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SINCE 1975

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INSTRUCTIONS

MODEL AV-HVX-1000A PULSE GENERATOR

S.N.:

WARRANTY

Avtech Electrosystems Ltd. warrants products of its manufacture to be free from defects in material and workmanship under conditions of normal use. If, within one year after delivery to the original owner, and after prepaid return by the original owner, this Avtech product is found to be defective, Avtech shall at its option repair or replace said defective item. This warranty does not apply to units which have been dissembled, modified or subjected to conditions exceeding the applicable specifications or ratings. This warranty is the extent of the obligation or liability assumed by Avtech with respect to this product and no other warranty or guarantee is either expressed or implied. There is no 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 pulse generator. FAILURE TO DO SO VOIDS THE WARRANTY PERTAINING TO THE OUTPUT SWITCHING STAGE.

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

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

AVTECH 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 AV-HVX-1000A Pulser is a high voltage pulse generator designed to be operated into a load impedance of 50 Ohms. The AV-HVX-1000A is designed as an instrument for lab experiments, calibration, component testing, beam steering, gating PMTs and MCPs, and other applications that require very fast and clean high speed pulses, or incorporated into an OEM system.

The AV-HVX-1000A utilizes a patented state-of-the-art high-speed power MOSFET as the high voltage switch, incorporated into a low impedance configuration featuring a multi-layer stripline-style output bus.

The AV-HVX-1000A requires an external high voltage DC supply (950V maximum), and an input trigger. The unit is available in either positive or negative polarities.

2.0 SPECIFICATIONS

INPUT HIGH VOLTAGE

Maximum Value..................................950 volts DC
Minimum Value...................................0 volts DC
Input High Voltage Connector...................Type N, Side Panel

OUTPUT HIGH VOLTAGE

Maximum Value...................................900 volts DC
Minimum Value...................................0 volts DC
Maximum Current.................................18 amperes
Means of adjustment........Controlled by Input High Voltage
Output High Voltage Connector..................Type BNC,
Side Panel

TRIGGER

Trigger Source..................................External
Trigger Input...................................+5V +/-1V,
Into 50 ohms
Trigger Rise Time...............................<6ns
Minimum Trigger Pulse Width....................75ns
Maximum Trigger Pulse Width....................10 us
Input Trigger Connector.........................Type BNC,
Side Panel

OUTPUT PULSE ELECTRICAL CHARACTERISTICS

Pulse Rise Time.................................6ns 900V
(10%-90%)

Pulse Width.....................................75ns to 10us,
Controlled by Input Trigger
Pulse Recurrence Frequency.......Single Shot to 1MHz, 5MHz
burst, controlled by input
trigger
Over/undershoot...<5%
Jitter.................................<100ps shot-to-shot
Delay Between Trigger and Output Pulse.................<40ns
Thermal Drift....................Approx 500ps to 1ns over ambient
to 50°C

GENERAL

Input AC Power....................110/220 VAC, 50/60Hz, Cord
provided
Dimensions......................8.32" L x 4.22" W x 1.72" D
Weight................................. .Approx. 3.5 lbs.

2.1 Maximum Duty Cycles

All measurements into 50 ohms.

V_{IN}	I_{OUT}	P_{PEAK}	DUTY CYCLE (MAX)
950V	19.0A	18.00KW	1%
525V	10.5A	5.50KW	4%
105V	2.1A	0.23KW	90%

2.2 Pulse Droop

All measurements into 50 ohms.

V_{IN}	PULSE WIDTH	PERCENTAGE DROOP
950V	1.0us	3.0%
950V	10.0us	24.0%
525V	1.0us	1.5%
525V	10.0us	16.0%
105V	1.0us	<0.5%
105V	10.0us	7.0%

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 AV-HVX-1000A Pulser.

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 AV-HVX-1000A 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 AV-HVX-1000A is grounded through the grounding conductor of the AC power cord. To avoid electrical shock, plug the AV-HVX-1000A 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 cover. Do not operate the AV-HVX-1000A while the cover is removed. The cover does 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 high voltage output of the pulse generator. 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 pulse generator 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 pulse generator 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 AV-HVX-1000A contains dangerous voltages and stored energy. AVTECH strongly recommends that all repairs and adjustments be performed by factory qualified personnel. AVTECH will not be responsible for personal injury or damage to the pulser 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 AV-HVX-1000A contains capacitors that are used as energy storage elements. When charged, these capacitors contain in excess of 1.5 joules of stored energy. This is sufficient energy to cause serious injury. Assure that the AC power cord is disconnected from the pulser, 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 AV-HVX-1000A Touching connections and/or components could result in serious injury.

4.0 OPERATING CONSIDERATIONS

4.1 Output

The AV-HVX-1000A is designed to operate into a load whose characteristic impedance is 50 ohms. An unterminated or improperly terminated output will cause excessive aberrations on the output waveform and could possibly damage the pulser. To ensure this does not occur, observe the following precautions:

- Use good quality 50 ohm coaxial cable and connectors;
- Make all external connections tight and as short as possible;
- Use good quality attenuators and/or loads. If using an attenuator, AVTECH recommends the Weinschel Engineering model 45-40-33. Small attenuators will not work correctly and can be harmed by the AV-HVX-1000A;
- Use terminators or impedance-matching devices to avoid reflections;
- Ensure that all external cables and hardware have adequate voltage and power ratings;
- Be extremely careful not to short the output of the pulser to ground, as this can cause damage to the pulser.

The AV-HVX-1000A can be used to drive capacitive, inductive and resistive loads other than 50 ohms. Please consult the factory for further applications information.

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 information in a pulse with a fast rise time. It is therefore important to keep these cables as short as is practical. For optimum performance, AVTECH recommends interconnecting cable lengths of 8" or less. When signal comparison measurements or time difference determinations are made, the two signals from the test device should travel through coaxial cables with identical loss and time delay characteristics.

4.3 Impedance Matching

If a pulse travels down a transmission line and encounters a mismatch, a reflection is generated and sent back along the line to the source. The amplitude and polarity of the reflection are determined by the impedance mismatch. If the reflected signal returns before the output pulse ends, it adds or subtracts from the amplitude of the pulse. This will distort the pulse shape and amplitude.

4.4 Trigger Input

An input trigger of +5V +/-1V into 50 ohms with a risetime of <6ns is required to gate on the AV-HVX-1000A. Departure from trigger requirements are met by any high quality low voltage pulse generator. The trigger should be set to +5V +/-1V into 50 ohms before the trigger cable is attached to the AV-HVX-1000A trigger input. The input trigger is transformer-coupled into a DS0026 CMOS Clock Driver which does not appear resistive to the input pulse generator. For this reason, the input trigger amplitude should be set using a 50 ohm load (e.g. a 50 ohm scope input) before connecting it to the AV-HVX-1000A. If the trigger input is greater than +5V into 50 ohms, pulse stretching can occur.

4.5 High Voltage Input

The AV-HVX-1000A is rated at a maximum input voltage of 950VDC. Proper precautions should be taken by the user to ensure that the maximum voltage is not exceeded.

4.6 Maximum Duty Cycle

The case of the AV-HVX-1000A (specifically the bottom panel) is used as the heat sink for the power circuitry. Therefore the case can get hot! Use caution when handling the AV-HVX-1000A after operation. The duty cycle percentages shown in TABLE 2.1 are limited by the cooling capabilities of the AV-HVX-1000A. Higher duty cycles can be obtained by forced air cooling of the enclosure, or for very high power applications (>1Kw), bolting the AV-HVX-1000A to a water or air cooled heat sink.

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, AVTECH.

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.
3. Remove top cover retaining screws. Inspect components and printed circuit board for 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 from 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 Mechanical Installation

As received, the unit is ready for bench use. If necessary, the unit can be bolted to an external heat sink for additional cooling (see Section 4.6 above) using the mounting flanges.

The AV-HVX-1000A is extremely rugged, and can be mounted to other equipment, hardware or benches using the mounting flanges. Physical orientation is not critical.

5.5 Electrical Check

Before proceeding, please review the precautions in Section 3.

5.5.1 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 AV-HVX-1000A set up the pulse generator output to deliver a 5V pulse (+/-1V) into 50 ohms, with a rep rate of approximately 5KHz, and a pulse width of 200-500ns.
3. Plug the power cord into the AC power input. The red indicator light should turn on, indicating that the AV-HVX-1000A 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 N connector of the AV-HVX-1000A labeled "HV IN, 950V MAX".
5. Connect the pulse generator to the BNC connector of the AV-HVX-1000A labeled "TRIGGER INPUT".
6. Connect an appropriate load to the BNC connector of the AV-HVX-1000A labeled "OUTPUT".
7. Monitor the voltage across the load, utilizing an appropriate attenuator.
8. Turn ON the high voltage power supply. Slowly increase the power supply to 100VDC. The AV-HVX-1000A should produce an output pulse of approximately 95V, with a pulse width and pulse recurrence frequency following that of the incoming trigger.
9. If there is no output from the AV-HVX-1000A, 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 AV-HVX-1000A connected to the AC input without high voltage and with all connectors in place for approximately one minute 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 AV-HVX-1000A Additional application information may be found in Section 7.0.

