User's Guide

MyoPacer EP

Manual Revision 7
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Introduction

Overview

The MyoPacer Family

MyoPacers are field stimulators designed to fit the specific needs of the myocyte research community. They offer bipolar pulses and a range of pulse durations (.4 ms - 24.0 ms),, frequencies (.010 - 99 Hz), and voltages (+/- 40 V) that are all user programmable and stored in non-volatile memory for easy restart. They have TTL inputs and outputs to allow synchronization with other components of an experiment.

The MyoPacers were designed to address three shortfalls of normal stimulators. The first improvement is the ability to smoothly increase frequency from one order of magnitude to the next. Many stimulators have one knob that selects order of magnitude and another that is a fine adjust. This setup means that to progress from .9 Hz to 1.0 Hz, the fine adjust must be turned all the way down, and then the order of magnitude increased. The MyoPacer dial/LCD interface allows a smooth progression.

The second advantage of the MyoPacer is that a crystal oscillator generates its time-base. This means that the pacing frequency is precise and absolutely reproducible from experiment to experiment

Large, instantaneous jumps between pacing frequencies can easily be done with the MyoPacer. Many times, researchers either have specific protocols that require a quick jump from one frequency to another or want to do repeated experiments during which they step through a series of frequencies. The MyoPacer allows pre-programming of multiple frequencies to allow fast and easy switching between predetermined frequencies.

The MyoPacer EP

The MyoPacer EP adds cardiac electrophysiology functionality. It was created to give researchers the capability of delivering pre-designed stimulation sequences for obtaining restitution curves and doing arrhythmia and defibrillation studies. It is based on the original MyoPacer and retains all of the original functionality, but adds the ability to generate off beats, delays, and multiple frequency protocols. The MyoPacer EP is designed around the strategy of creating multi-phase protocols. Each protocol can have up to 5 phases. A phase can be defined either as a pulse train

or a delay. If it is defined as a pulse train, a period or frequency must be selected. Phases end either after a programmed time / # pulses, or when a manual or external TTL trigger is received. The end of a phase will immediately initiate the next phase or, if on the last phase, the return to the first phase.

As traditional electrophysiological researchers have used the terminology S1, S2... to describe the various phases, the MyoPacer EP will automatically display the appropriate label when looking at a phase.

Features

- Digital adjustment of:
  - Frequency (0.010-99Hz)
  - Pulse duration (0.4-24 msec)
  - Voltage (up to +/- 40 V and 240 mA)
- Bi-polar pulses
- Current up to 240 mA
- Short circuit and open circuit protection of electronics
- Digital inputs and outputs
- Programmable multi-step protocols

Hardware

External Hardware

User Interface

Menu choices and current parameters are displayed on a 20x4 character LCD screen. To permit one-handed adjustment, we used an Encoder (or dial) that can be turned as well as clicked. The encoder is directly next to the display. In general, turning it will perform a scroll function and clicking the dial will perform a select function. On the LCD display, the cursor indicates current position, and carets indicate that the menu continues beyond the display and continuing to turn the encoder will perform a scrolling function

High Voltage Section

The high voltage section of theMyoPacer EP consists of two 2 mm tip jacks. The black is connected to Earth Ground. The red is connected to the high voltage amp through a reed relay, to ensure complete open circuit between pulses. The amplifier provides an output of up to +/-40 V and up to 240 mA

Connectors

The MyoPacer EP is connected to the stimulation electrodes a cable with 2mm tip plugs on one end and two pin receptacles which fit .037/.047 in diam pins on the other.

Pacing Indicators

The LED above the high voltage outputs will turn red to indicate a high voltage pulse. It will remain on for the duration of the pulse.

Digital Inputs

Advance In

This is only used in Sequence mode. The rising edge of a TTL pulse at the 'Advance In' input will initiate the next step if the trigger option has been selected in the Sequence Edit menu. The output pulse train will finish with the current pulse before switching steps. This means that the first pulse of the next step will not actually be synchronized with the Advance In input, but will occur at the end of the period of the previous pulse. The LED marked "Advance In" on the front panel will light during TTL high.

