

ISOLATED PROGRAMMABLE STIMULATOR

MODEL A13-65 OPERATION and APPLICATIONS



REVISED 8/14/2000

CI COULBOURN INSTRUMENTS

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GENERAL INFORMATION

The A13-65 is a general-purpose stimulator designed to serve a very wide variety of applications. It is suitable for uses ranging from stimulation via microelectrodes, implanted and cutaneous electrodes to tissue and organ baths. It may be used for lesioning or histological marking. It is indicated as an aversive shock stimulator in behavioral designs for escape/avoidance, CER (conditioned emotional response) response suppression, and other procedures. It is especially useful with large subjects requiring higher currents or for low time-density (pulse width) relationships. Precise feedback regulation and timing also make it ideal for iontophoresis.

The instrument is capable of monophasic or biphasic (polarity reversal) stimulation with a **constant current** (feedback regulated) or **constant voltage** (feedback regulated) output. It is totally isolated from line voltage by means of a shielded transformer and all inputs are optically isolated. The stimulus synthesis section is additionally isolated from the output and subject by an isolated power supply. The monitor output is also fully isolated from the oscilloscope.

The stimulus protocol (timing, amplitude, and pulse relationships of the actual electrical stimulus output) may be programmed on the keypad on the front of the instrument; or it may be programmed on a computer and downloaded to the stimulator via its LabLinc port. Programming is simple; the user is led through the setup of a protocol by a series of prompts on the front panel display. Simple yes/no responses or the entry of numeric values for time and amplitude are all that are required.

The unit can store up to 255 stimulus protocols which can be recalled by a keypad entry or by an on-line computer for instantaneous protocol change while running an experiment. The unit may be controlled by our Graphic State Notation behavioral software, and any of its stored protocols may be executed with the same ease as any auditory or visual stimulus in the environment.

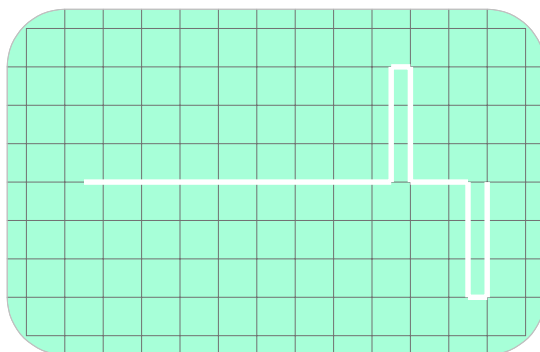
DEFINING TERMS

THE STIMULUS PROTOCOL

A stimulus protocol consists of (1) the stimulus pulse timing and polarity cycle, (2) the magnitude of the stimulus specified in voltage or current, and (3) the number of repetitions of the cycle in a burst.

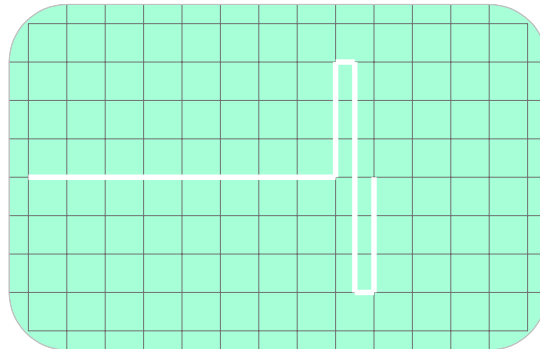
THE STIMULUS TIMING AND POLARITY CYCLE

The stimulus timing cycle consists of 4 time intervals: delay, first pulse, interpulse interval, and second pulse.



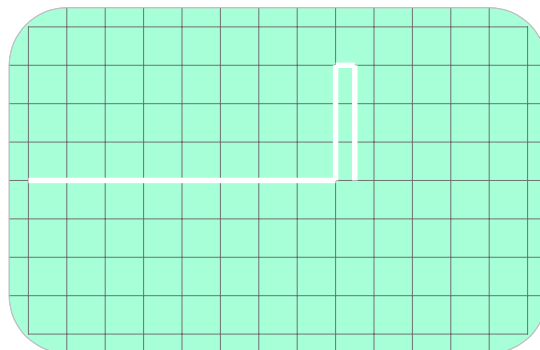
The “waveform” above is a “complete” stimulus cycle where all 4 times are specified and an amplitude is specified for the pulses. The delay is 16 milliseconds in duration, the first pulse is positive and is 1 millisecond in duration, the interpulse interval is 3 milliseconds in duration, and the second pulse is negative and 1 millisecond in duration.

The stimulus form on the previous page is a spaced biphasic design where the pulses are of opposite polarity and there is an interpulse interval between them. If we specify the interpulse interval to be zero as shown below, the output will go directly negative after the positive pulse and will not “stop at zero” for the interpulse interval as diagrammed below:

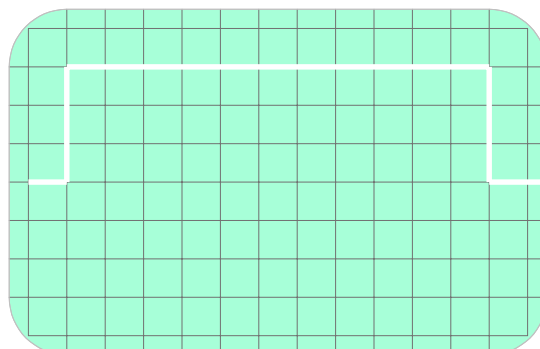


NOTE: For a zero or one-microsecond specification, the stimulator automatically enters two microseconds to accommodate minimum time intervals for gating into the free running clock and for the slew rate of the stimulus amplifier. The two-microsecond minimum may be ignored for typical millisecond range applications. Additionally, when a pulse is specified as zero time, even though a two-microsecond minimum time must elapse, the pulse output will be zero volts. (See “SYNCHRONIZED OPERATION” page 20.)

To generate a **monophasic** pulse stimulus, simply set the desired time and polarity for one of the two pulses and set the time for the other pulse duration and the inter-pulse interval to zero.

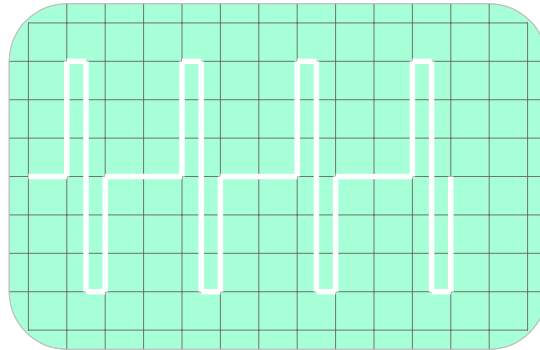


Setting a high current and a long time for the pulse duration(s) is the protocol tactic for **lesioning tissue** with a DC current.

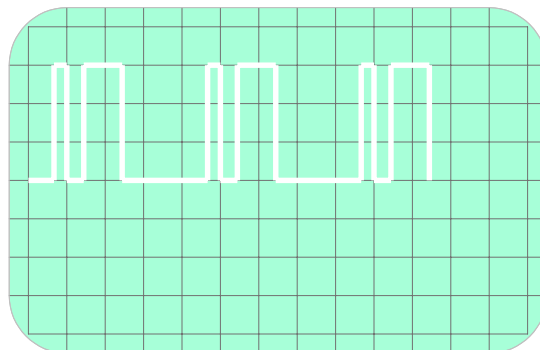


THE BURST

The burst is the complete stimulus protocol consisting of N stimulus cycles. Returning to the first stimulus cycle shown at the top of the previous page, if the programmer selects the number 4 under the “# in burst?” prompt, then the complete (storable) protocol consists of 4 repetitions of the stimulus cycle and looks like this:



To produce bursts of paired pulses of the same polarity separated by a greater time between the pairs, simply set both pulses to the same polarity and select a delay interval that is greater than the interpulse interval. You may use the same or different durations for the pulses in either mono- or biphasic stimuli. Then specify the number of repetitions in the burst as above (3 - dual monophasic repetitions are shown here).



