October 1992

ISOLATOR-10

STIMULUS ISOLATION UNIT

OPERATOR'S MANUAL

QUESTIONS? Telephone (415) 571-9400 or Fax (415) 571-9500

Part Number 2500-091 REV A

Printed in U.S.A.

SAFETY

The ISOLATOR-10 Stimulus Isolation Unit is not intended to be used and should not be used in human experimentation. The unit generates both high voltage and high current and care should be taken in its operation in any environment.

The ISOLATOR-10 Stimulus Isolation Unit is a constant current source, and so the voltage it produces is inversely dependent on the load resistance. The unit can output more than 150 Volts. It must therefore be handled at all times with caution.

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VERIFICATION

This instrument is extensively tested and thoroughly calibrated before leaving the factory. Nevertheless, researchers should independently verify the basic accuracy of the instrument using suitable test signals.

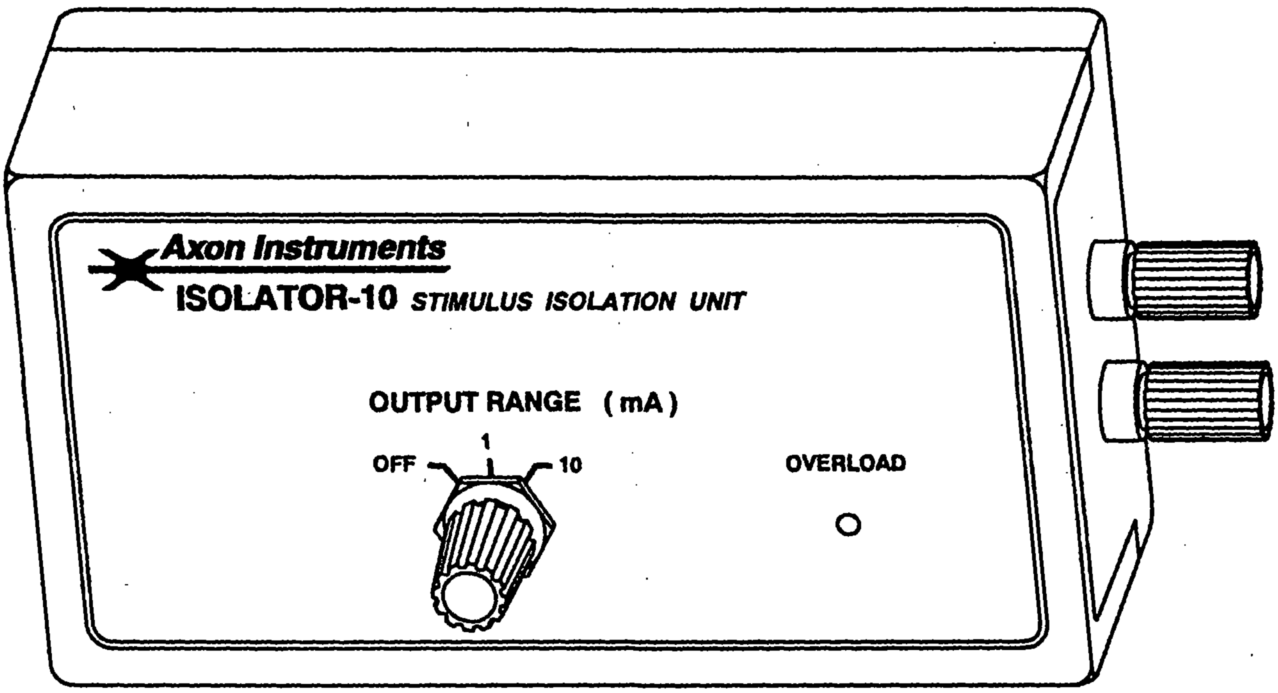
Axon Instruments
ISOLATOR-10 STIMULUS ISOLATION UNIT
OUTPUT RANGE (mA)
OFF
1
10
OVERLOAD

TABLE OF CONTENTS

INTRODUCTION

The ISOLATOR-10 is an isolated voltage-to-current converter that is designed to be used under the control of a data acquisition system, pulse generator, or arbitrary waveform generator. The unit accepts any stimulus waveform between ±10 V and converts it to an output current. The signal bandwidth of the ISOLATOR-10 is greater than 40 kHz, and the full-scale output current range may be set to ±1 or ±10 mA. Output amplitudes of the ISOLATOR-10 are accurate to within 1% and the output leakage current is less than 0.1% of full scale. All stimulus waveforms, amplitudes and timing are controlled by the input, so that once the ISOLATOR-10 is set up for an experiment, the unit does not have to be touched. The ISOLATOR-10 is as versatile as the stimulus generator driving it.

The ISOLATOR-10 is useful in applications that require a controlled current source or a current source uncoupled from ground. The device can provide up to 10 mA of controlled current output, and it faithfully follows a bipolar input waveform over its entire range of operation.

The basic operation of the ISOLATOR-10 Stimulus Isolation Unit is fairly simple. An analog input voltage is used to control a regulated current output. The current output is uncoupled from the system ground. Therefore, current flows only between the two outputs of the ISOLATOR-10, and does not flow to ground.

Axon Instruments also offers *another* Stimulus Isolation Unit, the ISOLATOR-11. The ISOLATOR-11 is triggered or gated by a TTL input, and produces a unipolar pulse. The amplitude, duration and polarity of the pulse are manually controlled by knobs and switches on the instrument.

Prior to using the ISOLATOR-10 Stimulus Isolation Unit for the first time, it should be tested as described in the *Functional Checkout* chapter (page 5) to verify that the instrument was not damaged during shipping.