WARNING

1. To avoid personal injury, do not remove the cover. Do not operate the AV-HVX-1000A while the cover is removed. The cover does not contain a safety interlock!

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

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

4. Pulsed power systems are capable of random triggering via transients and therefore when the pulse generator 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 5.5.1. When this is accomplished, the pulser can be adjusted for the particular application through the following procedure:

1. Monitoring the output of the AV-HVX-1000A on an oscilloscope utilizing an appropriate attenuator, set the output amplitude of the AV-HVX-1000A 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 AV-HVX-1000A. 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.

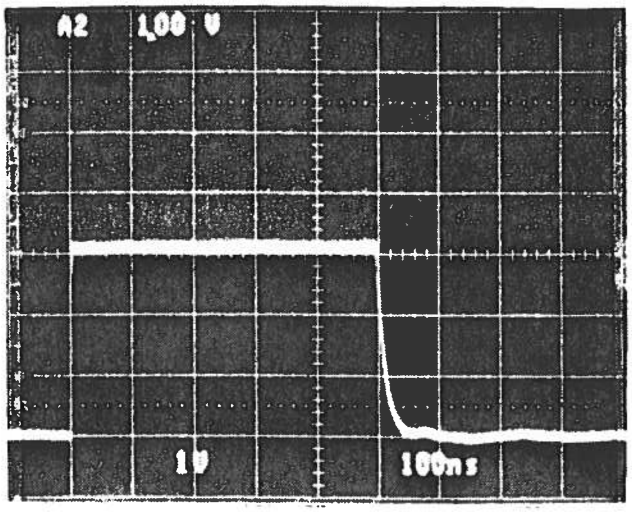
6.2 Power-Down Procedures

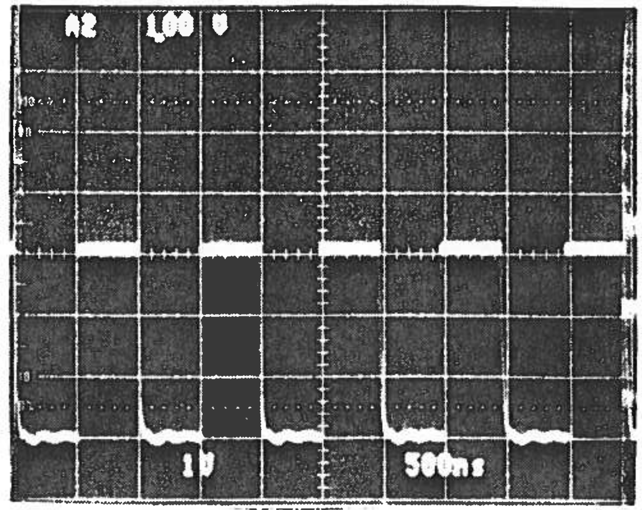
1. Set the output voltage of the high voltage power supply to zero and turn off the high voltage power supply.
2. Leave the AV-HVX-1000A connected to the AC input without high voltage and with all connectors in place for approximately one minute to bleed off the stored energy.
3. Disconnect the AC power to the unit.

7.0 EXAMPLE WAVEFORMS

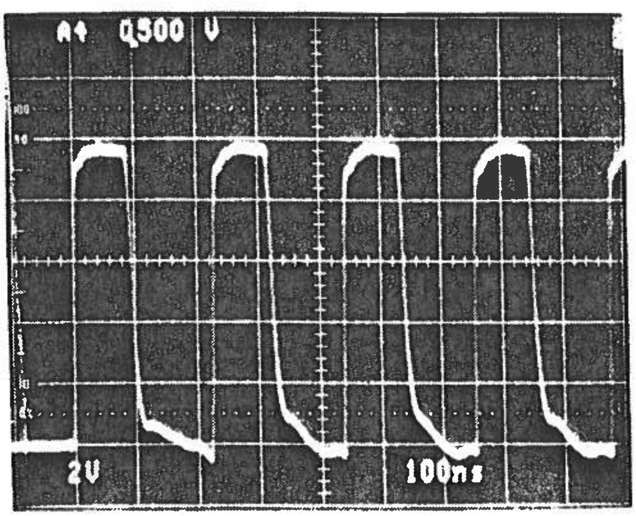
7.1 50 Ohm Resistive Load

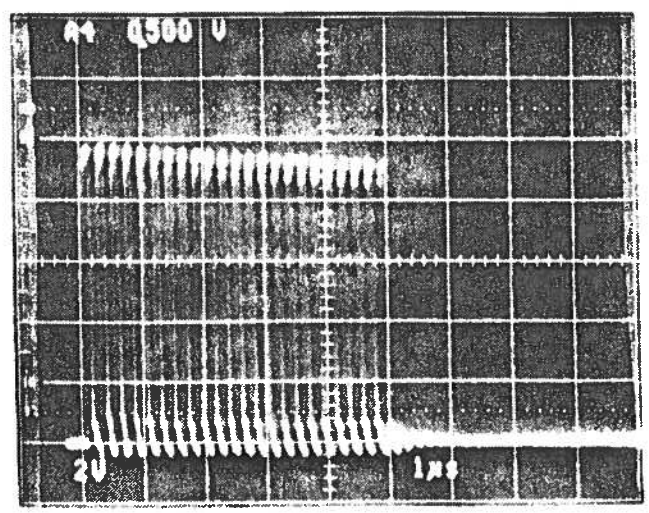
Input Voltage=105V, Pulse Width=500ns, Pulse Recurrence Frequency=1MHz, Load=50 ohms:





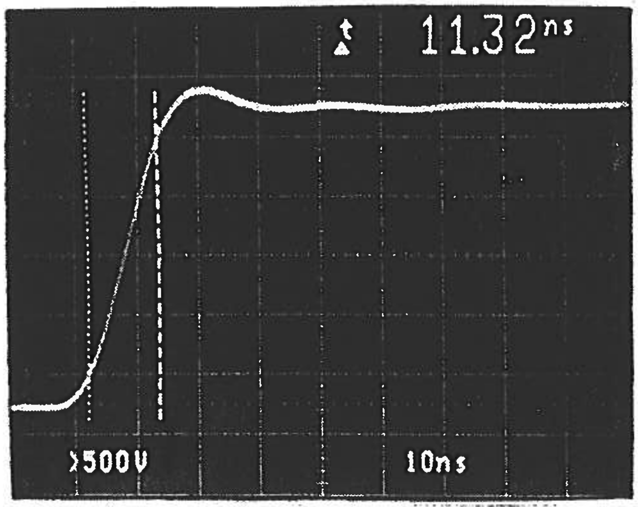
Input Voltage=950V, Pulse Width=100ns, Pulse Recurrence Frequency=4.5MHz (Burst Mode), Load=50 ohms:

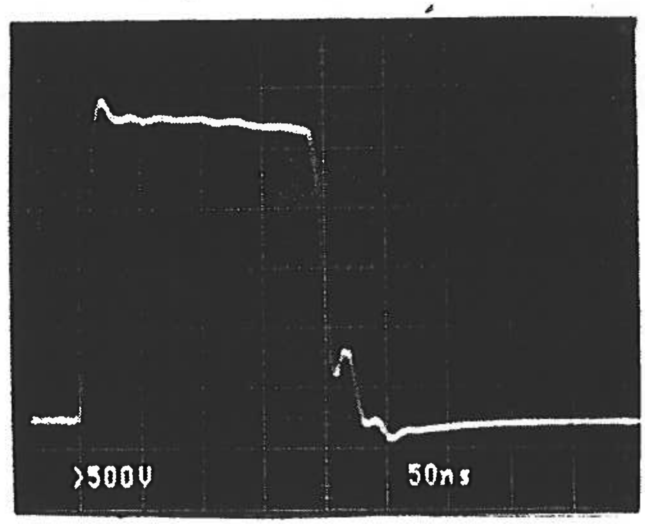




7.2 Inductive Load (Step-Up Transformer)

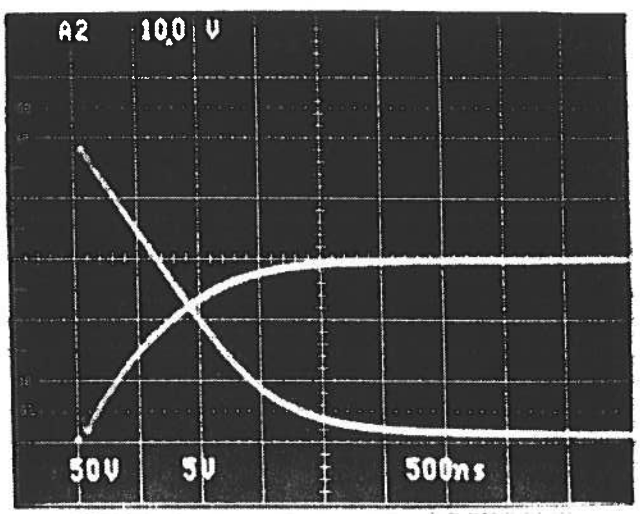
Input Voltage=950V, Pulse Width=200ns, Pulse Recurrence Frequency=500Hz, Oscilloscope Scale=1000V/DIV, Load=1000 ohm in secondary:

