SERIAL # _____

MODEL SIU7

PHOTOELECTRIC STIMULUS ISOLATION UNIT/ CONSTANT CURRENT UNIT

INTENDED USE

An accessory stimulus isolation, constant current unit for isolating stimulating electrodes and providing constant current in research applications.

PLEASE
DO NOT LOSE
THIS MANUAL

ONE MANUAL IS SHIPPED with each instrument.

No "shortages" recognized.

Additional copies may be purchased at cost by owners of the instrument, but it is necessary to give the exact model and serial numbers.

The cost $_____

GRASS INSTRUMENT DIVISION
Astro-Med, Inc. **Tel. 401-828-4000**
600 East Greenwich Avenue • West Warwick, RI 02893

Astro-Med, Inc
GRASS®
INSTRUMENT DIVISION

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WARNINGS

READ THIS BEFORE OPERATING SIU7

The output voltage and available current of this Stimulus Isolation Unit when coupled to Grass Stimulator, is large enough to be lethal or cause burns particularly with long durations and high current settings.

The state of the art is such that the potential danger to human and animal subjects from sustained stimulation even at low levels is still not completely understood.

Grass Stimulator Models S9 and SD9 have built-in ground isolation circuits. All other Grass Stimulators should be used in conjunction with Grass Stimulus Isolation Units to reduce the effects of ground leakage currents.

Grass Instrument Division of Astro-Med, Inc. waives any responsibility whatsoever for any injuries incurred to the operator of this instrument or to any animal or human subject as a result of the improper use or abuse of this Stimulator.

MODEL SIU7 PHOTOELECTRIC STIMULUS ISOLATION UNIT
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M574G96

Astro-Med, Inc
GRASS®
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STIMULUS ISOLATION UNIT
MODEL SIU7

The Model SIU7 is designed to be used for peripheral nerve stimulation in nerve conduction and evoked potential studies.

The compact unit is optically isolated, which minimizes effects of capacitance and allows close placement to the preparation

SPECIFICATIONS

Isolation — Less than 5pF to ground

Input — Compatible with Grass S10SCM, S10DSCM, S44, S48, S88, S11 and S8800 Stimulators

Output — Constant current output from 0.001 to 15 peak milliamperes with excellent isolation from ground, thus reducing stimulus artifact to a minimum;
Output current tracks numbers on stimulator volts dial, within ±20%;
Off duty leakage current less than one nanoampere

Current Ranges — 4 ranges:1 to 15mA, 0.1 to 1.5 mA, 10 to 150 µA, 1 to 15 µA

Polartiy — Reversing switch included

Power — Replaceable lithium batteries
approximate lab life: 2 years

Physical size — 3" W x 4" H x 2" D
(7.6cm x 10.2cm x 5.1cm)
Weight: 2 lbs. (0.9kg)

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S236G96

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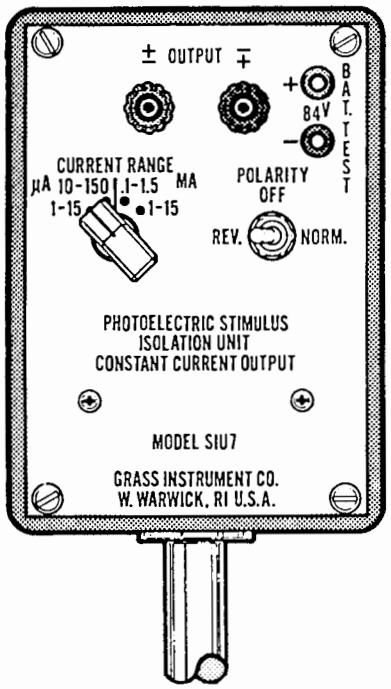
2 GENERAL CONSIDERATIONS

2.1 Design and Principle of Operation

2.1.1 The Grass SIU7 Photoelectric Stimulus Isolation Unit is an optically-coupled circuit designed to be connected in series with the output of an S10SCM, S10DSCM, S44, S48, S88, S11, S8800 and other compatible Stimulators and the stimulating electrodes to isolate the stimulus from ground, thus reducing stimulus artifact and provide constant current to the preparation. Precautions such as redundant isolation circuitry, short pulse durations and limited output current are incorporated in the SIU7.



MODEL SIU7D
PHOTOELECTRIC STIMULUS ISOLATION UNIT
FIGURE 2.1.1

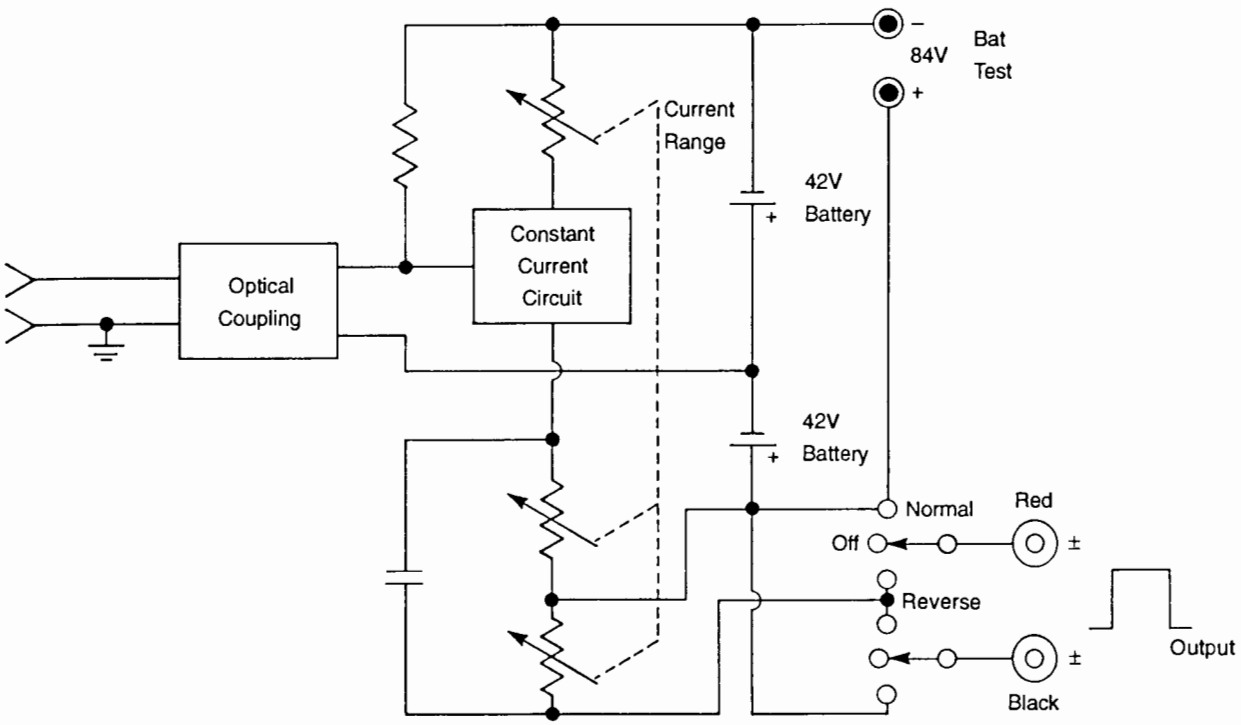
Additionally, on some models, an interlock is provided between the SIU7 and Stimulator which prevents the accidental use of the Stimulator without the SIU7 Isolation Unit. The source of energy for stimulus current is self-contained batteries. Because the unit is battery operated, it should be considered only for low energy applications in contrast to the Grass SIU5 series of isolation circuits which obtain the stimulus energy from the Stimulator itself. The SIU7 does not reproduce DC currents nor will it reproduce pulse durations above about 5 milliseconds.