Pulse In

This is only used in TTL Lock mode. The rising edge of a TTL pulse at the "Pulse In" input will trigger a high voltage output pulse if the device is in TTL Lock mode. The duration of the pulse remains programmable and is independent of the duration of the TTL input. Due to the settling time required by the closing of the relays, the pulse on the first well will occur 450 (+/-10)us after the rising edge of the TTL input. The LED marked "Pulse In" will light during TTL high.

TTL Outputs

Gate Out

The "Gate Out" output will emit a pulse train of TTL pulses exactly reflecting the high voltage output pulse train. The rising edge of the TTL pulse corresponds with the beginning of the high voltage pulse and the falling edge corresponds to the end of the high voltage pulse. The LED above the High Voltage Outputs will light during TTL high.

Aux Out

The "Aux Out" output is only used in Sequence mode to indicate the beginning of a step and must be enabled in the sequence edit menu of the desired step. In the case of a pulse train, the TTL pulse will occur in sync with the first pulse of the well the gate is locked to. In the case of a delay, the pulse will go high at the beginning of the delay, and remain high until the delay step has ended. The LED next to the BNC will light during TTL high.

USB

NOT CURRENTLY FUNCTIONAL: Will allow the user to program and save protocols from a computer interface.

Power on/off switch

Power to the MyoPacer EP is turned on and off with the switch located on the upper right half of the front panel. Flipping the switch to the 'on' position will cause the switch to light, and, after about 1 second, the LCD display will light up.

Power inlet with fuse

The MyoPacer EP has a Universal Wide Range Input power supply, with UL, CSA, TUV, and CE mark approval. This means it can be used with power grid voltages ranging from 85 to 265 V AC. A compartment in the power entry module hold one active 1.6 Amp/250V, 5x20mm slow blow fuse and one spare.

Internal Hardware

Pulse Train Control

The MyoPacer EP uses micro-controllers to process the interface and control the pulse train. Variables that are programmed are saved in non-volatile memory for quick and easy start up. Reed relays ensure an open circuit between pulses.

Trouble-Shooting

Please let me know if you have had problems so I can continue to improve the device. Also feel free to contact me if the following suggestions don't fix the problem.

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Always unplug device before opening box!

No Power

Make sure the power cord is plugged in firmly and connected to an active outlet. Unplug and check fuse. If necessary, replace with a active 1.6 Amp/250V, 5x20mm slow blow fuse .

Always unplug device before opening box!

Other odd behavior

Probably reflects a software bug. Powering off and on will likely help. If not, try selecting Re-Initialize on the second line of the main menu. This will restore all values to factory defaults. They can then be reset.

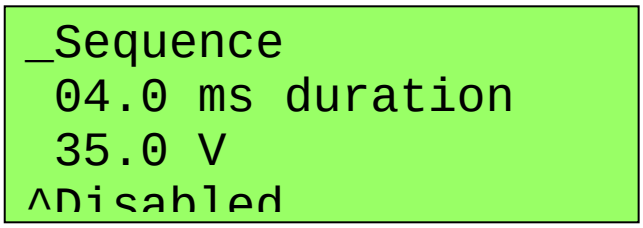
Software

Controlling the Pulse Train

Line 1: Manual Control

In future versions of code this line will offer a choice of USB control.

Line 2: Mode of Operation



There are 4 different modes of operation.

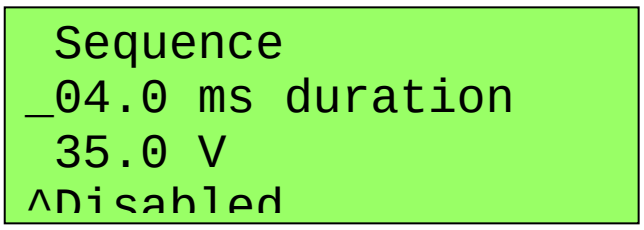
Basic This is the easiest mode in which to start pacing at a single frequency and make changes manually. Irregular pulses (see Irregular Pulses) are available in this mode.

Sequence The Sequence Mode should be selected if the user wishes to make programmable frequency changes, including single off-beats, delays, and rate changes. The advancement to the next step in the protocol can be triggered manually, from an external TTL signal, or from an internal timer. Irregular pulses (see Irregular Pulses) are also available in this mode.

TTL Lock In this mode, a TTL pulse on the "Pulse In" input will initiate a single high voltage pulse.