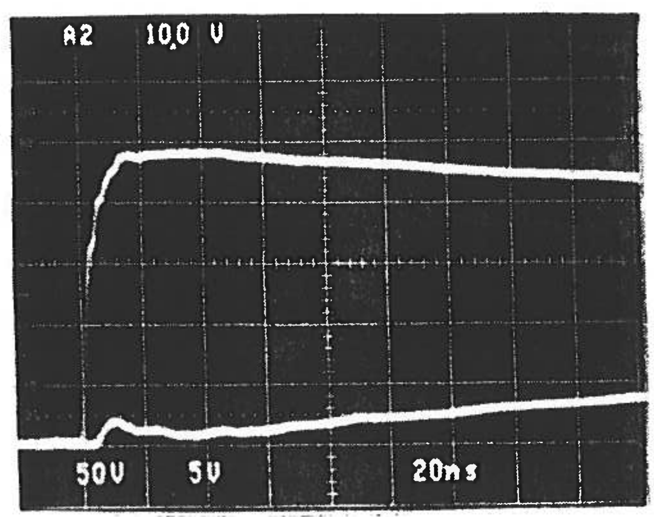




7.3 Capacitive Load

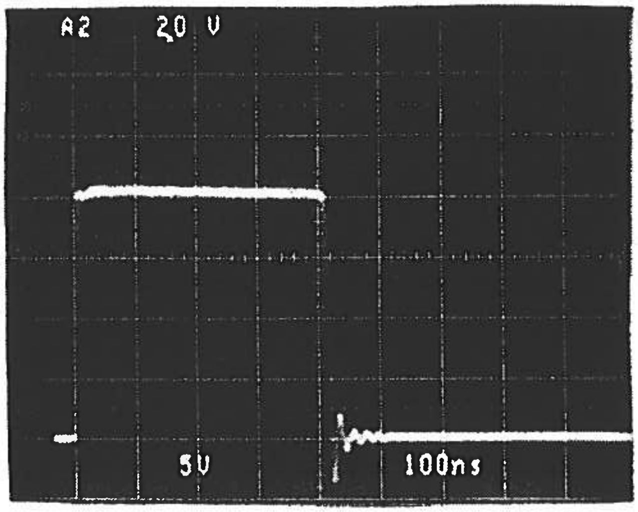
Input Voltage=150V, Oscilloscope Scale=5A/DIV, Load=0.1mF, 1KV Ceramic Capacitor, Traces show Voltage and Current:





7.4 <u>Current Source</u>

Input Voltage=575V, Pulse Width=400ns, Oscilloscope Scale=10A/DIV, Load=5 ohms:



8.0 TROUBLESHOOTINGR

WARNING

The AV-HVX-1000A contains capacitors that are used as energy storage elements. When charged, these capacitors contain in excess of 1.5 joules of stored energy. This is sufficient energy to cause serious injury. Assure that the AC power cord is disconnected from the pulser, 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 AV-HVX-1000A Touching connections or components could result in serious injury.

8.1 Troubleshooting Procedures

Before attempting to service or troubleshoot the AV-HVX-1000A, review the servicing safety summary in Section 3.0.

The power MOSFET utilized in the AV-HVX-1000A is mounted underneath the printed circuit board, and utilizes the case as a heat sink. In the unlikely event that the MOSFET 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, AVTECH customer service can be contacted for further assistance.

SYMPTOM	SOLUTIONS
1. Red LED does not illuminate	-AC power not plugged in. -Fuse(s) are blown. See fuse replacement instructions in Section 8.1.1.
2. 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. -Pulser is damaged. Contact AVTECH customer service.

8.1.1 Fuses

To avoid fire hazard or damage to the pulser, use only 3A fast blow fuses (Littlefuse #312003 or equivalent). Fuse replacement should be performed by qualified personnel only. Assure that the AC power cord is disconnected from the pulser, 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.

8.2 Factory Service

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

AVTECH ELECTROSYSTEMS LTD.

TEL: (613) 226-5772

FAX: (613) 226-2802

9.0 SYSTEM FAILURE MODES

The AV-HVX-1000A pulse generator is capable of generating large amplitude current pulses with very fast rise and fall times. There is no 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 pulse generator. FAILURE TO DO SO VOIDS THE WARRANTY.

9.1 Over-Current Failure

When the output is shorted, the AV-HVX-1000A can deliver up to 200A of current (depending on cabling, HV power supply setting, etc.). A current pulse of this magnitude is far in excess of the generator's maximum specification, and may cause damage to the pulse generator, load and/or associated cabling.

The output can be shorted by allowing the two output leads to touch each other, the "hot" lead to contact ground, load arcing, or a shorted load.

9.2 Over-Voltage Failure

One may incorrectly assume that the voltage across the MOSFET switching device could never exceed the 950V maximum input high voltage. It is possible to create voltages in excess of 950V by driving an open cable or by generating L di/dt spikes.

From transmission line theory it is known that a voltage pulse launched onto an open cable will cause the voltage to reflect back down the cable and double in amplitude. This voltage doubling will over-voltage the MOSFET and lead to pulse generator failure. Turning on the pulse generator with the load disconnected or opening the load while the pulse generator is operating may cause it to fail due to this voltage doubling effect.

L di/dt spikes are created when current flowing through an inductor is interrupted (i.e. current is turned off). The amplitude of the resultant voltage spike is defined by the formula:

$$V = L\ di/dt,$$

where L is the circuit inductance, di is the current value at turn off and dt is the time it takes for the current to get to zero (i.e. fall time). By monitoring the voltage output of the pulse generator, the user can measure L di/dt voltage spikes. With this measurement, the user can determine the actual voltage across the MOSFET switching device, with the formula:

$$V_{max} = [L\ di/dt] + V_{supply}$$

Where

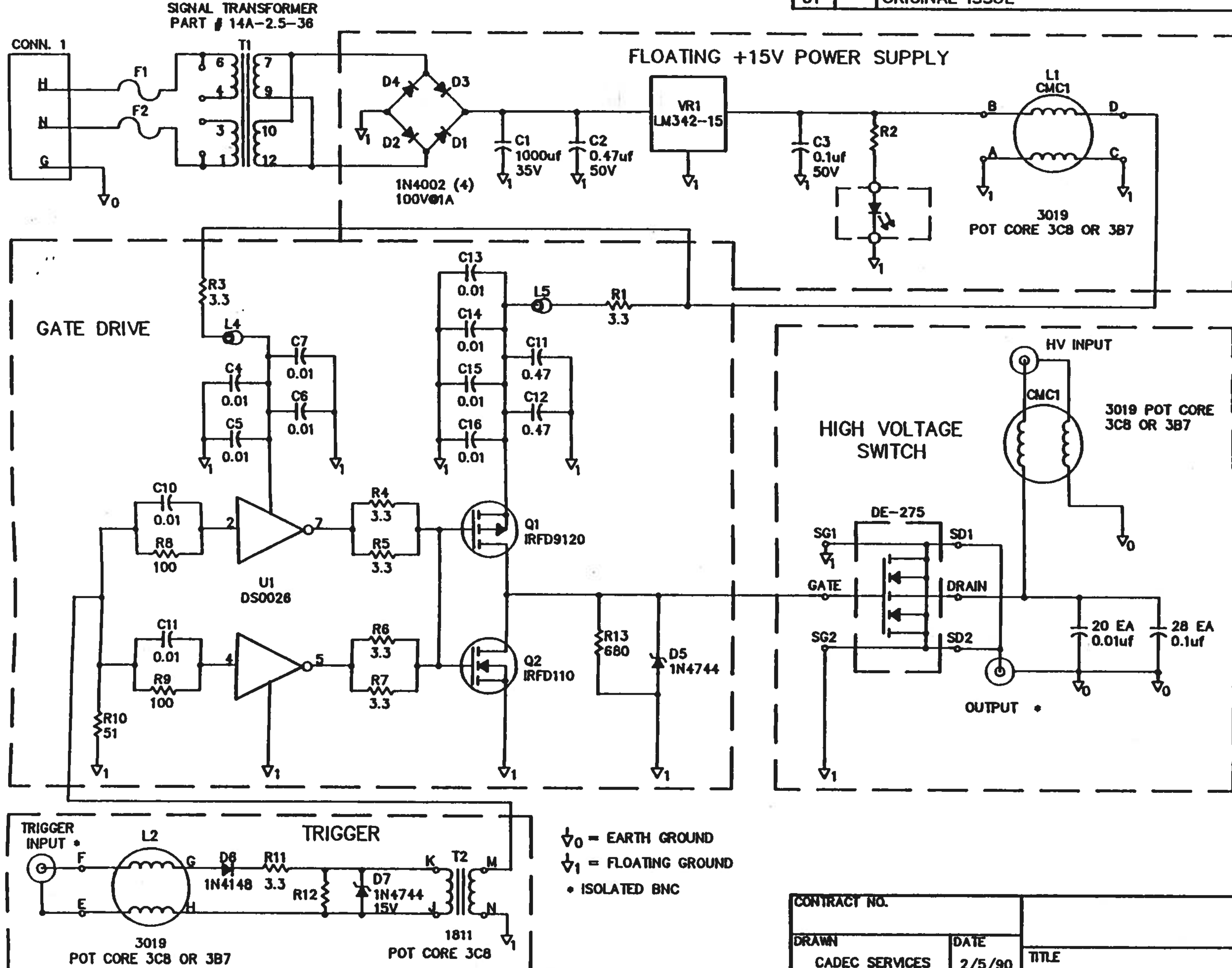
$L\ di/dt$ = peak of the negative-going spike;
V_{supply} = panel meter voltage;
V_{max} = 950 volts.