2.1.2 The danger of tissue damage, burns and shock due to improper stimulation parameters cannot be overstressed. High currents, long pulse durations and high pulse repetition rates all contribute to the dangers mentioned.

It is important to realize that a safe stimulus current applied to gross surface electrodes of fairly large surface area, may cause severe tissue damage when passed through small electrodes such as needles. Current ***density*** and the length of time the stimulus is applied are the real measure of possible damage, not just the current level.

EXTREME CAUTION SHOULD BE EXERCISED BY OPERATING PERSONNEL, HOWEVER, SINCE CONSIDERABLE POWER CAN BE DELIVERED FROM THE STIMULATOR DIRECTLY. Only authorized personnel, knowledgeable in the use of stimulating devices who are cognizant of the problems associated with electrical stimulation, should be permitted to use the stimulator. The choice of parameters used for the application are the responsibility of the investigator.

2.1.3 A light emitting diode, driven directly from the output voltage of the Stimulator, causes a current to flow through the photosensitive transistor which is isolated from ground. The current, proportional to the stimulus voltage, appears as an input signal to the constant current circuit. Output current, which is controlled by the CURRENT RANGE switch and the Stimulator VOLTS dial, is taken from the constant current output circuit. A POLARITY switch is also included. Refer to Figure 2.1.3. Since the SIU7 is capacitively coupled to the output terminals it is never possible under any condition to get DC current flow through the preparation.



SIU7D BLOCK DIAGRAM
FIGURE 2.1.3

3 CONNECTION OF THE SIU7 TO STIMULATORS

3.1 Power for SIU7 Operation

3.1.1 The SIU7 receives operating power from two sources. Modulating signal power for the INPUT circuit (optical-coupling) is obtained from the Stimulator square wave output. Power for the OUTPUT circuit and stimulus current is obtained from two 42-volt batteries located within the SIU7 case. Test jacks are provided for checking battery voltages. See Section 6.1.1a.

3.1.2 The SIU7 is wired for the specific Stimulator to be used. With the Grass S10DSCM, S11 or S10SCM Stimulators, a four-pin connector with a safety interlock is provided. When used with Grass S44, S48, S88 or S8800, a coaxial connector is supplied.

3.1.3 On all Grass Stimulators, it is necessary to set the VOLTS MULTIPLIER switch to the X10 (SIU) position.

NOTE: Do not connect either of the SIU7 terminals to ground if stimulus isolation is desired.

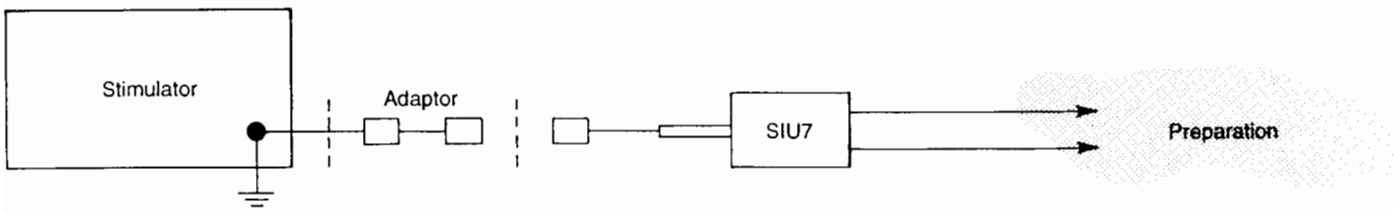
3.2 SIU7 Connection to Grass S88, S8800, S44 and S48 Stimulators

3.2.1 Connect the SIU7 cable to the OUTPUT connector on the Stimulator front panel. Set the VOLTS MULTIPLIER switch to the X10 (SIU) position.

NOTE: DO NOT connect the SIU7 to the S_1 S_2 monitor connector on the S88 Stimulator.

3.3 SIU7 Connection to Grass S10SCM, S11 and S10DSCM Stimulators

3.3.1 The SIU7 connects directly to these Stimulators with the cable provided. An interlock in the Stimulator connector prevents stimulus output voltage from the Stimulator when the SIU7 is not connected. This is an additional safety feature designed into these Stimulators.

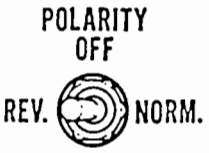


STIMULATOR CONNECTION
FIGURE 3.1.2

4 OPERATION OF THE SIU7

4.1 Output Voltage/Current Polarity

4.1.1 The POLARITY switch determines the polarity of the SIU7 output, independent of a ground reference, providing no grounds have been attached to the stimulating electrodes or their leads. In the NORMAL position, the red output terminal is positive with respect to the black output terminal.

