GRASS®

S88X

DUAL OUTPUT SQUARE PULSE STIMULATOR

USER &
SERVICE MANUAL

Release D

natus®
neurology

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Important

This manual is subject to periodic review, update, and revision. Customers are cautioned to verify that the manual's information applies to the software and hardware present in the equipment.

This product performs as described in this manual, and in accompanying labels and/or inserts, when assembled, operated, maintained, and repaired in accordance with the instructions provided.

This product must be cleaned and checked periodically. Do not use a defective product. Parts that are broken, missing, worn, or contaminated should be replaced immediately. If repair or replacement becomes necessary, call or write to request service advice from Grass.

This product must not be altered without the prior written approval of Grass. The user of this product shall have the sole responsibility for any malfunction that results from improper use, faulty maintenance, improper repair, unauthorized service, or alteration by anyone other than Grass.

The safety, reliability, and performance of this device can only be assured under the following conditions:

- If the device has been used according to the accompanying operating instructions.
- If changes or repairs have been carried out by Grass.
- If it is used in buildings having ground equalization wiring that complies with relevant UL, CSA, IEC or other local standards and regulations.

Intended Use

The S88X Stimulator is a general purpose, electrical stimulator for nerve and muscle that has a wide range of parameters to satisfy a wide range of research applications.

FOR USE BY QUALIFIED PERSONS ONLY. NOT INTENDED FOR THERAPEUTIC PURPOSES.

Warnings

READ THIS BEFORE OPERATING S88X

The available voltage and current from this Stimulator may, under some conditions, be sufficient to be lethal or cause burns, particularly with high duration and/or high voltage settings.

It is the responsibility of the investigator/user, to determine for any given application, the maximum safe levels of stimulation, and assure that such stimulation levels will not be exceeded. In many applications, the mechanisms of safe stimulation are not completely understood.

Parameters that affect safe stimulation levels are:

- Pulse Repetition Rate
- Pulse Duration
- Pulse Duty Cycle
- Voltage and/or Current Intensity
- Biphasic vs Monophasic Operation
- Total Time Exposure
- Electrode Impedance, Geometry, Area and Material

The S88X OUTPUT is NOT ISOLATED. Do not use on humans.

CONSULT GRASS IF YOU HAVE ANY CONCERNS ABOUT SAFE APPLICATION, PARTICULARLY WHEN USED WITH OTHER EQUIPMENT.

NATUS MEDICAL INCORPORATED WAIVES THE RESPONSIBILITY WHATSOEVER FOR ANY INJURIES INCURRED TO THE OPERATOR OF THIS INSTRUMENT, OR TO ANY ANIMAL OR HUMAN SUBJECT AS A RESULT OF THE IMPROPER USE AND/OR ABUSE OF THIS STIMULATOR.

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1 Specifications & Symbols Glossary

Specifications

Train Rate (S1 and S2)	1/100 sec to 99 TPS
Train Duration	1 msec to 99 sec
Rate (S1 and S2)	1/100 sec to 1000 PPS
Pulse Delay (S1 and S2)	10 µsec to 99 sec
Pulse Duration (S1 and S2)	10 µsec to 99 sec
Synchronous Outputs (TTL)	S1, S2, S1 Delay, S2 Delay, Train; Front panel BNC connectors, 50 ohm, 10 µsec pulses, can source/sink 20 mA peak
Synchronous Inputs (TTL)	Train Duration, S1 Delay, S2 Delay; Front panel BNC connectors, 4.75 kohm pullup to 5 volts
Stimulus Output	250 mV to 24 volts (monophasic) 250 mV to ±12 VDC (biphasic)
Peak Output Current	1 A
Output Protection	Yes, current limited
Output Impedance	<2 ohms
Maximum Power Out	24 W peak
AC Power	115/230 volts, 50/60 Hz, 100 watts maximum
Physical Size	19" W x 5.25" H x 12.5" D (48.3 cm x 13.4 cm x 31.8 cm)
Weight	10 lbs. (4.5 kg)
Regulatory	Safety: EN 61010-1:2001, UL 61010A-1, CSA C22.2 No. 1010.1-92 EMC: FCC Part 15, Subpart B, Class B, EN 61326:1998 Class B

(All specifications subject to change without notice.)

GLOSSARY OF SYMBOLS

Warnings & Cautions

2 Introduction

Safety Information

CAUTION
Misuse of this product may constitute a safety hazard. Please review the following.

WARNING
The S88X output is not isolated. Do not use on humans.

1. For use by qualified persons only.

2. Removal of the S88X Stimulator cover may expose you to lethal voltages and other hazards. Observe labels and caution notices.

3. 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.

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

5. Never expose the stimulator to rain or moisture as this can be a potential cause of fire or shock hazard. If the S88X is exposed to moisture, unplug it and have it checked by a qualified person.

6. The S88X cabinet has slots for ventilation purposes to prevent component overheating.

   a. Never cover the slots with cloth or any other material.

   b. Avoid placing the S88X over radiators or heat registers.

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

7. Operate the S88X only on the power sources as printed on the panel. Damage may result from incorrect voltage.

8. 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.

9. 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.

10. If this stimulator is to be used with an isolation output, use the proper Grass isolation unit accessory. Contact Grass for application information in writing.

11. Determination of the safe levels of the stimulation for each application is the responsibility of the investigator in charge.

12. The investigator in charge is responsible for assuring safe stimulation levels will not be exceeded.

Electromagnetic Compatibility Information

The included ferrite EMI suppression cores are required for compliance with EN61326. These should be attached to each output cable by opening the split core, then snapping it together over the cable so that the cable runs through the ferrite core. These should be placed near the output connector on the S88X.

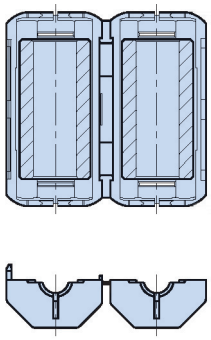

Figure 2-1: Ferrite EMI Suppression Core

3 General Considerations

Applications & Capabilities

The S88X is a dual output general purpose electrical stimulator for nerve and muscle stimulation procedures. Following in the tradition of Grass quality and reliability, the S88X is the next generation of the Grass stimulator line.

New Features Include:

- Digital controls—precise timing accuracy
- Bright display simplifies setup
- Independent or synchronous channel operation
- Monophasic and biphasic modes
- Dual train output
- High current output facilitates field stimulation
- New companion isolation units
- Software replacement

The built-in versatility of the S88X Stimulator makes it suitable for unlimited stimulation protocols. The S88X has four parameter control of the two independent outputs. In addition to single, repetitive, twin pulses, biphasic pulses, monophasic pulses, pairs of unlike pulses, trains of pulses, and post train pulses, continuous or trains of pulses are available at one output with continuous or discontinuous operation at the other output. The two outputs can be connected to the same preparation site providing the outputs are isolated from ground using the SIU-C, SIU-V, SIU-BI or the PSIU6X Stimulus Isolation Units. The S88X also includes the capability to introduce an arrhythmic pulse within a cycle of pulses, especially useful for research by cardiophysiologists studying atrial and ventricular fibrillation.

The S88X makes use of current technology in it's design. A DAC (Digital Analog Converter) is used to generate the output pulses, and a FPGA (Field Programmable Gate Array) to reduce the size.

Software can be updated via the USB interface connector located on the rear chassis. See CHAPTER 7 EXPLANATION OF CONTROLS for instructions.

The S88X is a general purpose stimulator and not intended for human stimulation procedures. The S88X is not designed for electroshock therapy, for the creation of localized brain lesions or for electroanesthesia.

The design includes Fail-Safe shutdown circuitry which limits the output current and prevents component damage in response to overload or accidental short circuiting of either output.

The S88X can provide three types of pulses; ***monophasic, biphasic,*** and ***twin***.
See Figure 3-1a, b, and c. As shown in Figure 3-1b, the biphasic mode provides equal and opposite amplitude phases. This mode is especially suited to applications where relatively long-term stimulation of implanted electrodes is anticipated and minimization of ion transfer from metal electrodes to tissue is desired.

Figure 3-1a:
Monophasic Waveform

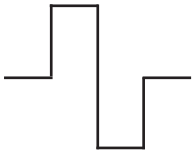

Figure 3-1b:
True Biphasic Waveform

All modes and timing parameters are displayed on the Vacuum Fluorescent Display. In general, the following steps are used to set parameters.

Figure 3-1c:
TWin Waveform

1. Select S1 or S2 FUNCTION, then use the TIMING thumbwheel dial to select the function.
2. Select appropriate PULSES and use the TIMING thumbwheel dial to select the pulse type.
3. Select the TIMING RATE, DELAY, and DURATION values and the TRAIN RATE and DURATION values using the TIMING left and right arrow keys and the thumbwheel dial.
4. Adjust the desired output voltage using the OUTPUT AMPLITUDE left and right arrow keys and the thumbwheel dial.

Note: To increase or decrease the rate, delay, duration or output amplitude use the left and right arrow touch-pad controls to select the digit to be changed. The number that is flashing is the number that is selected. Then use the thumbwheel control to increase or decrease that number.

