SERIAL # 95K00776

MODEL S48
SQUARE PULSE
STIMULATOR

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 $_____

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MODEL S48 SQUARE PULSE STIMULATOR
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MODEL S48 SQUARE PULSE STIMULATOR
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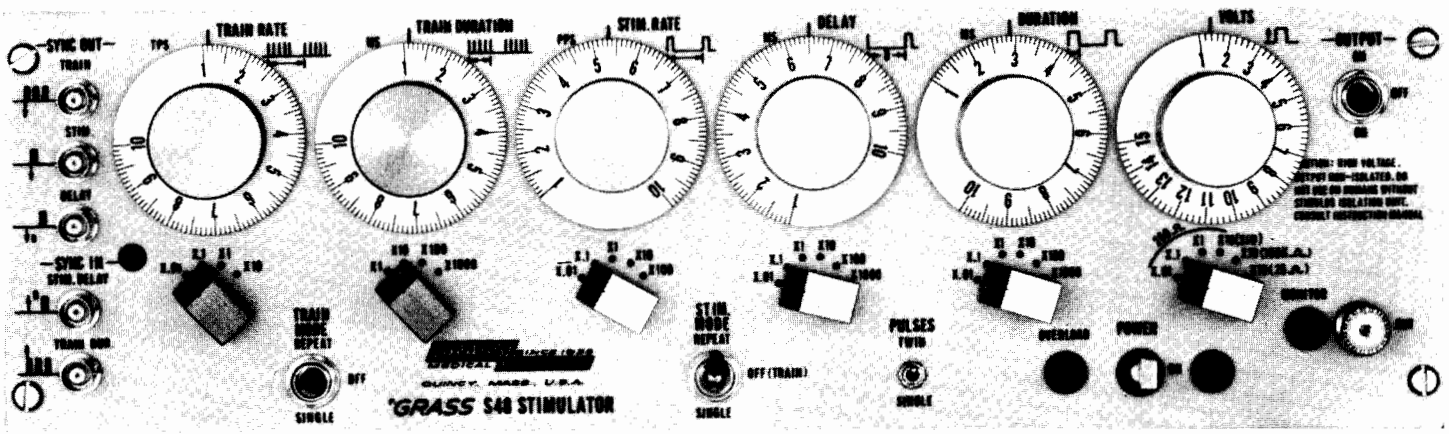
S48 STIMULATOR

Single, Repetitive or Trains
PC Compatible TTL Synchronization
External Analog Control of Timing



®*GRASS* MODEL S48 SPECIFICATIONS

DESCRIPTION

The S48 is a general purpose stimulator intended for nerve and muscle stimulation procedures with applications extending from single cell stimulation to entire muscle.

It can be set to deliver single, repetitive, twin pulses, trains of pulses and trains of twin pulses from its single output.

The constant voltage output is a positive nonisolated voltage and must be used with a companion stimulus isolation unit if human stimulation studies are performed. Companion Grass Stimulus Isolation Units are separately available for human stimulation and applications requiring isolation and/or constant current. Rackmount brackets supplied convert the table cabinet to rackmounting.

TRAIN RATE

- One/100 sec to 100 TPS (4 decades)
- Single or repetitive

TRAIN DURATION

- 1 ms to 10 sec (4 decades)

STIMULUS RATE

- One/100 sec to 1000 PPS (5 decades)
- Single or repetitive

DELAY

- 10 µs to 10 sec (6 decades)

DURATION

- 10 µs to 10 sec (6 decades)

SYNCHRONOUS OUTPUTS - TTL

- STIM, DELAY and TRAIN
- Front panel: 10 µs, 50 Ω
- Rear panel: 1 or 10 ms and TRAIN END

SYNCHRONOUS INPUTS - TTL

- STIM DELAY, TRAIN DURATION
- Trigger from rising or falling edge

REAR CONNECTOR (DB25S)

- All SYNC INPUTS and OUTPUTS
- External Analog Timing Control

VOLTS OUT

- 10 mV to 150 V (5 decades)
- Optional isolation units/constant current units available. Refer to separate specifications

PEAK OUTPUT CURRENT

- 150 mA with 1000 Ω load without isolation

OUTPUT IMPEDANCE

- 250 Ω nominal on all voltage ranges
- 25 Ω and 100 kΩ on highest range

AC POWER

- 115 or 230 volts, 50-60 Hz
- 70 watts peak; 15 watts standby

PHYSICAL SIZE

- 17-1/4" W x 5-1/4" H x 12-1/2" D (43.8 cm x 13.3 cm x 31.8 cm)
- 19" Rackmount brackets (48.3 cm) supplied
- Weight: 14 lb. 2 oz. (6.4 kg)

SEPARATE OPTIONAL STIMULUS ISOLATION UNITS

- SIU5: Constant Voltage Radio Frequency
- PSIU6: Constant Current Optical
- SIU7: Constant Current Optical
- SIU8T: Constant Voltage Transformer
- CCU1: Converts Constant Voltage to Constant Current, does not provide isolation

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SIU5 Stimulus Isolation Unit

featuring new ®*GRASS SAFELEAD*™ protected terminals

®*GRASS* MODEL SIU5 SPECIFICATIONS

APPLICATIONS

Use the Model SIU5 between a Grass Stimulator and the stimulating electrodes to minimize artifact. Excessive stimulus artifact tends to block recording instruments, often obscuring the recording of the response. Isolation of the stimulus signal from ground reference reduces the ground current between stimulating and recording systems (the primary source of stimulus artifact) and provides greater safety for direct human and animal stimulation. The SIU outputs can be connected in series so that stimulus voltage from various sources can be mixed even with the opposite polarities and introduced through a common pair of electrodes. One SIU will then be necessary for each stimulus output.

INPUT

Must be driven by S4, S8, S44, S48, S88, S11 or S8800 Stimulators. Powered by stimulus pulses – no additional power source is required. minimum power is required from stimulator to drive the SIU5 and thus reduce stimulus artifact to a minimum.

DESIGN

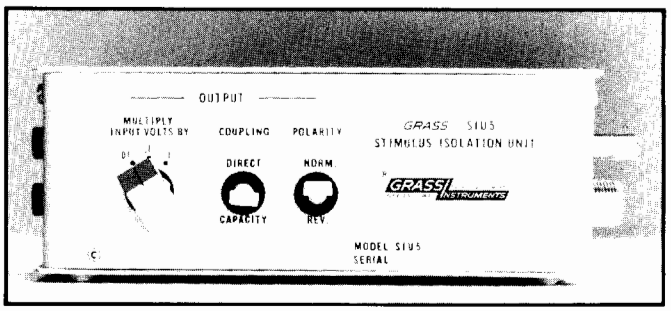
The SIU5 contains a radio frequency (RF) oscillator which is modulated by the Stimulator output. The oscillator is electromagnetically coupled via an RF transformer to a secondary coil whose impedance is balanced to ground at stimulus frequencies. The secondary voltage is demodulated by diodes and the RF filtered. Finally, the signal size is controlled by a decade attenuator. Input and output waveform are essentially identical, but the output voltage is nearly independent of ground. The output is not directly linear with input.

OUTPUT IMPEDANCE

Approximately 1000 ohms on X1 RANGE switch with the S8, S44, S48, S88, S11 and S8800, and 1500 ohms with the S4. On X0.1 and X0.01 SIU ranges, the output impedance is approximately 1000 ohms with all Stimulators. When combined with the Grass Model CCU1 Constant Current Unit, a constant stimulating current isolated from ground is obtained.

OUTPUT IMPEDANCE TO GROUND

Capacitive: balanced 25 pF to each output terminal.
Conductive: greater than 10^{12} ohms.



NOTE: The output terminals on this unit are recessed male 1.5 mm diameter (0.059-inch) *GRASS SAFELEAD*™ connectors conforming to the latest requirements of UL, CSA and FDA. Only recessed 1.5 mm diameter female leads will provide proper connection. These are available from Grass Instrument Company. Adaptors are provided with each unit to aid in altering existing leads.

COMMON MODE VOLTAGE

Including RF is reduced approximately 10 to 40 times over the range of 15 to 150 volts and 100 times over the range from 0.015 to 15 volts with the Model SIU5.

POLARITY

Reversible by a switch. No ground reference.

OUTPUT WAVEFORM

Square waves of Grass Stimulators are reproduced with negligible change on direct coupled (monophasic) operation. Capacity coupled operation can be selected by means of front panel slide switch.

VOLTAGE RANGE

10 millivolts to 150 volts on open circuit with the S4*, S8*, S44, S48, S88, S11 or S8800. For minimum stimulus artifact the Stimulator VOLTS MULTIPLIER switch should be at the lowest useable range and maximum volts scale used on the SIU5. Stimulator VOLTS control provides find adjustment. *15 millivolts with S4 and S8.

OTHER STIMULUS ISOLATION UNITS

PSIU6: optical isolated DC battery operated for small constant currents
SIU7: same as PSIU6 except capacity coupled for extra safety in clinical applications
SIU8T: transformer isolated, constant voltage

PHYSICAL SIZE: 2-1/2" x 3" x 7" Weight: 2-1/2 lbs. (6.4 cm x 7.6 cm x 17.8 cm) (1.1 kg)

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PSIU6 Stimulus Isolation Unit

featuring new ®*GRASS SAFELEAD*™ protected terminals

®*GRASS* MODEL PSIU6 SPECIFICATIONS

FOR USE ONLY ON ANIMALS – NOT FOR USE ON HUMANS

FOR PULSE & DC LOW CURRENT STIMULUS ISOLATION WITH HIGH IMPEDANCE ELECTRODES

ISOLATION – impedance to ground

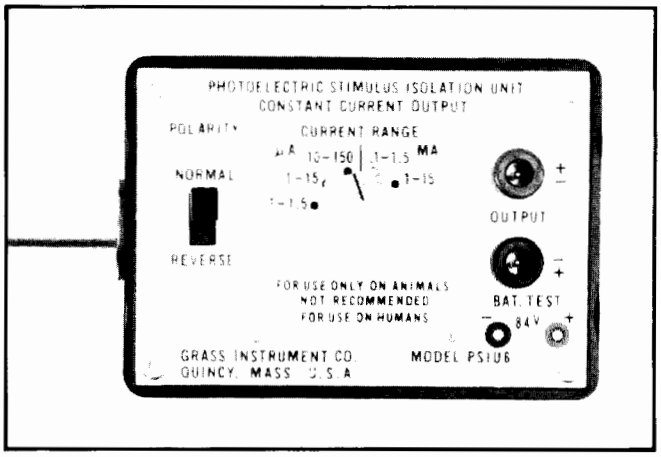
- Compact probe minimizes effects of capacitance (less than 5 pF to ground). For maximum reduction of stimulus artifact, the probe should be located as close to the preparation as possible.

INPUT

- Compatible with all Grass Stimulators without built-in stimulus isolation units, including the S4, S8, S44, S48, S88, S11 and S8800 square pulse Stimulators.

OUTPUT

- **The output terminals on this unit are recessed male 1.5 mm diameter (0.059-inch) *GRASS SAFELEAD*™ connectors conforming to the latest requirements of UL, CSA and FDA.** Only recessed 1.5 mm diameter female leads will provide proper connection. These are available from Grass Instrument Company. Adaptors are provided with each unit to aid in altering existing leads.
- Constant current output from 0.1 micro-amperes to 15 milliamperes with excellent isolation from ground, thus reducing stimulus artifact to a minimum.
- Output current of PSIU6 tracks numbers on stimulator volts dial within 20%.*
- Off duty leakage current less than one nanoampere.



- Current ranges*

0.1 μA	to	1.5 μA
1.0 μA	to	15.0 μA
10.0 μA	to	150.0 μA
0.1 mA	to	1.5 mA
1.0 mA	to	15.0 mA

POWER

- Powered by replaceable batteries with approximate lab life of 2 years when used under normal conditions at low duty cycle. Polarity reversing switch included.

OTHER STIMULUS ISOLATION UNITS

- SIU5: general purpose, RF coupled constant voltage output
- SIU7: same as PSIU6 except capacity coupled for extra safety in clinical applications
- SIU8T: transformer isolated, constant voltage

PHYSICAL SIZE

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

* When used with S4, S8, S44, S48, S88, S11 or S8800 Grass Stimulators.

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SIU7 Stimulus Isolation Unit

featuring new ®*GRASS SAFELEAD*™ protected terminals

®*GRASS* MODEL SIU7 SPECIFICATIONS

FOR PERIPHERAL NERVE STIMULATION IN CLINICAL NERVE CONDUCTION & EVOKED POTENTIAL STUDIES

ISOLATION – impedance to ground

- Compact unit minimizes effects of capacitance (less than 5 pF to ground) and allows close placement to the patient.

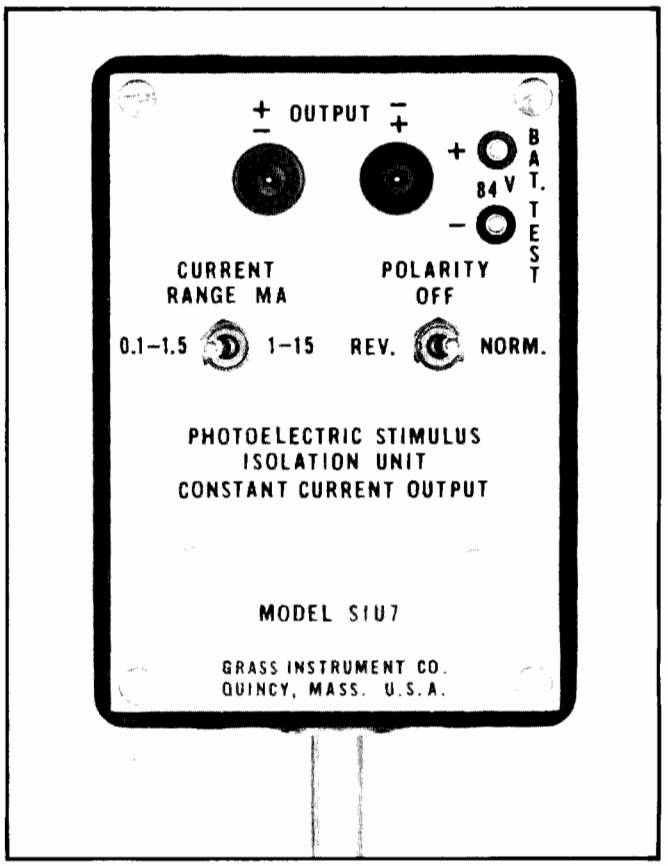
INPUT

- Compatible with S10SCM, S10DSCM, S4, S8, S44, S48, S88, S11 and S8800 Stimulators.

OUTPUT

- **The Output terminals on this unit are recessed male 1.5 mm diameter (0.059-inch) *GRASS SAFELEAD*™ connectors conforming to the latest requirements of UL, CSA and FDA.** Only recessed 1.5 mm diameter female leads will provide proper connection. These are available from Grass Instrument Company. Adaptors are provided with each unit to aid in altering existing leads.
- Constant current output from 0.1 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.
- Two peak current ranges* –
  0.1 to 1.5 milliamperes
  1.0 to 15.0 milliamperes

* When used with S10SCM, S10DSCM, S44, S48, S88, S11 or S8800 Grass Stimulators.



POWER

Powered by replaceable batteries with approximate lab life of 2 years when used under normal conditions. Polarity reversing switch included.

OTHER STIMULUS ISOLATION UNITS

- SIU5: general purpose, RF coupled constant voltage output
- PSIU6: optical isolated DC battery operated for small constant currents
- SIU8T: transformer isolated, constant voltage

PHYSICAL SIZE

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

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SIU8T Stimulus Isolation Unit

featuring new ®*GRASS SAFELEAD*™ protected terminals

®*GRASS* MODEL SIU8T SPECIFICATIONS

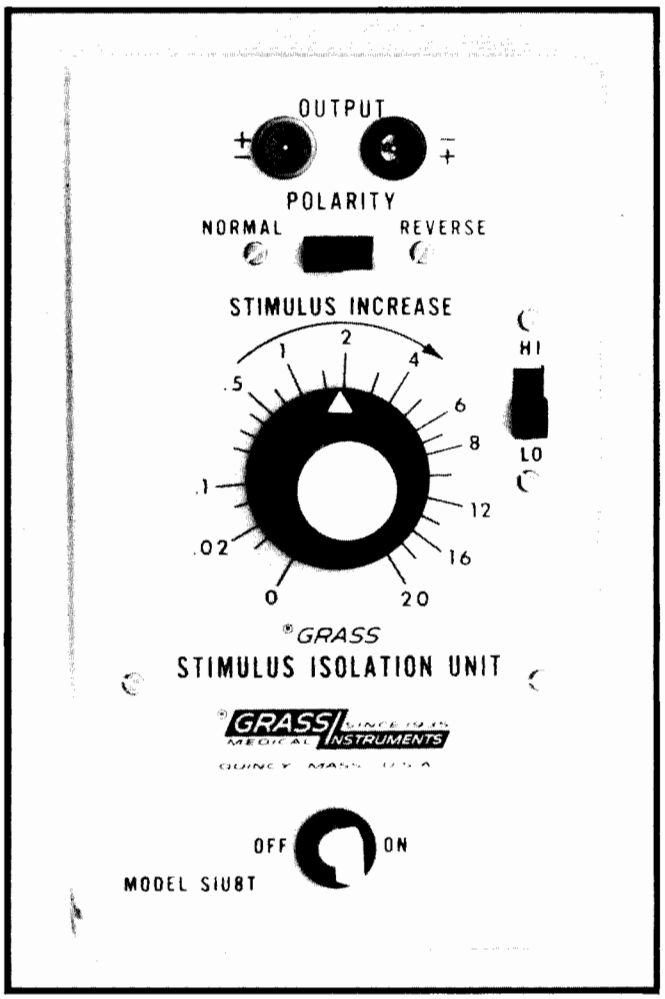
TRANSFORMER COUPLED

ISOLATION – impedance to ground
- Resistance 10^{12} ohms
- Capacitance 33 picofarads

INPUT
- From S4, S44, S48, S88, S10SCM, S10DSCM, S11, S8800 Stimulators
- Up to 1 millisecond square wave

OUTPUT (with 3 kilohm load)
- **The output terminals on this unit are recessed male 1.5 mm diameter (0.059-inch) *GRASS SAFELEAD*™ connectors conforming to the latest requirements of U_L, CSA and FDA.** Only recessed 1.5 mm diameter female leads will provide proper connection. These are available from Grass Instrument Company. Adaptors are provided with each unit to aid in altering existing leads.
- When driven from above Stimulators
  200 volts peak (HI output)
  125 volts peak (LO output)
- 1600 Ω source impedance maximum
- Essentially constant voltage
- 20 microsecond rise/fall times
- 25% decay at 1 ms pulse duration
- Polarity reversing switch
- On-Off switch
- Continuously variable stimulus intensity
- HI-LO intensity switch

PHYSICAL SIZE
- 3-5/8" W x 2-1/4" H x 6-1/16" Long (9.2 cm x 5.8 cm x 15.5 cm)
- Weight: 2 lbs. (0.9 kg)
- Cable Length: 17 feet (5.1 m)



OTHER STIMULUS ISOLATION UNITS
- SIU5: general purpose, RF coupled constant voltage output
- PSIU6: optical isolated DC battery operated for small constant currents
- SIU7: same as PSIU6 except capacity coupled for extra safety in clinical applications