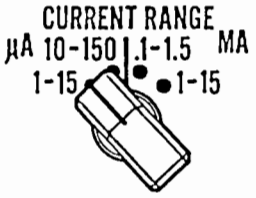


In the REVERSE position, the black output terminal is positive with respect to the red output terminal.

4.2 Current Ranges and Accuracy

4.2.1 The CURRENT RANGE switch on the SIU7 up to Model SIU7C provides two stimulus current ranges: 0.1 to 1.5 milliamperes and 1 to 15 milliamperes.

Beginning with the Model SIU7D, two additional ranges were added: 10 to 150 microamperes and 1 to 15 microamperes. The CURRENT RANGE switch is changed from a two-position toggle to a four-position rotary switch.



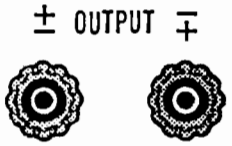
4.2.2 Control of current is made with the VOLTS dial on the Stimulator. Accuracy is about ±20% on all ranges under the following conditions:

Current Range	Maximum Electrode Impedance
1 to 15 mA	4,600 Ω
0.1 to 1.5 mA	46 kΩ
10 to 150 μA	460 kΩ
1 to 15 μA	4.6 MΩ

4.2.3 The SIU7 output is essentially constant current which means a high output impedance. If the electrode impedance is reasonably stable during an experiment, a constant voltage source produces constant current. However, certain types of electrodes and/or experimental conditions can provide a significant variation in electrode resistance. Under these conditions, a constant current source is more desirable. Refer to Section 8 for a detailed discussion on Constant Voltage vs. Constant Current Sources for Pulse Stimulation.

4.3 Output Binding Posts

4.3.1 The miniature, output binding posts on the SIU7A, SIU7B, and SIU7D accept either standard 0.081-inch (2 mm) diameter pin plugs or bare wires.



The SIU7C protected electrode terminals had no exposed conductors and were designed to accept only 1.5 mm diameter female connectors. Adaptors were supplied to convert male pins for use with the *SAFELEAD*™ terminal.

4.4 Leakage Current

4.4.1 The design of the SIU7 constant current circuit is such that there is always some small value of leakage current circulating in the output circuit with zero input voltage. This leakage current and any other DC fault current is not passed due to the capacitive coupling of the output pulse. The total leakage current is held to less than 10^{-9} amperes.

4.5 Biphasic Constant Current Stimulation

4.5.1 Symmetrical biphasic, constant current pulses may be delivered to a preparation as follows:

a. Connect one SIU7 to the S_1 output of an S88, S11 or S8800 Stimulator. See Figure 4.5.1.

b. Connect a second SIU7 to the S_2 output of the Stimulator.

c. Connect one electrode lead to the red (+) output binding post of one SIU7.

d. Connect the second electrode lead to the black (-) binding post of the second SIU7.

e. Connect the black (-) output binding post on the first SIU7 to the black (-) binding post of the second SIU7.

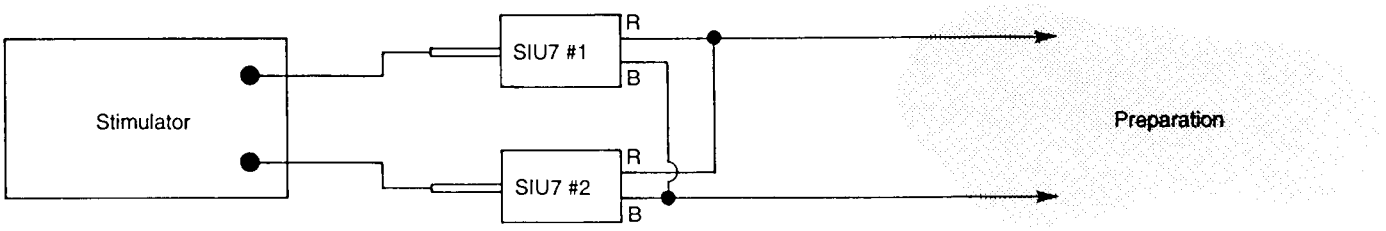
f. Connect the red (+) output binding post on the first SIU7 to the red (+) output binding post of the second SIU7.

g. Set the POLARITY switch on the first SIU7 to NORMAL.

h. Set the POLARITY switch on the second SIU7 to REVERSE.

NOTE: To avoid current cancellation, the S_1 and S_2 pulses should not overlap.

4.5.2 **Note:** When stimulating with low current through high impedance electrodes, the use of two SIU7 Units together at one preparation site is not recommended. Intervening tissue will affect the capacitance between electrode pairs and thus will divide the output current. Therefore, a discrepancy between the amount of current present in each SIU7 and actually delivered may result.



CONNECTION FOR BIPHASIC STIMULATION
FIGURE 4.5.1

5 WAVEFORM AND REGULATION

5.1 Waveform

5.1.1 Both the rise and fall time constants of the output pulse of the SIU7 (when measured with a CRO across a 1.0 kilohm resistor placed across the output terminals of the SIU7) are nearly identical to that of the Stimulator alone.

5.2 Regulation

5.2.1 The current deviation from a preset value, on either current range of the SIU7, is less than 5% for electrode impedances from zero to the maximum electrode impedances stated in Section 4.2.2.

6 SERVICE AND MAINTENANCE

6.1 Service

6.1.1 The SIU7 is completely solid-state and, except for periodic battery replacement, should not require frequent service. However, factory service is available and recommended if adjustments are necessary on the instrument. Make certain, however, that the malfunction is in the SIU7 and not in the Stimulator or other accessory equipment. Checking procedure is as follows:

a. If a malfunction in the SIU7 assembly is suspected, first check the two 42V batteries within the SIU7 by connecting a voltmeter across the battery test jacks. (The test jacks are wired across the two 42V batteries in series yielding a total open circuit of 84 volts.) To determine battery condition, however, it is best to measure the voltage while current is being drawn from the battery. See Section 6.2 for battery replacement information.

b. If difficulty is encountered, contact the Technical Support Services Department of Grass Instrument Division of Astro-Med, Inc. for further information.