This burst (or “train”) of 3 stimulus cycles will be presented upon the **onset** of each operate input, regardless of the length of the operate signal, be it longer or shorter than the burst. This is a “trigger” operate function rather than a “passive timed” or “run” operate function.

The number 1 may be selected for the burst in which case a single stimulus cycle will be presented upon the occasion of the onset of each operate input command. This allows signals that are longer than the desired duration of stimulation to be used to trigger a fixed, time duration shorter than the command signal. (See “Timed Stimulation” below.)

TIMED STIMULATION

Timed stimulation is an alternative to a counted burst of cycles. If “Yes” is the answer to the “timed stimulation” prompt, then the stimulus cycle will be repeated indefinitely as long as the operate input command persists. A stimulus cycle in progress at the offset of the operate command will be completed.

STIMULUS MAGNITUDE, CONSTANT CURRENT OR CONSTANT VOLTAGE

You will be prompted to select, a constant voltage or a constant current stimulus. If constant current is selected the current “waveform” will not vary as subject resistance changes. The stimulator will adjust voltage virtually instantaneously (see “Slew Rate” – page 23) to keep current constant as the stimulus cycle demands. Conversely, if constant voltage is selected, current will change in inverse proportion to subject resistance change as the voltage waveform follows the programmed stimulus cycle.

DELAYS

The stimulus cycle begins with the delay interval. The term delay was chosen for this interval because it is at the end of this interval that the sync (synchronization) pulse is issued. This pulse is used to synchronize stimuli to multiple sites with delays from separate stimulators.

NOTE: *There is an **additional fixed delay of 1 millisecond** (in addition to the delay from the beginning of the stimulus cycle to the first pulse) when using the stimulator in the normal mode. This delay is to allow time for the electrode shunt circuitry to settle. It is simply a fixed delay from the operate command onset to the actual commencement of the first stimulus cycle. It is of no consequence when the stimulus delivery bears no time relationship to other stimuli. The time from the beginning of the stimulus cycle to the first stimulus pulse, and the time between all subsequent pairs of pulses in a burst is the **user-programmed delay interval**. Do not confuse it with the shunt relay settling time delay, which occurs only once at the beginning of an operate command. This is discussed more fully in the **ELECTRODES** and the **SYNCHRONIZED OPERATION** sections.*

PROGRAMMING AND USING THE STIMULATOR

If you want to observe the stimulus waveform on an oscilloscope as you go through this section, connect the oscilloscope to the monitor output on the rear of the stimulator cabinet. A BNC-to-BNC cable is provided with the stimulator for convenience in connecting it to the oscilloscope. Connect one end of the BNC cable to the BNC output on the rear of the stimulator marked “MONITOR”. Connect the other end to the input of your oscilloscope. (See “**ISOLATED MONITORING** on page 24.)

You must also connect the 10K dummy load resistor (supplied) across the binding posts marked “stimulator output”. Any time you wish to monitor an actual stimulus output, you must have some sort of load across this output. If not tissue, then a resistor in the general range of typical tissue resistance.

POWERING UP

Turn on the power switch which is on the rear panel (to the left as you face the front of the cabinet). The display on the stimulator will fade in the name...



COULBOURN STIMULATOR

...followed by scrolling in the word:



READY

It will then momentarily display the total number of protocols stored in memory...



XXX Protocols Stored

...followed by the first prompt.

PROGRAMMING

CREATING PROTOCOLS

The first prompt given after power-up is...



Load Protocol?

If you enter "Yes", it will ask you for the stored protocol number. On the keypad, enter the number of the stored protocol you wish to use and press the "Enter" key.

The display will now ask if you wish to review parameters of the protocol you selected. "Yes" will take you to the parameter review sequence and "No" will take you to "Ready".

If you answer "No", it will ask you if you want to "Create a Protocol?"



Create a Protocol?

If you answer "No" to this prompt, it will take you to the "delete" routine. If you answer "Yes" to the "create" prompt, you will enter the sequence to create a new stimulus protocol. To create a complete protocol, the following parameters must be specified:

- Voltage or Current
- Magnitude
- The 4 Intervals:
 - Delay
 - Pulse 1 Duration (P1)
 - Interpulse Interval (IP)
 - Pulse 2 Duration (P2)
- Pulse 1 Polarity
- Pulse 2 Polarity
- Timed or Burst
- If Burst, How Many?

The prompt sequence follows the order above. At any time during the sequence, you may press "Cancel" and cancel the value of any parameter being displayed. A second press will cancel the previous parameter, and so on.

The first prompt in the “create” sequence is:



Constant Voltage?

If you answer “No”, it will ask...



Constant Current?

If you answer “No”, it will again ask...



Constant Voltage?

It will alternate on “No” responses until you respond “Yes”, at which point it will ask you to...



Enter Voltage

...or...



Enter Current

Now you enter the value of either the constant current or constant voltage desired and press the “Enter” key on the keypad.

Current may be specified from one microamp to 60 milliamps and voltage may be specified from one millivolt to 100 volts.

For values less than 1 volt, you may enter digits followed by milli or micro or you may use a leading decimal point.

(.)(1)(2)(5)(ENTER) will produce the same stimulus magnitude as:
(1)(2)(5)(Milli)(ENTER)

!!! CAUTION AND WARNING !!!

When you select a current above 10 milliamps or a voltage above 10 volts, a tone burst will occur, followed by a flashing light indicating high range, to warn you to use caution to avoid being shocked when handling the output leads or electrodes. ***Currents and voltages in the extreme high ranges can be lethal even via paths from cutaneous sites. Via any path, even 5 milliamps, is a very unpleasant stimulus.***

The flashing light will persist as long as the protocol is in the ready-to-use location in memory. The tone burst and light will also be activated if a stored protocol above these values is called up and loaded into the ready-to-use memory location.

The permissible high current and voltage values, as well as the very long pulse durations, are incorporated into the instrument design to serve applications such as **lesioning and stimulating whole organs in baths.**

After you select a current or voltage magnitude, the display will verify it momentarily and then take you to the 4 time sequence prompts — Delay, Pulse 1, Interpulse, and Pulse 2.

You may specify time from 2 to 65,535 microseconds or milliseconds. (All protocols are executed at the microsecond time base precision.)

A typical sequence looks like this:



Press (3)(0)(Milli)(Enter)



The display verifies entry and advances upon pressing “Enter”.



Press (1)(0)(Milli)(Enter)



Display advances upon pressing “Enter”.



Press (5)(Milli)(Enter)



Press (1)(0)(Milli)(Enter)

The display verifies and advances as before. You have now created a stimulus with a 30-millisecond delay, a 10-millisecond first pulse, a 5-millisecond interpulse interval, and a 10-millisecond second pulse.

The next step is to set the polarity of the two pulses



Pulse 1 Positive? Voltage?

Press "Yes"



Pulse 2 Positive? Voltage?

Press "No"



Pulse 2 Negative? Voltage?

Press "Yes"

As with current and voltage, these two prompts simply alternate until you enter "Yes".