Any time the test setup (e.g. interconnect cables and/or load resistance) is changed, it will be necessary to again verify that Vmax is no greater than 950 volts.

APPENDIX A

SCHEMATICS

REV	EC	DESCRIPTION	DA	BY	CHKD	ENG
01	–	ORIGINAL ISSUE				



▽0 = EARTH GROUND

▽1 = FLOATING GROUND

• ISOLATED BNC

NOTICE

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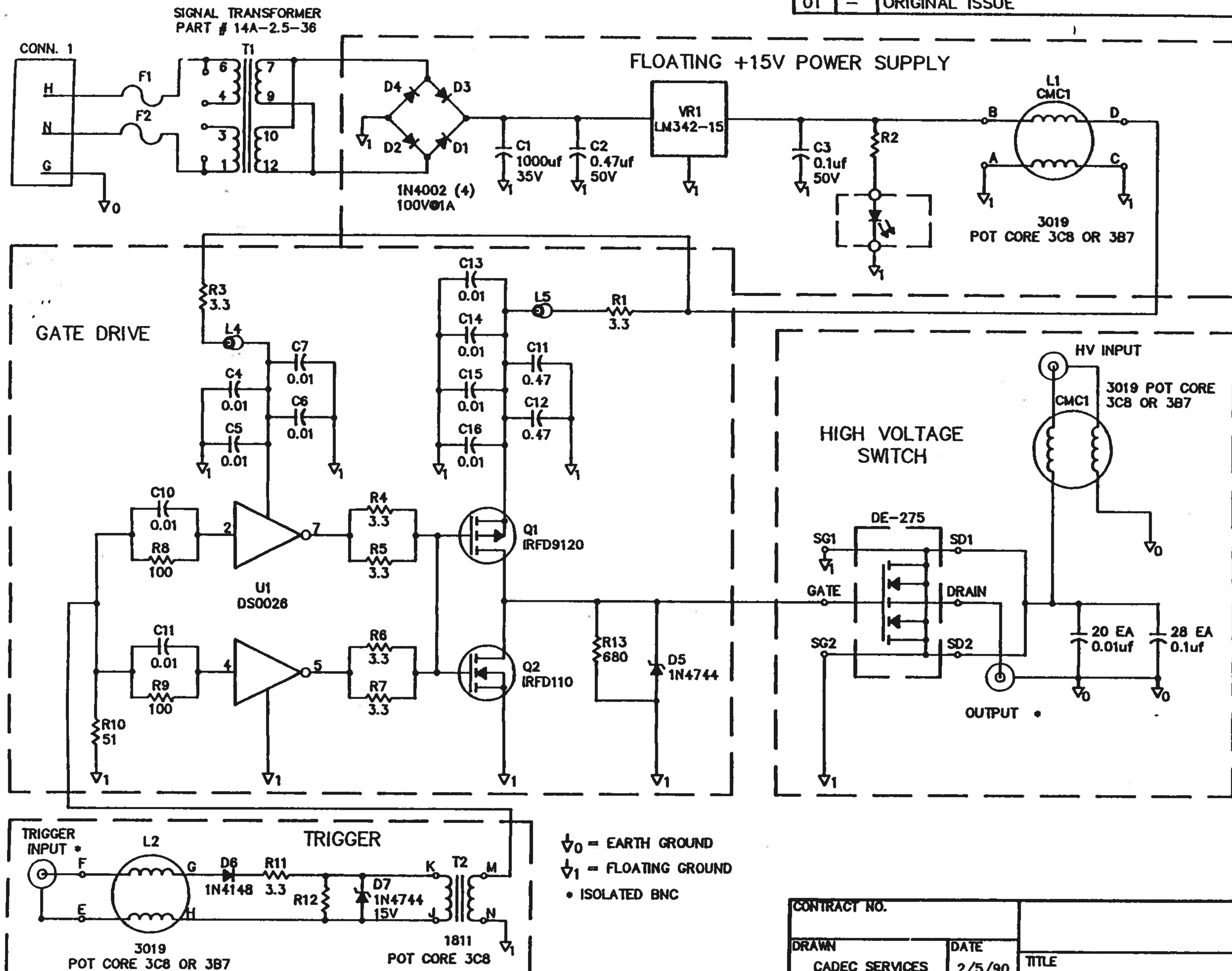
CONTRACT NO.		TITLE
DRAWN: CADEC SERVICES	DATE: 2/5/90	P PULSER SCHEMATIC
CHECK: [signature]	2/12/90	
DESIGN		
DESIGN ACTIVITY		SIZE: A — FCSM NO. — DWG NO. 5040-0001 — REV 01
CUSTOMER		SCALE — RELEASE DATE — SHEET 1 OF 1

REV	EC	DESCRIPTION	DATE	BY	CHKD	ENG
01	–	ORIGINAL ISSUE				



CONTRACT NO.		
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CHECK		2/5/90
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N PULSER
SCHEMATIC

SIZE	FCSM NO.	DWG NO.	REV
A		5040-00^^	01
SCALE	RELEASE DATE	SHEET 1 OF 1	

HV1000 PULSER

Directed Energy, Inc.
2301 Research Blvd., Ste. 101
Fort Collins, Colorado 80526
303/493-1901 FAX 303/493-1903

- ***INTRODUCTION TO THE HV1000 PULSER***
- ***USING THE HV1000 AS A CURRENT SOURCE***
- ***DRIVING TRANSFORMERS AND OTHER INDUCTIVE LOADS***
- ***PULSE STACKING (TO HIGHER VOLTAGES)***
- ***HOW TO MONITOR Ldi/dt***

05901M

■ INTRODUCTION TO THE HV1000 PULSER

The HV1000 Pulser is a state-of-the-art high frequency, high power module. Featuring DEI's patent pending FAST POWER™ MOSFET as the high voltage switch, the HV1000 enhances the precision and accuracy of many test and measurement laboratory applications. One advantage of the HV1000 Pulser is the ability to generate a fast high voltage or current pulse that has virtually no ringing or jitter. Another advantage is the wide range of applications that can be addressed because of the pulse width and frequency agility. Typical applications include instrument calibration, component testing, beam steering, spectrometry, and gating PMTs and MCPs.

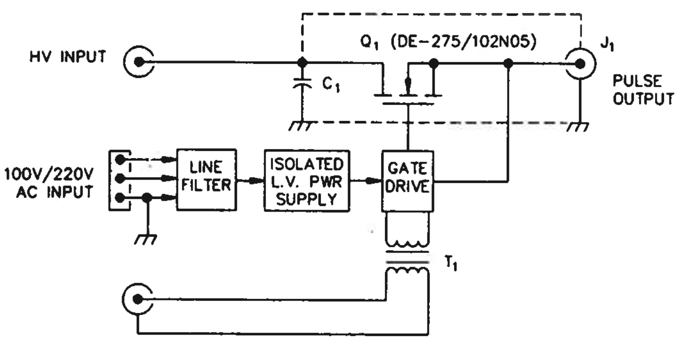


FIGURE 1.

