PROGRAMMABLE INTRACRANIAL SELF-STIMULATION (ICSS) CURRENT STIMULATOR

PHM-15X

USER'S MANUAL

DOC-012
Rev. 2.3

Table of Contents

Notes

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Diagrams

CHAPTER 1 | INTRODUCTION

This manual covers the PHM-150B, PHM-150B/2, PHM-152 and PHM-152/2 Current Stimulators. These devices are all square wave microamp (μA) stimulators designed for intracranial self-stimulation (ICSS) in behavioral tests. Each stimulator card offers two isolated constant μA current outputs, Site 1 and Site 2, which can be individually turned ON or OFF. Programmed parameters are common to each output; in other words, both sites will output the same waveform.

When the stimulator outputs are turned OFF, an internal electrical shunt (short) is automatically placed across these Stim Out output connectors preventing any static electricity charge build up to the attached intracranial electrodes. The shunt is removed as soon as the stimulator output is turned ON again.

The PHM-150B and PHM-152 are functionally identical with the exception that the PHM-152 offers an isolated Current Monitor Output connector and Sensitivity Range switch. This output may be connected to a conventional or storage oscilloscope or analog-to-digital converter to validate programmed settings as well as to monitor actual subject stimulation. The Sensitivity Range switch allows the user to select between 20 μA/V and 100 μA/V at the Current Monitor output.

The stimulators are packaged in a self-contained enclosure, which includes a dual isolated +/- 45-volt power supply and serial communications interface. The +/- 45-volt supply can provide the higher voltages necessary to comply with higher electrode resistances. The maximum current possible is related to the impedance of the electrode. Programmable stimulator parameters include Pulse 1 amplitude and duration, Pulse delay duration, Pulse 2 amplitude and duration, Frequency, and Pulse train duration.

Multiple stimulators (up to 16) may be daisy chained to a single High Speed Serial Interface (Med Associates model number DIG-729USB). A software CD that allows for stimulator control via MED-PC® is included with the stimulator. Also, a sample MED-PC® program called STIMTEST.MPC is provided for reference. For more information regarding MED-PC®, refer to the MED-PC® User's Manual and/or MED-PC® Programmer's Manual.

CHAPTER 2 | HARDWARE CONFIGURATION

Setting the Node Values

Each stimulator card in a system must be set to a unique network node value. The node value can be any value from 1 to 16. **The last stimulator card in the network requires that the terminate switch to be placed in the ON position**. When multiple stimulator systems are ordered, Med Associates will configure the node values and apply stickers near the top of the front panels indicating their value. In the event that a node value must be changed, refer to Figure 2.1 below.

Switches 1 to 4 of SW1 are the Node Select switches and Switch 7 is the Terminate Switch, which ends the network communication chain (see Figure 2.1 below). Switches 5, 6 and 8 have no function.
Node settings for stimulator cards 1 to 16 are shown in Table 2.1 below.

Table 2.1 - Setting Node Values

Node	Node Select Switches							
	1	2	3	4	5	6	7	8
1	OFF	ON	ON	ON	N/A	N/A	*	N/A
2	ON	OFF	ON	ON	N/A	N/A	*	N/A
3	OFF	OFF	ON	ON	N/A	N/A	*	N/A
4	ON	ON	OFF	ON	N/A	N/A	*	N/A
5	OFF	ON	OFF	ON	N/A	N/A	*	N/A
6	ON	OFF	OFF	ON	N/A	N/A	*	N/A
7	OFF	OFF	OFF	ON	N/A	N/A	*	N/A
8	ON	ON	ON	OFF	N/A	N/A	*	N/A
9	OFF	ON	ON	OFF	N/A	N/A	*	N/A
10	ON	OFF	ON	OFF	N/A	N/A	*	N/A
11	OFF	OFF	ON	OFF	N/A	N/A	*	N/A
12	ON	ON	OFF	OFF	N/A	N/A	*	N/A
13	OFF	ON	OFF	OFF	N/A	N/A	*	N/A
14	ON	OFF	OFF	OFF	N/A	N/A	*	N/A
15	OFF	OFF	OFF	OFF	N/A	N/A	*	N/A
16	ON	ON	ON	ON	N/A	N/A	*	N/A

* The last stimulator card in the network requires the Terminate Switch to be in the ON position.