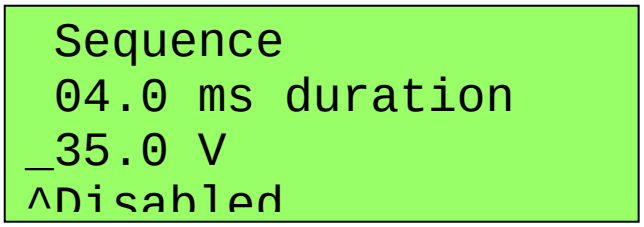
Re-Initialize This option will reload factory defaults of all values.

Line 3: Duration



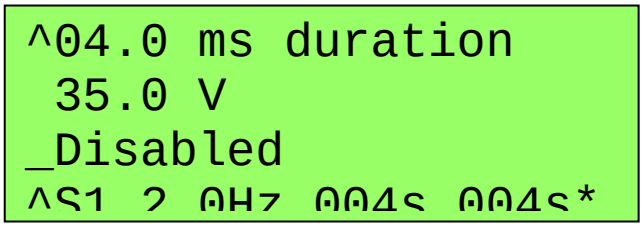
This adjusts the duration of each pulse between .4 and 24 msec. The output pulses will reflect the changes as the duration is tuned. To reduce electrolysis biproducts, the pulses that are emitted are all square bipolar pulses, so half of the chosen duration will be positive, half negative. To further reduce byproducts, the duration should be kept as short as possible. Standard values are in the 4-10 msec range. The upper range of the duration is recomputed each time to take current frequency and variability settings into account.

Line 4: Voltage



This adjusts the voltage of each pulse from 0-40V. To reduce electrolysis biproducts, the pulses that are emitted are all square bipolar pulses, so half of the chosen duration will be positive, half negative. There is a coarse adjust in 1 Volt increments and a fine adjust of .1 Volt increments. The output pulses will reflect the changes as the voltage is tuned.

Line 5: Enable/Disable Status



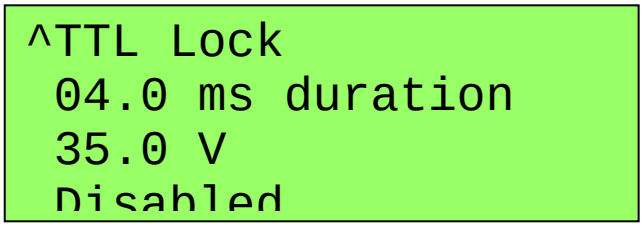
This setting initiates and ends the pulse trains. When pulses are Disabled, reed-relays in the high voltage path are opened, ensuring complete open circuit. These relays are also opened between pulses.

Frequency Control

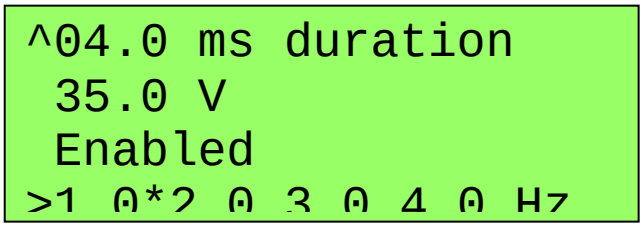
Lines 6-10 vary, depending on the mode of operation selected in line2.

TTL Lock

In this mode, all frequency control is external, so these lines are not present.

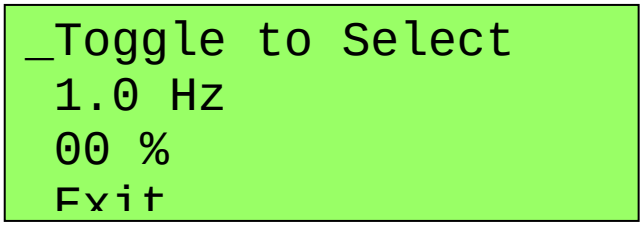


Basic



In Basic Mode, line 6 is the last line and consists of 4 frequencies in Hz written side by side. An asterisk is written after the frequency that is currently activated. When the knob is turned, the cursor will scroll horizontally through this line. Double click to activate the frequency, or single click to enter the Basic Edit Menu.

