Signal

Transcranial **M**agnetic **S**timulation
Toolbox
Configurations & Setup Guide

August 2019

The information in this guide was prepared and collated by the staff of Cambridge Electronic Design Limited with aid of the John Rothwell group of University College London.

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Table of Contents

TMS Toolbox – Configurations & Setup Guide

Introduction

This guide will aid you with setting up Transcranial Magnetic Stimulation (TMS) sampling configurations within Signal.

In the first section, we cover the general settings in each tab of the sampling configuration window. In the second section, we cover eight different experiment set ups that can be adapted further.

If you are new to the Signal software, it is recommended you follow all sections. If you are familiar with the software, using the check list and experiment configurations will be of most benefit.

The Signal help text covers all aspects of operating and making the most of the software. It can be accessed in the program at any point by pressing F1.

Sampling Configuration files

The accompanying toolbox contains basic sampling configurations for each of the experiments in this guide, which can be loaded in Signal to edit as required.

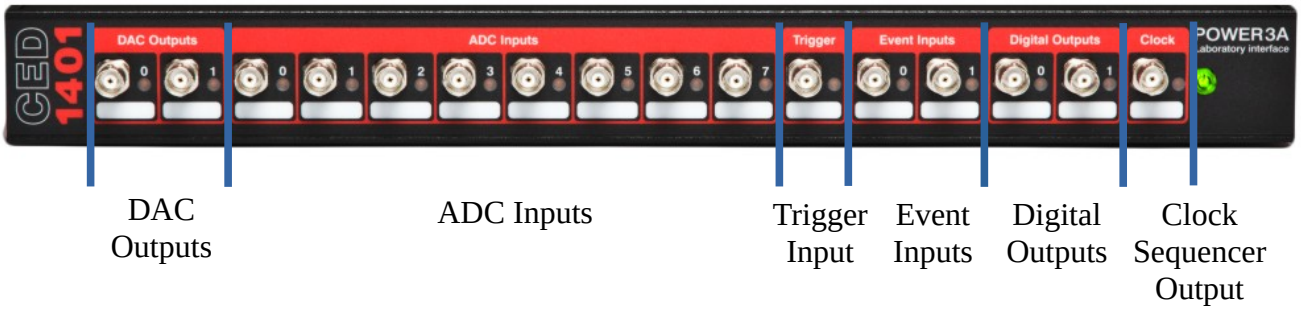
Safety Notice

Transcranial magnetic stimulators are devices capable of causing serious harm and should only be used by qualified practitioners. Before using a stimulator you should read the user's manual produced by the manufacturer paying particular attention to the warnings and precautions section.

Signal carries out checks to ensure the stimulator hardware is operating correctly. If communications between Signal and the stimulator break down then Signal will disarm the stimulator and terminate sampling. After sending new settings to a stimulator, Signal will read back the settings and disarm the stimulator and terminate sampling if the settings do not match. The status information obtained from the stimulator is also monitored and if there appears to be any problems Signal will again disarm the stimulator and terminate sampling.

It is your responsibility to ensure that Signal's control of a stimulator is set up in an appropriate and safe fashion for the intended use and to verify that it is operating correctly.

1401 Connections



DAC Outputs These ports produce varying voltage outputs in the +/- 5 volt or +/- 10 volt range. DAC outputs are typically used for controlling electrical stimulators.

ADC Inputs The ADC ports are your main waveform sampling input ports. These are enabled in the sampling configuration.

Trigger Input Connect the TMS device trigger output BNC to this port.

Event Inputs These inputs are used to record events, but are not used in this guide.

Digital Outputs The digital outputs produce TTL signals defined in the pulse outputs, and are used to trigger TMS stimulators. Connect the TMS device trigger input to the correct port in use.

Clock Sequencer Output This port produces an output when the 1401 sequencer is in use; we do not make use of this port in this guide.

Magnetic stimulator connectors For some stimulators a control cable is required, while other stimulators are controlled using a standard USB connection. Specifically when connecting to a dual-stimulator, an extra BNC cable is likely required to trigger the second unit.

Sampling Configuration settings

This section covers the settings available to you in the sampling configuration, and which ones you will need to consider when setting up Signal with a TMS experiment.

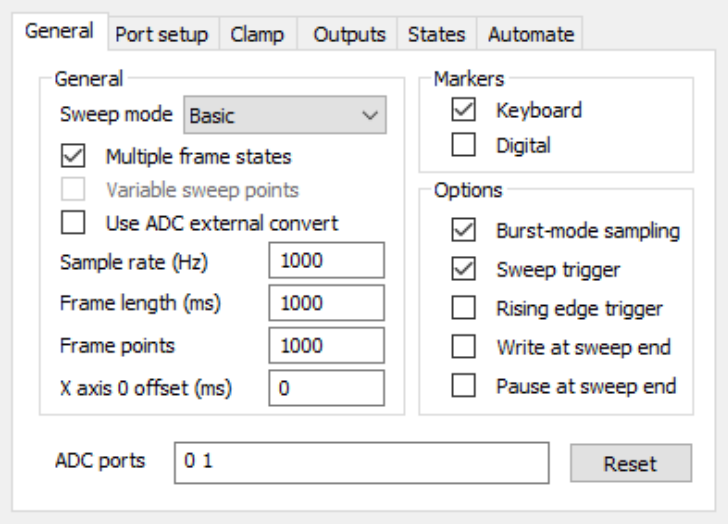
To start a fresh configuration open the sampling configuration from the 'Sampling' drop-down menu, or click the  icon in the toolbar.

To load a TMS sampling configuration from the toolbox into Signal, double click the configuration in windows explorer. Alternatively open the 'File' drop-down menu in Signal, select 'Load configuration...' and open the desired configuration.

Time units

It is possible within Signal to specify the time units as either seconds, milliseconds or microseconds. This guide is written in milliseconds, however to change your own settings at any point simply navigate to the preferences dialog:
Edit menu → Edit preferences... → Display tab → Show time as (drop-down box)

General Tab



Multiple frame states

Enable this option to allow Signal to control TMS devices. It is not required if the device will be controlled manually.

Multiple states can be used to do many things, but by far the most common and relevant to TMS studies is to allow a sampling configuration to produce individual sets of output pulses (one per state) and to automatically switch between these outputs during sampling. These states can therefore be used to define differing pulse intensities, times of pulses, number of pulses and so on.

Sample rate (Hz)

Sample rates are around 5000 Hz for TMS protocols, however this may be altered depending on your requirements.

Frame length

Frames are typically 200-500 ms to allow for full capture of responses, however can be shortened or lengthened as needed.

X axis 0 offset Zero on the x-axis appears at the start of the frame as default, or at the trigger time for peri-triggered sampling mode. This position can be moved by entering a non-zero value in this field. For instance, setting zero to the same time as the point of test stimulus may help better visualise the time of the response after the stimulus. This does not alter how and when sampling takes place, only how the times are displayed on the x-axis.

For the experiments detailed in this guide, the x axis is typically offset to the time of the "test" pulse delivery.

Markers Both markers are optional, but when using short frame lengths they are unlikely to be of use.

Burst-mode sampling With burst-mode sampling enabled, all of the ADC ports are sampled in a burst as close together as possible, with the interval between bursts being 1/Sample rate. With burst-mode sampling disabled the ADC ports will be sampled at exact known equal intervals, with the interval between samples being 1/(Sample rate * number of ADC ports).

Sampling in burst-mode ensures that the interval between samples on adjacent ADC ports is kept to a minimum and often allows the required ADC sampling rate to be achieved precisely. The intervals between samples on different channels will depend on the 1401 type, but can be as low as a couple of µs.

Whether to use burst-mode sampling depends on how you plan to handle your data. If you are recording multiple channels and plan to perform inter-channel calculations, it may be preferable to use burst-mode sampling to reduce the interval between channel sampling. If however it is more important to have equal intervals between all samples then equal interval sampling may be preferable.

Sweep trigger With sweep triggers enabled, a sampling sweep will not occur until a trigger has been detected, the sampling configuration determines what a trigger is. With sweep triggers disabled, a sampling sweep starts immediately. For the purposes of this guide, this option will only be enabled when using peri-triggered mode.

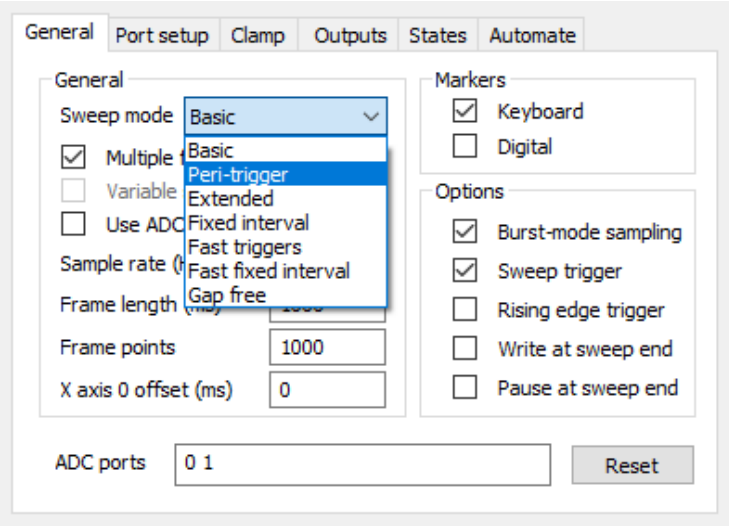
Rising edge trigger Sweep triggers normally occur on the falling edge of the supplied TTL pulse on the 1401 Trigger input, checking this option makes them occur on the rising edge. This option is not utilised in this guide.

Write at sweep end With this option enabled, sample sweeps are automatically written to disk when the sweep finishes. However this will occur as soon as sampling has started, any sweeps of the idle state will also be written to disk and are unlikely to have any useful data. For the experiments in this guide, it is better to leave this option disabled and instead use the 'Turn on writing with cycling' option in the states tab.

Pause at sweep end When enabled this pauses sampling at the end of each sweep. The experiments in this guide do not make use of this option, which is primarily used if the operator needs to make adjustments to their settings in-between sweeps.

ADC ports This box enables the ADC inputs for sampling.

Sweep mode



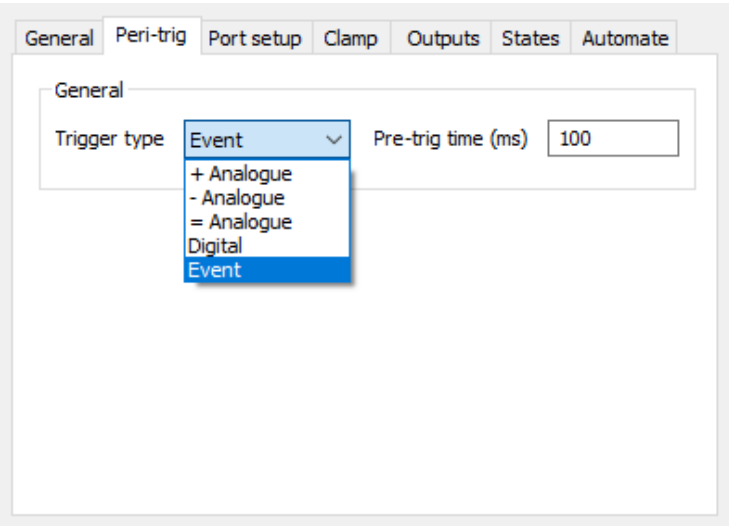
There are several choices for sweep mode, the two used most often for TMS studies are peri-trigger and fixed interval.

For a full breakdown of the other sweep modes, please refer to the help text within Signal.

Peri-trigger This mode allows a variety of triggers including threshold crossings on a sampled waveform channel, and allows data to be collected before the sweep trigger. Selecting this mode will make the peri-trig tab visible, and automatically enable burst-mode sampling.

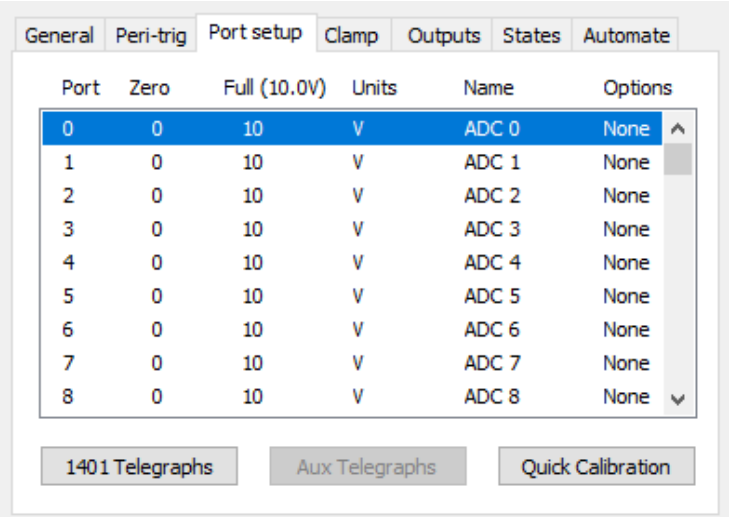
Fixed interval In this mode sweeps are internally timed so that they occur at the specified interval; a random variation in the interval can optionally be provided. Both the sweep interval and random variation are set using the pulses dialog used to define the outputs (see Pulse Configuration). External sweep triggers are not used in this mode.

Peri-trigger Tab



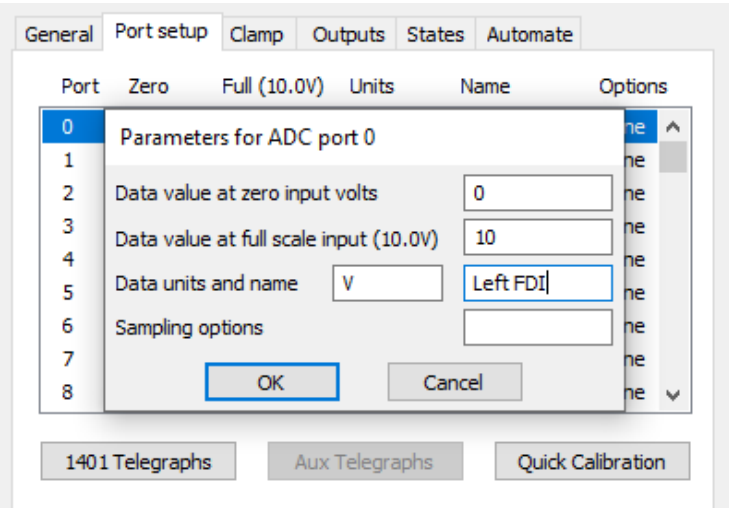
Trigger type For TMS studies the trigger type will be Event, where the trigger is via a TTL pulse. A sampling sweep is triggered when a TTL pulse is detected on the Trigger BNC input of the 1401 front panel. Ensure you specify an appropriate pre-trig time for data sampled before the trigger. The trigger output of the TMS device should be connected to the trigger input of the 1401 front panel.

Port setup Tab



The Port Setup tab defines settings for the individual ADC ports used to sample waveform channels. You can set the scaling and units for data sampled from a port, the name of the data channel created by sampling and specify online processing options for data from a port.

Double click a port to open its settings.

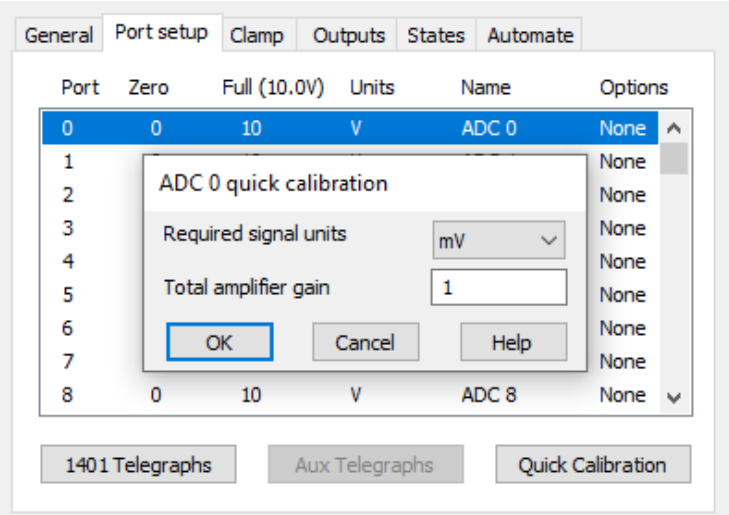


Here in the port parameters you can alter:
- Data value at zero input volts
- Data value at full scale input (5.0 or 10.0V)
- Data units and name

It is also possible to use the quick calibration to set up your ports.

Port setup Tab

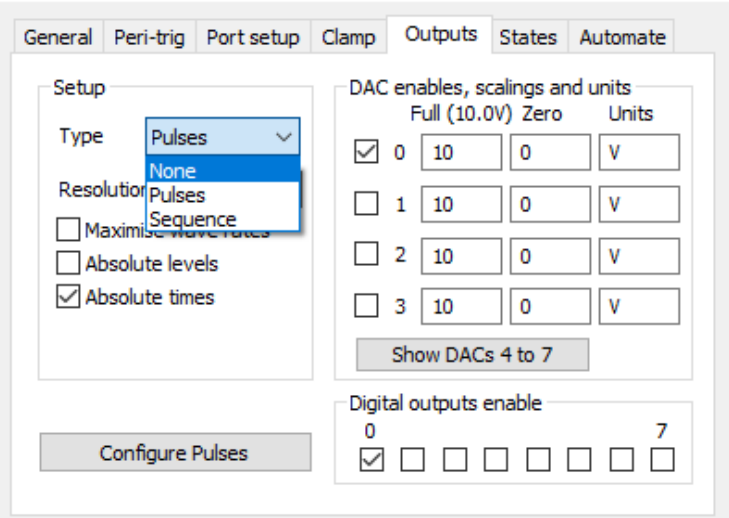
Quick Calibration



To calibrate, select the units from kV, Volt, mV, µV and nV, and enter the total amplifier gain applied to the signal between the preparation and the 1401 ADC input. If you have a headstage or other pre-amplifier don't forget to include that in your calculation of the gain. For TMS studies you will most likely be working in the mV or µV range.

For more information on conditioner setup, please see the Signal help text and your manufacturers manual.

Outputs Tab



The output tab is where the pulse configuration can be accessed. The pulses can be controlled by the sequencer language or interactively using a dialog. For more details of configuring pulses see the next section. This guide will focus on the graphical sequencer (Type: Pulses). Selecting pulse outputs reveals several controls to configure the pulses.

For more information about sequence files please see the help text within Signal.

Resolution This sets the timing resolution of the output pulses in milliseconds or microseconds. Setting this to 0.1ms is sufficient for most TMS configurations.

Maximise wave rates Enabling this allows the 1401 to prioritise output rates of arbitrary waveforms. However the experiment configurations in this toolbox rely on TTL pulses from the digital outputs, so this option is left disabled.

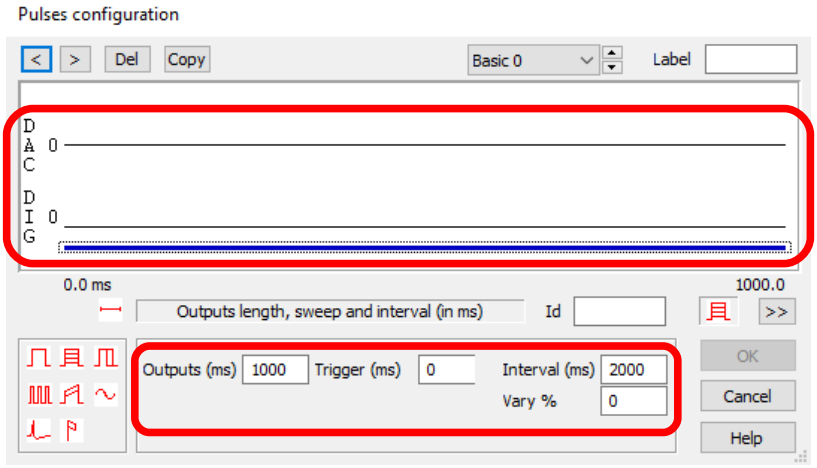
Absolute levels With absolute levels enabled, the pulse amplitude sets the level directly. Disabled, the pulse amplitude is added to the level before the pulse to get the actual pulse level. Again, for TMS studies this is not relevant when solely using TTL pulses.

Absolute times With this enabled, the pulse dialog allows you to enter the pulse start time directly. This is useful to have enabled for paired pulses and is made use of in the experiment examples.

DAC enables, scaling and units This section contains controls for each DAC. These control if a DAC is available for use and set the scaling and units with which DAC values are written.

Digital outputs enable This section contains check boxes to enable and disable the individual digital outputs for use. Select the check box to use a particular digital output port.

Pulse Configuration Selecting 'Pulses' in the drop down menu next to 'Type' and clicking the 'Configure Pulses' button will open a new window.

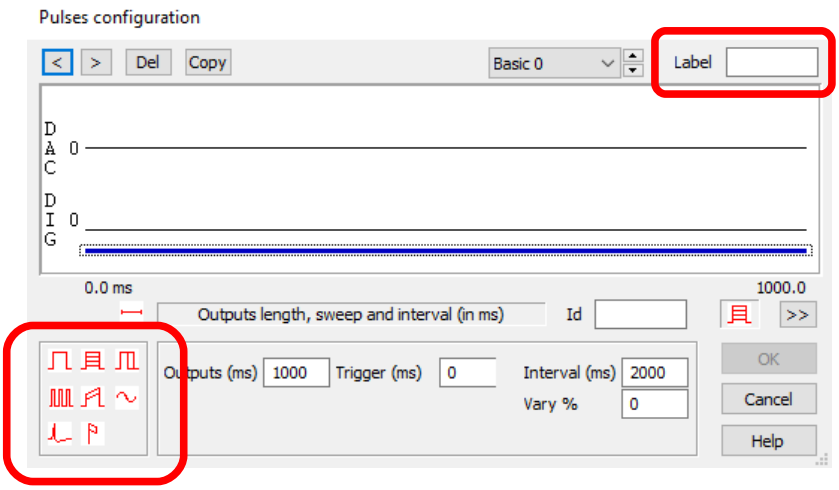


The pulse configuration window contains a white space for DAC and digital outputs enabled in the outputs tab.

If your sweep mode (general tab) is set to 'Fixed Interval', clicking the blue line at the bottom of the output space allows you to alter the output length, the trigger length, the interval between sweeps, and a % variation on this interval.

