TSC Dashboard Software

Help Manual

ISU ECpE Senior Design Group May14-03

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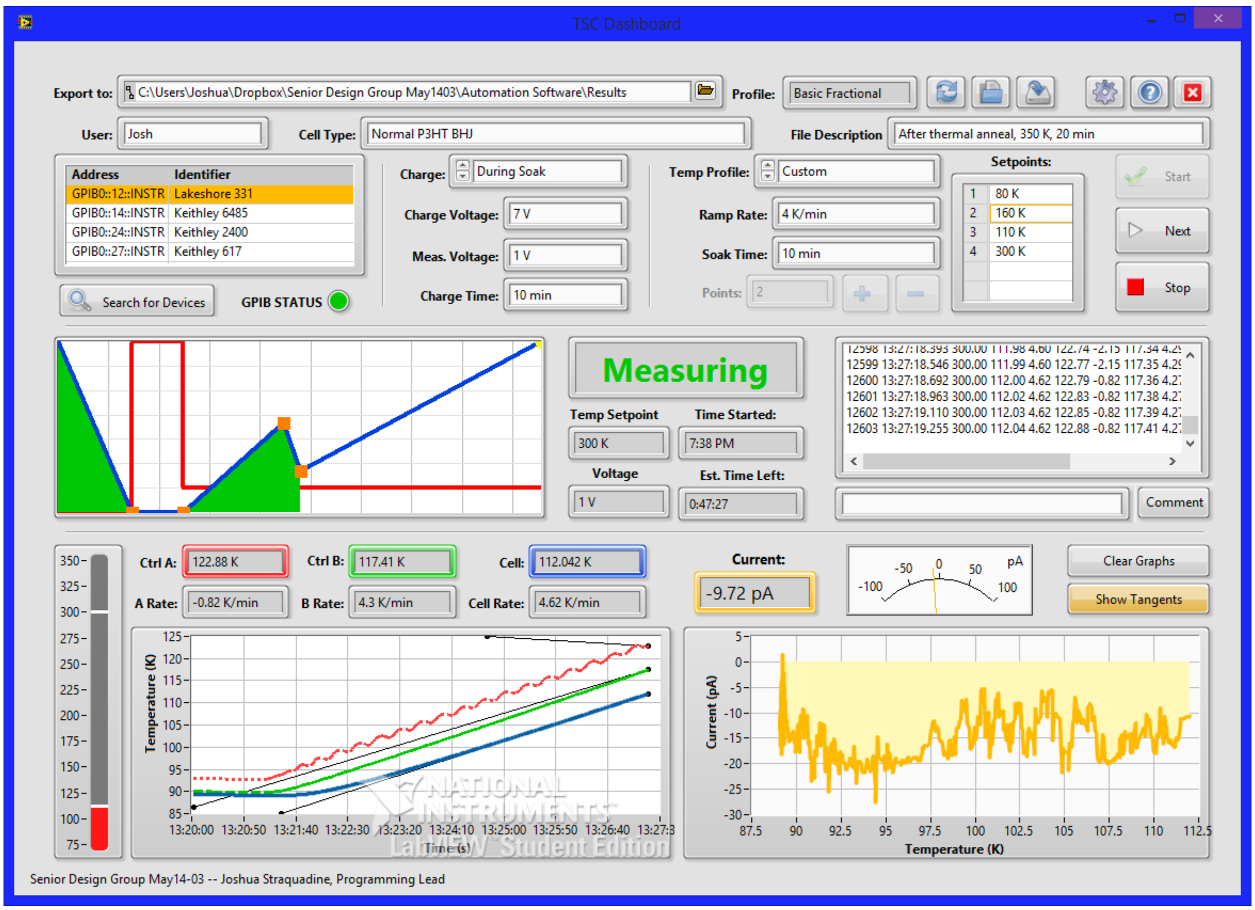
(*Team Leader and Programming Lead)

This program was written using LabVIEW Student Edition 2012. Compatibility with earlier versions of LabVIEW is not guaranteed.



Contents

1 Thermally Stimulated Current Experiment Process

1.1 Initialization/Parameter Entry

Immediately upon opening the program, the front panel is initialized for parameter entry. Using the File Controls, Profile Controls, GPIB Settings, and Experiment Parameters (described in Sections 2.1-2.4) as well as the Advanced Settings dialog (Section 3), the user has complete control over designing TSC experiments. This phase ends when the user completes the setup and clicks the "Start" button. At that point, any parameters are locked in until the experiment completes, or is aborted by the user.

1.2 Cooling

When the experiment begins, it automatically places the system in the cooling phase, in which the heater is turned off and the temperature allowed to drop. Depending on the chosen charge profile, the voltage source may or may not turn on during this phase. Once the sample reaches the desired temperature, this phase ends and the soak phase begins.

