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## **Hardware**

### **Thermal Transient Anemometer Control Unit**

The Control Unit for the TTA is a standard 2U rack mount size with dimensions of 17x13x3.5 inches (43.2x33.0x8.9 cm). All connectors with the exception of the power are located on the front of the unit and can be seen in Figure 1.

#### **Power Connector**

The power connector is a custom high current connector with 32 pins for applying the heating voltage to any given cell and one or more ground leads returning. The TTA ships with a custom 20 foot cable for the power delivery.

#### **Sense Connector**

The sense connector is a standard female micro DB50 SCSI II connector, as is the connector on the array end. The TTA will be shipped with a 20 foot male to male SCSI II cable, but any male micro DB50 to male micro DB50 SCSI II cable can be used.

#### **External Voltmeter**

A standard female BNC connector provides the connection for reading a -10 to 10 volt analog voltage from an external device such as a pressure transducer.

#### **External Trigger**

The top female BNC connector is the external trigger input, and should not be confused with the external voltage connector.

#### **Serial Port**

The serial port on the TTA uses a PS2 connector and requires a custom DB9 to PS2 cable that will be shipped with the TTA.

#### **Status / Communications LED**

The red LED above the serial port will continually flash about 4 times per second while the TTA is properly booted and ready to accept commands from the PC. This flashing will be interrupted and the LED will temporarily remain on or off while accepting and processing a command.

#### **Power Switch**

Turns the TTA on or off.

#### **Power LEDs**

The two green LEDs show the status of the power supply within the TTA.



Figure 1: Thermal Transient Anemometer



Figure 2: TTA Cable - TTA Side



Figure 3: TTA Cable - Array Side

## **GUI Overview**

Figure 4 shows the TTA Comm Interface for the Thermal Transient Anemometer with the various elements numbered for reference.

1. Flow Rate pane – all information pertaining to the air speed through a cell will be displayed here
2. Temperature Pane – all information pertaining to the temperature of a given cell will be displayed here.
3. Cell – each cell has one block in each information pane. The blocks will vary in color depending on the flow speed or temperature of the cell. Clicking on a cell's block will activate or deactivate it. Inactive cells will be changed to grey. The number of cell blocks shown will vary between 1 and 32 depending on the number of cells in the array calibration that has been loaded.
4. Cell Data – the numerical representation of the air speed or temperature of a given cell.
5. Cell Scale – shows the color for minimum and maximum flow / temperature. Clicking on the color bar will allow the user to change the colors and clicking
6. External Voltage – shows the voltage ranging from -10V to 10V from the external input from a device such as a pressure transducer.
7. Connect Button – opens a communication link to the TTA, this must be done prior to any commands or data being sent to or from the TTA.
8. Save to File – when cycling the cells, indicates whether or not the data will be written to a file.
9. Number of Cycles – selects the number of cycles to run. A value of zero or any non-numerical value will loop until the user manually stops the TTA.
10. Start Cycle – will measure each cell sequentially, starting over at the end of the array.
11. Start After Trigger – will wait for the external trigger, then start taking flow and temperature data.
12. Status Bar – gives information about the different aspects of the program when the mouse is hovered over them. Also gives status information while the TTA is cycling.
13. Progress bar – shows the relative progress of a set of cycles if the number of cycles box is set to a finite number
14. Status Log – the 500 most recent status updates will be displayed here until it is cleared. The status log can be shown or hidden through the View menu by choosing View GUI Log.
15. Pause Log Button – stops the Status Log from being updated. The most recent status update will still be shown in the Status Bar
16. Clear Log Button – clears the Status Log.

