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User's Guide for the 2.7-kJ Wire Burst Controller: Analog Modules, Inc. Model 880-317

by W Casey Uhlig and Jeff Cameron

NOTICES

Disclaimers

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User’s Guide for the 2.7-kJ Wire Burst Controller: Analog Modules, Inc. Model 880-317

W Casey Uhlig and Jeff Cameron
DEVCOM Army Research Laboratory

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14. ABSTRACT
The Analog Modules, Inc. Model 880-317 fixed pulse width controller supplies a single pulse varying from 0 to 3000 V with a pulsed width of approximately 400 µs. The module contains two 300-µF capacitors connected in parallel for a total of 600 µF, and an internal inductance of 15 µH and internal resistance of about 200 mΩ. The internal dump resistor for discharging the capacitors is 17 kΩ and requires approximately 1 min to be fully discharged. The purpose of this guide is to provide general instructions for the module's use with the modifications and Control Box as implemented and required to meet the US Army Combat Capabilities Development Command Army Research Laboratory's safe use guidance.

15. SUBJECT TERMS
Sciences of Extreme Materials, Terminal Effects, wire burst, pulse controller, pulse control module

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Contents

List of Figures

1. Introduction

The Analog Modules, Inc. Model 880-317 fixed pulse width controller supplies a single pulse varying from 0 to 3000 V with a pulsed width of approximately 400 µs. Figure 1 shows an example of an electrical pulse with the module set to 1500 V into a 42-mm-long copper (Cu) wire with a diameter of 125 µm. The output achieved a peak current of 3.44 kA. The module contains two 300-µF capacitors connected in parallel for a total of 600 µF, and an internal inductance of 15 µH and internal resistance of about 200 mΩ. The internal dump resistor for discharging the capacitors has a time constant of about 10 s. Thus, the internal dump resistor is on the order of 17 kΩ and requires approximately 1 min to be fully discharged. The purpose of this guide is to provide general instructions for the module's use with the modifications and control box as implemented and required to meet the US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory's (ARL's) safe use guidance. Therefore, further internal specifications will not be listed here but are included in the manufacturer's operating manual (see Appendix A).

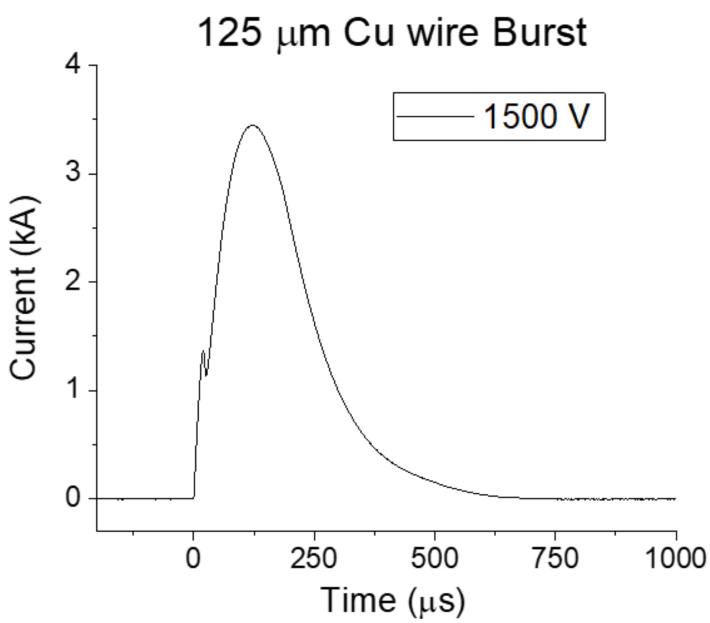

Fig. 1 Electrical pulse with a setting of 1500 V into a 125-µm Cu wire

2. Requirements

The pulser module requires 193–253 volts alternating current (VAC) single phase 15-A supply. Because the module does not have a power switch, it needs to be switched externally. We have also determined that the power can be supplied via a

240 VAC source or by using two legs of a 208 VAC three-phase source. The pulser is controlled and monitored via a 25-pin input connector to control the charge voltage, enabling charge, triggering, and so on. See Appendix A for the pinouts. The module VAC source and the 25-pin control connection is supplied by a control box custom built by ARL (see Fig. 2). The control box must be powered by an interlockable power source. By interlocking the control box, the power to the pulser module is interlocked and cannot be powered on unless the interlock is engaged. An interlocked 120 VAC power source is shown in Fig. 3.