The display is divided vertically. The left side displays the selected channel, S1 or S2, function, type of pulses; monophasic, biphasic, or twin, and the output amplitude (volts). The right side of the display is used for displaying the Delay, Duration, Rate, Train Rate and Train Duration. The graphical symbols accompanying the timing values indicate how the values apply to the waveforms. The right side of the display is also used for any error messages.

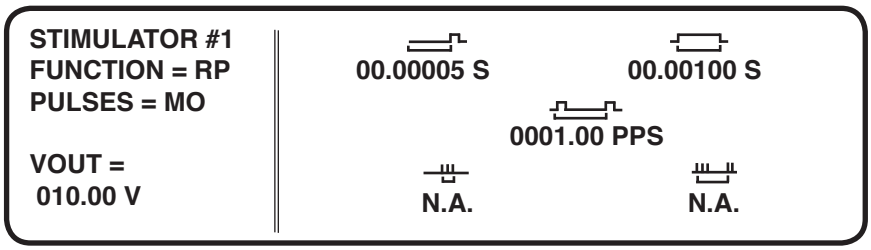

Figure 3-2: Vacuum Florescent Display

Several stimulus isolation units are available for use with the S88X:

Model SIU-V	Isolated constant voltage
Model SIU-C	Isolated constant current
Model SIU-BI	Isolated biphasic constant current
Model PSIU6X	Isolated battery-operated constant current

Selection of the isolation unit is made in the SETUP screen. (SETUP > CHOOSE STIMULUS ISOLATION UNITS)

Non-isolated stimuli can be delivered from the S88X directly. To facilitate connecting the S1 and S2 outputs in this mode, two special cables, CAB-21891 are provided with orders that do not include stimulus isolation units.

Accuracy & Waveform

All timing parameters are crystal controlled and are accurate to within ±0.00005%. This feature provides repeatability for the most demanding applications.

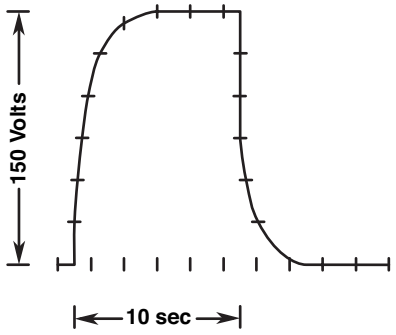

Figure 3-3: Pulse Waveform

Both the rise and fall times of the S88X output pulses are approximately 4 microseconds. Calibration of the duration is based on the average width of the pulse. Figure 3-3 illustrates the pulse waveform at a duration of 10 microseconds.

Because of this high accuracy, it is seldom necessary to monitor the stimulus. However, when complex pulse patterns are produced and until all basic modes of operation of the S88X are understood clearly, monitoring the output with an oscilloscope is advised. Figure 3-4 shows typical pulse waveforms obtainable with the S88X.

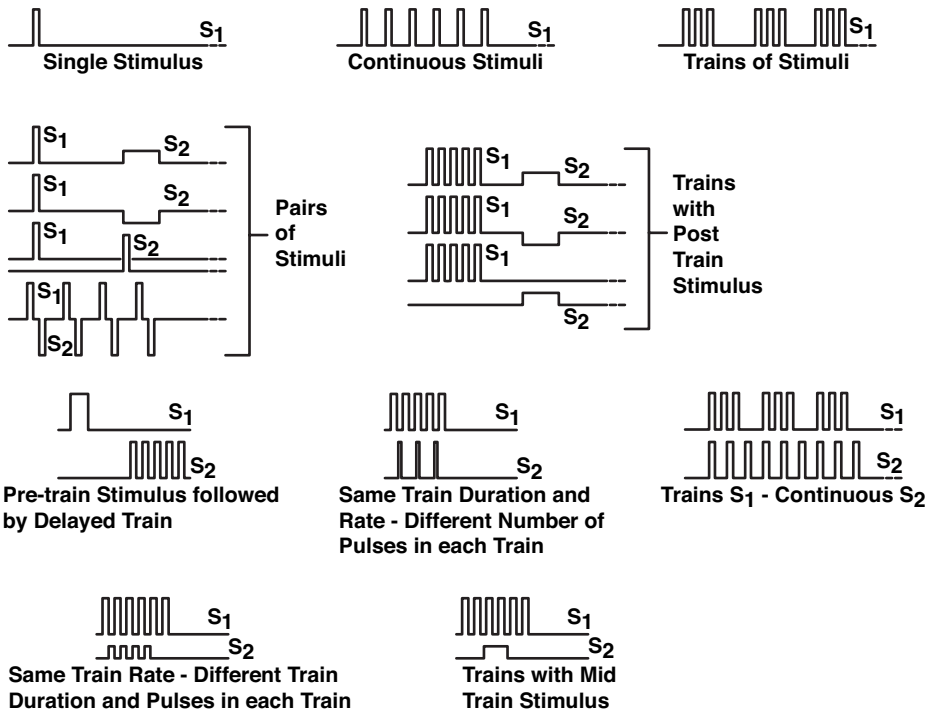

Figure 3-4: Typical Stimulus Waveforms

Line Voltage Requirements

The S88X has an IEC320 Power inlet for a standard 3-wire AC cable. The unit accepts 115 to 230 volts, 50/60 Hz. The maximum power is 100 watts. The S88X power inlet accepts a standard 3-wire AC Power cord. The input is 115-220 volts, 50/60 Hz and 100 watts. Fusing is in the S88X power supply.

Duty Cycle

Duty cycle is defined as the ratio of the time that the stimulus is ***on*** to the total period or interval. 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 (T=1/F), the DELAY and DURATION controls should not be set greater than T=1/2F which is equivalent to 50% duty cycle. 100% duty cycle occurs when a circuit is ***on*** continuously, as with DC.

Note: If TWIN or BIPHASIC PULSES are selected, the duty cycle is calculated as twice the pulse time divided by the period multiplied by 100.

The S88X duty cycle limit can be set in the SETUP function. The default value is set to 50%. Values from 0 to 99% are selectable. The S88X display will ***flash*** and limit the value when the selected duty cycle is exceeded while making a selection with the OUTPUT ON/OFF on. During setup, with the OUTPUT ON/OFF in the off position, a duty cycle message will display if the duty cycle is exceeded. In these messages, the DCWL value is a percentage and is the Duty Cycle Warning Level. When the output is initially turned on, all parameters will be checked against the duty cycle limit. If the limit is exceeded, a message will be displayed. The output will not be turned on until the output is below the duty cycle limit.

Example #1:

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 3-5.

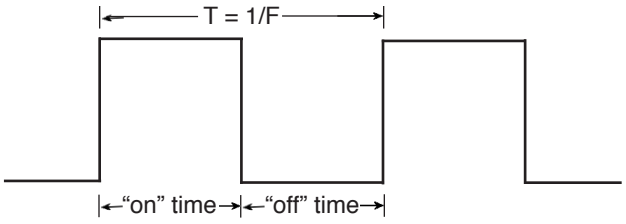

Figure 3-5: 50% Duty Cycle

The 50% duty cycle can never be exceeded if the DELAY and DURATION controls are set for less than 500 µs. If the DELAY circuit is not being used, always set the DELAY controls for less than 500 µs.

Most triggered circuits, such as those in the S88X, cannot be driven satisfactorily over 90% of their duty cycle. Although the stimulator will not be harmed if the duty cycle is exceeded, the stimulator calibration may be affected if operated above a 50% duty cycle.

The train duration should not exceed 50% of the TRAIN RATE settings.

Mounting & Installation

The S88X is housed in a compact cabinet 9" W x 5.25" H x 12.5" D (48.3 cm x 13.4 cm x 31.8 cm) and can simply be placed on a laboratory table. An optional Model S88XBT adjustable bench-top stand to mount one stimulator is also available. The S88X can also be rackmounted in a standard 19" equipment rack with the optional Model S88XRK rackmount brackets. When rackmounting, be sure to provide adequate spacing around the S88X for ventilation. Do not cover the ventilation holes in the S88X cabinet.

4 Description of Circuits

General

To distinguish the various functions of the S88X, color coding has been used.

S1 functions	= Blue
S2 functions	= Green
RATE, DELAY and DURATION	= Yellow
SYNC terminals	= Gray

Most switches are membrane touch-pad type offering extreme reliability. Settings are displayed on the front panel, bright, vacuum florescent display.

Power Supply

The S88X power supply provides highly regulated DC voltages for circuit operation. No adjustments are required. The following DC regulated voltages are generated:

+27 volts DC
+12 volts DC
+5 volts DC
+3.3 volts DC
+2.5 volts DC
-15 volts DC
VREF 2.5 volts DC

Output Circuit

The S88X is driven by a Digital Signal Processor (DSP). To create the output waveforms the DSP writes 16-bit binary values to a Digital to Analog Converter (DAC). The DAC puts out a voltage that corresponds to each value. The DSP can write a new value to the DAC every 10 µs. By varying the binary value written to the DAC the DSP can vary the output over time to produce the desired waveform. The DAC output is then multiplied by a factor of 10 and sent to the output of the S88X.