FUNCTIONAL DESCRIPTION

INPUT AND OUTPUT FEATURES

The ISOLATOR-10 has the following inputs and outputs:

(1) **COMMAND INPUT.** Both the current intensity and waveform of the ISOLATOR-10 are controlled by an analog input to the COMMAND INPUT. The sensitivity of this input is RANGE/10 mA per volt of input. The input range is ±10.0 V; and therefore at an OUTPUT RANGE setting of 10, the maximal output current is ±10.0 mA.

(2) **POWER AND COMMAND INPUT.** The unit is powered by an external power supply, the PWR-1 Power Pack.

In place of the PWR-1 Power Pack, the unit can also be powered as well as controlled by an AxoWave signal generator from Axon Instruments. If the unit is being controlled through the POWER AND COMMAND INPUT connector the COMMAND INPUT BNC should be disconnected.

(3) **OUTPUT.** The output is provided as two 4-mm banana plug jacks. Each is isolated from ground.

GENERAL FEATURES

(1) **Output Range.** A rotary switch can be set to a full-scale range of either 1 mA or 10 mA. For safety in setting up the instrument, the switch can also be set to off.

(2) **Overload light.** The Overload indicator light is active when the unit cannot supply the commanded current to the preparation.

(3) **Power light.** The Power light, located near the power receptacle, is on when the unit is powered up.

FUNCTIONAL CHECKOUT

Prior to using the ISOLATOR-10 Stimulus Isolation Unit for the first time, it should be subjected to a functional checkout to ensure the proper functioning of the instrument. All units are burned-in and thoroughly tested at the factory before shipping. If any shipping damage or problems with the functional checkout are observed, please call the factory.

For the initial checkout, make sure that the power is OFF.

Equipment required:

Oscilloscope
10 kΩ resistor (provided)
Analog signal generator
One BNC cable

(1) Check the line voltage fuse on the PWR-1 power pack. See the Supply Voltage section on page 10. Alternatively, the ISOLATOR can be powered by an AxoWave signal generator.

(2) Connect the PWR-1 power pack to the ISOLATOR-10 and plug in the power pack.

(3) Make sure that the OUTPUT RANGE is set to OFF.

(4) Place a 10 kΩ, high wattage resistor between the output banana jacks of the instrument.

(5) Connect the analog output of the signal generator to the COMMAND INPUT, unless the unit is connected to an AxoWave.

(6) Connect an oscilloscope to the output jacks of the instrument. The inputs to the oscilloscope can be differential, or one output of the ISOLATOR-10 can be grounded to the signal ground of the oscilloscope (the shield of an oscilloscope BNC input).

(7) Set the gain of the oscilloscope to 2 V/division and the sweep speed to 2 ms/division.

(8) Set the analog signal generator to generate a square wave of 10 V at a frequency of 100 Hz.

(9) Turn the OUTPUT RANGE to 1 mA. A square wave of 10 V will appear on the oscilloscope. The command current is 1 mA (10V x 0.1 mA/V). To produce this current across a 10 kΩ resistance, the unit produces a 10 V pulse. Turn up the sweep speed and measure the rise time of the output pulse—it should have a 10 - 90% rise time of approximately 45 µs.

(10) Return the oscilloscope setting to 2 ms/division. Reduce the output of the signal generator to 5 V. Turn the OUTPUT RANGE to 10 mA. The recorded voltage should be 50 V, as the unit now produces 5 mA of current across the resistor. As the command voltage is turned up to 10 V, the OVERLOAD light may signal that the unit has exceeded its output compliance of 100 V.

(11) Turn the OUTPUT RANGE to OFF, and remove the 10 kΩ resistor. There is now a very high resistance path between the outputs. Most command amplitudes will cause an OVERLOAD condition, as the unit is unable to pass the required current.

REFERENCE SECTION — GENERAL INFORMATION

STIMULATION OF BIOLOGICAL TISSUES

Repetitive stimulation of biological structures requires a precise reproducible waveform. The objective is to produce a rapidly changing potential gradient across or along the axis of an electrically active structure. The following factors need to be considered.

(1) When the stimulating electrodes are at some distance from the target structure, the current flow across the target structure is determined locally by a complex circuit of resistances and capacitances. The experimenter has little control over this equivalent circuit, but can control the spatial and temporal distribution of the field at the electrodes. Therefore, placement of the electrodes can have an important effect on the efficacy of stimulation. For example, cells with processes are best stimulated by current flowing along the longitudinal axis of the processes.

(2) The impedance of electrodes and surrounding tissues can change with time. If the stimulator produces a constant voltage pulse across the stimulating electrodes, the actual voltage gradient across the target structure will change when the system impedance changes. A stimulator with a *constant-current* output will produce a constant-voltage gradient across the target structure, regardless of impedance changes in surrounding structures. Therefore, constant-current stimulators, such as the ISOLATOR-10, are generally preferred to constant-voltage stimulators.

(3) In constant-current stimulators, as the impedance of the preparation changes, the output voltage will change to maintain a constant current. High compliance stimulators extend the range of system impedances over which stimulation is effective. With a voltage compliance of 150 V, the ISOLATOR-10 can produce at least a 10 mA current across a load of 10 kΩ. If the stimulator overloads, try to decrease the system impedance by increasing the electrode size or by placing the electrodes closer to the target structure.

(4) Electrically active structures are generally best stimulated by rapidly changing electrical fields. Of stimulating waveforms, a square pulse is generally most effective at the lowest current amplitude. To ensure that the target structure receives a square pulse, stray capacitance should be eliminated, as described below in the discussion of the stimulus artifact.

THE STIMULUS ARTIFACT

The experimenter who records from the system being stimulated must contend with the stimulus artifact. A stimulus artifact is produced when the current flow from the stimulator creates a voltage gradient that is sensed by the recording electrode. The stimulus artifact can be minimized by the following strategies.

(1) Use an isolated stimulator. Stimulus artifacts are produced when the recording and stimulating electrodes share a common ground. The best solution is generally to uncouple the two systems by using *bipolar* stimulating electrodes driven by the ISOLATOR.

