error codes supported by the PVX-4450.

9.3.1 GPIB Service Requests and Serial Poll

To support asynchronous notification of faults, subassembly errors and major status changes the PVX-4450 supports the GPIB service request line SRQ. When this line is asserted by the PVX-4450 it signifies there is an asynchronous event that needs host interaction. Either an error, a fault, or a change to the unit's status has occurred. The serial poll byte is loaded with the SRQ code. The serial poll byte will have the codes between 0xF0h and 0xFFh for faults where the lower five bits are used to encode five active faults. Additionally the serial poll byte is loaded with the values, 0xE0, 0xE1, or 0xE2 to notify the remote host of major status changes. These type of changes require the remote hosts control program to interrogate the PVX-4450 status. This helps to guarantee that there are no discontinuities between the software configuration at the remote host and the actual hardware configuration. Otherwise it is the remote hosts responsibility to maintain an accurate record of hardware status.

SRQ Code	Description	Action
0xE0	PVX-4450 Power Up Notification	Alert the remote host that the unit is on the GPIB bus
0xE1	Local to Remote Mode Change	Alert the remote host that the unit is now in remote mode
0xE2	Load Configuration Notification	Alert the remote host that a new configuration is loaded
0xF0	No Fault	None
0xF1	Unused	None
0xF2	Interlock Violation	Verify rear panel interlock connection to external circuitry
0xF4	Over current Violation	Load drawing to much current, make sure load is not too large of a C or R
0xF6	Both Interlock and Over current	See Above
0xF8	Unused	None

9.3.2 GPIB Programming Features and Configuration

The PVX-4450 has a default GPIB primary address of 1. This is the address set at the factory and it can be changed in the field using the GPIB:ADDR command discussed in Section 9.1.1. The secondary address is not supported by the PVX-4450. Data transmissions are configured to support the EOI termination. This means that no new line or termination character is needed or allowed. The GPIB bus will assert the EOI signal on the last data byte in a write alerting the PVX-4450 the end of data The GPIB bus returns a #0 in the output buffer when a command executes successfully, when a command fails the output buffer is loaded with the error code

and the SRQ byte is loaded with the error code for applications that support asynchronous The GPIB bus timing should be set at 2us. The user's GPIB interface should be the system controller also called the controller in charge. The GPIB host should use the controller protocol, but the PVX-4450 cannot be configured as system controller.

9.4 Error Codes

Error Code	Description	Action
0x41	Parsing Error: Word Not Recognized	Check keywords in data packet
0x42	Parsing Error: Bad String Pattern	Check string format in data packet
0x43	Parsing Error: Bad Data Format	Check data format in data packet
0x44	Parsing Error: Unrecognized Symbol	Check data packet for invalid symbols
0x45	Parsing Error: Bad String Format	Check fro extra spaces, or keystrokes
0x61	Internal HW Error: Calibration Out of Range	Calibration constant out of range
0xC1	Pulse Generator Error: Frequency Out of Range	Check requested frequency data validity
0xC2	Pulse Generator Error: Frequency Limited by Pulse Width	Check requested frequency data validity
0xC3	Pulse Generator Error: Pulse Width out of Range	Check requested pulse width data validity
0xC4	Pulse Generator Error: Pulse Width Limited by Frequency	Check requested pulse width data validity
0xC5	Pulse Generator Error: Delay Out of Range	Check requested pulse delay data validity
0xC6	Pulse Generator Error: Delay Limited by Frequency or Pulse Width	Check requested pulse delay data validity
0xC7	Pulse Generator Error: Duty Cycle Out of Range	Check requested duty cycle data validity
0xC8	Pulse Generator Error: Positive HV Supply Out of Range	Check requested positive HV set point data validity
0xC9	Pulse Generator Error: Negative HV Supply Out of Range	Check requested negative HV set point data validity
0xCA	Pulse Generator Error: Invalid Configuration	Check requested load or save configuration data validity
0xCB	Pulse Generator Error: Invalid Trigger Source	Check requested trigger source data validity

10.0 FACTORY SERVICE AND SUPPORT

For more information regarding your PVX-4450 system or for information pertaining to an operational problem, please contact the factory for further assistance:

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

11.0 WARRANTY

Directed Energy, Inc. (DEI) warrants equipment it manufactures to be free from defects in materials and factory workmanship under conditions of normal use, and agrees to repair or replace any standard product that fails to perform as specified within one year after date of shipment to the original owner. OEM, modified and custom products are waranteed, as stated above, for ninety (90) days from date of shipment to the original owner. This Warranty shall not apply to any product that has been:

I.   Repaired, worked on, or altered by persons unauthorized by DEI in such a manner as to injure, in DEI's sole judgment, the performance, stability, or reliability of the product;

II. Subjected to misuse, negligence or accident; or

III. Connected, installed, adjusted, or used otherwise than in accordance with instructions furnished by DEI.

DEI reserves the right to make any changes in the design or construction of its products at any time, without incurring any obligation to make any change whatever in units previously delivered.