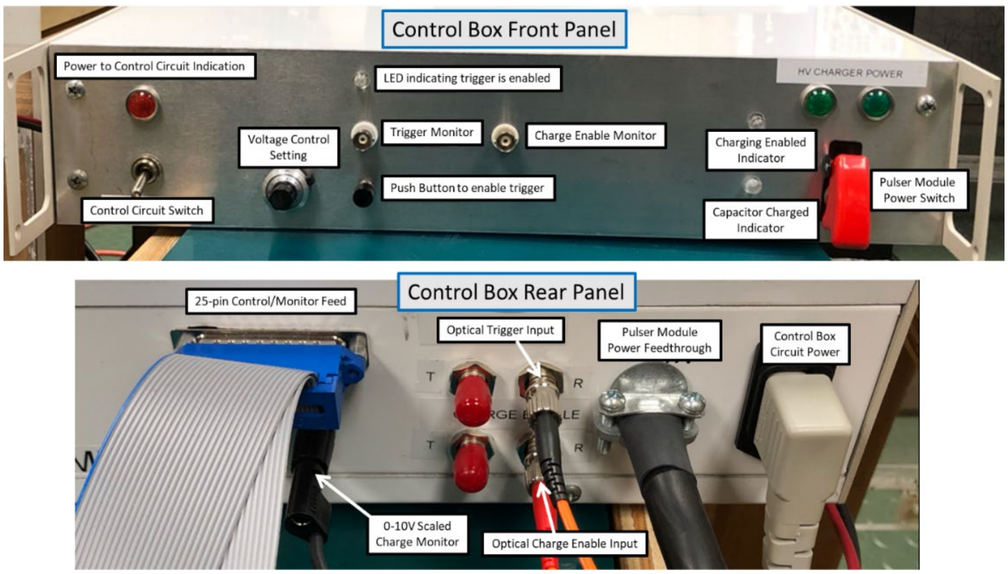

Fig. 2 **Control box front and rear panels**

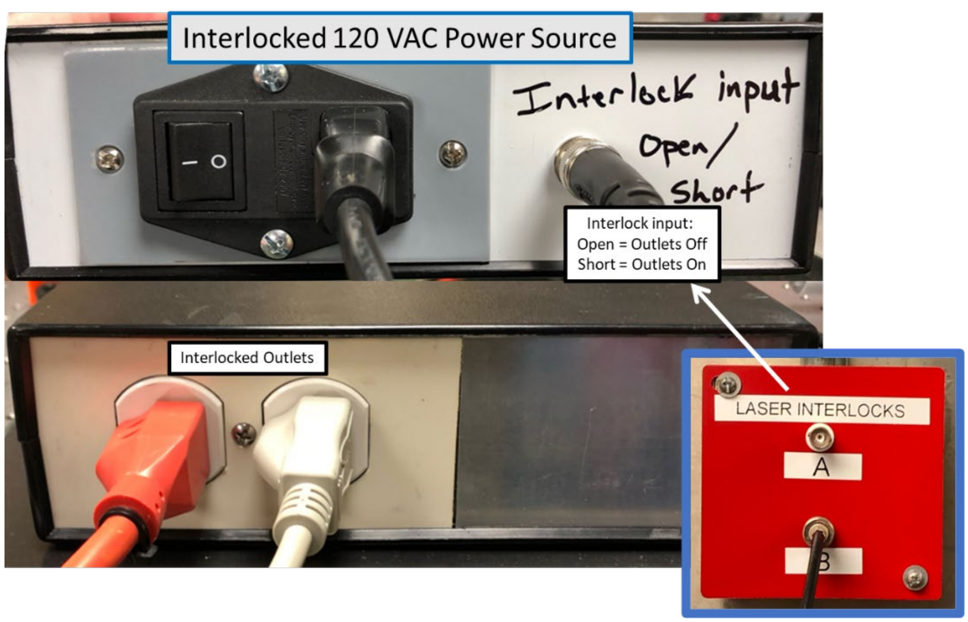

Fig. 3 **Interlocked power source for control box circuit and relay to dump resistor**

The pulser module was also modified by adding a direct connection to the internal capacitors to enable direct shorting and monitoring of the voltage on the capacitors. This connection is hard wired to a Ross relay, dump resistor, and 1/1000 high voltage probe (shown in Fig. 4). The Ross relay must also be powered by an interlocked power source. Thus, if the interlock is broken, the VAC power to the pulser will be turned off and the Ross relay will be closed. The time constant for the dump resistor circuit is 1.5 s and thus a charge of 3000 V will be reduced to less than 60 V in 6 s and will be fully discharged in less than 10 s.

Fig. 4 Modification to the pulser module for direct shorting and monitoring of the internal capacitors through a Ross relay and external dump resistor

To avoid high voltages in areas where personnel will be located during testing, charging and triggering must be controlled via fiber optic input. The charge enable must be high during charging and remain on during triggering. The pulser requires a trigger pulse length of 5 ms. Longer times can damage the system. However, any length trigger can be sent to the optical input; the control box circuit will output a single pulse and is set to 5 ms.

3. Procedure

1) With power disconnected to the Pulser and Control Box, connect a voltmeter to the 0–10 V charge monitor on the back panel of the Control

Box, and connect a second voltmeter to the output of the high voltage probe connected to the direct connect on the capacitors and verify 0.0 V.

2) Connect the burst wire or other load to Pulser high voltage output, optical inputs, and any other diagnostic required. If desired, a local monitoring of the trigger can be connected on the Control Box front panel.
3) Set the Voltage Control dial on the front of the Control Box to the desired value from 0 to 10 (see Section 4, Characterization for scaling values).
4) Ensure the interlock is NOT engaged and connect all power sources and interlocks.
5) Ensure the source used for the Charge Enable signal is off or in the low position.
6) Turn on Control Box Circuit Power switch and the Pulser Module Power Switch.
7) Ensure the area is clear of all personnel.
8) While standing a minimum of 8 ft from the Pulser, engage the interlock. The power lights on the front panel of the Control Box should be lit. If the trigger enable LED is not lit, press the enable trigger button on the front panel of the Control Box.
9) Press the Exit button on the interlock system and move to the experiment control area, making sure that the interlock system re-engages.
10) Ensure that you can monitor the voltmeters from step one via a remote camera.
11) Put on appropriate hearing protection.
12) Enable Charge and monitor the voltmeters to ensure proper charging to the desired voltage and note the actual charge voltage.
13) Send trigger. The wire should burst, or if there is a different load, discharge of the capacitors should be indicated by a drop in the voltage monitored on the voltmeter. The system will immediately begin to charge again.
14) Disengage the Charge Enable signal. The decay of the voltage on the voltmeters should be observable at the internal dump resistor rate.
15) Disengage the interlock system, but do not enter the area. After 10 s and visible verification that the voltmeters read 0.0 V, the area may be entered according to any wait times required for the air to be clear (e.g., if the wire was burst in open air).
16) After entering the room turn off the power switches on the front panel of the Control Box, turn off the power to the Interlocked Power Source, and turn off the originating power for the Pulser Module (i.e., via knife switch or unplug the 240 VAC).