1.3 Soaking

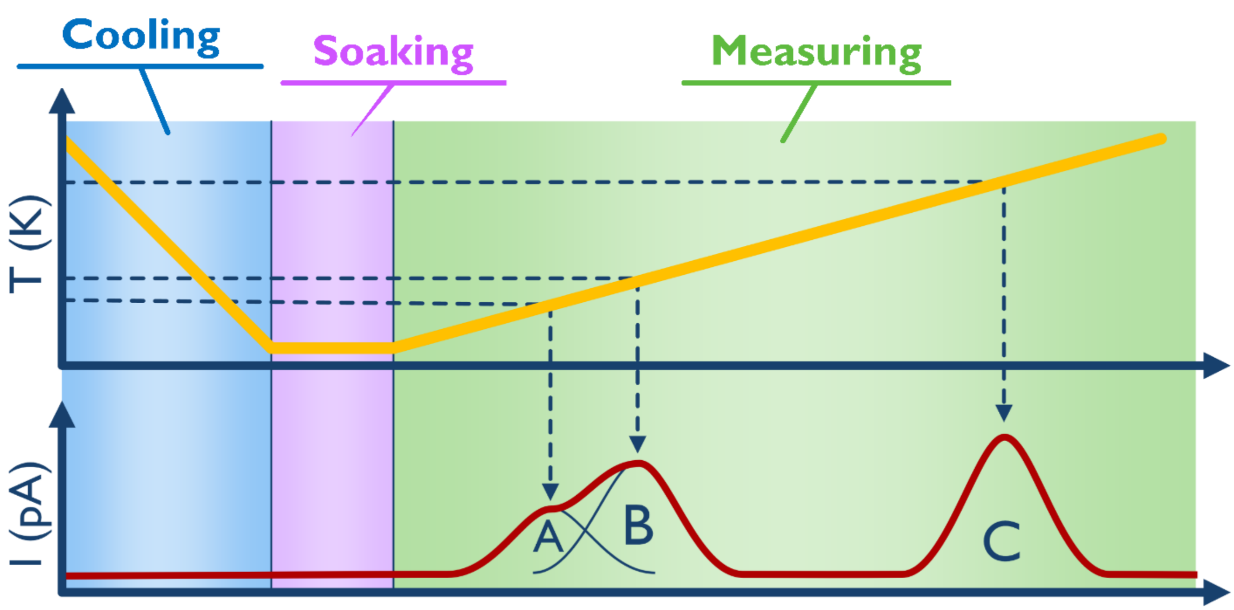
Reaching the desired temperature is not always enough to ensure a high-quality experiment. In order to minimize any thermal gradients, which may cause parasitic thermoelectric currents, the sample is allowed to soak at the desired temperature for a determined amount of time. This time period often also doubles as the charging period. The sample stays in this mode until the soaking time expires.

1.4 Measurement

Following the soak, the system enters the measurement phase. Here the system turns on the voltage source to the measurement voltage and proceeds to ramp to each input temperature in turn. When ramping up, the system controls the rate to match the desired ramp rate, and when ramping down the system does so as fast as possible by turning the heater off. The system forces the last setpoint to be 300 K, and the experiment is complete once this temperature is reached.

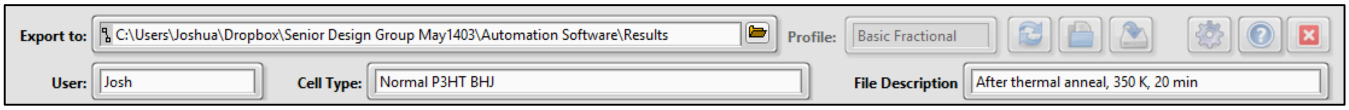
1.5 Completion

Once the system has completed its experiment, it will complete the export of the log file and reset the equipment to the defaults. It will then give the user an option to run another experiment or to close the program. If the user chooses to run another experiment, the system will by default keep the parameters from the last experiment.



2 Front Panel Anatomy

2.1 File Controls



2.1.1 Export Directory

The “Export To:” text box allows the user to specify the folder to which log files will be saved. Either type the name of the folder directly into the box, using the arrow keys to show wrapped text if the directory is too long, or click the small folder icon on the right side of the box. This opens up an explorer window, where the user can navigate to the desired folder. Once inside the folder, click on the “Current Folder” button on the bottom of the dialog. Log files will now be saved to this folder.