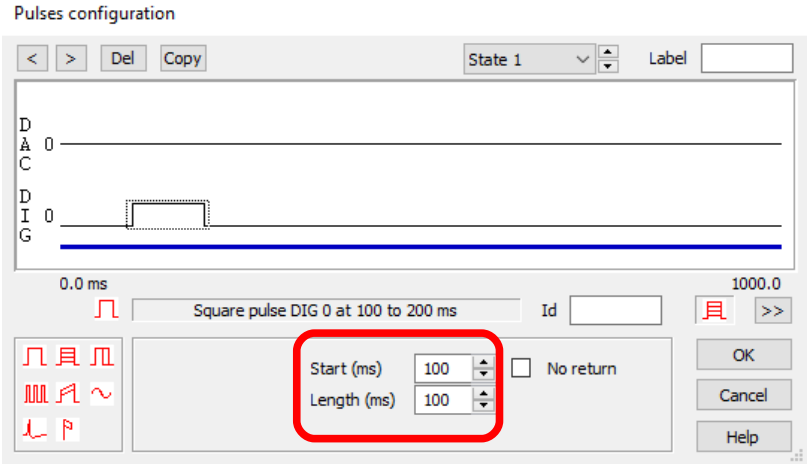
Intervals between sweeps are typically 4-6 seconds in TMS studies, to allow the TMS device to change intensity and recharge between sweeps. Please note that intervals are between the start times of sweeps and not between the end of one and start of the next. Your interval length should always be longer than your outputs length.

Pulse configuration
(continued)



Also within the Pulses configuration window, a label can be added to each state.

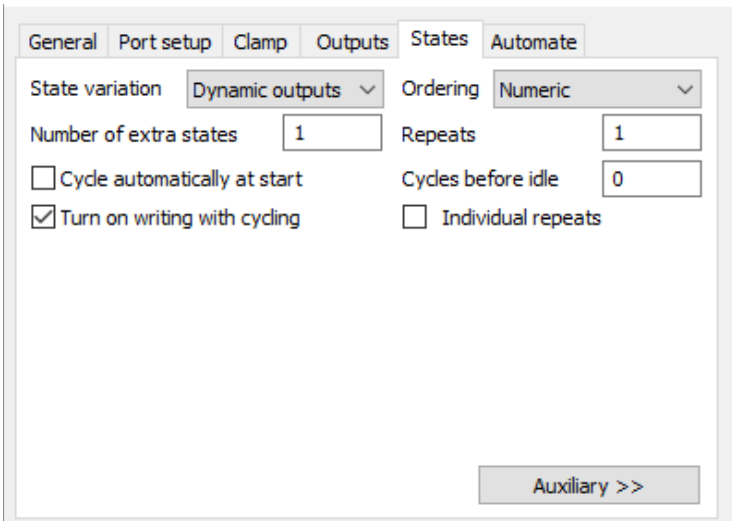
To add a pulse to an output channel, click a pulse symbol in the bottom left corner and drag it to the desired output.



Once in place, clicking on the pulse allows you to alter its parameters.

For a more detailed explanation on the types of pulses and the graphical sequencer in general, please see the Signal help text.

States Tab



The states tab is used to stipulate the number of extra states and how they are sequenced. Signal makes use of the extra states and reserves state zero as a background or idle state.

State Variation Only dynamic outputs will be covered in this document, as it is the most multi-purpose and useful for TMS studies. For full details of the different state variations please refer to the Signal help text.

Number of extra states This is equivalent to the number of different stimulator configurations within the experiment. We use separate states for differing pulse timings or intensities.

Repeats The number of times a sweep is repeated for each state. Most of the experiments in this toolbox use between 10-20 repeats.

Cycles before idle This defines how many sequence cycles before Signal moves to idling in state 0. Typically only 1 cycle is required. Set this to 0 if you require state sequencing to repeat indefinitely until manually stopped.

Turn on writing with cycling This will typically be enabled for TMS studies, and starts data being written to disk once 'Cycle' has been selected during sampling (i.e. moves on from state 0).

Cycle automatically at start Enabling this option will start Signal cycling between states immediately from the start of sampling. This is useful if you are ready to begin stimulus output immediately, however if you need to first observe your baseline measurements in state 0 it is best to leave this disabled.

Ordering The ordering can make a large difference to your experiment, and can be set to one of these options: numeric, random, semi-random, random repeated, protocol.

Protocol is not used in this guides experiments, to find out more about its operation please see the Signal help text.

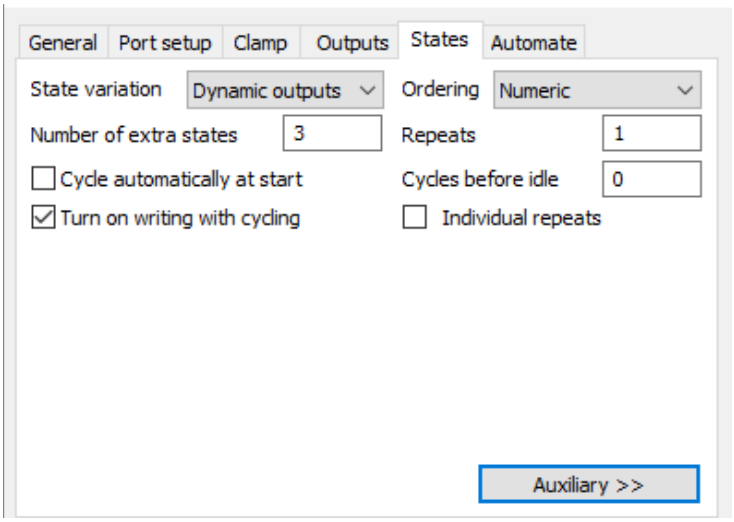
Numeric States are cycled in numerical order with each state being used the number of times set by Repeats. Once the last state has finished, one sequencing cycle has been completed. For example, a configuration with 3 states and 4 repeats on numeric sequencing would give:
1 1 1 1 2 2 2 2 3 3 3 3

Random In this mode, one cycle of the sequencing uses each state the number of times specified by Repeats, but the order of the states within a cycle is randomised. For example, a configuration with 3 states and 4 repeats on random sequencing may give:
2 3 2 1 3 3 1 2 1 3 1 2

Semi- Random This is an alternative method of randomisation where the states are not all randomised across a cycle but instead randomised within one set of states. For example, a configuration utilising 3 states and 4 repeats, the first 3 frames will always include one of each state in random order, as will the next 3 and so forth. One cycle of sequencing still consists of (states * repeats) = # frames. Therefore you may get:
2 1 3 3 1 2 3 2 1 1 2 3

Random Repeated In this method of randomisation only the order of the states is randomised, but each state repeats the number of times set by repeats. For example, in a configuration utilising 3 states and 4 repeats the first 4 frames will always be the same state as will the next 4, but the state numbers for each set of four will be random. Therefore this may give:
2 2 2 2 3 3 3 3 1 1 1 1

Auxiliary device addition

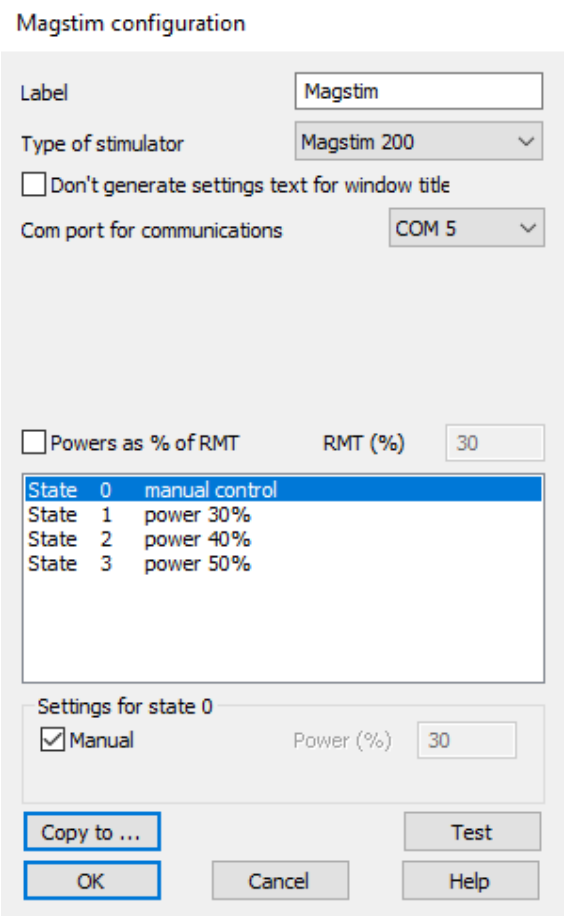


To add a TMS stimulator as an auxiliary device to Signal, click the 'Auxiliary' button and mouse over the menu to add device.

Other auxiliary devices you may wish to add, such as the Digitimer DS8R constant current stimulator, can also be added via this menu.

Please note, version 7 of Signal added the support for multiple auxiliary device addition. Previous versions only allow a single device to be controlled.

TMS setup
(Magstim e.g.)



Label The label can be changed to better denote or distinguish devices.

Type of stimulator Select the type of stimulator (available options will change depending on type selected).

Com port Select the com port the stimulator is connected to.

Powers as % of RMT Express the power output as either a percentage of maximum stimulator output (MSO) or as a percentage of resting motor threshold (RMT) by enabling "Powers as % of RMT" (added in Signal version 7.02). Enter the RMT (%) value in the corresponding box. This option can also be used to express the power as a percentage of active motor threshold (AMT).

Please note however, Signal will not allow you to define a power output % above the MSO. For example, if AMT is defined as 80% of MSO, the maximum percentage of AMT that can be used in the state settings is 125% (equivalent to 100% MSO).

Comply with all safety notices *given by your magnetic stimulators manual to ensure the well-being of the subject and operator during use.*

States list Clicking on a state shows options for that state.

Copy to … Clicking this allows you to copy settings from one particular state to another or more.

Test Once you have selected the correct com port, clicking this will check the connection between Signal and the TMS device.

State 0 State 0 is the idle state and should remain as manually controlled.

For further information on sampling configuration settings please see the help text which can be opened at any point in Signal.

For information on connecting your TMS device to a 1401, please refer to the beginning of this guide, the Signal help text for supported devices and the TMS device's manual.

***NOTE**:* The configurations included in this toolbox are set up with most TMS devices in mind, however special consideration should be taken to ensure they work with your own device.

Specifically with relation to DuoMAG stimulators, there are several caveats which cause these configurations to fail. Please see the end of this document for further detail and examples.

Check List

This checklist provides a quick reference for settings to be considered.

General Tab

Sweep mode	Peri-trigger or Fixed Interval
Multiple frame states	Enabled
Sample Rate (Hz)	5000
Frame length (ms)	200-500
X-axis offset (ms)	100 *(time of test pulse trigger)*
Burst-mode sampling	Optional
Sweep trigger	Enabled

Peri-trig Tab *(if enabled)*

Trigger type	Event
Pre-trig time (ms)	100

Port setup Tab

Ports	Ensure ADC ports in use are appropriately calibrated and labelled
Conditioner	Ensure any conditioner in use is calculated for and added to preferences window *(if applicable)*

Output Tab

DAC ports	Ensure DAC ports in use are appropriately calibrated
Digital outputs	Ensure Digital outputs in use are enabled
Type	Pulses
Resolution (ms)	0.1

States Tab

State variation	Dynamic outputs
Number of extra states	Same number as differing stimulator conditions
Ordering	Experiment dependent (Random or Semi-Random most often)
Repeats	Experiment dependent (usually between 10-20)
Turn on writing with cycling	Enabled

TMS setup

	Ensure device is added as auxiliary device
Type/Model:	Select the type and model of TMS device
Com port:	Select com port for TMS device
State 0:	Manual controlled (idle state)
States 1+:	Remaining states – ensure correct power output (either as % of MSO or RMT %) is correctly defined
	Please check any remaining settings specific for TMS device in use

Pulses configuration *(Output Tab)*

Frame Length	Ensure pulses for each state are set up as required
Interval	Frame length typically 200-500 ms
Test Pulse Time	Interval between sweeps generally 4000-6000 ms (variation ± 10%)
	The TMS test pulse is usually delivered at 100 ms into the frame

Experiment Configurations

Single pulse, single coil configurations

Any TMS stimulator capable of being controlled by Signal through the auxiliary device menu is compatible with the majority of single-pulse configurations, and are relatively easy to setup.

You will need to consider the number of states required, or if manual triggering is required. If operating the stimulator through Signal then the timing and length of pulses need to be configured via the pulse configuration, and the stimulus intensity configured through the TMS configuration in the axillary menu.

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1. Finding the motor threshold

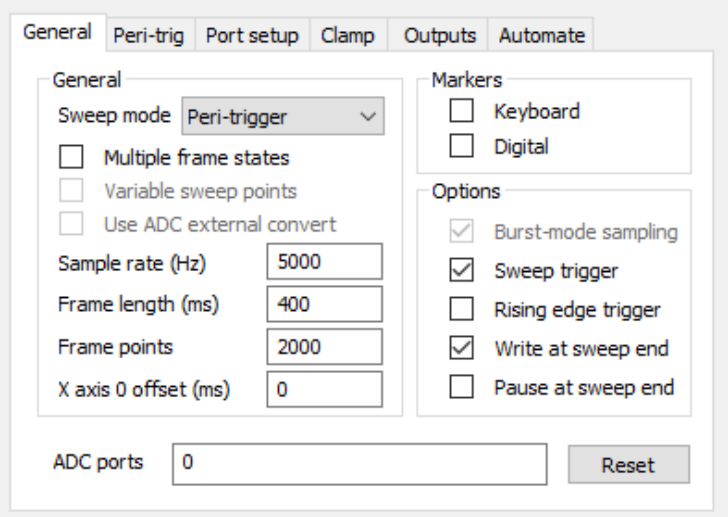
This is the most common TMS procedure and occurs once researchers have found the "hotspot", i.e. the spot on the head that gives the greatest response size for a given stimulus intensity. Traditionally the motor threshold has been defined as the stimulus intensity which gives a response above a pre-defined amplitude, e.g. 0.05 mV or 1 mV, on 50% of stimuli, e.g. 5/10 trials. Essentially you are looking for a stimulus intensity that gives an average response of a particular pre-defined size by increasing or decreasing the intensity until the criteria are met. This is most often done at rest (resting motor threshold – RMT), but can also be done during weak muscle contraction (active motor threshold – AMT).

Design

One way to achieve this is by manually plotting response amplitudes and counting how many of them exceed the threshold amplitude and adjusting the stimulus intensity manually until the criteria are reached.

Other methods are available to determine the motor threshold of a subject. One method is known as maximum-likelihood parameter estimation by sequential testing (ML-PEST). This is an adaptive threshold-hunting algorithm which has been incorporated into several researcher-built tools. These tools display the next stimulus intensity to apply to the subject and use an S-shaped metric function to model the probability of evoking an MEP at a given stimulus intensity. As such it can be incredibly useful for determining motor thresholds. CED is working to make these tools available for use in Signal, please look forward to it in a future update.

General Tab



Sweep mode Peri-trigger

Multiple frame states As the TMS device will be controlled manually in this configuration, this option is not enabled

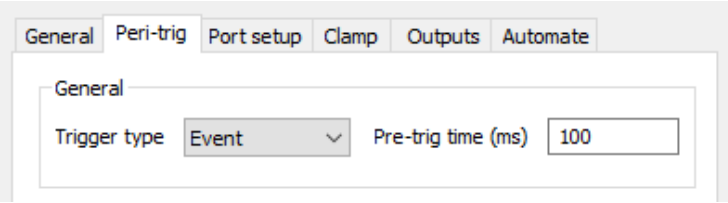
Please note Signal will not keep the stimulator active when not in this mode. See the information section at the end of this document for more detail.

Sweep trigger Enabled

Write at sweep end Optional

ADC ports Enable all ports in use

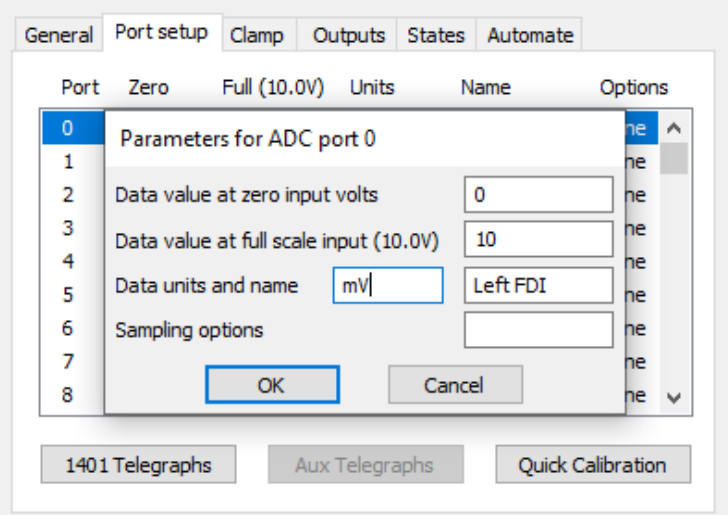
Peri-trig Tab



Trigger type Event

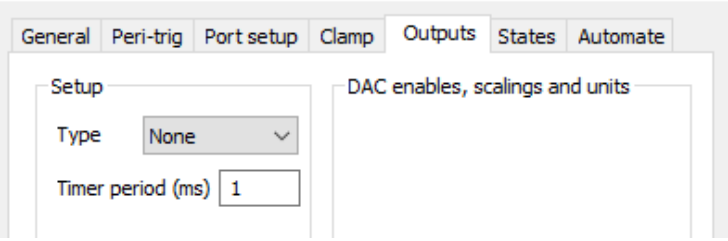
Pre-trig time (ms) 100

Port Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab



No outputs, the TMS device is being controlled manually

States Tab With the option 'Multiple Frame States' disabled, the states tab will not be available to view

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

2. TMS input-output / stimulus response (SR) curve

This procedure plots a range of stimulus intensities against the amplitude of the response to generate an input-output curve.

Design

Single TMS pulses are given at a set range of stimulus intensities, with the order of stimulus intensities randomised across trials.

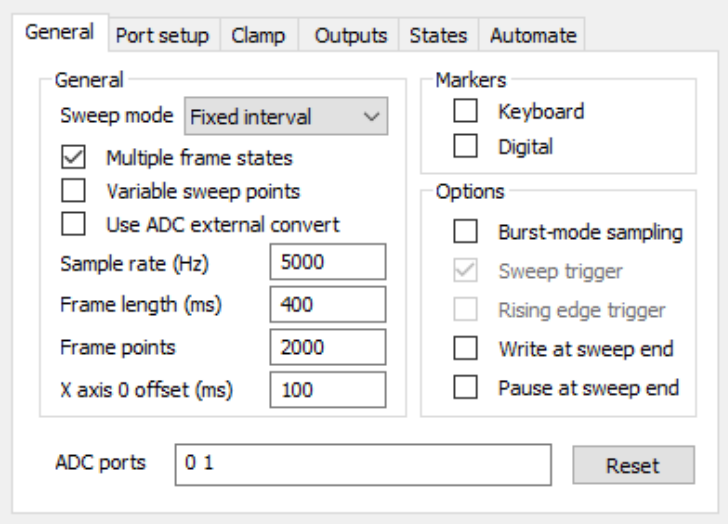
Each state in this experiment refers to a different stimulus intensity, so the number of different stimulus intensity inputs (and therefore states) must be determined first.

Stimulus Intensity

The stimulus intensity is usually expressed as either MSO% or MT%. For example, steps of 5-10% of MSO beginning from a pre-defined level, or 100-180% of RMT in 10% increments. Increments between stimulus intensity steps should be kept constant, e.g. 5 or 10%.

The stimulation power % to begin and end on will need to be decided, bearing in mind the safety and comfort of the subject.