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Constant Current Unit

featuring new ®*GRASS SAFELEAD*™ protected terminals

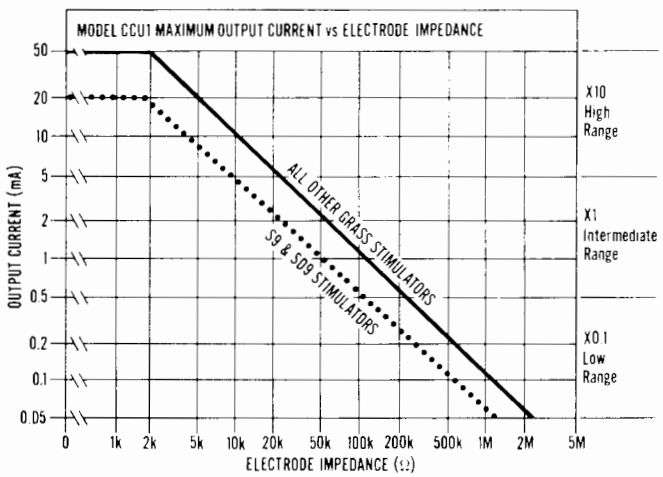
®*GRASS* MODEL CCU1 SPECIFICATIONS

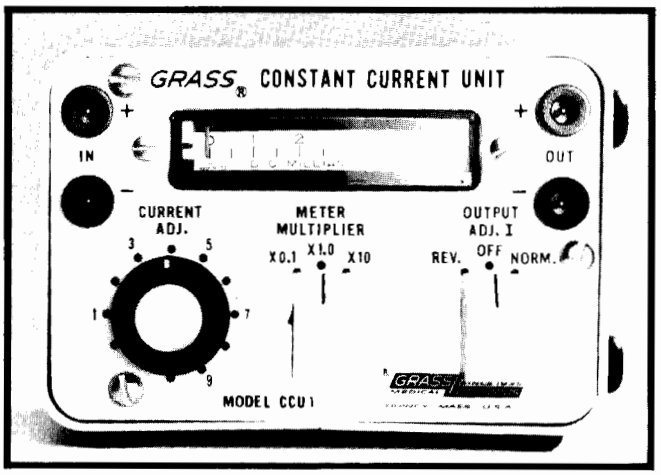
FOR CONSTANT CURRENT STIMULATION & DC LESION MAKING

- Current range: 50 µA to 50 mA, pulses or DC
- Meter indicates preset current
- Stimulus current variation less than 5%
- Current reversal switch
- Compatible with all Grass Stimulators

APPLICATIONS

The output of Grass Stimulators approximates constant voltage. In some cases, however, the significant stimulus parameter desired may be current. Certain types of electrodes and/or experimental conditions can produce a significant variation in electrode impedance. When such variations are expected, the Grass Model CCU1 can be used to convert constant voltage stimulation to constant current. Current is maintained constant by means of an "active" stabilized feedback circuit. The CCU1 is limited at high current levels by the power available from the stimulator. (See the figure below.) With electrode impedance of 1 megohm or higher, constant current with accurate wave shape is very difficult because of stray parallel resistances and capacitances. Applications include: cortical, depth, nerve and surface stimulation, clinical EMG stimulation, tissue lesion making with predetermined DC constant current, and other cases where changes in the selected value of stimulus current is not desired.





OUTPUT CONTROL

- **The output terminals on this unit are recessed male 1.5 mm diameter (0.059-inch) *GRASS SAFELEAD*™ connectors conforming to the latest requirements of U_L, CSA and FDA.** Only recessed 1.5 mm diameter female leads will provide proper connection. These are available from Grass Instrument Company. Adaptors are provided with each unit to aid in altering existing leads.
- Switch and meter allow precise adjustment of current through dummy resistance before stimulation. Meter monitors average current during stimulation.

OUTPUT CURRENT

- 50 µA to 50 mA in three decade ranges with maximum electrode impedance limited by stimulator source as shown on graph.

OUTPUT VOLTAGE (compliance)

- 100 volts maximum limited by stimulator source (determined by the output current and electrode impedance).

REGULATION

- Current deviation is less than 5% for electrode impedances from zero to the maximum electrode impedance as shown on graph.

MODE

- Rectangular pulses or steady DC as supplied from the stimulator or stimulator/SIU combination.

INPUT REQUIREMENTS

- Unidirectional rectangular pulse or DC source, 150 volts maximum.

PHYSICAL SIZE

- 4-3/4" W x 3-1/4" H x 5-1/2" D (12.1 cm x 8.3 cm x 14 cm) Weight: 1 lb. 12 ozs. (0.8 kg)

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2 INTRODUCTION

2.1 Safety Information

a. For use by qualified persons only.

b. Removal of the S48 Stimulator top cover may expose you to lethal voltages and other hazards. Observe labels and caution notices.

c. Never drop or push objects into the stimulator through cabinet slots, as it is possible to come in contact with hazardous voltages or cause damage.

d. If the cabinet is damaged, a shock hazard may exist. Unplug the stimulator and have it checked by a qualified person or contact Grass Instrument Company.

e. Never expose the stimulator to rain or moisture as this can be a potential cause of fire or shock hazard. If the S48 is exposed to moisture, unplug it and have it checked by a qualified person.

f. The S48 cabinet has slots or louvers for ventilation purposes to prevent component overheating.

1. Never cover the slots or louvers with cloth or any other material.

2. Avoid placing the S48 over radiators or heat registers.

3. Never place the stimulator in an enclosure unless proper ventilation is provided and all other related precautions taken.

g. Operate the S48 only on the power sources as printed on the panel. Damage may result from incorrect voltage.

h. The voltage/current output of this general purpose stimulator can be lethal or cause tissue damage if not used properly by persons trained in the application intended for this instrument.

i. Note the output of this general purpose stimulator is referenced to ground, i.e., one terminal of the output is ground. Also all sync inputs and outputs are also referenced to ground. To obtain stimulus potentials isolated from ground choose the appropriate Grass isolation unit.

j. If this stimulator is to be used on humans you must use the proper Grass Instrument Company isolation unit accessory. Contact Grass Instrument Company for application information in writing.

k. Determination of the safe levels of the stimulation for each application is the responsibility of the physician in charge.

l. The physician in charge, and the user are responsible for assuring safe stimulation levels will not be exceeded.

3 GENERAL FEATURES

3.1 Applications and Capabilities

3.1.1 The S48 Square Pulse Electrical Stimulator has six continuously variable parameters which can be set to deliver single, repetitive, twin pulses, trains of pulses and trains of twin pulses from its single output.

3.1.2 The constant voltage output is a positive, nonisolated voltage from a low impedance source and must be used with a companion stimulus isolation unit if human stimulation studies are to be performed. Several models of stimulus isolation units, both constant voltage and constant current types are available. See the specifications of SIU7, PSIU6, SIU5 and SIU8T units in this manual.

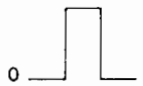
3.1.3 The S48 synchronous inputs and outputs and external control circuits have been carefully designed to provide the optimum synchronization and control characteristics when interfacing other peripheral instrumentation such as PC based acquisition systems, oscilloscopes, analyzers, etc. In addition to the individual front panel connectors, a multi-terminal rear panel control connector is supplied for convenient cabling.

3.1.4 The S48 is intended for nerve and muscle stimulation procedures with applications extending from single cell stimulation to entire muscle. The output circuit is capable of delivering appreciable power, especially when the S48 is used without a stimulus isolation unit. Some procedures such as field stimulation require considerable stimulus current, unobtainable from any stimulus isolation unit. The S48 has a FAIL-SAFE shut-down circuit that limits output current and prevents component damage in response to overload or accidental short circuiting of the output.

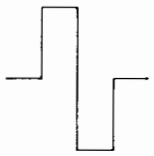
3.1.5 The S48 is supplied as a table-top unit and contains a tilt bail. However, rack-mounting at standard 19" (48.3 cm) is possible using the rackmount brackets supplied with the S48.

3.1.6 The S48 is a general purpose Stimulator and is not intended for operating room use. For human applications such as functional cortical mapping, and somatosensory procedures, the Grass Model S12 Stimulator should be considered. The S12 is a biphasic constant current stimulator with built-in isolation.

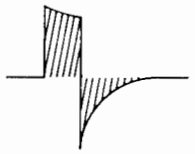
3.1.7 The S48 cannot deliver a true symmetrical biphasic pulse which is equal in positive and negative amplitudes and duration. However, if a Model SIU5 Stimulus Isolation Unit is used with the S48, a biphasic waveform can be produced which, although not symmetrical, does have a negative and positive component which is equal in effective energy (////// area under the curve) in terms of coulombs, if averaged over a sufficiently long period of time. It is possible to obtain a true symmetrical biphasic pulse by mixing the output pulses from two S48 Stimulators through two stimulus isolation units. See Section 8.9. Although the output of the S48 is constant voltage, it is possible to switch in a 100 kilohm resistor in the X10 (100KΩ) position of the VOLTS multiplier switch to obtain a 0.1 milliampere to 1.5 milliamperes (maximum) constant current output. See Section 5.9.



MONOPHASIC WAVEFORM
FIGURE 3.1.7a



TRUE BIPHASIC WAVEFORM
FIGURE 3.1.7b



EFFECTIVE BIPHASIC WAVEFORM
FIGURE 3.1.7c

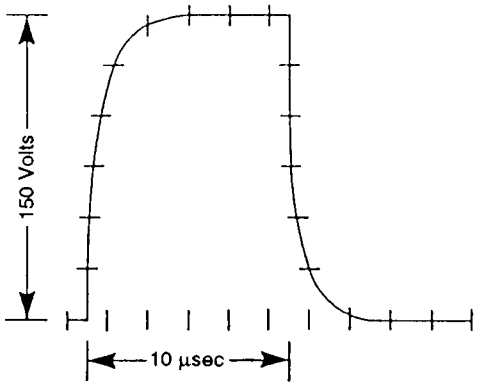
3.1.8 The S48 is compatible with all Grass Stimulators and Stimulator accessories, the SIU5, PSIU6, SIU7 and SIU8T Stimulus Isolation Units and the CCU1 Constant Current Unit. The specifications for these accessories have been included in this manual for your quick reference.

3.2 Accuracy and Waveform

3.2.1 All S48 timing parameters are accurate to within ±5%. The "open circuit" output voltage is also accurate to within the same tolerance. However, when driving low impedance preparations from the S48, the actual voltage delivered to the preparation will differ from the dial setting due to "loading" of the S48 output.

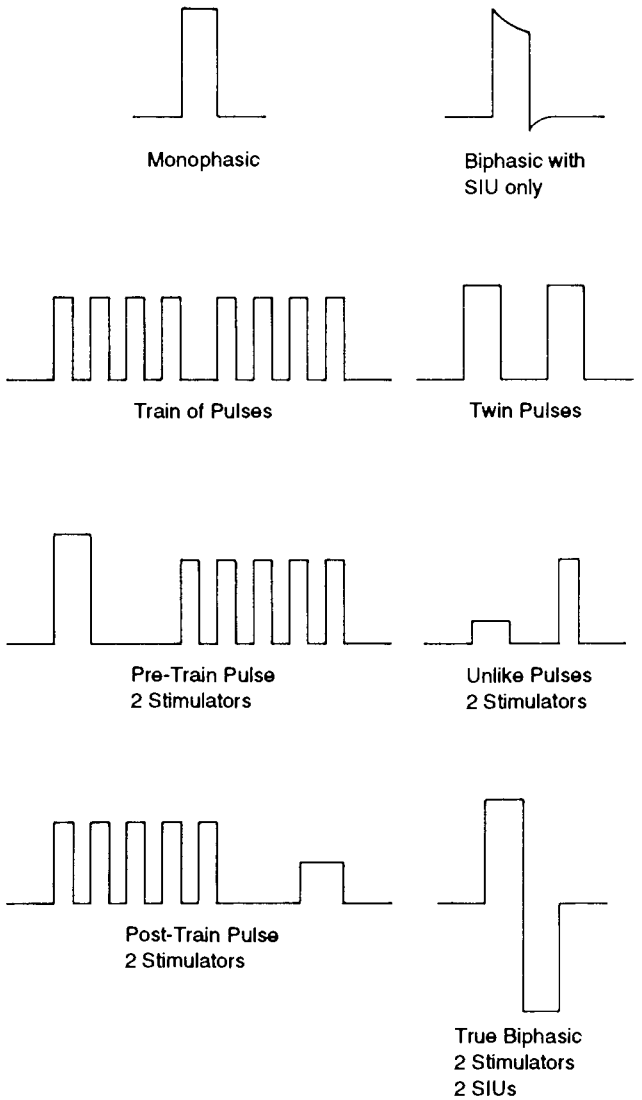
3.2.2 There is absolute independence of the timing parameters when the duty cycle (length of ON time to total period) is less than 50%.

3.2.3 Both the rise and fall times of the S48 output pulse are approximately 1.5 microseconds on all voltage ranges. Calibration of the duration is based on the average width of the pulse. Figure 3.2.3 illustrates the output waveform at a duration of 10 microseconds at 1000 PPS (pulses per second) and 150 volts.



PULSE WAVEFORM
FIGURE 3.2.3

3.2.4 Because of this accuracy, it is seldom necessary to monitor the stimulus. However, if complex waveforms are utilized, especially as generated from two stimulators, or until single stimulator operation is understood, monitoring the output with an oscilloscope is advised. See Section 8.4. Some typical pulse patterns from one or more S48s is shown in Figure 3.2.4.



TYPICAL STIMULUS WAVEFORMS
FIGURE 3.2.4

3.3 Line Voltage Requirements

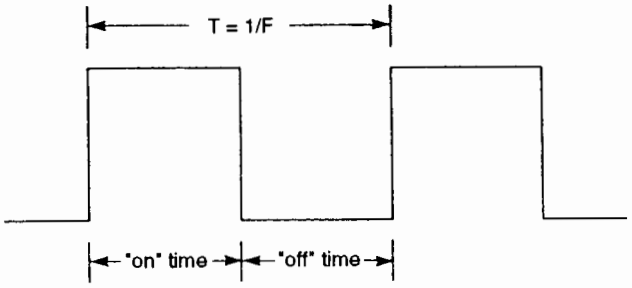
3.3.1 The S48 is wired to match the line voltage of the user. All domestic units are supplied for the standard 117 volt AC line and the S48 will operate properly from 105 to 130 volts AC. If specified at time of order placement, the S48 can be wired for 230 volt operation and will operate properly within a range of 210 to 260 volts. The line frequency must be 50 to 60 Hertz.

3.3.2 The S48 is fused with a 1-1/4 ampere SLO-BLO fuse for 117 volt operation, and with a 6/10 ampere SLO-BLO fuse for 230 volt operation. The maximum peak line current at 117 volts is 1.5 amperes, and at 230 volts is 0.75 amperes. This information is clearly labeled on the stimulator.

3.4 Duty Cycle

3.4.1 Duty cycle is defined as the ratio of the time the stimulus is "ON" to the total period or interval. 100% duty cycle occurs when a circuit is on continuously as with DC. Since the time from the start of one pulse to the start of the next pulse in seconds is the reciprocal of the "frequency" or PPS (Time = 1/Frequency), the DELAY and DURATION controls should not be set greater than about T=1/2F which is equivalent to 50% duty cycle.

Example: 50% duty cycle occurs if there is "on-off" symmetry as with a symmetrical square wave, where the "on" time (or pulse duration) is equal to the "off" time (or time between pulses) for one cycle. See Figure 3.4.1.



50% DUTY CYCLE
FIGURE 3.4.1

Since the maximum frequency selectable with the STIM RATE circuit is 1000 Hz, having a period of 1 millisecond, setting the DELAY and DURATION controls to less than 0.5 milliseconds (500 microseconds) will insure that 50% duty cycle will not be exceeded. If the DELAY circuit is not being used, simply set the DELAY controls for less than 500 microseconds. (Set DELAY multiplier to X.01.) It is important to note that duty cycles greater than 50% are seldom used in physiological stimulation procedures.

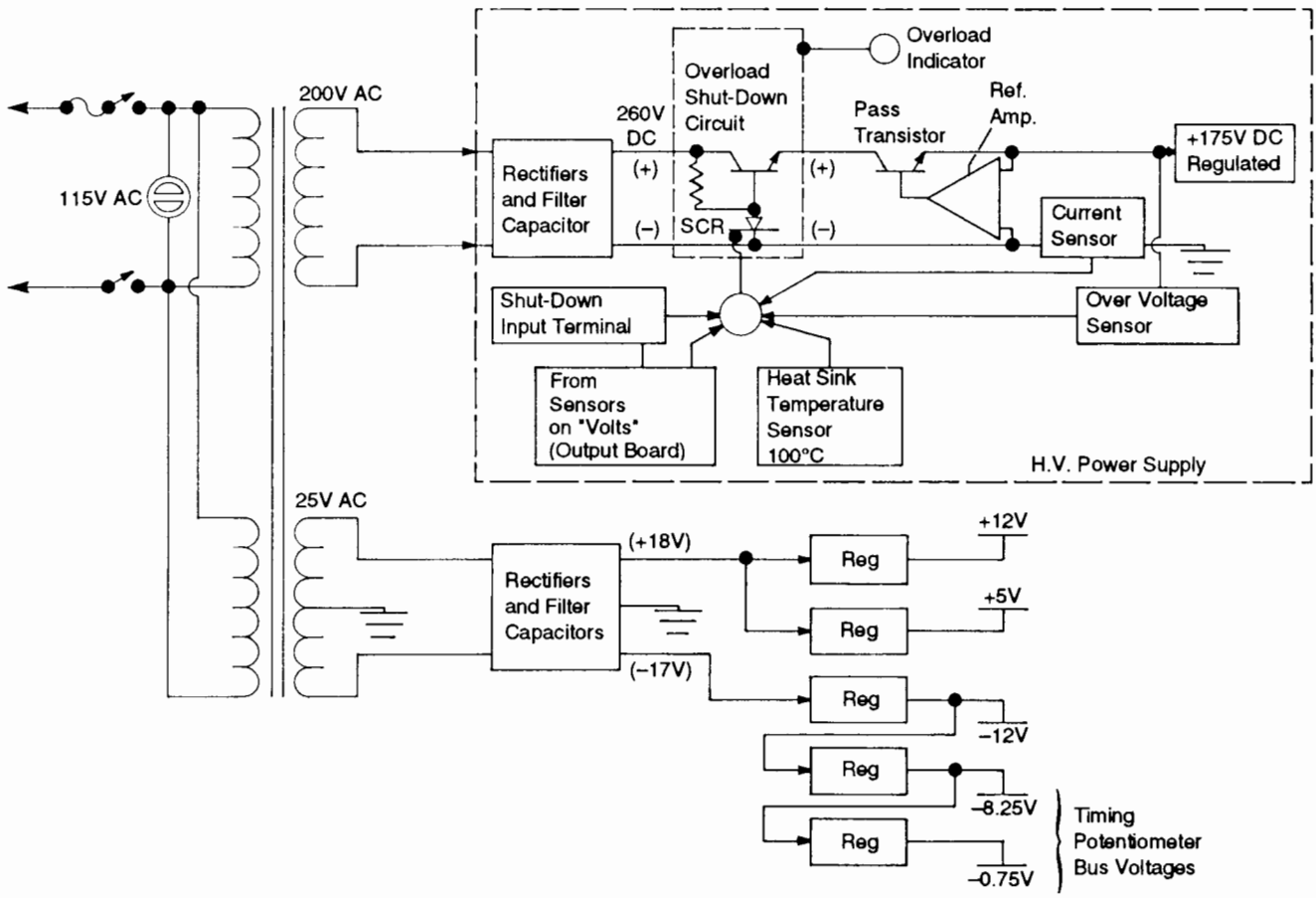
3.4.2 Most triggerable circuits, such as those used in the S48, cannot be driven satisfactorily over 90% of their duty cycle. Although there is no possibility of circuit component damage when operating at duty cycles greater than 50%, the calibration may be affected.