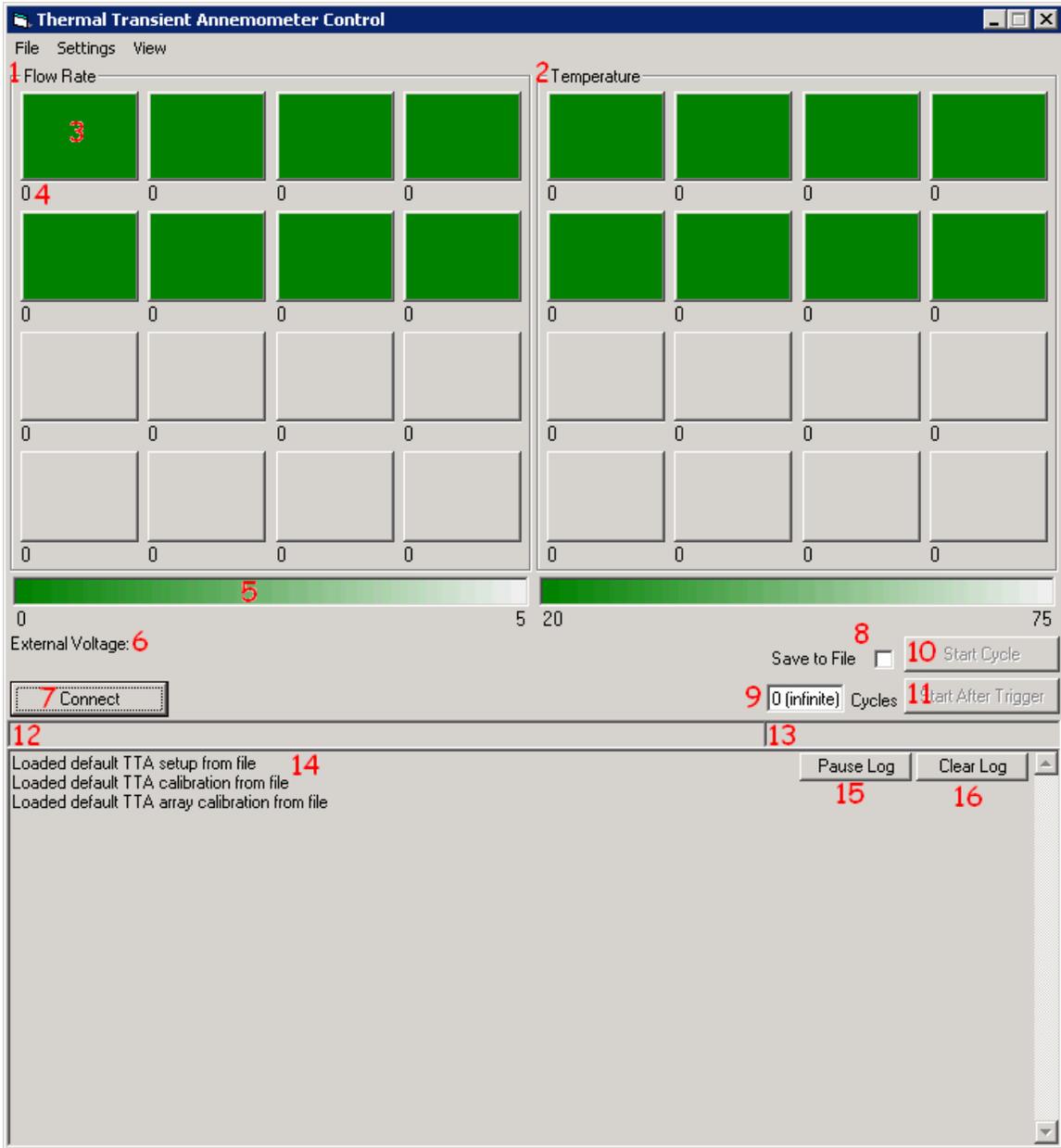
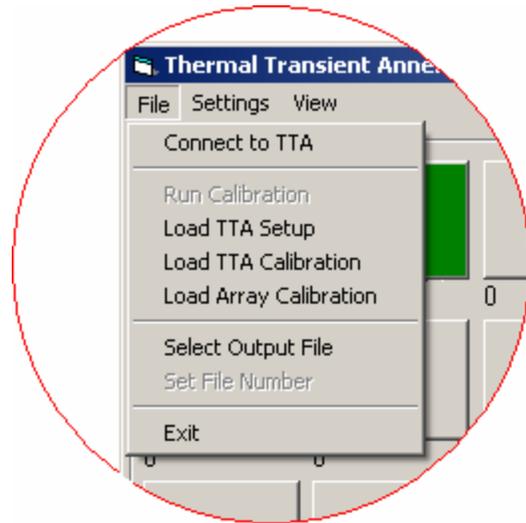


