

# EPhys Matlab Toolbox

Electrophysiology Experiment Software for TDT

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## Introduction

The EPhys toolbox for Matlab integrates with Tucker-Davis Technologies (TDT) OpenEx software package and real-time processing hardware to facilitate the design and control of electrophysiology experiments. The toolbox includes a control panel which runs the experiment, a protocol design utility for generation parameters for an experiment, and a utility for the automated calibration of simple acoustic stimuli. Some familiarity with the Matlab environment and basic principles of RPyds circuit design are important for implementing the EPhys toolbox. Creating new experiment protocols, however, requires no programming by the user; however, advanced dynamic Matlab scripts can be written to create more complex experiments.

There were several motivations for the designing the EPhys toolbox to extend OpenEx's capabilities. One motivation was to facilitate the design of complex multiparametric experiment protocols in a simple but powerful graphical user interface (GUI). This is accomplished with the Protocol Design Utility (**ProtocolDesign**) (p. 8).

A second motivation was to enable the use of high sampling rates (~200 kHz on some hardware) required for producing ultrasonic stimuli on the TDT real-time modules. The

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The **Function** column can take one of three options selected from a drop-down list. This field indicates whether the parameter tag is updated before each trial ("Write") or the value is read by EPhys Control Panel after each trial ("Read"). If both functions are required, then the "Write/Read" option should be selected. While most parameters will simply be used to update the parameter tags on the RPyds circuit, the "Read" functionality is useful for dynamic scripts.

## Values column

The **Values** column is the primary focus of the parameter table. This field is used to specify the values that the parameter (specified in the **Tag** column of the same row) will have for a protocol. In the example parameter table above, the "Frequency" parameter tag is associated with the values: **1000 2000 4000 8000 16000** (separated by spaces). These values will be used to update the "Frequency" parameter tag in the RPyds circuit example above. The same goes for the "Duration" parameter tag for the values: **25 50 100** (specified in milliseconds according to the Schmitt component requirements).

Instead of manually specifying a list of variables, the **Values** column will accept any Matlab code which evaluates to a scalar or vector. Any code which runs as a line item,

including function calls, in the Matlab command window will work in this field. For example, instead of specifying the values manually as in Figure 6, we could have also entered: `2000*2.^(0:3)` with the same result. Another example of valid input: `logspace(log10(1000),log10(42000),40)`

Clicking the **View Compiled** button (located below the table) brings up a new window with all permutations of specified parameter (Figure 7). In this Compiled Protocol table, each row starts with a trial number with each subsequent column a parameter value. Note that the total number of trials displayed in the table will be truncated if over 2000 trials are generated. The figure caption will indicate the total number of trials.

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For example: The circuit in Figure 5 (page 8) demonstrates a basic gated tone function. The **Frequency** parameter tag is linked to the **Freq** input of the Tone component and a second parameter labeled **~Frequency** is linked to the **Amp** input of the Tone component. This associated parameter should not be explicitly added to the parameter table in the Protocol Design Utility, but will be automatically generated when adding a calibration to the **Frequency** parameter. The values generated for the **~Frequency** parameter will be selected or calculated from the normalization curve in the calibration file. The result of this will be that each tone frequency presented during an experiment will be generated at a voltage which could produce a sound level (for example, 80 dB SPL) set during the calibration procedure. A PA5 programmable attenuator can then be used to attenuate the voltage to the intended sound level during an experiment.

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A few options (Figure 8) go along with each protocol file which control presentation of trials. The **Randomize** option will reorder the sequence of trials in a pseudorandom fashion.

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The **# Reps** field accepts a scalar value which indicates how many times to present each combination of parameters. A value of **5** would repeat all combinations of parameters 5 times.

The inter-trigger interval (ITI) field accepts either a single scalar value or two scalar values separated by a space (eg. **200 500**). If a single value is specified, then a constant time interval will be used between stimulus triggers. If two values are entered, then a random time interval will be used between trials within the specified range. The field is in milliseconds.

Finally, the name of a custom written function can be specified in the **Trial Select Function**. This function supplants and should extend the default trial selection functionality. This is an advanced topic which should be tested thoroughly before running an experiment. If a custom function is specified then it must be somewhere on the Matlab path.