Figure 2.1 - SW1 Switches

Node Select Switches   Terminate Switch
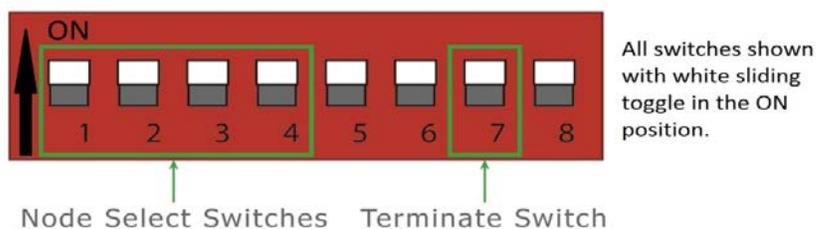
Programming in MedState Notation^{TM} is greatly simplified by using the Box or Chamber number as the Node value for each Stimulator (i.e. use Stimulator 1 in Box 1, Stimulator 2 in Box 2, Stimulator 3 in Box 3, etc.). By following this convention, the MedState Notation^{TM} special identifier BOX may be used as the Stimulator Node Value in the STIMON command so that a single procedure can be run for any test chamber. See Chapter 5| Controlling Stimulators in MED-PC®.

Hardware Guide

The PHM-15x system will include stimulator(s) and a PHM-152-COM Control Network card installed in an SG-510 Interface Cabinet as shown in Figure 2.2 below. The system utilizes a DIG-729USB Interface shown in Figure 2.3 below.

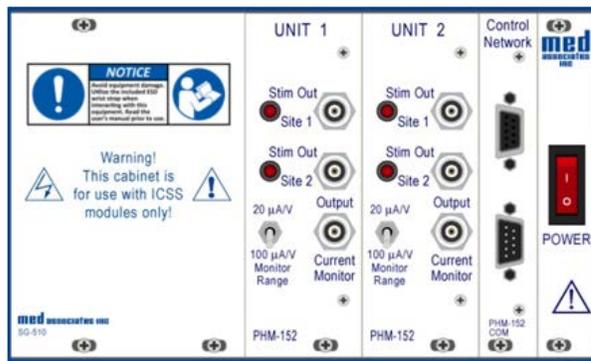*Figure 2.2 - SG-510 Cabinet with Stimulators and Control Network Card*

Figure 2.3 - DIG-729USB

Wiring Instructions

1. Using the included USB cable, connect the USB port on the computer to the USB port on the DIG-729USB as shown in Figure 2.4 below.

Figure 2.4 - Connect the Computer USB Port to the DIG-729USB

2. Using the SG-219ST (25') cable, connect the male DB-15 **INTERFACE** connector on the DIG-729USB to the female DB-9 connector on the Control Network (PHM-152 COM) card as shown in Figure 2.5 below.

Figure 2.5 - Connect the Control Network Card to the DIG-729USB
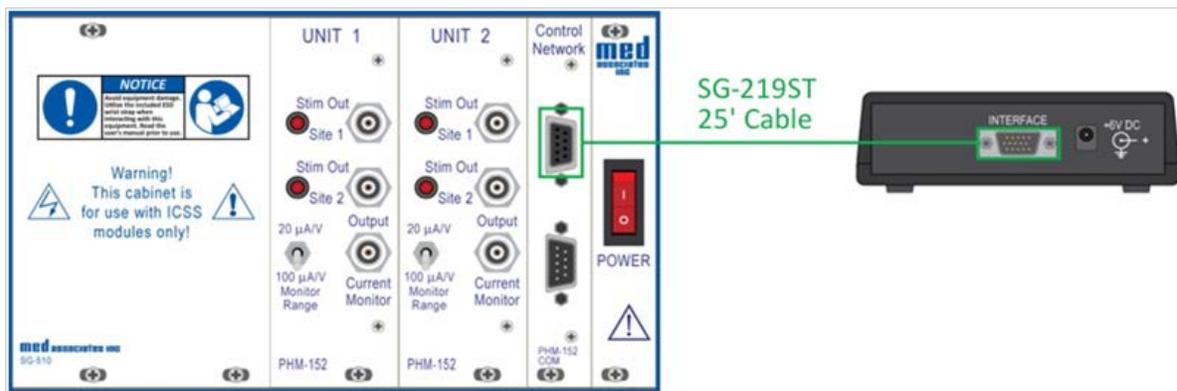
Connecting Additional Cabinets

To connect a second cabinet, use an SG-219G-10 (10') cable to connect the male DB-9 connector on the Control Network (PHM-152 COM) card in the first cabinet to the female DB-9 connector on the Control Network (PHM-152 COM) card in the second cabinet. Continue daisy-chaining cabinets in this fashion using the SG-219G-10 (10') cables until the last cabinet in the chain is reached as shown in Figure 2.6 below. Up to eight cabinets (16 stimulator cards) can be daisy chained to a single interface.