2.1.2 User

The “User” text box serves two purposes:

1. The name entered on the front panel is saved in the log file as a way to remind viewers of the file who ran the experiment and ease data analysis, which can often occur days or weeks after the experiment itself
2. During an experiment, the name remains visible on the front panel, such that if the user steps away from the system, others in the lab will know who is running the experiment.

Simply type a name in the box, then press <Enter> or click somewhere else on the front panel.

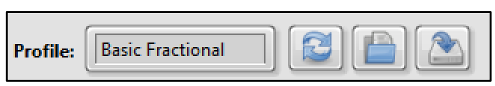
2.1.3 Cell Type

The “Cell Type:” text box allows the user to notate not only the cell type, but also any desired processing parameters or other unique identifiers. This identifier is the first part of the filename of the log file, as described more thoroughly in Section 4.1.1. Type the desired information into the box, then press <Enter> or click elsewhere on the front panel.

2.1.4 File Description

The “File Description:” text box serves only to add more information to the log file, to ease file identification at a later date. Simply type the desired information into the box, then press <Enter> or click elsewhere on the front panel.

2.2 Experiment Profile Settings



In order to decrease experiment setup time and improve repeatability, the program allows a user to save experiment profiles, which contain all of the parameters in the front panel (Section 2.4) and from the Advanced Settings panel (Section 3). Experiment profiles are easily legible text files (*.txt) which are saved in the “Profiles” subfolder of the program’s root directory. Please do not move or delete this folder.

The name of the current profile is displayed at the top of the front panel. If the name is followed by an asterisk (*) then one or more settings have been changed since the profile was last loaded. These changes are not automatically saved in memory, and will be lost if the user closes the program without saving them.

2.2.1 Save Experiment Profile

Once an experiment has been designed as desired and all of the parameters inputted, the user can save the experiment as a profile by clicking the Save button at the top of the front panel. This will open a small dialog in which the user is asked to input a profile name.
The filename cannot contain any of the following characters: \ / : * ? “ < > |

Upon clicking the "OK" button in this dialog, all of the current values on the front panel and in the advanced setting dialog will be saved under that name. If a profile with the name already exists, the user will be asked if they are sure they want to overwrite the file, as any old settings within that file will be lost.

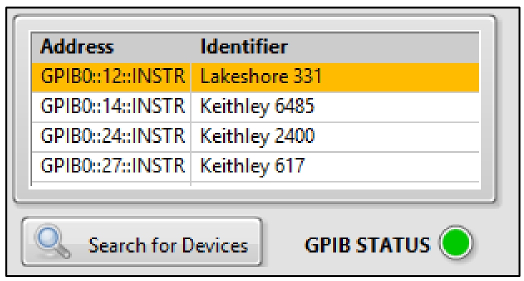
2.2.2 Load Saved Profile

Once a profile has been saved, it can easily be loaded by clicking the Load button at the top of the front panel. This will open a dialog showing the user all of the existing profiles in the Profiles folder. Select one by left-clicking on the name of the desired profile, then clicking OK. If any unsaved changes had been made to the parameters on the front panel or in the advanced settings, then they will be lost when the new profile is loaded.

2.2.3 Refresh profile

The "Refresh" button at the top of the front panel discards any changes that have been made to the settings on the front panel or in the advanced settings dialog and reloads the experiment profile named in the text box. Unsaved changes are irrevocably lost when this is done.

2.3 GPIB Addresses



The Dashboard program communicates with the necessary instrumentation through the GPIB protocol.

2.3.1 Connected Devices

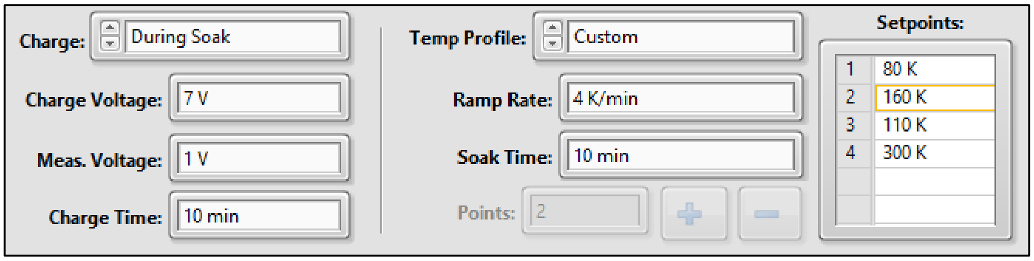
The "Connected Devices listbox" shows all of the devices which are compatible with the software.
The software is set up to communicate with the following devices: Lakeshore 331, Keithley 2400, Keithley 617, and Keithley 6485. If none of these are found, the listbox will display "GPIB Error—Check connection" in the first line. If at least one device is found, the system will still allow an experiment to take place, but will not report those data points which rely on the missing equipment.