The output of each amplifier is monitored to detect an over-temperature condition. The DSP monitors the output of this circuit to detect the over-temperature condition.

At initialization, the output circuits are disconnected from the output of the S88X. This prevents the output from generating outputs inadvertently. When the DSP gets to a particular point in the code, it connects the output circuits to the output of the S88X.

The output circuit also contains a low power section that takes as an input the amplified signals and puts out a composite signal used to monitor the output.

S1 & S2 Output Amplitude

The S88X S1 and S2 outputs are low impedance constant voltage outputs. Both outputs are current limited and short circuit protected. The maximum output current from each output is 1.1 amperes. The voltage can be varied from 0.25 to 24 volts. Accuracy is 0.1% of reading ±1 mV.

Amplitude is set by the OUTPUT AMPLITUDE thumbwheel dial. The output can swing between +24 volts and –12 volts maximum. For monophasic and twin pulses, the output is 24 volts maximum. When in the biphasic mode, the output is between –12 volts and +12 volts.

The available high output current can be used for special applications. Field stimulation of isolated tissue in tissue baths can be achieved. Vessel rings, strips of muscle and other preparations can be stimulated using field stimulation techniques. These setups typically utilize parallel plate electrodes submersed in various solutions for various drug testing and experimentation.

These applications with this type electrode submerged in baths present a very low resistance circuit load to the stimulator output requiring the stimulator to deliver large amounts of current. Most stimulators are not capable of driving large currents and tend to overload when used for this application. Additionally, the waveform becomes distorted and does not represent the normal output from the stimulator.

The high output current available is capable of stimulating multiple baths. The amount of current required by a bath depends on several factors. Bath size, type of bath solution, electrode size and spacing can determine the amount of current required. Monophasic and Biphasic pulses are selectable at the S88X.

To facilitate stimulating multiple baths, an output manifold, Model CEM simplifies connection from the S88X to the baths. This device has two inputs for connection from the S88X, S1 and S2 outputs. Four outputs are available for connection to up to four tissue baths.

5 Explanation of Controls

Explanation of Controls

The following section describes the S88X controls and their function.

Power

POWER is a rocker switch to control the AC power supplied via the AC cable assembly. This switch turns the S88X on or off.

Setup & Enter/Accept

The SETUP touch-pad control sets several modes as seen on the display. These are:

- DUTY CYCLE LIMIT
- CHOOSE STIMULUS ISOLATION UNITS
- LOAD SETUP
- SAVE SETUP
- TRAIN PARAMETERS FUNCTIONS

The ENTER/ACCEPT touch-pad control is used to enter and accept changes made in the SETUP.

See Chapter 7, Operation for more information.

Train Rate & Duration

The TRAIN RATE touch-pad control displays the current value. The TRAIN RATE is set with the TIMING left and right arrow touch-pad controls and the thumbwheel control.

TRAIN DURATION touch-pad control displays the current value. The TRAIN DURATION is changed with the TIMING left and right arrow touch-pad controls and the thumbwheel control.

Note: The left and right arrow touch-pad controls to select the digit to be changed. The selected digit will flash. Use the thumbwheel control to increase or decrease that number.

S1/S2 Timing Parameter Ranges

Train Rate

The Train Rate is adjustable from 00.00 to 99.99 trains per second (TPS).

Train Duration

The Train Duration is adjustable from 00.000 to 99.999 seconds.

S1/S2 Rate

The S1/S2 Rate is adjustable from 0000.00 to 1000.00 pulses per second (PPS).

S1/S2 Delay

The S1/S2 Delay is adjustable from 00.0000 to 99.99999 seconds.

S1/S2 Duration

The S1/S2 Duration is adjustable from 00.00000 to 99.99999 seconds.

Note: Setting the TRAIN RATE, S1/S2 RATE, or S1/S2 DURATION to zero will produce zero output.

S1 & S2 Controls

Function

The FUNCTION touch-pad control is used in conjunction with the TIMING thumbwheel control to select the S1 and S2 modes. The modes are listed below.

S1 Modes:

These four modes allow S1 and S2 to operate as completely independent stimulators.

- SINGLE PULSE (SP)
- REPEATING PULSE (RP)
- SINGLE TRAIN (ST)
- REPEATING TRAIN (RT)

The following two modes are externally controlled requiring an external trigger to the S1 DELAY SYNC IN or TRAIN DURATION SYNC IN terminal. (See Synchronous Inputs/Outputs later in this chapter for more information.)

- EXT CONTROL FROM "S1 DELAY" (SD)
- EXT CONTROL FROM "TRAIN DUR" (TD)

S2 Modes:

The first four modes allow S2 to operate as a completely independent stimulator.

- SINGLE PULSE (SP)
- REPEATING PULSE (RP)
- SINGLE TRAIN (ST)
- REPEATING TRAIN (RT)

The following modes synchronize S2 to S1.

- SYNC WITH S1 (SS)
- POST S1 TRAIN (PT)
- SYNC TRAIN TO S1 (TS)
- SINGLE ARRHYTHMIC (SA)

The last mode is externally controlled via a trigger pulse applied to the S2 DELAY SYNC IN terminal.

- EXT CONTROL FROM "S2 DELAY" (SD)

S1 & S2 Pulses

The S1 PULSES and S2 PULSES buttons allow selection of three types of stimulus waveforms; MONOPHASIC (MO), BIPHASIC (BI), and TWIN (TW) PULSES.

Figure 5-1a: Monophasic Waveform

Monophasic pulses are single phase positive pulses starting at zero volts and rising to a preset voltage, then returning to zero.

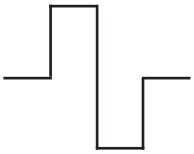

Figure 5-1b: True Biphasic Waveform

Biphasic pulses provide a positive phase followed by a negative phase of identical duration and voltage.

Twin pulses offer two identical pulses separated by the S1 or S2 delay settings.

Figure 5-1c: TWin Waveform

Single Pulses

The S1 SINGLE and S2 SINGLE buttons deliver single stimulus pulses when these functions are selected using the S1 and S2 FUNCTION touch-pad controls.

Output On/Off

The OUTPUT ON/OFF buttons control the output stimulus. There is no stimulus output unless the OUTPUT ON/OFF is ***on***. The output is on if the LED next to the touch-pad control is lit. All related synchronous output pulses are active.

Stimulus Timing Controls

The cluster of TIMING controls include S1/S2 stimulus, RATE, DELAY, DURATION, right and left arrow buttons, and a thumbwheel dial. These controls allow precise timing parameter settings for S1 and S2 as indicated on the display.

Output Amplitude

A thumbwheel dial and right and left arrow buttons control the S1 and S2 stimulus amplitude (voltage) as displayed on the front panel. Values between 0.25 and 24 volts can be selected. A four-pin connector provides the output stimulus and supply voltages for the optional Grass Stimulus Isolation Units. Two CAB-21891 output cables are supplied with the stimulator for applications requiring direct output without a stimulus isolation unit. A four-terminal connector provides the output stimulus and supply voltages for the optional stimulus isolation units. The wiring is listed below:

Terminal # 1	Stimulus Output
Terminals #2, 3	Ground
Terminal #4	+27 Volts (Power Supply)

The mating output connector can be ordered from Grass as part number CON-21917. Mating output cables of approximately 8 feet with tinned leads can be ordered as part number CAB-21891.

Sync Out (Synchronous Outputs)

Five BNC connectors provide synchronous output pulses for synchronizing ancillary equipment. These pulses are +5 volts at 10 microseconds duration. The output impedance is approximately 50 ohms. These outputs are capable for driving up to approximately 20 milliamperes.

SYNC OUT:

TRAIN	Coincident with the start of the train
S1	Coincident with the start of each S1 Stimulus pulse
S2	Coincident with the start of each S2 Stimulus pulse
S1 DELAY	Precedes the S1 Stimulus pulse by the S1 DELAY setting
S2 DELAY	Precedes the S2 Stimulus pulse by the S2 DELAY setting

SYNC IN (SYNCHRONOUS INPUTS)

The Sync Inputs are set up as "pull down" inputs. Without any connection to them, they are at a +5 volt level. When a connection is made from an external device, the +5 volts is "pulled down" to "0" volts awaiting a +5 volt trigger. If the trigger is applied, the input is enabled and the output is activated according to the timing parameters selected. Note that contacts can be used to activate the Sync Inputs. Closed contacts will "pull down" the input to "0" volts, and opening the contacts will provide the return to +5 volts to trigger the input.

Note: Activation of the Sync In circuits requires selecting the desired function for the circuit used. For example, to trigger the S1 Delay Sync In circuit, the Function = EXT CONTROL FROM S1 DELAY (SD) must be selected.

Three BNC connectors provide external synchronization from ancillary devices. These inputs are "pulled" up to 5 volts and require a TTL trigger pulse to enable the synchronization. All Grass stimulators having TTL compatible synchronous outputs are compatible. Older Grass stimulators that do not have TTL synchronous outputs are not compatible.