The stimulus cycle is now complete. You have selected a constant current or voltage mode, specified the magnitude, specified the time cycle, and selected the pulse polarities. All that remains is to select whether you want to control the presentation externally (either for a given time or for the duration of some other event), or to present a burst of a specified number of cycles on command. If the time of presentation will *always* be the same, use the burst mode and add up the time of stimulus cycles to equal total time you want. The external time mode is only provided to allow you to use *different* times or event durations on *different* presentations, or to terminate a fixed presentation interval before it is complete, dependent upon the occurrence of other events.

The next prompt is...



OPER = Counted Burst?

If you answer "No", the display will ask you...



OPER = External Time?

These two prompts also alternate until "Yes" is selected. If you answer "Yes" to the "External Time?" prompt, the display will go directly to "Setup Complete" and "Review Parameters?" This means that you have selected the timed operation mode, and you must provide a timed or event controlled operate signal from another instrument or system, or hold a manual pushbutton switch for the desired duration. The stimulus will be presented for the entire duration of the external operate signal (finishing the cycle in progress during which the operate signal was terminated).

If you answer “Yes” to the “Counted Burst?” prompt, it will ask you how many cycles you want per burst.



Enter # Cycles/Burst

Enter the number (up to 65535) of cycles desired. The display will verify as you press the digits.



XXXXX Cycles/Burst

This is the number of stimulus cycles that will be presented commencing at the *onset* of the operate command, no matter if the command is shorter or longer than the burst interval.

When you press “Enter”, the display will indicate...



Setup Complete

...and then ask if you want to...



Review Parameters?

If you enter “Yes”, the unit will go to the “review parameters” sequence. (Discussed in the next section.) If you answer “No”, it will go to the “Save Protocol?” prompt.



Save Protocol?

If you answer “Yes” it will go into the save sequence. (Discussed in the next section.) If you answer “No”, it will go to “Ready” indicating that it is ready to accept an operate command from either the operate key on the front panel or via the operate input on the rear panel.

REVIEWING AND CHANGING PARAMETERS

After loading or creating a stimulus protocol, you will see the “Setup Complete” message, and the prompt:



Save Protocol?

If you are sure your protocol is correct, a “No” answer will take you to “Save Protocol?”. A “Yes” answer produces a display of the first parameter in the sequence to be reviewed, either...



Constant Voltage

or...

A black rectangular box with the text "Constant Current" in a green, pixelated, monospace font.

...depending upon what was programmed for this protocol.

From this point, each press of one of the review arrow keys will step forward or backward through the parameters specified for this protocol.

When any parameter is being displayed, you may press "No" and you will be prompted to change or enter a new value for that parameter with the same prompt that was used in the "create" sequence.

You will automatically go back to the beginning of the "Review" sequence after you step forward through all parameters. This will allow you to review again if you made changes, or enter "No" and advance to the "Save" sequence. To exit the "Review" sequence before reviewing all parameters, simply press "Cancel".

Exiting either way takes you to "Save Protocol?".

SAVING PROTOCOLS

The "Save Protocol" sequence is offered after the "Review Parameters" sequence whether you use or bypass the review. The review and save sequences follow either the load or create sequences. The review sequence gives you the option to check a newly created protocol or to verify that the one loaded from memory is the one you want to use.

The "Save Protocol" routine is offered at the end of either sequence for the obvious purpose of making it possible to reuse a protocol many times without having to create it over and over again. Also, a number of protocols may be created, saved, and called up instantaneously (without download delays) by a computer during an experiment in interactive designs like self-stimulation. And last, but not least, storage can be used like a notebook. When you want to try something a little different, you can quickly load and modify, or create a new protocol to "see what happens". Assign it a memory number and store it. All you need to jot down at the time is the memory location. You can call it up and review it later to confirm the exact protocol.

When the save routine is offered, the prompt will be...

A black rectangular box with the text "Save Protocol?" in a green, pixelated, monospace font.

"No" will take you to "Ready". "Yes" will prompt...

A black rectangular box with the text "Enter Protocol #" in a green, pixelated, monospace font.

Press 1, 2, or 3 digits up to 255 followed by "Enter". If the location is free, the protocol will be saved under that number. If the location already has a protocol stored, the display will show...

Overwrite Protocol?

A “No” answer will prompt you to enter another number. A “Yes” answer will erase the existing protocol and save your current protocol in its place **if, and only if, the stimulator is functioning in the unprotected mode**. If the stimulator is functioning in the **protected mode**, and you attempt to overwrite, you will receive the message...

PROTECTED MODE

...followed by...

Enter Protocol #

...so that you can select another, unused number. *(This new number will be entered if the stimulator is in either the protected or unprotected mode.)*

After a protocol is successfully stored, the stimulator will advance to the “Ready” state.

The method by which the stimulator is placed in the PROTECTED OR UNPROTECTED MODE is discussed on a separate sheet (last page in the manual) that the primary user may opt to remove from the manual.

DELETING PROTOCOLS

Let's go back to the beginning...

After the start-up sequence, a “No” answer to...

Load a Protocol?

...and a “No” answer to...

Create a Protocol?

...the display will ask if you want the third option...

Delete a Protocol?

If you answer “No”, you will move to the fourth option, “Review Memory”. Successive “No” responses will take you through a loop of these 4 alternatives.

A “Yes” response to “Delete a Protocol?” will give you the opportunity to delete any protocol from memory you wish.

If the stimulator is in the **MEMORY PROTECTED** mode, you will be so advised. Otherwise, the following sequence is used to delete protocols:

A black rectangular box with the text "Delete a Protocol?" in a green, pixelated, monospace font.

“Yes”

A black rectangular box with the text "Enter # to be Deleted" in a green, pixelated, monospace font.

Press 1, 2, or 3 digits followed by “ENTER”.

A black rectangular box with the text "XXX Deleted" in a green, pixelated, monospace font.

After a brief display you will again see:

A black rectangular box with the text "Enter # to be Deleted" in a green, pixelated, monospace font.

It will continue to reappear after each deletion so that you can delete as many protocols as desired without having to go through the entire sequence. When you are finished deleting one or more protocols, simply press the “Cancel” button to return to “Load Protocol?”

DELETING THE ENTIRE MEMORY

To “Clean House” or delete all of the protocols stored in memory, enter 999 when asked for the number to be deleted.

A black rectangular box with the text "Delete a Protocol?" in a green, pixelated, monospace font.

“Yes”

A black rectangular box with the text "Enter # to be Deleted" in a green, pixelated, monospace font.

Press (9)(9)(9)(Enter).

A scrolling message will ask “Are you sure you want to delete ALL protocols?”

“Yes”



All Protocols Deleted

Protocols may also be deleted in the memory review branch so, if you can't remember which protocols are stored, you may want to review the contents of the protocol memory to find those you wish to delete.

REVIEWING MEMORY

The fourth and last main program branch is Memory Review. After making three successive “No” responses to “Load”, “Create”, and “Delete” prompts, you will be asked if you wish to:



Review Memory?

A “No” response returns you to “Load Protocol?”.

A “Yes” response results in the first (lowest numbered) memory location containing a stored protocol to be displayed like this:



XXX Load?(Y)Delete?(N)

The leading number in the prompt is the location of the first (lowest number) stored protocol. Pressing the forward review key (>) will advance you sequentially through each location where a protocol is stored, skipping any empty locations.

While any number is being displayed, you have the options to 1) load the protocol to review its parameters and/or, 2) use the protocol, or 3) to delete the protocol from memory.

As the display indicates, you must **use the “No” button to delete the numbered protocol** (if memory is not protected). The display reports it deleted, and advances to the next higher numbered protocol.