DEI's sole obligation, and buyer's sole remedies, under this agreement shall be limited to a refund of the purchase price, or at DEI's sole discretion, to the repair or replacement of products in kind that prove, to DEI's satisfaction, to be defective, when returned to the DEI factory, transportation prepaid by the buyer, within the warranty period. DEI shall in no way be liable for damages consequential or incidental to defects in its products, for failure of delivery in whole or in part, for injuries resulting from its use, or for any other cause.

Returns must be preauthorized and accompanied by a DEI return authorization number.

The foregoing states the entire warranty extended by DEI, and is given and accepted in lieu of 1) any and all other warranties, expressed or implied, including by not limited to the implied warranties of merchantability and fitness for any particular purpose and 2) any obligation, liability, right, claim or remedy in contract or tort.
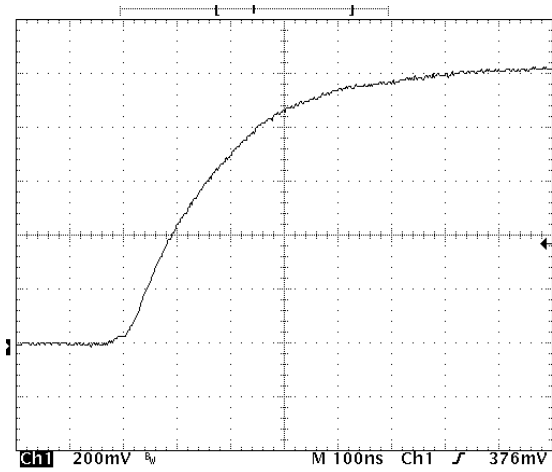
Appendix: Typical Output Waveforms

Unless otherwise noted, the output waveforms below were taken with the 1.5nF and 9nF test loads shown below. As can be seen in the photos, the rise and fall times can be varied by removing or changing the value of the series resistor:
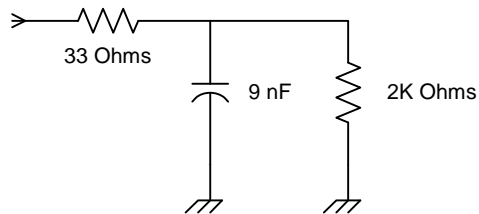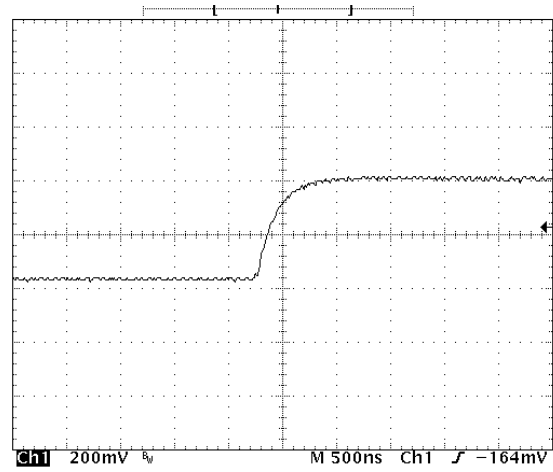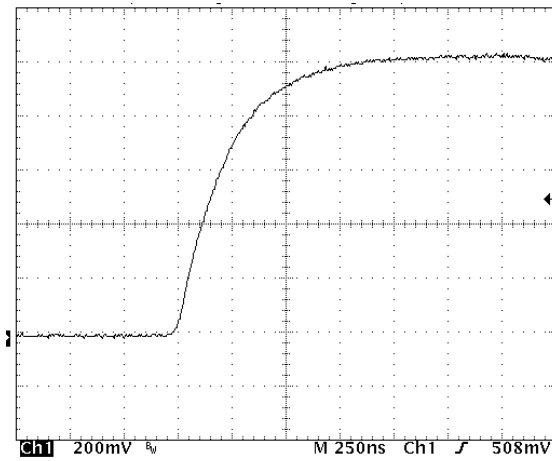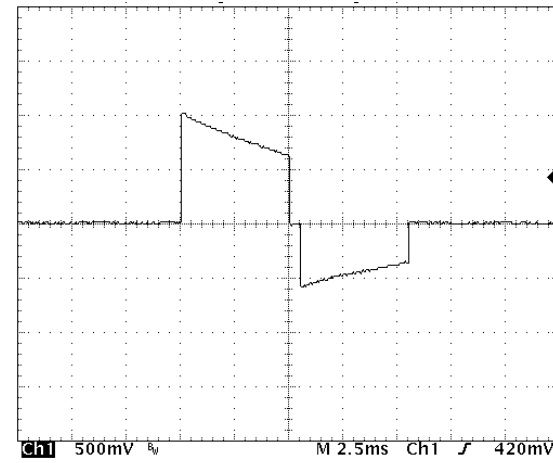