4. Characterization

The system was characterized by varying the dial on the control box front panel and monitoring the voltage that the capacitors were charged. The 0–10 V output on the back of the control box is a scaled indicator of the requested charge voltage representing 0–3000 V. The dial on the front panel is not a direct correlation of 0–10 setting, but rather a variable resistor in series with other resistance in the control circuit. However, the charge voltage scales very linearly with the setting on dial. Figure 5 shows the linear correlation and includes a list of settings required for potential common charge voltages. The linear fit yields:

$$\text{Dial Setting} = (\text{Desired Voltage}-383.6)/291.1$$

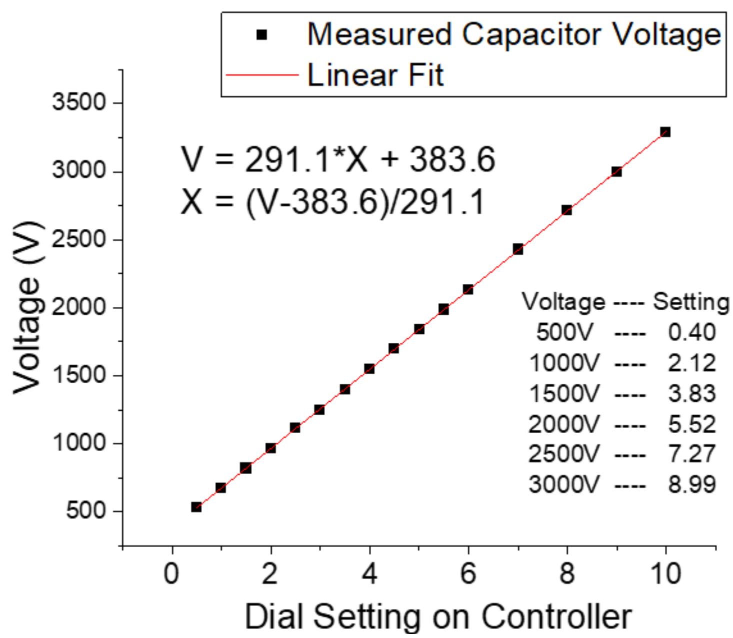

Fig. 5 Charge voltage vs. front panel dial setting

Cu wires of 125 µm diameter and 42 mm in length were burst using charge voltages from 500 to 2500 V. The current was monitored by a Pearson Model 101 current monitor connected at the high voltage output of the pulser as shown in Fig. 6. A model 101 has a voltage output proportional to the current of 0.01 V/A. Pearson current monitors have a 50-Ω impedance, thus if an oscilloscope is connected via a 50-Ω termination, then the ratio is 0.005 V/A.

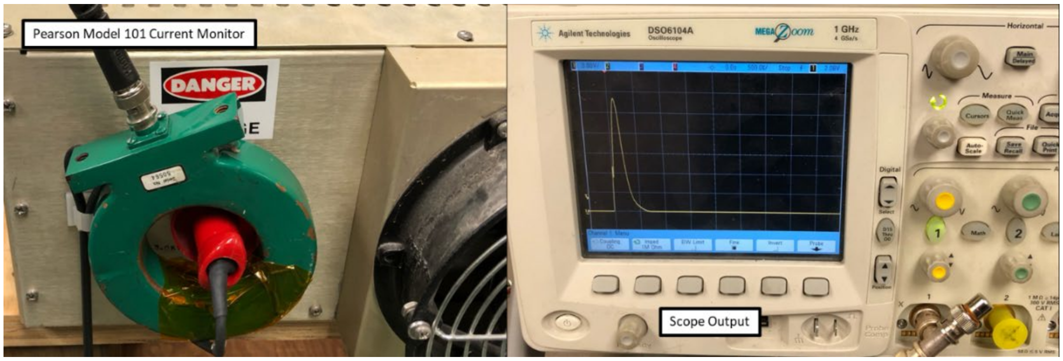

Fig. 6 Location of Pearson Model 101 current monitor and scope output

A simple 4.5-V battery source with a spring-loaded toggle switch and a push button was used to send the signal to enable charging and then trigger the pulser (respectively) as shown in Fig. 7. The output was fed to a TTL to Optic bit driver, which provided the transmission of the optical signals required for charging the pulser and firing.

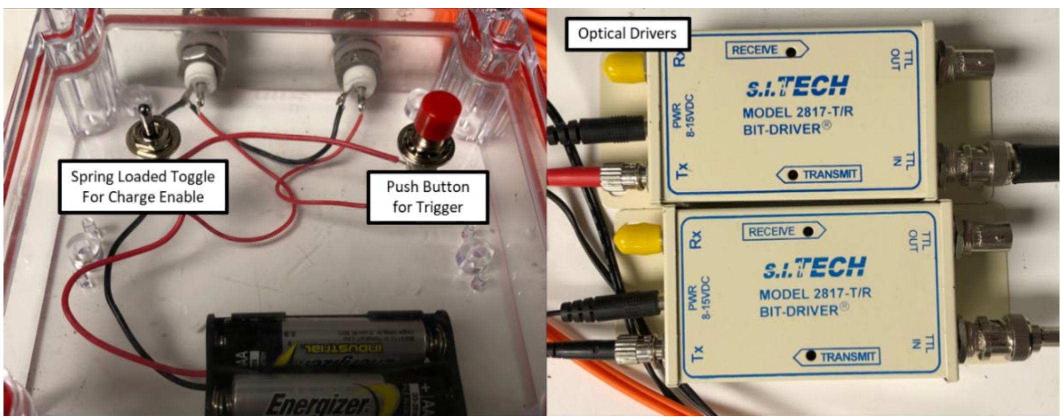

Fig. 7 Charging and firing box (left) and TTL to optic bit driver (right)

The pulse shape changed slightly as a function of applied voltage but generally maintained a total pulse width of just under 400 µs (see Fig. 8). The features in the current traces (early peak and then dip in current before rising) are likely artifacts of the wire melt, increase in resistance, vaporization, and then plasma cloud generation. Without further tests including various wire diameters and materials, it is impossible to say definitively that the features of the pulse are not inherent to the pulser.