(2) Decrease the pulse duration. Often the recorded response follows the stimulus with a latency. There is a trade-off between stimulus amplitude and duration that will produce a stimulus artifact that is over before the response is recorded.

(3) Change the placement of the stimulating electrodes. A change in the placement of the stimulating electrodes will often have a dramatic effect on the stimulus artifact.

(4) Decrease capacitance coupling. Every system has some finite capacitance coupling to ground, and hence transient current will flow across that capacitance and be recorded by an amplifier referenced to ground. To decrease capacitance coupling:

(a) Decrease the length of leads between the ISOLATOR-10 and the electrodes. This is most readily achieved by locating the ISOLATOR-10 inside the Faraday cage.

(b) For the output leads, do not use a cable with a grounded shield.

(c) If using bipolar electrodes, minimize broadcast by using twisted pair leads.

GANGING TOGETHER ISOLATORS

The outputs of two or more ISOLATORS may be connected together to yield either increased current or increased waveform complexity. The outputs of the two ISOLATORS should be connected in parallel (+ pole to + pole and - pole to - pole), as shown below. This circuit will double the effective current range.

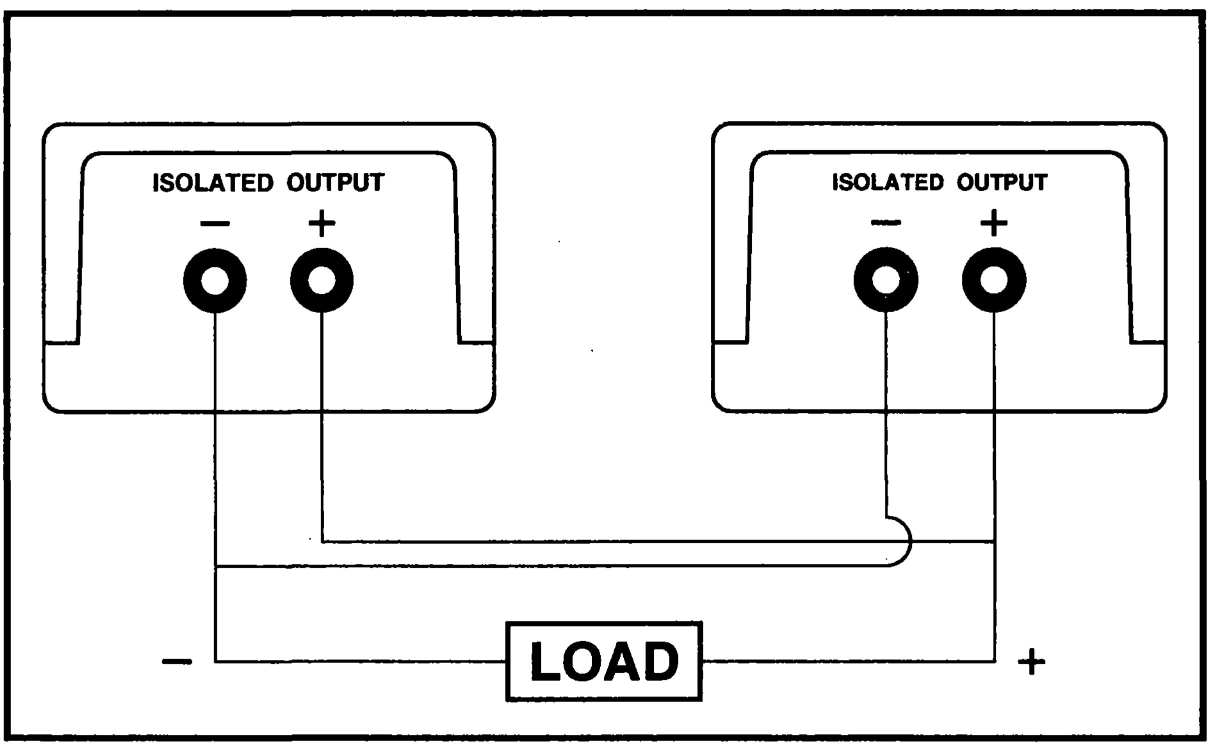

Figure 1. Two ISOLATORS in Parallel.

POWER SUPPLY VOLTAGE SELECTION AND FUSE CHANGING

Power supplied by the PWR-1 POWER PACK

The ISOLATOR-10 requires a regulated ±15 V power supply. This is provided by the Axon Instruments PWR-1 Power Pack. The PWR-1 operates from all international supply voltages. The two input ranges are:

1) 115 V : For 100 V_{ac} to 125 V_{ac} operation.

2) 230 V : For 200 V_{ac} to 250 V_{ac} operation.

Note: When shipped, the AC mains fuse and fuse holder are removed from the back of the PWR-1 Power Pack and placed in a bag taped to the power supply. All instruments shipped from Axon Instruments are set for a supply voltage of 115V_{ac}. If the supply voltage is **not** 115 V_{ac}, have a qualified electronics technician perform the supply voltage change procedure according to the following instructions:

To change the supply voltage setting:

1) **Disconnect the power cord**

2) Use a screwdriver or similar device to pry open the fuse holder, located beneath the line cord connector.

   For 115 V operation — slide out the tab connector and insert it so that "110 V" appears in the window of the fuse holder.

   For 230 V operation — slide out the tab connector and insert it so that "240 V" appears in the window of the fuse holder.

3) Reconnect the power cord.