SYNC IN:

TRAIN DUR	Generates a train from either S1 or S2 with the train duration set by the TRAIN DURATION control
S1 DELAY	Triggers the S1 Delay to delay the onset of the S1 Stimulus
S1 DELAY	Triggers the S2 Delay to delay the onset of the S2 Stimulus

Monitors

S1/S2 LED Monitors

Green LEDs adjacent to the S1 OUT and S2 OUT connectors illuminate with each stimulus pulse.

Output On/Off LED Monitors

Green LEDs adjacent to the S1 OUTPUT ON/OFF and S2 OUTPUT ON/OFF touch switches light when this function is selected.

Output Monitor

A BNC connector on the S88X rear panel provides a low level waveform output of the S1 and S2 stimuli for monitoring purposes. This output is referenced to ground. When the CHOOSE STIMULUS ISOLATION UNITS selection in the SETUP is set to NONE, the monitor output is 1/10th of the S1 and S2 voltage selected by the Output Amplitude controls.

If the SIU-C, or SIU-BI stimulus isolation unit is selected, the Monitor Output voltage does not vary.

USB Interface

The USB connector on the S88X rear panel provides system software upgrades. For more information, see Chapter 9 Troubleshooting & Maintenance, Field Software Upgrade.

Duty Cycle Limitations

Duty cycle is defined as the ratio of the time that the stimulus is ***on*** to the total period or interval. 100% duty cycle occurs when a circuit is continuously on, 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 50% duty cycle.

The S88X SETUP function provides for changing the Duty Cycle limits. The default value is 50%. Values from 0 to 99% can be selected.

Note:  The S88X display will flash when the selected duty cycle value is exceeded while making a selection with the OUTPUT ON/OFF on. Reduce the timing parameters below the 50% limit.

During setup, with the OUTPUT ON/OFF in the ***off*** position, a duty cycle message will display if the user attempts to turn on the output and the duty cycle is exceeded. In these messages, the DCWL value is a percentage and is the Duty Cycle Warning Level.

6 Computer Contol

Computer Control

S88X can be controlled by a computer connected via a USB cable. There are several methods for doing this:

1. S88X Host Control Software provides a virtual control panel for S88X which provides all of the features and settings accessible from the hardware front panel. Settings can be stored and recalled for ease of use.

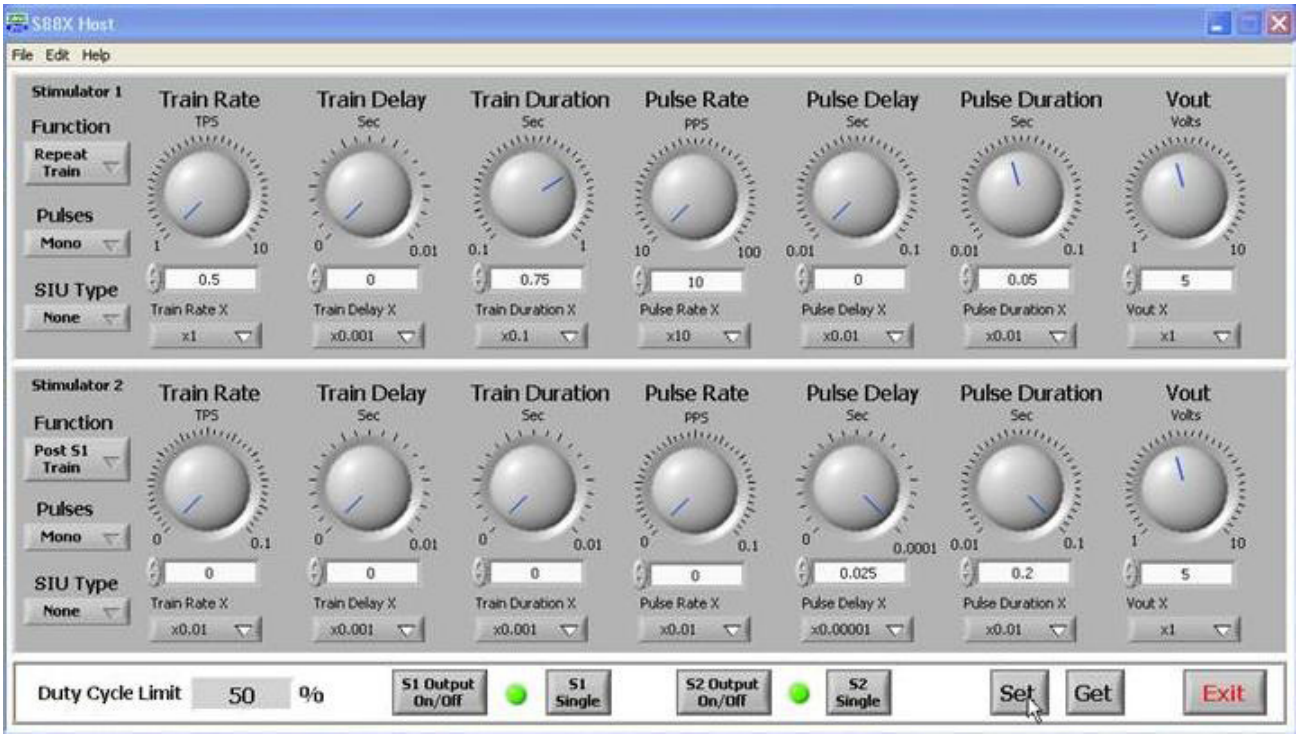

Figure 6-1: Host Control Software

2. Programmer API. A driver (.dll) and programming interface allows C++ and C# developers to control the S88X. A demo C# interface is available as an example.

3. A Python module and driver allows users of this popular, easy-to-use scripting language to control S88X functions. Settings can be changed from the command line or loaded from saved scripts.

7 Operation

Setup

The SETUP touch-pad control sets several modes as seen on the display. These are:

- DUTY CYCLE LIMIT
- CHOOSE STIMULUS ISOLATION UNITS
- LOAD SETUP
- SAVE SETUP
- TRAIN PARAMETERS FUNCTIONS

The ENTER/ACCEPT touch-pad control is used to enter and accept changes made in the SETUP.

Duty Cycle Limit

The Duty Cycle Limit default setting is 50%. Values from 0 to 99% can be selected. To change the limit proceed as follows.

1. Press the SETUP touch-pad control.
2. Press the ENTER/ACCEPT touch-pad control.
3. Use the TIMING thumbwheel control to increase or decrease the value.
4. Press the ENTER/ACCEPT touch-pad control again.

Choose Stimulus Isolation Units

To connect the Grass Stimulus Isolation Units to the S88X proceed as follows.

1. Press the SETUP touch-pad control.
2. Toggle down the list to CHOOSE STIMULUS ISOLATION UNITS by using the TIMING thumbwheel control.
3. Press the ENTER/ACCEPT touch-pad control.
4. Use the TIMING thumbwheel control to select S1 STIMULUS ISOLATION UNITS and press the ENTER/ACCEPT touch-pad control again.
5. Select the SIU to be used – SIU-V, SIU-C, SIU-BI, or PSIU6X connected to the S1 OUT using the TIMING thumbwheel control and press the ENTER/ACCEPT control.
6. Repeat for setting up the S2 Stimulus Isolation Unit as required.

When set up properly, the SIU Model will be displayed in the left side of the display when either the S2 FUNCTION or S2 FUNCTION is selected.

See the separate SIU operating manuals for more information.

Load Setup & Save Setup

When the POWER to the S88X is turned on, the S88X will display the last set of parameters used. In addition, it is possible to save up to 9 sets of stimulating parameters for use again.

Setting up the S88X Parameters

To set up the parameters to be used proceed as follows.

1. Select the FUNCTION, PULSES, RATE, DELAY, DURATION and OUTPUT AMPLITUDE as is appropriate for the study. Basic Modes of Operation later in this chapter offers many basic setups.

Note: To increase or decrease a value use the left and right arrow touch-pad controls to select the digit to be changed. The number that is flashing is the number that is selected. Then use the thumbwheel control to increase or decrease that number.

Saving the S88X Setup

1. Press the SETUP touch-pad control.
2. Toggle down the list to SAVE SETUP by using the TIMING thumbwheel control and press the ENTER/ACCEPT touch-pad control.
3. SAVE TO SETUP NUMBER x will be displayed. (NUMBER x can be adjusted from 1 to 9 by using the TIMING thumbwheel control.)
4. Press the ENTER/ACCEPT touch-pad control again.

Loading a Set of S88X Saved Parameters

1. Press the SETUP touch-pad control.
2. Toggle down the list to LOAD SETUP by using the TIMING thumbwheel control and press the ENTER/ACCEPT touch-pad control.
3. LOAD FROM SETUP NUMBER x will be displayed. (NUMBER x can be adjusted from 1 to 9 by using the TIMING thumbwheel control.)
4. Press the ENTER/ACCEPT touch-pad control again.

Train Parameters Functions

To select TRAIN PARAMETERS FUNCTIONS proceed as follows.