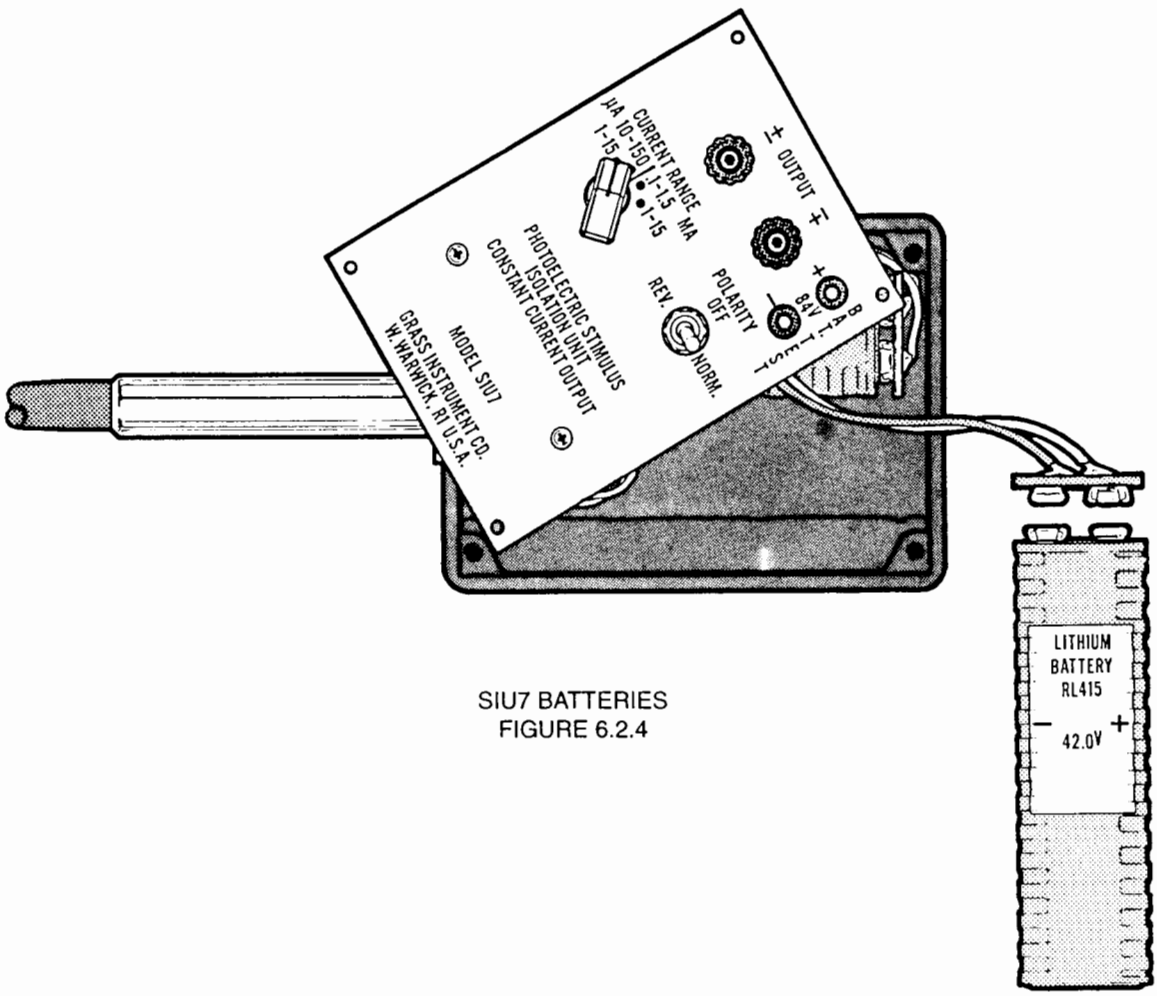
6.2 Battery Life and Replacement

6.2.1 The batteries in the SIU7 are two 42V Type RL415. Replacement batteries may be obtained from Grass Instrument Division of Astro-Med, Inc.

6.2.2 The SIU7 battery life is a function of duty cycle and output current. Therefore, whenever possible, use short durations and low output currents.

6.2.3 Batteries should be replaced when the voltage measured at the test jacks reads 70 volts or lower. The SIU7 will, however, continue to operate with reduced maximum output current with battery voltages as low as 54 volts.

6.2.4 When replacing batteries, disconnect the SIU7 from the Stimulator, remove the four screws securing the panel, and carefully lift the panel from the SIU7 case exposing the batteries. Replace the batteries, making sure that the polarized connectors are seated firmly on the batteries. Replace the panel. Refer to Figure 6.2.4 for further information.

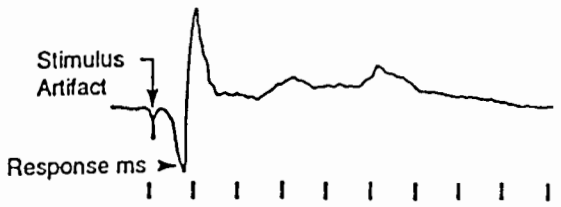


SIU7 BATTERIES
FIGURE 6.2.4

7 ARTIFACTS, STIMULUS ISOLATION, CONSTANT CURRENT AND MIXING

7.1 Stimulus Artifact

7.1.1 When a stimulus pulse is introduced to a preparation to evoke a response, an electrical artifact appears in the recording instrumentation as the result of the spread of the stimulus current to the recording electrodes. This artifact precedes the evoked response in time as indicated in the CRO record of Figure 7.1.1. The delay between stimulus artifact and the evoked response is dependent upon stimulation parameters and the characteristic properties of the preparation.

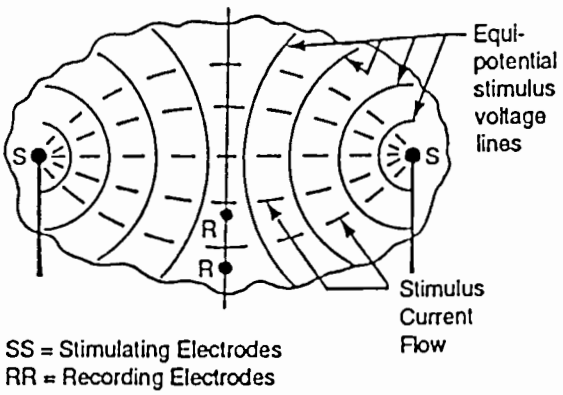


STIMULUS ARTIFACT
FIGURE 7.1.1

7.1.2 Some stimulus artifact is desirable to establish the time of stimulation. However, excessive stimulus artifact may obliterate the display of the desired response as is often the case when small evoked potentials are sought after a stimulus pulse of excessive amplitude or duration.