General Tab



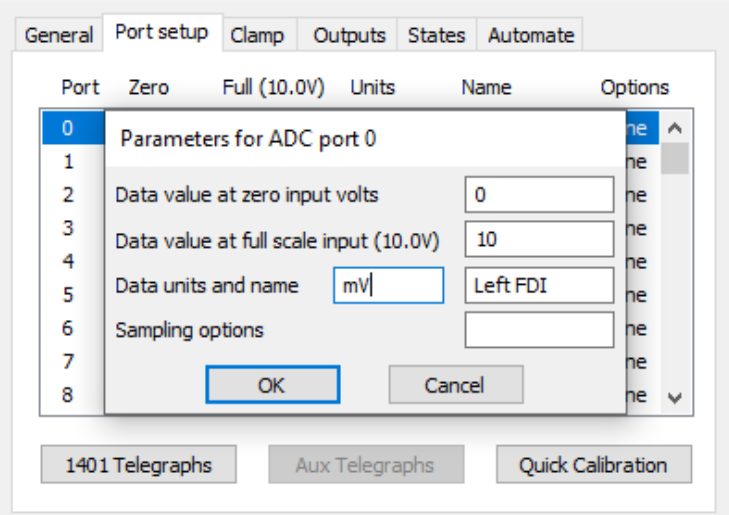
Sweep mode Fixed interval

Multiple frame states Enabled

Burst Mode sampling Optional

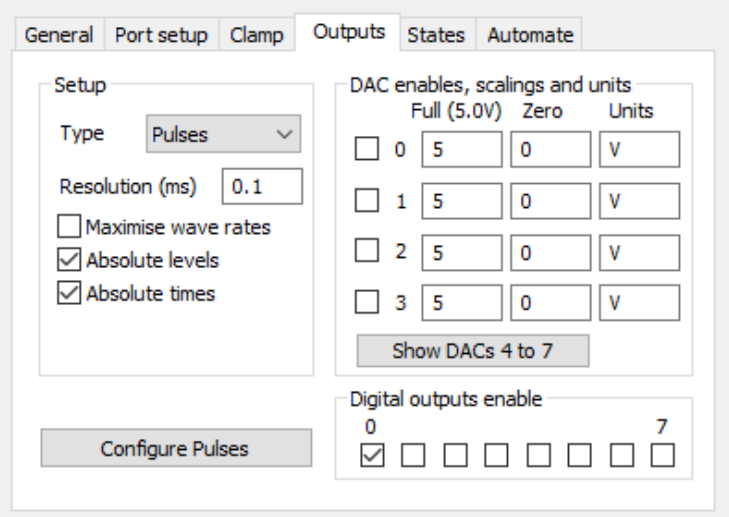
ADC ports Enable all ports in use

Port Tab



Edit as required, account for any amplifier gain in your settings

Output Tab

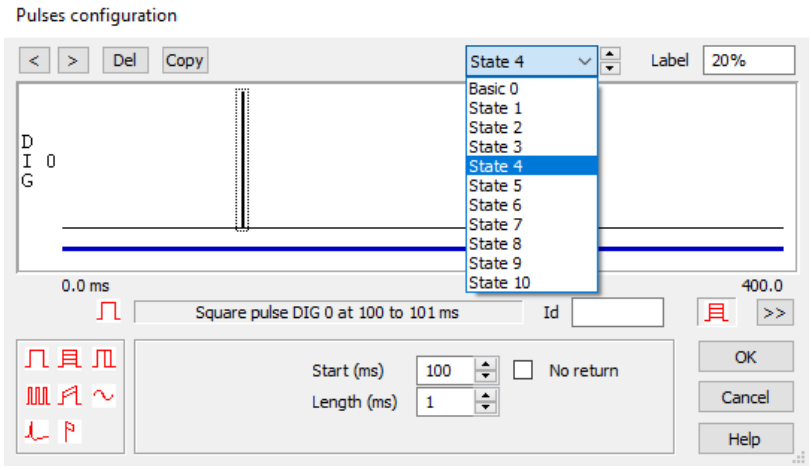


Type Pulses

Resolution (ms) 0.1

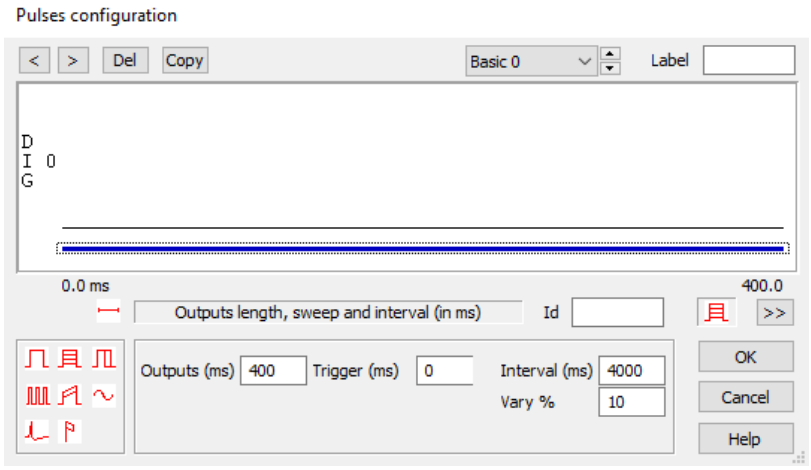
Digital outputs Enable 0 by ticking its corresponding box

Pulse Configuration



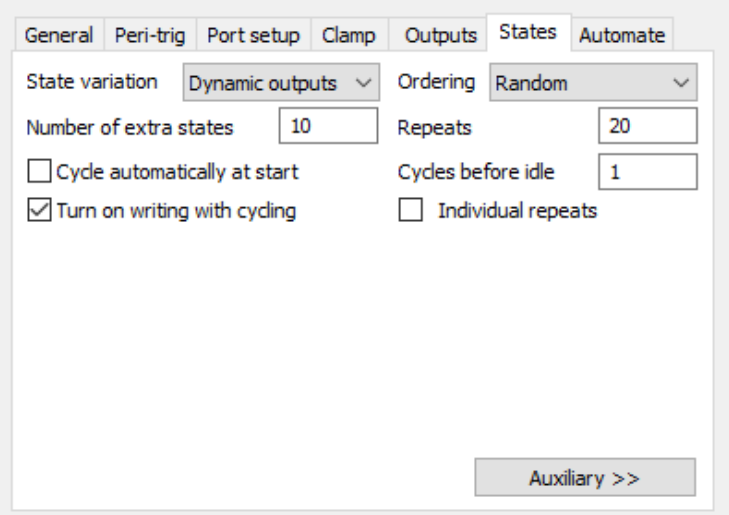
A single pulse has been generated for digital output 0 at 100ms into the sweep for 1ms for each state except state 0 (the idle state)

Edit the labels for each state, corresponding to the power output % of the TMS device



Each state has an output length of 400ms, an interval between sweeps of 4000ms and a variance of 10%

States Tab



Extra states 10 – one for each stimulus intensity (edit as required)

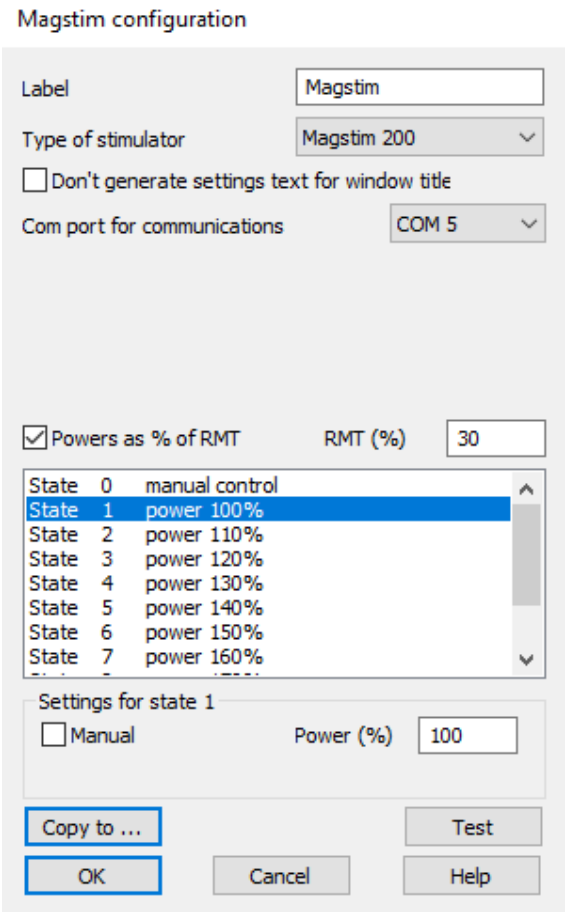
Repeats 10 – 20 (edit as required)

Cycles before idle 1

Ordering Either Random or Semi-Random

Turn on writing with cycling Enabled

TMS Device



Label Enter desired name for TMS device

Type of stimulator Select correct model
This experiment requires only a single stimulator output.

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box
If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

State 1 – 10 These states are set up with different intensities and only the single pulse. The intensities will need to be altered based on working in RMT% or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

CED Fast MEP Script

Programmers at CED have developed a script for Signal in conjunction with Michael Grey (University of East Anglia at time of publication) and Mark van der Ruit (Delft University at time of publication) which can be used to obtain input-output curves.

This script is freely available from our website under Downloads → Scripts → Signal Scripts → Control → "Quickly acquire a TMS stimulus response curve"
http://ced.co.uk/downloads/scriptsigcont

This script is an online script for quickly (under 5 minutes) acquiring data for a stimulus response curve in a Transcranial Magnetic Stimulation procedure using stimulators from Magstim, MagVenture, DuoMag and Mag&More. Presently the script is written to work with Magstim stimulators, however the script can be adapted to work with available stimulators from the above mentioned. Presently the script works with both Magstim Rapid and 200 devices.

Knowledge of the participants' resting motor threshold is advantageous. We advise that you run a hot-spotting procedure first.

There are two parts to the script, the first is to test the connection with the stimulator. The second part is where data collected from the participant is recorded to a data file and plotted to an XY view with the option of plotting a Boltzmann sigmoid curve after at least 10 data points have been recorded.

The script allows the user to set a stimulus intensity range using maximum and minimum input fields in a dialog, from which a random intensity will be drawn from the range and used for stimulating the participants' brain.

Please read the user guide before attempting to use the script, and we suggest you trial the script before using with a subject to ensure it is fully operational with your equipment setup.

Experiment Configurations

Protocols involving paired TMS pulses through a single TMS coil

Paired pulses, single coil configurations

These types of configurations are generally suited to dual stimulators in order to obtain the shortest inter-pulse intervals. The configurations are relatively easy to setup, similar to single pulse configurations except that it is generally preferred to setup individual pulses on separate digital outputs (e.g. conditioning pulse on digital output 0, test pulse on digital output 1) and route them to the separate stimulators for independent triggering and firing.

It should be noted however that stimulators of different types or makes are not compatible. For example a single coil could not be connected to a MagStim 200 and a DeyMed DuoMAG MP.

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3. Short-interval intracortical inhibition (SICI)

This protocol involves alternating between a single "test" pulse to generate the baseline or test response, and closely-spaced pairs of pulses where the first pulse is used to condition the response to the test pulse (hence "conditioning" pulse).

Design

This experiment has two designs, either the interval between the pulse pair is altered randomly across trials (interval SICI) or the interval between the pulse pair is fixed and the intensity of the conditioning pulse is altered (SICI input-output curve).

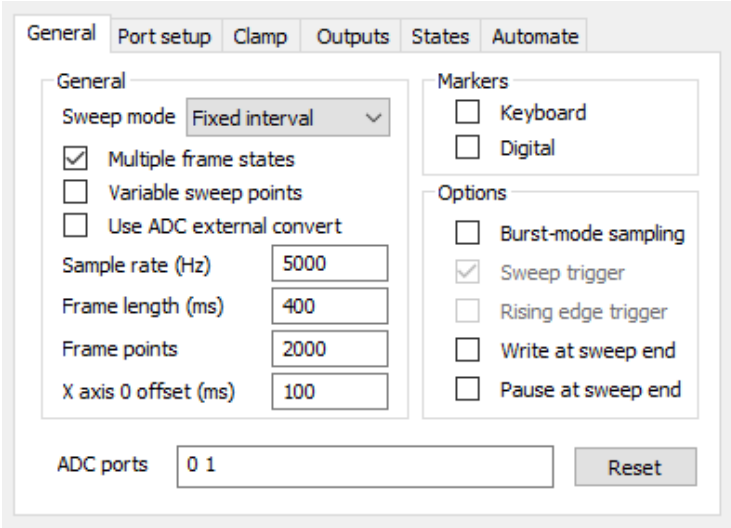
The pulses are delivered individually to two stimulators, with both firing through a single coil (e.g. Magstim BiStim or Deymed dual DuoMAG MP).

Interval SICI

This experiment design utilises 2-6 states. The first state contains the test pulse alone, with the remaining states utilising pairs of pulses where the conditioning pulse precedes the test pulse by 1-5 ms in 1 ms intervals, and the intensity of each pulse remains fixed.

The conditioning pulses intensity is usually lower than the test pulse and expressed relative to a pre-determined threshold (e.g. 50-80% of RMT).

General Tab



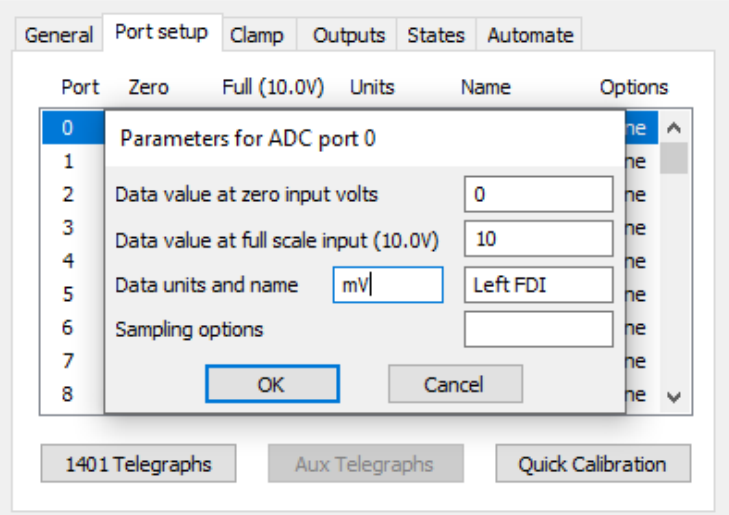
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

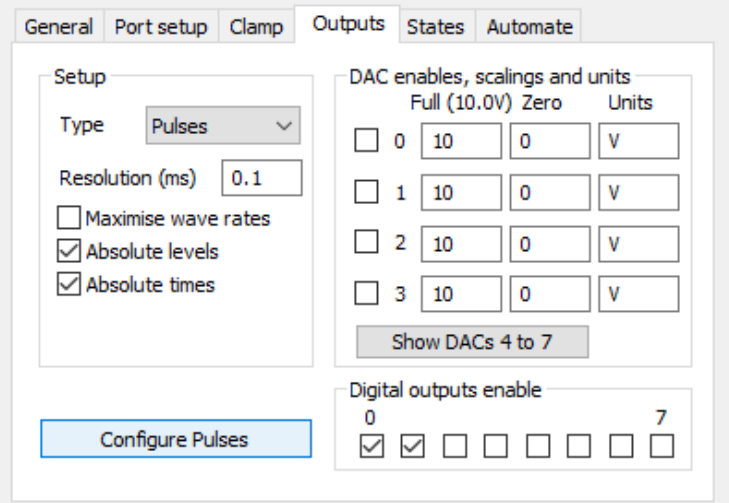
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

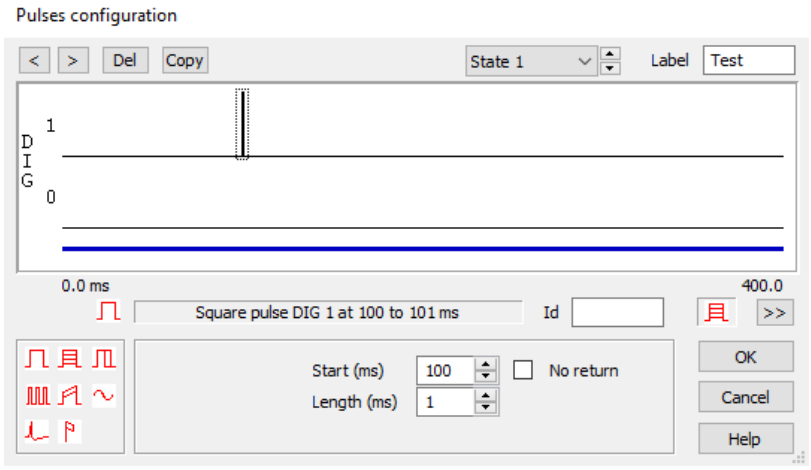


Type Pulses

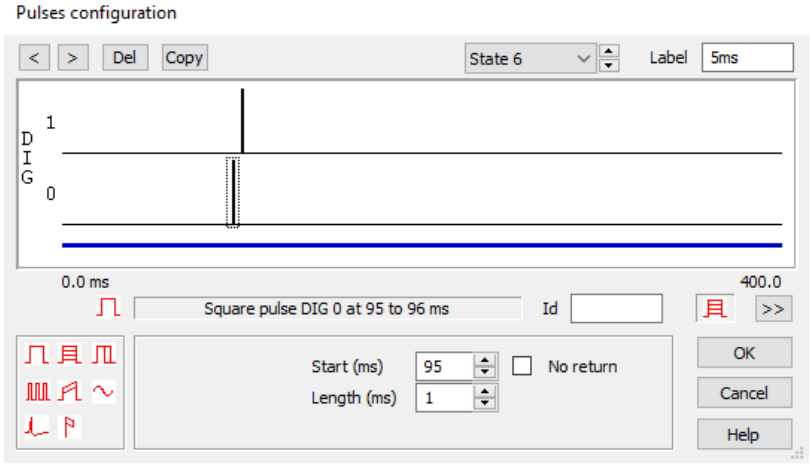
Resolution (ms) 0.1

Digital outputs Enable 0 and 1

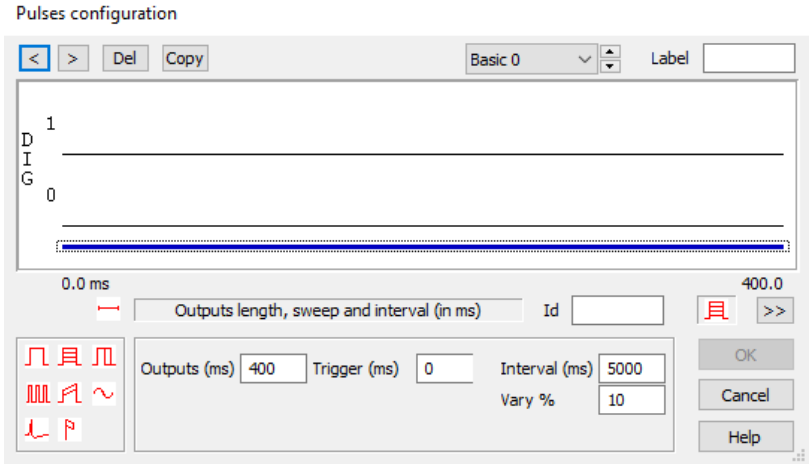
Pulses Configuration



State 1 contains only the test pulse on digital output 1, starting at 100ms into the sweep for 1ms

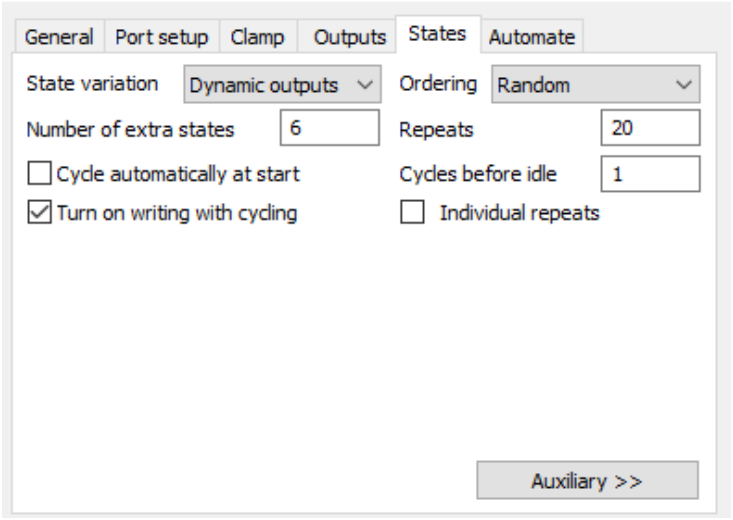


States 2 through 6 contain the test pulse on digital output 1 starting at 100ms into the sweep, and the conditioning pulse on digital output 0 preceding this. The time between the conditioning pulse and test pulse increments by 1ms in each state (1ms – 5ms).



Each state is 400ms in length, with a 5000ms interval between sweeps and 10% variance

States Tab



Extra states 6 – one for each test pulse increment

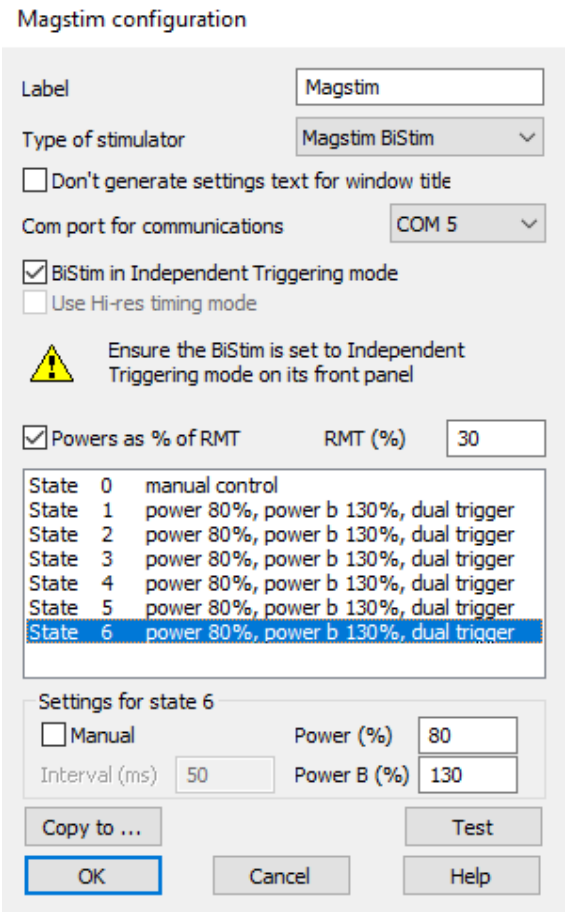
Repeats 10 – 20

Cycles before idle 1

Ordering Either Random or Semi-Random

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment design requires two TMS stimulators operating through a single coil, such as a Magstim BiStim or a Deymed dual DuoMAG MP

Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box

If operating the TMS device as percentage of MSO, leave these fields blank

State 0 Leave as manual controlled

States 1 – 6

This configuration uses the Magstim BiStim device as an example. In each state, Power a (conditioning pulse – digital output 0) is set to a lower RMT% value than Power b (test pulse – digital output 1). These values will need to be changed as needed dependent on whether working in RMT% or MSO%.

Even though State 1 does not contain a conditioning pulse, power a is set to the lowest intensity required, but with no pulse output power a will not fire. This is because when cycling between states it can take some time to discharge the stimulator to 0%, therefore the stimulator may not be charged in time for the next state. If for example power a of state 1 was set to 0%, in a cycle of State 3 → State 1 → State 4, the stimulator would go from 80% → 0% → 80%. It is better for the stimulator to instead remain at 80%.

Please be aware however that this configuration is not applicable to all TMS devices, consult the information section of this document for your TMS device configuration set up.

Please also note, if using a BiStim with two triggers (digital output 0 + digital output 1), the BiStim will need to be configured to 'Independent Triggering mode'. Set this on the front panel of the BiStim and tick the corresponding box in the Signal configuration. Please see the information section at the end of this guide for more information.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

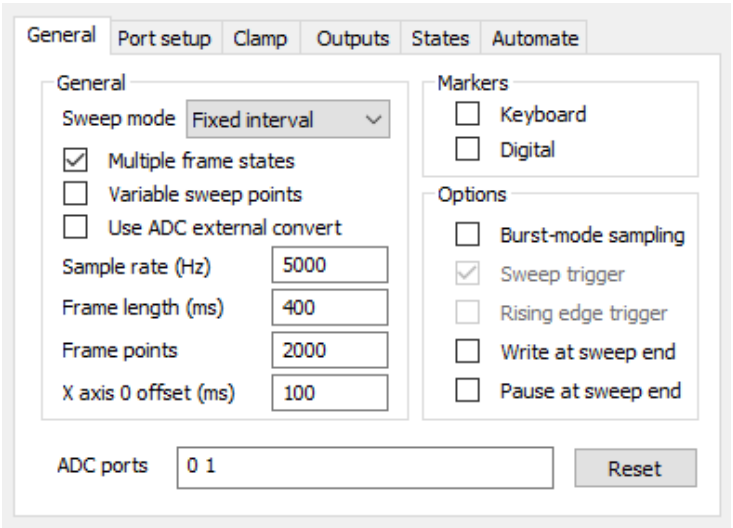
SICI input-output curve

This method utilises 4 states. The first state comprises a singular test pulse, with the remaining states involving pairs of pulses where the intensity of the conditioning pulse varies across states. The intensity of the test pulse remains fixed and the interval between pairs of pulses remains fixed.