EPhys Control Panel (**EPhysController**) (p. 9) accomplishes this by offloading stimulus triggers to the host computer. This approach, which has certain considerations discussed later, reduces the overhead (number of circuit components) required on to run an RPyds circuit which frees up additional processing power for circuit components required for various stimulation paradigms. An additional advantage of using the host computer to control stimulus triggering is the added capability for using custom Matlab scripts to dynamically select the next stimulus parameters based on previously acquired data (such as spike counts, field potential power, button presses, etc).

Thirdly, a Calibration Utility (**CalibrationUtil**) (p. 15) automates calibration of acoustic sources and creates standardized calibration files which can be used to normalize sound levels of parameters (such as stimulus frequencies).

Finally, the use of high-channel electrode arrays has dramatically increased the size and complexity of electrophysiological datasets. Efficiently maintaining, managing, and accessing these very large datasets is greatly facilitated by the use of a common database structure. To address this, the EPhys toolbox includes GUIs which can be used to upload acquired data and stimulus parameters to an SQL server as well as GUIs to navigate, access, and visualize stimulus-evoked responses.

# Hardware Recommendations, Software Requirements & Installation

## Hardware recommendations

The minimum requirements of EPhys toolbox are those of the installed version of Matlab and TDT software. The EPhys toolbox was developed on a standard quad-core processor personal computer with 4 GB of memory running Windows 7 64-bit operating system.

## Required software

The EPhys toolbox was designed in Matlab version R2011a and higher. The EPhys toolbox does not require any additional toolboxes to function; however, EPhys uses the OpenDeveloper ActiveX controls which can be obtained from TDT. OpenDeveloper is designed to interface with electrophysiology data structures and the OpenEx software suite to run an experiment.

If installing Matlab for the first time, it is recommended to Matlab install to a directory such as “C:\MATLAB\R2012b” (or whatever the current version) and not to the default “Program Files” directory. Installing into the default “Program Files” directory may cause problems with permissions when updating with TortoiseSVN on Windows Vista and later.

Currently, the EPhys toolbox is distributed using a software versioning (svn) system hosted by GoogleCode and additional software will be required to obtain the latest releases of the EPhys toolbox software (see next section).

## Obtaining and Using SVN

The software versioning system (svn) requires third-party software to be installed locally on the computer which will be used with the EPhys toolbox. TortoiseSVN is a free software package and can be downloaded here: <http://tortoisesvn.net/downloads.html>. Download and install the latest TortoiseSVN software version for your operating system (32-bit or 64-bit) using default options. Once installed, follow these steps to obtain the EPhys software:

1. Create a new folder called “work” in the Matlab root directory such as “C:\MATLAB\work”
2. Open the work folder in a Windows Explorer, right-click in the white space to open a context menu, and click the “SVN Checkout...” menu item.

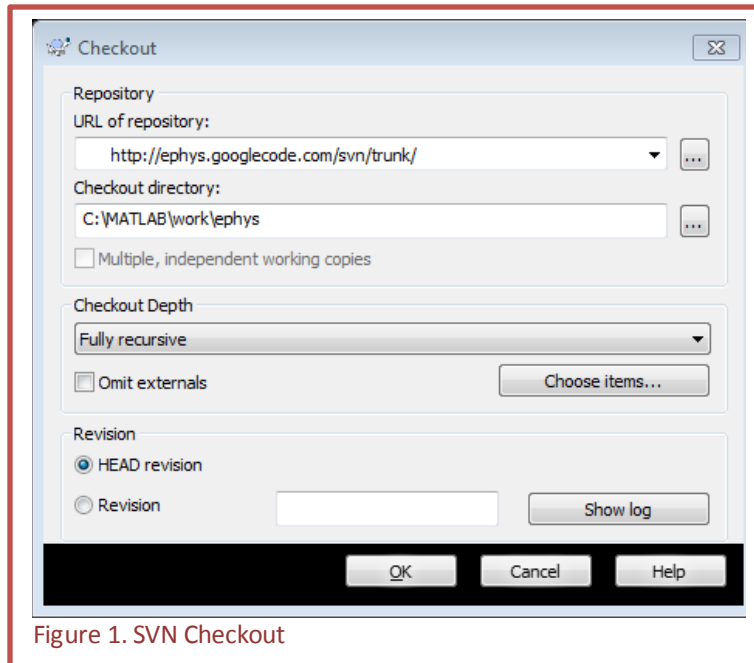


Figure 1. SVN Checkout

3. Enter the following information into the Checkout prompt and click OK.
  - a. URL of repository: <http://ephys.googlecode.com/svn/trunk/>
  - b. Checkout directory: C:\MATLAB\work\ephys
4. A dialog should appear as the EPhys software is downloaded.