7.2 Sources and Reduction of Stimulus Artifacts

7.2.1 Excessive stimulus artifact results when the recording electrodes unavoidably measure the field distribution of the stimulus voltage through the preparation. The size of the stimulus and the proximity of the recording and stimulating electrode pairs contribute to the artifact amplitude. See Figure 7.2.1.



STIMULUS VOLTAGE FIELD DISTRIBUTION
FIGURE 7.2.1

NOTE: For optimum recording results, use independent stimulating and recording electrodes and keep recording electrodes perpendicular to stimulus current flow, if possible.

7.2.2 To alleviate stimulus artifact:

a. Isolate the stimulus pulse from ground and thereby reduce the circulating ground currents between the stimulator, preparation and recording instrument.

b. Space stimulating and recording electrodes as far from each other as possible and position them for maximum cancellation of field effects.

c. Use as small a stimulator pulse with as short a duration as is possible (approximately 0.1 milliseconds).

7.2.3 If the field distribution pattern of stimulus current causes substantial stimulus voltage between the recording electrodes, the resulting artifact cannot be avoided.

7.3 Stimulus Isolation

7.3.1 The S11, S44, S48, S88 and S8800 are compatible with Grass Stimulus Isolation Units Models SIU5, PSIU6, SIU7 and SIU8T.

7.3.2 Isolation of the signal from ground is most effective in the reduction of those artifacts due to ground currents arising from the stimulating and recording systems which are conductively joined by the preparation. When stimulus isolation is used during cortical stimulation, and in similar instances when a large volume of tissue surrounds closely spaced stimulating electrodes, the stimulus current sets up a three-dimensional field pattern, wherein the strength of the field usually decreases with the cube of the distance from the stimulating electrode. Isolation of the stimulus from ground in this instance is particularly effective because it reduces ground currents. Stimulus isolation is particularly necessary with multichannel recording. It is also valuable from the standpoint of safety, because it isolates the stimulating electrodes from ground. It has the further advantage of permitting direct addition of stimuli of either algebraic sign.

7.3.3 The high quality, general purpose Stimulators, S11, S44, S48, S88 and S8800 do not have "built-in" isolation and constant current circuits because these are not always desirable. The more limited Grass S9 series do have built-in isolation but not constant current output. In many applications, a very low output impedance of high power is required and is featured in the S11, S44, S48, S88 and S8800. Such an output will stimulate in solutions, will drive a long lead line or other capacitive loads without degrading the stimulus pulse. This is not possible with a high impedance source (constant current). It is possible and economical to drive isolated and high impedance circuits, but it is not economical to build low impedance outputs from high impedance sources. Furthermore, it is most often desirable to have the isolating and constant current circuits as close to the preparation as possible to preserve the isolation and fidelity of the stimulus. Thus, separate cabinets for these circuits are preferred. Furthermore, not all applications require SIUs and/or CCUs. The argument for this system is like that for high impedance probes for amplifiers.

The characteristics of the Grass SIUs permit the shielding of stimulating and recording electrode leads, thus reducing the capacitive coupling between recording and stimulus leads. For maximum reduction of artifact, the SIU should be placed as close to the preparation as is possible. Ideally, short unshielded leads to the electrodes should be used and every attempt should be made to reduce conduction and capacitance between the output leads, recording leads and ground to a minimum. If it is not possible to use short electrode leads, use 2-wire shielded low capacitance cable.

8 APPENDIX

8.1 Constant Voltage vs. Constant Current Sources for Pulse Stimulation

8.1.1 While the principal factor responsible for electrical stimulation is current, the amount of voltage required to produce this current is a function of the impedance presented by the electrodes and the surrounding tissue. This varies widely. Some procedures, such as the production of massive seizures in animals, utilize large, low impedance electrodes and yet require relatively high voltage. In the stimulation of single cells with microelectrodes, however, even though the current is in microamperes or less, the electrode impedance is high and consequently a high voltage is also required. In other cases, both voltage and current may be low.

8.1.2 "CONSTANT VOLTAGE" inherently means a low impedance source. In this case, the voltage waveform is preserved to the electrode. Current waveform and phase are only dependent on the load impedance. A low source impedance can be relied on to provide the source voltage at the electrode metal-liquid interface independent of cable and similar shunt capacitances.

8.1.3 "CONSTANT CURRENT" on the other hand infers a very high source impedance. Its drawback is that it is difficult, if not impossible, to preserve either current or voltage waveform values when cable, lead or similar shunt capacities are in the "real circuit". This is particularly true with currents below 10 microamperes and gets worse with smaller currents and consequently higher source and load impedances. On the other hand, "Constant Current" sources offer the advantage of being able to "preset" currents for higher currents and lower impedances, and to provide currents more independent of tissue and electrode impedances. "Constant Current" sources are especially practical with large currents (over 100 microamperes). For DC stimulation "Constant Current" is most advantageous and shunt capacities have no effects.

8.1.4 Everything is relative though, and ratio of source and load impedances (including the resistive and capacitive components) need to be evaluated for proper understanding of "Constant Voltage/ Constant Current". What is more important to recognize is that frequently the current or voltage that is measured in the lead wires is hardly the same as it appears at the interface of the tissue and electrode because of diffusion. Furthermore, it should be remembered that the important stimulus parameter is current density, i.e., amperes per unit area at the specific responding tissue.

$$\frac{\text{Amperes}}{\text{mm}^2}$$

APPENDIX
Sections 8.1 - 8.2

A general purpose Stimulator, such as the S11, S44, S48, S88 or S8800 must satisfy the greatest number of applications and represent the most desirable compromise between voltage and current requirements. A low source impedance is also required to drive such accessories as the SIU and CCU. The output, therefore, is a low impedance "constant voltage" emitter follower type. The output source impedance of the S11, S44, S48, S88 and S8800 Stimulators is 250 ohms on the X.01, X.1 and X1 positions of the VOLTAGE MULTIPLIER switch and can be selected to be 250 ohms, 100 kilohms or 25 ohms in one of the three X10 positions. The X10 (SIU) position is used in conjunction with all Stimulus Isolation Units and for most direct stimulating applications. The X10 (100 KΩ) position is used to provide a constant current output in the range of 0.15 to 1.5 mA, providing electrode impedances are 10 kilohms or less. The X10 (25Ω) position is useful when electrode impedances are low and/or when large stimulating currents are required. The S11, S44, S48, S88 and S8800 Stimulators can deliver up to 150 mA to the preparation. Currents over 150 mA are possible with a slight modification to the appropriate plug-in printed circuit board. Consult the factory for details.