It is important that the cable lengths mentioned above are used. If the cable lengths are exceeded, equipment malfunction may occur.

Figure 2.6 - Daisy Chaining Cabinets
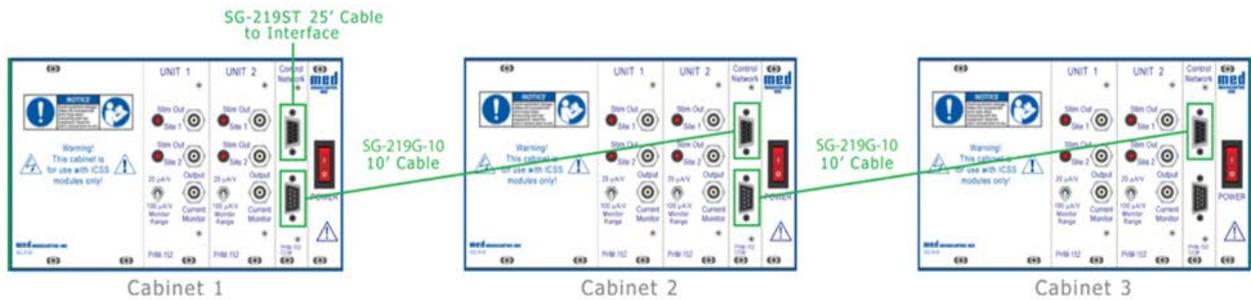
Stimulator Output

Output from the stimulator is via a standard BNC connector. Med Associates offers several cables and adapters:

Part Number	Description
PHM-155A	5' BNC to BNC Cable
PHM-155B	10' BNC to BNC Cable
PHM-155C	Female BNC to Female Banana Adapter

Viewing the Constant Current Output with an Oscilloscope

When attempting to use an oscilloscope to <u>temporarily</u> view the constant current (square wave) output waveform from either the Site 1 or Site 2 connectors for verification of proper operation, it is important to remember that the output is a current waveform, not voltage. To view the waveform from Site 1 for instance, a 'load' resistor must be placed across the Site 1 BNC connector. A 10K Ohm (1/2 Watt rated) substitution load resistor works well for this purpose. The voltage across the substitution load resistor will be related to the current delivered using the following equation:

*Current (microamps) = (Peak Voltage (Volts) / Resistance (Ohms))*1,000,000*

The Site 1 and Site 2 output waveforms can be viewed with an Input channel of the oscilloscope connected across the Stim Out load resistor. Med Associates can provide a 10K Ohm substitution resistor, Part # PHM-152SC-10K, that allows a convenient interconnection between the Stim Out BNC connector and the input channel BNC connector on the oscilloscope. If using a 2-channel oscilloscope,

Channel 2 can be connected – temporarily – across the substitution load resistor and Channel 1 can be connected to the Current Monitor Output – continuously – as described in the Viewing the Waveform Using the Current Monitor Output with an Oscilloscope on Page 6. In this way the user can confirm that both outputs – Stim and Current Monitor – are able to produce a proper output when the Stim Out Site is actively connected to the implant electrodes.

The connection of an oscilloscope to a Stim Out connector, as described above, should only be temporary. Continuous monitoring of the Stim Output pulse train with an oscilloscope or data acquisition equipment should be done via the Current Monitor Output.

Viewing the Waveform Using the Current Monitor Output with an Oscilloscope

The waveform produced at the Current Monitor Output connector is a voltage representation of the constant current flowing through the Site 1 or Site 2 load (either the test subject or the 10K Ohm substitution resistor discussed above). To view the waveform from the Current Monitor BNC connector, the load resistor (as described above) or a subject via electrodes must be connected to either the Site 1 or Site 2 connector.

Connect a Male-BNC to Male-BNC patch cable from the Current Monitor Output connector to a channel of an oscilloscope. This output is ground-referenced so the measurement does not need to be made differentially.

When the stimulator is producing a current waveform through the subject, the voltage representation of the current will be shown on the scope connected to the Current Monitor Output.