The GPIB Status indicator light glows green if the GPIB bus is active and at least one compatible device has responded to the query. If no devices have been found, the indicator light turns red.

2.3.2 Search for Devices

The "search" button sends out a general identification query to every device on the GPIB bus. Every device responds with its bus address, manufacturer, model number, and other relevant information. This data is then used to update the Connected Devices listbox (Section 2.3.1) and the GPIB Status indicator.

2.4 Experiment Parameters



The experiment parameters section of the front panel allows the user to enter all of the desired settings to design the experiment. These parameters are only available up until the user begins the experiment, at which point they are locked in and become static on the front panel. The setpoints will remain visible, as a reminder to the user of what is being run.

2.4.1 Charge Types

2.4.1.1 During Soak

When "During Soak" is selected, the charging voltage will be applied to the system when the cooling phase ends and the soak phase begins. The charging voltage will be applied for the duration of the "Charging Time" (Section 2.4.4) which must be less than or equal to the "Soak Time" (Section 2.4.7). If the charging time is less than the soak time, no voltage will be applied during the time period after the charge time has expired and before the measurement begins.

2.4.1.2 While Cooling

When the "While Cooling" option is selected, the charging voltage will be applied at the beginning of the cooling phase, and will remain on until the soak phase begins. This allows for non-isothermal filling of trap states. Under this configuration, zero voltage bias will be applied to the sample during the soak phase. With this configuration, there is no option to input the charge time, as it depends on the cooling rates of the sample.

2.4.1.3 Until Measurement

Under the "Until Measurement" configuration, the charging voltage is applied during the entirety of both the cooling phase and the soak phase. With this configuration, there is no option to input the charge time, as it depends on the cooling rates of the sample.

2.4.2 Charge Voltage

The "Charge Voltage" setting on the front panel dictates the voltage applied to the cell during the charging phase, as explained in Section 2.4.1. The voltage is constant at this value and accurate to the rated accuracy of the voltage source instrument attached to the system.

2.4.3 Measurement Voltage

Once the temperature ramp-up has begun, the system applies the "Measurement Voltage" to the sample, which helps to collect de-trapping electrons and create the thermally stimulated currents. This voltage is constant from the end of the soak cycle until the end of the experiment.

2.4.4 Charge Time

When the "During Soak" option is selected for the charge type (see Section 2.4.1) the "Charge Time" option dictates the duration of the charging phase. The charging voltage is applied for that duration, starting at the beginning of the soak cycle. The charge time must be less than the soak time so that the measurement voltage can be applied at the beginning of the ramp-up.

2.4.5 Temperature Profiles

2.4.5.1 Basic Ramp

The "Basic Ramp" option simply lowers the sample to the desired temperature, soaks for the desired time, and then increases the temperature continuously at the desired rate until the temperature returns to 300 K. This mode supports no more than two temperature setpoints, and the second must always be 300 K for safety reasons.

2.4.5.2 Base/Peak

The "Base/Peak" option creates the option of conducting fractional emptying experiments, with the stipulation that each cooling cycle returns the sample to the original baseline temperature. This mode requires three or more setpoint values, the first of which is the baseline temperature, and each successive temperature is the height of a temperature peak. No charging or soaking will occur between peaks. While the height of each peak is variable, all of the ramp-up phases will occur at the same rate The number of peaks can be changed using the "+" and "-" buttons next to the "Points" indicator (Section 2.4.8) The final peak value must be 300 K for safety reasons.

2.4.5.3 Custom

The "Custom" option allows users complete control over the temperature profile of the experiment, and requires at least 4 setpoints. The first setpoint should be the lowest, as this is where the soak will take place. Each successive point can be the height of a peak or the depth of a valley between peaks. No soaking or charging will take place between successive peaks, and all ramp-up phases will occur with the same ramping rate. The number of points can be changed using the "+" and "-" buttons next to the "Points" indicator (Section 2.4.8)

2.4.6 Ramp Rate

The "Ramp rate" field allows the user to define the rate at which the temperature ramps up during the measurements. The number chosen here will have no effect on the cooling sections, as temperature rate controller is disconnected and the heater forced off for cooling phases. In temperature profiles with more than one heating phase, all phases are subject to the same heating rate.

2.4.7 Soak Time

The "Soak time" defines how long the temperature will be held at the first setpoint once it is reached. If the "during soak" charging option is selected, the soak time must be greater than or equal to the charge time. Regardless of the number of peaks in the temperature profile, the soak time is only applied after the cooling phase.