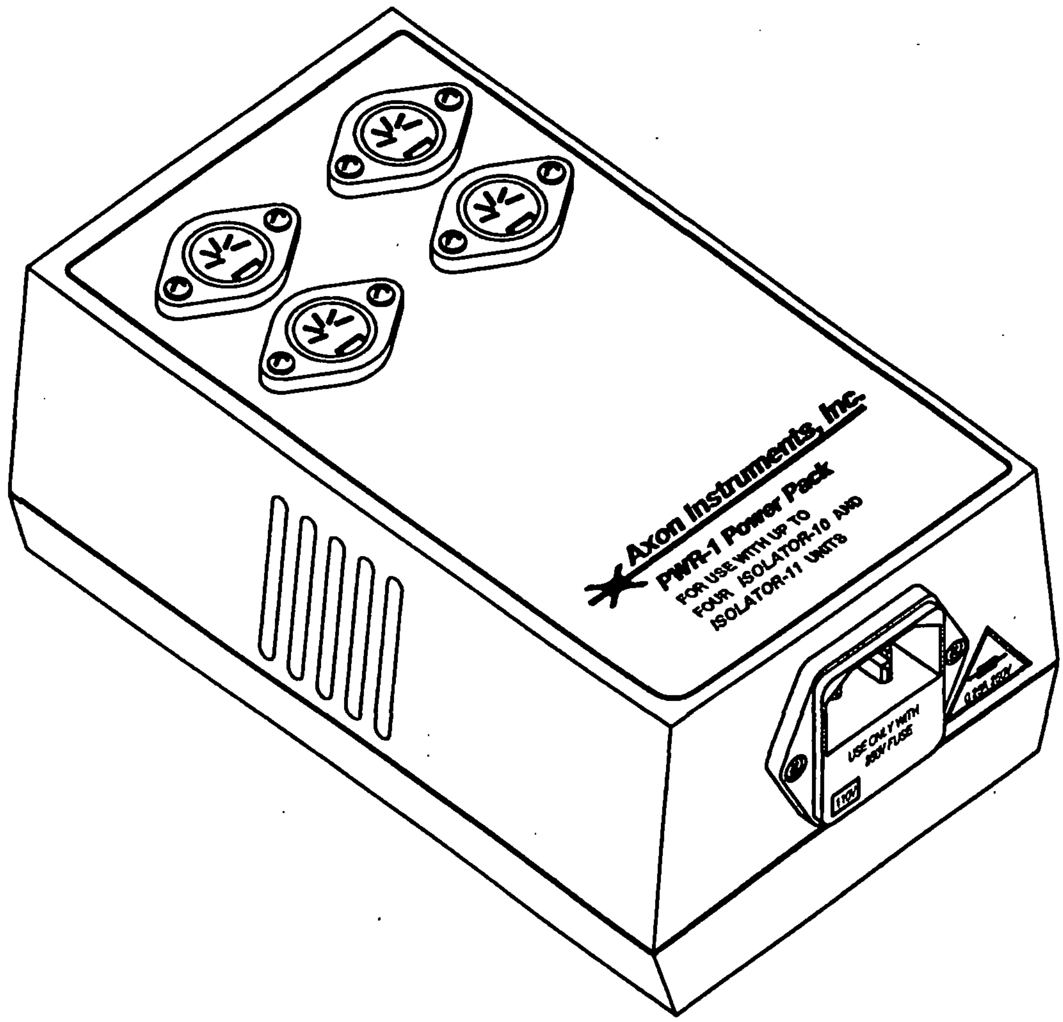

Figure 2. The PWR-1 Power Pack.

Changing The Fuse

The PWR-1 Power Pack uses a 500 mA, 250 V, slow acting, 5 x 20 mm fuse for both voltage ranges.

Before changing the fuse investigate the reason for its failure.

To change the fuse:

1) **Disconnect the power cord.**

2) Use a screwdriver or a similar device to pry open the fuse holder, located beneath the power line connector.

3) Replace the fuse with another fuse of the same rating.

4) Reconnect the power cord.

Power Supplied by the AxoWave Waveform Generator

The ISOLATOR-10 can also be powered and controlled by the AxoWave waveform generator. Both the regulated power supply voltages and the analog command voltage are supplied by the AxoWave unit through a single cable attached to the POWER AND COMMAND INPUT. If the ISOLATOR-10 is connected to an AxoWave unit, disconnect any external input to the COMMAND INPUT. Refer to the AxoWave manual for additional information.

GROUNDING AND HUM

Grounding

The ground line from the AC line connector is passed through the PWR-1 Power Pack to the output connector for use as the cable shield.

Hum

Line-frequency pickup, often referred to as hum or line-frequency noise, is a common problem in low-level recordings. Hum can occur not only at the line frequency but also at multiples of it.

The PWR-1 and its attached ISOLATOR unit, if used correctly, should not introduce hum into the recording system. The following procedures should be followed:

1) Locate the PWR-1 Power Pack outside the faraday cage.

2) Because it is powered by a regulated DC source, the ISOLATOR unit can be placed inside the faraday cage. The cable connecting the PWR-1 Power Pack to the ISOLATOR is shielded and will not act as an antenna.

3) The cables that provide power and provide the BNC command should not run near the AC line transformers of other equipment.

4) Try to ground auxiliary equipment from a single ground distribution bus.

SAFETY

The ISOLATOR-10 Stimulus Isolation Unit and the PWR-1 Power Pack are not intended to be used and should not be used in human experimentation.

EXPANSION

One PWR-1 Power Pack can supply power to any combination of four ISOLATOR-10 and ISOLATOR-11 Stimulus Isolation Units. Alternatively, the AxoWave waveform generator can power and control multiple ISOLATOR-10 or ISOLATOR-11 Stimulus Isolation Units.