The Sensitivity Range switch allows the user to scale the monitor waveform to show either 20 µA/V (1 Volt of vertical deflection on the oscilloscope for each 20 µA of current flow) or 100 µA/V (1 Volt of vertical deflection on the oscilloscope for each 100 µA of current flow).

For instance, if the Sensitivity Range switch is set to the 20µA/V range and Current Monitor waveform shows a 5-Volt peak signal, then the peak current through the subject should be 100 µA.

CHAPTER 3 | SAFETY LOCK-OUT

Output Monitor Safety Lock-Out Protection

The signal output of each Stimulus generating channel is continuously monitored for harmful levels of DC current that could be passed to the stimulus site.

During the generation of an active pulse-train, each output channel will check for the presence of an all-negative or all positively oriented signals that could cause harm to the test animal. In the event of such an occurrence, the output amp of that channel will spontaneously shut down to a lock-out state.

The occurrence of an error event of this nature can be the result of a hardware failure caused by exposure to static electricity. Also, the state can be induced by incorrect pulse-train parameters that send an all-negative or all-positive going signal at the highest current settings.

The safety lock-out event is marked by both of the "Stim-out" site LEDs flashing simultaneously. When this happens, the main cabinet must be powered off to reboot the channel that is flashing the error. If the effected channel returns to the lock-out state after multiple attempts to reset, this is an indication that the channel has developed a hardware problem and must be returned for repair to Med Associates.

CHAPTER 4 | TESTING THE HARDWARE

Running MED Test

To run MED Test, click **Start** on the Windows® taskbar, then **All Programs > MED Associates > MED Test,** then the **MED Test** application. Once MED Test is open, select **Misc Modules > PHM-15X**. Refer to Figure 4.1 below.

Figure 4.1 - MED Test Menu
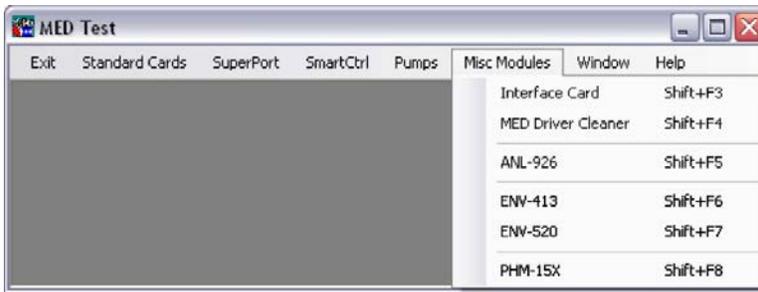
For testing PHM-150B or PHM-152 units, select **PHM-152** in the Mode Box. Refer to Figure 4.2 below.

Figure 4.2 - PHM-15X MED Test Form
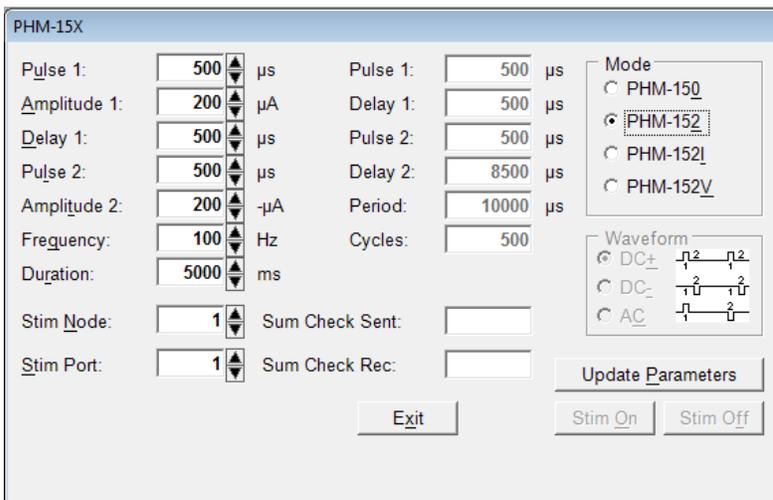
Nine Waveform Parameters governing the stimulus pulse train are displayed with default values on the left side of the screen as indicated.

Each parameter may be changed within the range specified in the Operating Parameters list given in Table 4.1 shown below. However, they are not mutually exclusive (i.e. Pulse and Delay values must be compatible with Duration and Frequency values.) Error messages will appear when incompatible values are selected.