4 DESCRIPTION OF CIRCUITS

4.1 Power Supplies

4.1.1 The S48 power supply provides highly regulated DC voltages for circuit operation. The following voltages are generated:

+175 volts DC for output circuits
+5 volts DC for timing circuits
+12 volts DC for timing circuits
-12 volts DC for timing circuits



S48 POWER SUPPLY
FIGURE 4.1.1

4.2 Stim and Train Rate

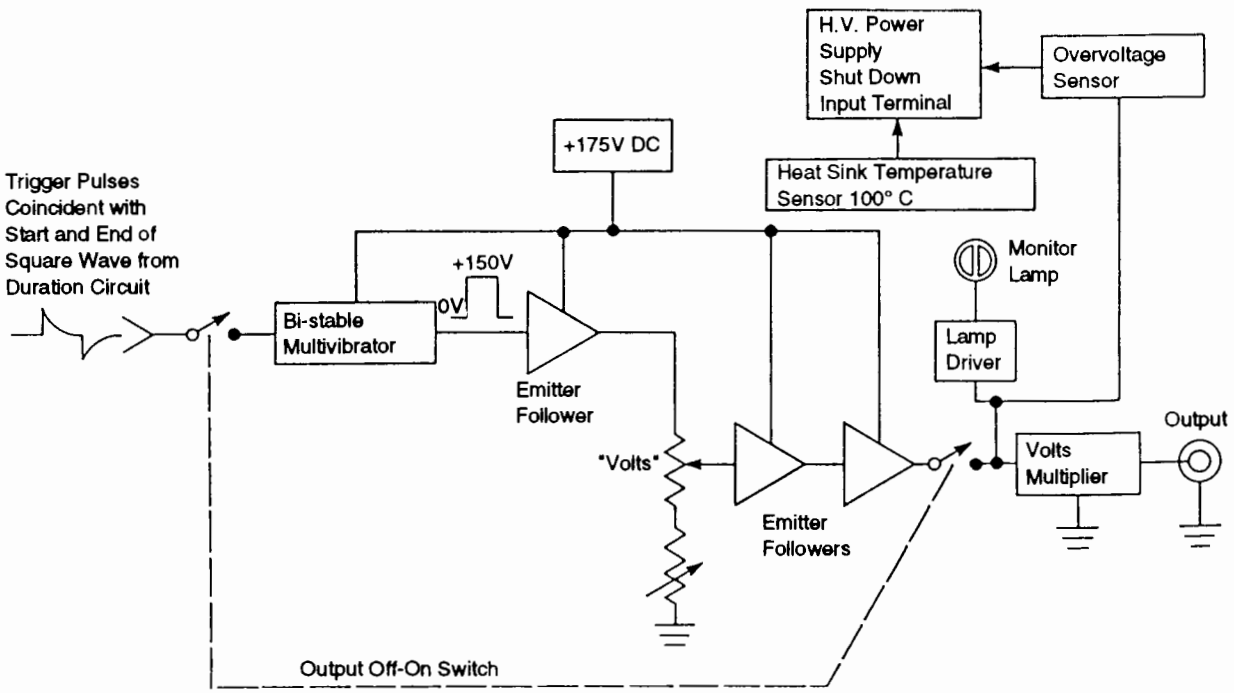
4.2.1 The STIM and TRAIN RATE circuits are free running oscillators with the MODE switch in the REPEAT position. These circuits will oscillate continuously when in the REPEAT mode. The TRAIN RATE frequency (TPS or trains per second) covers a range of 0.01 to 100 trains per second. The STIM RATE frequency has a range of 0.01 to 1000 PPS (pulses per second). The dials span a range of 1 to 10 and are continuously variable. The multiplier switches located below the dials provide decade range changes. The combination of the two controls sets the frequency.

4.3 Delay, Duration and Train Duration

4.3.1 The DELAY, DURATION and TRAIN DURATION circuits are monostable circuits or "one-shot" circuits that must be enabled or triggered into operation. In response to a short positive pulse, these circuits are triggered out of their stable state. The time required for the circuit to return to its stable state determines the delay or duration and is controlled by the DELAY and DURATION settings. Both delay and duration parameters have a very wide range – from 10 microseconds to 10 seconds in six ranges. The TRAIN DURATION has a range of 1 millisecond to 1 second in four ranges.

4.4 Volts

4.4.1 The output VOLTS circuit is powered from the +175 volt power supply. The voltage output can be varied from 10 millivolts to 150 volts in four ranges as determined by the VOLTS dial and VOLTS multiplier switch. See Section 5.9 for an explanation of the three X10 VOLTS multiplier switch settings.

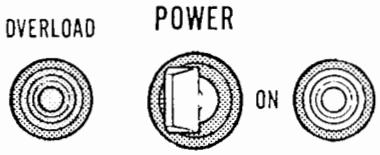


S48 OUTPUT CIRCUIT
FIGURE 4.4.1

5 OPERATIONAL CONTROLS

5.1 Power and Output

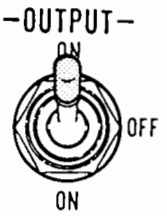
5.1.1 The POWER toggle switch is flanked by the ON pilot lamp and the red OVERLOAD lamp. In the ON position, the pilot lamp will glow orange, indicating that line power is being supplied to the instrument.



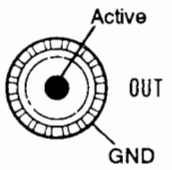
POWER SWITCH
FIGURE 5.1.1

5.1.2 The OVERLOAD lamp will glow red in the event of an overload or short circuit at the output. No output is available from the S48 during an overload condition. To "reset" the stimulator, turn the POWER switch OFF for a few seconds and then back to the ON position. (See Section 9.2.1.)

5.1.3 The OUTPUT-ON-OFF-ON lever switch is located in the upper right hand corner of the front panel. The OUTPUT lever switch must be in one of the ON positions for voltage to be delivered at the output. The lever switch remains in the upper ON position for continuous voltage at the output. The lever switch remains in the lower ON position only as long as it is depressed. It will return to the OFF position as soon as it is released. However, pulses are delivered at a rate preset by the timing circuits throughout the time the switch is depressed. The STIM MODE and TRAIN MODE switches determine whether single, repetitive, or trains of pulses are delivered. See Section 5.3.



5.1.4 The OUT connector is a coaxial UHF connector. The mating connector, Type PL259, is supplied with the accessories. When making a cable, connect the cable shield to the outer conductor. Connect the inner lead of the cable to the inner or active terminal.



If a Stimulus Isolation Unit was supplied, a cable is provided for connection to the OUT connector.

This statement is clearly visible on the front panel above the OUT connector and is placed to remind personnel that this unit should not be connected to a human subject or patient unless a stimulus isolation unit is used. Applying the direct output to a pair of stimulating electrodes will ground the patient and jeopardize safety.

5.1.5 The polarity of the output voltage is positive with respect to the chassis ground. Polarity can only be changed when using a stimulus isolation unit. The stimulus isolation unit "floats" the ground referenced S48 output voltage making it appear similar to a battery voltage, having a plus and a minus output neither of which is connected to ground. Once isolated, the output can be reversed. All the Grass Stimulus Isolation Units have polarity reversing switches.

5.1.6 The maximum peak output power from the S48 is about 22 watts, assuming 150 milliamperes output current into a 1000 ohm load. The S48 is capable, however, of delivering approximately 300 milliamperes into low impedance loads, such as is encountered during field stimulation.

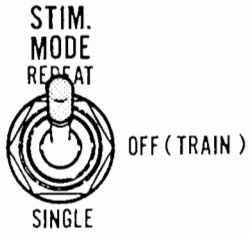
5.1.7 The S48 output impedance is determined by the position of the VOLTS multiplier switch. See Section 5.9 for information about the application of each output.

VOLTS multiplier switch	**Output Impedance**
X.01 to X10(SIU)	250 ohms
X10(100KΩ)	100 kilohms
X10(25 Ω)	25 ohms

5.1.8 The MONITOR lamp adjacent to the OUT connector will glow indicating stimuli are being delivered. The lamp will flash at the same frequency and duration as that selected with the RATE and DURATION controls. In the event of an overload, the MONITOR lamp will go out and the OVERLOAD lamp will illuminate. (See the reset instructions in Section 9.2.)

5.2 Stim Mode Switch and Twin Pulses Switch

5.2.1 The STIM MODE switch is a three-position lever switch with a center OFF (TRAIN) position. With the switch set to the up REPEAT position, repetitive pulses at a rate set by the STIM RATE circuit are generated. Placing the switch in the down SINGLE position will initiate a single stimulus pulse only. This position is spring loaded and will return to the center OFF (TRAIN) position when not depressed. When the STIM MODE switch is in the OFF position, trains of pulses as set by the TRAIN RATE and TRAIN DURATION circuits and controlled by the TRAIN MODE switch can be delivered. To obtain an output stimulus, the OUTPUT lever switch must be in one of the ON positions.



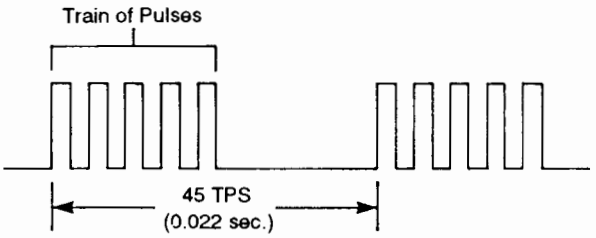
5.2.2 The PULSES switch is provided to generate an identical pulse pair (TWIN) primarily for refractory measurements. With this switch in the TWIN position, two identical pulses are generated and the time between them can be varied with the DELAY control. When in the TWIN position, placing the STIM MODE switch in the SINGLE position will generate a twin pulse pair. Placing the STIM MODE switch in the REPEAT position will generate repetitive twin pulse pairs.

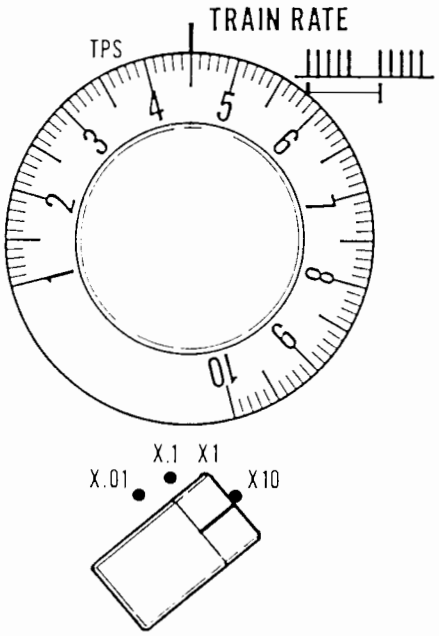
5.3 Train Mode

5.3.1 The TRAIN MODE switch is a three-position lever switch that interacts with the STIM MODE switch. Either single or repetitive trains of pulses can be generated with precise control. In the REPEAT position, with the STIM MODE lever switch in the OFF (TRAIN) position, repetitive trains are generated as set by the TRAIN RATE and TRAIN DURATION controls. Placing the TRAIN MODE switch in the SINGLE position will initiate a single train of pulses with the duration set by the TRAIN DURATION controls. For either single or repetitive trains to be delivered, the OUTPUT lever switch must be set to the ON position. The number of pulses in the train are controlled by the STIM RATE controls.

5.4 Train Rate Controls

5.4.1 The TRAIN RATE controls include the TRAIN RATE dial and the four-position multiplier switch located beneath the dial. The TRAIN RATE dial allows the train rate to be varied in a continuous fashion in a 10:1 range. The multiplier switch changes the ranges in decades. Together, the range is one train every 100 seconds (multiplier at X.01) to 100 TPS (trains per second) (multiplier at X10). If, for example, the TRAIN RATE dial is set to 4.5, and the multiplier is set to X10, the TRAIN RATE is 45 TPS (trains per second).





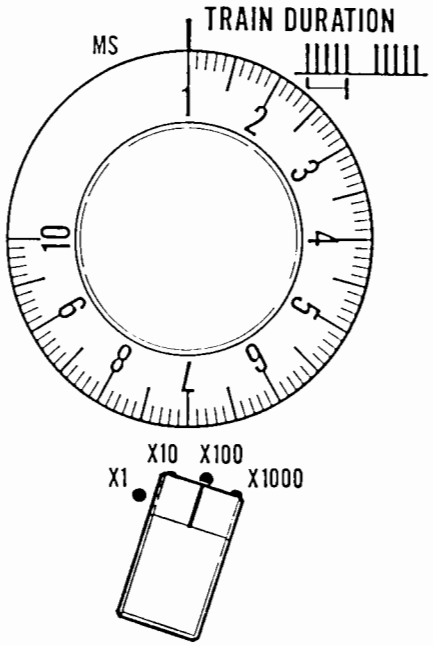
TRAIN RATE CONTROLS
FIGURE 5.4.1

5.4.2 The MONITOR lamp will illuminate with each pulse in the train providing the OUTPUT switch is ON. At fast stim rates, the lamp will illuminate continuously for the duration of the train.

5.5 Train Duration Controls

5.5.1 The TRAIN DURATION controls include the TRAIN DURATION dial and the four-position multiplier switch located beneath the dial. The TRAIN DURATION dial allows the train duration to be varied in a continuous fashion with a 10:1 range. The multiplier switch changes the ranges in decades. Together, the range is 1 millisecond minimum to 10 seconds maximum. It is important to understand that the ***STIM RATE and the TRAIN DURATION settings determine the number of pulses in the train***. The train duration square wave modulates or turns on and off the STIM RATE circuit.

For example, if the TRAIN RATE is set to 1 TPS, and the TRAIN DURATION is set to 100 milliseconds, a STIM RATE of 50 PPS will generate 5 pulses in the train each second. See Figure 5.5.1b.



TRAIN DURATION CONTROLS
FIGURE 5.5.1a

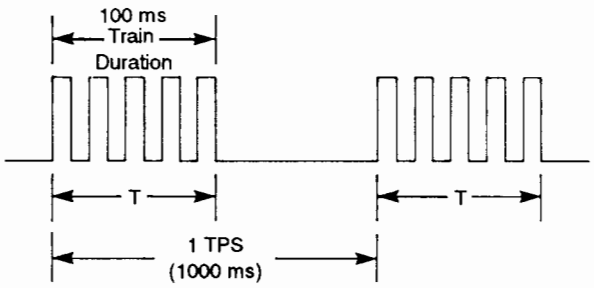
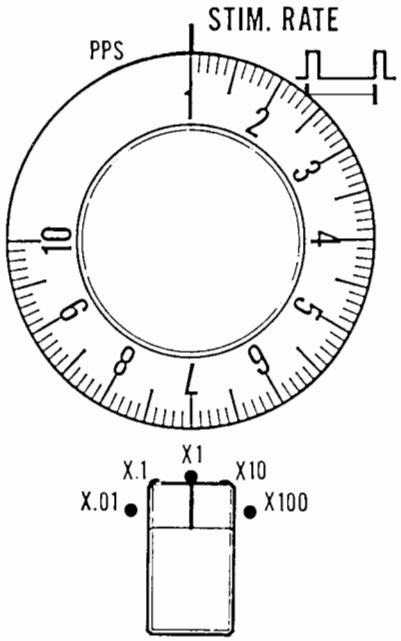


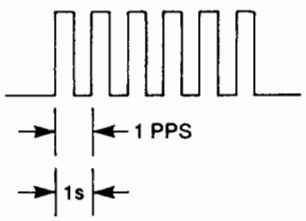
FIGURE 5.5.1b

5.6 Stim Rate Controls

5.6.1 The STIM RATE controls are similar to the TRAIN RATE controls; a dial and five-position multiplier switch provide stim rates in PPS (pulses per second) from 1 pulse every 100 seconds to 1000 PPS. When in the TRAIN mode, the STIM RATE determines the number of pulses in the train.

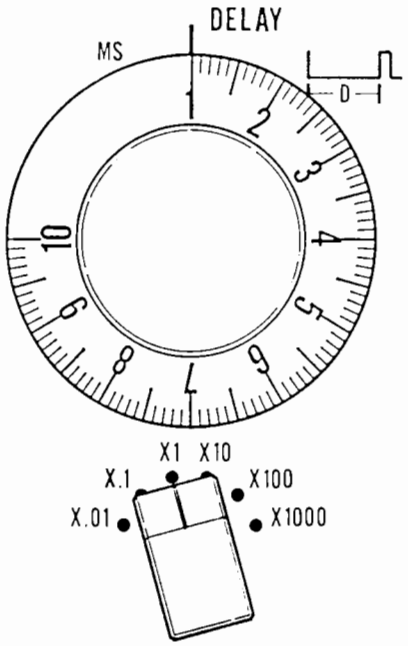


STIM RATE CONTROLS
FIGURE 5.6.1

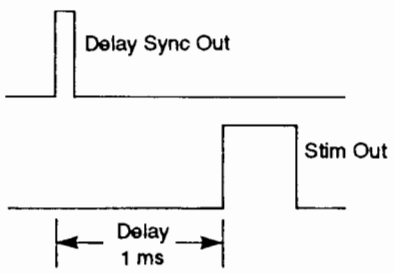


5.7 Delay Controls

5.7.1 The DELAY controls allow delays from 10 microseconds to 10 seconds in six ranges. A DELAY dial and decade multiplier switch provide the DELAY control. Delay is measured from the beginning of the DELAY SYNC OUT trigger to the onset of the stimulus pulse. In the TWIN pulse mode, it represents the time between the pulse pair. When in a DELAYED TRAIN mode, a special application which involves triggering the DELAY circuit which then turns on the TRAIN DURATION circuit, the delay represents the time between the externally applied trigger onset and the start of the train. (See Section 6.1.4.)

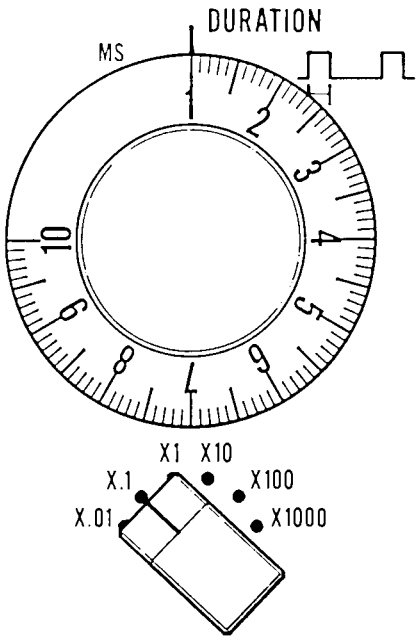


DELAY CONTROLS
FIGURE 5.7.1

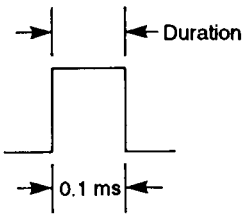


5.8 Duration Controls

5.8.1 The DURATION controls allow individual stimulus pulse durations of 10 microseconds to 10 seconds in six ranges. A DURATION dial and decade multiplier switch provide the DURATION control. The duration setting should not exceed 50% of the stim rate interval to prevent 50% duty cycle.