Figure 1 is a block diagram of the HV1000 positive output version. The DE-Series FAST POWER™ MOSFET is driven by a floating gate drive circuit which is powered by a +15V isolated power supply and controlled through the isolation pulse transformer T_1. Q_1, C_1 and their internal connection to J_1 is a multi-layer stripline topology in order to provide extremely low reactive terms at the output port J_1. The HV is designed to approximate a voltage source. The internal source impedance of the HV1000 is near 2.5 ohms.

When the pulse is launched into 50 ohm cables, the mismatch is <4% with approximately a 95% conversion efficiency. This is shown in the clean output pulse in **Figure 2.** The HV1000 is operating at an output slew rate of approximately 150kV/μs (ΔV = 810V, Δt = 5.5ns - Waveform C voltage).

The current to sustain this voltage pulse is supplied by C_1 of **Figure 1.** C_1 is approximately 3μF, which will store approximately 1.5 joules of energy. This implies the droop characteristics as shown in **Figure 3.** Increasing the size of C_1 will yield a commensurate reduction in droop as given by

$$C_1 = I_O t/\Delta V_D$$

Where $\Delta V_D = (V_O)\ D\%$, $I_O = V_O/R_L$, t = PW max.

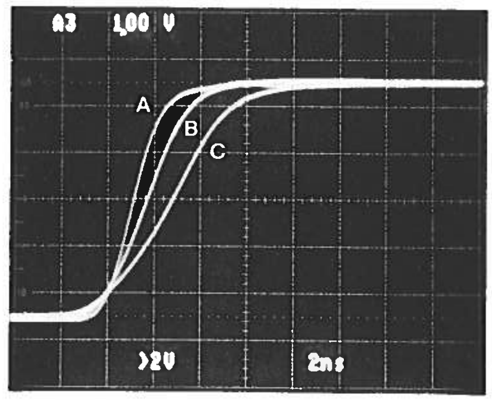


FIGURE 2. HV1000 voltage ranges from 0 to 950 volts

SPEED, POWER, FREQUENCY
(All measurements into 50Ω)

WAVE LINE	V_{IN}	V_{OUT}	t_r	I_{OUT}	P_{PEAK}	DUTY CYCLE (MAX.)*
A	105V	100V	3ns	2.1A	0.23KW	90%
B	525V	500V	4ns	10.5A	5.50KW	4%
C	950V	900V	6ns	19.0A	18.00KW	1%

*Maximum duty cycle can be increased by bolting the HV1000 to water or air cooled heat sink.

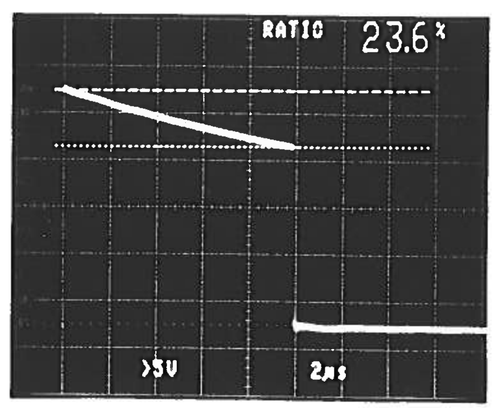


FIGURE 3. 900V into 50Ω

PULSE DROOP
(All measurements into 50Ω)

V_{IN}	PULSE WIDTH	PERCENTAGE DROOP
950V	1.0μs	3.0%
950V	10.0μs	24.0%
525V	1.0μs	1.5%
525V	10.0μs	16.0%
105V	1.0μs	<0.5%
105V	10.0μs	7.0%

The HV1000 is a non-avalanche technology, which presents several advantages to the user.

First, as shown in **Figure 4a,** it means very low jitter. This scope photo shows the HV1000's jitter to be <50ps. Second, it implies a high power handling capability, as shown by the ability of the HV1000 to deliver a kilowatt to the load with proper cooling. Third, non-avalanche technology also means pulse width and frequency agility, as shown in **Figures 4b, 4c** and **4d.**

Although the HV1000 is designed to operate into load impedances of 50 ohms, it can tolerate loads from approximately 5 ohms to in excess of 1000 ohms with a commensurate degradation in wave form fidelity and power.

With its low jitter and drift, pulse width and frequency agility, high voltage and high power output, as well as fast rise times and small size, the HV1000 offers a versatile and economical pulse source for a wide range of applications in science and industry.

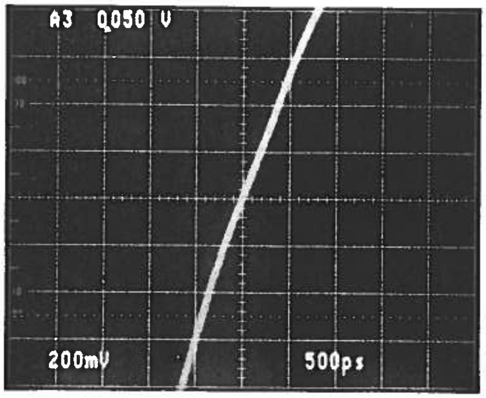


FIGURE 4a.

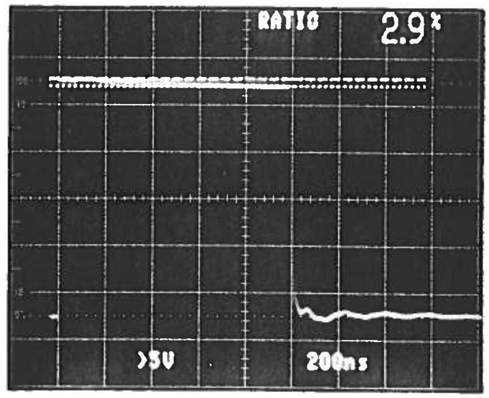


FIGURE 4c.
V_{DS} = 950V.
PW = 1μs.

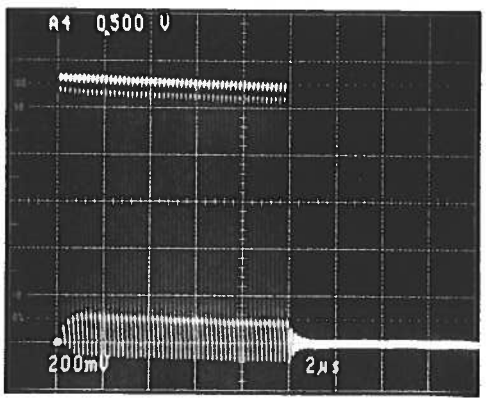


FIGURE 4b.
4.5 MHz Burst;
900V into
50 ohms

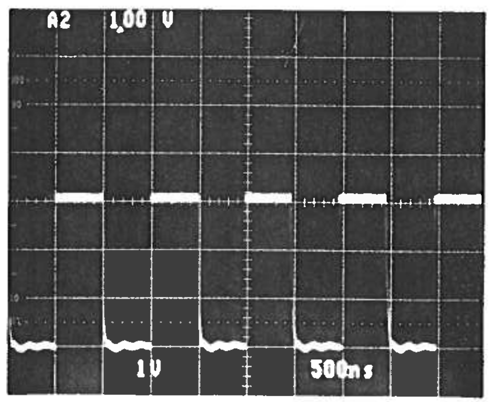


FIGURE 4d.
V_{DS} = 105V.
$V_O \sim$ 100V.
PRF = 1MHz.
PW = 500ns.

■ USING THE HV1000 AS A CURRENT SOURCE

Figure 5 shows the HV1000 configured as a high current source.

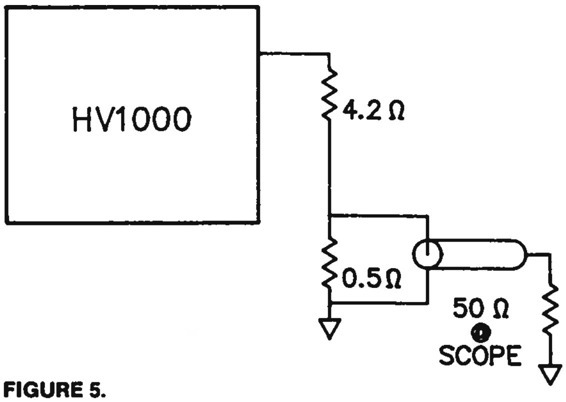


FIGURE 5.

The circuit uses a 4.2 ohm carbon composition resistor and a 0.5 ohm current viewing resistor (CVR). The output of the HV1000 is launched on a BNC to PCB connector on a transmission line structure. The load can be placed between the 0.5 ohm CVR and the 4.2 ohm resistor, or in lieu of the 4.2 ohm resistor.