REFERENCE SECTION — PRINCIPLES OF OPERATION

THE ISOLATION BARRIER

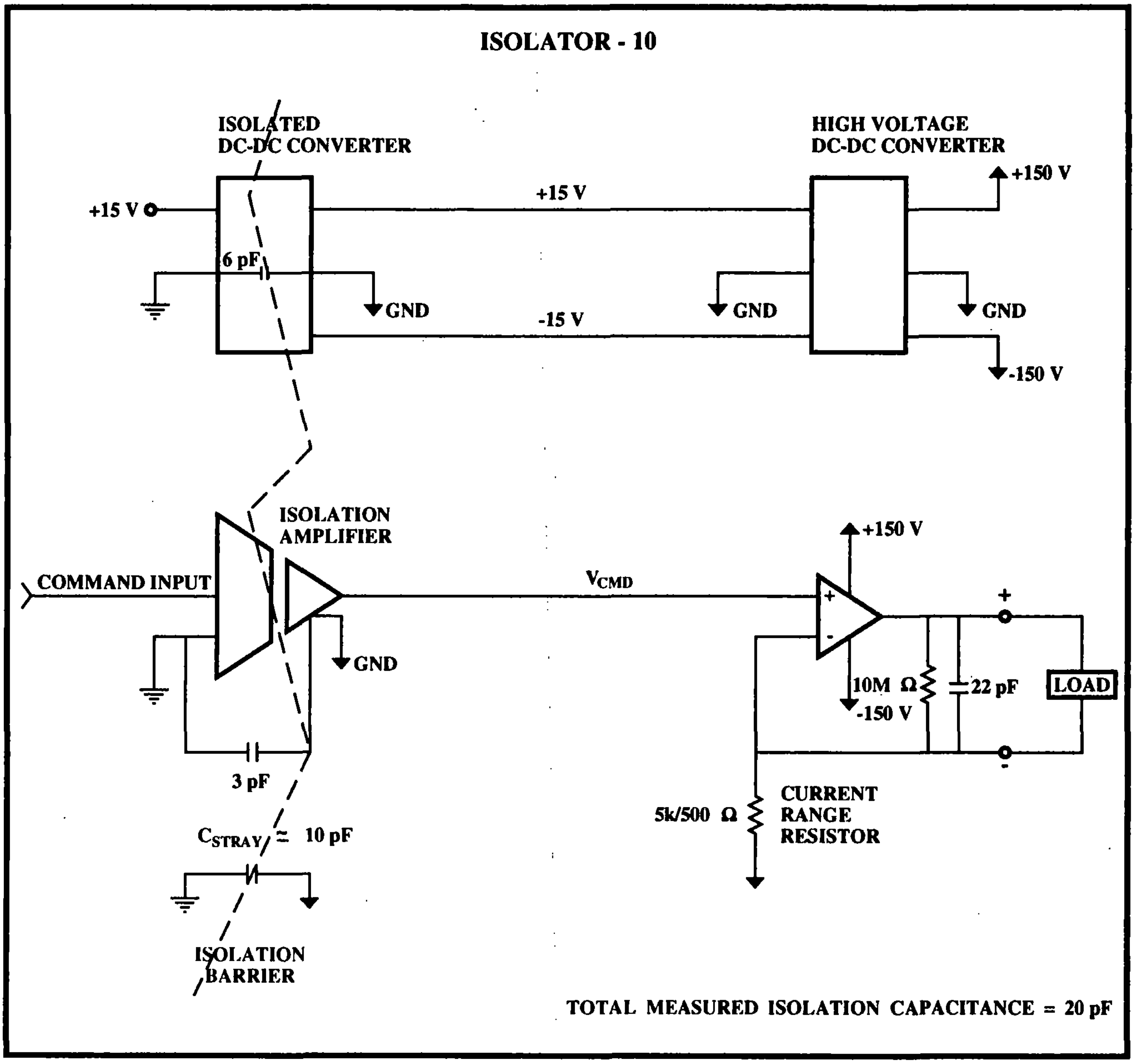

Figure 3. The Isolation Barrier of the ISOLATOR-10 Stimulus Isolation Unit.

Power Supply

As shown above, the ISOLATOR-10 contains two internal power supplies. An externally supplied 15 V source powers a very high isolation DC-DC converter that generates an isolated ±15 V. This isolated voltage powers a second DC-DC converter that produces the high compliance ±150 V.

Amplifier

The COMMAND INPUT is fed into an optically-coupled isolation amplifier. Its isolated output controls a high-compliance output amplifier. Switchable current-range resistors determine the output range. In parallel with the output, a feedback resistor limits the voltage output when no load is present. A capacitor in parallel attenuates high frequency noise on the output.

ISOLATION CAPACITANCE, MEANING, AND SOURCES

The ISOLATOR achieves a very high isolation while being powered by AC line voltage. One measure of merit when speaking of isolation is the impedance measured between the common of the input circuit and the common of the output of the device. This isolation impedance minimizes the stimulus artifact when recording in the stimulated preparation. It also prevents stimulus breakthrough to adjacent tissues. Both of these problems are caused by the stimulus current flowing to some common other than the common of the stimulator. The isolation impedance is modeled as a resistance with a parallel capacitor. If any impedance exists between the preparation and the input common, the stimulus current is given another return path to the current source. This stray impedance is in series with the isolation impedance, and therefore a high isolation impedance insures that most of the stimulus current will flow through the desired load. The isolation resistance of approximately $10^{11}\Omega$ makes a negligible contribution to the stimulus artifact. Isolation capacitance makes a more significant contribution.

The total isolation capacitance is actually the sum of many tiny parallel capacitors between the isolated and non-isolated commons. These stray capacitances can be lumped into two main sources, the stuffed circuit board and the internal cabling.

Both the circuit board and components that span the isolation barrier contribute to the isolation capacitance. The electrical components which cross the barrier are transformers and optocouplers. The transformers have capacitance between the primary and secondary windings, and the optocouplers have input-output capacitance due to the proximity of the photodiode to the LED and stray capacitance across the device package. The dielectric material of the printed circuit board creates an additional stray capacitance between the input and output commons on the board. These capacitances typically total 13 pF.