Use the “Yes” button to load the protocol. This will load the protocol and allow you to review the parameters. You may skip the review query with a “No”, go to “READY”, and use the protocol. When you use this tactic to review a specific protocol's parameters, you have gone to the main load sequence. After reviewing the parameters of a specific protocol, if you wish to continue from where you were in the memory review sequence, you must step through the “create”, “delete”, and all of the lower numbered protocols stored in memory.

A press of the “cancel” button in this branch takes you back to the beginning, “Load Protocol”. To advance to the next protocol, use the review “>” button.

DELIVERING STIMULI

After loading or creating and, if desired, reviewing or modifying a protocol, the stimulator will go to the “ready” mode indicated by...



READY

If you have just created or modified and then stored a protocol, it is also automatically loaded as the ready-to-use protocol, just as if it had been loaded directly from memory.

The stimulator may be operated, that is, commanded to deliver the currently loaded stimulus protocol to the stimulator output, **only when it is in the “Ready” mode**.

Any time the stimulator is in the ready mode, a “cancel” key press will take you back to “Load?” so that you may load or advance to create another protocol quickly.

Any time the stimulator is actually delivering a stimulus, a “cancel” key press will immediately stop stimulation in progress without finishing the stimulus cycle (you will want to do this if, for example, you are lesioning tissue and it starts to crackle and smoke) and return you to “ready”.

NOTE: STIMULUS DELIVERY IS DELAYED

*There is a one millisecond delay between the onset of a stimulus “operate” command and the actual onset of the user-programmed delay, which begins the stimulus timing sequence. The reason for delaying is to allow the electrode shunting micro reed relays time to transfer the output leads from a shunt (dead short) to the output of the stimulus circuit. The electrical configuration is shown in the **ELECTRODES** section below.*

*You may override this function if you want to present a stimulus precisely synchronized with stimuli from other stimulators, or with stimuli presented in other sensory modalities (e.g., visual or auditory), or as an immediate stimulus consequence of responses of physiological or behavioral origin. (See **SYNCHRONIZED OPERATION** section.)*

ELECTRODES

Electrode cables should always be kept as short as possible to minimize resistive and capacitive effects on the stimulus signal. For constant voltage stimulation, electrode resistance and capacitance has a minimal effect on the stimulus signal.

For constant current stimulation, however, electrode resistance and cable capacitance have a more dramatic effect on the stimulus signal. For optimum results, electrode resistance should be 10K Ohms or less. If it is not practical to get electrode resistance down to that value, then electrode cable capacitance must be minimized. These restrictions on electrodes and cable apply to high-frequency signals and fast rise and fall pulses. Minimal length electrode cable and minimal electrode resistance will help prevent distortion of the stimulus signal. If the stimulus signal is a low-frequency signal or a pulse train with slower rise and fall time requirements, electrode resistance and cable capacitance effects are less critical.

THE ELECTRODE SHUNT

The electrode output is connected (and, thus, the electrodes) to the stimulus driver output during stimulation, and to a dead short circuit when the stimulator is not being operated. Transfer of the relay contacts occurs upon the occasion of an operate command. The transit time of the relay contacts varies in the range of 400 to 500 microseconds. To insure time for the relay to transfer and settle, we delay the onset of the entire actual stimulus (including the user-specified stimulus delay) by one millisecond. A precise, clock-timed interval of 1000 microseconds is used to insure a constant delay every time the stimulator is operated, rather than the variable delay inherent in individual relays.

The purpose of the shunt is to short the electrode leads: 1) to discharge the tissue, especially when using monopolar stimuli, to prevent tissue capacitive and battery effect buildup over trials. 2) to short out off-state, semi-conductor, micropotential leakage. 3) to short out inductively coupled micropotentials which may develop in the leads if they lie beside high current cables in feedthroughs to special environments, (e.g., behavioral or environmental test arenas). 4) to disconnect the subject/tissue from the stimulator to prevent picofarad capacitive coupling from the circuit board, connector shell, panel, or transformer inter-winding shield, from developing even a small potential when the subject is in contact with other sources of current

(e.g., similar picofarad leakage from an isolated behavioral shocker or a physiological amplifier's leakage or excitation potential).

NOTE: *The stimulator output section is electrically isolated by optical coupling of control signals and by a floating power supply. No path exists via direct continuity, semiconductors, or inductive coupling. Only the negligible, unavoidable, capacitive coupling mentioned above exists. It is below the level to develop a liminal stimulus but may, if the leads were not shunted, contribute to a small amount of tissue charging or damage when the subject is connected to a voltage source and the stimulator for very long periods.*

The delay for the shunt relays is precisely timed by a timer, not by the actual (variable) time it takes for the relay to switch (~ 500 microseconds).

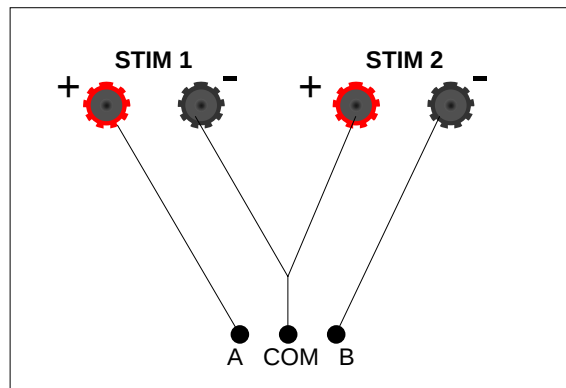
This delay can be reduced 1000-fold to the one microsecond variable delay of synchronizing with the one microsecond clock tick window by using electronic operate commands rather than hand switch or relay closures, and by "pre-opening" the shunt. (See the "SYNCHRONIZED OPERATION" section, page 20.)

ELECTRODE CONNECTIONS

Electrodes are connected to the binding post terminals on the rear of the cabinet marked "Isolated Stimulus Output". The "+" and "-" outputs refer to the polarity with respect to the named polarity of the pulses in the protocol. A pulse specified to be positive will be positive at the "+" output; a pulse specified to be negative will be positive at the "-" output with respect to the "+" output.

MULTIPLE ELECTRODES & STIMULATORS

If two stimulators are used and each is connected to its own (separate) two-pole site, there will be no current flow between the electrodes of the separate stimulators and the respective (separate) pairs of two-pole sites. The sites may be referenced in common by connecting one of the outputs of each stimulator in common. The pattern shown below results in current paths indicated for polarities for each stimulator.



(Stimulator 1 +) - (Stimulator 2 off): Electrode A + to Common

(Stimulator 1 -) - (Stimulator 2 off): Common + to Electrode A

(Stimulator 1 off) - (Stimulator 2 +): Common + to Electrode B

(Stimulator 1 off) - (Stimulator 2 -): Electrode B + to Common

(Stimulator 1 +) - (Stimulator 2 +): Electrode A + to Common, Common + to Electrode B

(Stimulator 1 -) - (Stimulator 2 +): Common + to Electrode A and Electrode B

(Stimulator 1 +) - (Stimulator 2 -): Electrode A + to Common, Electrode B + to Common

(Stimulator 1 -) - (Stimulator 2 -): Common + to Electrode A, Electrode B + to Common