The versioning system allows those using the software to easily update files for updates and bug fixes by right-clicking the parent folder (such as: "C:\MATLAB\work\ephys") and selecting "SVN Update" from the context menu. This system also provides the opportunity for distributed collaboration on future software developments.

A wiki page can be found at <https://code.google.com/p/ephys/wiki/Intro>. This wiki provides a place where issues can be raised, discussed, and addressed with software fixes. This requires a Google account.



## EPhys Toolbox Overview

The EPhys toolbox for Matlab is designed to integrate with the OpenEx software package provided by TDT. The OpenWorkbench program, included in the OpenEx package, should be used to define which TDT real-time hardware will be used during an experiment. Please refer to the TDT OpenWorkbench documentation for details on how to do this.

### Creating a New Experiment

The procedure for designing new experiments with EPhys begins with assigning labels and RPvds files to the TDT hardware modules using the Device Navigator of OpenWorkbench (TDT). While labels are arbitrary in reality, descriptive labels should be used in practice. One example would be to use the label **Stim** for a module (such as an RP2.1, RX6, RZ6, or other module) which will be used to control stimulation during the experiment, such as a speaker or light. If multiple stimulus modules are to be used in an experiment then names such as **Stim1** and **Stim2**, or **SpeakerStim** and **LightStim** can be used (**Error! Reference source not found.**). One or multiple data acquisition modules (such as an RX5, RZ5, or other module) can be assigned a label in a similar manner (**Acq**, for acquisition device, is used in Figure 2). Note that not all modules need to be populated. The labels assigned in the Device Navigator of OpenWorkbench will be used to direct parameters during protocol design using the EPhys toolbox.

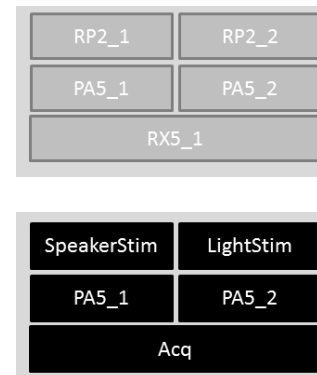


Figure 2. Unpopulated (top) and populated (bottom) device navigator

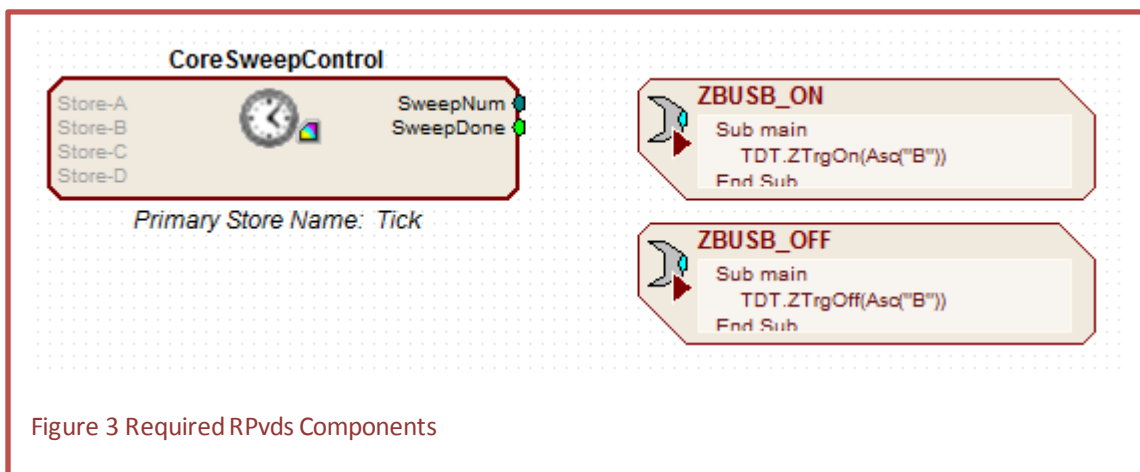
*NOTE: Programmable Attenuator PA5 modules should be labeled PA5 followed by a suffix if desired as is in the example in Figure 2.*

An RPvds file (with the extension .rcx) should be assigned to each real-time module which is defined in the Device Manager (see TDT documentation for details). The conventions for designing RPvds files for use with OpenWorkbench are outlined in the TDT documentation and should be followed. There are a few requirements for RPvds circuit designs when using EPhys to control experiments that will be discussed next.