Basic Edit Menu



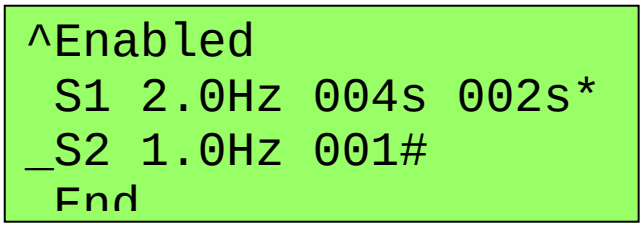
First Line Click to Activate this frequency and return to main menu.

Second Line Turn the knob to edit the frequency. There is a coarse and fine adjust. If the edited frequency is the one activated, the pulse train will reflect the changes as the frequency is tuned. The frequency has a range of .01 Hz to either 99 Hz, or the maximum possible given pulse duration and number of channels (max freq = channels * (duration +.5 ms)).

Third Line This line sets the maximum variability of the pulse train. For most purposes, this should be set to 00%. An upper limit may be enforced based on duration and frequency settings. For irregular pacing, please see the Irregular Pacing section.

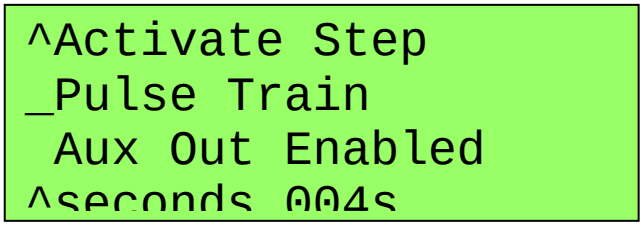
Forth Line Exit returns you to the main menu without activating the frequency

Sequence



Sequence mode offers the user the ability to program multistep (up to 5 steps) protocols. The main menu presents a summary of the protocol and displays the current timer. Scroll the cursor to the line to be edited and click to enter the Sequence Edit Menu. The example above shows a two step protocol. Pulses are output for 4 seconds at a rate of 2.0 Hz, a single 1.0 Hz pulse is output, and then the sequence ends, at which point the pulse train will loop back to the beginning. A continuous pulse train with an offbeat every 5 seconds is the result. The "002s" marker in the upper right reflects that there are 2 seconds still remaining in step S1. The asterisk at the end of S1 indicates that a TTL pulse will be output on the "Aux Out" BNC on the first pulse of the step.

Sequence Edit Menu



First Line Click to Activate this Step and return to main menu.

Second Line There are three step types that can be selected on this line.

- **Pulse Train** Indicates a series of High Voltage pulses of a specified frequency will be output for the duration of this step.
- **Delay** Indicates the High Voltage outputs will remain off for the duration of this step.
- **End** Indicates that the protocol has ended and a return to the beginning of step 1 will immediately follow.

Third Line

- **End** In the case that "End" was selected on the second line, the third line is the last line of the edit menu and simply Exits back to the main menu.

In all other cases

The "Aux Out" output is enabled or disabled on this line. If enabled, a TTL pulse will be output at the beginning of this step. In the case of a pulse train, the TTL pulse will occur in sync with the first pulse of the well the gate is locked to. In the case of a delay, the pulse will go high at the beginning of the delay, and remain high until the delay step has ended.

Forth Line

The method of determining the duration of the Step is set on this line. There are four options: number of minutes, number of seconds, number of pulses, and trigger.

Minutes and Seconds

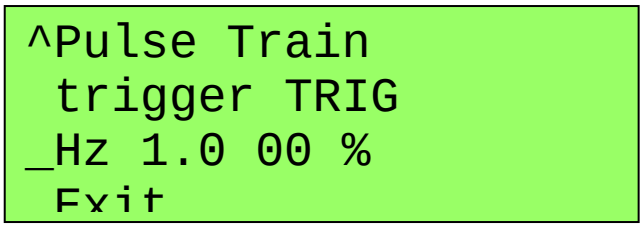
Set period of time on this line. An internal timer will count down the designated period of time. The output pulses train will finish with the current pulse before switching steps. (ie. If the frequency is 0.5 Hz and the timer is set for 3 seconds, the second pulse will take an additional second before the next step is initiated to make a total of 4 seconds. The timer does move to the next step and will begin counting down independently of when the frequency change has actually occurred.)