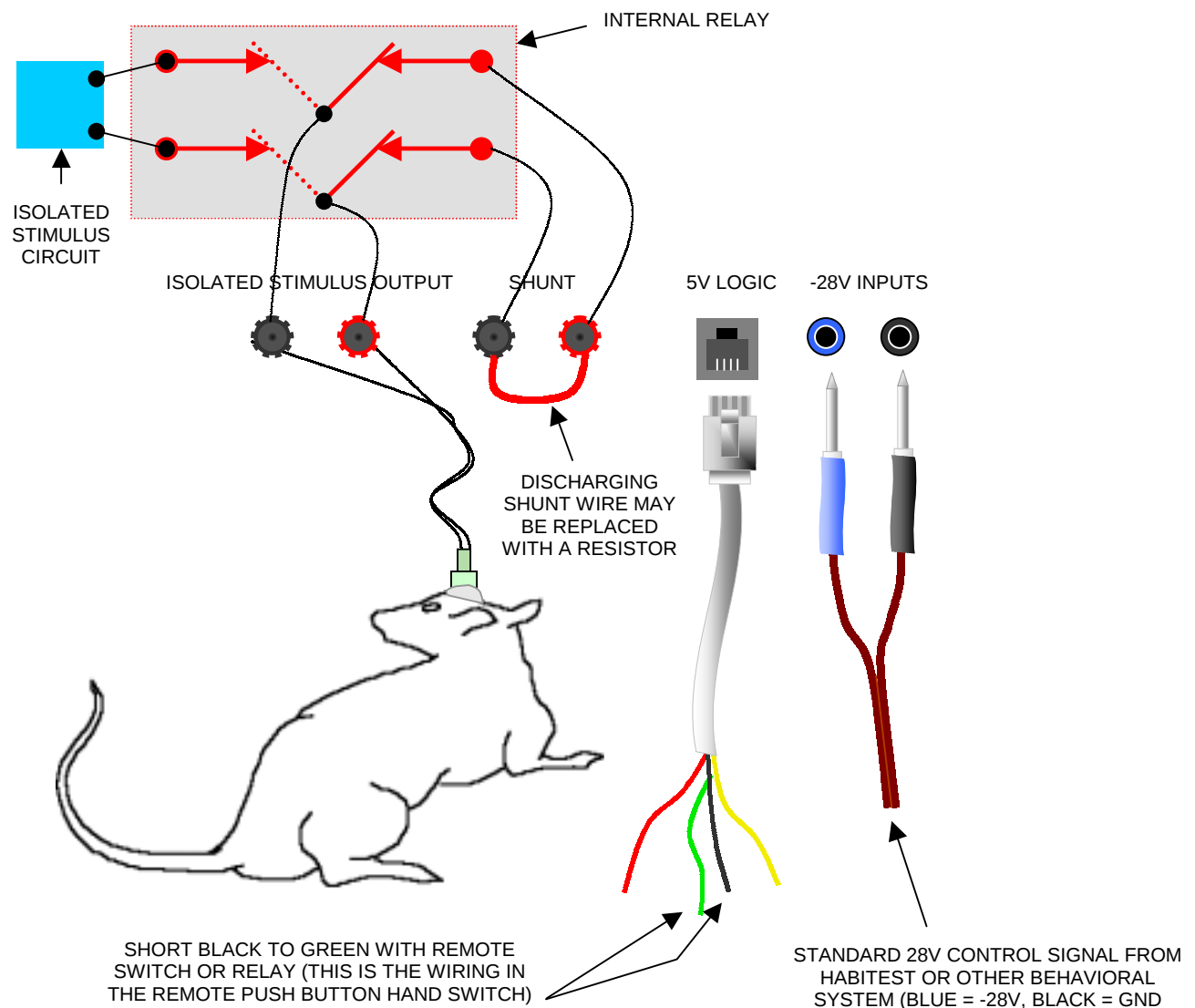
OPERATING THE STIMULATOR

OPERATE CONTROLS

In addition to the front panel operate key, there are provisions on the rear panel for 5-volt, 28-volt, and remote switch closure commands.

You may operate the stimulator by using any of the following:

- 1) The "operate" key on the front of the unit.
- 2) The (supplied) remote hand switch (which connects to the rear panel).
- 3) A +5 volt digital logic signal from any 5-volt interface, computer output, or other instrument.
- 4) A -28 volt signal from any behavioral test system environmental control driver or interface.
- 5) Any remote switch or relay contact closure.



28-VOLT INPUTS

First let's cover -28 volt operation. The box to the right (next to the power switch and cord) in the drawing on page 18, labeled "28V INPUTS", allows 28-volt control signals (behavioral test system standard) to either operate the stimulator, or to "pre-close" the shunt relay for synchronized operation.

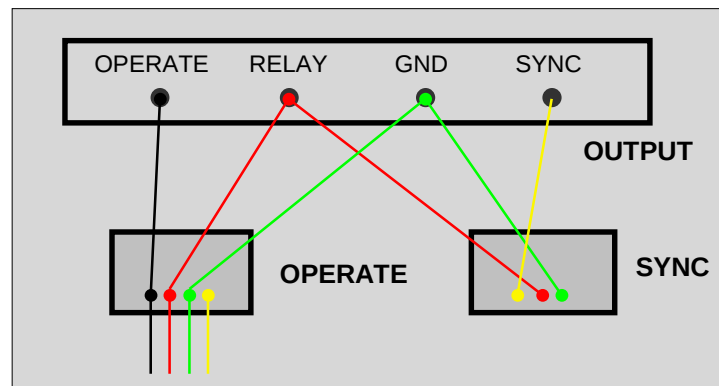
When using the unit with -28 volt systems, reference the (black) .080 jack to the control system ground and command either input (relay or operate) with a -28-volt signal. In the CI Habitest system, use the "AUX" output on the back of the Linc. Connect the black lead to the black jack ("COM" ground) and the blue lead (-28-volt control signal) the blue jack. The cable supplied has color-coded blue and black ends to help you keep the connections straight (illustration on previous page).

5-VOLT AND SWITCH CLOSURE OPERATION

The center section on the rear panel labeled "5V (low true)" is for 5-volt operation from other systems and for remote switch closure operation.

Remote switch closure operation is available via the telephone type jacks simply because we have provided a ground reference for externally powered drivers on one of the pins, and this ground reference may be shorted back to the "operate" and "relay" command input (low true logic) pins. The diagram on the previous page shows the color codes for the wires in the stripped wire connector supplied with the unit.

The illustration below shows the pass-through connections for the telephone type connectors used when synchronizing multiple stimulators.



Shorting (by remote switch or relay contacts) green to black will operate the stimulator. Shorting green to red will "preclose" the shunt relay for synchronized operation.

REMOTE HAND SWITCH OPERATION

The remote hand switch supplied with the unit simply shorts green to black. If you are using a protocol in the burst mode, it will deliver a burst. If the protocol calls for timing, it will stimulate for as long as you hold the button.

5-VOLT (LOW TRUE) LOGIC OPERATION

By referencing ground (the green wire) to your system ground, a ground logic level (low true assertion or high true negation) will operate the relay via the red wire and start the burst or run the stimulus for the time it is applied to the black wire.

SYNCHRONIZED OPERATION

The major use for the synchronized mode of operation is to deliver stimuli from two or more stimulators to different electrode sites with a timing precision of one microsecond. Synchronizing with auditory and visual stimuli may also be accomplished using the synchronized mode.