### RPvds Requirements

For the majority of experiment designs, the EPhysController (discussed on page 13) controls parameter values and timing of stimulation of the TDT hardware modules (defined in the OpenWorkbench Device Navigator; see page 6). EPhysController first updates all parameter

tags on real-time modules as well as any PA5 programmable attenuators, and then uses the **zBus B** trigger issue a synchronised trigger pulse across all real-time modules. In order to accomplish this from Matlab two custom scripts must be included on one of the RPvds modules



in use. The two script components in Figure 3 must be titled **ZBUSB\_ON** and **ZBUSB\_OFF** and may be copied from an example RPvds document.

The **CoreSweepControl** macro (left component in Figure 3) handles module synchronization and is required to be included in every RPvds file. This macro is available in RPvds by clicking the Components menu and selecting Circuit Macros.

*Note: If using multiple RPvds circuits, each CoreSweepControl macro must have a unique primary store name. This can be modified by double clicking the macro object in RPvds, clicking the Setup tab, and then Change button. Any four letter name can be used (eg, Tock).*

## Protocol Design Utility (`ProtocolDesign`)

The Protocol Design Utility is a graphical user interface which is used to specify the values of parameters for an experiment. A simple example of this would be to specify all frequency and sound level combinations for a tone-evoked receptive field experiment. Instead of manually specifying every frequency/level combination, of which there may be hundreds or thousands of combinations, one can use the Protocol Design Utility to specify which frequencies and which sound levels should be presented and the utility permutes these parameters to create a list of stimuli for the experiment.

### Creating a New Protocol

Before creating a new protocol, an OpenWorkbench project should be created as described above (see Creating a New Experiment on p. 6). The Protocol Design Utility can be launched in two ways. The command `ProtocolDesign` can be entered into the Matlab command window directly. Alternatively, clicking the “P” icon on the

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Finally, the name of a custom written function can be specified in the **Trial Select Function**. This function supplants and should extend the default trial selection functionality. This is an advanced topic which should be tested thoroughly before running an experiment. If a custom function is specified then it must be somewhere on the Matlab path.

EPhys Control Panel (**EPhysController**) (p. 9) toolbar will launch the utility.

### Adding/Removing Modules

Creating modules in OpenWorkbench was covered in an earlier section (see Creating a New Experiment, p 6). The labels for modules defined in OpenWorkbench can be added to or removed from the protocol design by clicking the “+” or “-” buttons, respectively. Clicking the “+” button will launch a dialog box in which the user should enter the label (capitalization matters) of one module at a time.

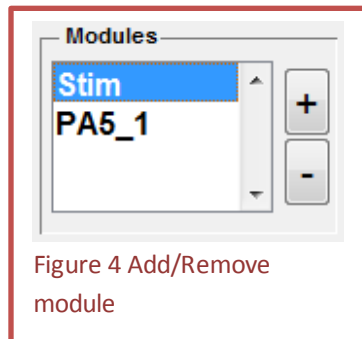


Figure 4 Add/Remove module

### Working With Parameter Tags

Once a module has been added to the protocol, parameters can be specified using the table on the right of the Protocol Design Utility.

The R Pvds circuit ot the right is a simple example of an R Pvds circuit which plays tones of various frequencies and durations. The R Pvds circuit to the right is one realization of such a design. The parameter tags (ParTag components) called **Frequency** and **Duration** are linked to the **Freq** parameter of the Tone generating component and the **Thi** parameter of the Schmitt logic component, respectively (the **~Frequency** tag is discussed on page 10).

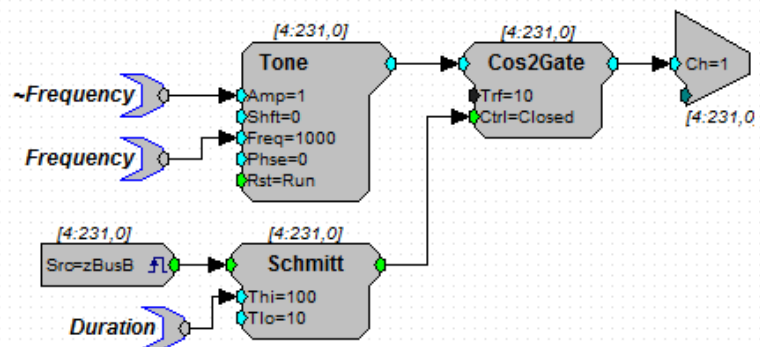


Figure 5 Example R Pvds circuit using parameter tags (ParTag component)