1. Press the SETUP touch-pad control.
2. Toggle down the list to TRAIN PARAMETERS FUNCTIONS by using the TIMING thumbwheel control.
3. Press the ENTER/ACCEPT touch-pad control.
4. S1 TRAIN DELAY, S2 TRAIN DELAY, TYPE OF TRAIN PARAMETERS, and TRAIN SYNC LOCATION will be displayed. Select the desired function by using the TIMING thumbwheel control.
5. Press the ENTER/ACCEPT touch-pad control again.

S1 & S2 Train Delay

Applications occasionally require an adjustable delay before a train of pulses is delivered to the preparation. The S1 TRAIN DELAY and S2 TRAIN DELAY function allows the placement of the delay prior to the onset of the train. *For example,* suppose it is desired to deliver a single train of pulses from the S1 output with the following parameters:

Train Delay	= 1 second
Train Duration	= 200 ms
Number Pulses in Train	= 10
Pulse Duration	= 1 ms
Output Amplitude	= 10 volts

The setup should be as follows:

1. Press the SETUP touch-pad control and select TRAIN PARAMETERS FUNCTIONS.
2. Press ENTER/ACCEPT and select S1 TRAIN DELAY, then ENTER/ACCEPT.
3. In the next display, set the S1 TRAIN DELAY to 01.000 (seconds), and press ENTER/ACCEPT.
4. Select S1 FUNCTION and select FUNCTION = SINGLE TRAIN (ST).
5. Select the TRAIN DURATION and enter 00.200 (seconds).
6. Select TIMING RATE and enter 0050.00 PPS.
7. Select TIMING DELAY and set to minimum.
8. Select TIMING DURATION and set to 00.00100 (seconds).
9. Set the OUTPUT AMPLITUDE to 010.00 (volts).
10. To initiate the train, press the S1 SINGLE touch-pad control.

Train Sync Location

The Train synchronous output can be selected to be coincident with the start of the train or at the end of the train duration. Selection is made by the following procedure.

1. Select SETUP, then TRAIN PARAMETERS FUNCTIONS, then ENTER/ACCEPT.
2. In the display, select TRAIN SYNC LOCATION, then ENTER/ACCEPT.
3. Select START OF TRAIN DURATION or END OF TRAIN DURATION, then ENTER/ACCEPT.

Type of Train Parameters

This selection changes the train parameters (rate and duration) from one pair (single) for both outputs to two pairs (dual), one for each output. Selection of the parameters is made by the following procedure.

1. Press SETUP, select TRAIN PARAMETERS FUNCTIONS, then ENTER/ACCEPT.
2. Select TYPE OF TRAIN PARAMETERS, then ENTER/ACCEPT.
3. Select DUAL TRAIN PARAMETERS or SINGLE TRAIN PARAMETERS, then ENTER/ACCEPT.

SINGLE PULSES

Single Pulses (S1 or S2, with or without delay) initiated from the S88X SINGLE button.

1. Turn the POWER switch ***on***.
2. Select S1 (or S2) FUNCTION.
3. Use TIMING thumbwheel to select SINGLE PULSE (SP).
4. If delay is required, select the DELAY pushbutton. The display indicates the delay values in seconds.
5. Use left and right arrow keys to select the digit to be changed.
6. Use the TIMING thumbwheel to select a value between 0 and 9.
7. Select the TIMING DURATION pushbutton. The display indicates the duration value in seconds.
8. Use the left and right arrow keys to select the digit to be changed.
9. Use the TIMING thumbwheel to select a value between 0 and 9.
10. Set the OUTPUT AMPLITUDE in volts using the OUTPUT AMPLITUDE thumbwheel and the left and right arrow keys.
11. Depress the OUTPUT ON/OFF button.
12. Depress the SINGLE button to initiate the output single stimulus.
13. To synchronize other devices to the stimulus, connect either the S1 (or S2) SYNC OUT (no delay), or the S1 DEL (or S2 DEL), if delay is required, to the other device synchronous input.

Note: Single pulses with or without delay can be initiated from an external trigger source with the S1 or S2 FUNCTION set to the SYNC TO S1 DELAY, or SYNC TO S2 DELAY. Connect the trigger to either the S1 DEL (S1) or the S2 DEL (S2) SYNC IN.

Repetitive Pulses (S1 or S2)

1. Select S1 or S2 FUNCTION, and use the thumbwheel to select S1 (or S2) REPEATING PULSES.
2. Depress the TIMING RATE button to access the rate timing. Use the left and right arrow keys and the thumbwheel to select a rate between 0.01 and 1000 PPS (Pulses per Second).
3. Select the TIMING DELAY button and use the left and right arrow keys and the thumbwheel to set the desired delay value observing the 50% duty cycle limitation.
4. Select the TIMING DURATION button and use the left and right arrow keys and the thumbwheel to set the desired duration value observing the 50% duty cycle limitation.
5. Set the OUTPUT AMPLITUDE in volts using the thumbwheel and the left and right arrow keys. Voltages between 0.01 and 24 can be selected.
6. Depress the OUTPUT ON/OFF button.
7. To synchronize other devices to the stimulus, connect either the S1 (or S2) SYNC OUT (no delay), or the S1 DEL (or S2 DEL) if delay is required, to the other device synchronous input.

Single Trains (S1 or S2)

1. Select S1 or S2 FUNCTION, and use the thumbwheel to select S1 (or S2) FUNCTION = SINGLE TRAIN (ST).
2. Select TRAIN DURATION button and set the duration of the train using the left and right arrow keys and the thumbwheel between 0.001 and 99.999 seconds.
3. Depress the TIMING RATE button to access the rate timing. Use the left and right arrow keys and the thumbwheel to select a rate between 0.01 and 1000 PPS (Pulses per Second). This rate will become the number of pulses within the selected TIMING DURATION.
4. Select the TIMING DELAY and use the left and right arrow keys and thumbwheel to set the desired delay observing the duty cycle limit. This delay will be the time from the S1 Delay Sync Out to each stimulus pulse in the train.
5. Select the TIMING DURATION and use the left and right arrow keys and thumbwheel to set the pulse duration observing the duty cycle limit.
6. Select the OUTPUT AMPLITUDE voltage and select the OUTPUT ON/OFF to ***on***.
7. Depress the S1 (or S2) SINGLE button to initiate a single train.

If it is desired to provide a ***Delay before the Train***, do the following:

1. Depress the SETUP button, then use the TIMING thumbwheel to select the TRAIN PARAMETERS FUNCTIONS from the list on the display.
2. Depress the ENTER/ACCEPT, button and select the S1 TRAIN DELAY (or the S2 TRAIN DELAY) using the TIMING thumbwheel.
3. Depress the ENTER/ACCEPT, button to open the S1 TRAIN DELAY setting in the display.
4. Use the left and right arrow keys and the TIMING thumbwheel to set the desired TRAIN DELAY. When the single train is initiated, a sync pulse will occur prior to the start of the train at the TRAIN sync out.

Repeating Trains (RT) S1 or S2

1. Depress the S1 FUNCTION button and use the TIMING thumbwheel to select REPEATING TRAIN function.
2. Depress the TRAIN RATE button and select the desired rate using the left and right arrow keys and the TIMING thumbwheel. The rate is from 0.01 to 99.99 TPS.
3. Depress the TRAIN DURATION button and select the desired duration using the left and right arrow keys and the TIMING thumbwheel. The duration is from 0.01 to 99.999 seconds.
4. Depress the TIMING RATE button and select the desired pulse rate (this will be the number of pulses in the train). The rate can be from 0.01 to 1000 PPS.
5. Depress the TIMING DELAY button and select the desired delay.
6. Depress the TIMING DURATION button and select the desired pulse duration.
7. Set the OUTPUT AMPLITUDE (voltage), and depress the OUTPUT ON/OFF button.

S1 Special Modes

Sync to S1 Delay

This mode is intended for applications when an external device is to be used to control the S1 output. The connection from the external device must connect to the S1 DELAY SYNC IN and be a positive 5 volts for triggering to occur. An S1 output pulse will be produced with each input trigger pulse. Delay between the trigger and the onset of the S1 output is controlled by the S1 DELAY setting. See Chapter 5 for information regarding the Sync Inputs.

Sync to Train Duration

This mode is intended for delivering a train of pulses from S1 by an external device. The connection from the external device must connect to the TRAIN DUR SYNC IN. Each trigger pulse will deliver a train with the Train Duration, Rate, and Pulse Duration set by the S88X. The onset of the train can be delayed using the Train Delay in the SETUP as follows:

1. Depress the SETUP button and select the TRAIN PARAMETERS FUNCTION.
2. Depress the ENTER/ACCEPT button and select the S1 TRAIN DELAY using the TIMING thumbwheel.
3. Depress the ENTER/ACCEPT button and set the S1 TRAIN DELAY using the left and right arrow keys and the TIMING thumbwheel, and depress the ENTER/ACCEPT key.

S2 Special Modes

Sync with S1 (SS)

In this mode, S2 is synchronous with S1. Each S1 pulse will produce an S2 pulse. If delay is required between the S1 and S2 pulses, the S2 DELAY can be used.