SETTING UP SYNCHRONIZED OPERATION

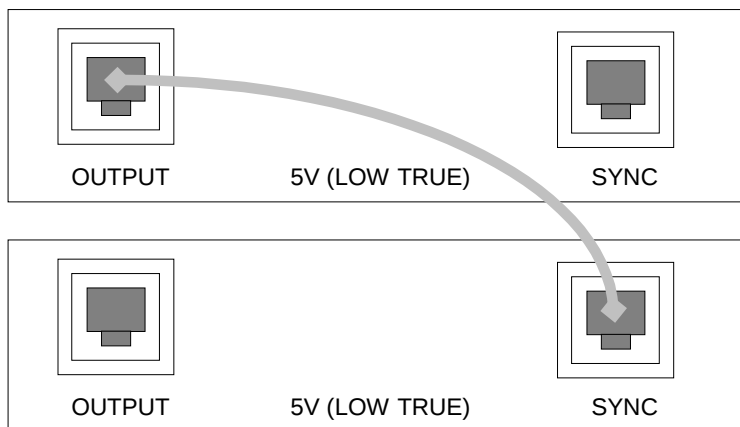
Before the “relay” command inputs can be used, the “options switch” (in the bank of switches above the oscilloscope “monitor” output) must be set. The first switch (the leftmost) must be in the up position. When in the up position, the relay input in both the 5-volt and 28-volt section will respond to commands. When a relay command is given, you must wait at least one millisecond before giving an operate command since the relay must still go through the transfer and settle.

SYNCHRONIZING MULTIPLE STIMULATORS FOR MULTIPLE SITES

To allow stimulating different sites using two stimulators with precisely delayed pulses; a sync pulse is provided from the stimulator. It is this sync pulse which becomes the operate command for the other stimulator(s). The sync pulse is issued at the end of the delay interval coincident with the onset of P1. A sync pulse could be issued at other points in the stimulus cycle, but this is the most useful place. This placement allows a master stimulator to initiate “N” slaves in a parallel fashion or in a sequential cascade (or ripple) with each unit initiating the next. The important thing is that, in any arrangement, the stimulators provide all of the timing and remain in sync throughout multiple stimulus cycles.

THE SYNC CONNECTOR

Each stimulator is provided with a daisy-chain sync connector, which is to be connected from the output of the first unit to the input of the next.

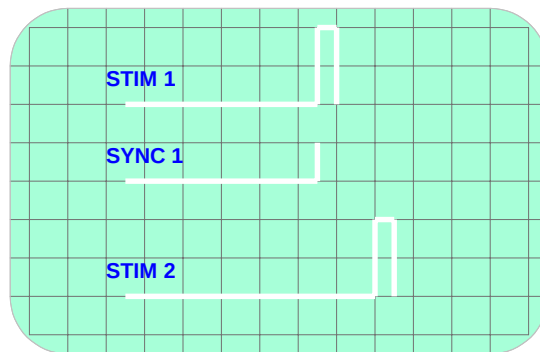


This allows the first stimulator to pass its “relay close” command to all of the rest and to pass its sync pulse to the operate input of the next stimulator in the chain. The sync connection, using the sync connector cable provided with the unit, is shown above. The upper stimulator is the master and the lower stimulator is the synchronized slave.

Let's consider two stimulators and two sites. As discussed under “*ELECTRODE CONNECTIONS*” on page 17, these stimulators may deliver stimuli to two isolated bipolar sites or to two sites with a common reference. Either or both sites may receive one or two pulses of a given polarity in the monophasic mode between the pulse or pulses at the other site. In addition, the protocols for each site may be monophasic or biphasic with current flowing in only one direction, or in both directions using opposite polarities for P1 and P2 in one or both protocols. You can see from the chart on page 17 that even with just two stimulators and four electrodes there are many monophasic-biphasic, single or dual pulse, isolated or common reference combinations.

Let's look first at just two stimulators stimulating two *isolated* sites via four electrodes (two for each site). Note that no current will flow from either of the two electrodes at one site to either of the two at the other. We shall assume that the shunt relays have been operated via either the 28-volt input or the red wire and, of course, the sync jumper cable is connected between the output of stimulator #1 and the input of stimulator #2.

Both stimulators now are ready to respond instantly to an operate command. If each stimulator is loaded with a protocol for a one-cycle burst of a single-pulse, a monophasic stimulus of one millisecond; the first has a delay of ten milliseconds (5divisions), while the second has a delay of three milliseconds, the time lines will look like this:

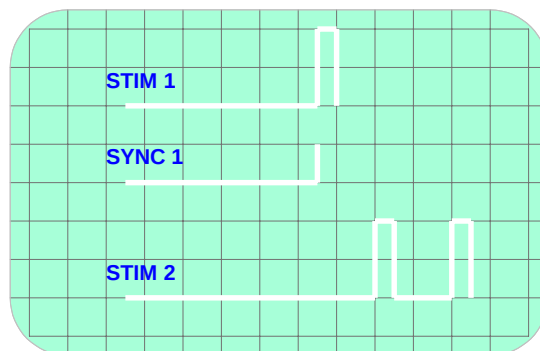


Notice that the delay of the second unit places its pulse onset three milliseconds later than the onset of the first unit resulting in a two-millisecond “dead time” between the pulses, since the first pulse is one millisecond long.

Now, suppose we want two pulses at site 2 (from stimulator 2) for each stimulation episode. The protocol for the first remains the same; a one-cycle burst, a 10-millisecond delay, and a single one-millisecond pulse. We have two options for the second stimulator — either change the protocol to a two-cycle burst, or use both pulses in a single cycle.

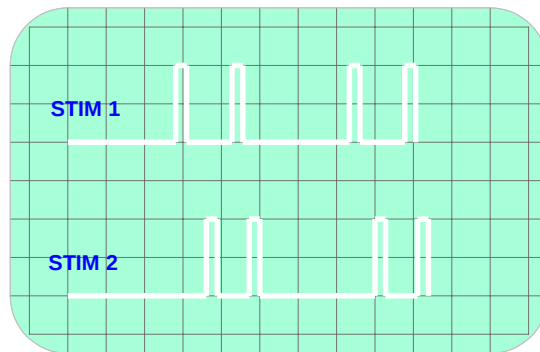
To use the first option, we create a protocol for the second stimulator — delay - 3 milliseconds, first pulse - 1 millisecond, (here you have a choice to make the delay at site two between pulse 1 and pulse 2 different from site one, pulse 1 to site two, pulse 1, but let's just make it 3 milliseconds) delay - 3 milliseconds, second pulse 0 - 1 millisecond, number in burst - 1.

The other option is -- delay - 3 milliseconds, pulse 1 - 1 millisecond, IPI - zero, second pulse - zero, number of cycles in the burst - 2. Using either of these protocols in the second stimulator will result in the (same) time line below.

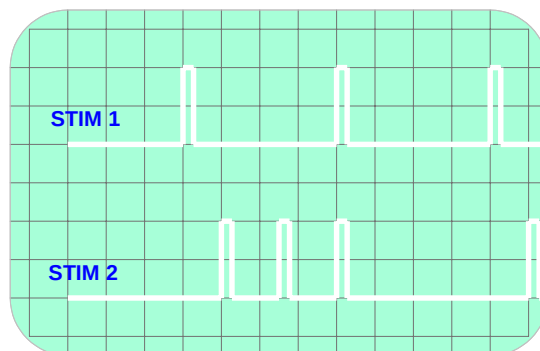


To repeat the entire two-stimulator, two-site event N times, all that is necessary is to repeat the first stimulator's cycle N times in a burst, but — and this is a very important but — don't forget that the second stimulator is executing its two pulses during the delay of the first.

If we change the first stimulator's protocol to a burst of two pulses 5 milliseconds apart, the time line looks like this:



However if we try to fit 3 pulses spaced 3 milliseconds apart in the second stimulus, it won't work. Having a burst of 3 pulses in unit 2 without extending the delay in unit 1, will produce this result:



Since unit 2 is still “busy” when the second sync pulse arrives at the operate of unit 2, it will simply be ignored and you will get the three-pulse burst from unit 2 on every other pulse from unit 1. This is conceivably a usable tactic, but be careful that you don't do it unknowingly.