Figure 4: TTA Comm Elements

## Menus

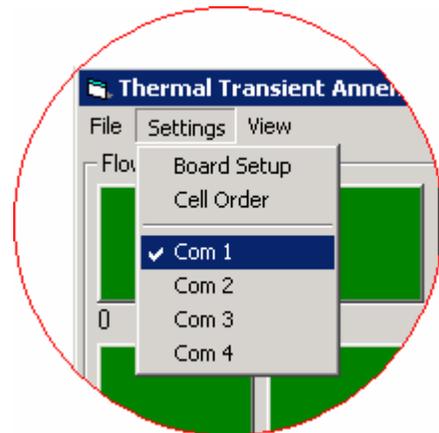
### File Menu

- Connect to TTA – serves the same function as the Connect button on the main GUI window attempting to communicate with the TTA on the chosen serial port at a variety of baud rates.
- Run Calibration – opens the calibration window. This is done prior to the TTA shipping, and should never have to be accessed by the end user. This option will be enabled once the TTA is connected.
- Load TTA Setup – Loads values such as baud rate, sample number and sample frequency from a file.
- Load TTA Calibration – loads a calibration for the TTA from a file. This file will be included with the TTA and includes the information necessary to perform accurate resistance and voltage measurements.
- Load Array Calibration – loads the calibration for a specific array of up to 32 cells from a file. This file will be included with any TTA array and includes the information about the individual tungsten wires necessary to calculate overheats, temperatures and air flow.
- Select Output File – allows the user to choose the file for data output.
- Set File Number – allows the user to set up automatic numbering of sequential data output files. This option will be enabled after a data output file is chosen.
- Exit – closes the program.



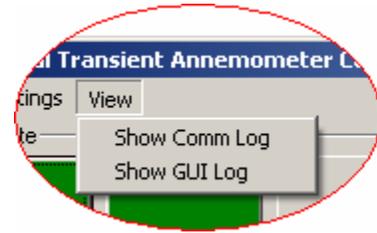
### Settings Menu

- Board Setup – opens the board setup window where baud rate, sample number, sample frequency, and overheat can be specified.
- Cell Order – opens the cell order window where the user can define the order in which the cells will be run.
- Com 1 – Com 4 - allow the selection of the serial port being used.



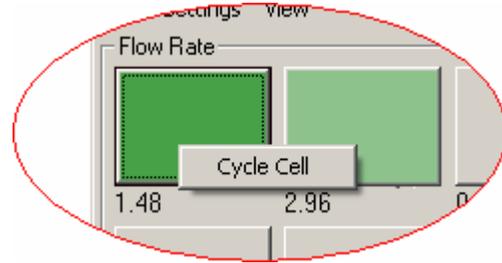
## View

- Show Comm Log – shows the information flow between the TTA and the GUI. Generally has no use beyond debugging purposes.
- Show GUI Log – will expand the bottom of TTA Comm to show a real time log of the user activities.



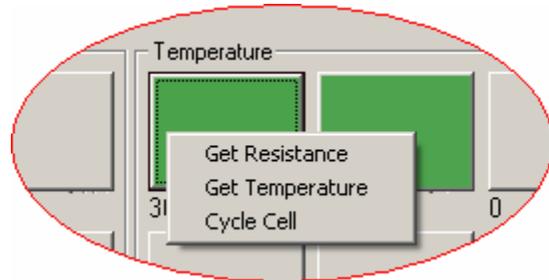
## Flow (right click)

- Cycle Cell – runs the chosen cell one time, without affecting any other cells.



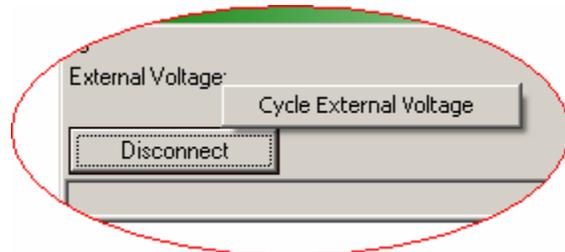
## Temperature (right click)

- Get Resistance – updates the number below the cell to show the electrical resistance of the wire in ohms. Does not update the color switch.
- Get Temperature – updates the number below the cell to show the average temperature of the tungsten wire. Does not update the color switch
- Cycle Cell – runs the chosen cell one time, without affecting any other cells.