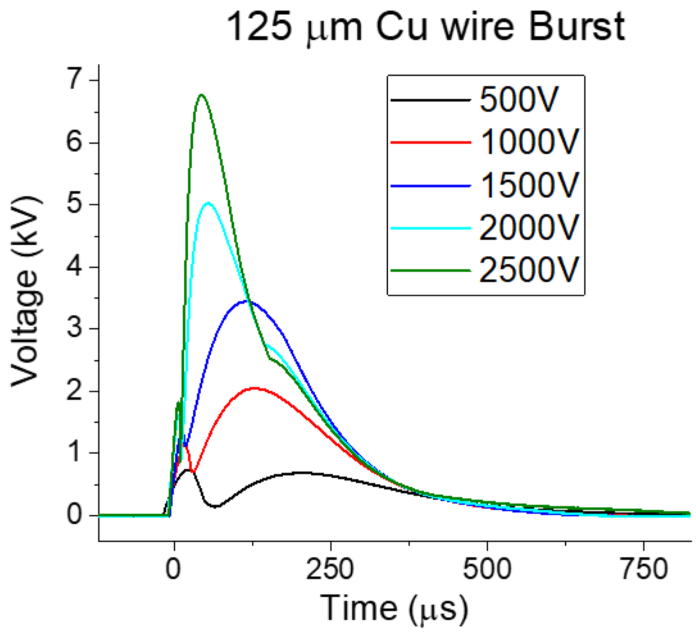

Fig. 8 Current traces for charge voltages ranging from 500 to 2500 V

To test the repeatability of the pulser as a system, the control dial was set to 3.83, which corresponds to a 1500 V, and a Cu wire was burst. The dial was then moved away from the setting and set again to 3.83 and fired again. Figure 9 shows that the pulse is very repeatable with peak currents of 3402 and 3448 A. The variation is likely due to the resolution of the dial setting and small resistance differences in connecting the fine wire. However, less than 2% variation in peak currents seems very reasonable and not likely due to the instrument.

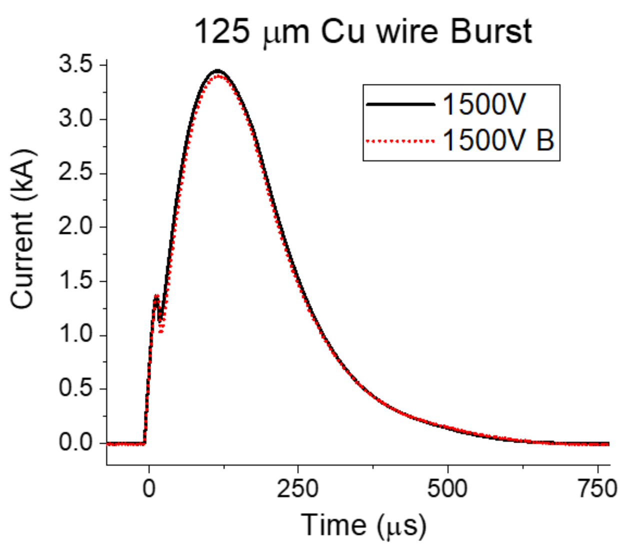

Fig. 9 Comparison of current traces from a bursting wire with the charge voltage set to 1500 V for two separate experiments to test repeatability

The peak current scaled fairly linearly with the charge voltage. This is shown in Fig. 10.

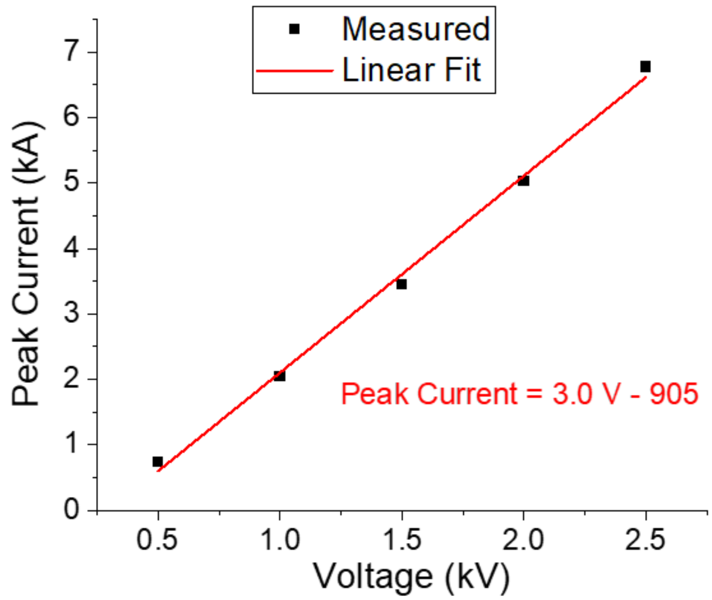

Fig. 10 Peak current as a function of charge voltage setting for a 125-µm Cu wire

5. Conclusion

A Control Box and characterization of the Analog Modules, Inc. Model 880-317 fixed pulse width controller was completed. The pulser supplies a single pulse varying from 0 to 3000 V with a fixed pulse width of approximately 400 µs. The Control Box provides a means to charge and trigger the system remotely via fiber optics to meet ARL's safe use guidance.

Appendix A. Operating Manual

This appendix appears in its original form, without editorial change.

Below is a copy of the original manufacturer's operator manual as well as a later version obtained directly from the company.