The test pulse intensity is expressed as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of RMT).

The conditioning pulses intensity is typically lower than the test pulse and usually expressed relative to a pre-determined threshold (e.g. 70-90% of AMT).

General Tab



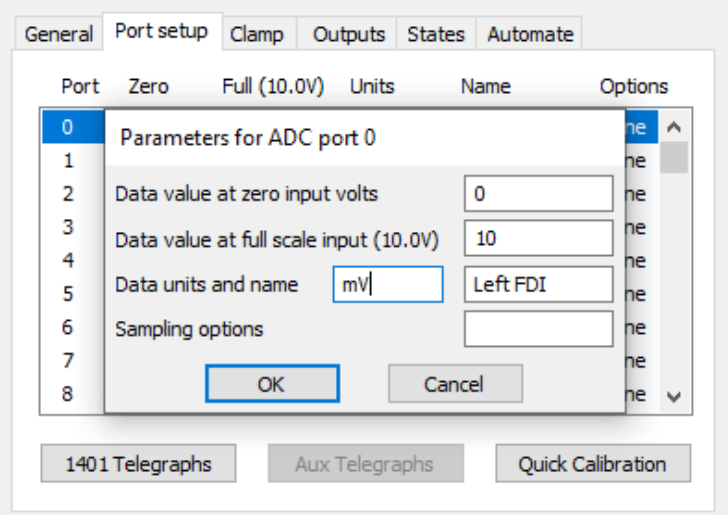
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

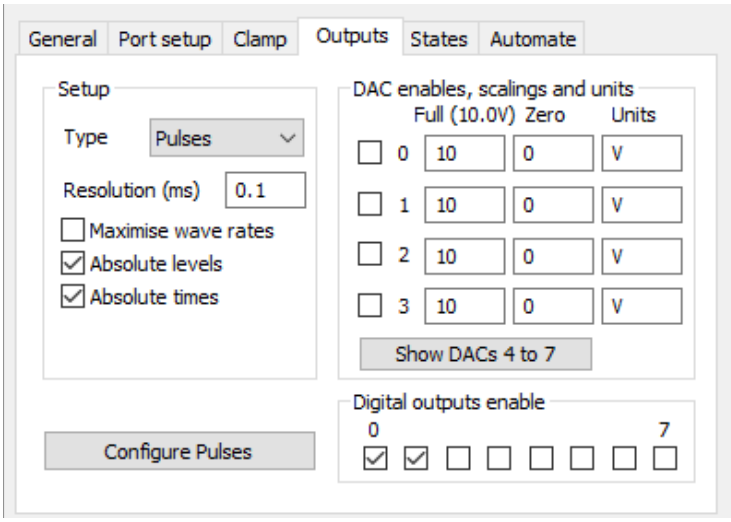
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

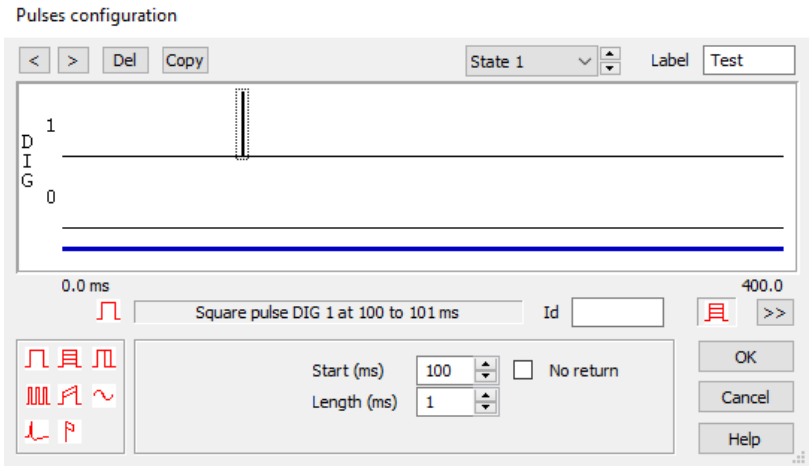


Type Pulses

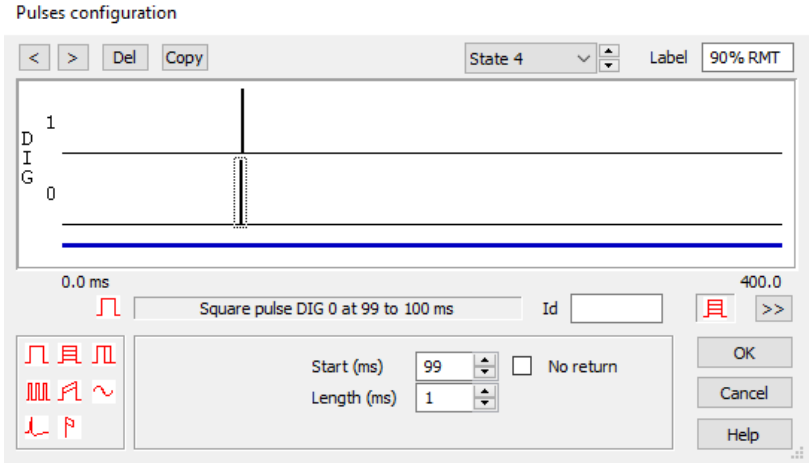
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

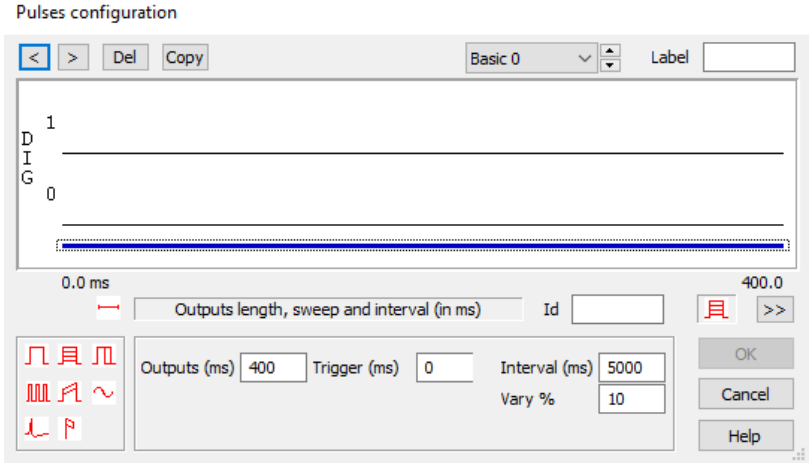
Pulse Configuration



State 1 contains a single test pulse on digital output 1 starting at 100ms into the sweep for 1ms

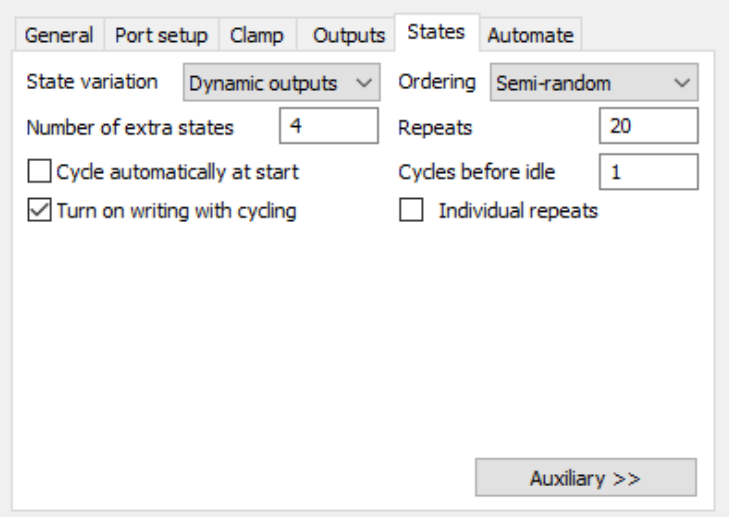


States 2 through 4 each contain the same number of pulses, with the conditioning pulse (digital output 0) preceding the test pulse (digital output 1) by 1ms



All states are set to 400ms in length with an interval of 5000ms and an interval variation of 10%

States Tab



Extra states 4

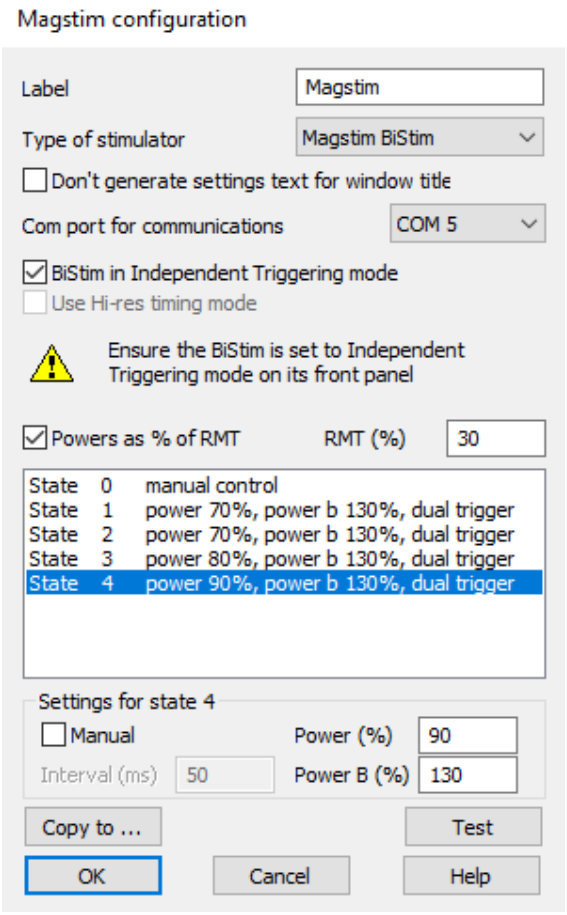
Repeats 10-20

Cycles before idle 1

Ordering Random or Semi-Random

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment setup requires two TMS stimulators operating through a single coil, such as a Magstim BiStim, or a Deymed dual DuoMAG MP

Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box
If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 4 This configuration uses a BiStim device as an example. In each state, power a (conditioning pulse – digital output 0) is set to a lower RMT % value than power b (test pulse – digital output 1). The intensity of the conditioning pulse varies between states in fixed increments. These values will need to be changed as needed dependent on working in RMT % or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

4. Intracortical facilitation (ICF)

This protocol involves alternating between a single "test" pulse to generate the baseline or test response and closely-spaced pairs of pulses, where the first pulse is used to "condition" the response to the test pulse.

Design

The design of this experiment is very similar to SICI, except the interval between pairs is longer (10-20 ms). In fact, it is sometimes measured at the same time as Interval SICI simply by adding the extra states with longer intervals between pulses.

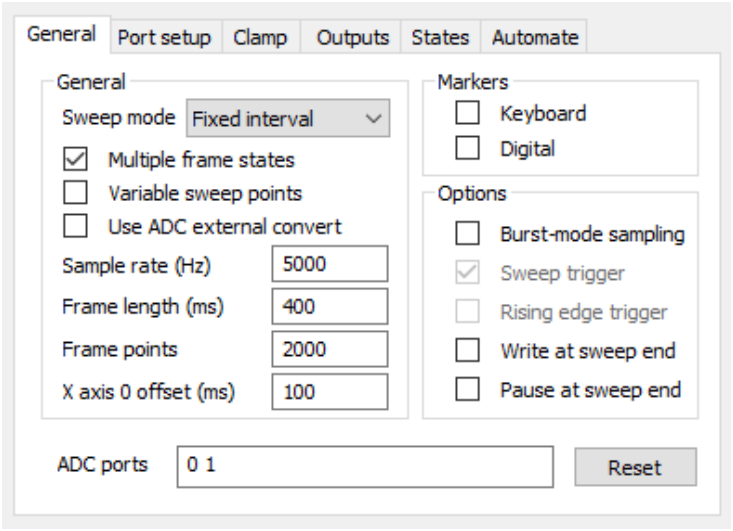
There are usually 2-4 states, the first state being the test pulse alone and the remaining states involving pairs of pulses where the conditioning pulse precedes the test pulse by 10-20 ms (in 5 ms steps). The intensity of each pulse remains fixed.

The test pulse intensity is usually as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of RMT).

The conditioning pulses intensity is typically lower than the test pulse and usually expressed relative to a pre-determined threshold (e.g. 80-120% of AMT or 70-90% of RMT).

The pulses are delivered individually to two TMS stimulators, with both stimulators firing through a single coil (e.g. Magstim BiStim or Deymed dual DuoMAG MP).

General Tab



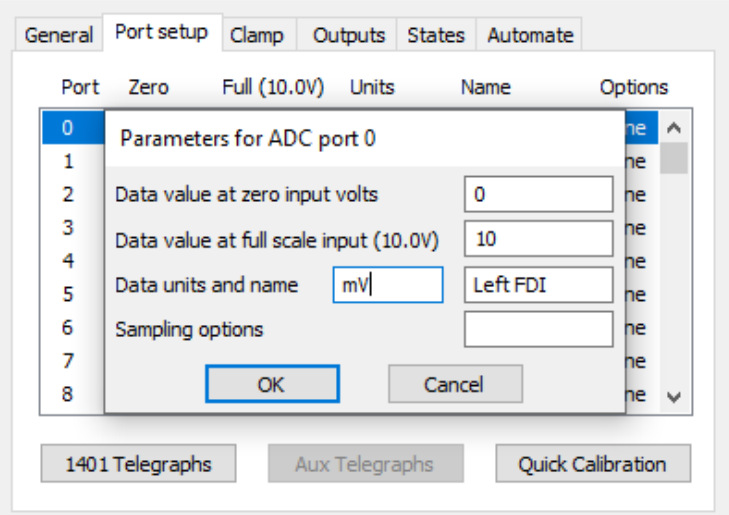
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

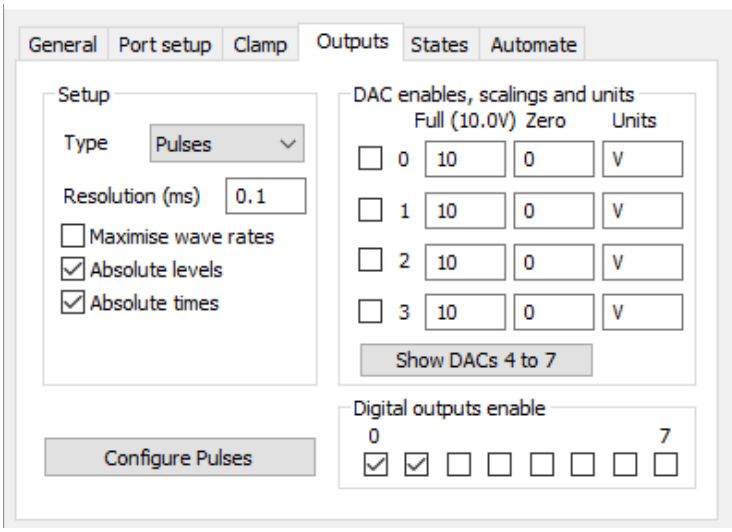
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

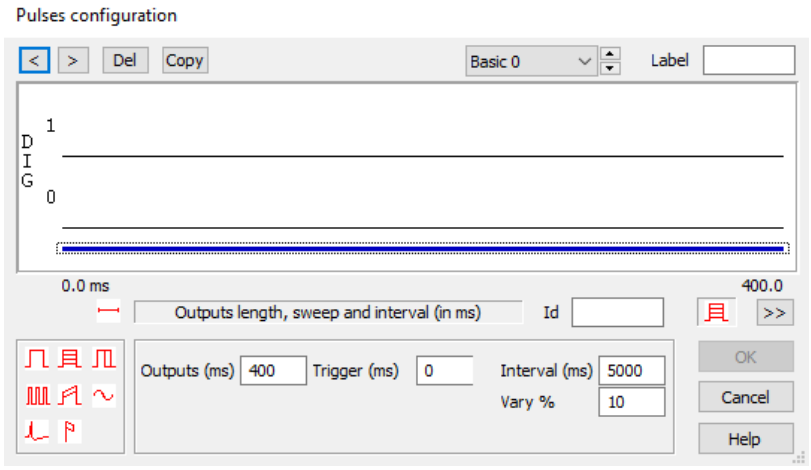


Type Pulses

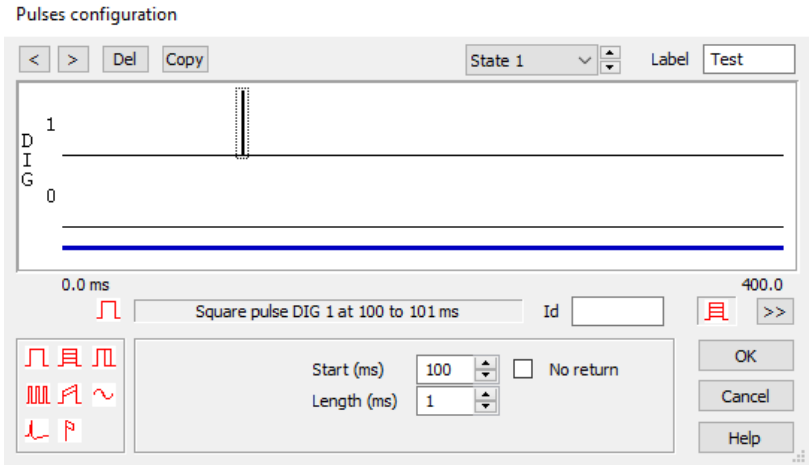
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

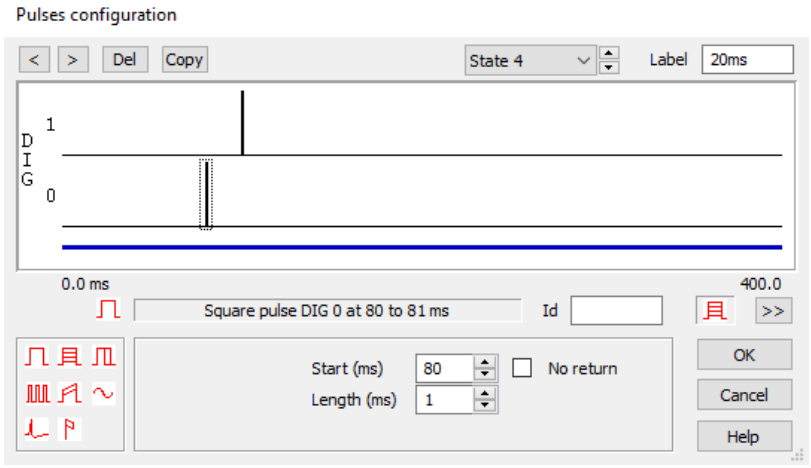
Pulses Configuration



All states are set to 400ms in length with an interval of 5000ms and an interval variation of 10%

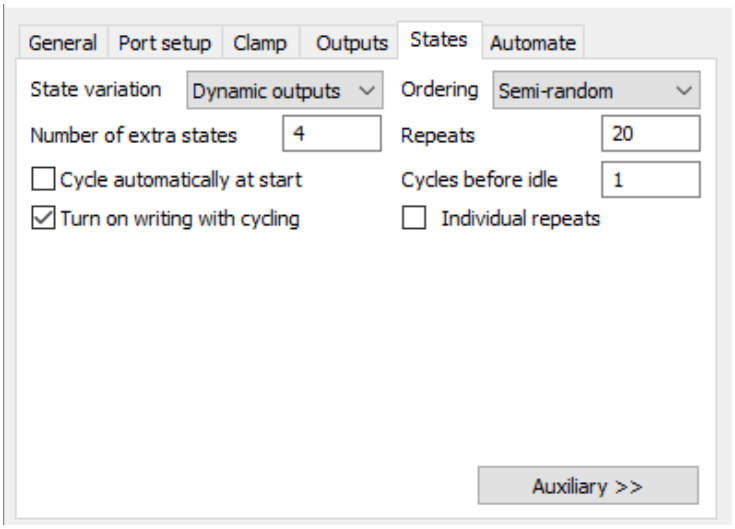


State 1 contains a single test pulse on digital output 1, starting at 100ms into the sweep



States 2 through 4 each contain the same number of pulses, with the conditioning pulse (digital output 0) preceding the test pulse (digital output 1). The interval between the conditioning pulse and test pulse increments by 5ms in each state (5ms – 20ms).

States Tab



Extra states 4

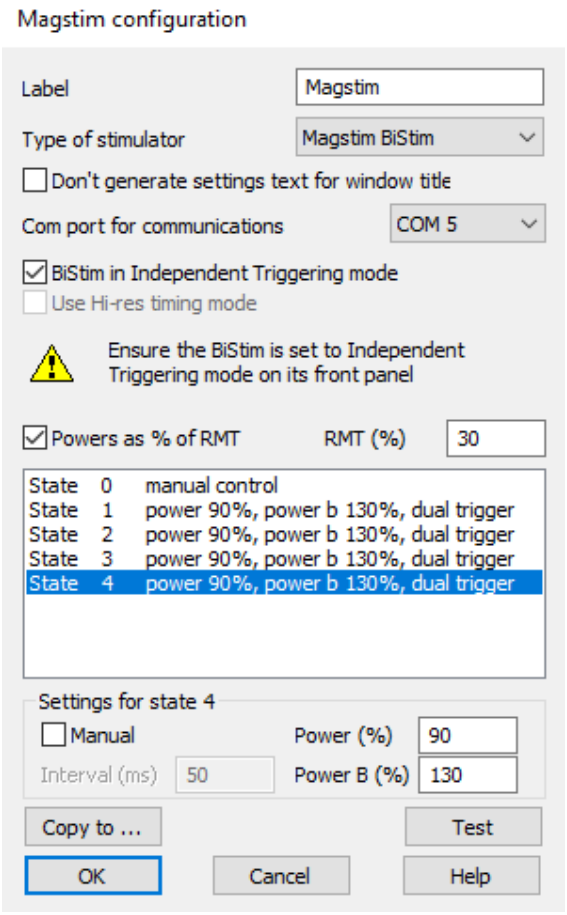
Repeats 10-20

Cycles before idle 1

Ordering Random or Semi-Random

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment setup requires two TMS stimulators operating through a single coil, such as a Magstim BiStim or a Deymed dual DuoMAG MP

Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box
If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 4 This configuration uses a BiStim as an example. In each state, power a (conditioning pulse – digital output 0) is set to a lower RMT % value than power b (test pulse – digital output 1). The intensity of the conditioning pulse and test pulse remains fixed in each state. These values will need to be changed as needed dependent on working in RMT % or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

5. Short-interval intracortical facilitation (SICF)

This protocol involves alternating between a single "test" pulse to generate the baseline or test response, and closely-spaced pairs of pulses where the second pulse is used to "condition" the response to the test pulse, which now comes first.