## External Voltage (right click)

- Cycle External Voltage – updates the External Voltage value.



## Connecting to the TTA

### Communications Port Selection

TTA Comm does not automatically connect to the TTA upon launching. Before any commands can be sent back and forth, the user must connect to the TTA. TTA Comm uses one serial port, generally this will be Com 1 or Com 2, but ports 1 through 4 may be chosen from the settings menu as seen in Figure 5. Com 1 will be chosen by default the first time the program is run, and if the correct port is not known, it is recommended to start with Com 1 and work from there.

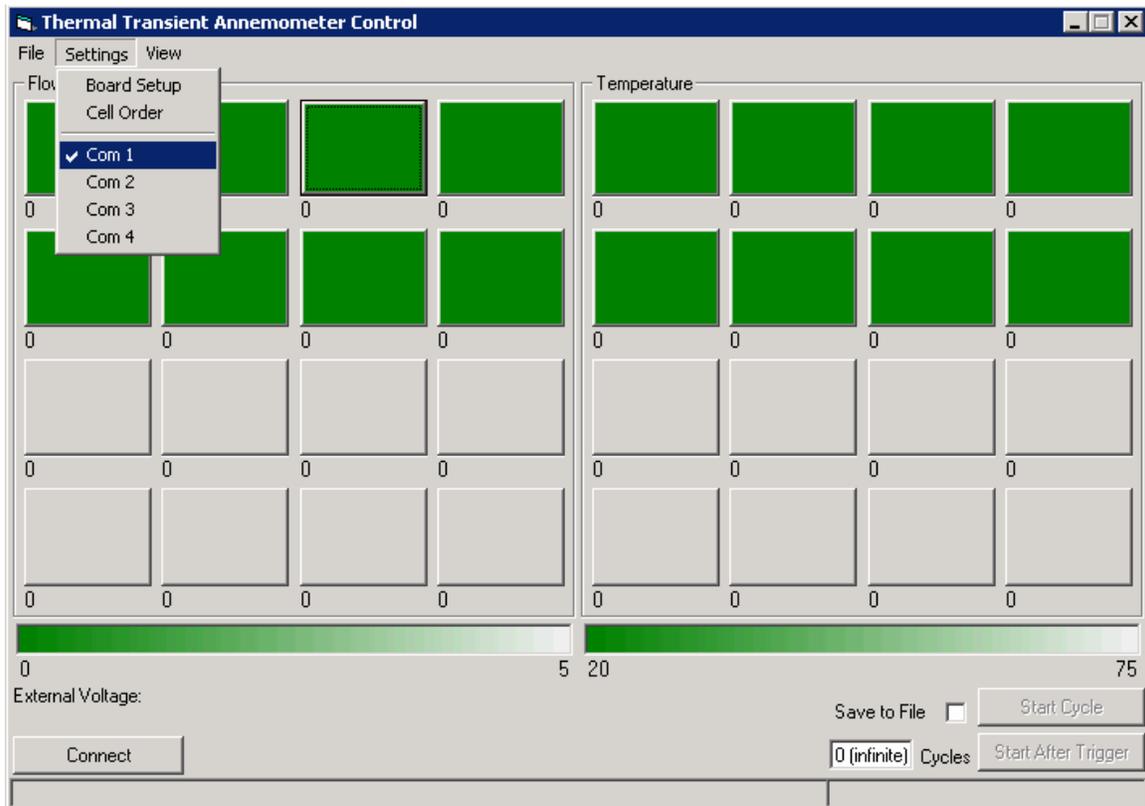


Figure 5: Settings Menu

### Communications Attempts

Once a Com port is chosen, clicking the Connect button will attempt to communicate with the TTA on the chosen port. On power up, the TTA will initially be set to Comm settings of 19200, 8, n, 1. It is recommended that the baud rate be left at 19200, but baud rates of 9600 and 38400 are also supported. The baud rate can be set under the Board Setup item in the Settings menu.

In the event that the baud rate is changed from the default and either TTA Comm or the TTA hardware is subsequently restarted, it is possible that the TTA and the PC will not be at the same baud rate. To account for this chance, if TTA Comm is unable to

communicate with the TTA at the currently set baud rate, it will then scan through the other allowable baudrates looking for one that does work.