DWG#: 6396
REV: 1
FILE#: 6396_1.doc
DATE: 020227
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OPERATING MANUAL
FOR
MODEL 880-317

FIXED PULSEWIDTH CONTROLLER

Analog Modules, Inc.
126 Baywood Avenue
Longwood, FL 32750

Approval: Tim Ayres
Timothy Ayres, Product Manager

John Harwick, Product Engineer

Charles G. Smith, V.P. Engineering

DWG#: 6396
REV: 1
FILE#: 6396_1.doc
DATE: 020227
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TABLE OF CONTENTS

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

The *Model 880-317* Laser Controller is an OEM type power supply capable of driving small wire loads.

The system is a fixed pulsewidth, single mesh, PFN driver. The PFN energy is variable through adjustment of the capacitor charge voltage. The maximum capacitor voltage is 3000 VDC. The power supply is capable of delivering 1250W maximum ramp power to the PFN.

The PFN is designed to drive a 0.004 wire load that will disintegrate when the PFN discharges.

DWG#: 6396
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CAUTION

READ THIS BEFORE PROCEEDING FURTHER

The voltages generated by this equipment are LETHAL. To avoid electrocution, good care and judgment must be used. The safety interlocks are provided for your protection and should never be disabled or defeated. Covers should not be removed without first disconnecting the AC power lines servicing this equipment. All storage capacitors should be discharged before any attempt is made to enter the unit, or move connectors or output cable. If any doubt exists, check capacitors with a HV probe or voltmeter. Ensure all metal boxes are connected to ground.

When shipping, the rack boxes should be appropriately supported or removed to avoid damage due to shock. Inspect all cables for looseness at connectors and visual damage. Do not support units by front panel only -- use multiple supports. Protect exposed power and output connections from human touch.

Once the power has been removed, or the high voltage has been disabled, allow at least one (1) minute for the voltage to bleed from the capacitor energy storage bank.

DWG#: 6396
REV: 1
FILE#: 6396_1.doc
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Pin #	Signal		Description
1	Intlk Com.	Output	Connects to the common terminal of one pole of the cover switch. Pins 1 & 14 together provide an external indication of the cover switch status
14	Intlk N/O	Output	Connects to the N/O terminal of one pole of the cover switch. Pins 1 & 14 together provide an external indication of the cover switch status.
2	Program V	Input	A 0-10V scaled differential input to control the output voltage of the chargers. 10V equals the full scale output of the charger. The charger will output a voltage proportional to this program input only when the Enable line is active. Input impedance is 4kΩ. (Figure 2)
15	Program Rtn	Input	This pin goes to the inverting input of the differential amp controlling the program voltage.
3	Enable	Input	A 5V, 10mA input signal activates the Enable line. This is an optically isolated input. This signal gates the circuitry that controls the enable lines on all of the high voltage charger control lines and the dump circuit. Removing the enable signal activates the PFN dump circuit. (Figure 1)
16	Enable Rtn		This pin is connected to the Enable line opto isolator diode cathode.
4	Trigger	Input	A 5V, 10 ma input signal will trigger the high voltage pulse. This signal is optically isolated. The trigger pulsewidth determines the quench time for the charger. The minimum recommended trigger pulsewidth is 5mS. This trigger pulsewidth must be adjusted to prevent the charger from running during the PFN discharge. The trigger signal will be blocked from passing on to the high voltage control circuits when the enable line is not active. (Figure 1)
17	Trigger Rtn		This pin is connected to the trigger line opto isolator diode cathode.
5, 6	+24V	Input	This pin connects to a +24V source to power peripheral devices. The available current draw is 500mA maximum.
18, 19	+24V Rtn	Input	This is the return pin for the +24V source.
7	HV Sense	Output	A differential amp monitors the PFN voltage, and outputs a proportional signal on this pin 10V full scale. The source impedance is 100Ω. (Figure 4)
20	HV Sense Rtn		This is a signal ground for the HV sense signal that is common to +24 Rtn. It is strongly recommended that this signal be monitored differentially by the end user. Directly connecting this pin to the user control circuit ground may cause ground loops and other undesirable signal interference.
8	Chassis		This pin is common to chassis. It may be used for cable shielding.
9	Charged	Output	Opto isolator transistor output. 24V maximum, 10mA sink. Pin 9 is the collector, pin 22 is the emitter. The transistor turns on when the power supply has reached regulation. (Figure 3)
22	Charged Rtn		
10	Overtemp	Output	Opto isolator transistor output. 24V maximum, 10mA sink. Pin 10 is the collector, pin 23 is the emitter. The transistor turns on when the power supply has overheated. (Figure 3)
23	Overtemp Rtn		

4

DWG#: 6396
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SECTION 2

SET-UP AND INTERFACE

2.0 SET-UP AND INTERFACE

Make all connections as indicated in the attached System Interconnection Diagram.

2.1 Power Requirements

198-253 VAC Single Phase 15A

Via line cord.

Please note that the AC power input to the unit is hard wired in the system. There are no AC switches of any kind inside the unit. Once power is applied to the line cord, the system is fully powered. The line cord must be connected to a switched AC source of adequate rating.

2.2 System Interfaces

Please refer to the attached interface drawing.

System I/O Connector:
25 Pin female D Connector:

SECTION 3

OPERATING INSTRUCTIONS

3.1 Start-Up Procedure

1. Establish control signals to the 25 pin I/O connector on the rear panel. Verify that the Program voltage, Enable, and Fire signals are all inactive.

2. Apply AC Mains voltage to the system.

When it is desired to arm the system for firing:

3. Apply 5V to the enable line.
The capacitor dump circuit will also be turned off at this point, and the power supply modules enabled.

4. Apply the desired voltage to the program line.
The power supply modules will charge the capacitor bank to the selected voltage. Both the HV Sense output, and the Charged indication signal can verify this. The system has a high voltage watch dog circuit to prevent prolonged short circuit operation of the capacitor charging modules. If the PFN does not reach full charge within a pre-programmed period of time, the capacitor charging modules will be disabled.