The second source of stray capacitance is the internal cabling. Panel controls and input/output connectors require a certain amount of cabling inside the enclosure, and performance specifications require some of these cables to be shielded. Wires which connect to the isolated side of the circuitry pass by wires which connect to the non-isolated side and add to the isolation capacitance. If these wires are shielded the capacitance added between commons can become quite large. The problem is further aggravated when the enclosure used is conductive. The wires that form the internal cables then share an additional capacitance to the enclosure itself. The ISOLATOR-10 is designed to minimize such strays, and the cabling typically contributes about 7 pF.

These two primary sources of isolation capacitance combine for a typical total of 20 pF in the ISOLATOR-10. These very high isolation impedances insure that both the stimulus artifact and stimulus breakthrough will be kept to a minimum.

HIGH FREQUENCY GROUND LOOP PHENOMENON

The ISOLATOR achieves its high isolation, in part, due to a high frequency DC-DC converter which generates the required isolated power. As described, the transformer which performs the power transfer has capacitance between its primary and secondary windings. If the output terminal of an

ISOLATOR is tied to the non-isolated common, the switching action of the DC-DC converter, along with the winding capacitance, causes high frequency current to flow in a ground loop.

The most likely case in which this occurs is when measuring across the output terminals with a scope probe hooked to one terminal and the scope ground lead hooked to the other. The scope ground lead grounds the output terminal to the input common through the scope. This creates a high frequency ground loop from the ISOLATOR input common, across the transformer capacitance, through the isolated supply lines, through the load resistance, and back through the scope to the input common.

A current flows through this loop due to the switching action of the DC-DC converter. For a given cycle of the converter, one half of the primary coil has a positive dV/dt and the other has a negative dV/dt relative to the isolated common. These voltage changes across any stray capacitance yields a net current flow between the non-isolated and isolated commons. This current flowing through the load resistance will appear as noise on the oscilloscope. As the switching of the DC-DC converter occurs at 400 kHz, this noise is well outside normal recording bandwidths.

To measure across the output terminals without creating a ground loop, use a differential input oscilloscope. If two high impedance scope probes are used, there is no path for the high frequency current to return to the input common, and therefore no current will flow.

TROUBLE SHOOTING

(1) General

If a problem is encountered please disconnect all instruments and probes from the ISOLATOR-10. Work completely through the Functional Checkout that commences on page 5. This can often uncover a problem in the set up of the ISOLATOR-10. If the problem persists, please call Axon Instruments for assistance.

(2) No response

Check the fuse in the PWR-1 power supply. Check the cable that connects the power supply to the ISOLATOR.

SPECIFICATIONS

All specifications at 25°C.

ISOLATOR-10 STIMULUS ISOLATION UNIT

ANALOG INPUT	
Signal Type:	Bipolar analog signal
Input Signal Range:	±10 V DC full-scale range
Safe Input Voltage:	±30 V
Input Impedance:	1 MΩ minimum
ANALOG OUTPUT	
Output Signal:	Bipolar current, isolated from ground
Output Current Range:	Selectable, ±1.00 mA or ±10.0 mA full scale
Output Voltage Compliance:	±100 V minimum loaded ±160 V maximum unloaded
Output Power:	1.0 W minimum
Leakage Current:	1.0 µA max. at 1 mA range 10.0 µA max. at 10 mA range
TRANSFER FUNCTIONS	
Analog Bandwidth:	40 kHz
Response Time:	10 - 90% response time to step command: < 10 µs
Transconductance Gain:	x0.10 mA/V at 1 mA range x1.0 mA/V at 10 mA range
Transconductance Accuracy:	±1.0% of full scale
ISOLATION	
Barrier Resistance:	100 GΩ, isolated output to ground, measured at 100 Hz
Barrier Capacitance:	25 pF max. 20 pF typical

NOISE

Output Noise:	**0.1 Hz - 100 kHz:**	0.90 μA_{rms}	5 $\mu A_{p\text{-}p}$
	0.1 Hz - 10 kHz:	0.50 μA_{rms}	3 $\mu A_{p\text{-}p}$
	0.1 Hz - 1 kHz:	0.17 μA_{rms}	1 $\mu A_{p\text{-}p}$

Peak-to-peak noise is estimated using a factor of six times the measured rms value. Values vary with load resistance.

OTHER FEATURES	
Overload Indicator:	Overload is detected if the output voltage reaches the limit of its compliance. LED display remains on for 200 ms minimum.
Power On:	LED display indicates that the ISOLATOR-10 is powered on.

CONNECTORS	
Command Input:	BNC. Center conductor connected to positive input; shield connected to ground
Output:	Two 4.44 mm banana jacks with screw terminals
Power and Command Input:	5 pin DIN female connector
ACCESSORIES PROVIDED	
	Power Connect Cable Manual 10 kΩ, 1 W resistor
POWER AND DIMENSIONS	
Voltage and Current:	+15 V at 170 mA -15 V at 18 mA
Dimensions:	*Box:* 5.9" (150 mm) long, 3.2" (80 mm) wide, 2.0" (50 mm) high *Box with connectors:* 7.4" (188 mm) long, 3.2" (80 mm) wide, 2.8" (72 mm) high
Net Weight:	13 oz. (373 gm)

PWR-1 Power Pack

ANALOG OUTPUT	
Output:	+15 V at 0.56 A -15 V at 100 mA
Output Power:	10 W
Output Noise:	4 mV_{p-p} in 100 kHz bandwidth 2.5 mV_{p-p} 60 Hz ripple at 90% of full load
POWER AND DIMENSIONS	
Line Voltage:	105-130 V_{ac} or 210-260 V_{ac}. User selectable by switch in fuse holder.
Line Frequency:	50-60 Hz
Power:	Draws 200 mA at maximum load
Fuse:	0.5 A slow 5 x 20 mm
Cabinet Dimensions:	5.7" (145 mm) long, 3.2" (80 mm) wide, 2.6" (65 mm) high
Net Weight:	1.5 lbs (681 gm)

REFERENCES

SUGGESTED READING MATERIAL

Geddes, L. A. & Baker, L. E. (1989) *Principles of Applied Biomedical Instrumentation*. New York: John Wiley & Sons.