The **Frequency** and “Duration” parameter tags are entered (case sensitive) into the “Tag” column in the Protocol Design Utility parameter table. The other columns of the table are

Tag	Function	Buddy	Values
Frequency	Write/Read ▼	< NONE > ▼	1000 2000 4000 8000 16000
Duration	Write/Read ▼	< NONE > ▼	25 50 100

Figure 6 Protocol Design Utility parameter table with example of parameter tags (ParTag) specified in the RPyds circuit.

used to specify the values and how the parameter functions.

	Stim.Frequency	Stim.Duration
1	16000	50
2	2000	25
3	4000	25
4	8000	25
5	8000	50
6	2000	50
7	4000	50
8	1000	50
9	1000	25
10	2000	100
11	16000	100

Figure 7 Example of a compiled

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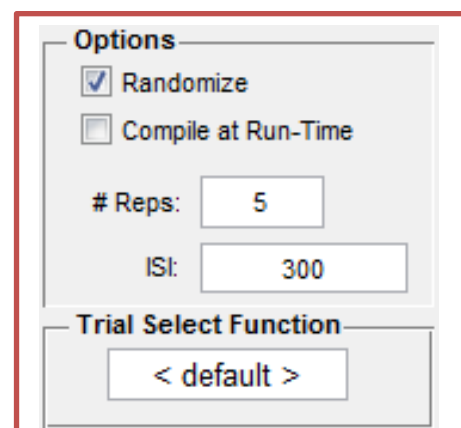


Figure 8 Protocol Design options

interval will be used between trials within the specified range. The field is in milliseconds.

Finally, the name of a custom written function can be specified in the **Trial Select Function**. This function supplants and should extend the default trial selection functionality. This is an advanced topic which should be tested thoroughly before running an experiment. If a custom function is specified then it must be somewhere on the Matlab path.

## **EPhys Control Panel** (EPhysController)

The EPhys Control Panel controls physiology experiments in conjunction with OpenEx software. To launch the program, enter **EPhysController** into the Matlab command window and hit enter. To begin an experiment:

1. OpenProject must be open on the same computer and the OpenWorkbench Device Manager (see on page 6) should be set for the intended experiment.
2. Create a new tank or select an existing tank using the left panel of the EPhys GUI.
3. Click the **Locate Protocols...** button and select a directory containing one or multiple protocol files.
4. Click **Record** to begin an experiment.
5. Progress of the experiment will be displayed at the bottom of the EPhysController and the software will automatically stop after finishing and reset for the next protocol.