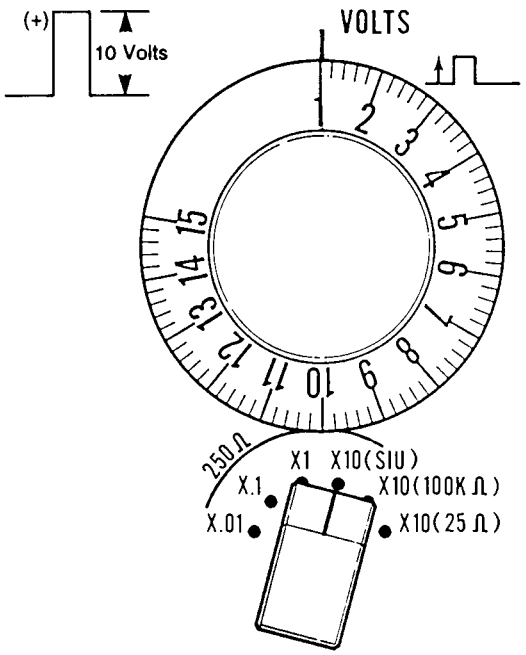


DURATION CONTROLS
FIGURE 5.8.1



5.9 Volts Controls

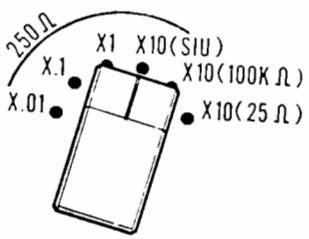
5.9.1 The output pulse amplitude (volts) is determined by the VOLTS dial and the six-position VOLTS multiplier switch. The "open circuit" voltage is the setting of the VOLTS dial and the VOLTS multiplier switch. With a VOLTS dial setting of 1 and a VOLTS multiplier setting of X10, the "open circuit" voltage will be 10 volts. The minimum output voltage is 10 millivolts (1 x 0.01). The maximum is 150 volts (15 x 10).



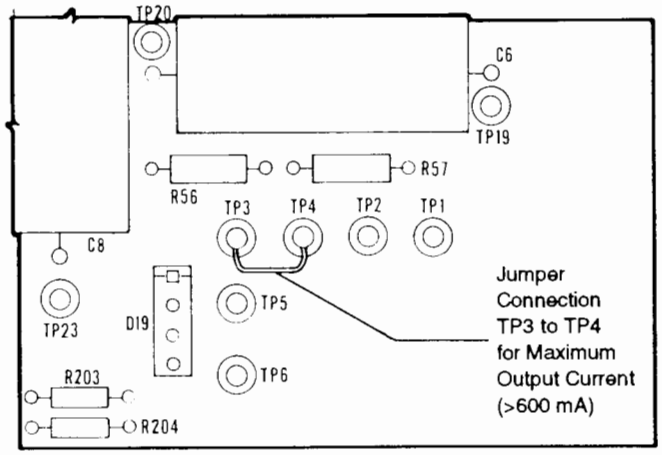
VOLTS CONTROLS
FIGURE 5.9.1

NOTE: The "open circuit" voltage implies that the load connected to the S48 output is of sufficiently high impedance so there is no loading (or very little loading) on the S48 output circuit. Under these conditions, the open circuit voltage is the same as the voltage across the load. If the load impedance is less than about 10 times the S48 output impedance, some loading will occur causing a drop in the voltage across the load. Under these conditions, the voltage across the load will be about 10% less than the S48 voltage dial setting.

5.9.2 The output impedance is 250 ohms in the first four positions of the VOLTS multiplier switch: X.01, X.1, X1 and X10(SIU). The X10(SIU) position is intended for all Grass Stimulus Isolation Units. Two additional X10 positions are provided. The X10(100KΩ) position provides a "constant current" output of 0.1 milliamperes (dial setting of 1) to 1.5 milliamperes (dial setting of 15) by insertion of a 100 kilohm resistor in the output circuit (nonisolated). See Figure 5.9.2a. For a discussion of constant current vs. constant voltage output, refer to Section 10.



VOLTS MULTIPLIER
FIGURE 5.9.2a



JUMPER CONNECTION
ON MAIN PC BOARD
FIGURE 5.9.2b

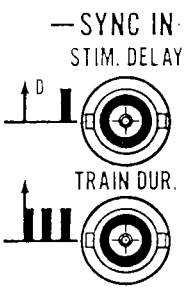
5.9.3 The X10(25Ω) position provides a low impedance output for use with low impedance electrodes to obtain a relatively high current output. In this position, the S48 is capable of delivering up to 300 milliamperes. A minor circuit change made by repositioning a jumper lead on the S48 main PC board will increase the output current to about 600 milliamperes. See Figure 5.9.2b.

5.9.4 Prior to stimulation, set the VOLTS multiplier to X.01 and the VOLTS dial to 1. When ready to stimulate, gradually increase VOLTS dial until threshold is achieved. If, at a VOLTS dial setting of 10, the stimulus is not strong enough, reduce the VOLTS dial setting to 1 and switch the VOLTS multiplier to X.1. Repeat increasing the VOLTS dial until threshold is achieved. Always approach the threshold from the low voltage level, never from the high voltage level or you may traumatize the preparation with excessively high stimulus currents.

6 SYNCHRONOUS INPUTS AND OUTPUTS

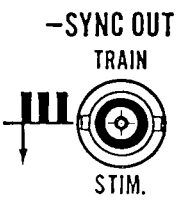
6.1 Synchronous Inputs

6.1.1 Synchronous inputs are provided to facilitate external control or driving the S48 from other devices. In this mode, the external trigger repetition rate controls the STIM RATE or TRAIN RATE depending on the sync input used. Two synchronous inputs are provided on the S48; the STIM DELAY SYNC IN and the TRAIN DURATION SYNC IN. These are BNC connectors located on the left side of the front panel. These sync inputs are also provided on the J5 25-pin connector on the rear panel. Terminal #20 is the SYNC IN TRAIN DURATION and terminal #21 is the SYNC IN DELAY. (Refer to Table 6.1 for a listing of the J5 connector terminals vs. function.)



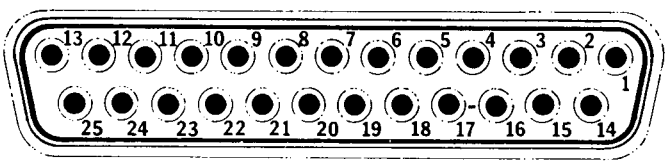
The graphic symbols to the left of the SYNC connectors are intended to illustrate the type of synchronous signal; a downward arrow indicating an output, an upward arrow indicating an input. The location of the arrow on the graphic pulse pattern depicts the timing.

For example, the TRAIN SYNC OUT symbol depicts a downward arrow, beginning at the start of the train. The sync then is an output pulse that is in synchrony with the train onset.



Terminal No.	Function
1	Extended Duration Train Sync Out
2	Extended Duration Train Duration Sync Out
3	Extended Duration Delay Sync Out
4	Extended Duration Stim Sync Out
5	No Connection
6	No Connection
7	No Connection
8	Train Rate External Voltage Control
9	Stim Rate External Voltage Control
10	No Connection
11	No Connection
12	Train External Single Control
13	Train External Repeat Control
14	Stim External Single Control
15	Stim External Repeat Control
16	No Connection
17	No Connection
18	Common Line of Single/Repeat Mode Switch
19	No Connection
20	Train Duration Sync In
21	Delay Sync In
22	No Connection
23	No Connection
24	+5 Volts DC
25	System Ground

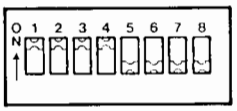
S48 J5 EXTERNAL CONTROL CONNECTOR
TERMINALS VS. FUNCTIONS
TABLE 6.1



J5 25-PIN CONNECTOR
LOCATED ON REAR PANEL
FIGURE 6.1.1

SYNCHRONOUS INPUTS AND OUTPUTS
Section 6.1

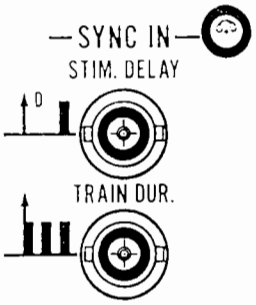
6.1.2 The synchronous inputs are set for TTL level triggering voltages (+5V) and expect a transition from 0 volts to a positive 5 volts. The SYNC IN input impedance is greater than 100 kilohms. The minimum voltage is about +3.5 volts. Any voltage lower than this may not trigger the unit. Some devices may provide a "negative going" trigger voltage. Generally, these devices have a trigger source that is at a +5 volt level, and when enabled, goes negative towards 0 volts. It is possible to change the S48 SYNC INPUTS to trigger on this "negative going" voltage. Switch #7 of SW1 at the rear panel of the S48 can be set to trigger on negative going trigger voltages. This single switch alters all of the S48 SYNC INPUTS.



SWITCH	1	2	3	4	5	6	7	8
	T.R.	T.D.	DELAY	STIM.			SYNC IN POLARITY	TRAIN DELAY
FUNCTION	SYNC OUT				X	X		
ON ↑	1 MSEC DURATION						–	ON
OFF ↓	10 MSEC DURATION						+	OFF

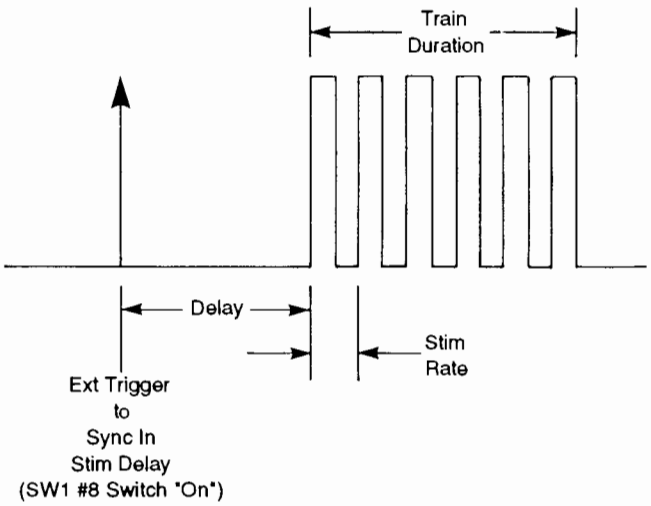
SW1 SWITCHES
LOCATED ON THE REAR PANEL
FIGURE 6.1.2

An indication of proper externally applied trigger pulses is provided by the flashing of the "sync in" LED adjacent to the SYNC IN connectors. A trigger signal of proper polarity and voltage at any one of the sync inputs will produce one flash per trigger.



6.1.3 When using the SYNC IN STIM DELAY, set the STIM MODE lever switch to the OFF (TRAIN) position. This will disable the STIM RATE circuit and prevent erratic triggering of the DELAY circuit. When using the SYNC IN TRAIN DURATION, set the TRAIN MODE lever switch to the OFF position.

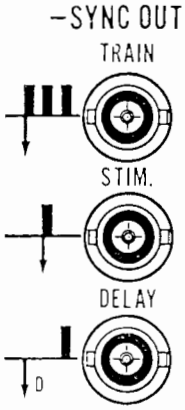
6.1.4 Triggering the SYNC IN TRAIN DURATION provides onset of the train coincident with the trigger pulse. They will be in synchrony. If the application requires some delay between the onset of the trigger pulse and the start of the train (TRAIN DELAY), the #8 switch on SW1 can be used. Placing this switch in the UP, ON position will provide train delay. The amount of delay can be set with the DELAY controls. This mode places the DELAY circuit before the TRAIN DURATION, so the trigger initiates the DELAY circuit, which then enables the TRAIN DURATION. The trigger must be applied to the STIM DELAY SYNC IN for this mode of operation.



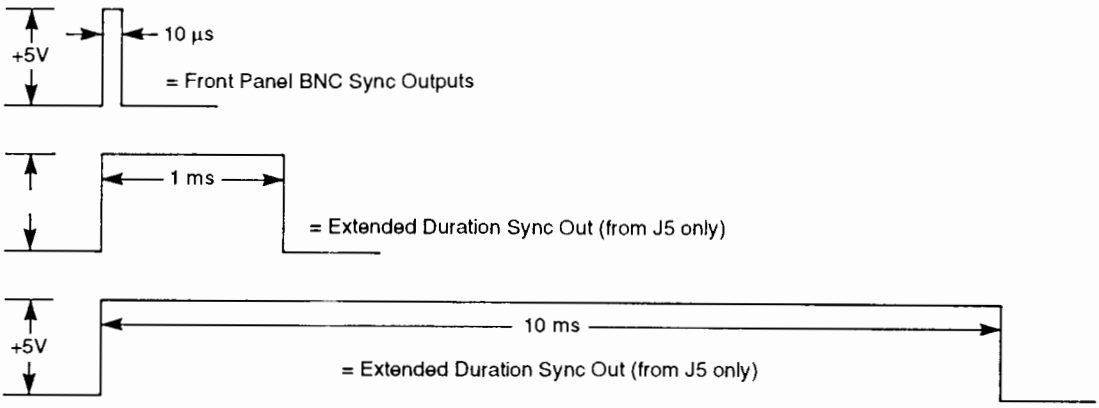
TRAIN DELAY
FIGURE 6.1.4

6.2 Synchronous Outputs

6.2.1 Three synchronous outputs are provided for synchronizing the S48 with external devices such as oscilloscopes, data acquisition systems, analyzers, etc. The connection is via the BNC connectors on the front panel of the S48. The sync pulses are 10 microseconds duration at 5 volts amplitude. The output impedance is 50 ohms. One additional sync pulse coincident with the end of the train duration is also available from pin #2 of the J5 connector.



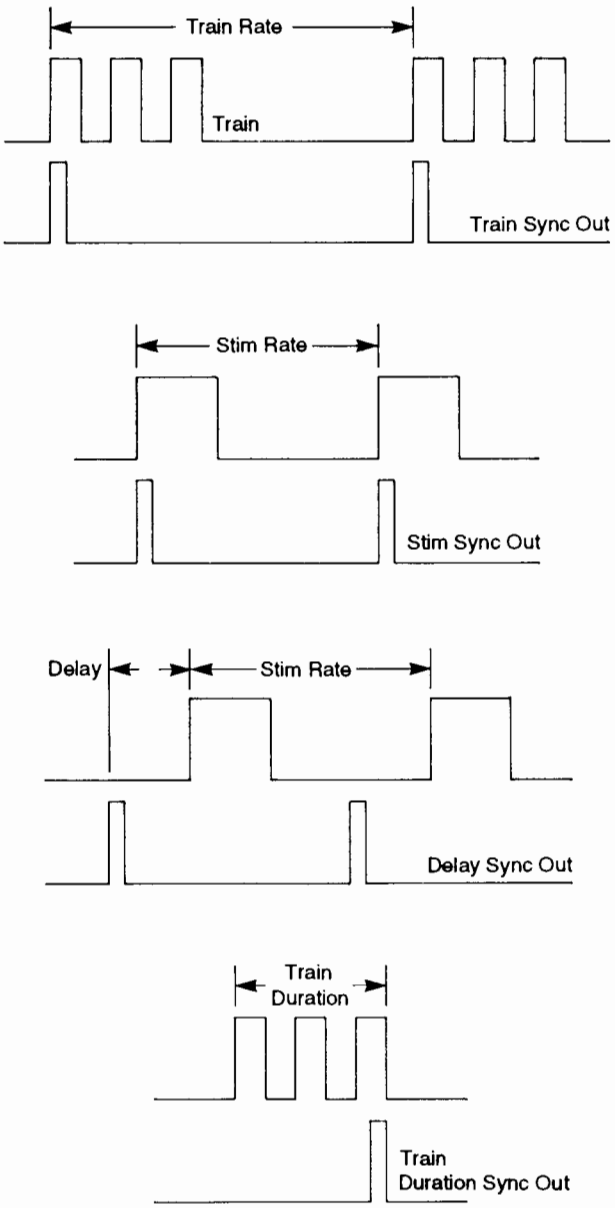
6.2.2 Extended duration versions of these sync out pulses are available at the J5 25-pin connector on the S48 rear panel. See Table 6.1. Since the normal sync out pulses from the BNC connectors are of very short duration, problems triggering some data acquisition systems related to clock sampling rates may occur. The sync outputs available at the J5 connector can be selected as either 1 or 10 milliseconds duration to facilitate triggering these systems. The selection of the duration is made via the SW1 switches. See Figure 6.1.2. These switches do not change the front panel BNC sync output durations.



SYNC OUT PULSES
FIGURE 6.2.2

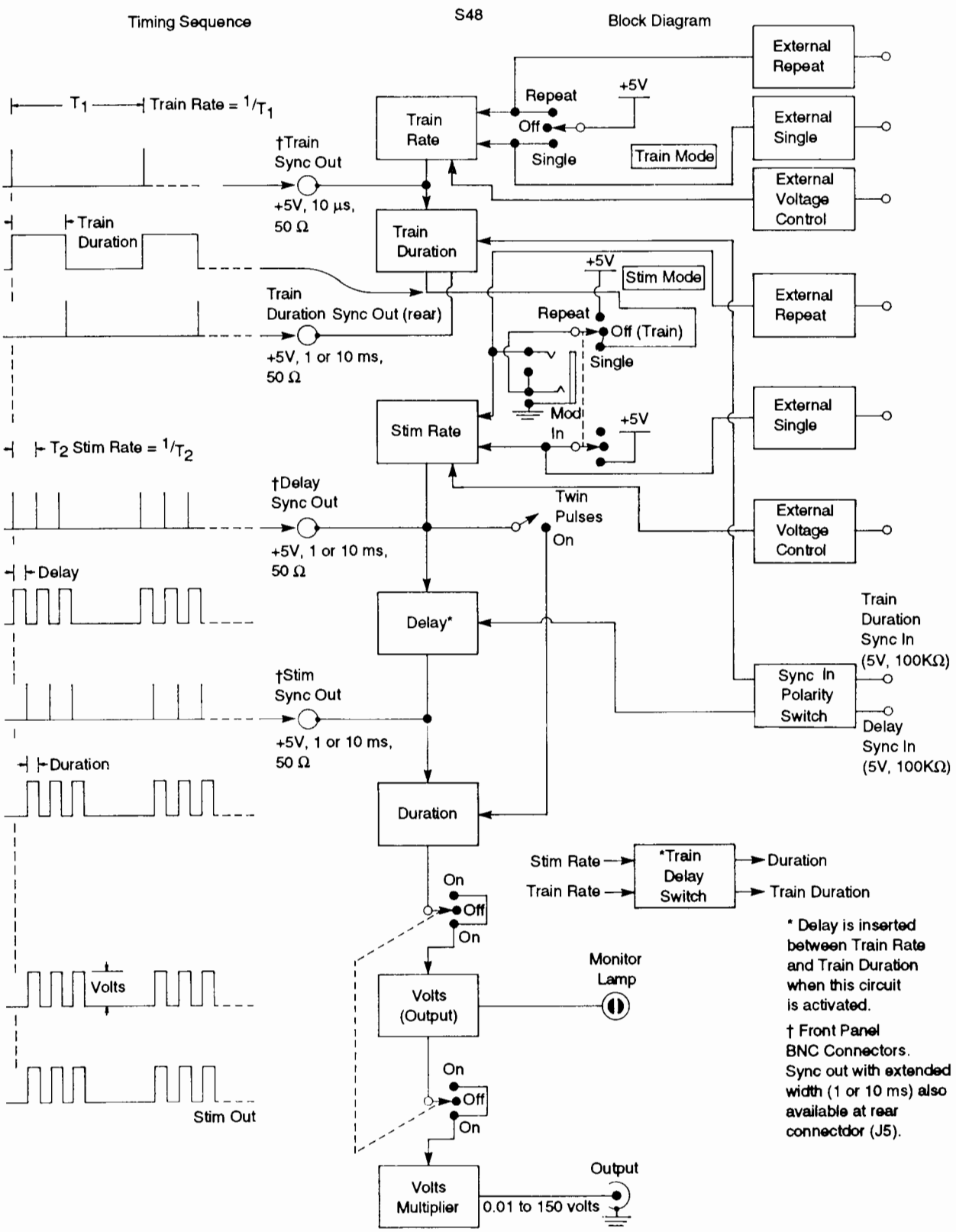
6.2.3 The TRAIN SYNC OUT is coincident with the start of the train. The SYNC OUT STIM is coincident with the start of ***each*** stimulus pulse. The DELAY SYNC OUT ***precedes*** the stimulus pulse by an amount set with the DELAY controls. The TRAIN DURATION SYNC OUT is coincident with the end of the TRAIN DURATION.