Goldstein, N. N. & Free, M.J. (1979) *Foundations of Physiological Instrumentation, A Source Book with Experiments*. Springfield, Illinois: Charles C. Thomas.

Loeb, G. E. and Gans, C., (1986). *Electromyography for experimentalists*. Chicago: University of Chicago Press.

CIRCUIT DIAGRAMS

The ISOLATOR-10 Stimulus Isolation Unit was delivered with a complete set of circuit diagrams and a parts list. Please take care not to lose these because there is a charge for their replacement.

WARRANTY

We warrant every ISOLATOR-10 Stimulus Isolation Unit and PWR-1 Power Pack to be free from defects in material and workmanship under normal use and service. For 12 months from the date of receipt we will repair or replace without cost to the customer any of these products that are defective and which are returned to our factory properly packaged with transportation charges prepaid. We will pay for the return shipping of the product to the customer. If the shipment is to a location outside the United States, the customer will be responsible for paying all duties, taxes and freight clearance charges if applicable.

Before returning products to our factory the customer must contact us to obtain a Return Merchandise Authorization number (RMA) and shipping instructions. Failure to do so will cause long delays and additional expense to the customer. Complete a copy of the RMA form on page E-1 and return it with the product.

This warranty shall not apply to damage resulting from improper use, improper care, improper modification, connection to incompatible equipment, or to products which have been modified or integrated with other equipment in such a way as to increase the time or difficulty of servicing the product.

This warranty is in lieu of all other warranties, expressed or implied.

WARNING

Shipping the ISOLATOR-10 and PWR-1

The ISOLATOR-10 should be properly packaged before shipping, in order to avoid damage in transit.

In general, the best way to package the ISOLATOR-10 is in the original factory carton. If this is no longer available, we recommend that you carefully wrap the ISOLATOR-10 is in at least three inches (75 mm) of foam or "bubble-pack" sheeting. The wrapped ISOLATOR-10 should then be placed in a sturdy cardboard carton. Mark the outside of the box with the word FRAGILE and an arrow showing which way is up.

We do not recommend using loose foam pellets to protect the ISOLATOR-10. Instruments tend to migrate in loose pellet packaging and can be damaged if the carton is dropped by the shipper.

It is your responsibility to package the instrument properly before shipping. If it is not, and it is damaged, the shipper will not honor your claim for compensation.

RETURN MERCHANDISE AUTHORIZATION

RMA No. ____________________ **Date of RMA** ____________________

Shipping check list:

[ ] 1. Package instrument with at least 3 inches of packing material all around.
[ ] 2. Enclose a completed **copy** of this form.
[ ] 3. Write RMA number on outside of package.
[ ] 4. Pre-pay freight for door-to-door delivery.

Model ____________________ Serial No. ____________________

[ ] In warranty [ ] Out of warranty

Customer's purchase order No. ____________________
(not required for warranty repair)

DESCRIPTION OF PROBLEM: ____________________

____

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Customer's Shipping Address:
Name ____________________
____
____
____
____
Phone (___) ____________________

Customers Billing Address:
Name ____________________
____
____
____
____
Phone (___) ____________________

Send completed form with merchandise to:

Axon Instruments, Inc.
1101 Chess Drive
Foster City, CA 94404
U.S.A.

Write RMA number on outside of package.

REVISION RECORD			
REV	DESCRIPTION	DATE	APPRVD
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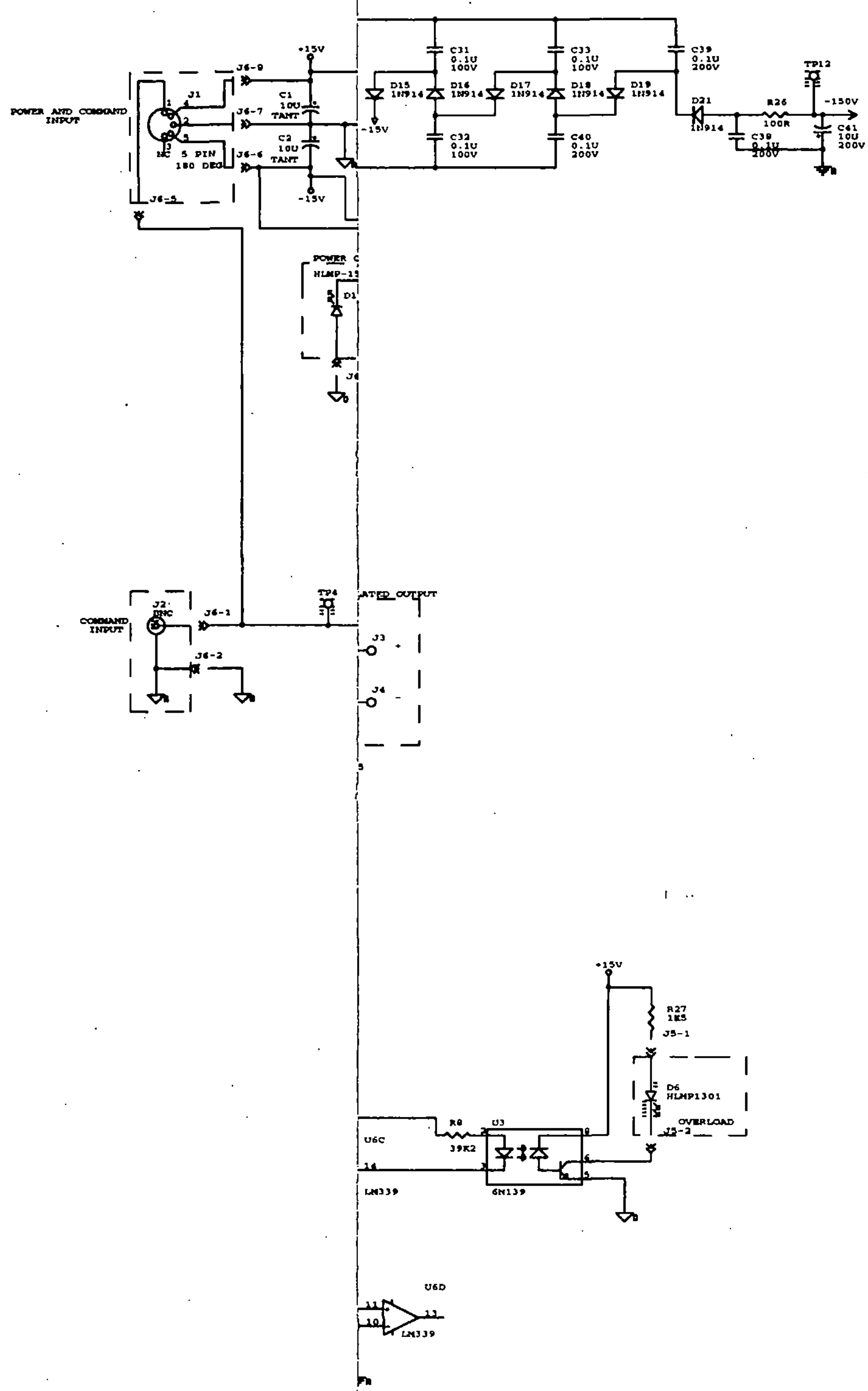
D	REWIRED J1. PER ECO #820.	11/16/92	JoAnna