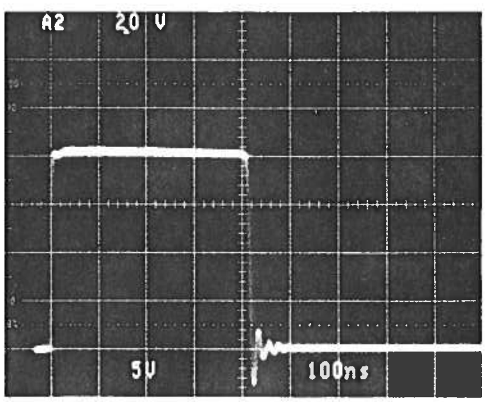


FIGURE 6.
10A/DIV
V_{DS} = 575V

Figure 6 is a current waveform measured at the CVR. With a drain voltage of 575V, a 40A pulse was produced. The rise and fall time of the current to the 40A level is of the order of the HV1000 specification. The HV1000 is rated for a peak current of 18A into 50 ohms, however, very narrow pulses are achievable and within the safe operating limits of the unit.

Because of the high current and the non-uniform impedance on the output of the pulser, an inductive term can appear in the circuit. For example, if we have a series inductive term of only 50nH, a current pulse of 40A, and a Δt of 6ns, we find that

Given $V_{DS} = L_S\, di/dt + V_{DR} = L_S\, \Delta I / \Delta t + V_{DR}$

Where $\Delta t = 6E^{-9}$
$\Delta I = 40A$
$L_S = 50E^{-9}$
V_{DR} = Applied Voltage HV Supply

Then $V_{DS} = 50E^{-9} \times 40/6E^{-9} + V_{DR}$
$V_{DS} = 333V + V_{DR}$

as illustrated in **Figure 7**.

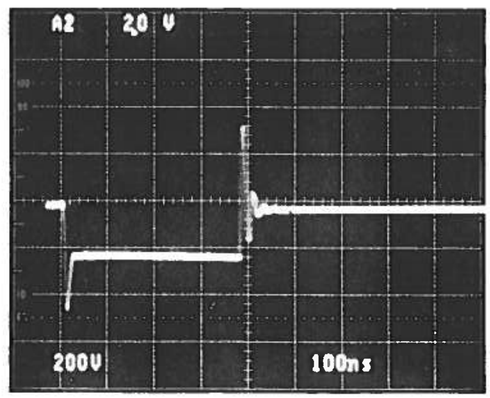


FIGURE 7.
HV1000 V_{DS}

Though the supply voltage is only 575V, the L di/dt term peaks at just over 900V. It is important to note that the absolute maximum voltage rating of the DE-Series FAST POWER™ MOSFET in the HV1000 is 1000V, therefore, when configuring the pulser as a current source, one must take care not to exceed this rating. V_{DS} should be measured as shown in **Figure 23.**

■ DRIVING TRANSFORMERS AND OTHER INDUCTIVE LOADS

The HV1000 Pulser features a DEI Series high voltage MOSFET. Because the DEI Series MOSFET is capable of considerably faster turn on and turn off times than a conventional MOSFET, it is necessary to protect the circuit against transient feedback spikes which are common when driving inductive loads, i.e., step-up transformers.

Figure 8 shows a 5-to-1 step up transformer through a 6 ohm resistor. It is terminated in 1000 ohms and a clamp diode.

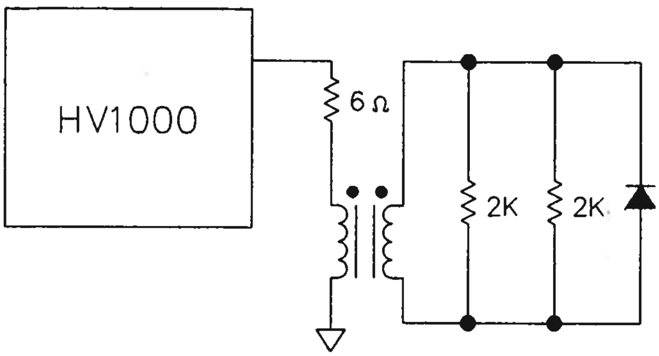


FIGURE 8.

Transformers represent a load of a highly inductive nature because of the inherent leakage inductance term. When driving all inductive loads, two precautions must be taken to protect against damage to the power MOSFET: 1) limit current to the maximum peak current capability of the MOSFET and 2) monitor the amplitude of the voltage spike caused by L di/dt as shown in **Figure 23.**

To limit the maximum peak current to 40 amps, the user should install a series resistor between the output of the HV1000 and the inductive load. The value of this resistor will be determined by the operating voltage. At 40 amps, the user is limited to a maximum pulse width of 3 micoseconds.

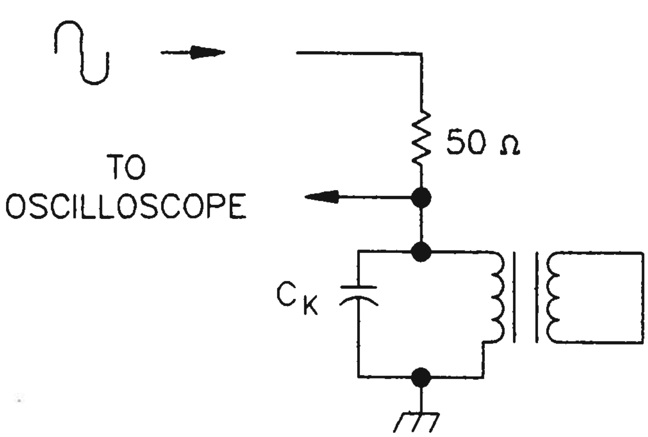


FIGURE 9.

Figure 9 shows a test set-up that will allow the user to measure leakage inductance of a transformer. To determine the leakage inductance, first short the secondary and then connect a capacitor of known value across the primary of the transformer. An oscilloscope probe is then connected across the primary. Drive the primary of the transformer with a sine wave through the 50 ohm series resistance. By tuning the frequency to maximum voltage on the oscilloscope, the resonance frequency can be found. Then

Given: $f_r = \frac{1}{2\pi\sqrt{LC}} \Rightarrow L = \left(\frac{1}{f_r\, 2\pi \sqrt{C}}\right)^2$

Where: L = leakage inductance
C_2 = known capacitance

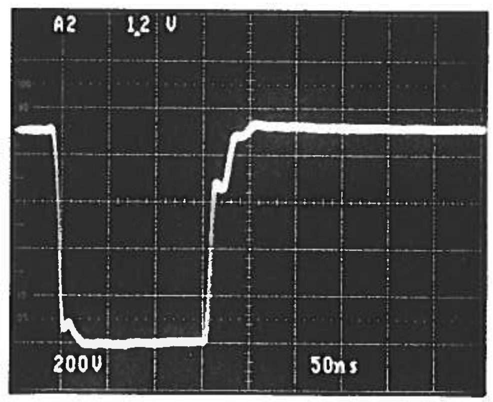


FIGURE 10a.

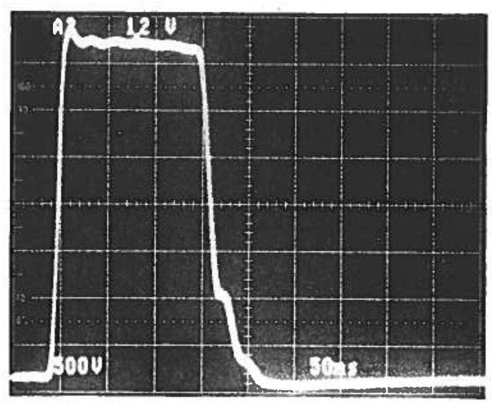


FIGURE 10b.

The waveforms in **Figures 10a** and **10b** show the drain voltage fall, which is 900V to ground, and the output is a 4kV pulse with a FWHM of 160ns and a 10-90% rise time of 10ns. This is due to the leakage inductance and the stray capacitance of the transformer.

Figure 11 shows the same transformer, but now the device is heavily terminated in the secondary.

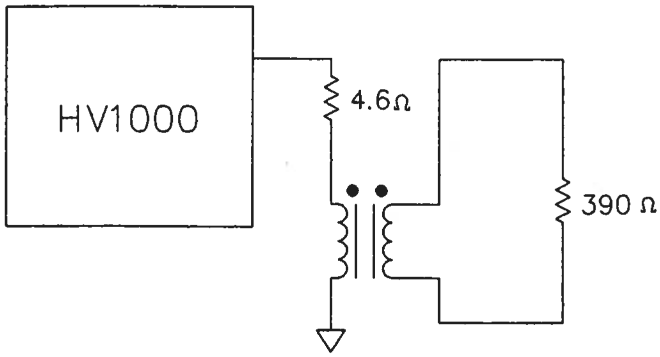


FIGURE 11.