2.4.8 Points

The numerical "Points" input dictates how many different temperature setpoints are used in the experiment. Under the Basic Ramp profile (Sec. 2.4.5.1), only two setpoints are used, so the "points" indicator is disabled. In the Base/Peak and Custom modes, any number of points above three and four, respectively, are allowed. Adding and subtracting points is accomplished by clicking the "+" and "-" buttons next to the numerical box.

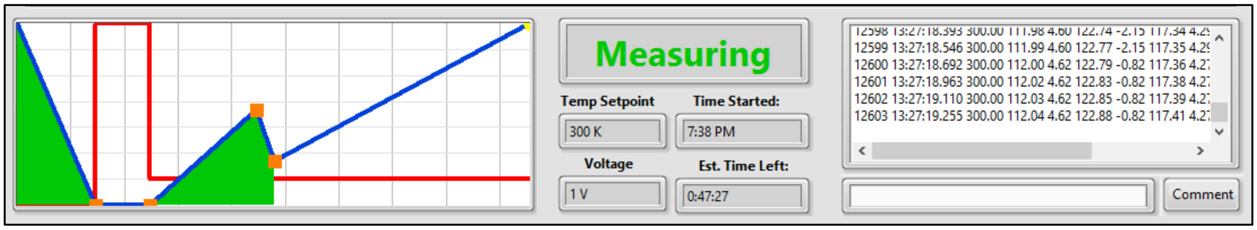
2.4.9 Setpoints

The "Setpoints" box allows the user to type in temperatures (in Kelvin) to use in designing the experiment. The entries in the box are limited by the following constraints:

- The number of boxes allowed to have values is limited by the "points" indicator (Section 2.4.8)
- The value of each setpoint must be within the maximum and minimum temperature ranges as defined within the advanced settings dialog.
- The last point must always be 300 K for safety reasons

The impact each setpoint has on the experiment as a whole will be defined by the chosen profile type (Section 2.4.5)

2.5 Experiment Progress Section



2.5.1 Schematic Timeline

Before an experiment is commenced, the schematic timeline gives the user a quick overview of the parameters, making it quick and easy to find and correct small errors or typos before the experiment takes place. The red line shows the voltage to be applied, while the blue line shows the temperature ramps to be conducted. While the timeline is not clickable and has no direct interactivity, the orange squares denote which vertices on the graph may be altered under the selected temperature and charging schemes. The timeline updates after every change of settings.

During an experiment, the progress of the experiment is shown by a small yellow dot, which is located at the present temperature setpoint on the graph. A green fill line moves across the graph as well, showing all of the setpoints which have already been achieved. The point does not move linearly as a progress bar would, but rather moves only at the transitions between setpoints.

The timeline is not to scale. The axes are arbitrary, and the y-axis for the temperature curve is in fact logarithmic. Do not attempt to read parameters from the timeline--read them from the numerical inputs instead.

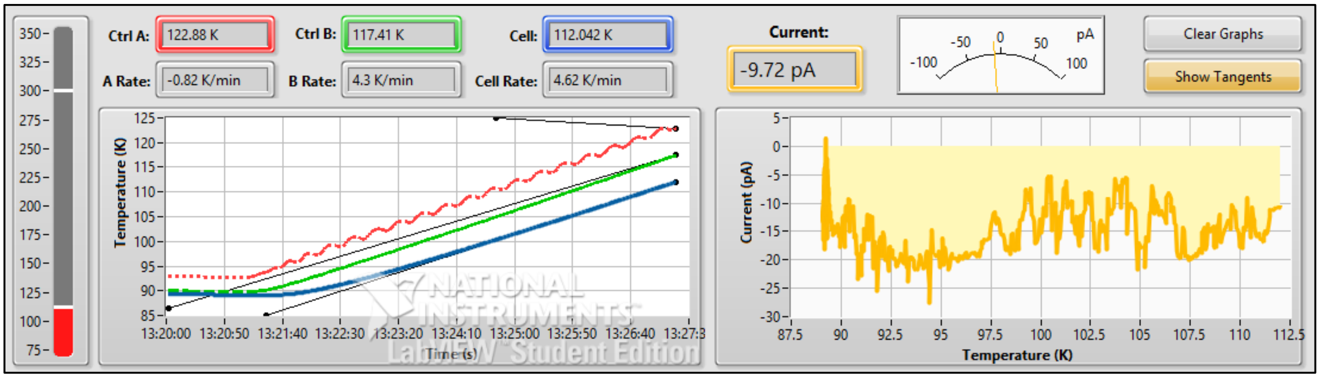
2.5.2 Progress Indicators

The five progress indicators between the schematic timeline and the log output window indicate present values for the experiment phase (Cooling, Soaking, and Measuring), the temperature setpoint, and the voltage. Also, the time when the experiment was started (measured at the moment the “Start” button was pressed) and a rough estimate of the remaining time until the end of the experiment.