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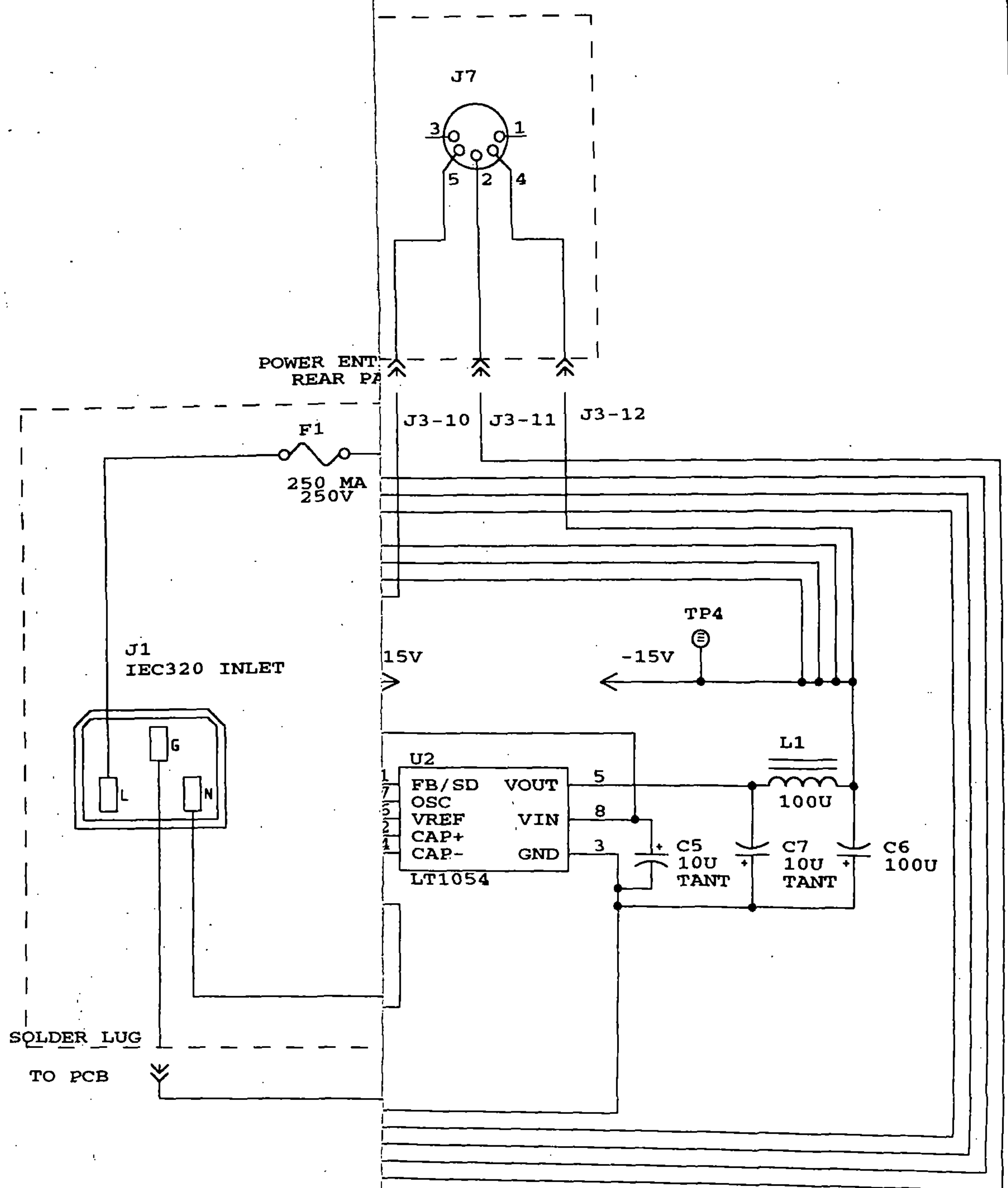

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