The important thing to remember is to make sure that all subordinate time cycles have adequate delay intervals from superordinate, controlling stimulators, to finish their protocols before the next sync pulse. Also, don't forget that when using times in single digits of microseconds, the minimum two-microsecond values can add up to cause occlusion. (See “*SLEW RATE AND MINIMUM PULSE TIME*” next page.)

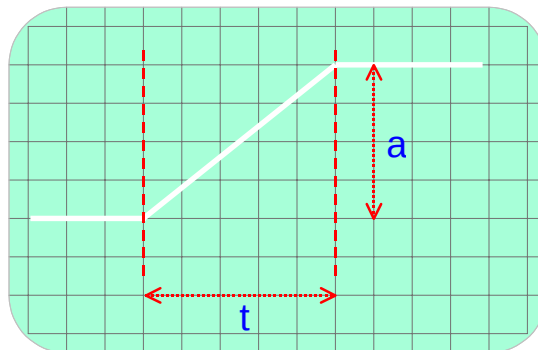
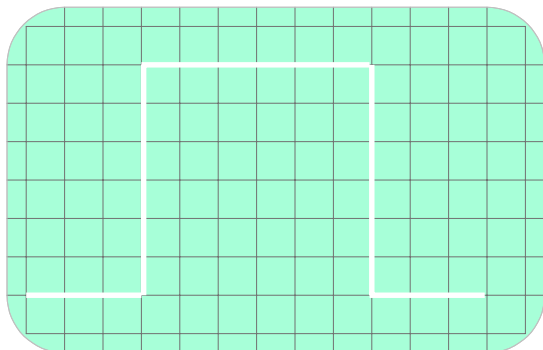
TIMING THE SHUNT DELAY

When operating the stimulator(s) in the synchronized mode, it is important to time the shunt relay as nearly as is practical to coincide with the stimulation episode to preserve the benefits of the shunt.

It would have been possible to design the stimulator to allow the master (or first) stimulator in a chain to control a slave's relays, but this would limit slave operation to being a total temporal subset of the master's stimulus cycle. As you can see in one of the diagrams above, the cycle of the first stimulator terminates before the second. A little reflection (and experience in designing multi-site protocols) reveals that this would have severely limited applications — especially those using common reference, “indifferent” electrodes.

SLEW RATE; MINIMUM PULSE TIME

Slew rate is the measurement of the speed with which an amplifier or similar electronic circuit can change voltage from one level to another. To this point, we have shown “square waves” like the one on the left:

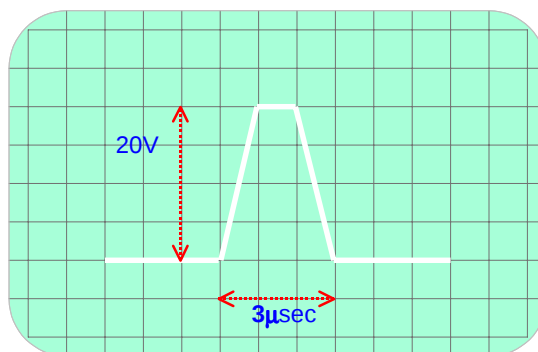
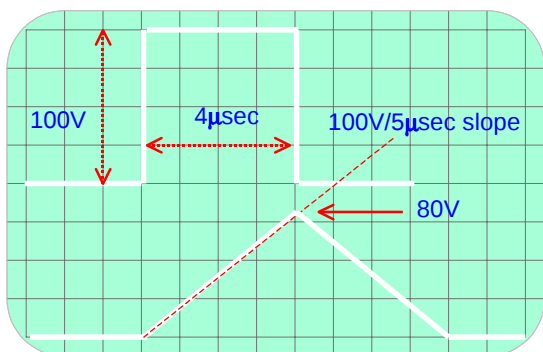


If we magnify the time line to show the leading edge of this signal, you can see that the transition from the bottom (lower voltage) to the top (peak voltage — the one you specify in creating a protocol) takes time as shown to the right. The time it takes, as you might expect, increases with larger value transitions. If the output must go from zero to one volt, the transition time with the type of currently available, reasonably priced components we use, takes only a fraction of a microsecond. However, to make the transition from 0 to 100 volts takes considerably longer, something around 5 microseconds.

The stimulator will automatically convert any pulse specification of less than two microseconds to a two-microsecond minimum value. Up to a 10-volt output level, the stimulator will reach full voltage with no further concern from the user except to remember the adding up of times in synchronized operation when using long bursts of very brief, single-digit, microsecond-range pulses.

NOTE: When you specify zero time, even though a minimum time value of two microseconds is used internally by the stimulator, the voltage or current is gated off so that no stimulus pulse is delivered.

Practically speaking, the only range that the user needs to be concerned with is the high range between 10 and 100 volts. For example, if you were to specify a 5-microsecond, 100-volt pulse (or a current that, with the tissue resistance in your preparation, results in a 100-volt excursion), the output of the stimulator would not be able to “follow” the specified cycle. The result would look like the illustration to the left.



Considering this, you must limit your pulse time specification to the slew rate or the rate at which the stimulator can follow the pulse specification. Slew rate may be specified in amplitude change per unit time, i.e., 20 volts/microsecond (=100 Volts/5 microseconds). In fact, this is a good value to use as a guideline with the stimulator. In the figure to the right it will guarantee a “flat top” on the pulse, meaning that the output will reach full voltage as shown.

Another consideration in setting pulse widths is the method by which the pulse is timed. For reasons of precision we use a crystal-controlled, free-running clock to generate a pulse stream time reference. The beginning of the stimulus cycle is initiated on the next clock tick. If the delay interval is specified as zero and the first pulse is specified as one microsecond in duration, both will be converted to two microseconds, and the actual onset of the first stimulus pulse could be from just over one microsecond to two microseconds after the operate command.

Once the cycle is initiated, all times subsequent to the delay, P1, IPI, and P2, occur without the indeterminate delay of gating into the free-running clock between ticks. Each transition takes place precisely on a clock tick, in sequential order, as do subsequent cycles in a burst. Thus, long bursts of N cycles remain synchronized within the precision of the crystal clock.

The limitations of slew rate and the indeterminate fraction of a microsecond delay pose no practical problem in using the stimulator. Latency, propagation delays, depolarization time constants, and the like, are considerably longer than these values.

MONITORING AND BIOPOTENTIAL RECORDING

Monitoring the **actual stimulus signal** across a 10k Ohm resistor at the stimulus output with an oscilloscope will indicate if any signal distortion is present resistor (the resistor is supplied - remove before it connecting the subject). **The oscilloscope should only be used for setting up and checking since output isolation is lost if a grounded oscilloscope is connected to the isolated stimulus output.**

ISOLATED MONITORING

An isolated output is provided to permit monitoring of the signal sent to the final stage of the stimulus output section. It is isolated so that the signal may be monitored while the subject/preparation is being stimulated without ground referencing the subject via the oscilloscope ground. **A 6-foot BNC to BNC cable is provided with the unit to make connection directly to your oscilloscope without using a probe.**

The monitor output auto-ranges for convenience in connection to oscilloscopes without the use of attenuating networks. The monitor output will represent the signal in a 0 to 10-volt range for three decades of stimulus magnitude.