Design

The design of this experiment is similar to SICI, except for the greater time resolution of the interval between pairs (0.2 to 0.3 ms steps) and with the test pulse set to a higher intensity than the second (which is the opposite of the previous configurations).

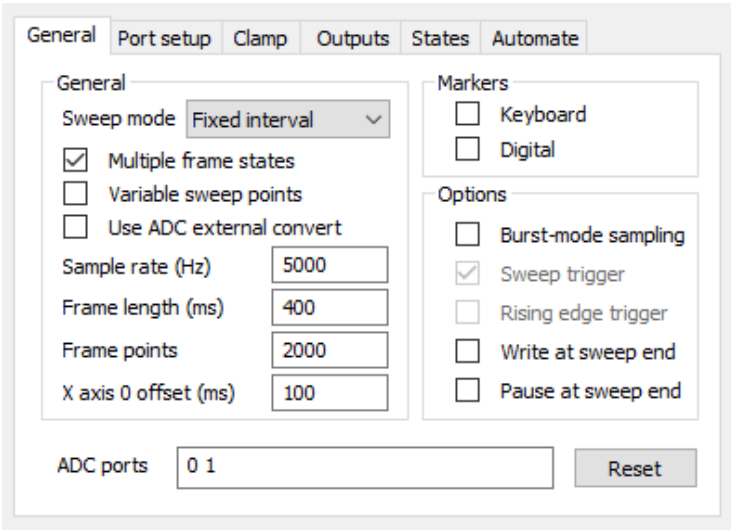
Up to 24 states are used, one with the test pulse alone and the remaining states involving pairs of pulses where the conditioning pulse follows the test pulse by 0.9 to 5.4 ms (in 0.2-0.3 ms intervals). The intensity of each pulse remains fixed.

Specifically for this experiment, there are 10-20 repeats for the single test pulse state and a smaller number (8-12) of repeats for the remaining states.

The test pulse intensity is expressed as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of resting motor threshold). The conditioning pulse intensity is lower than the test pulse and also expressed relative to a pre-determined threshold (e.g. 80-110% of RMT).

The pulses are delivered individually to two TMS stimulators, with both stimulators firing through a single coil (e.g. Magstim BiStim or Deymed dual DuoMAG MP).

General Tab



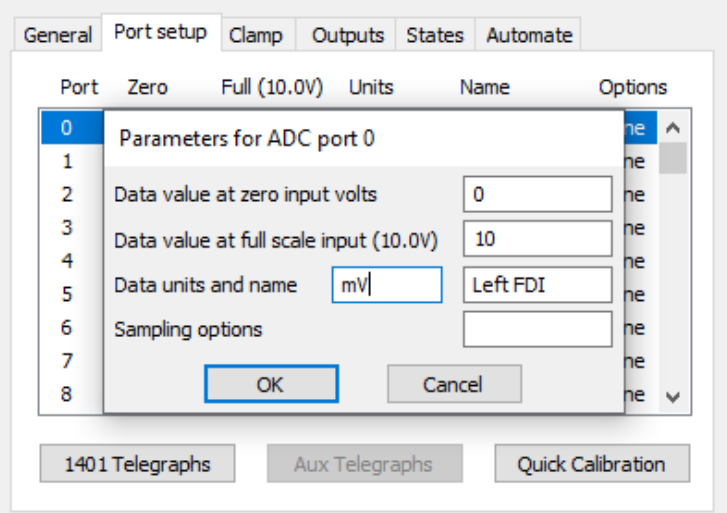
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

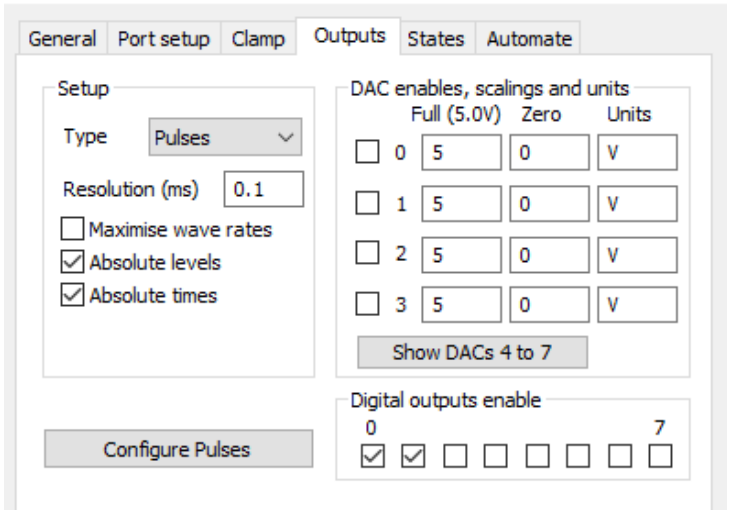
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

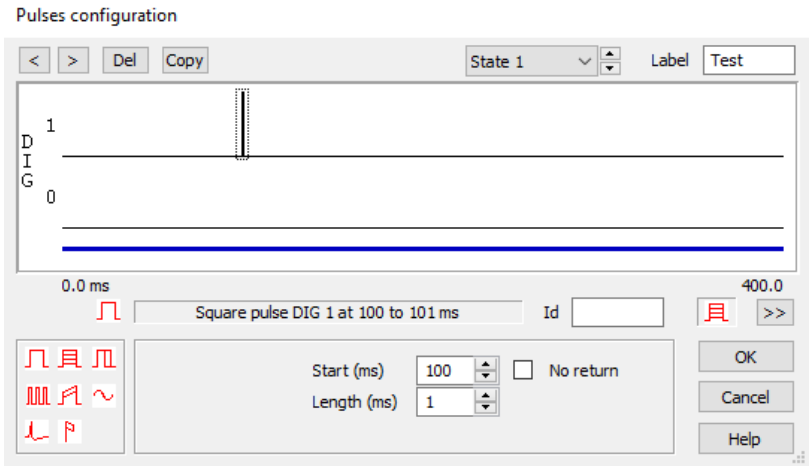


Type Pulses

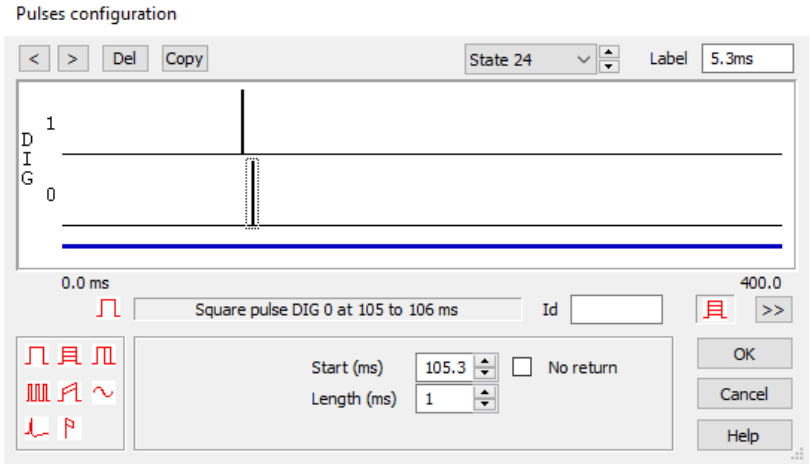
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

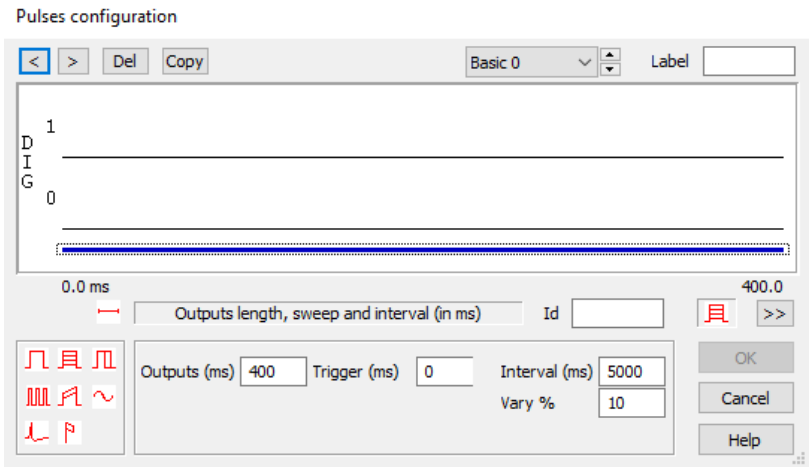
Pulse Configuration



State 1 contains a single test pulse on digital output 1, starting at 100ms

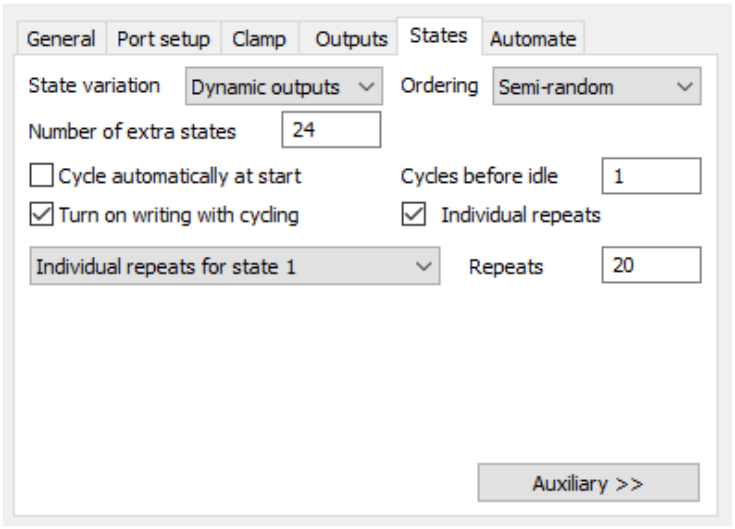


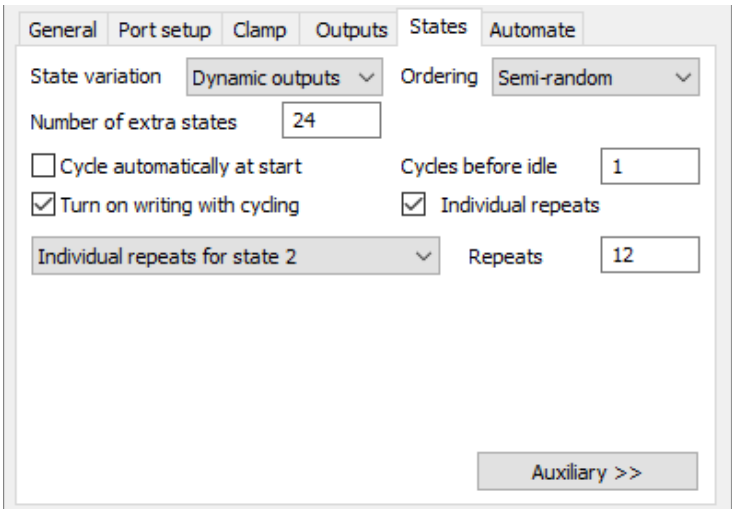
States 2 through 24 each contain a single test pulse on digital output 1 at 100ms into the sweep and a single conditioning pulse on digital output 0 after the test pulse, with the interval incrementing by 0.2ms in each state (between 0.9ms to 5.3ms)



All states are set to 400ms in length with an interval of 5000ms and an interval variation of 10%

States Tab





Extra states 24

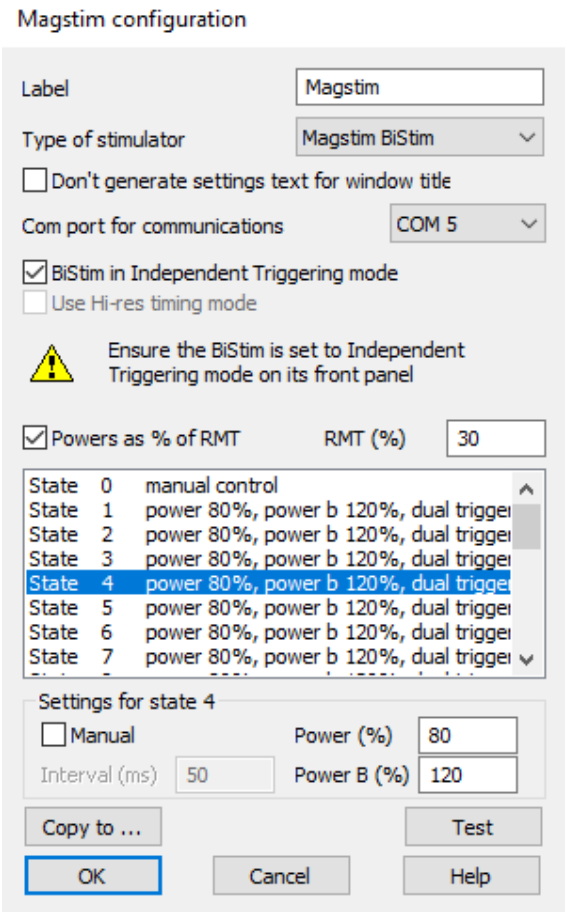
Individual repeats Enabled
State 1 (test pulse only) – 10 to 20 repeats
States 2 through 24 (test pulse preceding conditioning pulse) – 8 to 12 repeats

Cycles before idle 1

Ordering Semi-random or Random.

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment requires two TMS stimulators operating through a single coil, such as a Magstim BiStim or a Deymed dual DuoMAG MP

Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box
If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 24 This configuration uses a BiStim device as an example. In each state, power a (conditioning pulse – digital output 0) is set to a lower value of RMT % than power b (test pulse – digital output 1). The intensity of the conditioning pulse and test pulse remains fixed in each state. These values will need to be changed as needed dependent on working in RMT% or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

6. Long-interval intracortical inhibition (LICI)

This protocol involves alternating between a single "test" pulse (to generate the baseline or test response) and pairs of pulses with a longer interval (up to 200 ms) between them, where the first pulse is used to "condition" the response to the test pulse.

Design

The design of this experiment is similar to SICI except that the interval between pairs is much longer (100-200 ms). Frame lengths have been extended to 500ms in this configuration to allow for the longer interval times.

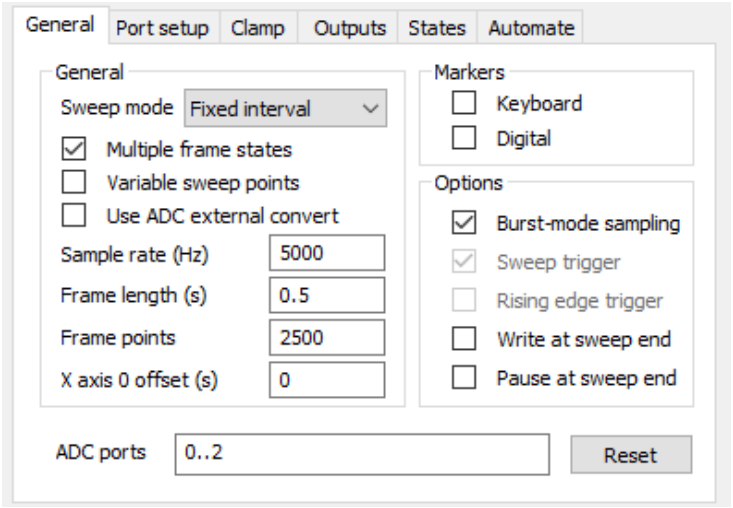
For this experiment 2-4 states are used, one with the test pulse alone and the remaining states involving pairs of pulses, where the conditioning pulse precedes the test pulse by 100-200 ms (in 50 ms intervals). The intensity of each pulse remains fixed.

The test pulse intensity is expressed as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of RMT).

The conditioning pulses intensity is usually the same as the test pulse intensity and expressed relative to a pre-determined threshold (e.g. 120-130% of RMT).

The pulses are delivered individually to two TMS stimulators, with both stimulators firing through a single coil (e.g. Magstim BiStim or Deymed dual DuoMAG MP).

General Tab



Sweep mode Fixed interval

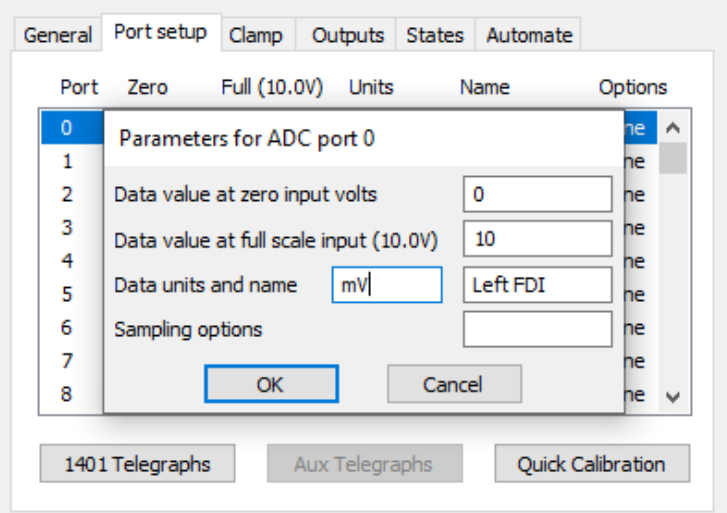
Multiple frame states Enabled

Frame length 500ms

Burst-mode sampling Optional

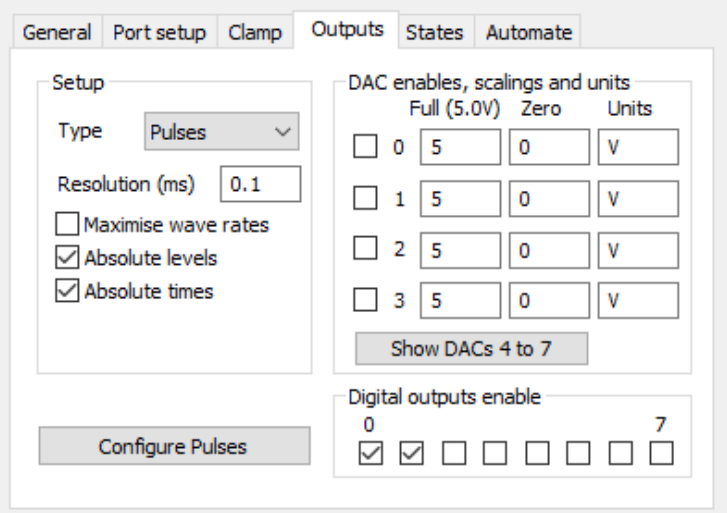
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

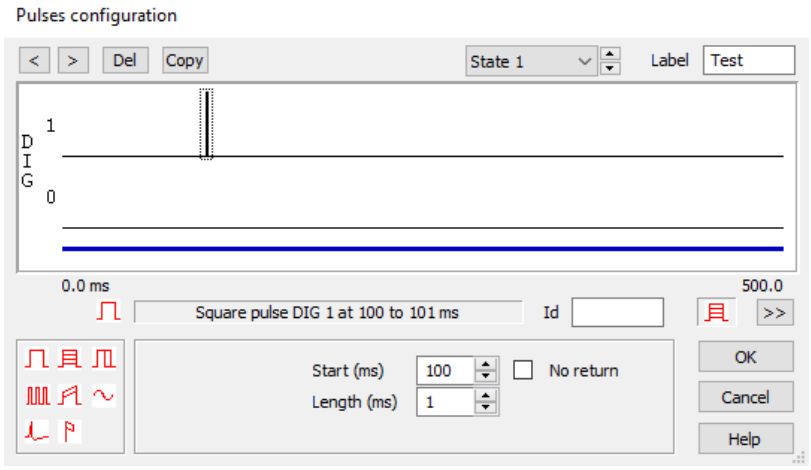


Type Pulses

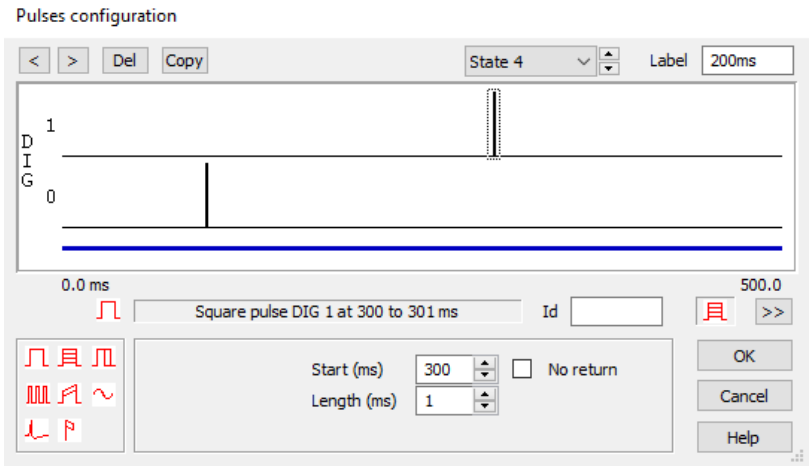
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

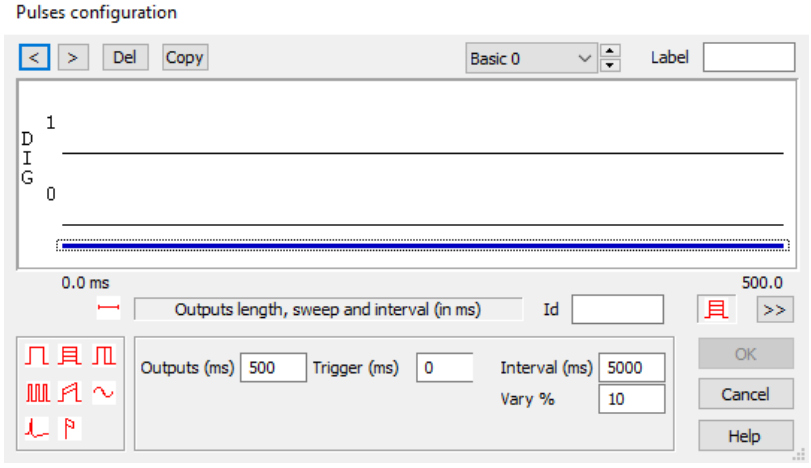
Pulse Configuration



State 1 contains a single test pulse on digital output 1, starting at 100ms

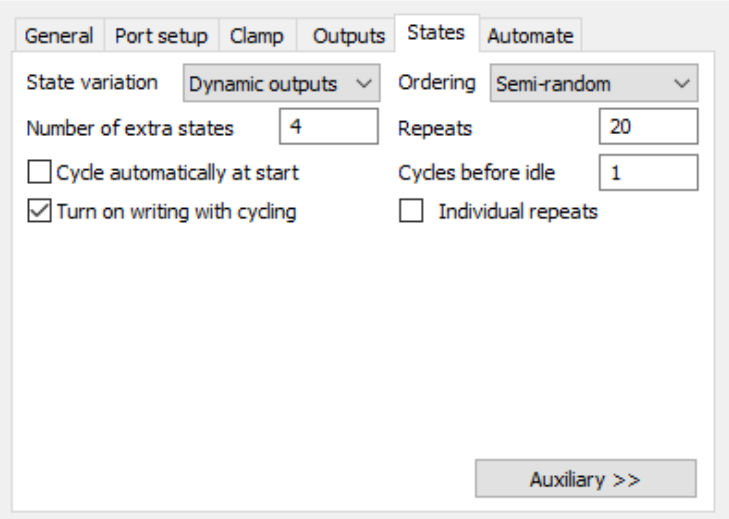


States 2 through 4 each contain a single conditioning pulse on digital output 0 at 100ms into the sweep, and a single test pulse on digital output 1 after the test pulse. The interval between the test and conditioning pulse increments by 50ms in each state (100 – 200ms).