For example, it is desired to deliver monophasic pulses at the same pulse rate of 50 PPS from S1 and S2 outputs but separated by a 20 millisecond delay. Note that the pulse durations and output voltages can be the same or
different. The following procedure lists the settings.

1. Select S1 FUNCTION, then S1 REPEATING PULSES (RP).
2. Select S1 PULSES, then MONOPHASIC.
3. Select TIMING RATE, and set to 0050.00 PPS.
4. Select TIMING DELAY and set to minimum.
5. Select TIMING DURATION and set to desired pulse duration (observe 50 % duty cycle limit).
6. Select S2 FUNCTION, then FUNCTION = SYNC WITH S1 (SS).
7. Select S2 PULSES, then MONOPHASIC.
8. Select TIMING DELAY and set to 00.0200 (seconds).
9. Select TIMING DURATION and set to desired pulse duration (observe 50% duty cycle limit).
10. Turn the S1 and S2 OUTPUT ON/OFF to ***on***.

Post S1 Train (PT)

This mode provides a Train from S1 followed by a single pulse from S2 (post train). The Delay from the end of the Train to the onset of the post train pulse can be set using the S2 DELAY. The post train S2 pulse duration is set by the S2 DURATION.

The following example lists the settings required to deliver a single S1 train of 5 monophasic, 1 millisecond pulses in 500 milliseconds duration, followed by a 3 second delay, then a single 2 second duration monophasic S2 pulse.

1. Select S1 FUNCTION, then FUNCTION = SINGLE TRAIN (ST).
2. Select S1 PULSES, then MONOPHASIC.
3. Select TRAIN DURATION, then enter 00.500 seconds.
4. Select TIMING RATE, then enter 0010.00 PPS.
5. Select TIMING DELAY, then enter 00.00005 seconds.
6. Select TIMING DURATION, then enter 00.00100 seconds.
7. Select S2 FUNCTION, then FUNCTION = POST S1 TRAIN (PT).
8. Select S2 PULSES, then MONOPHASIC.
9. Select TIMING DELAY, then enter 03.0000 seconds.
10. Select S2 DURATION, and enter 02.00000 seconds.
11. Set the S1 and S2 OUTPUT AMPLITUDE to the desired voltage values.
12. Depress both the S1 and S2 OUTPUT ON/OFF to ***on***.
13. Depress the S1 SINGLE touch-pad control to initiate the stimulus.

Sync Train to S1 (ST)

Generating a train of pulses from S2 triggered from S1 is possible with the S2 Function in the Sync Train to S1 mode. Each S1 pulse produces a train from S2. If delay is required between the S1 pulse and the S2 Train, the S2 Train Delay can be used.

The following example lists the settings required to deliver a single S1 monophasic pulse of 5 milliseconds duration followed by a 2 second delay, then an S2 train of 25 monophasic pulses each having a duration of 2 milliseconds.

1. Depress SETUP, then select TRAIN PARAMETERS FUNCTIONS, then ENTER/ACCEPT.
2. Depress S2 TRAIN DELAY, then enter 02.000 seconds and ENTER/ACCEPT.
3. Depress S1 FUNCTION, then FUNCTION = SINGLE PULSE (SP).

4. Depress S1 PULSES, then MONOPHASIC.
5. Depress TIMING DELAY and enter 00.000005 seconds.
6. Depress TIMING DURATION, then enter 00.00200 seconds.
7. Depress S2 FUNCTION, and select FUNCTION = SYNC TRAIN TO S1 (TS).
8. Depress S2 PULSES, and select MONOPHASIC.
9. Depress TIMING RATE, and enter 0010.00 PPS.
10. Depress TIMING DELAY, and enter 00.00001 seconds.
11. Depress TIMING DURATION, and enter 00.00200 seconds.
12. Set the S1 and S2 OUTPUT AMPLITUDE to the desired voltage values.
13. Depress both the S1 and S2 OUTPUT ON/OFF to ***on***.
14. Depress the S1 SINGLE touch-pad control to initiate the stimulus.

Single Arrhythmic (SA)

The Arrhythmic mode produces a single pulse from S2 following an S1 pulse. The S2 pulse must be initiated with the S2 SINGLE button. The DELAY between the S1 pulse and an arrhythmic S2 pulse is set by the S2 Delay. The S1 can be single pulses or repetitive pulses.

The following example lists the settings required to deliver a single 2 millisecond monophasic S2 arrhythmic pulse following a delay of 200 milliseconds after an S1 pacing pulse. The S1 pacing rate is 60 B/M (1 PPS).

1. Depress S1 FUNCTION = REPEATING PULSE (RP).
2. Depress S1 PULSES, then MONOPHASIC
3. Depress TIMING RATE and enter 0001.00 PPS.
4. Depress TIMING DELAY and enter 00.000005 seconds.
5. Depress TIMING DURATION and enter 00.00100 seconds.
6. Depress S2 FUNCTION and select FUNCTION = SINGLE ARRHYTHMIC (SA).
7. Depress S2 PULSES and select MONOPHASIC.
8. Depress TIMING DELAY and enter 00.20000 seconds.
9. Depress TIMING DURATION, and enter 00.00200 seconds.
10. Set the S1 and S2 OUTPUT AMPLITUDE to the desired voltage values.
11. Depress both the S1 and S2 OUTPUT ON/OFF to ***on.***

The S1 output will deliver 1 PPS (60 B/M). To deliver the S2 ARRHYTHMIC pulse, depress the S2 SINGLE touch-pad control.

Sync to S2 Delay

This mode is intended for applications when an external device is to be used to control the S2 output. The connection from the external device must connect to the S2 DELAY SYNC IN and be a positive 5 volts for triggering to occur. An S2 output pulse will be produced with each input trigger pulse. Delay between the trigger and the onset of the S2 output is controlled by the S2 DELAY setting.

Twin Pulse Mode

The TWIN PULSE mode is available on both S1 and S2. This special mode provides two identical pulses separated by an adjustable delay. The amplitude (voltage) is the same for both pulses in the pair. The TWIN PULSE mode is intended for applications such as refractory studies in muscle and nerve research.

Biphasic Pulse Mode

BIPHASIC PULSES are available on both S1 and S2. This mode produces a positive pulse immediately followed by a negative pulse. These pulses range from 0 to +12 volts. This mode is used to minimize ion transfer from electrodes to tissue.

Non-Isolated Mode

Ground referenced Biphasic pulses are available from both S1 and S2 outputs by selecting the Biphasic (BI) S1 and S2 Pulses function. This mode produces a positive pulse immediately followed by a negative pulse in a voltage range of 0 to +12 and 0 to -12 volts. The primary application is for the prevention of ion transfer.

Isolated Mode

Isolated, symmetrical, biphasic constant current pulses can be generated from either output using the Model SIU-BI biphasic isolated constant current units. Three current ranges are provided; 1 to 10 mA, 0.1 to 1.0 mA, and 0.01 to 0.1 mA. The maximum pulse duration is 1 ms/phase. The duration and current of each phase is identical and the separation between phases is fixed.

When using the SIU-BI, the CHOOSE STIMULUS ISOLATION UNIT setting must be SIU-BI for proper operation.

Biphasic Modes using by combining two stimulus isolation units and both S1 and S2 outputs. Note that the duration of each phase can be different as well as the delay between phases. Also, the amplitude of each phase can be different.

Using two SIUV units (Biphasic Constant Voltage)
Connect one SIU-V to the S1 Output and a second SIU-V to the S2 Output. Select the SIU-V in the CHOOSE STIMULUS ISOLATION UNIT setup screen for both S1 and S2. Select Monophasic (MO) for the Pulses selection. Select the Sync with S1(SS) S2 Function and use the S2 Delay to separate the pulses.

Connect the output terminals of the two SIU-Vs in series and reverse polarity on one SIU-V. (See SIU-V USERS MANUAL, CHAPTER 5, CONNECTIONS FOR MIXING THE S88X OUTPUTS.) The S88X Delay circuit is used to separate the two pulses.

Using two PSIU6X units (Biphasic Constant Current)
Connect one PSIU6X to the S1 output and a second PSIU6X to the S2 output. Select the PSIU6X in the CHOOSE STIMULUS ISOLATION UNIT setup screen for both S1 and S2. Select Monophasic (MO) for the Pulses selection. Select the Sync with S1 (SS) S2 function and use the S2 Delay to separate the pulses.

Connect the output terminals of the PSIU6X units in parallezl and reverse polarity of one of the PSIU6X.

Using two SIU-C units (Biphasic Constant Current)
Connect one SIU-C to the S1 output and a second SIU-C to the S2 output. Select the SIU-C in the CHOOSE STIMULUS ISOLATION UNIT setup screen for both S1 and S2. Select Monophasic (MO) for the pulses selection. Select the Sync with S1 (SS) S2 function and use the S2 Delay to separate the pulses.

Connect the output terminals of the SIU-C units in parallel and reverse the polarity of one of the SIU-C units.

See separate user manuals for the Stimulus Isolation Units for more additional information.

MONOPHASIC PULSE MODE
This mode produces single pulses from 0 to +12 volts. They are used for stimulation when neither Twin Pulses or Biphasic Pulses are required.