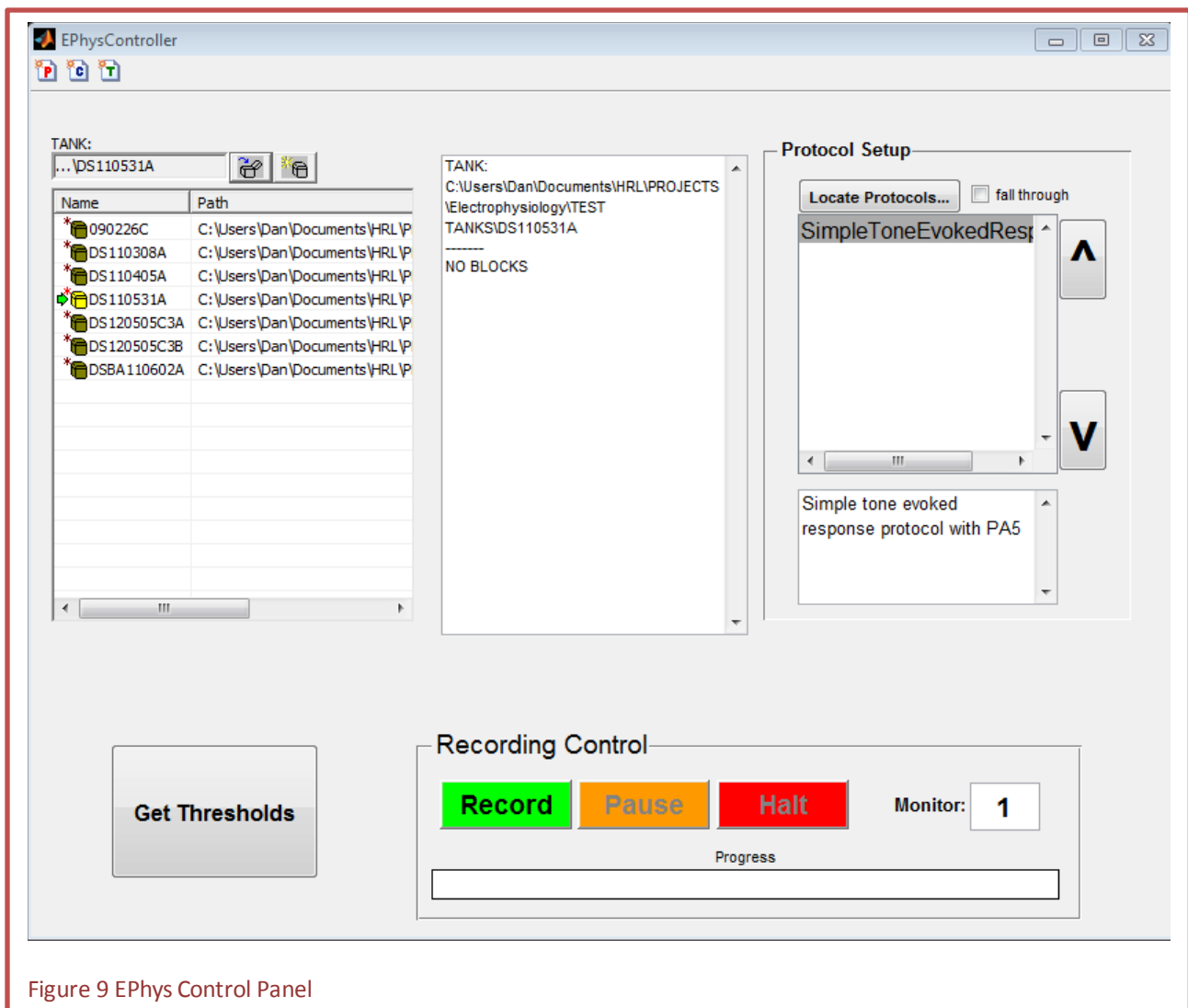


Figure 9 EPhys Control Panel

## Calibration Utility ([CalibrationUtil](#))

The screenshot shows the 'Calibration Utility' window. It has a title bar with the MATLAB logo and the text 'Calibration Utility'. The interface is divided into several sections: 'Hardware', 'Stimulus', and 'Calibration'. The 'Hardware' section contains a 'Stim' group with 'GB', 'RX6', '1', and '100 kHz' dropdowns, and an 'Acq' group with 'RP2' and '1' dropdowns. The 'Stimulus' section has a 'Tone' dropdown. The 'Calibration' section shows '57.4 mV RMS = 114 dB SPL' and 'Ref. Piston Norm = 100 dB SPL'. A large 'Run' button is on the right.