During the process of establishing communication with the TTA, the Connect button will be changed to Abort. Clicking the Abort button will cause TTA Comm to cease it's attempts to communicate with the TTA. Upon successful connection, the Connect button will be change to Disconnect, and the Start Cycle and Start After Trigger buttons seen at the at the bottom left of the GUI will be enabled.

## Setup

### TTA Settings Window

The TTA setup window as seen in Figure 6 can be accessed through the Settings menu under Board Setup. For general use, these settings will not require modification; however controls specific to the TTA control box can be set here if desired.

1. Number of samples sets the number of A/D samples that are taken. This value applies to the number of samples taken during the thermal decay, as well as the number of samples averaged when measuring external voltage or wire resistance. A setting of less than 300 will result in a warning window that the number of samples may be insufficient for reliable data. Transfer of the sample data accounts for a large fraction of the time taken to cycle a cell, so it should be kept in mind that increasing the number of samples will result in a longer cycle time.
2. Sampling frequency sets the frequency that the chosen number of samples is taken at. If the sample frequency is set below 2000 samples per second, a warning window will be shown with a warning that the frequency might be insufficient to capture the desired data from the thermal decay curve.

Experimentally, the wires have been found to return to ambient temperature after approximately 150ms at zero flow. The default number of samples and sampling frequency has been chosen to match this time. In general the number of samples divided by the sampling frequency should be kept at 0.15 or slightly higher. Other combinations will result in either insufficient or excessive data.

3. The ratio of hot resistance to cold resistance can be set in the overheat box. Higher overheat may result in a more accurate reading, but risks ruining the wire. An overheat of 1.7 is recommended, and overheats of 2.0 or higher will be canceled.
4. The Baud Rate setting determines how fast data is transferred between the TTA and PC. Faster rates will shorten the overall cycle time, but increase the risk of corrupted data or communications errors.

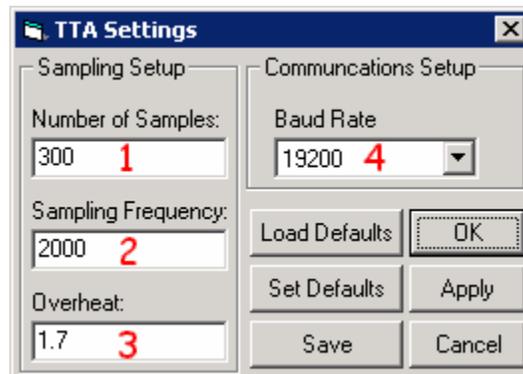


Figure 6: TTA Settings

## TTA Cell Selection

In the TTA Comm GUI, each rectangular block represents one cell of the array. Each block is also a button. Clicking the block will toggle the activity status of the cell. If active, the cell will be shaded according to the last data measured for that cell. Inactive cells will be shown in grey. The status of a cell does not affect the cell order, it simply causes the cell to be skipped when it's turn arrives. Deactivating cells will shorten the cycle time for the remaining cells, allowing a subset of the array to be run faster than the full array. Cells can be activated or deactivated without stopping the current cycle of the TTA.

## TTA Cell Order

Upon loading, TTA Comm is set to run the cells sequentially starting with cell 1 and ending with the highest numbered cell in the array. This will be done without any adjustment from the user at runtime. In the case that this is not desirable, the TTA is capable of running cells out of the standard sequential order.

The array cells can be reordered by choosing Cell Order from the Setting menu which will bring up the window seen in Figure 7. Upon loading, the current cell order will be shown. Active cells will have a white box, while inactive ones will be grey. By changing the numbers shown below each cell, the cell order can be redefined. Each cell must have a specified order, even if it is inactive at the time. Re-ordering the cells is a matter of swapping orders. When a number is changed for a cell it will automatically swap order with the cell currently using the number. Attempting to enter a value outside the range of cells or an erroneous value will cause the cell to retain its current order.

Using Figure 7 as an example, cells 1 through 8 would be run in reverse order. Cells 9 through 16 are deactivated and thus regardless of order, will not run. If cells 9 through 16 were later activated in the main GUI window, they would run in sequential order. If any of cells 1 through 8 were later deactivated, they would be skipped, but the rest of the cells would continue to run in order. If Cell 8 were changed to be 3<sup>rd</sup> in the running order, then Cell 6, which is currently 3<sup>rd</sup> would be changed to running 1<sup>st</sup>.