8 Artifact, Stimulus Isolation & Constant Current

Stimulus Artifact

When a stimulus pulse is introduced to a preparation to evoke a response, an electrical artifact appears in the recording instrumentation as the result of the spread of the stimulus current to the recording electrodes. This artifact precedes the evoked response in time as indicated in the oscilloscope record of Figure 8-1. The delay between stimulus artifact and the evoked response is dependent upon stimulation parameters and the characteristic properties of the preparation.

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.

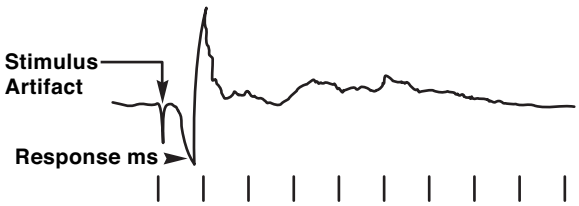

Figure 8-1: Stimulus Artifact

Sources & Reduction of Stimulus Artifacts

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.

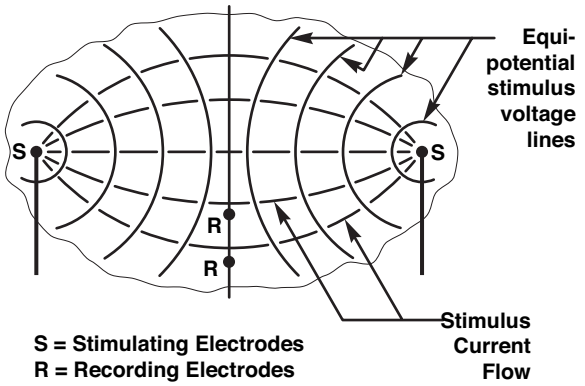

Figure 8-2: Stimulus Voltage Field Distribution

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

To alleviate stimulus artifact:

- Isolate the stimulus pulse from ground and thereby reduce the circulating ground currents between the stimulator, preparation and recording instrument.
- Space stimulating and recording electrodes as far from each other as possible and position them for maximum cancellation of field effects.
- Use as small a stimulator pulse with as short a duration as is possible (approximately 0.1 ms).

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

Stimulus Isolation

Warning:
The S88X output is not isolated. Do not use on humans.

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 multi-channel recording. Is is also valuable from the standpoint of safety, because it isolates the stimulating electrodes from ground. It has the further advantage of permitting direct addition of stimuli of either algebraic sign.

In many applications, a very low output impedance of high power is required and is featured in the S88X. 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. 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.

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

Stimulus Current Monitoring

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 8-3.

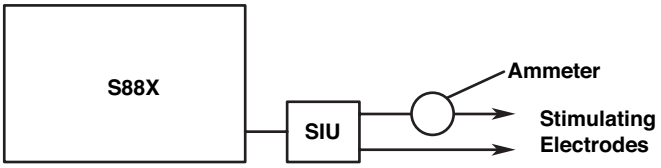

Figure 8-3: Measuring Current

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.,

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

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, see the Appendix included in this manual.

Oscilloscope monitoring of instantaneous stimulus current can be accomplished by monitoring the voltages generated across a series resistor with an oscilloscope. 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. According to Ohm's Law, then:

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

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

When a 10 ohm resistor is used as shown, each milliampere of stimulus current results in a voltage drop of 10 mV across this resistor. With the oscilloscope calibrated for a sensitivity of 10 mV/cm, each centimeter of deflection on the tube face equals 1 mA of stimulating current. If the oscilloscope cannot be calibrated as low as 10 mV/cm, use a higher resistance to correspond to the sensitivity of the oscilloscope. Figure 8-4 shows the stimulus electrode voltage being monitored on Channel 1 and the current being monitored on Channel 2.

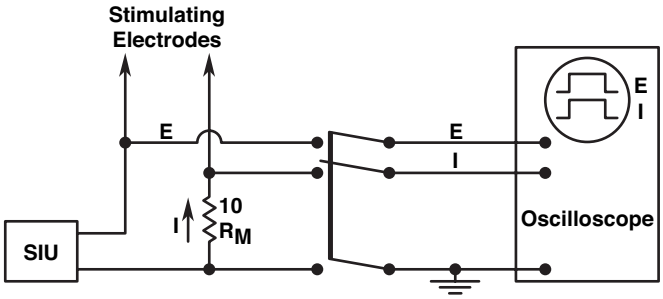

Figure 8-4: Oscilloscope Monitoring

It is not possible to maintain stimulus isolation when this method is used, since the input of most oscilloscopes is referred to ground. When stimulus isolation is necessary, measure current periodically during the experiment as shown in Figure 8-4, 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.

If stimulus isolation is not required, use the circuit shown in Figure 8-4 without the three-pole switch, but wired as if the switch were in the monitor position. This permits continuous current monitoring. The oscilloscope should be operated with one input terminal grounded.

9 Troubleshooting & Maintenance

General

If the S88X display does not light up during power up, check to see that thepower cord is attached to the S88X and to a standard 3-wire AC receptacle. If it still will not power up, check the outlet to be sure there is power, by connecting another device to the outlet.

The S88X contains no field replaceable modules or parts. ***Do not remove covers or attempt to troubleshoot or make repairs inside the cabinet.*** Malfunctioning units should be returned to Grass for repairs.

Reset Circuitry

The S88X circuitry is designed to protect internal components in the event of a short circuit or temperature increases within the output circuits. If such an event occurs at either the S1 or S2 output, the output will be shut down and an error message will display S1 OVER TEMP or S2 OVER TEMP. To reset the circuitry, depress the OUTPUT ON/OFF control for the S1 or S2 output.

Troubleshooting Tips

If problems occur during external control of the S88X via the SYNC IN circuits, check that the appropriate S1 FUNCTION or S2 FUNCTION has been selected. If the function is correct for the desired mode, try another sync input cable to rule out a possible break in the cable. Check that the synchronizing signal is appropriate for external control.

Field Software Upgrade

Field firmware changes can be made via the USB interface. Follow the steps below:

1. Locate a Windows PC with USB 2.0 interface.
2. Copy the S88Xusb.sys file (on distributed media) into the windows/system32/drivers directory.
3. Turn on the S88X. When it is finished booting, connect the USB port on the rear panel of the S88X to the PC USB port.

Note: The connecting cable must be a USB 2.0 type. It will have the cable type printed on the cable.

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4. The New Hardware Wizard should start and request a *.inf file. The S88Xusb.inf file will be on the distributed media. Press browse and navigate to the media, then select the S88Xusb.inf file. Press OK to finish the installation.

Note: Steps 2 and 4 only need to be done once. After that, the PC will recognize the S88X automatically.

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5. Start application S88XUPGRADE.exe (on distributed media).
6. Click on Start Upgrade button. The application will find the S88X, download the new firmware and the S88X will restart using the new firmware.

A Appendix

Constant Voltage vs. Constant Current Sources for Pulse Stimulation

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.

"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.

"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 µA 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 µA).

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.

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

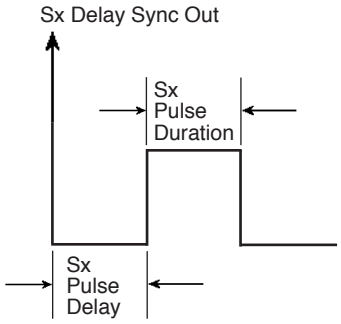
A general purpose Stimulator, such as the S88X must satisfy the greatest number of applications and represent the most desirable compromise between voltage and current requirements. A low source impedance is required to drive accessory stimulus isolation units including the SIU-V, SIU-C, SIU-BI, and PSIU6X. The S88X output is a low impedance "constant voltage" output having a source impedance of less than 0.2 Ω. The S88X can deliver up to 1.1 ampere from each output especially useful for field stimulation procedures.

Accessory units are available for connection to the S88X. Both the SIU-V and SIU-C feature radio frequency isolation. ***The SIU-V*** is a constant voltage unit having an output impedance of approximately 1000 Ω. This unit is similar to the previous Model SIU5 isolation unit in functionality. ***The SIU-C*** is a constant current unit with three current ranges of 1 to 10 mA, 0.1 to 1.0 mA, and 0.01 to 0.1 mA. The SIU-C combines isolation and constant current in a single design. ***The SIU-BI*** is a biphasic constant current isolation unit and provides a positive pulse phase followed by a negative phase constant current pulse pattern. ***The PSIU6X*** is an optically isolated, constant current unit with batteries supplying the constant current output. Five current ranges provide current from 0.1 µA to 15 mA.