All states are set to 500ms in length with an interval of 5000ms and an interval variation of 10%

States Tab



Extra states 4

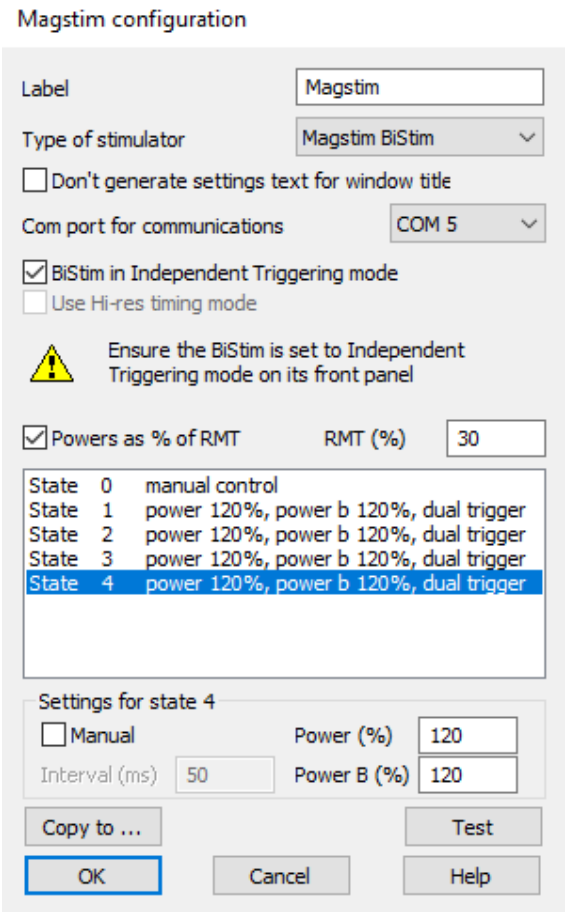
Individual repeats 10-20

Cycles before idle 1

Ordering Semi-random or Random

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment setup requires two TMS stimulators operating through a single coil, such as a Magstim BiStim or a Deymed dual DuoMAG MP

Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box
If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 4 This configuration uses a Magstim BiStim device as an example. In each state, Power a (conditioning pulse – digital output 0) is set to the same value as Power b (test pulse – digital output 1). The intensity of the conditioning pulse and test pulse remains fixed in each state. These values will need to be changed as needed dependent on working in RMT% or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

Experiment Configurations

Protocols involving paired TMS pulses through separate TMS coils

Paired pulses, two coil, configurations

These types of configurations are essentially the same as single pulse, single coil configurations except there are two stimulators each with their own settings.

A single pulse from one digital output will control one stimulator, and another pulse from another digital output will control the other stimulator. Both stimulators need to be set up through the auxiliary menu, and the pulses configured on the corresponding outputs in the pulses configuration.

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7. Inter-hemispheric inhibition (IHI)

This protocol involves alternating between a single “test” pulse to generate the baseline or test response delivered through one coil, and pairs of pulses, one pulse delivered through the test coil and the other through a secondary coil.

Design

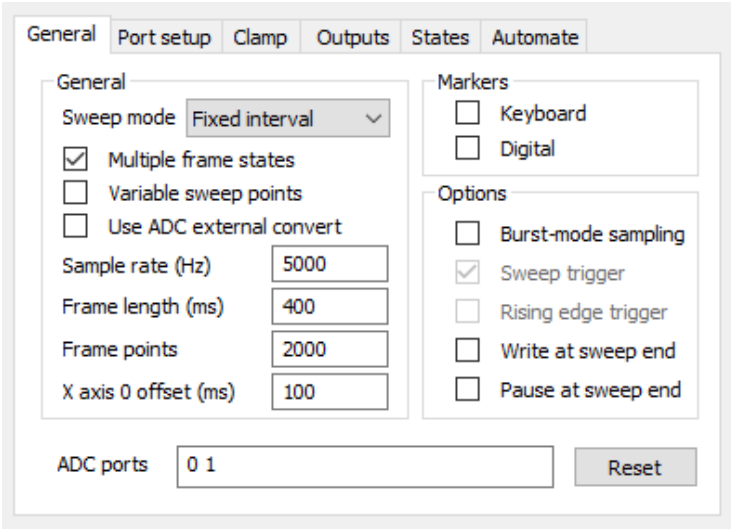
This experiment requires two independently triggered stimulators, but unlike before two stimulation coils will be required. The coils will have a firing interval of between 8-12 ms, set up through the pulses configuration dialog.

The protocol will utilise 2-4 states, the first of which contains the test pulse alone and the remaining states involving pairs of pulses where the conditioning pulse precedes the test pulse by 8-12 ms (in 2 ms intervals). The intensity of each pulse remains fixed across the states.

The test pulse intensity will be expressed as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of RMT).

The conditioning pulses intensity will usually the same as the test pulse intensity or expressed relative to a pre-determined threshold (e.g. 120-130% of RMT).

General Tab



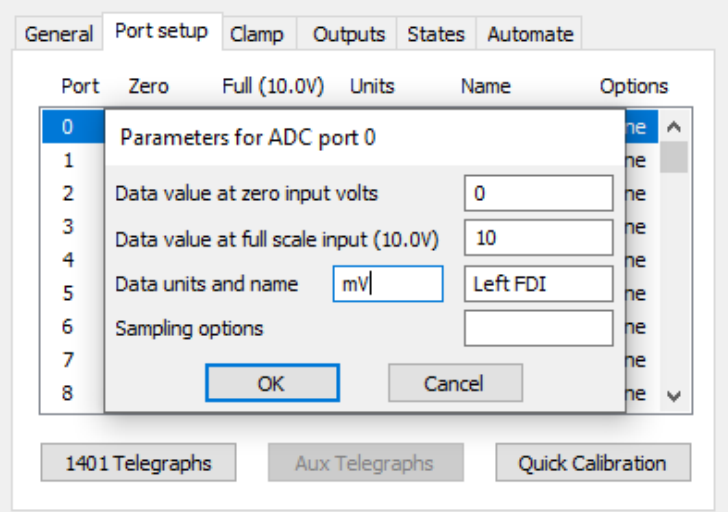
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

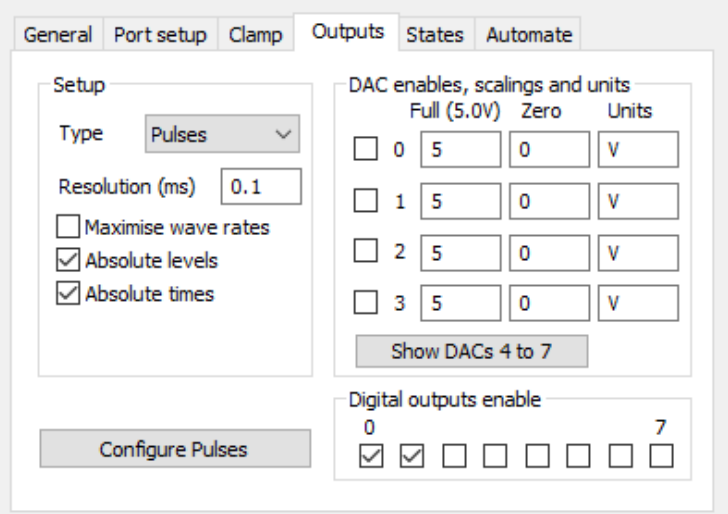
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

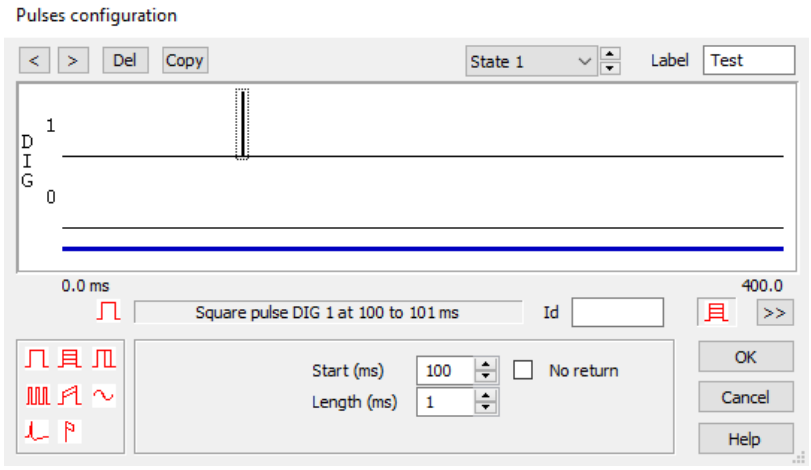


Type Pulses

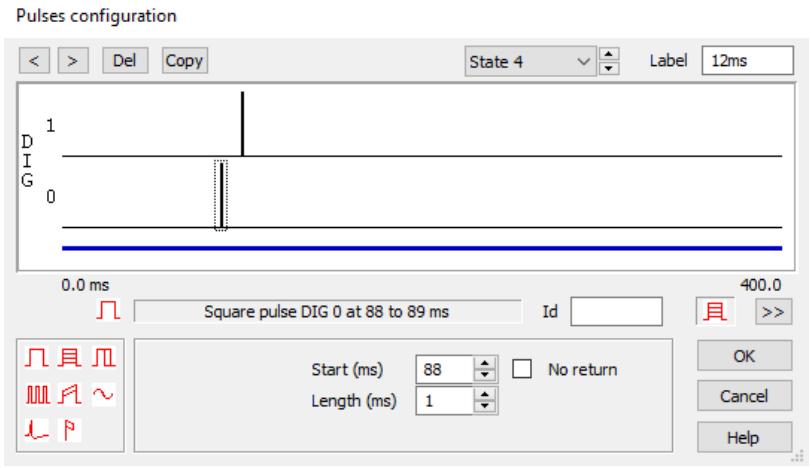
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

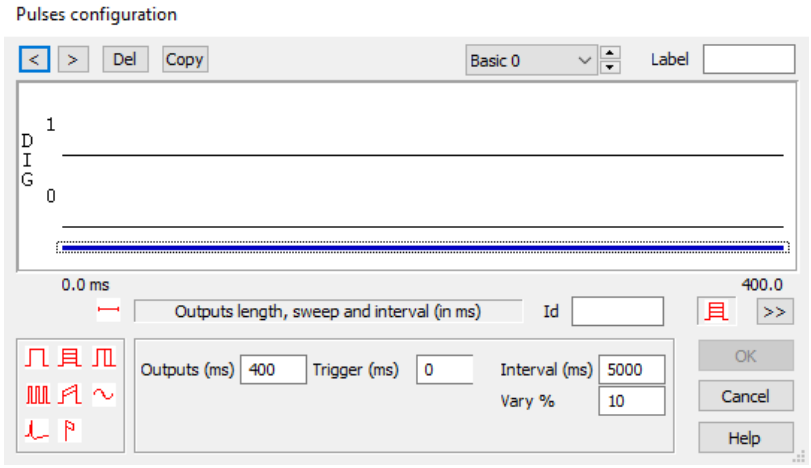
Pulse Configuration



State 1 contains a single test pulse on digital output 1, starting at 100ms

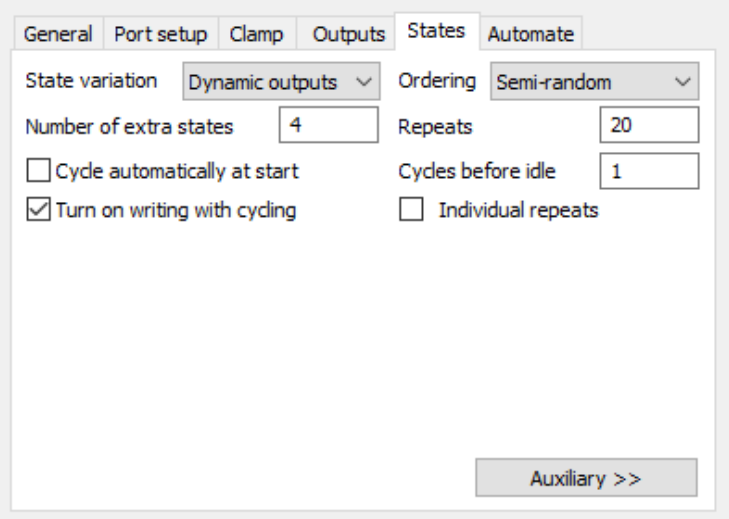


States 2 through 4 each contain the same number of pulses, with the conditioning pulse (digital output 0) preceding the test pulse (digital output 1). The interval between the conditioning pulse and test pulse increments by 2ms in each state (8ms – 12ms).



All states are set to 400ms in length with an interval of 5000ms and an interval variation of 10%

States Tab



Extra states 4

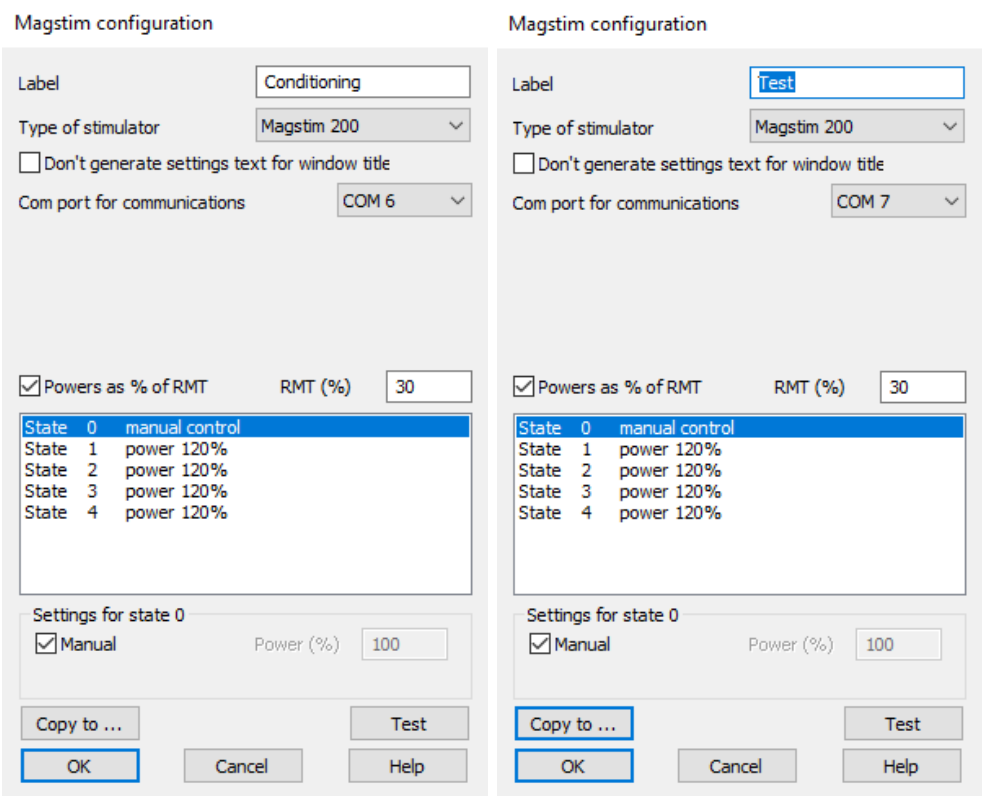
Repeats 10-20

Cycles before idle 1

Ordering Random or Semi-Random

Turn on writing with cycling Enabled

TMS Device



As previously stated, this experiment requires two TMS stimulators operating through individual stimulation coils. As such you will likely need to set up two individual configurations, one for the conditioning pulse and one for the test.

If operating a version older than v7.0 of Signal it is possible to use the Dual Magstim 200² configuration to carry out this experiment.

Label Enter desired names for TMS stimulators

Type of stimulator Ensure correct models are selected

Com port Select the correct com ports each stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box

If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 4 This configuration uses two Magstim 200² stimulators as an example. The conditioning pulse has been set up to com port 6, and the test pulse to com port 7. The intensity of the pulses is the same across all states and for both types of pulses. These values will need to be changed as needed dependent on working in RMT% or MSO%.

Please consult the beginning of this guide, the Signal help text, and your TMS stimulators manual for correct connections between the 1401 and the stimulator.

Experiment Configurations

Protocols coupling TMS and electrical stimulation.

8. Short-latency afferent inhibition (SAI)

This protocol involves alternating between a single test TMS pulse to generate the baseline or test response, and pairs consisting of TMS and electrical stimuli delivered to a peripheral nerve, e.g. at the wrist.

Design

This experiment is designed with both a magnetic stimulator and electrical stimulator. The electrical stimulus is used to condition the response to the TMS pulse, and is often delivered via a Digitimer DS7A or a newer DS8R.

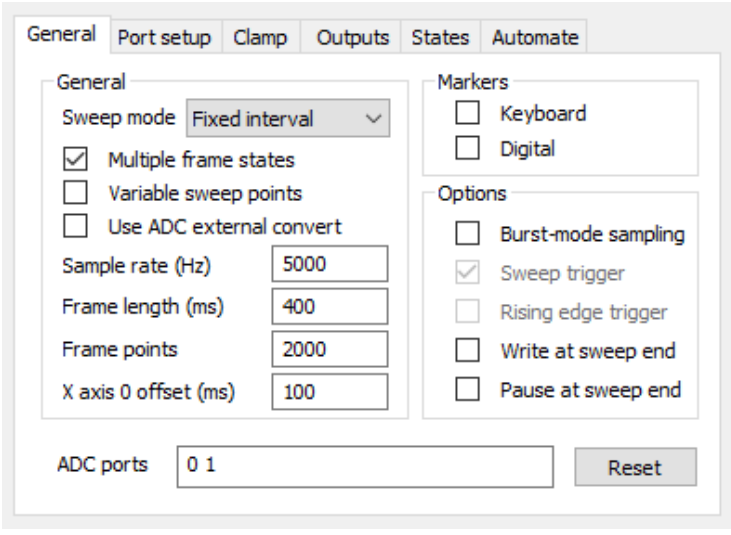
The design utilises 2-7 states. The first contains the test pulse alone, with the remaining states involving pairs of TMS and electrical pulses, where the conditioning electrical pulse precedes the TMS test pulse by 20-30 ms (in 1-2 ms intervals). The intensity of each pulse remains fixed.

The electrical pulse sensory threshold will need to be independently determined prior to performing this experiment.

The test pulse intensity is expressed as a % of MSO or relative to some pre-determined threshold (e.g. 120-130% of RMT). The conditioning electrical pulse intensity is expressed relative to a pre-determined peripheral nerve threshold (e.g. 100-300% of sensory threshold).

In this configuration, the TMS will be triggered on digital output 0, and the electrical stimulator on digital output 1.