Figure 12a shows drain voltage fall with 800V DC potential. Note that the L di/dt term has appeared and is now at 900V. The output, shown in **Figure 12b,** is approximately 2kV and looks much crisper and flatter. Rise time is of the order of 10ns to 2kV.

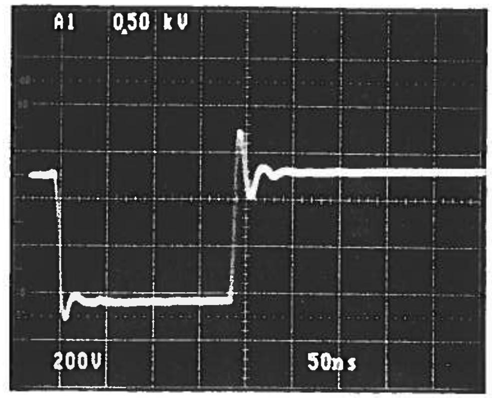


FIGURE 12a.

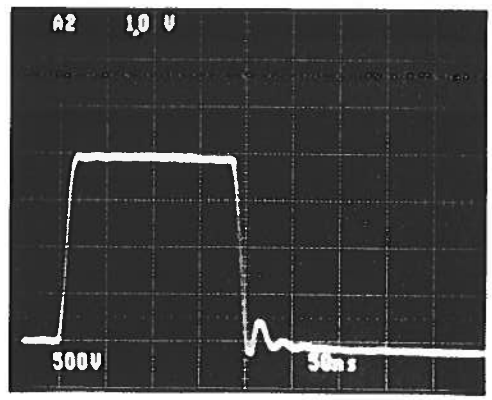


FIGURE 12b.

■ PULSE STACKING

Pulse stacking by superposition can be accomplished by a travelling wave structure, differentially driven deflection plates, and RF combining.

A travelling wave structure is illustrated in **Figure 13.**

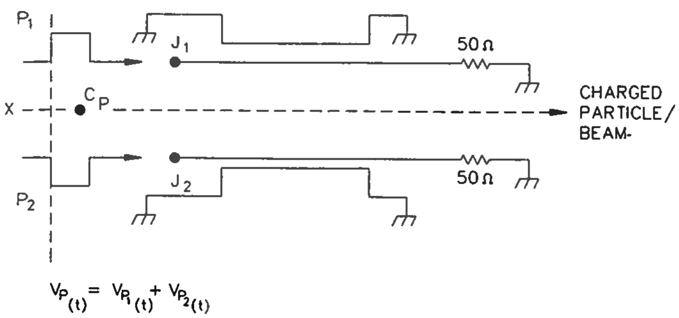


FIGURE 13.

The two pulses P_1 and P_2 are launched such that they are not only in time but also in position synchronization as well, as shown by

(A) $V_{P(t)} = V_{P1(t)} + V_{P2(t)}$

The pulses P_1 and P_2 form a travelling wave which moves with the charged particle beam C_P along the X axis. The HV1000 is an excellent choice for this type of application, with a positive HV1000 to launch P_1 at J_1 and a negative HV1000 to launch P_2 at J_2. The pulse stability in the form of low jitter and low thermal drift of the HV1000, along with its pulse width, frequency agility, and its voltage capability, allows the user to design and implement travelling wave structures with expanded capability.

Differential electro-static deflection is shown in **Figure 14.** In this configuration, the pulses P_1 and P_2 from two HV1000s are present in time synchronization as the charged particle or beam passes between the deflection plates.

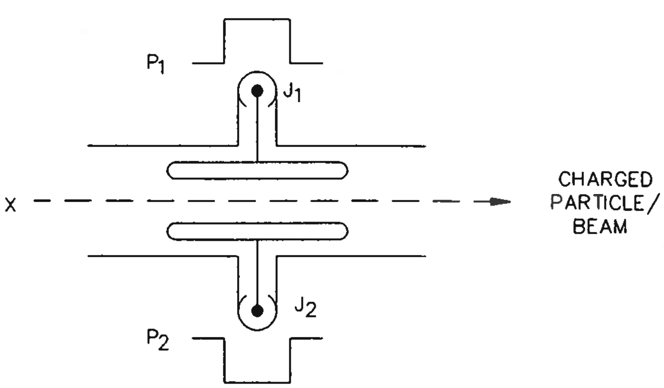


FIGURE 14.

Or the HV1000s can be configured as shown in **Figure 15,** where one plate is grounded and the remaining plate is driven.

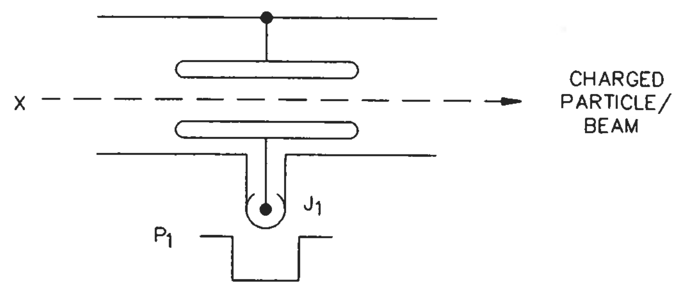


FIGURE 15.

In either case the load can be purely capacitive or resistive and capacitive. Furthermore the deflection scheme of **Figure 14** or **Figure 15** lends itself to a technique which allows the maximum pulse width of the HV1000 to be greatly extended in conjunction with enhanced turn-off edge capability. This is illustrated in **Figure 16.**

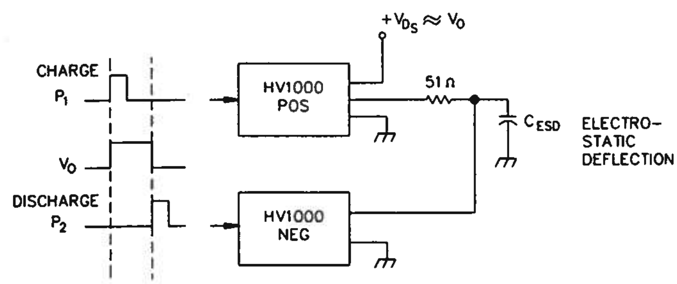
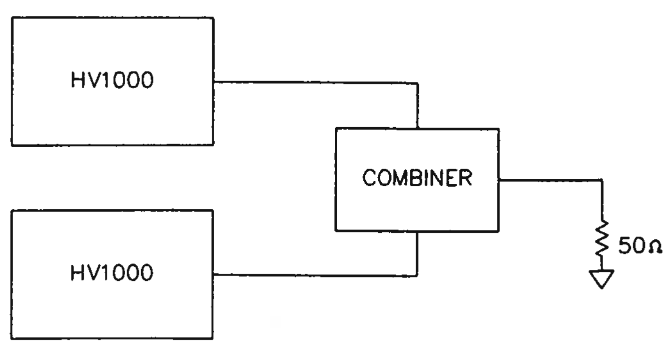


FIGURE 16.

Here the positive HV1000 is driven with an input gate P_1 to erect the leading edge of the pulse V_0 and the negative HV1000 is gated with P_2 to create the falling edge of V_0. Since the off state impedance of the HV1000 is >1 megohms, the droop in V_0 pulse is quite small.

Figure 17 shows the setup for pulse superposition (pulse stacking) using an RF style combiner.



PULSE STACKING

FIGURE 17.

With this technique the pulses are summed in time at the load position (50 ohms). This technique can be used to increase the deflection voltage for either a travelling wave structure or an electro-static deflector.

As shown in **Figure 18,** using two positive HV1000s and DEI's RF Combiner, the user can generate two pulses which are exactly the same pulse width, and their sum provides almost 1500V. The difference between the nominal 900V output of a single HV1000 and the 750V output of two HV1000s is the fact that the combiner now presents a 25 ohm load to the HV1000. More voltage is lost across the power switch internally, therefore the overall efficiency drops.

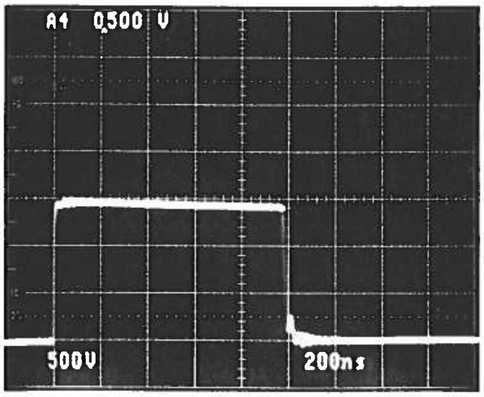


FIGURE 18.