6.2.4 The TRAIN SYNC pulse is only generated when the TRAIN MODE lever switch is in the REPEAT or SINGLE position. Similarly, the STIM and DELAY sync outputs are only available with the STIM MODE lever switch in the REPEAT or SINGLE position. The OUTPUT lever switch does not have to be ON to obtain these sync out pulses.



SYNCHRONOUS OUTPUTS
FIGURE 6.2.3

SYNCHRONOUS INPUTS AND OUTPUTS
Section 6.2

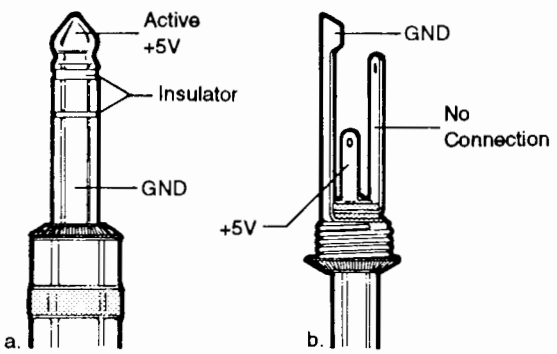


S48 TIMING SEQUENCE and BLOCK DIAGRAM

FIGURE 6.2.1

6.3 Modulate Input (Mod-In)

6.3.1 The MOD-IN (Modulate In) phone jack, located on the rear of the S48, is wired in parallel with the STIM RATE circuit bypassing the TRAIN RATE and TRAIN DURATION circuits. It provides a means of externally modulating (turning on and off) the STIM RATE circuit. The same function is served by the TRAIN controls. The MOD-IN jack is included so that the S48 can be controlled remotely or its ranges extended beyond those available internally. The modulating square wave should be +5 volts (TTL level) with respect to ground. The voltage should be applied to the tip of the phone plug. See Figure 6.3.1a. The outer shell should be ground. The mid terminal should have no connection. The correct phone plug would be Switchcraft #297 or the equivalent. See Figure 6.3.1b. The STIM MODE switch must be in the OFF (TRAIN) position.



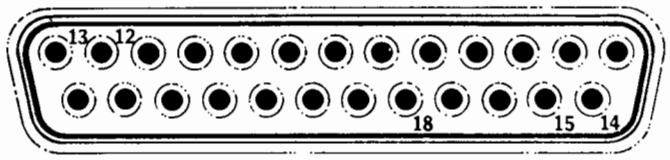
SWITCHCRAFT #297 PHONE PLUG
FIGURE 6.3.1

6.3.2 The MOD-IN phone jack can also be used for remote control of the S48 when the STIM MODE switch is set to the REPEAT mode of operation. This is done by connecting one side of a normally open switch to the tip of the phone plug and the other side to the mid terminal of the phone plug. When the switch is closed, a continuous train of pulses is produced for as long as the switch is held closed. The STIM MODE switch must be in the REPEAT position and the OUTPUT switch in the upper ON position.

6.4 External Control

6.4.1 In some instances, it may be desirable to control the S48 from a normally open contact closure such as provided by relays and switches. Provision for this type of control is included at the J5 connector. Terminals #12, #13, #14, #15, along with Terminal #18 as the common terminal, provide this function. Terminal #12 is the SINGLE control for the TRAIN circuit. Terminal #13 is the REPEAT control for the TRAIN circuit. Terminal #14 is the SINGLE control for the STIM circuit and Terminal #15 is the REPEAT control for the STIM circuit.

6.4.2 For this type of operation, the MODE switch, either TRAIN or STIM depending on the desired control, must be placed in the OFF position. For example, by placing the STIM MODE switch and the TRAIN MODE switch in the OFF positions, and connecting a pair of normally open contacts between Terminal #18 and Terminal #12, the contact closure will produce a single TRAIN. The following table lists the various possibilities of this type of control.



J5 CONNECTOR
FIGURE 6.4.2

Connect Terminal #18	**For:**
to Terminal #12	Single Train
to Terminal #13	Repetitive Trains
to Terminal #14	Single Stim
to Terminal #15	Repetitive Stim

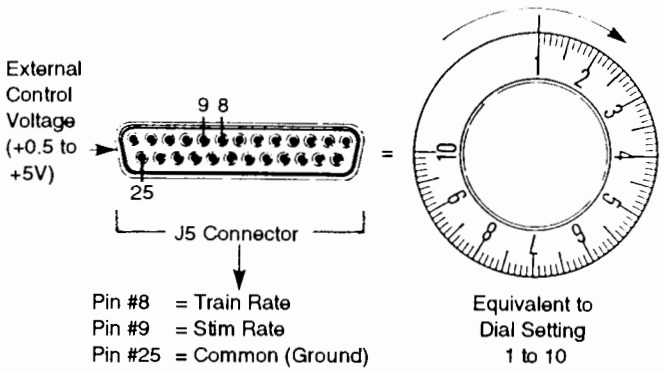
TABLE 6.4

6.4.3 Note that this type of operation emulates the front panel MODE lever switches. When using the REPEAT modes for either TRAIN or STIM, the contact closure must be held long enough to produce the desired repetition rate for TRAINS or STIM.

This same function can be initiated by connecting +5V TTL level control lines to Terminals #12, #13, #14 and #15. As with the contact closure method, the voltage must be held long enough to produce the desired repetition rates.

6.5 External Voltage Control of Stim and Train Rate

6.5.1 Recognizing there may be certain applications requiring the need to change either the stim rate or train rate in a controlled fashion, a circuit has been provided in the S48 to allow this type of external control. The circuit is a linear voltage control circuit and is designed around a voltage range of between +0.5 and +5 volts for a 10:1 change in the rate. The +0.5 volt level corresponds to the "1" dial position, and the +5 volt level corresponds to the "10" dial position of either the STIM RATE or the TRAIN RATE circuits.



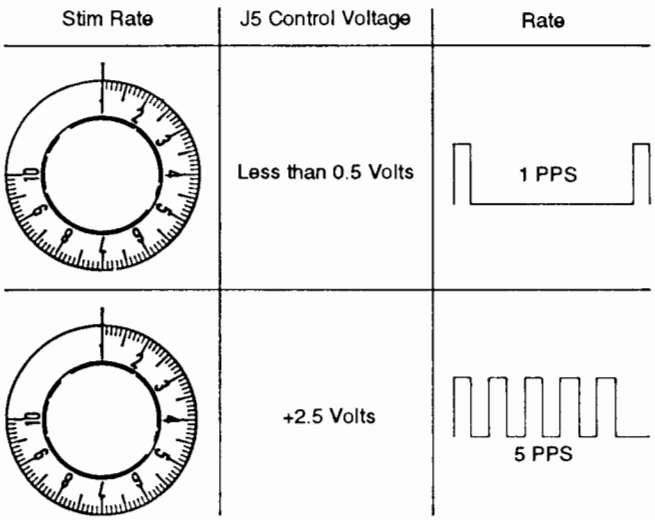
EXTERNAL CONTROL
FIGURE 6.5.1

6.5.2 The circuit is so arranged that when the external voltage control signal is connected to the J5 connector, it takes precedence over the front panel controls. The TRAIN or STIM MODE switches must be in the REPEAT position for the function being used.

6.5.3 The TRAIN RATE and STIM RATE decade ranges are controlled by the multiplier switches associated with the parameter being used. For example, when externally voltage controlling the STIM RATE circuit, with the STIM RATE multiplier switch set to the X1 position, the rate will be from 1 to 10 PPS. Switching the range switch to X100 will provide an externally controlled range of 100 to 1000 PPS.

6.5.4 To externally voltage control the TRAIN RATE circuit, apply the voltage between pin #8 and the GROUND pin #25 of the J5 connector. pin #8 must be positive with respect to pin #25. To externally voltage control the STIM RATE circuit, apply the positive voltage between pin #9 and the GROUND pin #25 of the J5 connector.

6.5.5 This type of control is especially useful when it is desired to switch between two rates within the same 10:1 range. One rate can be the front panel dial setting, which is established with the externally applied voltage less than 0.5 volts. When the applied voltage is switched to a different level, corresponding to the second rate, the rate is switched automatically. For example, suppose it is desired to switch between a stim rate of 1 PPS and 5 PPS. Setting the STIM RATE dial to 1 PPS will provide the first rate desired, when the applied voltage is less than 0.5 volts. Changing the applied voltage to +2.5 volts will provide the rate change to 5 PPS. The output of a second stimulator can be used to provide the external control voltage.



EXTERNAL CONTROL OF RATE VIA J5 CONTROL VOLTAGE
FIGURE 6.5.5

7 MODES OF OPERATION

7.1 Single or Repetitive Pulses

7.1.1 Example: To obtain repetitive 5 volt pulses of 20 per second, delayed 2 milliseconds from the start of the oscilloscope sweep, each pulse with a duration of 2 milliseconds, first make the following settings on the S48 dials:

Controls	Setting
STIM RATE multiplier	= X10
STIM RATE dial	= 2
DELAY multiplier	= X1
DELAY dial	= 2
DURATION multiplier	= X1
DURATION dial	= 2
OUTPUT-ON-OFF-ON	= UP, ON
STIM MODE	= REPEAT
VOLTAGE multiplier	= X1
VOLTS dial	= 5
TWIN PULSES	= SINGLE

a. Connect the output cable to STIM OUT.

b. Connect the SYNC OUT – DELAY to the external synchronous input (time base) of the oscilloscope. Set the oscilloscope sync trigger selector switch to EXTERNAL (+) AC.

c. Plug the AC cable in, and turn the POWER switch to ON.

d. Set the oscilloscope vertical sensitivity to about 2.0 volts per division and the oscilloscope sweep speed to 1 millisecond/division. Adjust the oscilloscope synchronizing controls until one pulse appears on the screen. The vertical deflection should be approximately 2.5 divisions with a delay from the start of the sweep of 2 milliseconds and a pulse width of 2 milliseconds.

7.1.2 With this pattern in mind, observe the effects of changing the setting of the DELAY and DURATION controls, as well as the proper use of the VOLTS dial and its multiplier switch to obtain progressive increases in output voltage.

7.1.3 To obtain single pulses of the duration, delay and voltage indicated above, depress the STIM MODE switch to SINGLE. The STIM MODE control is a spring loaded lever switch which delivers only one pulse each time it is depressed and returns to the OFF position when released.

7.1.4 For external control of this mode, the following methods can be used.

a. Place STIM MODE to OFF (TRAIN) position and apply external trigger at a rate of 20 PPS to the STIM DELAY SYNC IN.

b. Apply contact closure to pins #15 and #18 at J5 connector (STIM MODE OFF).

Either method will produce repetitive pulses.

7.2 Twin Pulses (Alike)

7.2.1 The TWIN PULSES switch on the S48 permits twin pulses of identical voltage and duration to be obtained from a single stimulator for nerve and muscle refractory time measurements.

7.2.2 The rate at which the pairs of pulses are produced is determined by the STIM RATE controls. With the TWIN PULSES switch in the ON position, twin pulses are delivered in either the SINGLE or REPEAT position of the MODE switch. Both members of the pair are alike in duration and voltage, as determined by the respective dial settings. The DELAY controls are used to vary the separation between the pulse pair and is measured from the start of the oscilloscope sweep (onset of the first pulse) to the onset of the second pulse.

7.2.3 The procedure for obtaining twin pulses is as follows:

a. Connect output cable to S48 and oscilloscope.

b. Synchronize the oscilloscope by connecting its external synchronizing input to the SYNC OUT DELAY of the S48.

c. Set controls for desired amplitude and duration. Respect the 50% duty cycle so that the off time between a pair of pulses equals or exceeds the individual pulse duration. (See Section 3.4.) To satisfy this condition, the delay must be equal or greater than twice the duration.

d. Set STIM RATE for the desired repetition rate.

e. Set the PULSES switch to TWIN.

f. Set the ON-OFF-ON toggle switch to UP-ON for continuous twin pulses.

7.2.4 For nerve and muscle refractory time measurements, the delay controls govern the time between the onset of the first and the onset of the second twin pulse. To establish refractory time, start with a low frequency and an excessively long delay time between the twin pulses to assure full response for each stimulus. Gradually reduce the delay time until there is first intermittent, then no response to the second pulse. Refractory time is established as the time when the response disappears, not when it reppears again after extending the delay time between pulses. Read the refractory time from the DELAY controls. This is best observed with two pulses per sweep of the oscilloscope.

7.2.5 To obtain trains of like pulses, follow the directions given in Sections 7.2.1 to 7.2.4 and then:

a. Set the number of trains of twin pulse pairs to be delivered per second with the TRAIN RATE controls.

b. The duration of each train of twin pulses is determined by the TRAIN DURATION settings.

c. Set the STIM MODE switch to OFF (TRAIN).

d. Set the TRAIN MODE switch to either REPEAT for repetitive trains of twin pulses, or to manually deliver a single train of twin pulses, depress the toggle switch to the SINGLE position.

7.2.6 For external control of this mode, the following methods can be used.

a. Place the STIM MODE to OFF (TRAIN) position and apply external trigger pulses, one for each of the pulses in the twin pair with the interval desired to create the proper delay between them. The PULSES switch has no control over this method.

b. Apply contact closure between pins #15 and #18 at the J5 connector for repetitive twin pulses, or use pins #14 and #18 for single twin pulses. The PULSES switch must be in the TWIN position for this method.

c. Apply contact closure between pins #13 and #18 for repetitive trains of twin pulses. The PULSES switch must be in the TWIN position for this method.

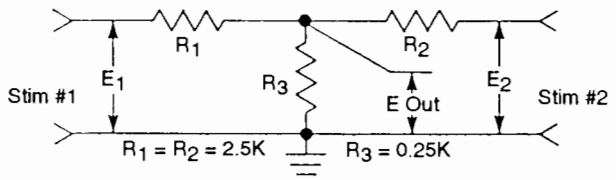
7.3 Mixing the Outputs of Two Stimulators

7.3.1 The outputs from two stimulators can be mixed through two stimulus isolation units to obtain a greater variety of pulse patterns than is possible from one S48. Directions for various applications are found in the sections that follow.

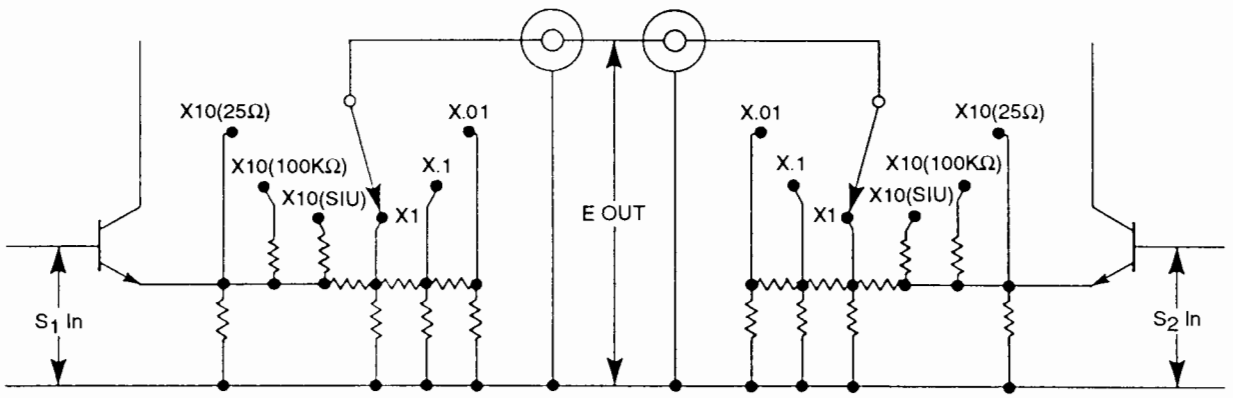
7.3.2 If stimulus isolation units are not used and the outputs are not isolated from ground, the outputs can be mixed by either of the following ways.

a. An external circuit must be constructed between two stimulators as shown below in Figure 7.3.2a.

b. The alternative method consists of connecting the outputs of the two stimulators is shown in Figure 7.3.2b below. ***However, never add the outputs of two stimulators by this method with the voltage multiplier switch of either stimulator in the X10 position.*** Severe damage to one or both stimulators will result if the voltage is higher than 15. When this method of mixing is employed, the actual voltage from each stimulator is one-half of the voltage output reading.



EXTERNAL CIRCUIT BETWEEN TWO STIMULATORS
FIGURE 7.3.2a

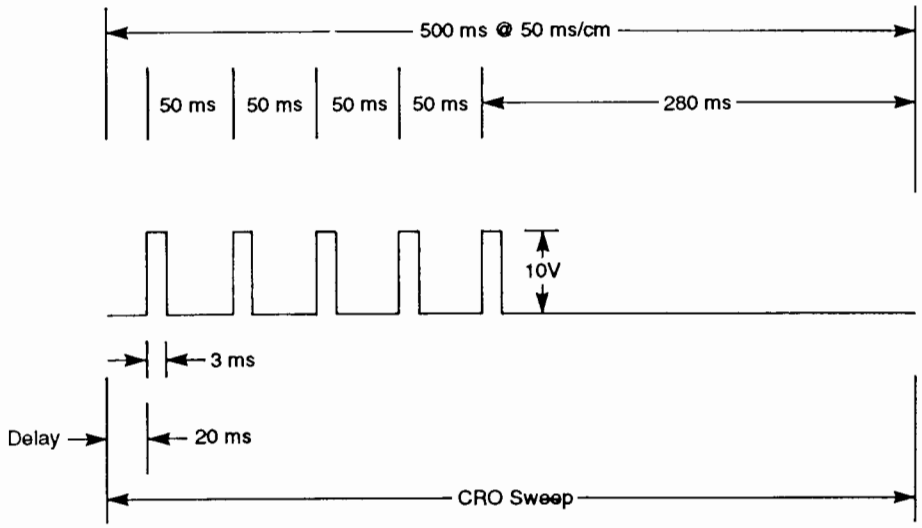


CONNECTING OUTPUTS OF TWO STIMULATORS
FIGURE 7.3.2b

7.4 Trains of Pulses (Single or Repetitive)

7.4.1 To obtain a repetitive train of five pulses every 2 seconds, each pulse 3 milliseconds duration, lasting 200 milliseconds, set the S48 controls as follows:

Controls	Setting
POWER	= ON
STIM RATE dial	= 2
STIM RATE multiplier	= X10
DELAY dial	= 2
DELAY multiplier	= X10
DURATION dial	= 3
DURATION multiplier	= X1
OUTPUT	= UP, ON
STIM MODE	= OFF (TRAIN)
VOLTS dial	= 10
VOLTS multiplier	= X1
TRAIN RATE dial	= 5.0
TRAIN RATE multiplier	= X0.1
TRAIN DURATION dial	= 2.2
TRAIN DURATION multiplier	= X100
TRAIN MODE	= REPEAT for continuous trains of pulses OR SINGLE for a single train of pulses
PULSES	= SINGLE



TRAINS OF PULSES STIMULUS SEQUENCE
FIGURE 7.4.1

7.4.2 Oscilloscope ***connections*** and ***settings***:

a. Connect the S48 output to the high side of the oscilloscope input.

b. Connect the SYNC OUT TRAIN of the S48 to the oscilloscope external synchronous signal input ("trigger input").

c. Set the oscilloscope TIME BASE to 50 milli-seconds/centimeter and vertical sensitivity to 5 volts per centimeter.

d. Adjust the oscilloscope sync trigger control to obtain one sweep per train. The whole train of five stimuli should appear in the first 5 centimeters of the sweep.