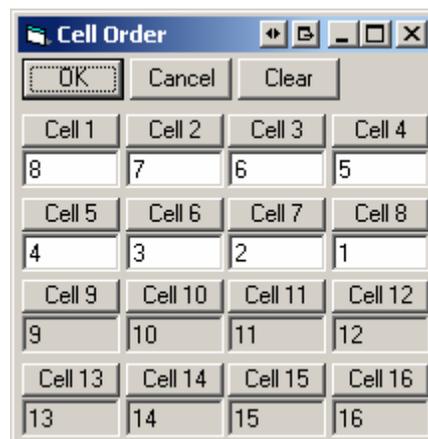


Figure 7: Cell Order

## **Calibration**

### **Summary of Calibration Data**

Calibration is done prior to the TTA and accompanying array being shipped. Due to the properties of the tungsten wires, the TTA should never need recalibration by the end user. There are two independent calibration files one specific to the TTA control box and one specific to the set of TTA wire arrays being used. The TTA specific calibration does not need to be changed to run different arrays, as the array specific calibration does not need to be changed to run the same array on different TTA control boxes.

All files which hold calibration or settings data are saved in plain text format. Upon loading, the file is checked to contain a proper header and the correct amount of data. If the file appears to be invalid, the user will be warned and the calibration data will not be loaded.

### **Loading Calibrations**

#### *Default*

The set of calibrations which go with the original TTA control box and array will be stored in the install folder for TTA Comm as DefaultTTACal.txt and DefaultArrayCal.txt. These files will automatically be loaded upon starting the TTA Comm software. Alternative calibrations do not need to be loaded unless the TTA control box or TTA arrays are not those originally shipped with the software being used.

#### *Manual*

If the default files are not present, or contain undesired information, the user can load alternative calibrations through the GUI's file menu. This will be necessary if different arrays are to be used on the same TTA control box. The calibrations are stored as plain text files, but the GUI will check to ensure that they contain a proper header and the correct amount of data, and will warn the user if the file was invalid.

### **Running Calibrations**

Calibration is done prior to the TTA and accompanying array being shipped, but the calibration interface is built into TTA Comm. The calibration interface can be accessed through the File menu by choosing Run Calibration. This will open the window shown in Figure 8. This portion of the manual is included for completeness, but should not be attempted by the user as the included calibration files could be overwritten.

Running a calibration requires

1. A minimum of two precise, high wattage (100W or greater) resistors, around 10 Ohms. Three or more different resistances are preferred for calibration of the cold resistance and overheat resistance measurements.
2. At least two precise voltage sources, with three or more being preferred for calibration of the voltmeter.
3. A controlled 27 degree Celsius environment for cold resistance measurement.
4. At least two uniform, controlled temperatures in which a cell can be placed for the temperature calibration.

- At least three uniform, controlled flows in which a cell can be placed for the velocity calibration.