9nF Test Load
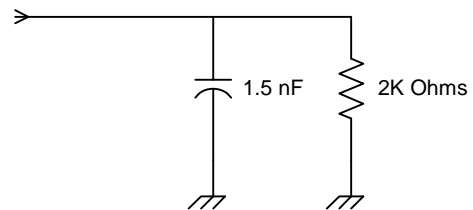
1.5nF Test Load

+1000V 348ns Positive Rise Time,
9nF Test Load With 33 Ohm Series
Resistor Removed

-600V 379ns Negative Fall Time, 9nF Test
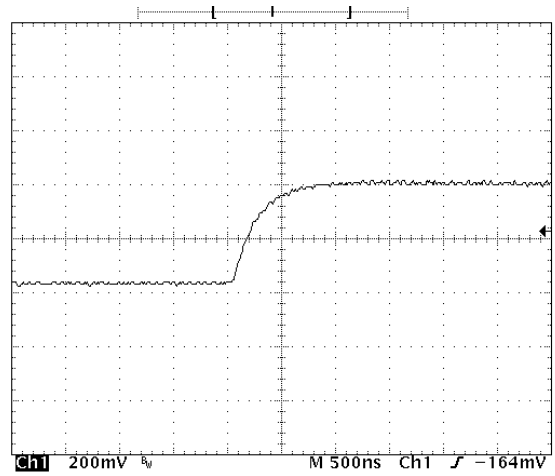Load With 33 Ohm Series Resistor
Removed

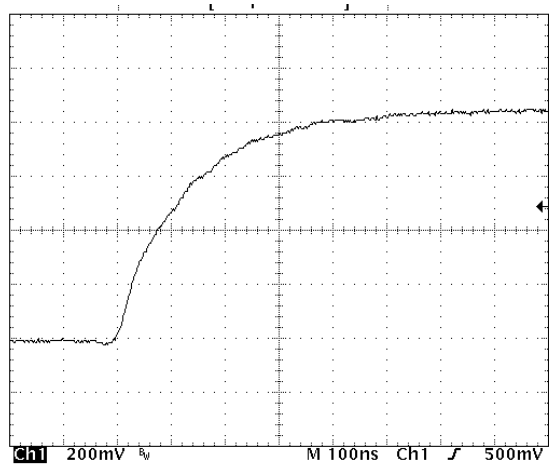+1000V 496ns Positive Rise Time
9nF Test Load

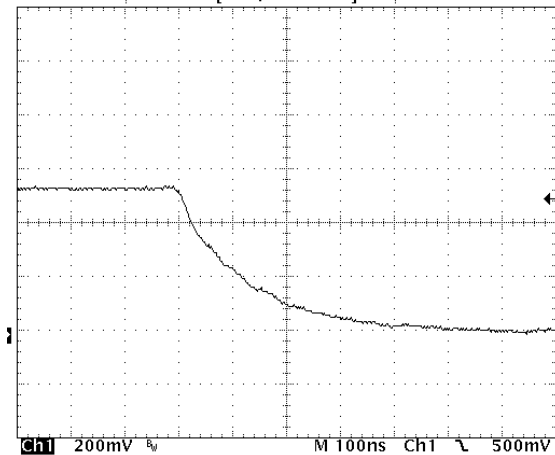+1000V Positive, -600V Negative
9nF Test Load
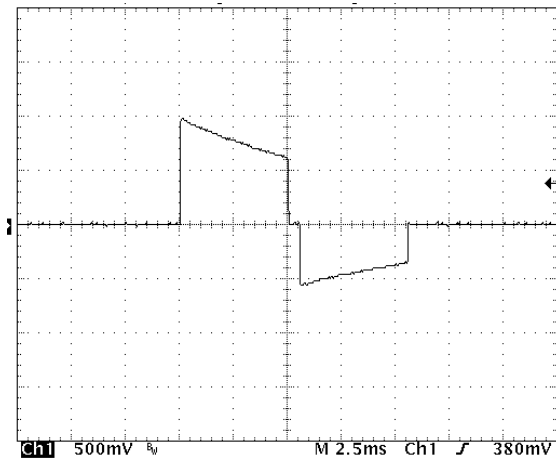
+1000V Positive, -600V Negative
1.5nF Test Load

-600V 451ns Negative Fall Time
9nF Test Load

+1000V 303ns Positive Rise Time
1.5nF Test Load

-600V 291ns Negative Fall Time
1.5nF Test Load