2.5.3 Log File Readout and Comment Button

The log file window shows in real time the data being written to the log file. To save processing power and improve computation time, the log window only displays the last 800 lines. Using the scroll bar, the user can pause the log temporarily and examine any events of interest, until those lines are out of range or until the mouse pointer leaves the log window. To ease analysis, th user also has the ability to insert comments into the log file by typing a message into the input box beneath the log output and pressing the “Comment” button. The text of the comment is appended to the end of the next line to be recorded after the button was pressed, so it should be noted that these comments are qualitatively, not quantitatively useful.

2.6 Data Indicators



2.6.1 Numerical Temperature and Current Indicators

The numerical indicators along the top all display the most recent values of their labeled quantity.

Ctrl A/B: These indicators show the temperature measured by the A and B sensors from the Lakeshore 331 controller.
A/B Rate: These indicators show the calculated time rate of change of the A and B Lakeshore inputs.
Cell: The temperature measured on the surface of the cell
Cell Rate: The calculated time rate of change of the temperature of the cell
Current: The measured current through the cell

2.6.2 Thermometer Indicator

The thermometer indicator on the far left is a graphical depiction of the present cell temperature (the white marker at the top of the red fill) and the present temperature setpoint (the other white marker).

2.6.3 Temperature Graph

The temperature graph displays three different curves, which are color-coded with the numerical indicators they represent (Section 2.6.1). The red line is the temperature of the A sensor, the green line is the B sensor, and the blue line is the cell temperature. When the tangent lines are activated, three black lines appear and match the slopes of each of the three curves.

2.6.4 Current Graph

The yellow graph on the right displays the measured current through the sample. A faint yellow fill appears between the current and the line denoted by zero current. The X axis of the graph is temperature, not time, so the line appears to move backwards when cooling and may even move in loops depending on experiment conditions.

2.6.5 Clear Graphs Option

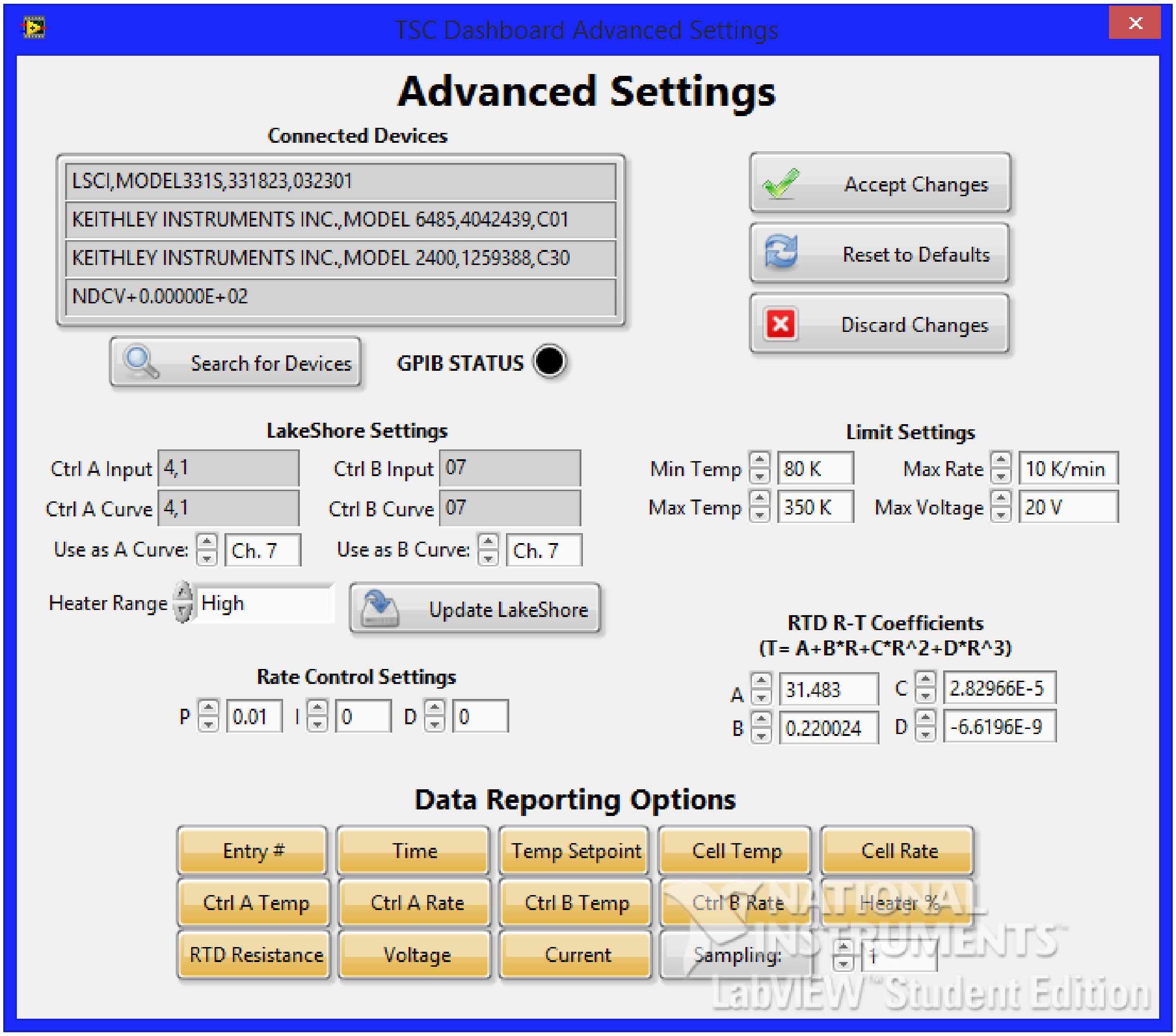
Pressing the "Clear Graphs" button irrecoverably deletes the data in the temperature and current graphs. No data is lost, and ALL of the data, before and after the clear, will still be saved into the log file, but that data cannot be retroactively brought back into the graphs on the software. Clearing the graphs is useful whenever the system transitions to a new phase, or to exclude large transients.