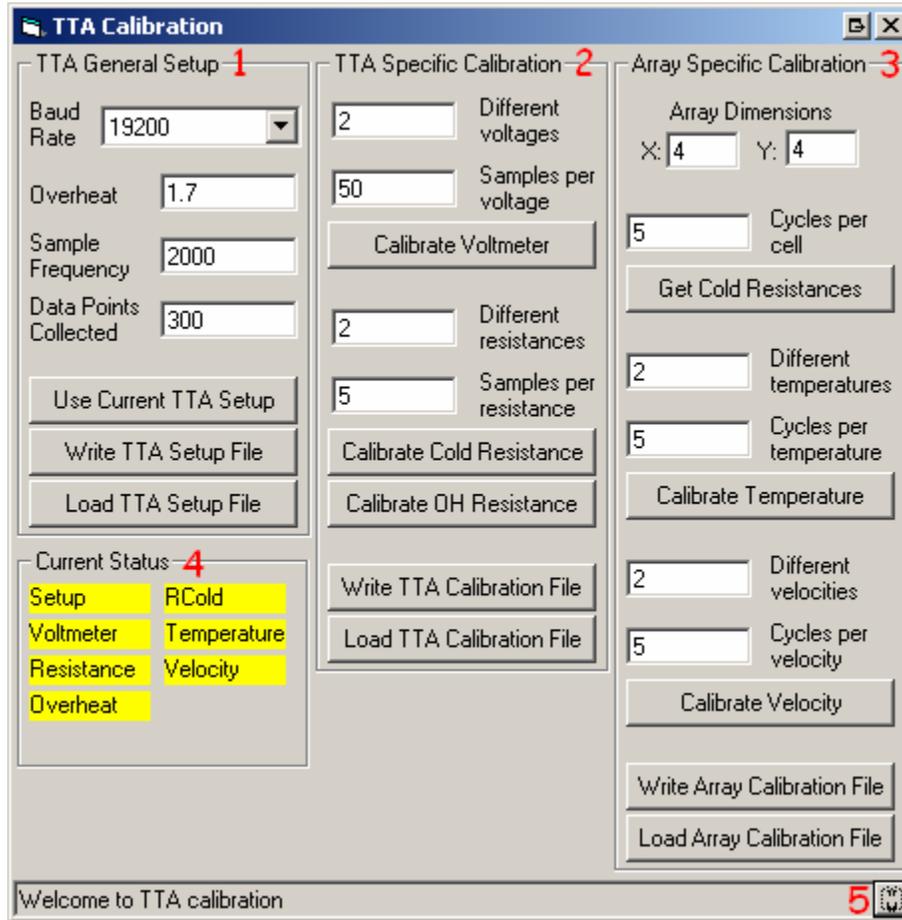


Figure 8: TTA Calibration Window

Each of the panes numbered 1 through 3 controls a different calibration file. The buttons at the bottom of each pane can be used to either write the current calibration data to a file, or read calibration data from an existing file. Each part of the calibration relies on the previous part(s), and thus the previous part(s) must be completed prior to continuing with the next calibration.

### TTA General Setup

The General Setup pane (1) has the same settings as the Board Setup window discussed earlier. The only addition made in the calibration window is the ability to load and save a setup file. The Use Current Setup button will accept the current values listed without any reading or writing from a file. This may be useful if different settings are desired for calibration, but do not need to be saved for general use. When choosing the values for General Setup, the same rules should be followed as in the Board Setup window of Figure 6.

- Higher baudrates will reduce cycle time, but make the TTA communications more error prone.

2. An overheat of significantly less than 1.7 will decrease the accuracy of flow measurements, while an overheat of significantly greater than 1.7 chances damage to the tungsten wire.
3. A sample frequency less than 2 kHz may be too slow for accurate flow measurement.
4. Fewer than 300 data points may be insufficient for accurate measurement, while greater than 300 generally will not increase the accuracy of flow measurement, but may improve voltage and resistance measurements.
5. Frequency and number of points combinations for which points / frequency is much greater than 0.15 will cause a longer cycle time with no real benefit for flow measurement.

### TTA Specific Calibration

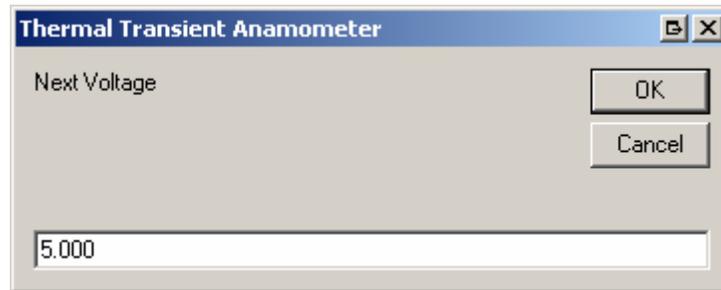
The TTA specific calibration pane (2) contains the controls to setup and run calibrations pertaining to the internal operation of the TTA control box, but is not specific to any single cell array. The TTA Specific Calibration requires that the values from the TTA General Setup be properly loaded or set prior to running. A file containing the TTA Calibration will be included with the TTA and loaded automatically when TTAComm is started. There are three sub-sections of the TTA calibration for voltage, resistance, and overheat measurement. Loading a TTA calibration from a file overwrites the current data for all three sections. Running any one of the three sub-calibrations overwrites only the data for that portion of the calibration allowing recalibration of any one part while retaining the rest of the calibration data.