Also using two positive HV1000s, one can generate a pedestal pulse, as shown in **Figure 19,** then superposition a smaller pulse on top of it. The timing of these two pulses is completely arbitrary. By utilizing superposition, as well as the frequency and pulse width agility of the HV1000, the user can generate complex pulse patterns and wave shapes.

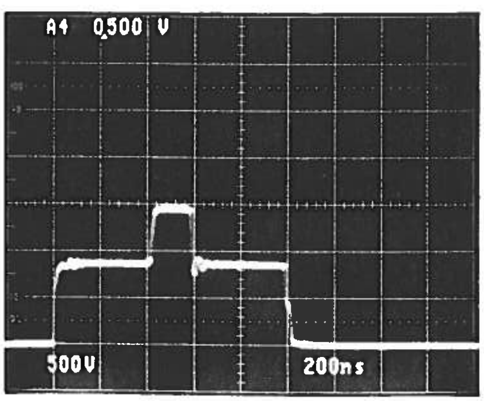


FIGURE 19.

Many applications require a longer pulse width than is possible with a single HV1000. By using a positive HV1000, a negative HV1000, and an RF Combiner, along with the technique shown in **Figure 20,** the pulse width can be extended to virtually DC. A secondary benefit of the technique is that it reduces the amount of average power required from the power supply.

The plates used for beam deflection/steering, Pockels cells, and MCPs generally appear as a small capacitive load. A typical configuration to drive such a load often consists of the pulse generator, an interconnect cable (typically 50 ohm coaxial), the load and a 50 ohm resistor

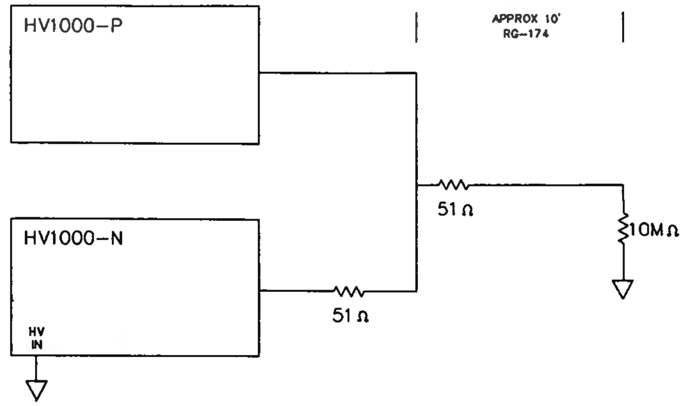


FIGURE 20.

to provide the correct termination impedance for the pulser as well as the cable. However, though this configuration works, the 50 ohm terminator represents an additional load. In fact, the load, as seen by the power supply and pulse generator, is no longer only the small capacitive load, but, in fact, is the 50 ohm terminating resistor. This configuration increases the average power requirement to the degree it becomes no longer feasible to drive 50 ohm terminator because of high power dissipation.

The technique shown in **Figure 20** allows the user to drive the cable without the 50 ohm termination. A resistor is placed in a series termination. The key is for the user to series terminate to ground. With this technique the user only needs to supply the charge to charge the capacitance, unlike when the pulse is terminated into 50 ohms and power must be supplied during the entire pulse width. With the series termination technique, the user can create a pulse as long as desired, as shown in **Figures 21a** and **21b.**

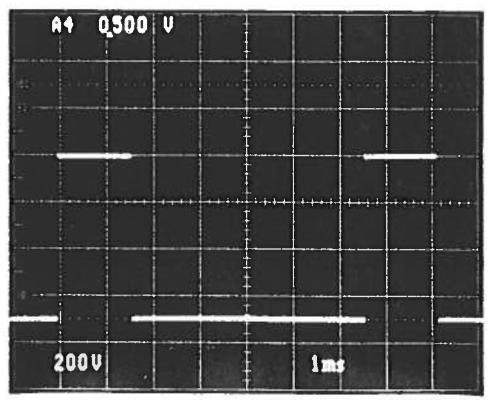


FIGURE 21a.

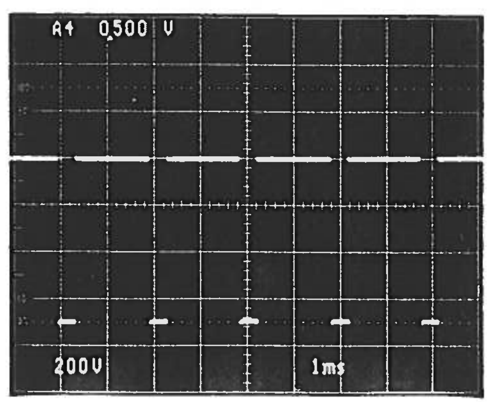


FIGURE 21b.

■ HOW TO MONITOR Ldi/dt

Precautions

The HV1000 has an internal capacitance of $3\mu F$.
HIGH VOLTAGE MAY BE PRESENT!

DO NOT ATTEMPT TO MAKE OTHER MEASUREMENTS EXCEPT AS DESCRIBED BELOW.
SOME CIRCUIT ELEMENTS ARE FLOATING AT HIGH VOLTAGE!

To measure the Ldi/dt we recommend the use of: a) a Tektronix 6009 High Voltage Probe (100X) and b) a 200 MHz or faster scope.

Carefully proceed as follows:

1. Make sure all power is OFF.
2. Remove cover.
3. With connectors pointed away from you (see **Figure 23**) locate J_1. The center pin of the coax is the output and the shield is tied to ground.
4. Place the center pin of the probe to the center pin of the coax. Place the spring loaded ground pin on the shield. **NOTE:** Take care that the probe is properly inserted. If it is inserted backwards, it will short the output to ground.
5. Slowly bring up the power supply while observing the waveform on the scope. The Ldi/dt term will be seen on the turn off edge of the waveform, as shown in **Figure 22.**

To insure that the voltage rating of the HV1000 is not exceeded, use the following formula

$$V_{max} < V_{supply} + :Ldi/dt:$$

Where

Ldi/dt = peak of the negative going spike
V_{supply} = HV IN
V_{max} = 950V

For example, from the waveform shown

$$V_{max} = 340V + :-200V: = 540V$$

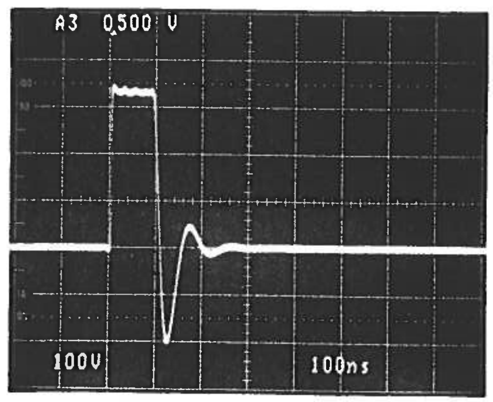


FIGURE 22.

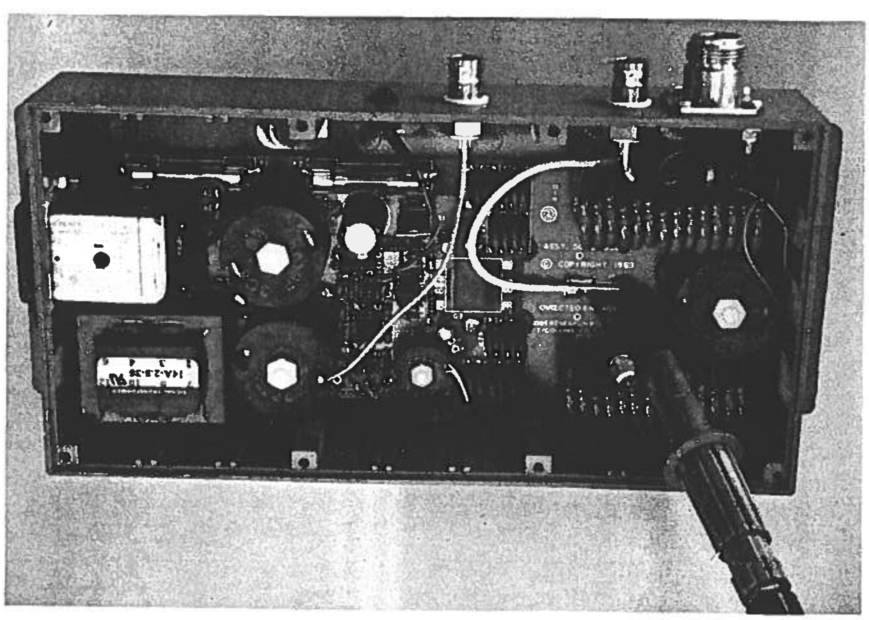


FIGURE 23.
Correct probe placement.

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