7.4.3 Note the effect of changing the values of the various parameters. Note especially the effect of the TRAIN DURATION controls on the length of the train and consequently the number of pulses in the train. Note that the STIM RATE control can change the number of pulses in the train but not the length of the train.

7.4.4 To display one pulse for each sweep, set the oscilloscope TIME BASE to 1 milli-second/centimeter. (Connect the oscilloscope sweep trigger input to SYNC OUT DELAY. Set the DELAY multiplier switch to X1.)

7.4.5 To display the whole train, proceed as in Sections 7.4.2 to 7.4.4.

7.4.6 For external control of this mode, the following methods can be used.

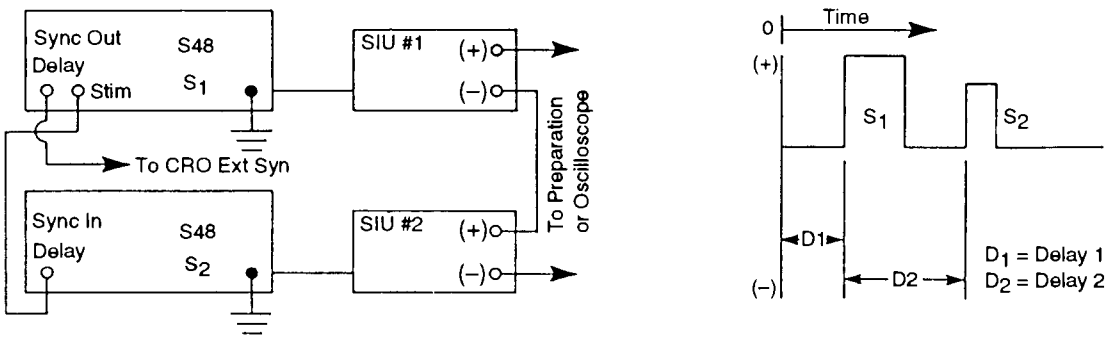
a. Place TRAIN MODE and STIM MODE switches to OFF. Apply external trigger at a rate of every 2 seconds to the TRAIN DURATION SYNC IN for repetitive trains.

b. Apply contact closure to pins #13 and #18 at J5 connector for repetitive trains.

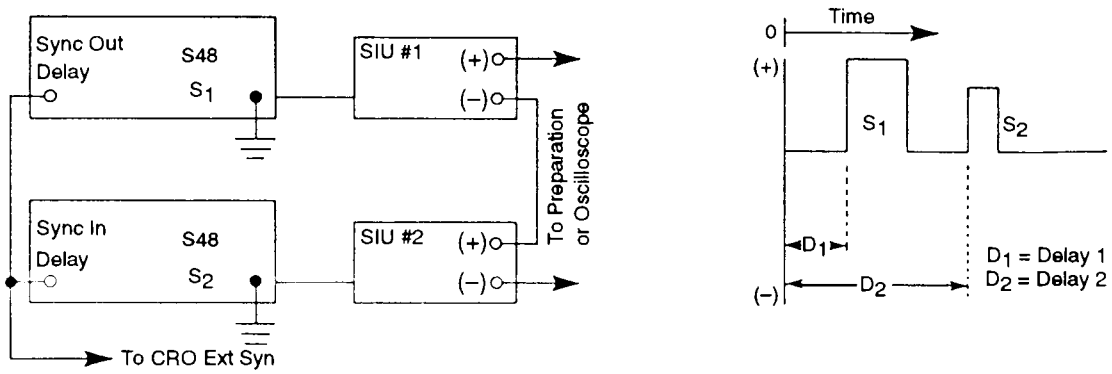
c. For single trains, apply contact closure to pins #12 and #18 at J5 connector.

7.5 Pairs of Repetitive Unlike Pulses Using Two S48 Stimulators and Two SIUs

7.5.1 The combination of two S48 Stimulators yields pairs of repetitive unlike pulses, with each member of the pair independently variable in duration and voltage. By connecting SYNC OUT STIM of Stimulator #1 to SYNC IN DELAY of Stimulator #2, one variable delay alters the time between the start of the sweep and the leading edge of the first stimulus and the second variable delay, then alters the time between the leading edge of the first and second stimuli. See Figure 7.5.1a and Section 7.5.2, Procedure A, which follows. By connecting SYNC OUT DELAY of Stimulator #1 to SYNC IN DELAY of Stimulator #2, as described in Section 7.5.3, Procedure B, one variable delay alters the time between the start of the sweep and the leading edge of the first stimulus and the second variable delay then alters the time between the start of the sweep and the leading edge of the second stimulus. See Figure 7.5.2b and Section 7.5.3, Procedure B, which follows.



CONNECTIONS FOR PAIRS OF UNLIKE PULSES
FIGURE 7.5.1a



CONNECTIONS FOR PAIRS OF UNLIKE PULSES
FIGURE 7.5.1b

7.5.2 ***Procedure A***: To produce a pair of pulses having the following characteristics, see Table 7.5.2a.

PULSE #	**1**	**2**
FREQUENCY	50 PPS	SYNC from S_1
DURATION	2 ms	1 ms
VOLTAGE	8 volts	5 volts
DELAY	2 ms from start of sweep	6 ms from start of sweep

TABLE 7.5.2a

a. With both stimulators off, ground them together and connect them to their respective stimulus isolation units. Then connect the outputs of the SIUs to stimulate and monitor through a single electrode pair as shown in Figure 7.5.1a. (Different electrode pairs may be used, if desired, however.)

b. Connect SYNC OUT STIM of Stimulator #1 to SYNC IN DELAY of Stimulator #2.

c. Connect a wire from SYNC OUT DELAY to the external synchronizing input of the oscilloscope.

d. Make the following dial settings as indicated in Table 7.5.2b below, and then turn both stimulators on, allow a few minutes warm up, and adjust the oscilloscope until the pairs of pulses are seen. Suggest 2 milliseconds/centimeter oscilloscope sweep speed, 5 volts/centimeter vertical sensitivity.

Stimulator Control	**Stimulator #1**	**Stimulator #2**
STIM RATE	50 PPS	- - -
DELAY	2 ms	4 ms
DURATION	2 ms	1 ms
VOLTS	8 volts	5 volts
OUTPUT	REPEAT	OFF
SIU5 Control	**SIU #1**	**SIU #2**
COUPLING	DIRECT	DIRECT
POLARITY	NORM	NORM
MULTIPLIER	1	1

TABLE 7.5.2b

7.5.3 ***Procedure B***: In this case, the object is to produce a pair of pulses with the following characteristics. See Table 7.5.3a.

STIMULATOR	S1	S2
STIM RATE	50 PPS	SYNC from S1
DURATION	2 ms	1 ms
VOLTAGE	8 volts	5 volts
DELAY	2 ms from start of sweep	6 ms from start of sweep

TABLE 7.5.3a

a. With both stimulators off, ground them together and connect them to their respective stimulus isolation units. Then connect the outputs of the SIUs to stimulate and monitor through a single electrode pair as shown in Figure 7.5.1a. (Different electrode paris may be used, if desired, however.)

b. Connect SYNC OUT DELAY of Stimulator #1 to SYNC IN DELAY of Stimulator #2.

c. Connect a wire from SYNC OUT DELAY to the external synchronizing input of the oscilloscope.

d. Make the following dial settings as indicated in Table 7.5.3b below.

Stimulator Control	Stimulator #1	Stimulator #2
STIM RATE	50 PPS	- - -
DELAY	2 ms	6 ms
DURATION	2 ms	1 ms
VOLTS	8 volts	5 volts
STIMULUS	UP, ON	UP, ON
MODE	REPEAT	OFF
SIU5 Control	**SIU #1**	**SIU #2**
COUPLING	DIRECT	DIRECT
POLARITY	NORM	NORM
MULTIPLIER	1	1

TABLE 7.5.3b

e. Turn both stimulators on, allow a few minutes warm up, and adjust the oscilloscope until the pairs of pulses are seen.

7.5.4 When stimulators are connected in either of the preceding manner, and a single pair of pulses is desired, depress the MODE switch on Stimulator #1 from the OFF position to SINGLE.

7.6 External Control via Sync In

7.6.1 Driving the S48 from externally generated pulses to deliver single, repetitive and trains of pulses is possible using the synchronous inputs. The trigger voltage must be a minimum of 3.5 volts and normally should have a positive transition. However, if the trigger voltage is "negative going", it can be used by setting switch #7 of SW1 at the rear of the S48 to the ON position. (See Section 6.1.2.)

7.6.2 **Producing single or repetitive externally triggered stimulus pulses:** use the STIM DELAY SYNC IN. Each trigger pulse received at this terminal will produce a single stimulus pulse. The DELAY circuit is triggered. In this mode, set the TRAIN MODE and STIM MODE lever switches to the OFF center positions. The TRAIN RATE, TRAIN DURATION and STIM RATE controls are inoperative. Set the DELAY, DURATION and VOLTS controls for the desired settings.

7.6.3 The stimulus onset will be delayed from the trigger onset by the DELAY setting. If no delay is desired, set the DELAY to minimum (10 microseconds). With each trigger applied, the red LED adjacent to the SYNC IN STIM DELAY will light indicating proper triggering.

7.6.4 **Producing single or repetitive externally triggered stimulus trains (no delay):** use the TRAIN DURATION SYNC IN. The STIM MODE lever switch must be set to the REPEAT position. The TRAIN MODE lever switch must be set to the OFF position. Each trigger pulse received will produce a train of pulses. The TRAIN DURATION circuit is triggered, which modulates (turns on) the STIM RATE circuit for the length of time determined by the TRAIN DURATION controls. The number of pulses in the train is controlled by the STIM RATE controls. For example, if the TRAIN DURATION is set for 1 second, and the STIM RATE is set for 100 PPS, the train will consist of 100 pulses, etc.

7.6.5 Each trigger pulse will cause the red LED to flash indicating proper triggering. The onset of the train will be coincident with the leading edge of the trigger pulse. There is no delay.

7.6.6 **Producing single or repetitive delayed trains:**

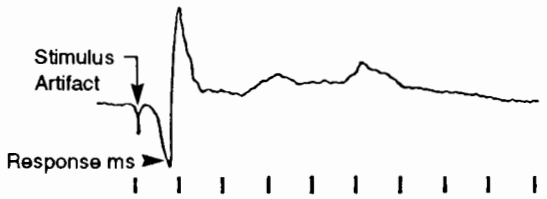
NOTE: Set the SW1 switch #8 "ON" to provide delay between the onset of the trigger and the onset of the train.

Use the STIM DELAY SYNC IN. The TRAIN MODE switch must be set to the OFF position. The STIM MODE switch must be set to the ON position. Each trigger pulse will produce a delayed TRAIN. The amount of DELAY will be controlled by the DELAY controls. The DELAY circuit is triggered, which triggers the TRAIN DURATION circuit.

8 ARTIFACTS, STIMULUS ISOLATION, CONSTANT CURRENT AND MIXING

8.1 Stimulus Artifact

8.1.1 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 preceeds the evoked response in time as indicated in the CRO record of Figure 8.1.1. The delay between stimulus artifact and the evoked response is dependent upon stimulation parameters and the characteristic properties of the preparation.

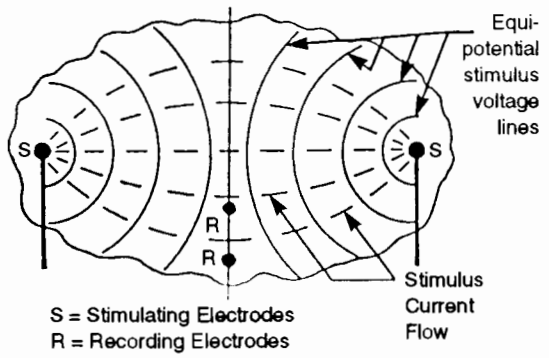


STIMULUS ARTIFACT
FIGURE 8.1.1

8.1.2 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.

8.2 Sources and Reduction of Stimulus Artifacts

8.2.1 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 8.2.1.



STIMULUS VOLTAGE FIELD DISTRIBUTION
FIGURE 8.2.1

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

8.2.2 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).

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

8.3 Stimulus Isolation

8.3.1 The S11, S44, S48, S88 and S8800 are compatible with Grass Stimulus Isolation Units Models SIU4678, SIU5, PSIU6, SIU7 and SIU8T. These stimulators are not compatible with Grass Models SIU4 and SIU478.

8.3.2 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, a condition which is particularly desirable in the operating room. It has the further advantage of permitting direct addition of stimuli of either algebraic sign.

8.3.3 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.

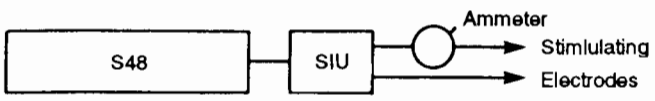
8.3.4 Additional information and operating details are further discussed in the specific Stimulus Isolation Unit Manual.

8.3.5 Stimulus isolation provides safety for human stimulation by removing any ground connection on the patient.

8.4 Stimulus Current Monitoring

8.4.1 It is often desired to measure the actual stimulus current. There are two ways of measuring the stimulus current. A DC ammeter can be connected in series with the stimulating electrodes or an oscilloscope can be utilized.

When using a milliammeter or microammeter, it should be placed in series with the stimulating electrodes. Stimulus isolation can be maintained if the meter is isolated with an SIU from ground. See Figure 8.4.1.



MEASURING CURRENT
FIGURE 8.4.1

8.4.2 With long duration pulses and very long pulse intervals, the meter will provide accurate measurements of peak current. When moderate frequencies and durations are used, the meter will indicate average current. Peak current of a simple repetitive pulse can be calculated by the following:

$$\text{Peak Current} = \frac{\text{Average Current x 100}}{\text{Duty Cycle Percent}}$$

Where Duty Cycle is defined as:
the percent "ON TIME", i.e.,

$$\text{Percent Duty Cycle} = \frac{\text{Pulse Duration}}{\text{Pulse Interval}} \text{ x 100}$$

then by substitution,

$$\text{Peak Current} = \frac{\text{Average Current x Pulse Interval (ms)}}{\text{Pulse Duration (ms)}}$$

If the repetition rate of the stimulus is close to the resonant frequency of the meter, however, it will be impossible to read the meter accurately. This method cannot be used for biphasic stimuli.

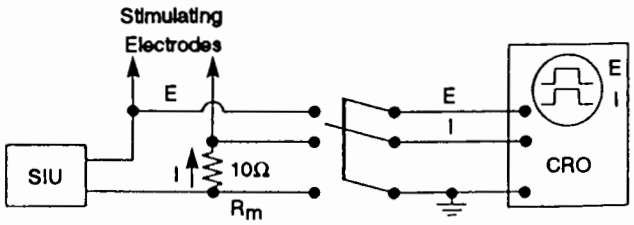
For further discussion, the Appendix, Section 10, the CCU and the SIU specification sheets are included in this manual for your reference.

8.4.3 CRO monitoring of instantaneous stimulus current can be accomplished by monitoring the voltages generated across a series resistor with a CRO. Use a series resistor whose value is very small relative to that of the stimulating electrodes and construct a circuit as shown in Figure 8.4.3. According to Ohm's Law, then:

$$I = \frac{E}{R}, \text{ or}$$

$$\text{Stimulating Current} = \frac{\text{Measured Voltage (Oscilloscope)}}{\text{Measuring Resistance } (R_m)}$$

When a 10 ohm resistor is used as shown, each milliampere of stimulus current results in a voltage drop of 10 millivolts across this resistor. With the CRO calibrated for a sensitivity of 10 mV/cm, each centimeter of deflection on the tube face equals one milliampere of stimulating current. If the CRO cannot be calibrated as low as 10 mV/cm, use a higher resistance to correspond to the sensitivity of the CRO. Figure 8.4.3 shows the stimulus electrode voltage being monitored on Channel 1 and the current being monitored on Channel 2.



CRO MONITORING
FIGURE 8.4.3

8.4.4 It is not possible to maintain stimulus isolation when this method is used, since the input of most CROs is referred to ground. When stimulus isolation is necessary, measure current periodically during the experiment as shown in Figure 8.4.3; then, by using the three-pole switch, isolate the measuring circuit as shown. If "before stimulus" and "after stimulus" measurements are identical and none of the dial settings have been altered, it can be assumed that the current has remained at a fixed value between measurements.

8.4.5 If stimulus isolation is not required, use circuit shown in Figure 8.4.3 without the three-pole switch, but wired as if the switch were in the monitor position. This permits continuous current monitoring. The CRO should be operated with one input terminal grounded.

8.5 Constant Current Output from the S48

8.5.1 The output impedance of the S11, S44, S48, S88 and S8800 Stimulators is low and essentially give a constant voltage. Relatively, the SIU4678 and SIU5 do the same (1000 to 2000 ohms output impedance).

The Grass Constant Current Unit (CCU1) can be used directly at the output of the S11, S44, S48, S88 and S8800, or in tandem with the SIU4678 or SIU5 Stimulus Isolation Units. It does not provide isolation in itself since it is driven by the incoming signal voltage. It requires no batteries and its range is from 50 microamperes to 50 milliamperes. It contains a meter for estimating current. (See Section 8.6.)

The Grass PSIU6 is an optically isolated and constant current unit. Its dynamic output impedance ranges from 600 megohms at 0.1 microampere to 4 kilohms at 15 milliamperes. It requires expendable batteries and it should be used primarily for low energy, low duty cycle applications. ***The PSIU6 is intended for animal use only and must not be used on people.***

The S48 has a selectable 100 kilohm output (referred to ground) which is an effective constant current source for electrodes of 10 kilohms or less.

For further discussion, see Section 9 and the CCU, SIU5, PSIU6, SIU7 and SIU8T specification sheets included in this instruction manual for your reference.

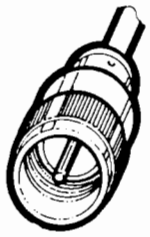
The SIU7 is similar to the PSIU6 in design. It is, however, intended for clinical procedures and has pulse duration limitation of approximately 5 milliseconds. There are two peak current ranges: 0.1 to 1.5 and 1 to 15 milliamperes. The output of the SIU7 is capacity coupled and will not produce a DC component in the output.

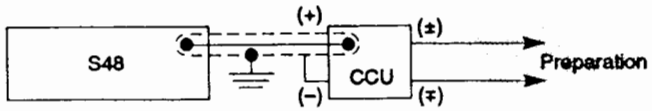
8.6 Constant Current with the CCU1 without Ground Isolation

8.6.1 An accessory Constant urrent Unit is available for current ranges from 50 microamperes to 50 milliamperes. It is compatible with all Grass Stimulators and can be used in combination with the Stimulus Isolation Units.

Additional information and operating details are further discussed in the CCU1 Instruction Manual.

8.6.2 Due to a wide variety of input connections to the CCU1, no cable is supplied. If a CCU1 is to be used with the S48, a shielded cable is desirable with a UHF (PL259) mating connector to the S48 on one end and a single or dual banana plug connection at the CCU1 end. See Figure 8.6.2. Connect the ground lead from the S48 to the negative (–) black binding post on the CCU1 and the active lead to the positive (+) red binding post.