General Tab



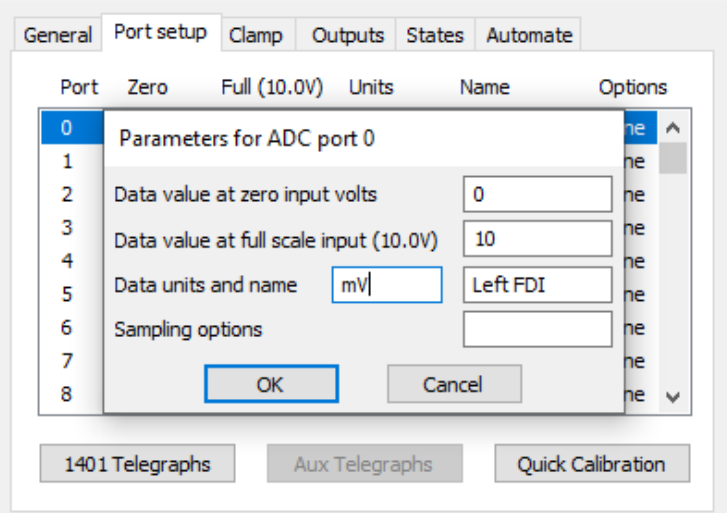
Sweep mode Fixed interval

Multiple frame states Enabled

Burst-mode sampling Optional

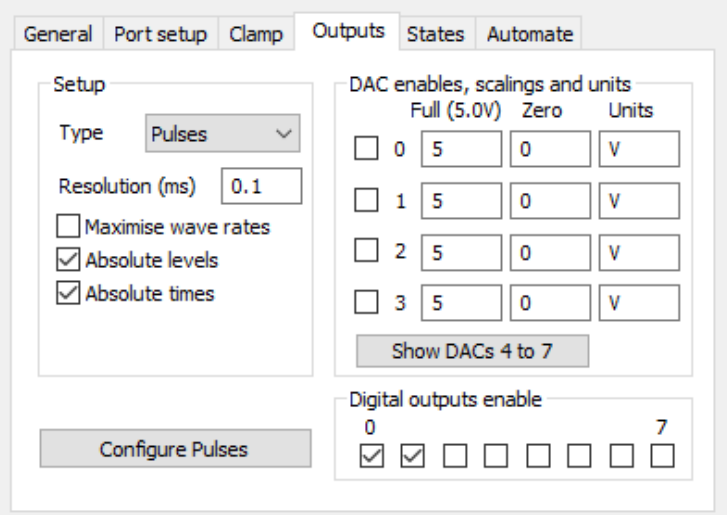
ADC ports Enable all ports in use

Port Setup Tab



Edit as required, account for any amplifier gain in your settings

Outputs Tab

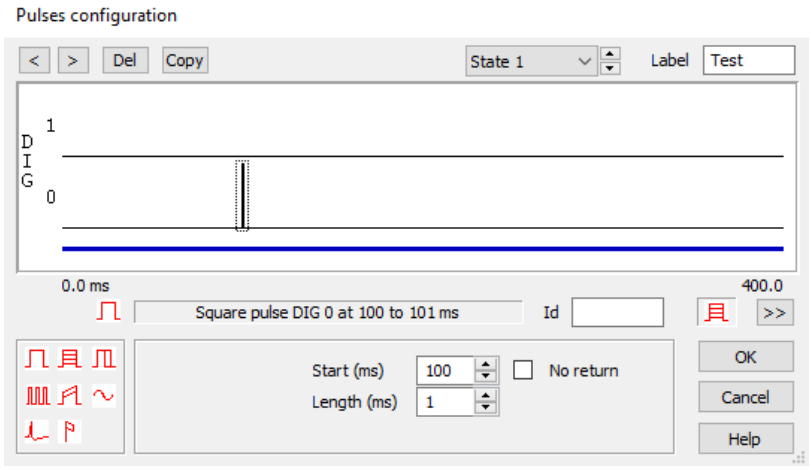


Type Pulses

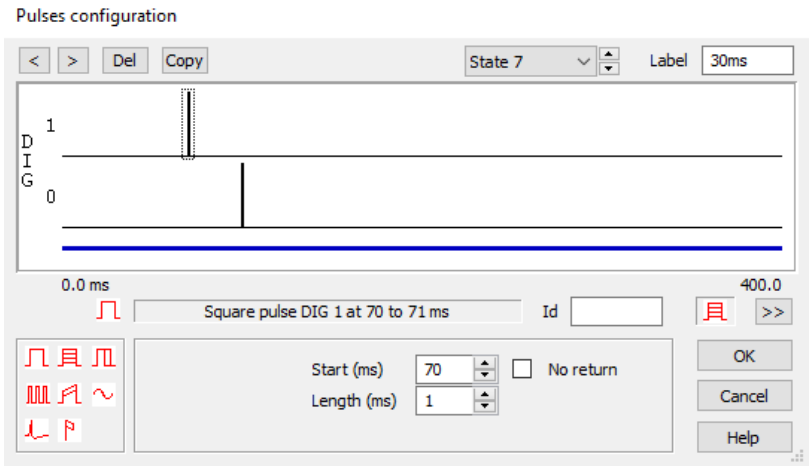
Resolution (ms) 0.1

Digital outputs 0 and 1 enabled

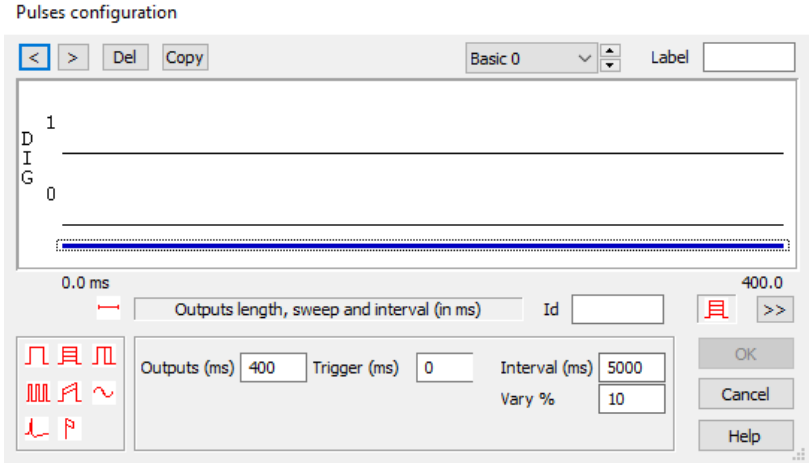
Pulse Configuration



State 1 contains a single test pulse on digital output 0, starting at 100ms into the sweep

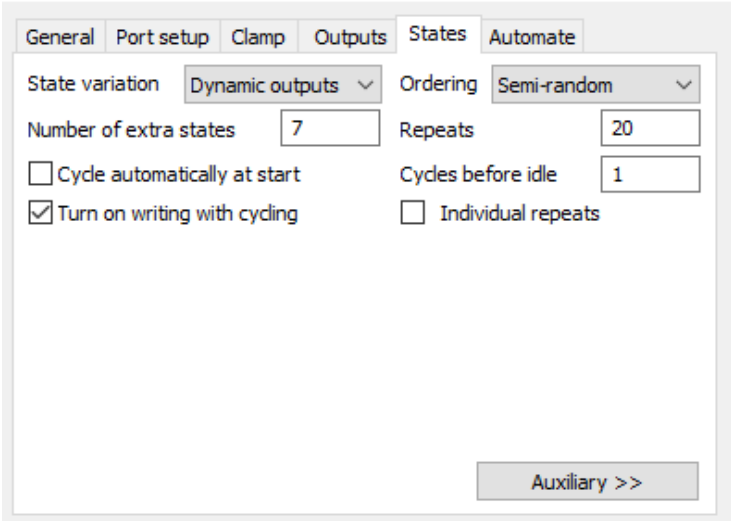


States 2 through 7 each contain the same number of pulses, with the conditioning pulse (digital output 1) preceding the test pulse (digital output 0). The interval between the conditioning pulse and test pulse increments by 2ms in each state (20ms – 30ms).



All states are set to 400ms in length with an interval of 5000ms and an interval variation of 10%

States Tab



Extra states 7

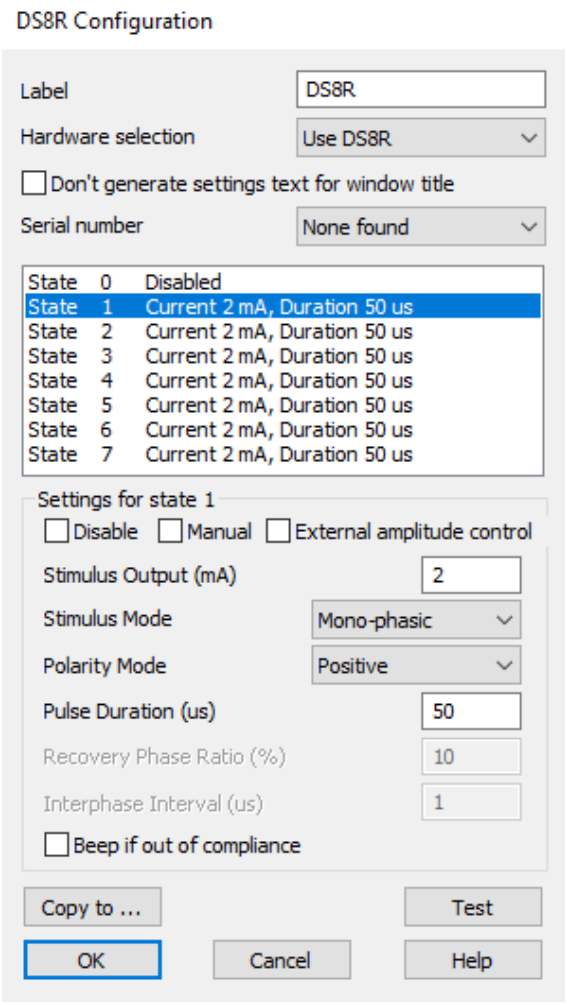
Repeats 10 – 20

Cycles before idle 1

Ordering Semi-random or random

Turn on writing with cycling Enabled

Stimulator Device



Label Enter desired name for DS8R device

Hardware selection Ensure correct model is selected

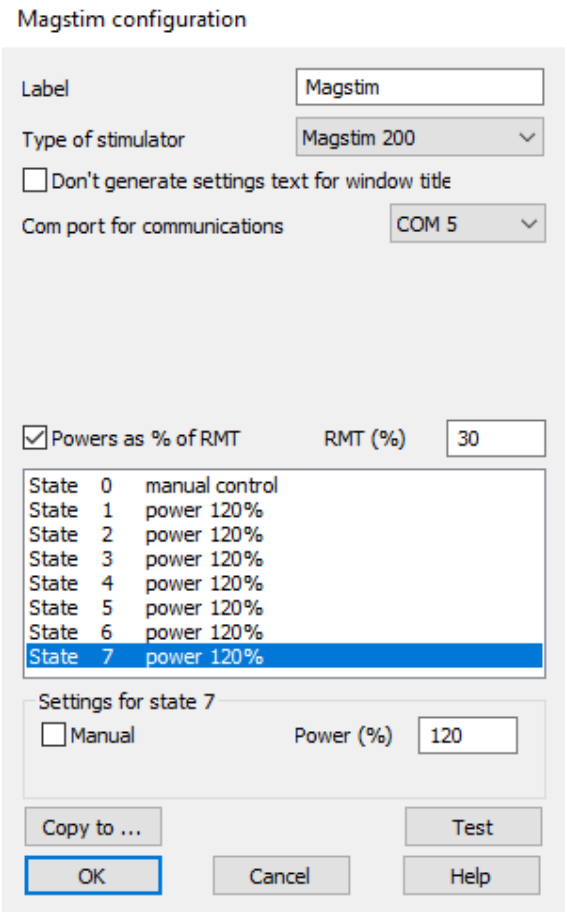
Serial number Select the correct device from the drop down list

State 0 – 1 State 0 is the idle state and can be disabled or set to manual. Similarly for State 1 (test pulse only) this can also be set to manual or disabled.

States 2 – 7 Configure your desired stimulus settings for these states, defining your output (mA), stimulus mode (mono-phasic or bi-phasic), polarity (positive, negative or alternating), and your pulse duration (µs).

Please consult the beginning of this guide, the Signal help text, and your electrical stimulators manual for correct connections between the 1401 and the stimulator.

TMS Device



Label Enter desired name for TMS device

Type of stimulator Ensure correct model is selected

Com port Select the correct com port the stimulator is connected to

RMT (%) If operating power output as a percentage of RMT, enter the RMT% value obtained in experiment 1, and tick the corresponding box

If operating the TMS device as percentage of MSO, leave these fields blank.

State 0 Leave as manual controlled

States 1 – 7 This configuration uses a Magstim 200 device as an example. In each state, the intensity (test pulse – digital output 0) remains fixed. These values will need to be changed as needed dependent on working in RMT% or MSO%.

Please consult the beginning of this guide, the Signal help text, and your magnetic stimulators manual for correct connections between the 1401 and the stimulator.

TMS configurations – Further information

This section expands on several points raised in the previous sections, and will discuss specific TMS stimulators and their setup in configuring your own your own set up.

Multiple Frame States and Signal controlled TMS stimulators

As mentioned in the general section, a safety feature of most TMS stimulators will cause the stimulator to disarm after a period of disuse (most often one minute). When multiple frame states is enabled, and the TMS stimulator is added to the configuration, Signal will periodically send out a control signal during sampling to keep the stimulator armed. This allows you to operate in manual mode freely, with long inter-pulse intervals, or with long intervals between sweeps without worry of the device disarming.

Cycling states and 0% power output

It is important to be aware that assigning a state with 0% power output can increase the recharge time of the stimulator. This is because it can take more time for a stimulator to discharge to 0% and then recharge back to a higher level. It is therefore possible that the time of stimulus firing may be missed without increasing the interval between sweeps. Specifically with Magstim devices, to avoid this it is best to assign states with no stimulus with the lowest intensity required and instead provide no pulse output from the 1401. This will ensure the stimulator does not fire, but can still quickly alter its power output for the next state when cycling.

This does not apply to other devices (e.g. dual DuoMAG MP) where a pulse output is always required. However these devices do not generally suffer from the increased recharge time when switching to a 0% power output.

Auxiliary device addition

With the release of version 7 of Signal, up to 10 auxiliary devices can be added to your configuration and supported by Signal during sampling. In versions prior to 7, only one device is supported.

Table of TMS Devices The following table lists the names of individual TMS devices and provides their compatibility with Signal and the 1401, as well as their control connection type.

	TMS Device	Triggered by 1401	Auxiliary device support	Connection type
Magstim	200[2]	✓	✓	Serial
	BiStim	✓	✓	Serial
	Rapid[2]	✓	✓	Serial
Deymed	DuoMAG MP	✓	✓	USB
	DuoMAG XT	✓	✓	USB
	DuoMAG MP-Dual	✓	✓	USB
	DuoMAG Quad (QPS)	✓	×	USB
MagVenture	MagPro R30	✓	✓	Serial
	MagPro X100	✓	✓	Serial
	MagPro R30+MagOption	✓	✓	Serial
	MagPro X100+MagOption	✓	✓	Serial
	MagPro R20	×	×	None
	MagPro Compact	×	×	None
	MagPro R100	✓	×	Serial/BNC
Mag&More	PowerMAG lab 30	✓	×	8 pin DIN
	PowerMAG lab 100	✓	×	8 pin DIN
	PowerMAG EEG 30	✓	×	8 pin DIN
	PowerMAG EEG 100	✓	×	8 pin DIN
	PowerMAG ppTMS	✓	✓	USB
	PowerMAG QPS	✓	×	USB
Neurosoft	Neuro-MS	✓	✓	USB
	Paired Neuro-MS	✓	✓	USB

Supported TMS devices

The following sections provide a run down of the supported TMS devices, their compatibility with the TMS Toolbox, and any special considerations that need to be adhered to.

MagStim 200²

A single Magstim 200² stimulator is capable of most single pulse configurations.

It is possible to configure paired pulses with a single stimulator, however due to the recharge time the inter-pulse interval could be significantly longer than desired, hence it is more desirable to use either a BiStim or similar dual stimulators operating through a single coil.

MagStim BiStim

When operating the BiStim it is recommended to use it in 'Independent Triggering mode', which will allow the master unit and slave unit to be triggered separately. This mode makes the BiStim the ideal pair of stimulators to use with paired pulses and a single coil. Ensure the 'Independent Triggering mode' box is ticked in the TMS configuration, and that the stimulators are set to this mode by the front panel before use. This is detailed as Independent Bistim Triggering (IBT) mode in the stimulators manual.

All of the paired pulse configurations with a single coil in this toolbox are compatible with the BiStim.

MagStim Rapid

The Magstim Rapid is mostly used to create rapid-fire stimuli from a single pulse. Most of the paired pulses configured in this toolbox are incompatible with the Rapid, as the configurations use multiple digital outputs.

It is possible to configure the Rapid to deliver paired stimuli from a single pulse, but the frequencies would need to be configured in the TMS configuration, and the time of first pulse in the pulses configuration. As such it is simpler to set up and visualise in the pulse outputs with a BiStim or similar dual stimulators.

Dual Magstim 200²

Dual Magstim 200²s are a good setup for paired pulse configurations operating through two coils, one for each stimulator. This device type under Magstim in the auxiliary device addition is the same as adding two individual 200² devices to the auxiliary menu. The reason this type exists is due to previous versions of Signal only supporting one auxiliary device.

It should be noted a BiStim can be used as two individual 200² units by disconnecting the connecting module and attaching a coil to each stimulator. Setting up the configurations is relatively simple in that the pulses will use separate digital outputs, with the Dual Magstim 200² device added through the axillary menu.

DuoMAG XT / MP

A single DuoMAG unit is very similar to a single MagStim 200 stimulator in terms of configuration, suitable for most single pulse, single coil configurations.

Again it is possible to configure paired pulses with a single stimulator, however due to the recharge time the inter-pulse interval could be significantly longer than desired, hence it is more desirable to use either a DuoMAG MP-Dual or similar dual stimulators operating through a single coil.

DuoMAG MP-Dual

Much like the BiStim, dual DuoMAG MPs are setup with the top stimulator as the master unit, and the bottom as the slave unit.

The stimulators will need to be set up through the auxiliary device menu, and 'Independent triggers' mode selected to control them individually. However, there are several features of the DuoMAG MP-Dual which render the majority of the configurations in this toolbox incompatible.

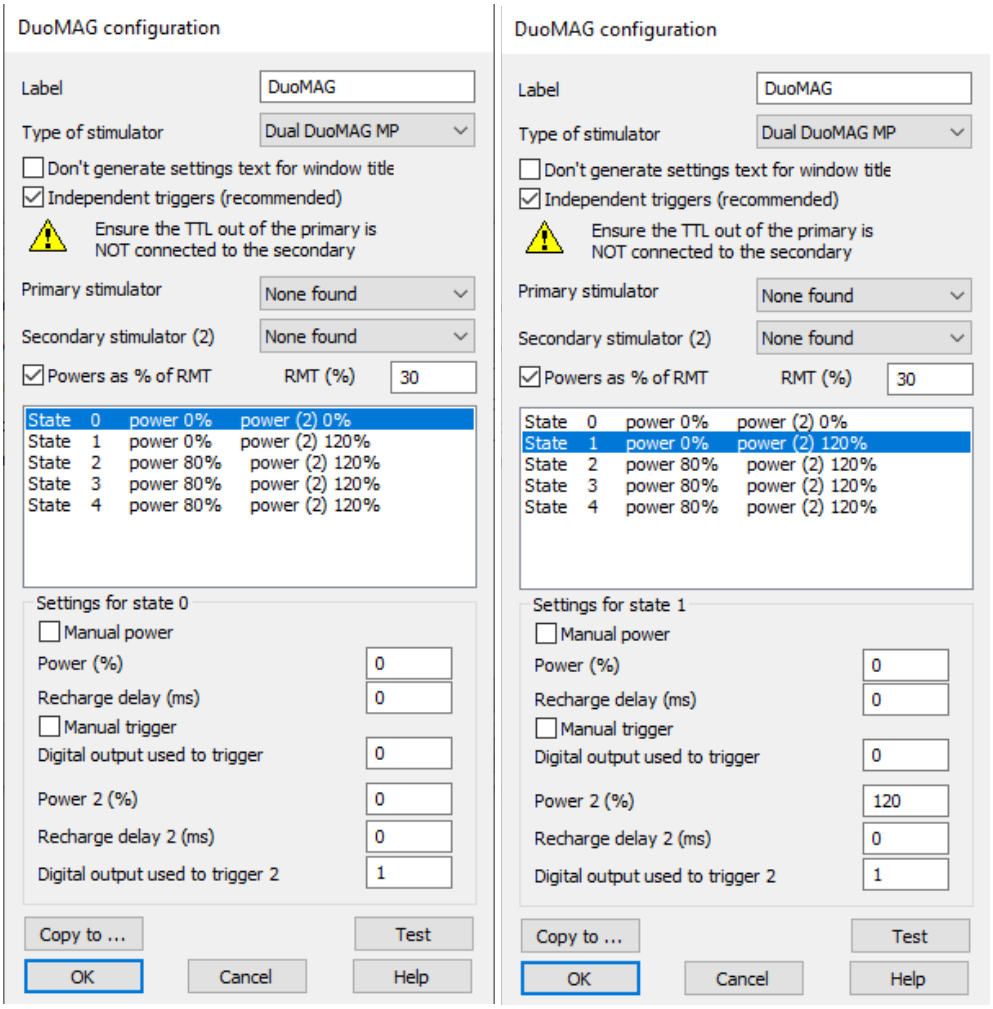
Firstly, a built-in safety measure of the DuoMAG MP ensures that the slave unit cannot fire through the same coil before the master unit. Therefore any pulse configuration must have a pulse output timed correctly, with whichever the digital output the master unit is connected to containing the first pulse.

Secondly, when in 'Independent triggers' mode, the dual DuoMAG MP will not operate unless there is a pulse in each connected digital output for each state. Therefore, if there was a state where only the master unit is to fire, a pulse would need to be configured for both the master and slave units in that state, but the intensity of the slave unit set to zero.

Finally, when in external triggering mode a minimum time delay between master and slave stimulation must be complied with when both the stimulators are connected to one coil. The stimulation can be performed either at the same time or with a minimum delay of 1ms. If this restriction is not complied with and a time delay smaller than 1ms is used, it may lead to damage of the magnetic stimulators.