Pulses

Pulses is only an option if the step type is a pulse train. Set number of pulses on this line. In this case, the number of pulses are counted down. Note: The pulse occurs at the beginning of the step, followed by the rest of the period. This exact definition is important to the number of pulses that needs to be set and to the interaction with TTL IO. (Example 1: In the case of a protocol ending in a single off beat followed by a delay, two pulses actually have to be specified because the change of period occurs after the first pulse. In the case of the pulse followed by a delay, the period in effect just adds to the delay. Example 2: If the "Aux Out" is enabled in a single offbeat situation, it will fire on the pulse before the offbeat, not following.)

Trigger

This setting means that the step will continue until a TTL pulse is input to the "Advance In" BNC or until the user manually double clicks on a step line to use the "Activate Step" function. The output pulse train will finish with the current pulse before switching steps. This means that the first pulse of the next step will not actually be synchronized with the "Advance In" input, but will occur at the end of the period of the previous pulse. There are a few reasons to use this option. It allows an external source to trigger a step change. It also allows an easy way to manually control the switching of steps. By making the last step of a protocol a Delay with a triggered duration, it presents a method of going through the protocol only once, instead of looping back to the beginning.



Fifth Line

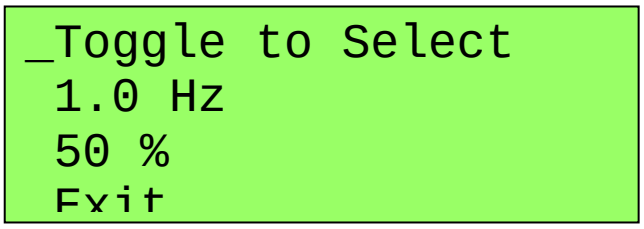
In the case of a Delay, the fifth line simply Exits back to the Main Menu. In the case of a Pulse Train, the fifth line is where the frequency is set. In a sequence the frequency may be set either by frequency or period by selecting either Hz or s. Then, turn the knob to edit the frequency/period. There is a coarse and fine adjust. If the edited frequency is the one activated, the pulse train will reflect the changes as the frequency is tuned. This line also sets the maximum variability of the pulse train. For most purposes, this should be set to 00%. Frequency and variability settings

may have an upper limit based on pulse duration. For irregular pacing, please see the Irregular Pacing section.

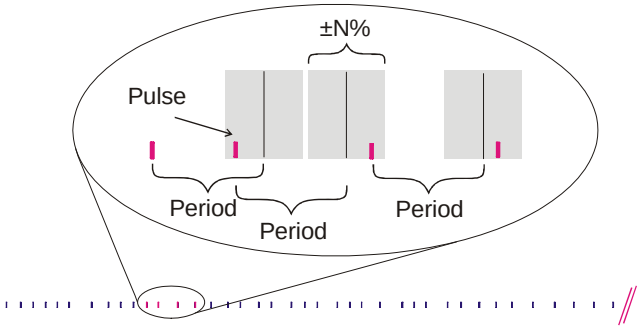
Sixth Line Exit returns you to the main menu without activating the frequency

Examples of Extra Features in the EP version

Irregular Pacing



The irregular pacing feature produces pseudo-random variation of a specified frequency within a definable percentage window and guarantees average effective rate over 100 pulses. For example, if a frequency of 1 Hz with 50% variability is selected, 100 pulses will have occurred after 100 seconds, but the period between any two pulses can be anything from 500 ms to 1500 ms. In actuality, the basis for the variability is a list of numbers from 1 to 100 that were randomly shuffled and saved. Therefore, the pulse train will repeat every 100 pulses, and the same settings will always produce the same pulse train.



Arrhythmia Protocols

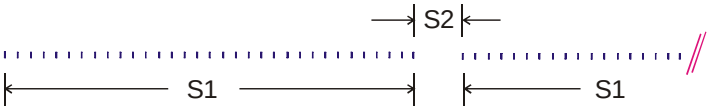
Insert an offbeat pulse at a fixed interval

```
^Enabled
 S1 2.0Hz 004s 002s
_S2 1.0Hz 001#
 End
```

Define step one of the sequence to be a pulse train with desired frequency and length.

Define step two of the sequence to be a pulse train with desired frequency and duration of one pulse.

Define step three of the sequence to be the End of Sequence.