Waveform Parameters

Figure 4.3 - Sample Waveform with Two Pulse Pairs in the Train
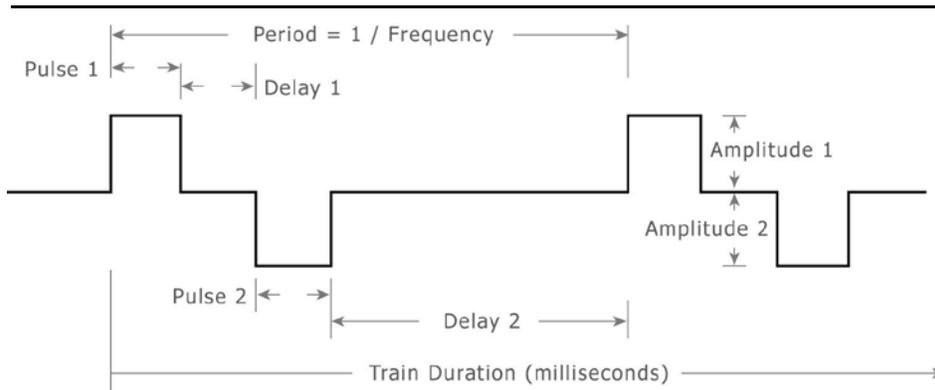
The waveform shown in Figure 4.3 above illustrates two complete cycles. Each cycle is made up of a positive pulse (Pulse 1), a delay (Delay 1), a negative pulse (Pulse 2) and a second delay (Delay 2). All these parameters including the period (time between cycles) and the total ON time duration of the waveform are user programmable. See Table 4.1 below for minimum and maximum operating parameters.

Table 4.1 - Operating Parameters

Description	Default Value	Allowable Range
Pulse 1	500 µs	60 – 32,000 µs
Amplitude 1	200 µA	0 – 1000 µA
Delay 1	500 µs	60 – 32,000 µs
Pulse 2	500 µs	60 – 32,000 µs
Amplitude 2	200 µA	0 – 1000 µA
Delay 2	(*1)	60 – 500,000 µs
Frequency	100 Hz	1 – 2000 Hz (*2)
Duration	5000 ms	(*3)
Stim Node	1	1 – 16 (*4)
Stim Port	1	1 – 2 (*4)

(*1) Not directly adjustable.
    Automatically set by the formula (1,000,000 / Frequency) – (Pulse 1 + Delay 1 + Pulse 2).
(*2) Limited by the Pulse and Delay parameters.
(*3) Must permit a minimum of one cycle.
(*4) Must correspond with module setting.

NOTE 4: Period is the total time for one cycle or the sum (Pulse 1 + Delay 1 + Pulse 2 + Delay 2).

Activating the Stimulator

Once the desired parameters have been selected, they must be sent to the Stimulator hardware. Click on the "Update Parameters" button to do this. A number should appear in the "Sum Check Sent" box. If communication was successful, the "Sum Check Rec" box should contain the same number. If the "Sum Check Rec" box contains a different number, check the hardware connections and node values (see, Setting the Node Values, page 2).

CHAPTER 5 | CONTROLLING STIMULATORS IN MED-PC®

The PHM-150B/PHM-152 is compatible with MED-PC® Version 2.08 and higher. Because the stimulator commands STIMULATE, STIMON, and STIMOFF are passed as a Pascal procedure they must be enclosed in tildes (~). Also note that the semicolon line terminator inside the tilde is required. This does not replace the semicolon used to separate multiple commands in the same statement as required in MedState Notation™.

STIMULATE

The STIMULATE command sets up all stimulus parameters for the stimulator and retains them until changed or power is turned OFF. It is not necessary to issue a STIMULATE command each time the stimulator is turned ON.

Syntax: ~Stimulate(MG, P1, P2, P3, P4, P5, P6, P7, P8);~

Where: MG = The MED-PC Global Parameter.

                P1 = The Stim Node value (1 to 16).

                P2 = The Width of Pulse 1 (60 to 32,000 μs).

                P3 = The Amplitude of Pulse 1 (1 to 1000 μA).

                P4 = The Delay between Pulse 1 & Pulse 2 (60 to 32,000 μs).

                P5 = The Width of Pulse 2 (60 to 32,000 μs).

                P6 = The Amplitude of Pulse 2 (1 to 1000 μA).

                P7 = Frequency (1 to 2000 Hz).

                P8 = Duration in milliseconds.