To re-activate the charging modules, the Enable signal must be removed, and then re-applied. The chargers will not operate otherwise.

SEC

DOCUMI

4.0 DOCUMENTATION

Drawing Title

Interface Diagram

Interconnection Diagram

Misprinted missing info

5. The wire load is now ready to be
signal of 5ms or greater on the trigg

The trigger pulse also acts as a
The pulsewidth of the trigger sig
cause the HV power supply t
discharge process.

3.2 Power-Down Procedure

a. Remove the trigger signal.

b. Remove the Program voltage.

c. Remove the HV Enable signal.

d. Switch off the AC Mains to the ur

While operating the system it is impo

The capacitor dumping circuit has been
in the capacitor bank. As with all resi
power limitations.

Cycling the enable line on and off may
the dump circuit.

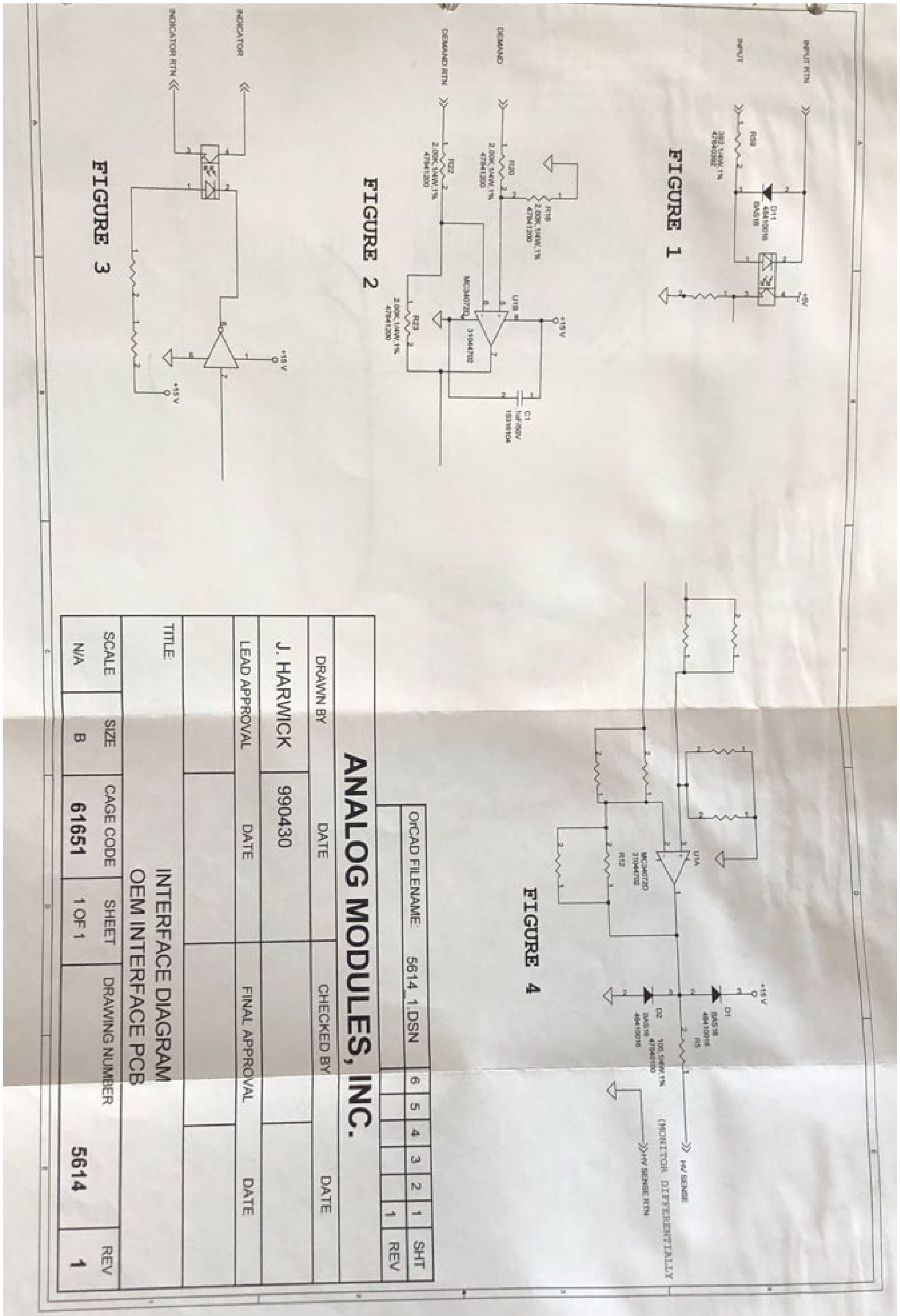
FIGURE 1
FIGURE 2
FIGURE 3
FIGURE 4
INPUT RTN
INPUT
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DEMAND RTN
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HV SENSE RTN
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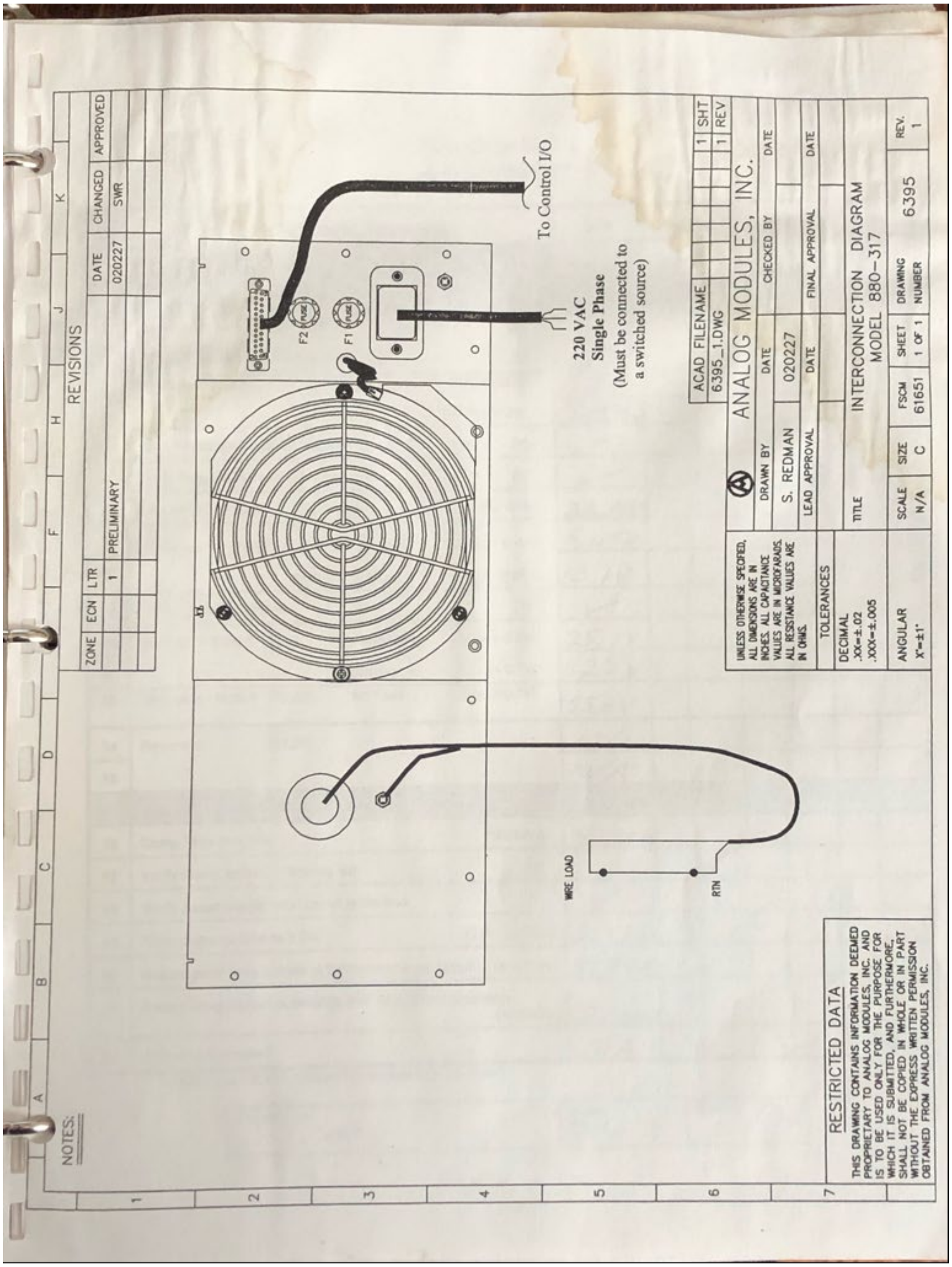
REVISIONS
ZONE ECN LTR
1 PRELIMINARY
DATE 020227
CHANGED SWR
APPROVED
NOTES:
To Control I/O
220 VAC
Single Phase
(Must be connected to a switched source)
F2
F1
WIRE LOAD
RTN
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S. REDMAN
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TITLE
INTERCONNECTION DIAGRAM
MODEL 880-317
SCALE N/A
SIZE C
FSCM 61651
SHEET 1 OF 1
DRAWING NUMBER 6395
REV. 1