SELECTED STIMULUS VOLTAGE	SELECTED STIMULUS CURRENT	MONITOR OUTPUT VOLTAGE
0 to 1 V	0 to 1 mA	0 to 10V @ 1V
1V to 10V	1mA to 10 mA	0 to 10V @ 10V
10V to 100V	10mA to 60 mA	0 to 10V @ 100V

BIOPOTENTIAL RECORDING

To **record** from the preparation (subject) **via the stimulation electrodes** while the stimulator is **not stimulating**, remove the shunt (jumper) from the binding posts and connect the recording amplifier to them. If you are using a single ended (2-lead) amplifier, connect the positive (signal) input to red and the negative (ground or reference) input to black. This will provide a reference for recording to maintain "right reading" charts or oscilloscope traces. It will earth ground the subject if the ground electrode from your amplifier is true earth ground (not floating); however it will only do this during recording **not** during stimulation. (See the illustration on the next page.)

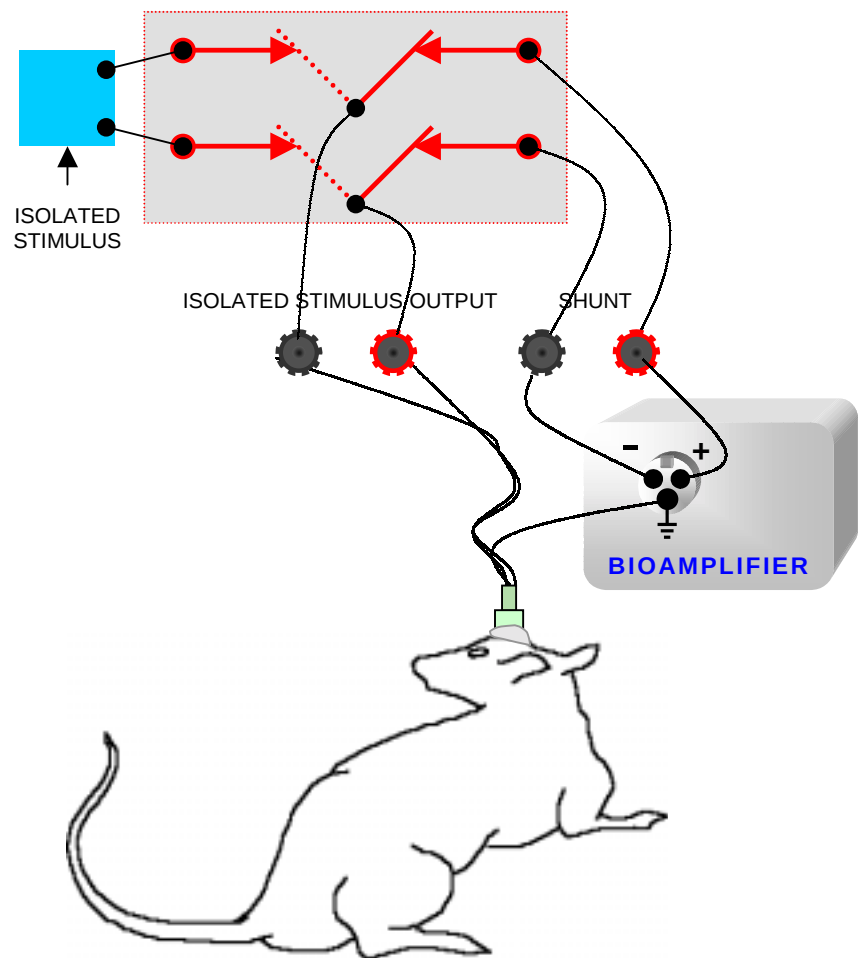
If you are using a differential amplifier, connect the positive input to red, the negative input to black and the common (ground or reference) either to black, directly to the subject, or both.

Note: Don't forget to replace the shunt when you are not recording from the stimulating electrodes!

To record from separate electrodes on the same subject, connect the single ended input lead or differential input leads where desired on the subject and connect the common (ground or reference) electrode to the black binding post marked "Isolated Ground Reference" above the black shunt binding post.

Note that the subject is not "switched away" from the amplifier's ground reference under this circumstance so the subject will be connected to whatever ground reference the amplifier has between and during stimulation. If that reference is earth ground, the stimulator's output is no longer isolated. It is for this reason that you should **always use an isolated amplifier when recording from separate electrodes**.

You may find, depending upon ground line noise conditions in your building, that you get better performance using one or the other rather than both of the ground reference connections shown above. Also, if you use shielded electrodes you may find the best place to reference the shield is the subject alone without the isolated ground reference connection.



VIEW OF REAR PANEL

SPECIFICATIONS

Constant Voltage: +/- 100 volts maximum. Entered as millivolts or volts. Minimum Resistance = 1.6K Ohm.
Constant Current: +/- 60 milliamps maximum. Entered as microamps or milliamps. Maximum resistance = 2K Ohm.

Parameter Timing (Delay, P1, IPI, P2): Crystal-controlled. Valid time parameters are 0-65535 microseconds or milliseconds.

Stimulus Duration: Internally counted - 65535 cycles/burst max. OR externally controlled by the operate input on rear panel.

Pulse Polarity: P1 and P2 are individually controlled and may be set either positive or negative. NOTE: If zero time is entered for P1 or P2 that pulse will be OFF.

Pulse Rise Time: 10V/microsecond.

NOTE: Times less than two microseconds are internally set to two microseconds. However, if P1 or P2 time was set to zero, they will NOT be enabled and will NOT produce a stimulus output pulse.

Control: Microprocessor controlled with front-panel keypad data entry and a 1x20 display.

Timing Accuracy: Better than 1%.

Amplitude Accuracy: Typically +/- 1%, Maximum +/- 2%.

High Range Warning: > 10 volts constant voltage or > 10 milliamps constant current.

Stored Protocols: Up to 255 may be stored. Internal nonvolatile RAM, battery life expectancy ~ 10 years.

Front Panel Indicators: Power, Stimulating, High Range (flashes when in high range), Current Mode, Voltage Mode and Dot-Matrix alphanumeric display.

Manual and Remote Control via Rear Panel: -28V inputs; operate, relay, and ground.

Input Modular Connector: 5V Input - Operate, Relay, and Ground; 5V Output - Sync (indicates start of P1)

Output Modular Connector: Use modular-modular cable to the next stimulator's input connector.

Remote Hand Switch: Supplied with a 7 ft. cord, must be connected to Input Connector.

Isolated Stimulator Outputs: +/- 125V max. @ 60 mA, red & black binding post.

Monitor Output: +/- 10V max. BNC; +/- 10 volt signal for 0 to +/- full scale output for any constant current or constant voltage range.

Power Requirements: 35 watts, 115VAC-50/60Hz OR 220/240VAC-50/60Hz (specify on order).

Dimensions: 3-1/2 inches high x 17-1/2 inches wide x 13-1/2 inches deep.

Weight: 20 lbs.

Supplied Accessories: Remote Hand Switch - 7 ft.; Modular Cable with Stripped End - 7 ft.; Modular-to-Modular Cable - 6 ft.; BNC-to-BNC Cable - 6 ft.

PROTOCOL NUMBER LOG (Copy Sheet)

[illegible]

COULBOURN INSTRUMENTS, L.L.C. 7462 PENN DRIVE, ALLENTOWN, PA 18106 USA
INTERNET - www.coulbourn.com E-MAIL - sales@coulbourn.com FAX (610) 391-1333 TEL (610) 395-3771

PROTECTION OF PROTOCOLS

(Protected Mode for Storing, Editing and Deleting)

This page is separate from the rest of the manual so that the primary user may share the instrument with other users with the assurance that they will be unable to erase or modify protocols.

To set the unit to the protected mode, place the second switch in the “Options” switch bank on the rear panel to the up position. To set it back to the unprotected mode, just place the switch back in the down position.