8.1.5 Accessory units are available for connection to the output of the S11, S44, S48, S88 and S8800 Stimulators. ***The SIU5*** is a radio frequency (RF) type of isolation unit with an output impedance of approximately 1000 ohms. ***The SIU8T*** is a transformer coupled constant voltage isolation unit. No DC component will appear in the output. Maximum duration is about one millisecond as a near square wave. ***The PSIU6*** is an optically isolated Constant Current Unit providing currents from 0.1 microamperes to 10 milliamperes. ***The SIU7*** is an optically isolated Constant Current Unit having a maximum pulse duration of 5 milliseconds. ***The CCU1*** is a Constant Current Unit providing currents from 50 microamperes to 50 milliamperes but does not isolate the stimulator output from ground reference. However, the CCU1 can be used in conjunction with the SIU5 in which case the stimulus would be isolated from ground.

8.2 References

Gerken, G.M. A calibrated system for electrical stimulation of the brain. *Electroencephal. clin. Neurophysiol.*, 35: 652-653, 1973.

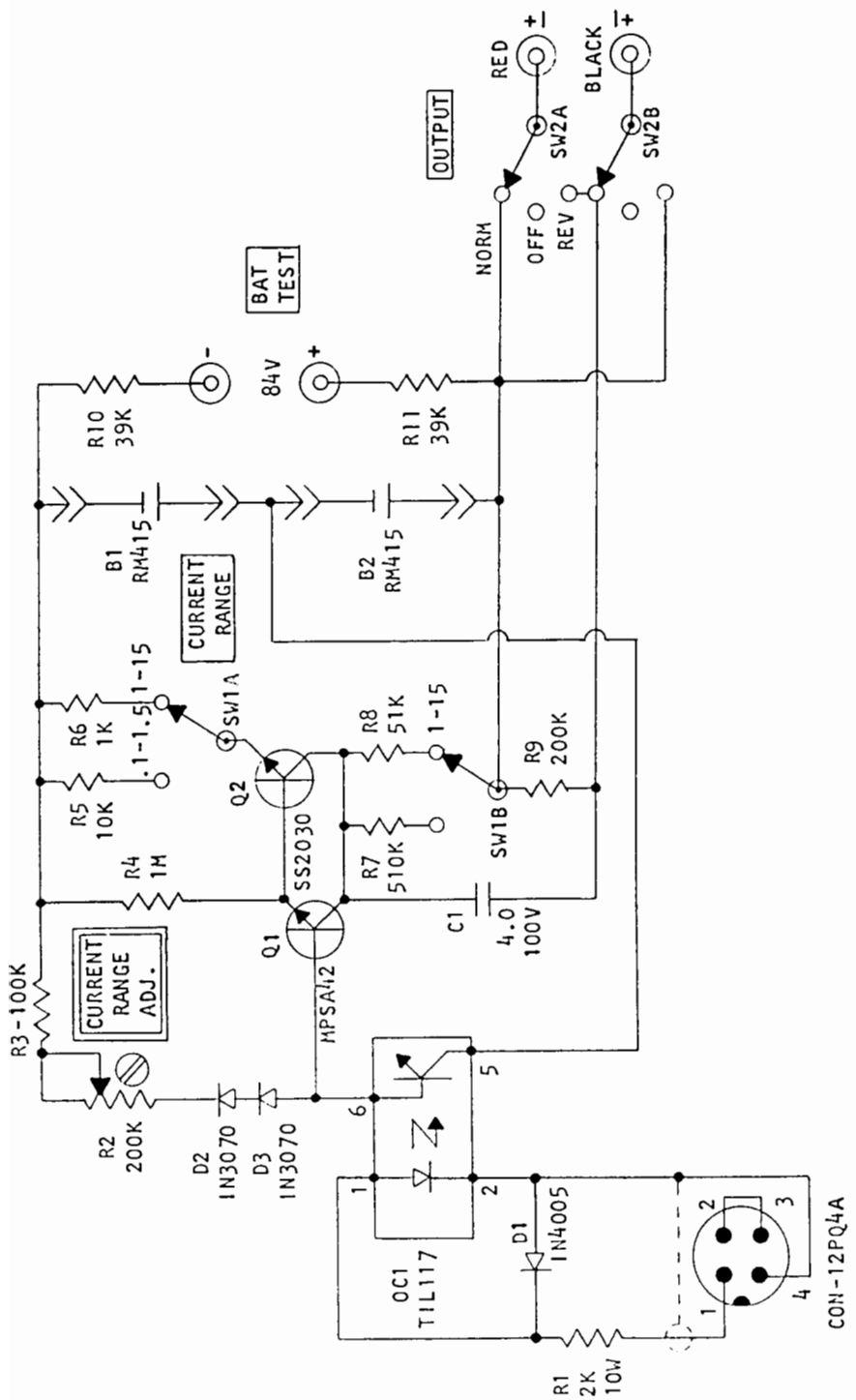
9 CIRCUIT DIAGRAMS

9.1 Explanation of Circuit Diagrams

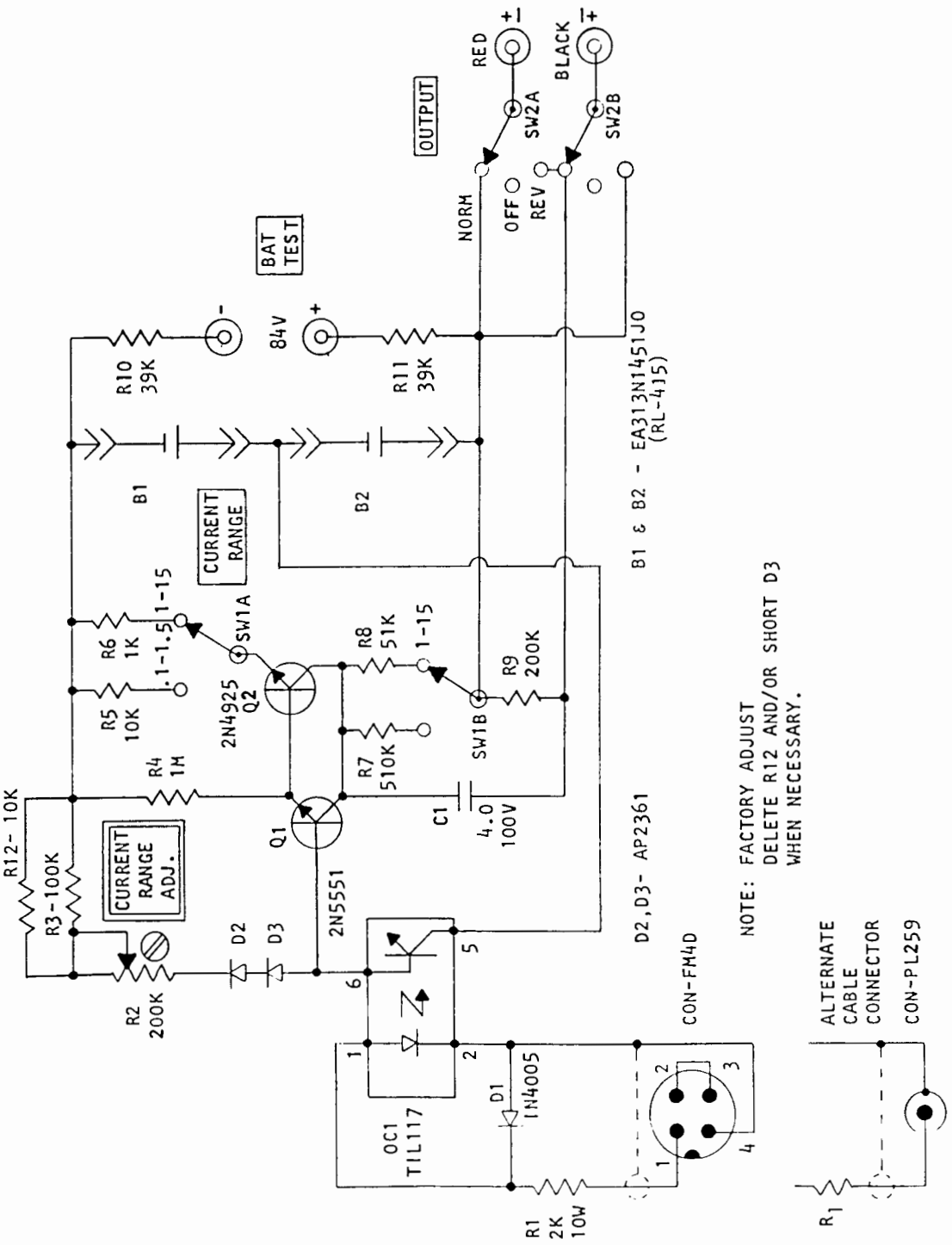
9.1.1 This manual contains all of the circuit diagrams with values of components for all models which have evolved from the basic design. The succession of design changes are indicated by the last letter subscript and are in alphabetical order. For instance, the basic design SIU7 is followed with a letter subscript such as A, B, C, D, etc. as in SIU7F which represents a change from the SIU7E. There may have been minor changes in a few components within any model with the same subscript letter. The circuit presented here with a certain subscript letter would be the last one prior to the introduction of a more substantial change, such as when the SIU7F supersedes the SIU7E. The last subscript circuit in this manual is the latest one available at the date of publication.

To identify the appropriate circuit, check the last letter subscript of your instrument model number and identify with the circuit print with exactly the same model number.