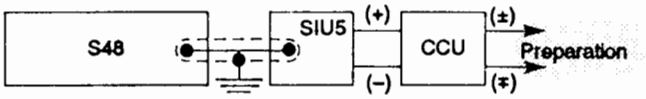




NONISOLATED
CONSTANT CURRENT UNIT CONNECTION
FIGURE 8.6.2

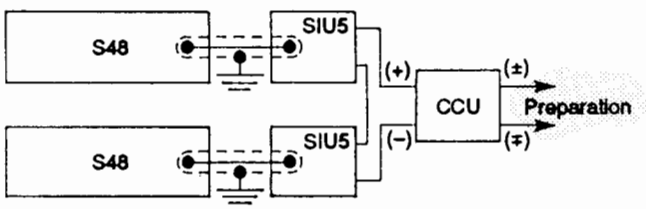
8.7 Constant Current and Stimulus Isolation with the SIU5

8.7.1 If both a Constant Current Unit and a Stimulus Isolation Unit are to be used, connect the S48 in series with the SIU and, in turn, with the CCU1 as shown in Figure 8.7.1.



SINGLE SIU & CCU CONNECTION
FIGURE 8.7.1

8.7.2 If the desired polarity and current of two stimuli at the electrodes is the same, one CCU1 can be used with two S48s and two SIUs in series as is shown in Figure 8.7.2. Pulses of opposite polarity are not possible with this method. In this case, the stimulus intensity at the electrodes is varied by the CURRENT ADJ control on the CCU1 and output voltage of the stimulator and SIU is set to maximum. Polarities as shown in Figure 8.7.2.

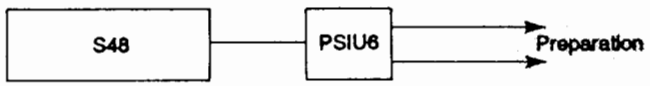


TWO SIUs & CCU CONNECTION
FIGURE 8.7.2

8.8 Constant Current with the PSIU6 (not for use on humans)

8.8.1 The Photoelectric Stimulus Isolation Unit, Model PSIU6, can be used when stimulus isolation is desired with a constant current output in the range of 0.1 microampere to 10 milliamperes.

8.8.2 The PSIU6 cable is connected directly to the output connector of the S48. The electrodes are connected to the two output terminals of the PSIU6. See Figure 8.8.2.

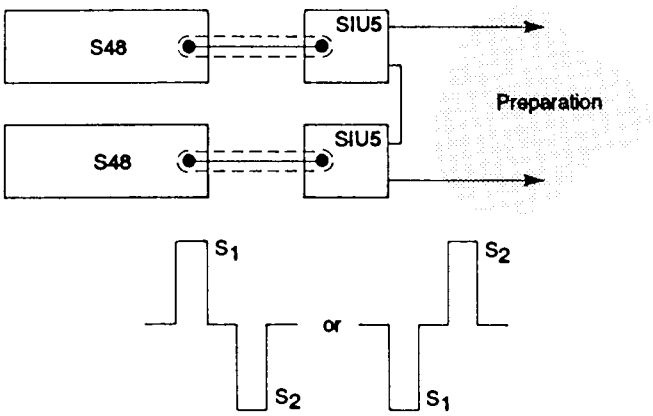


STIMULUS ISOLATION UNIT CONNECTION
FIGURE 8.8.2

8.8.3 The VOLTS multiplier switch of the S48 is set at X10 (SIU) and range is controlled at the PSIU6. Vernier control of current is made at the S48 VOLTS dial.

8.9 Mixing S_1 and S_2 Outputs through Two SIU5s to get True Addition and/or Biphasic Waveform

8.9.1 ***Outputs less than 15 volts***. S_1 and S_2 outputs can be mixed and introduced into the same pair of electrodes by connecting two respective SIUs in series. Figure 8.9.1 illustrates the outputs of two SIUs connected in series and to one pair of electrodes. Polarity reversal of either S_1 or S_2 is also possible without any further consideration if the MULTIPLY INPUT VOLTS BY switch on the SIU5 ***are not in the X1 maximum position***. In this case, the outputs of the SIUs may be connected in series (preferred), or in parallel. Polarity reversal of the stimulus can only be accomplished by the POLARITY switch on the SIU.



BIPHASIC PATTERN
FIGURE 8.9.1

8.9.2 ***Outputs over 15 volts***. When the multiplier switch on the SIU5 has to be in the highest range position (X1), some restrictions to mixing outputs apply:

a. ***Same polarity*** - no restrictions.

b. ***Opposite polarity from two SIUs***:

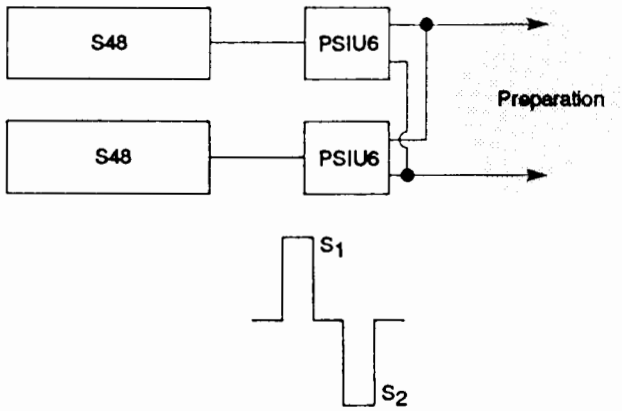
1. Connect SIU5s *in series only.*

2. For SIU5 or SIU4678, electrodes (or total load) of impedance over 25,000 ohms - no restrictions.

For electrodes (or total load) of less impedance than in (2), connect a parallel resistor across the output terminals of both SIU5s, about 2,000 ohms for the SIU5 and SIU4678. There will be loss of maximum voltage output from the SIUs because of this loading in proportion to the total electrode or load resistance and the source impedance of the SIUs. (1000 ohms on the SIU5 and SIU4678.) Maximum voltage with this system could be as low as 50 volts or less.

8.9.3 ***Do not*** try to mix PSIU6 and SIU5 or SIU4678 isolation. It is possible to mix the SIU5 and SIU4678 units. Additional information and operating details are further discussed in the specific Stimulus Isolation Unit Manual.

8.9.4 Since the PSIU6 provides a constant current output, inherently its output impedance is very high, therefore the outputs of the PSIU6 and the SIU5 (which is constant voltage and low impedance) should never be mixed. With constant current stimulation, the presentation of the current waveform is sometimes a problem since, more often than not, the electrode impedance is very high. Deterioration of the voltage and current waveform *at the electrode site* is the result of stray capacitance which shunts the high impedance electrode. The PSIU6 can deliver a minimum current of 0.1 microampere into an electrode impedance of 600 megohms and a maximum current of 10 milliamperes into an electrode impedance of 600 ohms. It is apparent that waveform preservation is more of a problem at the low current levels. It should also be mentioned that when mixing the outputs of two PSIU6s, as is shown in Figure 8.9.4, the interconnecting leads between the two units and to the preparation should be as short as possible to minimize stray capacitance effects. Usually waveshape problems are much more difficult to control when mixing the outputs of two isolation units, especially for very small currents.



BIPHASIC CONSTANT CURRENT
FIGURE 8.9.4

9 TROUBLESHOOTING

9.1 Overload Reset Circuitry

9.1.1 An overload or short at the output of the S48 trips the shutdown circuitry in the high voltage Power Supply which shuts off the 175 volts high voltage Power Supply. Concurrently, the OVERLOAD lamp goes on and the MONITOR lamp goes off.

9.1.2 To reset, shut POWER off for 5 to 6 seconds, correct overload or short circuit condition and then turn POWER on. The OVERLOAD lamp should be off and the MONITOR lamp should be on.

9.1.3 It the unit will not reset and there are no apparent short circuits or overloads, contact the Repair Service Department at Grass Instrument Company to obtain a replacement S48.

9.1.4 In addition to shutting down in the event of an overload or short circuit at the output, the S48 will also shut down due to excessive temperature rise of either the HIGH VOLTAGE power supply board or the OUTPUT board heat sink. A thermoswitch calibrated to actuate at 100°C (212°F) is mounted on each heat sink. These thermoswitches will not usually actuate unless the S48 is operated for extended periods of time at high duty cycles and high output current.

To reset, in the event one of the thermoswitches does shut down the S48, shut the POWER off for a period of time sufficient to allow the heat sink to cool down below 100°C (212°F) and then turn the POWER on.

9.2 Procedure

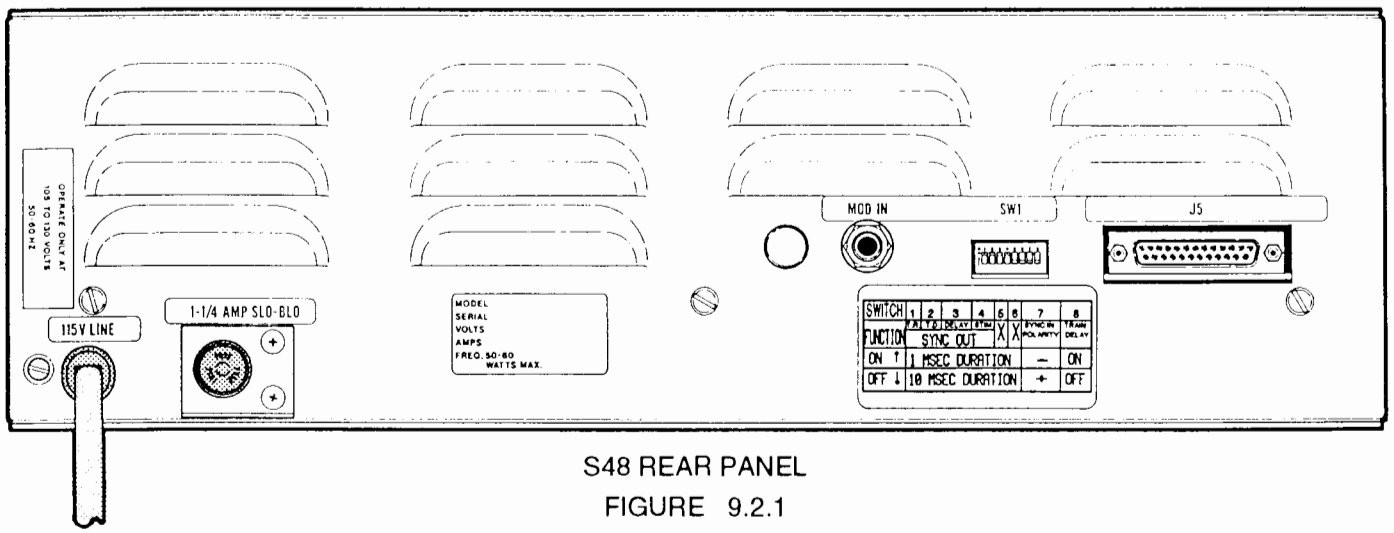
9.2.1 In the event of a malfunction, proceed as follows:

a. Check the POWER lamp. If it is not ON, with the S48 connected to the line voltage receptacle, and the S48 POWER switch ON, check the fuse at the rear of the S48. If the fuse is blown, replace it with a spare fuse and try operating the S48. If the fuse is good, verify that the AC receptacle is active by plugging in another device such as a lamp, etc.

b. Recheck the settings of the S48 controls to make sure they are set properly. (A switch may be in the wrong position.)

c. If the S48 is being controlled externally, check that the controlling device is operating properly and providing the proper control voltage.

d. If it is still not possible to operate the S48 properly, contact the Grass Repair Service Department.



S48 REAR PANEL
FIGURE 9.2.1

10 APPENDIX

10.1 Constant Voltage vs. Constant Current Sources for Pulse Stimulation

10.1.1 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 microamps 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.

10.1.2 "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.

10.1.3 "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.

10.1.4 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 10.1 - 10.2

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 (25 Ω) 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.

10.1.5 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 for clinical procedures. 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. It is intended for clinical procedures. ***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

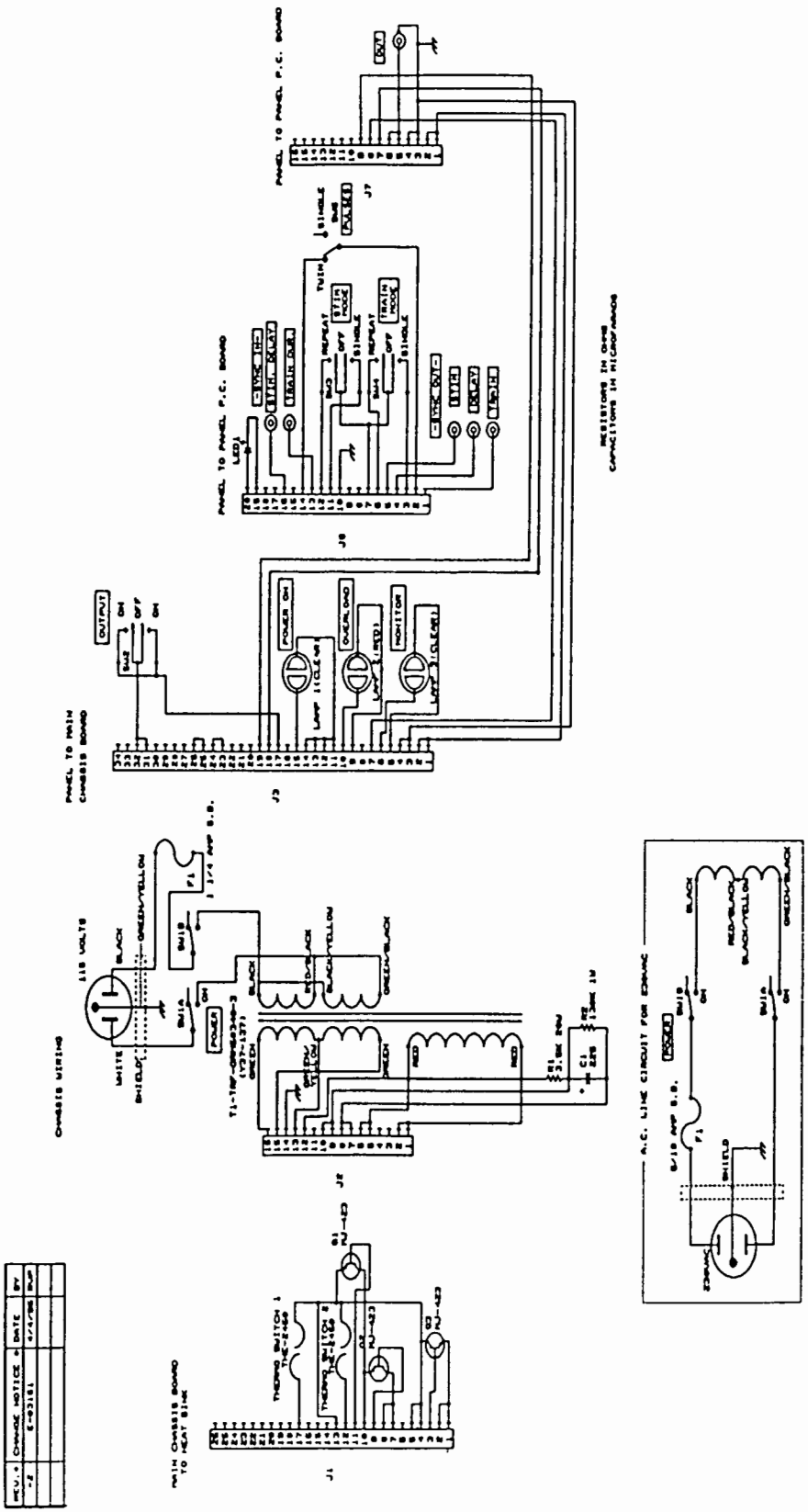
10.2 References

Moore, E.N. and M. Bloom. A method for intracellular stimulation and recording using a single micro-electrode. *J. Ap. Physiol. 27:* 734-735, 1969.

Tuganowski, W. Simple method of stimulation and recording with a single microelectrode. *J. Ap. Physiol. 33:* (1) 130-131, July, 1972.

Vaughan, W. and S. Locke. A circuit for stimulating and recording through a single-capillary micro-pipette. *IEEE Trans. Biomed. Eng. BME-18:* 71-72, 1971.