NOTE 5: P1 through P8 may be numbers, variables, or array variables. Array variables must be expressed using square brackets P[1], not the normal parenthesis ( ) used in MedState Notation™.

STIMON

The STIMON command selects the output port and turns the stimulator ON. Allow at least one clock tick between the STIMULATE command and the STIMON command (i.e. do not place both commands in the same State.)

Syntax: ~StimOn(MG, P1, P2);~

Where: MG = The MED-PC Global Parameter.

                      P1 = The Stim Node value (1 to 16).

                      P2 = The Stim Port to turn ON (1 or 2).

NOTE 6: P1 and P2 may be numbers, variables, or array variables. Array variables must be expressed using square brackets P[1], not the normal parenthesis ( ) used in MedState Notation[TM].

STIMOFF

STIMOFF is identical to STIMON and may be used to terminate a stimulus train prior to the duration setting. Since most pulse trains are quite short this command is seldom used. For extended periods of stimulation, however, it would be possible to set duration for some maximum value and actually turn stimulation ON and OFF with these two commands.

Syntax: ~StimOff(MG, P1, P2);~

Where: MG = The MED-PC Global Parameter.

                      P1 = The Stim Node value (1 to 16).

                      P2 = The Stim Port to turn OFF (1 or 2).

NOTE 7: P1 and P2 may be numbers, variables, or array variables. Array variables must be expressed using square brackets P[1], not the normal parenthesis ( ) used in MedState Notation[TM].

STIMTEST.MPC Sample MedState Notation[TM] Program

The STIMTEST.MPC sample protocol shown below is included on the PHM-15X installation disk.

```
\ Copyright (C) 2016 MED Associates, All rights reserved.

\ STIMTEST.MPC

\ This program demonstrates how to properly call the MED-PC commands that start
\ and stop the PHM-15X Stimulators.

\ When the program is loaded it will set up the default values and then wait for
\ the START command.

\ When the START command is received the program will send the selected values
\ down to the Stimulator.  The program will now wait for a response on either
\ the Left or Right Lever.

\ If a Left Lever response is received, then the program will turn on Port 1
\ (Stim Site 1) on the stimulator at the selected values.

\ If a Right Lever response is received, then the program will turn on Port 2
\ (Stim Site 2) on the stimulator at the selected values.

\ A K1 pulse will turn off the Stimulator and exit the program.

\ Stimulate - Sets up the stimulation parameters for the stimulator.

\ StimOn    - This command selects the output port and turns the stimulator ON.
\             Allow at least one clock tick between the Stimulate command and
\             the StimOn command (i.e. do not place both commands in the same
\             State.)

\ StimOff   - Used to stop a stimulation prior to the end of the pre-established
\             duration setting.

\ MG  - This is the MED-PC Global Pointer.  It allows the PHM-15X to pass back
\       information about any errors that might have occured.

\ BOX - This parameter specifies which PHM-15X the command is for.  When this
\       program is running in Box 1, then the BOX parameter will equal 1 and the
\       PHM-15X that is set to Node 1 will receive the command.  When this
\       program is running in Box 2, then the BOX parameter will equal 2 and the
\       PHM-15X that is set to Node 2 will receive the command, etc.  This
\       allows the same program to be run in multiple Boxes and control the
\       different Chambers.

\ Inputs
^LeftLever  = 1
^RightLever = 2

\ Outputs
^LeftLever  = 1
^RightLever = 2
^Pellet     = 3
^Dipper     = 3  \ If both Pellet and Dipper are ordered
                 \ It will be necessary to change one of these
^LeftLight  = 4
^RightLight = 5
^HouseLight = 7
^Pump       = 8
```

```
\ A() = Control Variables with Assigned Aliases as Defined
Var_Alias Pulse 1 Width (us)              = A(0)  \ Default = 500 us
Var_Alias Pulse 1 Amplitude (uA)          = A(1)  \ Default = 200 uA
Var_Alias Delay between Pulse 1 and 2 (us) = A(2)  \ Default = 500 us
Var_Alias Pulse 2 Width (us)              = A(3)  \ Default = 500 us
Var_Alias Pulse 2 Amplitude (uA)          = A(4)  \ Default = 200 uA
Var_Alias Frequency (Hz)                  = A(5)  \ Default = 100 Hz
Var_Alias Duration (ms)                   = A(6)  \ Default = 5000 ms


^Width1    = 0
^Amp1      = 1
^Delay     = 2
^Width2    = 3
^Amp2      = 4
^Frequency = 5
^Duration  = 6


\ List Working Variables Here
\  H = Stimulation Duration in MED Ticks


DIM A = 6

\ K-Pulses Used in this Program

\  K1 = Turn off the Stimulator and exit the program

\***************************************************
\               STIMTEST Schedule
\  S1 - Set Default Values
\       Pulse 1 Width             (500 us)
\       Pulse 1 Amplitude         (200 uA)
\       Delay between Pulse 1 and 2  (500 us)
\       Pulse 2 Width             (500 us)
\       Pulse 2 Amplitude         (200 uA)
\       Frequency                 (100 Hz)
\       Duration                  (5000 ms)
\***************************************************
S.S.1,
S1,
  0.01": SET A(^Width1)  = 500, A(^Amp1) = 200, A(^Delay)    = 500;
         SET A(^Width2)  = 500, A(^Amp2) = 200, A(^Frequency) = 100;
         SET A(^Duration) = 5000 ---> S2


S2,
  #START: ---> S3
  1": SHOW 1,Width 1,A(^Width1),   2,Amp 1,A(^Amp1), 3,Delay,A(^Delay);
      SHOW 4,Width 2,A(^Width2),   5,Amp 2,A(^Amp2), 6,Freq,A(^Frequency);
      SHOW 7,Duration,A(^Duration) ---> S2

S3,     \ Send the values to the Stimulator
  0.01": ~Stimulate(MG, BOX, A[0], A[1], A[2], A[3], A[4], A[5], A[6]);~;
         SET H = A(^Duration) / 1000 * 1" ---> S4

S4,     \ Wait for command to turn Stimulator On
  #R^LeftLever:  ~StimOn(MG, BOX, 1);~ ---> S5
  #R^RightLever: ~StimOn(MG, BOX, 2);~ ---> S5

S5,     \ Make sure the User can't send another StimOn
        \ command while the Stimulator is running.
  H#T: ---> S3
```

```
\**************************************************
\                    KILL ROUTINE
\**************************************************
S.S.2,
S1,
  #K1: ~StimOff(MG, BOX, 1);~ ---> S2

S2,
  0.01": ~StimOff(MG, BOX, 2);~ ---> STOPKILL


\**************************************************
\              SHOW PARAMETER VALUES
\**************************************************
S.S.3,
S1,
  #START: ---> S2

S2,
  1": SHOW 1,Width 1,A(^Width1),   2,Amp 1,A(^Amp1), 3,Delay,A(^Delay);
      SHOW 4,Width 2,A(^Width2),   5,Amp 2,A(^Amp2), 6,Freq,A(^Frequency);
      SHOW 7,Duration,A(^Duration) ---> S2
```