Exercise Protocols

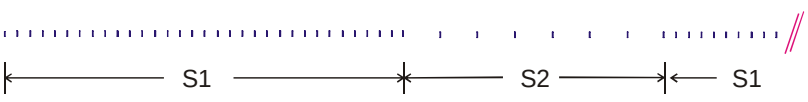
Run multiple pulse trains with individually programmable frequency and duration.

```
^Enabled
 S1 2.0Hz 060m
_S2 1.0Hz 660m 212m
 End of Sequence
```

Define step one of the sequence to be a pulse train with desired frequency and length.

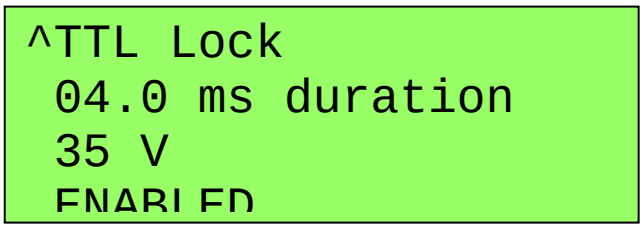
Define step two of the sequence to be a pulse train with desired frequency and length.

Define step three of the sequence to be the End of Sequence.



Examples Using the Digital Inputs and Outputs

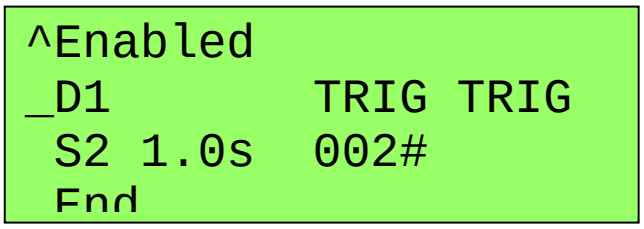
Pulse In: Synchronize pulses to an External TTL pulse train



Set the mode to TTL Lock and make sure the voltage is set and pulses are enabled.

Connect a TTL signal into the "Pulse In" BNC. The rising edge of a pulse will initiate the high voltage pulses. There is a 450 (+/-10) usec delay before output pulse is generated due to the closing and opening of the relays.

Advance In: Initiate an Event with an External TTL

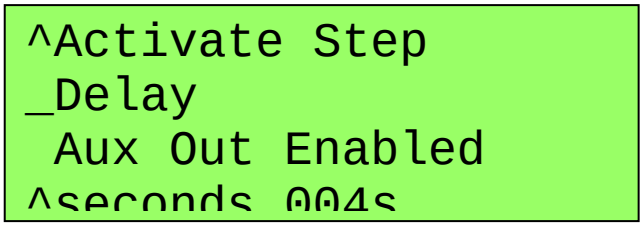


The settings shown above create a situation such that no high voltage output pulses will fire until the rising edge of a TTL signal has been sensed at the "Advance In" input. One pulse will be fired beginning 450 (+/-10) usec after this rising edge, and a second pulse will fire one second later. The pulse train will then remain disabled until another TTL signal is sensed.

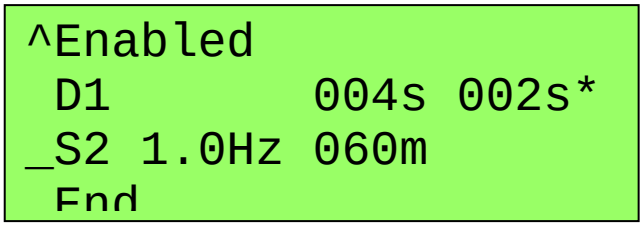
Gate Out: Place Marks in Data Acquisition

The Gate Out will output a TTL concurrent with each high voltage pulse (the rising edge is at the beginning of the pulse, and the falling edge is at the end of the pulse).

Aux Out: Control an External Piece of Hardware



Select “Aux Out Enabled” on the desired step.



The Aux Out feature will be marked with an asterisk on the main page.

A TTL signal will now be output on the “Aux Out” BNC once an hour. The rising edge will correspond to the beginning of the delay, and the falling edge to the end of the delay, in this case creating a 4 second pulse. If the Aux Out had been enabled on a Pulse Train step, the output pulse would be concurrent both in initiation and duration with the first pulse of the step.

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