The examples overleaf will better explain how a configuration with these caveats in mind would look:

TMS Configuration
Dual DuoMAG MP
State 0 and State 1

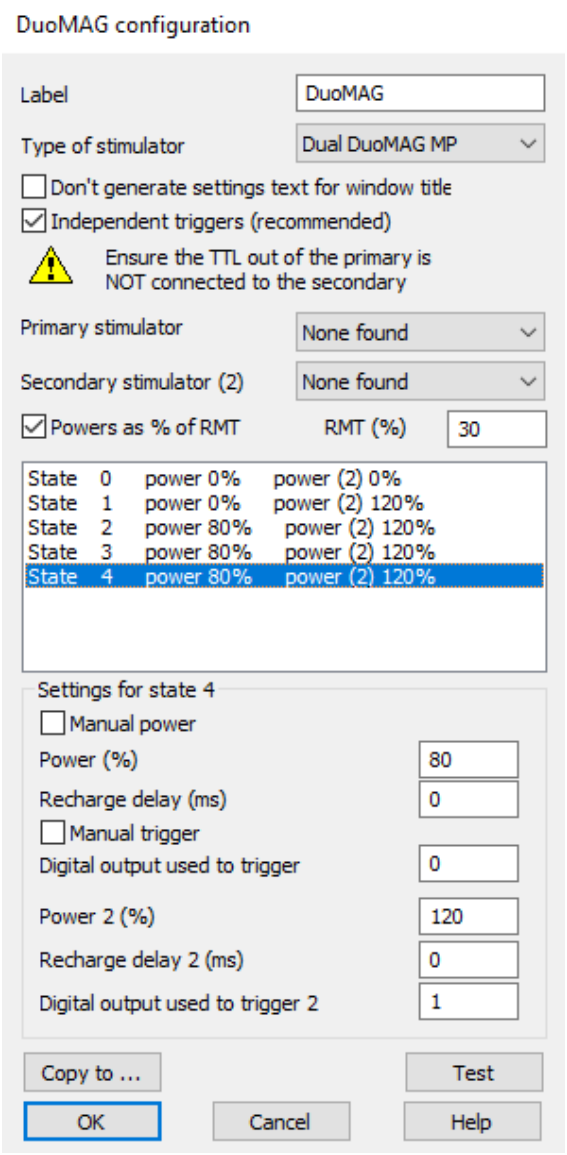


Independent triggers: Enabled
Power 1—master unit—conditioning pulse—digital output 0
Power 2—slave unit—test pulse—digital output 1

State 0 Power 1 and Power 2 set to 0%

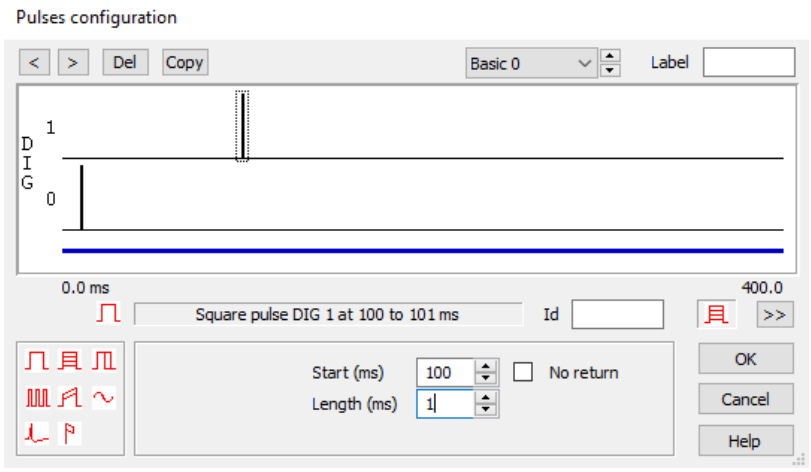
State 1 Power 1 set to 0% and Power 2 set to 120% of RMT

TMS Configuration
(continued)
State 2 – 4



States 2 – 4 Power 1 is set to 80% and Power 2 is set to 120% of RMT

Pulse configuration
State 0

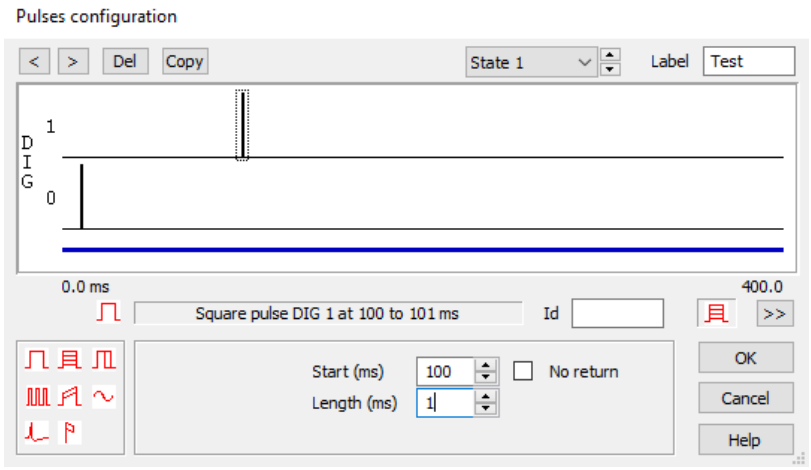


Pulse Configuration *(continued)*

State 0

Even though both Power intensities of the state are set to 0, each digital output contains a pulse set up in the pulse configuration. The pulse output through the master unit (digital output 0) must come before the slave unit (digital output 1).

State 1



Again, even though the intensity of Power 1 is set to 0%, a pulse is set to the master unit (digital output 0) before the slave unit (digital output 1).

State 2 – 4

These states will be the same as the configurations in the toolbox, with the pulses set to the timings required.

MagPro R30
MagPro X100

Each of the single MagPro stimulators is capable of performing all single pulse configurations in this toolbox.

It is possible to configure paired pulses with a single stimulator, however due to the recharge time the inter-pulse interval could be significantly longer than desired, hence it is more desirable to use either a MagPro unit with the MagOption or similar dual stimulators operating through a single coil.

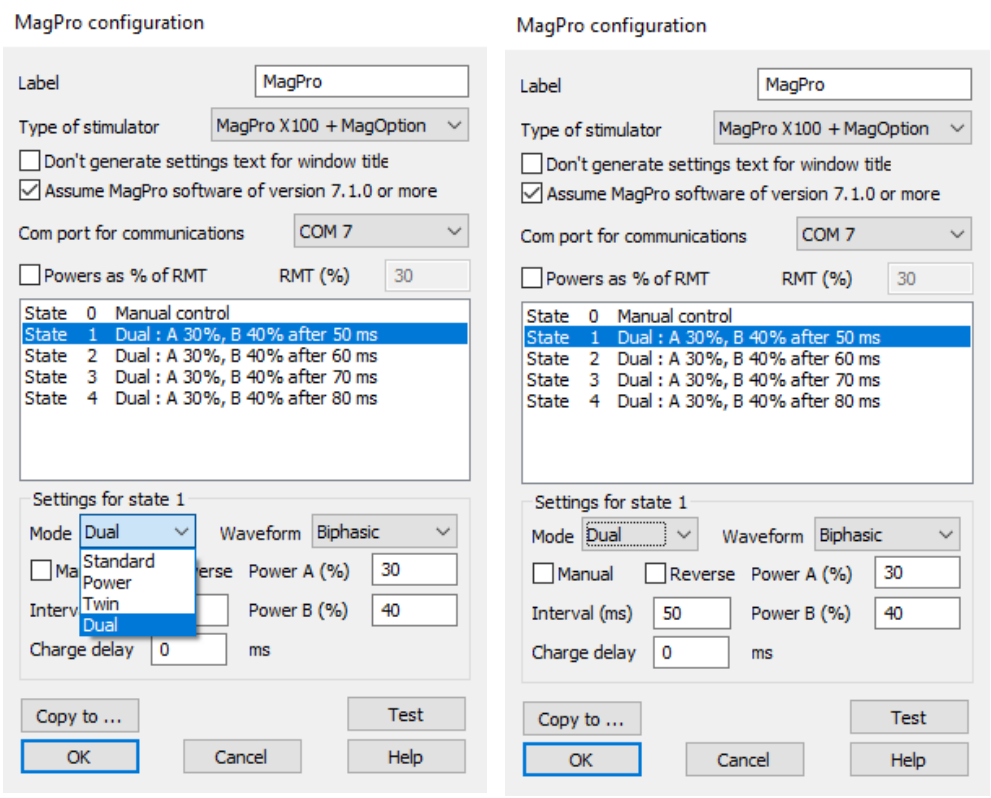
MagPro R30 + MagOption
MagPro X100 + MagOption

When combined with the MagOption, each of the MagPro devices is capable of delivering paired pulses at different power % outputs. However due to the setup of the devices, they are not suitable for most of the paired pulses configurations in this toolbox, as the pulses are not independently triggered by separate digital outputs.

The pulses need to be configured for each state in the auxiliary window, with the pulse interval, and power output % defined. To trigger the pulses you would then need to configure a TTL pulse in the pulses configuration of the Output tab in your sampling configuration. The first of the paired pulses would begin once the MagPro receives this TTL pulse.

An example is included overleaf, where the pulse interval increases by 10ms between states.

TMS Configuration
MagPro X100 + MagOption



Using the 'Mode' drop down menu allows to select from the following modes: 'Standard', 'Power' (X100 only), 'Twin', and 'Dual'. Either the 'Twin' or 'Dual' modes can be used for paired pulses.

In the examples above, 'Dual' mode has been selected which allows you to specify the power output % of the main unit (Power A) and the secondary unit (Power B). Selecting 'Twin' mode allows you to specify the output of the secondary unit as a fraction of Power A (a value between 0.2 and 5 can be entered).

The interval (ms) between pulses is also specified in each state. The above example increases the interval by 10ms in each state, with State 0 being manually controlled.

For further information, please consult the help text and the devices manual.

PowerMAG ppTMS

The PowerMAG ppTMS is capable of delivering two magnetic pulses of different intensities. Unlike the other devices however, there is no option to set this device to an 'independent triggering mode'. There is also no manual option available in Signal for this device. Furthermore, it is not possible to trigger the ppTMS with the 1401.

The device operates in configuring sequences of pulses for each stimulator through the TMS configuration window. As such this device is not compatible with most of the paired pulse configurations in this toolbox. The pulses need to be configured for each state, with the inter-stimulus interval, inter-train interval, inter-train interval variation, and repeats of stimulations all defined in the dialog.

PowerMAG ppTMS
Continued

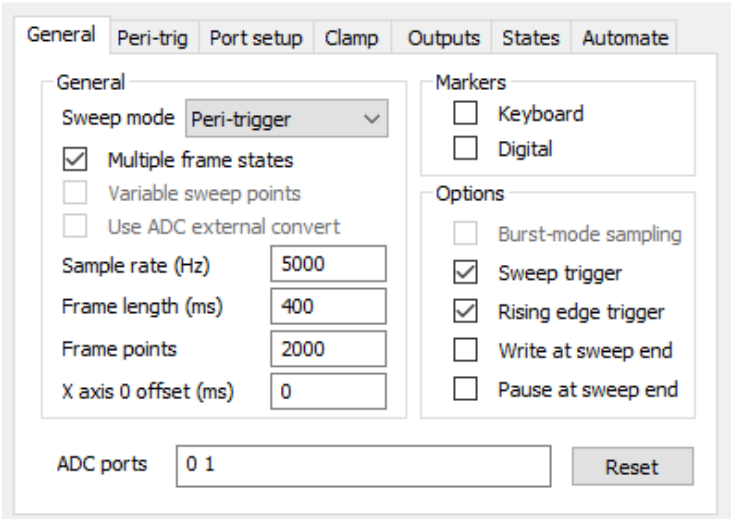
The sequence is initiated when the Signal sampling state changes. All of the stimulations within a given state use the same power level, so you should only need a different Signal sampling state when you need to change the power levels. There is an extra timing delay introduced by reprogramming the ppTMS when the sweep changes so in general you should try to avoid unnecessary state changes.

Each stimulation generates a TTL output pulse which is used to trigger the 1401 and cause a sampling sweep to be taken, so when the state changes a preset number of trigger pulses will be generated (as set by the PowerMAG configuration), after which no more stimuli or trigger pulses will occur until the PowerMAG is reprogrammed with a new sequence of stimuli. This means that your design of the stimuli generated by the PowerMAG must match the pattern of states sequencing set within Signal, or data acquisition will 'hang' waiting for sweep triggers that never occur.

PowerMAG ppTMS
Example

Consider this example of a sampling configuration that uses Numeric states sequencing, with two repeats of each state. This means that the PowerMAG stimulation sequence that is defined for each state must contain at least two stimuli. If the settings for state 4 only cause a single stimulus to occur then when sampling switches to state 4 it will set up the stimulator and then start to wait for sweeps of data. The first sweep will be triggered without problems, but the trigger for the second sweep will not occur and sampling will hang while waiting for the second sweep for state 4 to occur. So it is very important that you bear this restriction in mind while designing your experiments.

General Tab
PowerMAG ppTMS



Sweep mode Peri-trigger

Multiple frame states Enabled

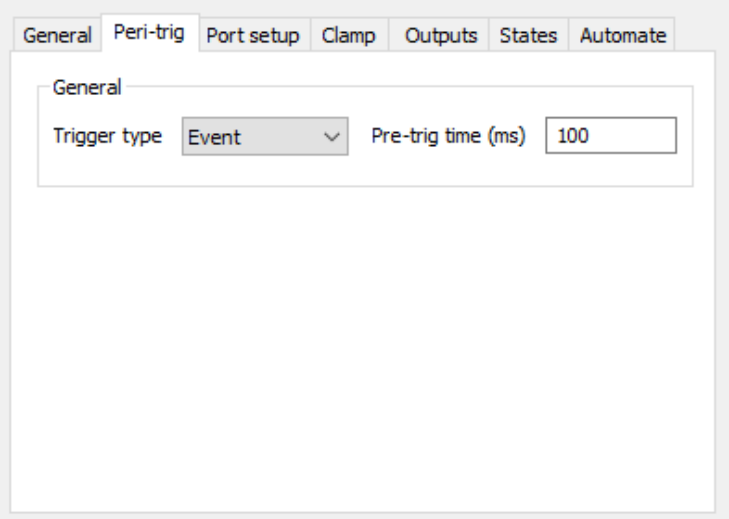
Sweep trigger Enabled

Rising edge trigger Enabled

Write at sweep end Optional

ADC ports Enable all ports in use

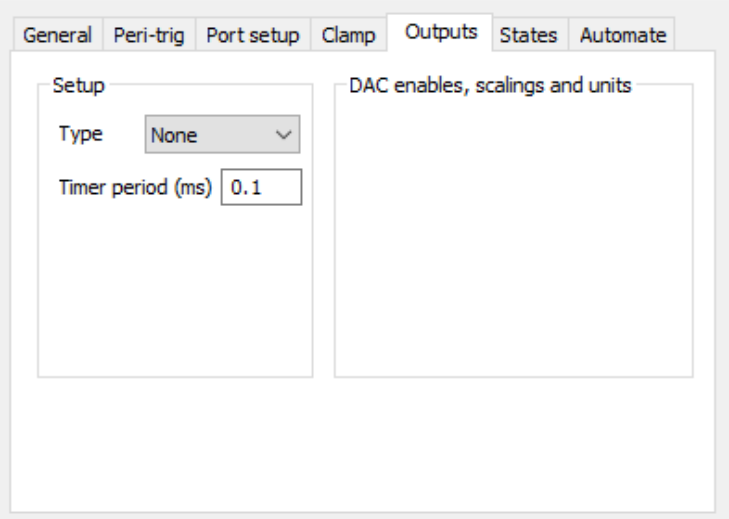
Peri-trigger Tab
PowerMAG ppTMS



Trigger type Event – the PowerMAG ppTMS will trigger a sweep for each stimulation. Connect the trigger-out connector on the rear of the ppTMS to the trigger-input on the front of the 1401

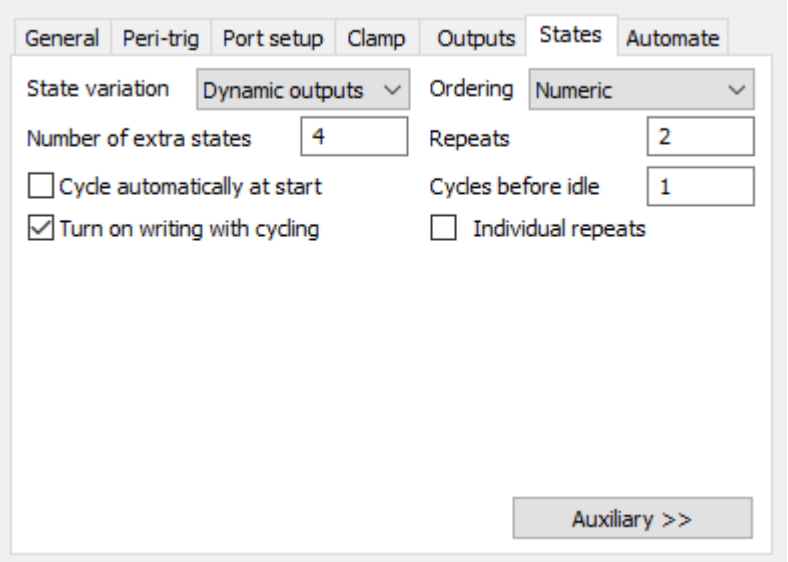
Pre-trig time (ms) 100

Outputs Tab
PowerMAG ppTMS



Type None – the 1401 cannot trigger the PowerMAG ppTMS

States Tab
PowerMAG ppTMS



Extra states 4 – use one state for each stimulation intensity

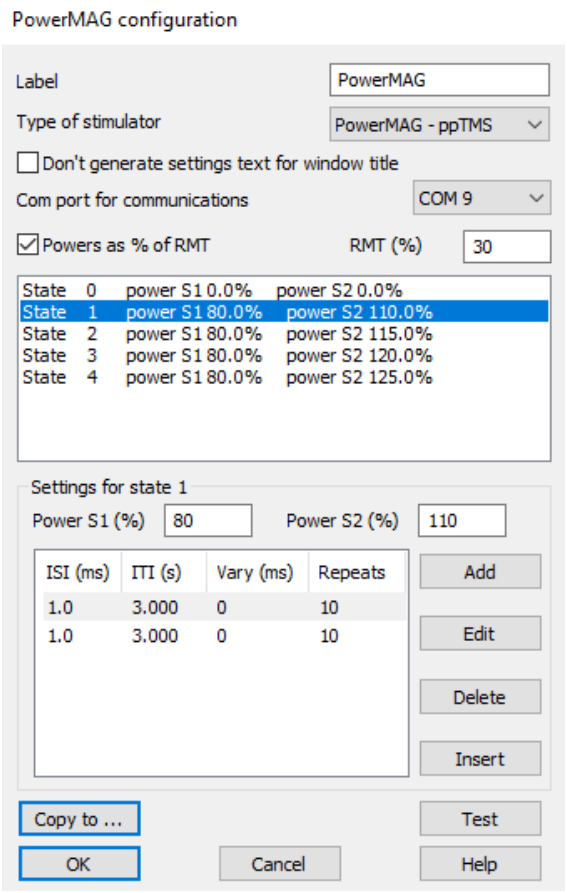
Repeats 2 – this will define the number of stimulations in each state

Cycles before idle 1

Ordering Numeric – other ordering methods can be used

Turn on writing with cycling Enabled

TMS Configuration
PowerMAG ppTMS



State 0 will still be our idle state, but with no manual mode the power intensity % of each unit has been set to 0.

Clicking on a state and then the 'Add' button to the right will open the 'Pulse Pair Values' dialog, which allows you to specify the parameters for your pulses. The number of stimulations must match the number of repeats specified in the States tab.

Please refer to the device manufacturers manual and the Signal help text for more information in setting up your PowerMAG device with Signal.

Neuro-MS Monophasic

A single Neuro-MS Monophasic stimulator is capable of most single pulse configurations.

It is possible to configure paired pulses with a single stimulator, however due to the recharge time the inter-pulse interval could be significantly longer than desired, hence it is more desirable to use either a Neuro-MS Paired Monophasic unit or similar dual stimulators operating through a single coil.

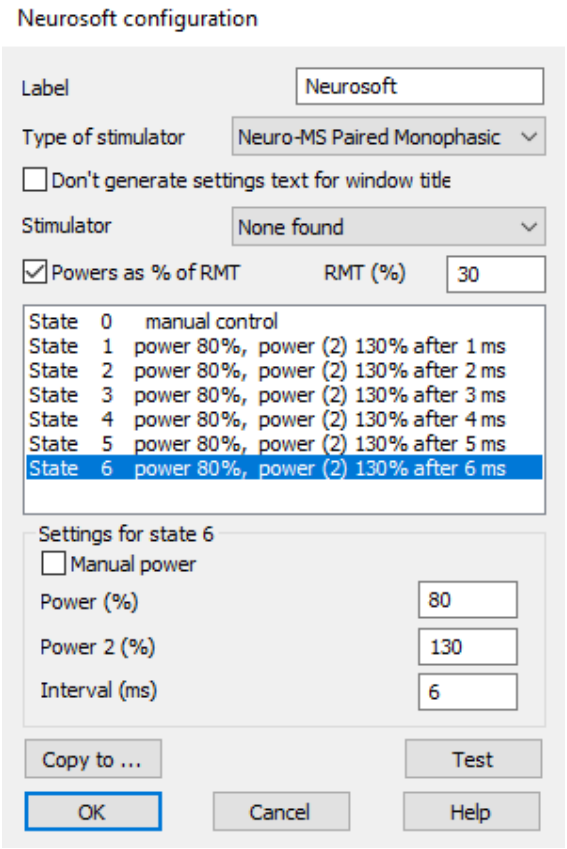
Neuro-MS Paired Monophasic

The Neuro-MS paired monophasic is capable of delivering paired pulses at different power % outputs. However due to the setup of the devices, they are not suitable for most of the paired pulses configurations in this toolbox, as the pulses are not independently triggered by separate digital outputs.

The pulses need to be configured for each state in the auxiliary window, with the pulse interval, and power output % defined. To trigger the pulses you would then need to configure a TTL pulse in the pulses configuration of the Output tab in your sampling configuration. The first of the paired pulses would begin once the Neuro-MS receives this TTL pulse.

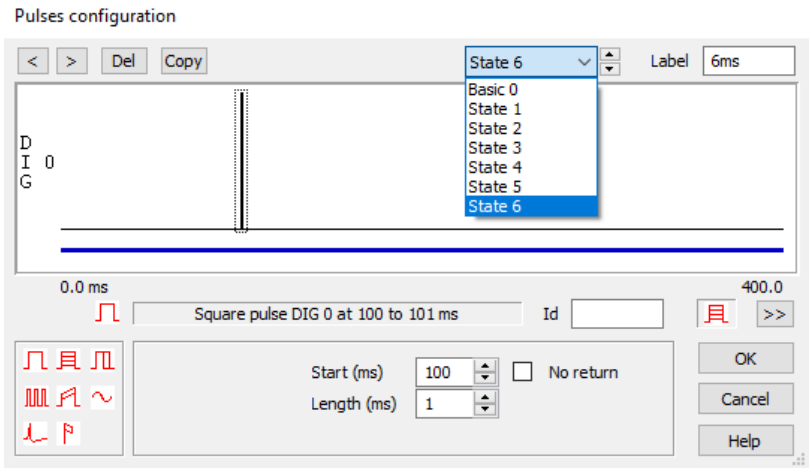
An example is included overleaf, where the pulse interval increases by 1ms between states.

TMS Configuration
Paired Neuro-MS



In this example, state 0 has been set to manual control. For states 1-6 the power output of the primary stimulator has been set to 80% of RMT. The power output of the secondary stimulator has been set to 130% of RMT. The interval between the two pulses increments by 1ms in each state from 1-6ms.

Pulse Configuration
Paired Neuro-MS



A single pulse has been generated on digital output 0 for each state except state 0, at 100ms into the sweep for 1ms in length.