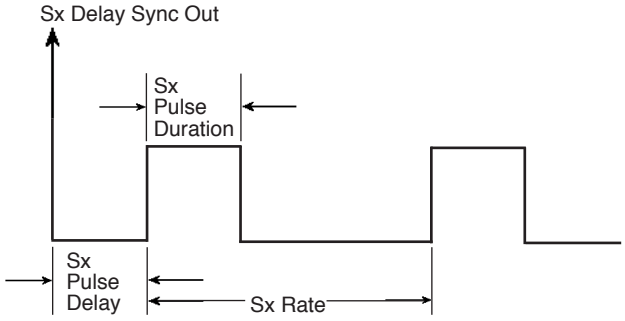
B Appendix

S88X Timing Diagrams

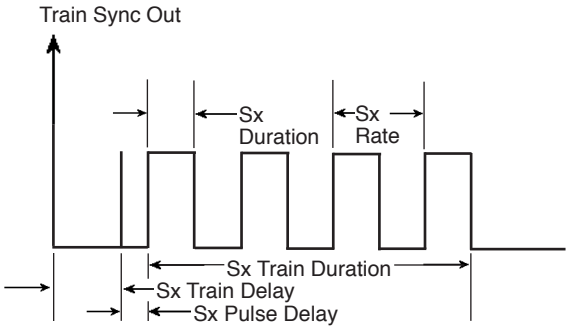
Function = Single Pulse (SP)
Sx = S1 or S2



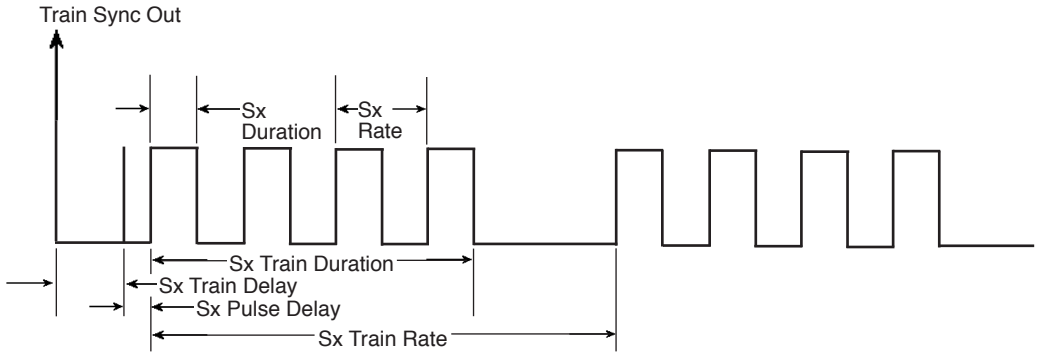
Function = Repeating Pulse (RP)
Sx = S1 or S2



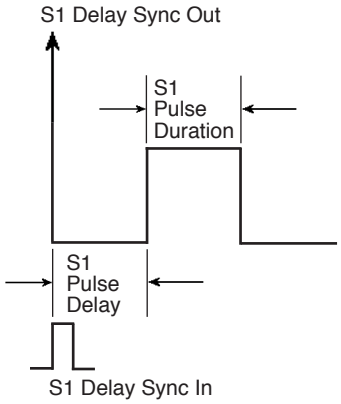
Function = Single Train (ST)
Sx = S1 or S2



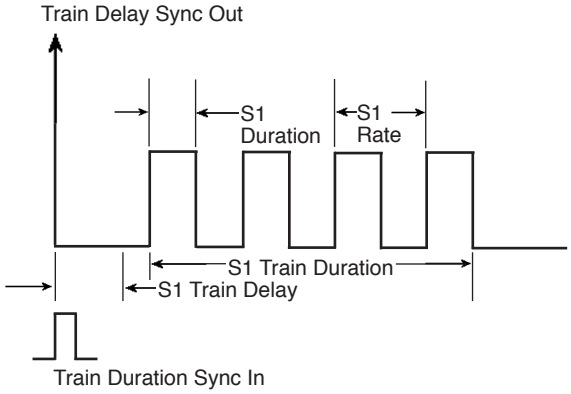
Function = Repetitive Train (RT)
Sx = S1 or S2



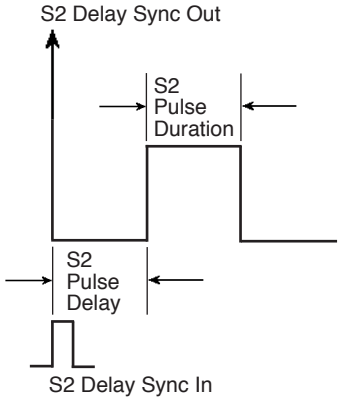
S1 Function = Ext Control from S1 Delay (SD)



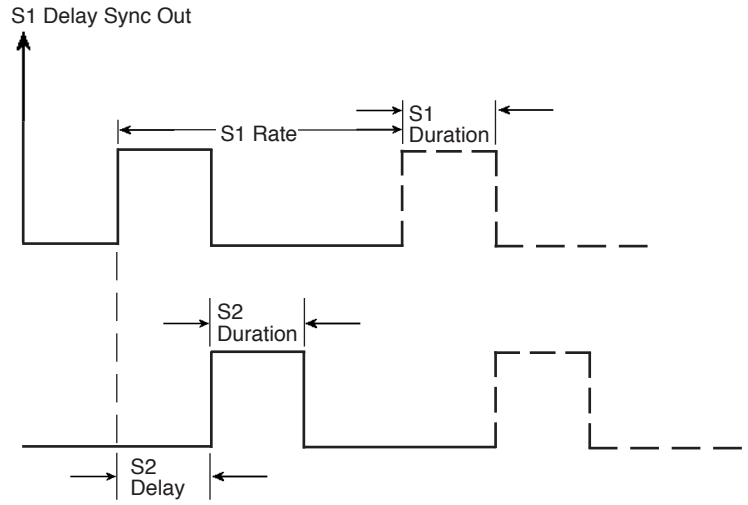
S1 Function = Ext Control from Train Duration (TD)



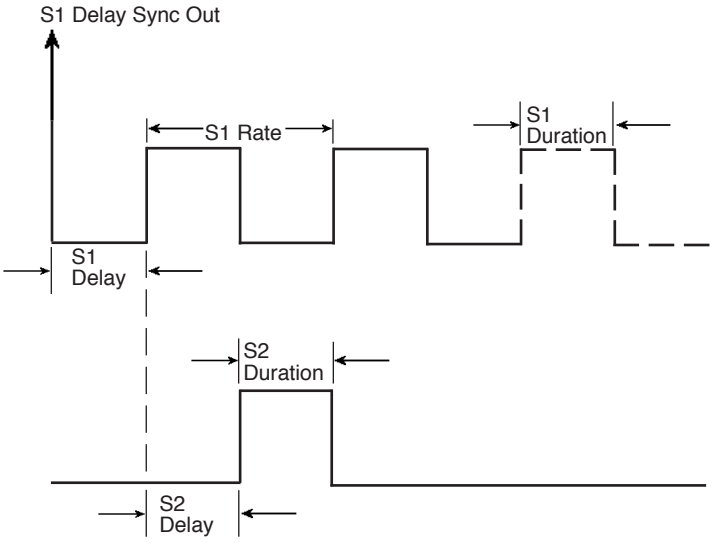
S2 Function = Ext Control from S2 Delay (SD)



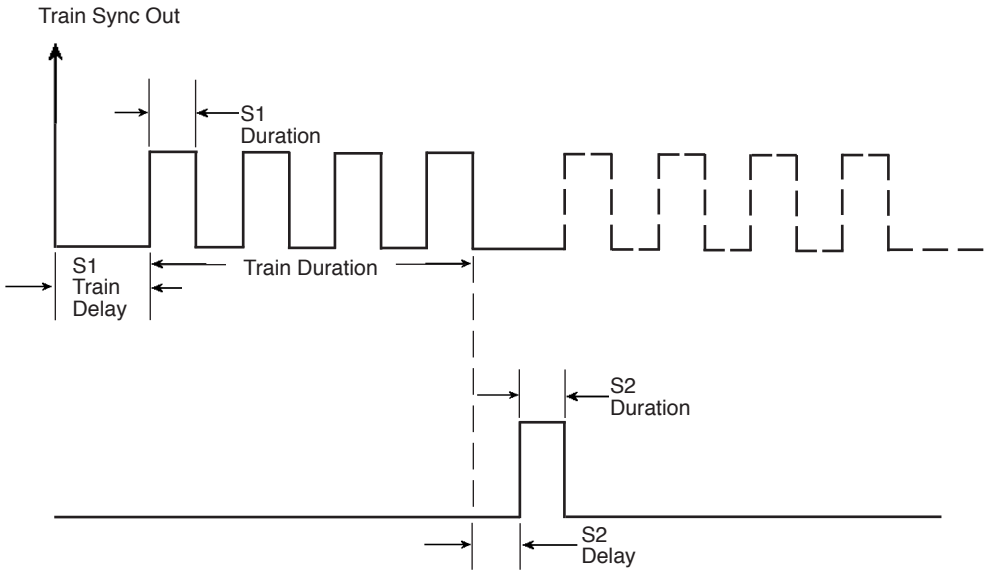
S2 Function = Sync with S1 (SS)
S1 = Single, Repeating, or Trains



S2 Function = Single Arrhythmic (SA)
S1 = Repeating



Function = Post S1 Train (PT)
S1 = Single or Repeating Trains



S2 Function = Sync Train to S1 (TS)
S1 = Single or Repeating