REVISIONS

DCN	LTR	DESCRIPTION	DATE	CHANGED	APPROVED

C

Special Modifications

Customer: US Army
Job #: 10459
Date: 2-27-02
Revision: 1 | Revision: Date: 2-27-02

Approval

Project Engineer	Stamp	Date
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TOLERANCES
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XX = N/A
XXX = N/A
ANGULAR
X = N/A

TITLE
TEST DATA SHEET
MODEL 880-317

SCALE	SIZE	FSCM	SHEET	DRAWING NUMBER	REV.
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FILE#: 6391_1.DOC
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DCN#:

Test Data Sheet
Model 880-317

	Test [pin#, rtn#] (Tolerance)	S/N 78982	S/N N/A	S/N N/A	S/N N/A
	25 PIN I/O				
1	Verify Cover Interlock Operation [1,14] (Y)	✓			
2	HV Enable Blocked (Y)	✓			
3	Program V [2,15] 5V = X V out (1450<X<1547)	1511V			
4	10V = X V out (2975<X<3025)	3008V			
5	Verify HV Enable Operation @ 4.5V input [3,16] (Y)	✓			
6	Verify Trigger Operation @ 4.5V input [4,17] (Y)	✓			
7	Record 24V Output [5,6-18,19] (23-27V)	26.6V			
8	HV Sense [7,20] 1500 V = X V out (4.9-5.1V)	5.05V			
9	3000V = X V out (9.8-10.2V)	10.1V			
10	Verify Chassis Continuity [8] (Y)	✓			
11	Charged - Note 1 [9,22] Not Regulating (>pin5-0.5V)	25.1V			
12	Regulating (< 0.7V)	.25V			
13	Overtemp - Note 1 [10,23] No Fault (>pin5-0.5V)	25.0V			
14	Reserved [11,24]	N/A			
15		N/A			
	System Operation (tolerance)				
16	Dump Time to < 60V (<60Sec.)	40sec			
17	Verify Fan direction - blowing out (Y)	✓			
18	Verify power supply short circuit protection (Y)	✓			
19	Record charge time to 3.0kV (2.0 – 2.2 sec)	2.1sec			
20	Record peak lamp current at 3.0KV discharge, 600μF (4.5-7KA)	8136A			
21	Record lamp current pulsewidth FWHM at 2.8KV discharge (<600uS)	200uS			
22	Burn-In not required	N/A	✓	✓	✓