2.6.6 Show Tangents Option

Activation the "Show Tangents" button will draw thin tangent lines on the temperature graph, allowing for a graphical comparison of the ramping rates between inputs and over time. The presence or absence of these graphs does not affect the data collection nor the data logging.

3 Advanced Settings Dialog

Clicking on the gear icon on the front panel before starting an experiment brings up a new pane, which gives the user access to a number of new parameters as can be seen below.



3.1 GPIB Controls

The GPIB section of the advanced settings pane is similar to the section on the front panel (Section 2.3) but instead contains the raw GPIB identification strings from the connected instruments. Similar to that section, the refresh button resends the IDN command to see what devices are connected.

3.2 LakeShore Settings

The LakeShore temperature controller has several important settings which are integral to the operation of the TSC chamber.

The "Input" value for the LakeShore tells the LakeShore the type of sensor which is connected to its input. The "curve" number tells the Lakeshore how to convert the resistive or voltage values its measures into current. The input designators will only change if the cryostat system has to be rewired with new sensors, and can be done on the front panel of the LakeShore in that case. The curves are also fairly unlikely to change, and a new calibration curve must be entered manually. However, the advanced settings option makes it possible to change the calibration curve. To do so, simply change the "Use as A Curve" and "Use as B Curve" inputs to the proper value, and then click the "Update LakeShore" button.

The "Heater Range" option dictates the highest value of the heater power which will be allowed. High corresponds to 25 W, Medium corresponds to 2.5 W, and Low corresponds to 0.25 W. Regardless of this setting, the heater will still be turned off during cooling phases.

3.3 Rate Control Settings

In order to accurately control the ramp rate during the measurement cycle, a PID (Proportional, Integration, Differentiation) control loop has been programmed into the TSC Dashboard. Any change in the physical setup may cause either an offset in the ramp rate or rate oscillations. Either case can be addressed by properly retuning the PID coefficients. By default, they are P=0.2, I=0.1, D=10, as determined by a series of tests. Because of the nature of PID controllers, excessive deviations from these default numbers may make the symptoms significantly worse.

3.4 Limit Settings

In order to protect the sample, as well as to ensure that experiment setpoints remain within reasonable bounds, the limit settings on the advanced settings pane allow the user to define extreme values. When entering values on the front panel, the software will automatically coerce the value to be in the ranges defined by the limit settings.

3.5 RTD R-T Coefficients

The RTD used in this design to make contact to the sample surface has R-T characteristics governed (in the important TSC range) by a third order polynomial function:

$$T = A + BR + CR^2 + DR^3$$

Our calculated line of best fit between 80 and 350 K is defined by:

$$A = 31.483$$
$$B = 0.220024$$
$$C = 2.82966 \times 10^{-5}$$
$$D = -6.6196 \times 10^{-9}$$

If a new calibration is required, these parameters can be tweaked by changing these values here.

3.6 Data Reporting Options

The Data Reporting section of the Advanced Settings pane consists of 14 buttons and one numerical input. The first 13 buttons each represent columns of data in the log file. If the button is activated (turned orange) then that column will appear in the TSC log file, and it will be excluded if it is deactivated (turned grey).