**Calibration Utility**

**Hardware**

**Stim**

GB RX6 1 100 kHz

**Acq**

RP2 1

**Stimulus**

Tone

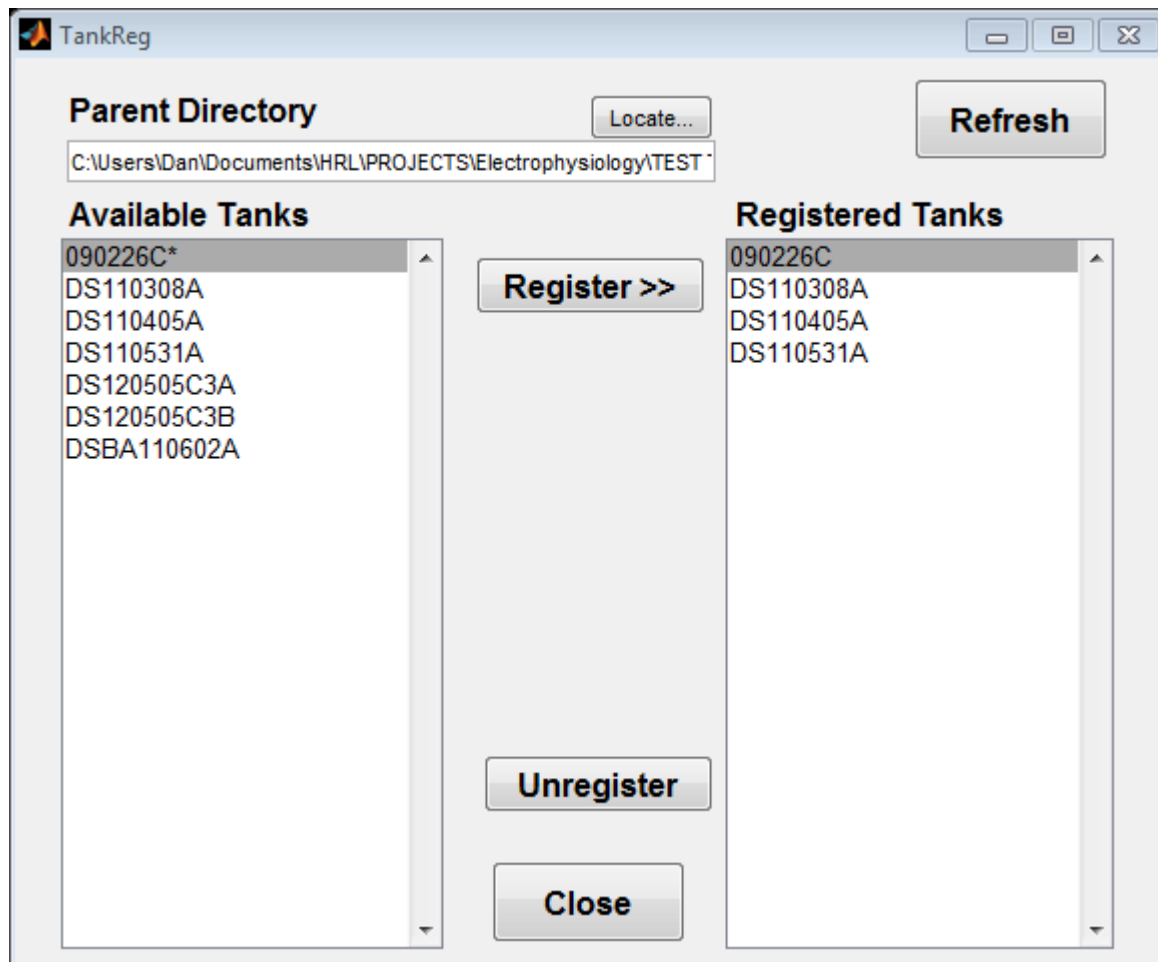
**Calibration**

57.4 mV RMS = 114 dB SPL

Ref. Piston Norm = 100 dB SPL

**Run**

## Tank Registration (TankReg)



## Database Browser (DB\_Browser)

The screenshot displays the DB\_Browser application window. At the top, a 'Settings' tab is active, showing a dropdown menu for 'Databases' set to 'ac\_hp\_salicylate\_acute'. Below this, there are five main panels: 'Experiments', 'Tanks', 'Blocks', 'Channels', and 'Units'. Each panel contains a list of items, with some items highlighted. The 'Units' panel also features a line graph showing a signal over time, with a scale factor of  $\times 10^{-4}$ . The graph shows a sharp dip around 10 units, followed by a rise and then a plateau. Below the graph are buttons for 'show all', 'Exclude', 'Get Spiketimes', 'Get Protocol', and 'Get LFP'.

**Settings**

**Databases**

ac\_hp\_salicylate\_acute

**Parameters** **Plot**

**Experiments**

- 090814
- 090825
- 090810
- 090902
- 090908
- 090917
- 091001
- 091007
- 091014
- 091102
- 091109
- 091109b
- 091118
- 091118b

☐ show all **Exclude**

**Tanks**

- baseline-SS [090908A]
- 0h-SS [090908B]
- 1h-SS [090908C]
- 8D]
- 3h-SS [090908E]
- 4h-SS [090908F]

☐ show all **Exclude**

**Blocks**

- eFRA [1]
- tRLF [2]
- Spont [3]

☐ show all **Exclude**

**Channels**

- AC001
- AC002
- AC003
- AC004
- AC005
- AC006
- AC007
- AC008
- AC009
- AC010
- AC011
- AC012
- AC013
- AC014
- AC015
- AC016
- HP017

☐ show all **Exclude**

**Units**

- MUA (18852)
- SU1 (5113)

$\times 10^{-4}$

2  
1  
0  
-1  
-2

10 20 30

☐ show all **Exclude**

**Get Spiketimes**

**Get Protocol** **Get LFP**