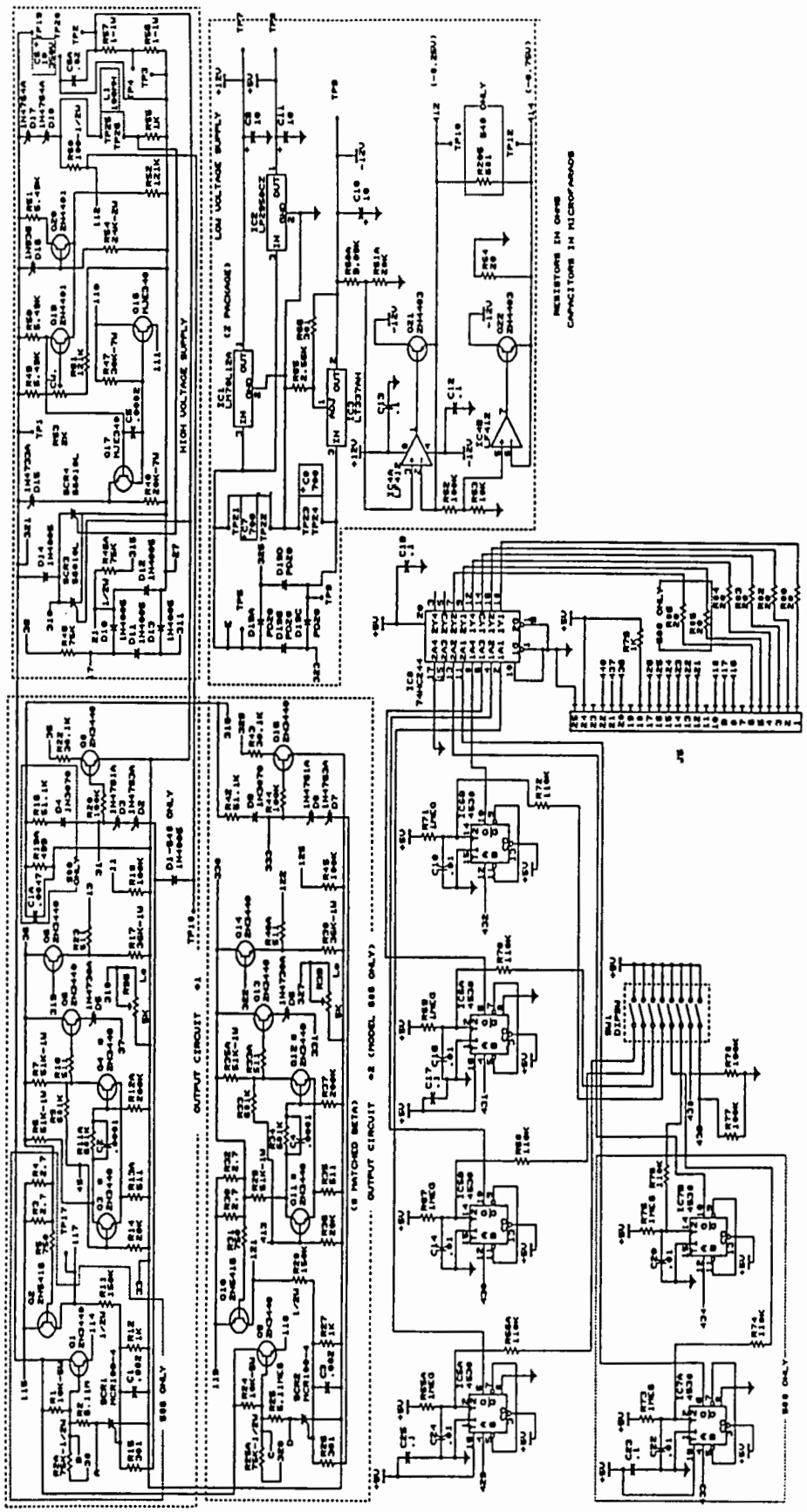
CIRCUIT DIAGRAMS
Section 11.1



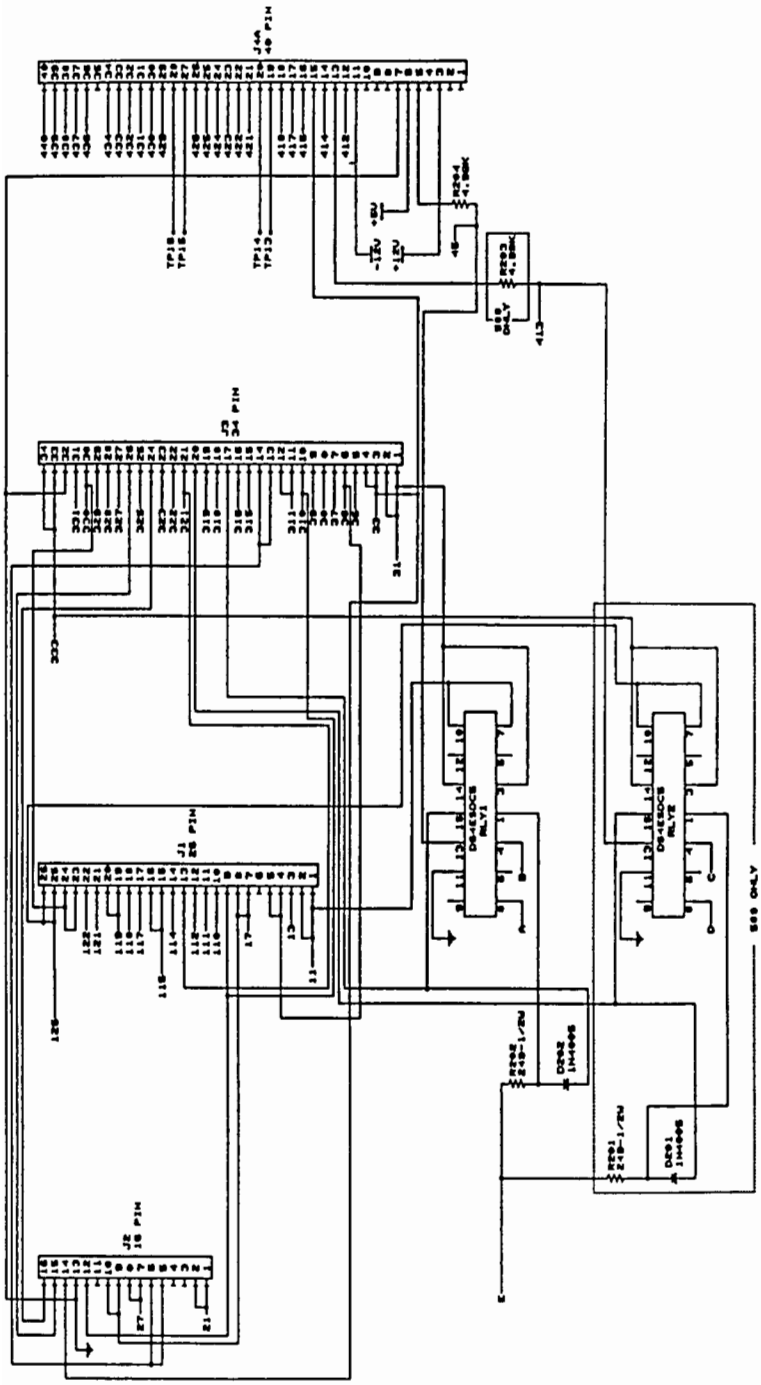
MODEL S48H STIMULATOR CHASSIS/PANEL CIRCUIT DIAGRAM – #51645-2

(Part 1 of 1)

CIRCUIT DIAGRAMS
Section 11.1



MODEL S48H MAIN CHASSIS P.C. BOARD #7684-2 – #51628-4
(Part 1 of 2)



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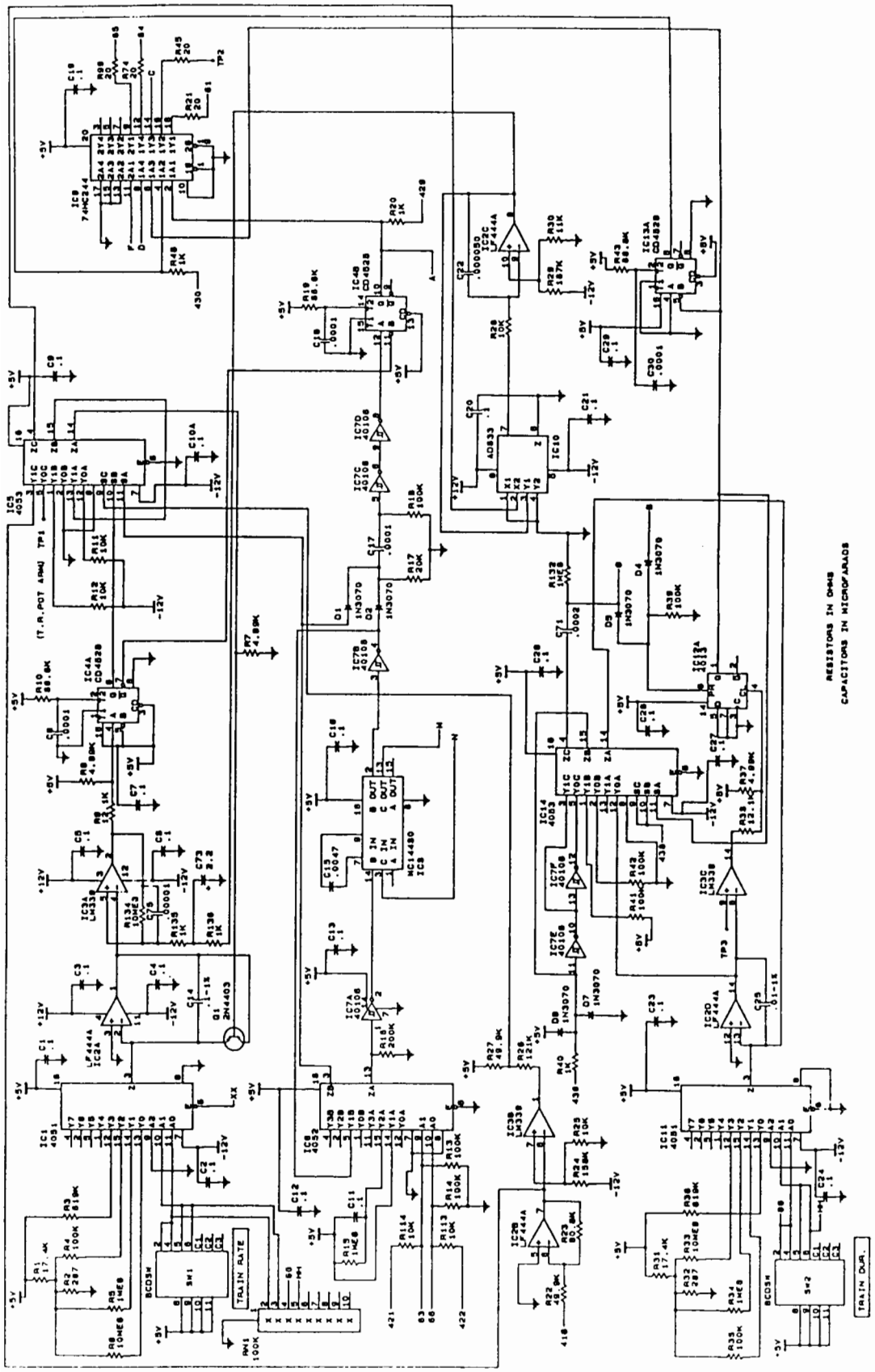
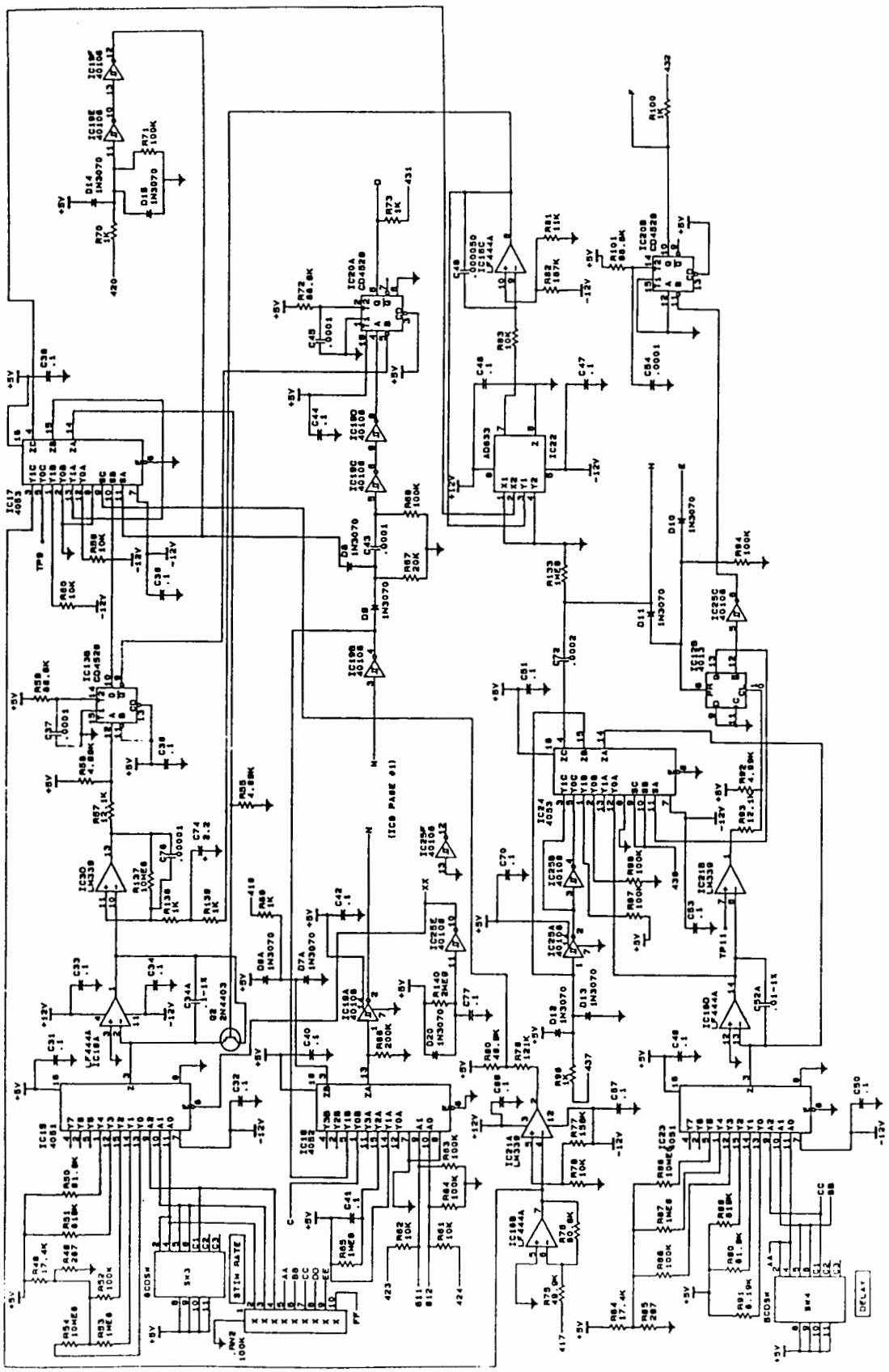
(Part 2 of 2)

CIRCUIT DIAGRAMS
Section 11.1



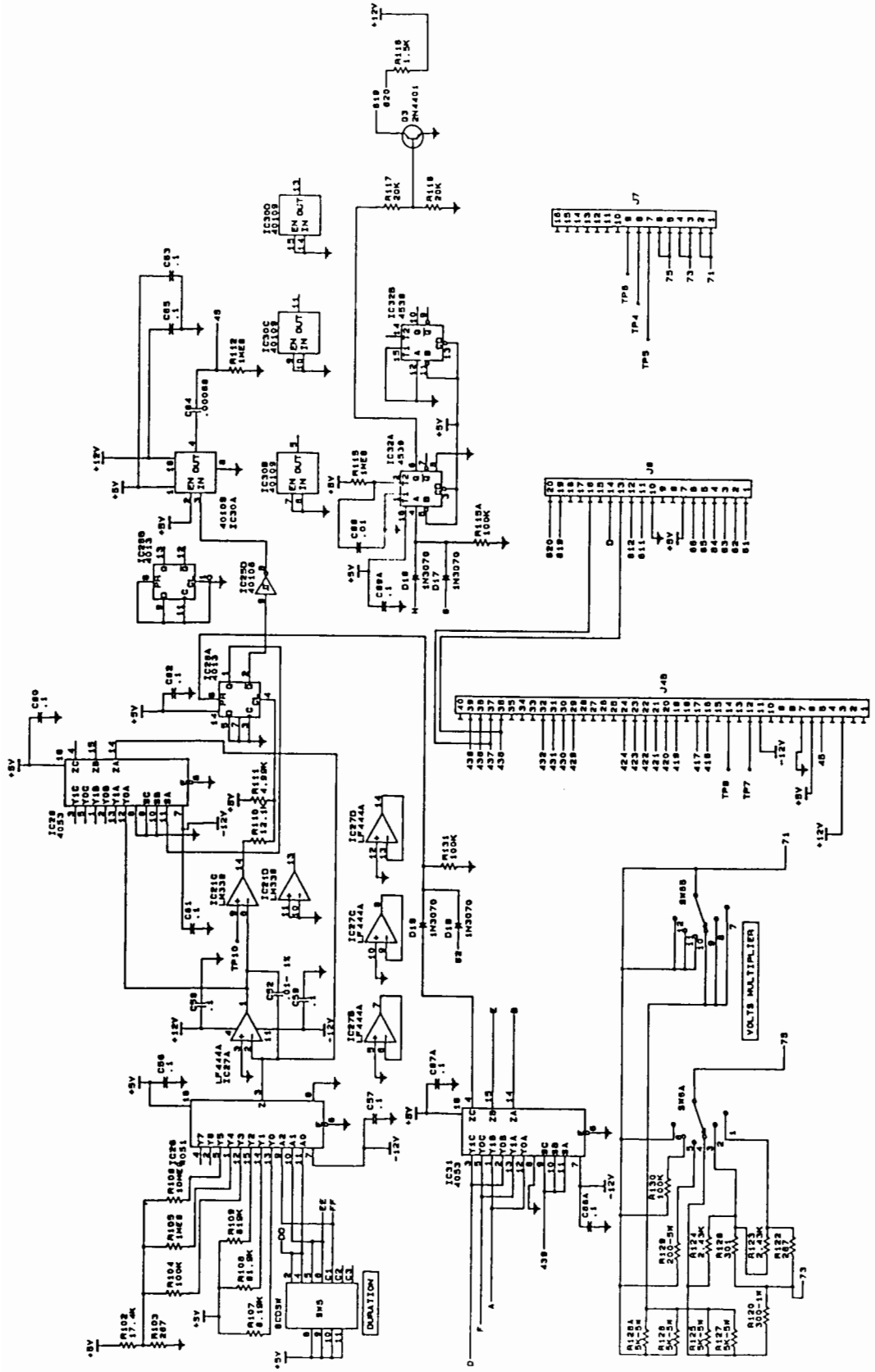
MODEL S48H PANEL P.C. BOARD #7680-2 – #51629-4
(Part 1 of 3)

CIRCUIT DIAGRAMS
Section 11.1



MODEL S48H PANEL P.C. BOARD #7680-2 – #51629-4
(Part 2 of 3)

CIRCUIT DIAGRAMS
Section 11.1



MODEL S48H PANEL P.C. BOARD #7680-2 - #51629-4
(Part 3 of 3)

ONE-YEAR LIMITED WARRANTY

JULY 1995

SUPERSEDES ALL PREVIOUS WARRANTIES

GRASS INSTRUMENT DIVISION, Astro-Med, Inc. WARRANTS this instrument to the original purchaser (who is the same end user) only. The warranty is not transferable. Material, workmanship and performance as specified are guaranteed:

1. if the *GRASS* seal (when present) is not broken,
2. if there is no evidence of abuse, attempted repairs or modifications without Grass authorization,
3. only if genuine Grass replacement parts are used,
4. only if the instrument is used for its specified uses,
5. if the instrument has not been resold or used in a larger system incorporating non-Grass products which were not approved by Grass for compatibility.

THIS WARRANTY IS BINDING FOR ONE YEAR from date of initial delivery and is limited to: servicing and/or replacing any instrument or part thereof (except batteries and expendable supplies) returned to the factory for that purpose with transportation charges prepaid and which to the company's satisfaction are found to be malfunctioning.

WARRANTY DISCLAIMERS

Any implied warranties arising out of this sale, including but not limited to the implied warranties of merchantability and fitness for a particular purpose, are limited in duration to the above one (1) year period. Grass Instrument Division, Astro-Med, Inc. shall not be liable for loss of use of the instrument or other incidental or consequential costs, expenses or damages incurred by the purchaser.

Some states do not allow the exclusion or limitation of implied warranties or consequential damages, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights, and you may also have other rights that vary from state to state.

DAMAGE UPON ARRIVAL

Each instrument leaves our plant after rigorous tests and performs as specified. The instrument may receive rough handling and damage in transit. The shipment is insured against such damage. The buyer must report in writing immediately any concealed or apparent damage to the last carrier. Report any damage also to us, and issue an order for replacement or repair. Our invoice for such service will then be evidence in the claim. Hold all packaging material.

MALFUNCTIONS OCCURRING WITHIN WARRANTY PERIOD

Our prices include replacement of malfunctional parts, modules and even complete instruments when all conditions of sale are met and if we decide it necessary. It does not include:

1. provide for any transportation charges,
2. provide for services not performed or authorized by us,
3. provide for the cost of repairing instruments which have obviously been abused, modified, or subjected to non-intended uses or to unusual environments for which they have not been designed.

We will discuss by phone or letter suspected malfunctions or aspects of instrument operation which may be unclear. Advise us of the nature of the malfunction before returning an instrument for repair. Many times a simple suggestion will solve the problem without returning anything. In the case of a malfunction properly diagnosed by Grass Instrument Division, Astro-Med, Inc. as being within a "plug-in" module, circuit board or other part which can readily be replaced without impairment of the instrument fidelity by a procedure which does not require a service man, then it is the responsibility of the owner to make such replacement under the direction of the company with a suitable replacement furnished by the company under the terms of the warranty. The owner has the responsibility for the return or to bear the cost of the replaced unit when requested.

WARRANTY ON SPECIFICATIONS

Grass Instrument Division, Astro-Med, Inc. reserves the right to make changes in design and specifications without notice and without any obligation to install such changes in units previously purchased.

Grass Instrument Division, Astro-Med, Inc. warrants each instrument to satisfy printed specifications available to the purchaser on formal request thirty days prior to date of scheduled delivery. Specifications are the average of typical measurements made on production units under controlled conditions. Statistical variations in individual units due to normal component variations are to be expected and should not alter the intended use of the instrument. However, when parameter characteristics are critical, tolerances are specified and guaranteed. Operating characteristics can be expected to change slightly from printed specifications with age and long term use.

Unless the exact tolerances of any parameter of any instrument are specified on the purchase order and specifically agreed to by Grass Instrument Division, Astro-Med, Inc. it is assumed that our standard production tolerances will satisfy all contractual responsibility.

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