Activating the final button, "Sampling", will configure the log file only to contain those records for which the entry number is a multiple of the integer entered in the numerical box directly next to the button. Those other records will not be saved, so this function is only recommended for extremely long TSC measurements, for which the time-resolution is non-critical and the un-sampled log file is prohibitively large.

3.7 Saving Advanced Controls

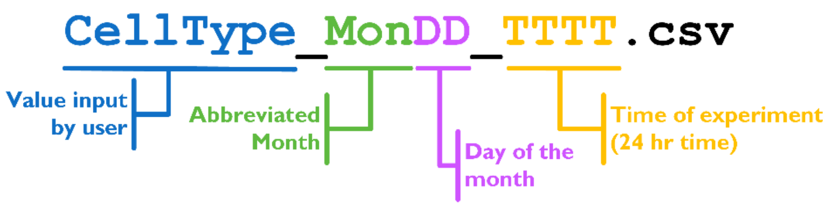
When the advanced settings have been configured as desired, press the "Accept Changes" button. Just like the inputs on the front panel, the advanced settings are not saved in memory until a profile is saved with those changes (see Section 2.2.1). Unless such a profile is created and loaded, the advanced settings will remain at the default values.

4 Log Files

At the completion of each experiment, the TSC Dashboard system exports a CSV file containing all of the collected data, as well as a header containing all of the experimental parameters.

4.1 Filename

The log file is automatically given a name which has the following format:



4.2 Header

The first section of each log file states clearly the parameters used for the experiment. The header is reproduced here, where the content of the orange boxes will vary depending on the specific parameters of the experiment.

THERMALLY STIMULATED CURRENT	
MEASUREMENT CONTROL PANEL	
--	
ISU ECpE Senior Design Group May14-03	
Joshua Straquadine	Martin Andersen
Mouhamadou Diallo	Nicholas Rodriguez
--	
Version 1.0	January 2014
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Experiment Settings:	
Profile Name:	Default
Export Folder:	C:\Desktop\TSC\...
User:	Josh
Cell Type:	P3HT:PCBM
Comment:	
Charge:	During Soak
Charge Time (min):	2
Charge Voltage (V):	5
Meas. Voltage (V):	1
Temp Profile:	Basic Ramp
Ramp Rate (K/min):	5

Soak Time (min):	2
No. of Setpoints:	2
Setpoints (K):	80, 300
Output Format:	T,T,T,T,T,T,T,T,T,T,T,T
Sampling Rate:	1
Heater Range:	High
P:	0.2
I:	0.1
D:	10
A:	31.483
B:	0.220024
C:	0.000028
D:	0
Max Rate:	10
Min Temp:	80
Max Voltage:	20
Max Temp:	350
--	
Run Started at 14:33 on Sunday 04 13 2014	
--	

4.3 Data Format

Depending on the data output settings chosen by the user on the advanced settings pane, these columns can be excluded or included at will. All of the options, in the order in which they may appear if included, are shown below.

#	Time	Set T (K)	Cell T (K)	Cell Rate (K/min)	LS Ta (K)	Ta Rate (K/min)	LS Tb (K)	Tb Rate (K/min)	Heater (%)	RTD Res (Ohm)	V (V)	I (pA)
0	2:33:25 PM	80	299.2	0	298.65	0	297.13	0	0	1100.999	5	512.557
1	2:33:25 PM	80	299.16	-7.66	298.64	-2.3	297.1	-6.9	0	1100.87	5	489.099
2	2:33:25 PM	80	299.14	-7.84	298.63	-2.91	297.08	-7.42	0	1100.796	5	452.626

If the "Sampling" option is activated, then only lines in which the "#" column is a multiple of the chosen sampling rate will be reported in the log file, and the other data will be lost. For this reason, using a large sampling rate is not recommended, and sampling should only be used if the log files become too large to be used.

5 Interfacing with Hardware

The software interfaces with four different instruments:

- Keithley 6485
- Keithley 617
- Keithley 2400
- Lakeshore 331

To connect these four instruments together, GPIB stacking cables are used. The exact configuration of these cables does not matter, as long as every instrument is connected to the same daisy chain.

The software also uses a KUSB-488A USB-GPIB adapter to communicate between the computer and these instruments. Unfortunately, the drivers for the KUSB-488A adapter are written by Keithley, and are therefore not compatible with the LabVIEW built in drivers. If your computer is not recognizing the KUSB-488A:

- Uninstall the National Instruments GPIB drivers on your system
- Navigate to the Keithley website and download the newest KUSB-488A drivers
- Install the Keithley drivers on your system
- Reboot your system and try again

6 Still stumped?

Drop the design team a line by emailing jstraquadine@gmail.com!