Examples Using STIMULATE and STIMON

The following examples are functionally equivalent. Brain stimulation reward is used as the reinforcement for an FR-10 schedule. 80 µA pulses, 200 µs in width (100µs delay) are delivered for 0.5 seconds at a frequency of 125 Hz.

Example A:

```
S.S.1,
S1,
  0.01": ~Stimulate(MG, BOX, 200, 80, 100, 200, 80, 125, 500);~ ---> S2

S2,
  10#R1: ~StimOn(MG, BOX, 1);~ ---> S2
```

Example B:

```
LIST P = 0, 200, 80, 100, 200, 80, 125, 500

S.S.1,
S1,
  0.01": SET P(0) = BOX;
         ~Stimulate(MG,P[0],P[1],P[2],P[3],P[4],P[5],P[6],P[7]);~ ---> S2
S2,
  10#R1: ~StimOn(MG, P[0], 1);~ ---> S2
```

APPENDIX A | SOFTWARE INSTALLATION

Programs written in MedState Notation™ must be translated and compiled before they can be executed in MED-PC®. A copy of the protocol is present in the MED-PC® installation directory, for example, "C:\MED-PC\MPC\", after the PHM-15X software installation program has been run.

To translate and compile the protocols, refer to the MED-PC® Programmer's Manual. On the computer running MED-PC®, open the Windows® Start menu, select **All Programs > MED Associates > MED-PC > Manuals** to access the Programmer's Manual.

APPENDIX B | CONTACT INFORMATION

Please contact Med Associates, Inc. for information regarding any of our products.

For Technical questions, email support@med-associates.com.

For Sales questions, email sales@med-associates.com.

Visit our website at www.med-associates.com.