Note 1: Use 2.42K ohm pullup resistor to pin 5. (24V)

Technician:	Date:	Stamp:
[illegible]	5-1-03	

2 of 2

DWG# 6391
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DATE 020227
DCN#

Test Data Sheet
Model 880-317

	Test [pin#, rtn#] (Tolerance)	S/N 78241	S/N N/A	S/N N/A	S/N N/A
	25 PIN I/O				
1	Verify Cover Interlock Operation [1,14] (Y)	✓			
2	HV Enable Blocked (Y)	✓			
3	Program V [2,15] 5V = X V out (1450<X<1547)	14.96			
4	10V = X V out (2975<X<3025)	3006			
5	Verify HV Enable Operation @ 4.5V input [3,16] (Y)	✓			
6	Verify Trigger Operation @ 4.5V input [4,17] (Y)	✓			
7	Record 24V Output [5,6-18,19] (23-27V)	26.6v			
8	HV Sense [7,20] 1500 V = X V out (4.9-5.1V)	5.08v			
9	3000V = X V out (9.8-10.2V)	10.19V			
10	Verify Chassis Continuity [8] (Y)	✓			
11	Charged - Note 1 [9,22] Not Regulating (>pin5-0.5V)	26.6V			
12	Regulating (< 0.7V)	.17V			
13	Overtemp - Note 1 [10,23] No Fault (>pin5-0.5V)	14.5V			
14	Reserved [11,24]	N/A			
15		N/A			
	System Operation (tolerance)				
16	Dump Time to < 60V (<60Sec.)	38sec			
17	Verify Fan direction - blowing out (Y)	✓			
18	Verify power supply short circuit protection (Y)	✓			
19	Record charge time to 3.0kV (2.0 – 2.2 sec)	2.1sec			
20	Record peak lamp current at 3.0KV discharge, 600µF (4.5-7KA)	6345A			
21	Record lamp current pulsewidth FWHM at 2.8KV discharge (<600uS)	500us			
22	Burn-In not required	—			

Note 1: Use 2.42K ohm pullup resistor to pin 5. (24V)

Technician:	Date:	Stamp:
LE	2-27-02	

2 of 2

Electrical Specification

Model 880-317

Rev.: 2
Date: February 26, 2002
TMA

---Power Input:

Voltage - 198-253 VAC,1φ via line cord.

Current - ≈6A @ 1000W output with 230VAC input.

Protective Earth Ground - 1/4" stud.

PFN:

Capacitance - 2ea 300 uf +/- 10%

Inductance - 15 uH +/- 10%

Lamp Output:

Voltage - 3000 VDC max.

PFN Current Rating - 55A RMS max. continuous, 8,000A peak.

Output Power - 1000W continuous

Size:

Chassis - 6.5" x 17" x 21"

Front Panel - 19" x 7"

Electrical Specification

Model 880-317

Rev.: 2
Date: February 26, 2002
TMA

I/O Specifications:

25 pin D connector: (rear panel)

Pin	Signal Description		
1-	Intlk Com.	Output:	Connects to the common terminal of one pole of the cover switch. Pins 1 & 14 together provide an external indication of the cover switch status.
14	Intlk N/O		Connects to the normally open terminal of the cover switch.
2-	Program V	Input:	0-10V differential input to control the output voltage of the chargers. Active only when enable is active. Input impedance is 4kΩ.
15-	Program Rtn	Input:	This pin goes to the inverting input of the differential amp controlling the program voltage. Input impedance is 4kΩ.
3-	Enable	Input:	5V, 10mA input signal enables the power supply. Opto isolator input. This signal gates the circuitry that controls the enable lines on all of the charger control lines, all simmer enable lines, and the dump circuit. Removing enable signal activates Dump circuit.
16-	Enable Rtn		Opto isolator input diode cathode.

Electrical Specification

Model 880-317

Rev.: 2
Date: February 26, 2002
TMA

4-	Trigger	Input:	5V, 10mA input signal will trigger the flashlamp. Opto Isolator input. The trigger pulse width determines the quench time for the charger. The trigger signal will be blocked from passing on to the high voltage control circuits when the Enable is not active.
17-	Trigger Rtn		Opto isolator input diode cathode.
5,6-	+24V	Output:	+24V source to power peripheral devices. 500mA Maximum draw.
18,19-	+24V Rtn	Output:	Return path for a +24V.
7-	HV Sense	Output:	A differential amp monitors the PFN voltage, and outputs a signal on this pin 10V full scale. The source impedance is 100Ω.
20-	HV Sense RTN		Signal ground common to +24 Rtn. It is strongly recommended that the HV sense signal be monitored differentially by the end user.
8-	Chassis		This pin is common to chassis for use as shielding.
9-	Charged	Output:	Opto isolator transistor output. 24V maximum, 10mA sink. Pin 9 is the collector, pin 22 is the emitter. The transistor turns on

			when the power supply has reached regulation.
22-	Charged Rtn		Opto isolator input diode cathode.
10-	Overtemp	Output:	Opto isolator transistor output. 24V maximum, 10mA sink. Pin 10 is the collector, pin 23 is the emitter. The transistor turns on when the power supply has overheated.
23	Overtemp Rtn		Opto isolator input diode cathode.
11-	Reserved		
24-	Reserved		
12-	Reserved		
25-	Reserved		
21-	Reserved		
13-	Reserved		

Electrical Specification

Model 880-317

Rev.: 2
Date: February 26, 2002
TMA

Revision History:

Rev. 1 010613 -	New specification based on 880-260.
Rev. 2 020226 -	Changed RMS current from 25A to 55A, deleted simmer sense output from interface description.
Rev. 3	

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