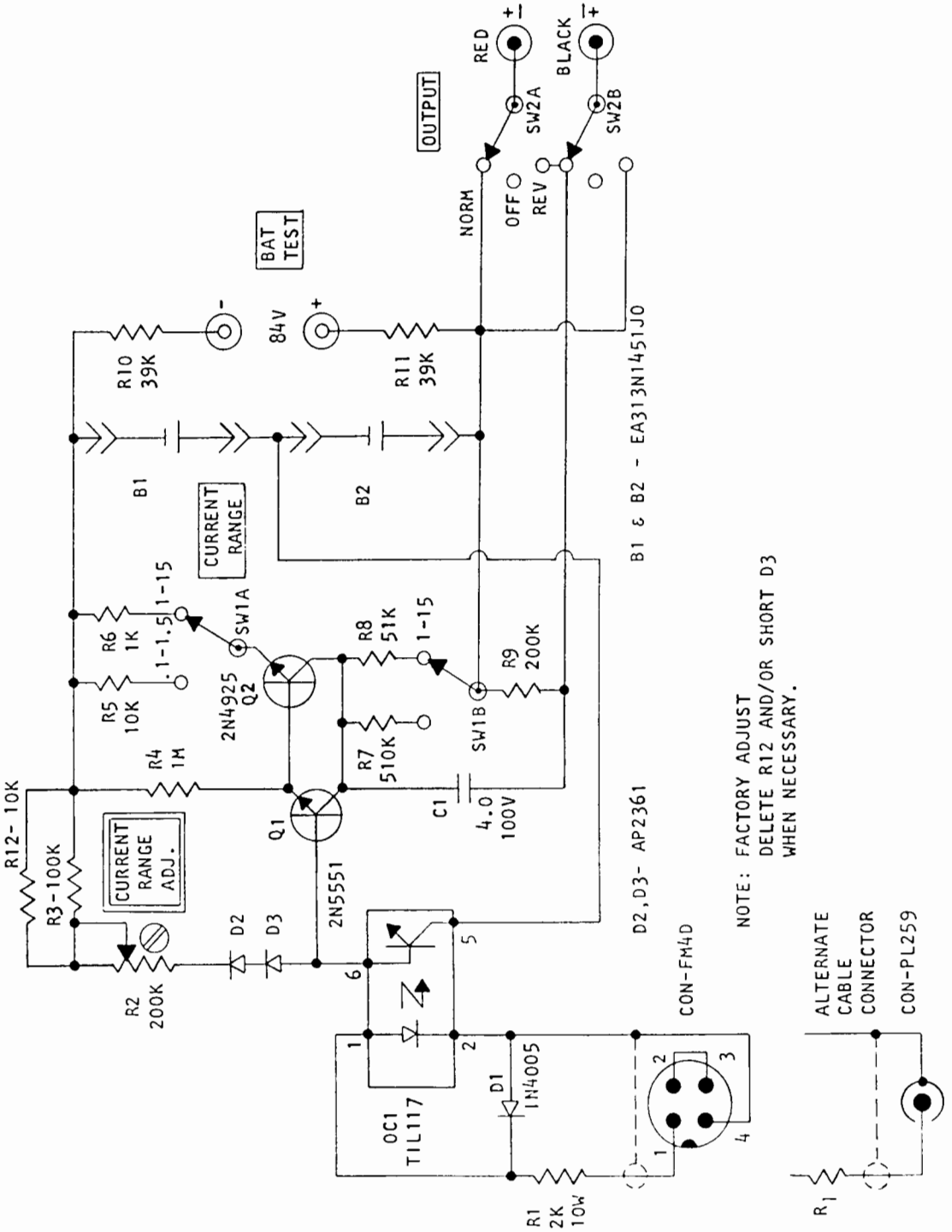
CIRCUIT DIAGRAMS
Section 9.1



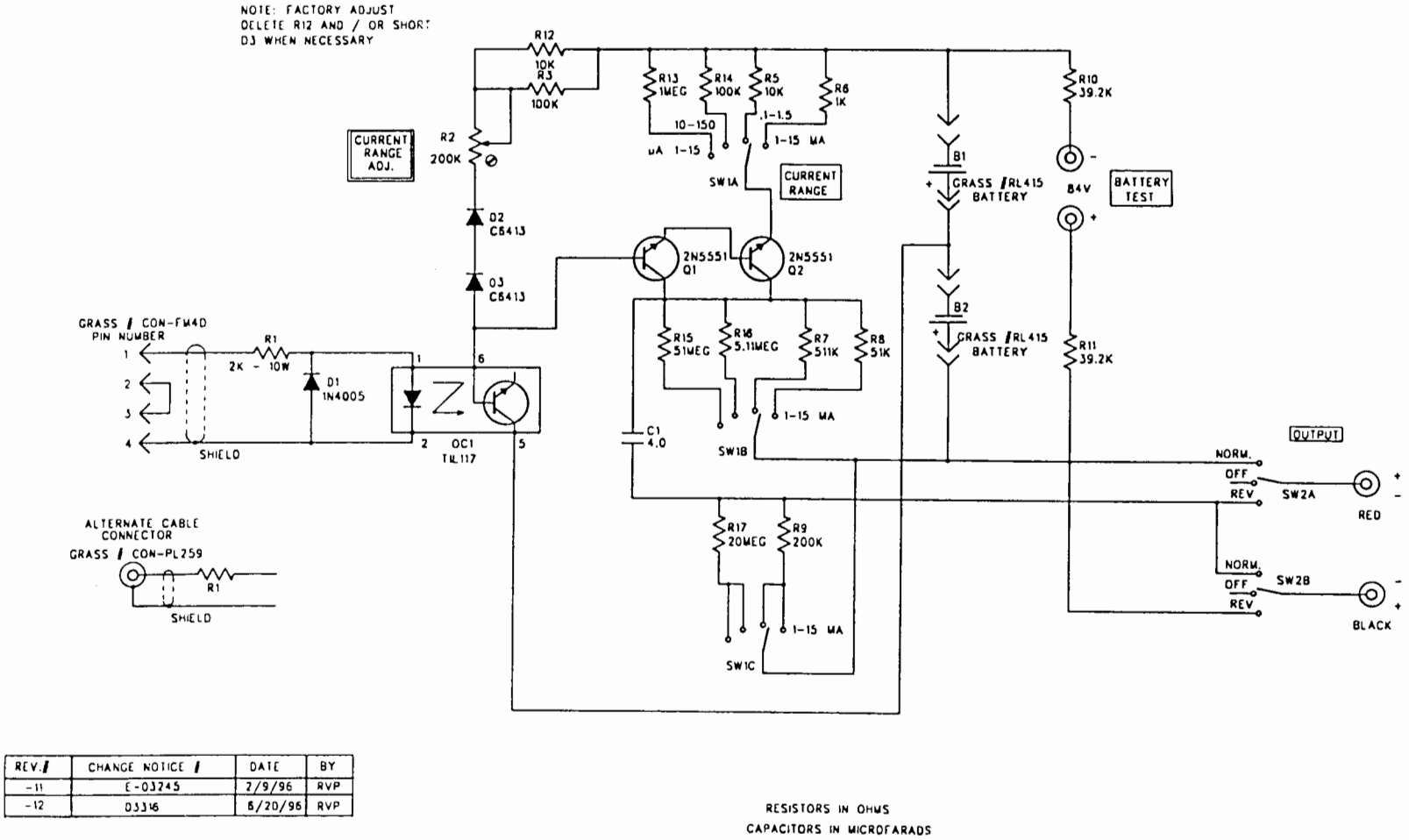
MODEL SIU7A STIMULUS ISOLATION UNIT CIRCUIT DIAGRAM - #50914-3
(Part 1 of 1)



MODEL SIU7B STIMULUS ISOLATION UNIT CIRCUIT DIAGRAM - #50914-9
(Part 1 of 1)



MODEL SIU7Ω STIMULUS ISOLATION UNIT CIRCUIT DIAGRAM - #50914-10
(Part 1 of 1)



REV. /	CHANGE NOTICE /	DATE	BY
-11	E-03245	2/9/96	RVP
-12	03316	8/20/96	RVP

RESISTORS IN OHMS
CAPACITORS IN MICROFARADS

MODEL SIU7D STIMULUS ISOLATION UNIT CIRCUIT DIAGRAM - #50914-12
(Part 1 of 1)