For each sub-calibration, there are two options that must be set prior to starting the calibration: the number of voltages or resistances and the number of samples at each value. A minimum of two values are required since the calibration relies on a curve fit for the Analog to Digital conversion. For the greatest accuracy, a large number of values ranging from -10 to 10 volts for voltage calibration, and 5 to 15 ohms for the resistance calibrations should be used. The number of samples sets how many packets of data are requested from the TTA. Each packet will contain in itself the numbers of data points set in the setup pane. For the settings seen for resistance in Figure 8, 5 samples x 300 points per sample would be taken for each resistance value. This means that the end measurement would be the average of 1500 A/D conversions.

For all three sections of the calibration, it is important to use precise voltages or resistances. For the Overheat Resistance calibration, the resistance will be measured based on the amount of current flowing through the resistor when approximately 30 volts is put across the wire. The resistors used for calibration should be close to the hot resistances of a wire, from about 10 to 12 Ohms. This means that the resistor must be able to dissipate at least 90 watts of power for a period of several seconds. For the most accurate calibration, the resistor must be able to handle this much power without appreciable change in resistance due to heat.

Once the values and sample numbers are entered, clicking the Calibrate button will start a series of prompts which will accept the current value from the user. An example of this prompt for voltage calibration can be seen in Figure 9. Before clicking OK, the appropriate voltage or resistance should be connected to the TTA. In the case of resistance, the proper resistor must be connected to channel 1 as all other channels are

ignored. After clicking OK, the TTA will take the necessary data, during which time it is important that the voltage or resistance not be changed. Once the next prompt comes up, it is safe to change the voltage or resistance connected. The user will be prompted for the number of values previously entered in the calibration window. Clicking Cancel on any prompt will discard the current calibration attempt and revert to the old data.



**Figure 9: Prompt for Calibration Information**

### TTA Array Calibration

The TTA Array Calibration (3) houses calibration control specific to the array or arrays being used, which do not vary with the TTA control box. It does however rely on the measurements from the TTA, and thus the TTA Specific Calibration must be completed or loaded from a valid calibration file prior to the TTA Array Calibration.

The first part of the Array Calibration which must be set is the size of the array being used. The software currently recognizes only a single rectangular array, and the GUI display will be adjusted based on the dimensions entered for the array calibration. If multiple arrays are being used via splitting the cable, the user will have to enter the information as a single array and keep track of which cells belong to which arrays and/or ignore cells that are non-existent in the array. Changing the dimensions of the array automatically invalidates all previously loaded or recorded array calibration information.

When reading cold resistance, the only setting necessary is the number of cycles to run each cell. The calibration routine will then cycle through the cells in order, checking the resistance. For this portion of the calibration, the array must be placed in a controlled 27 degree Celsius environment.

The temperature and velocity calibrations have settings which control the number of sample values and number of cycles to run each cell, similar to the voltage and resistance routines. As with the other calibrations, the more discrete values used for either flow or temperature, the better the calibration outcome will be. For the velocity calibration only, a minimum of three different velocities are needed for a successful calibration. Once started, the user will be prompted for each temperature or flow value. Once a valid number is entered, the calibration routine will sequentially prompt the user to align each of the array cells with the flow or temperature. If any of the prompts are canceled, the active portion of the calibration will fail and any calibration data loaded prior to starting the routine will be retained.

### Status Indicators

The status indicators (4) give the user feedback on what aspects of the calibrations have been completed. The yellow bars seen in Figure 8 will change color depending on the current status of the calibration. The possible colors are red, yellow and green.

- Red indicates that no valid data is loaded for the given calibration. Either no calibration was loaded, or a calibration attempt failed after rewriting some or all of the previous data.
- Yellow indicates that the calibration contains valid data. This data could have come from one of three sources: a default calibration file that was loaded when the software was run, a calibration file that was loaded by the user either before or after opening the calibration windows, or from a successfully completed calibration that has been saved to a file by the user.
- Green means that the indicated portion of the calibration has been successfully run, and the calibration data updated, but has not yet been saved to a file.

Attempting to write a file with any of the calibration indicators being yellow or red will cause a prompt to warn that (red) faulty data, or (yellow) old data not from a fresh calibration, will be written to the file.

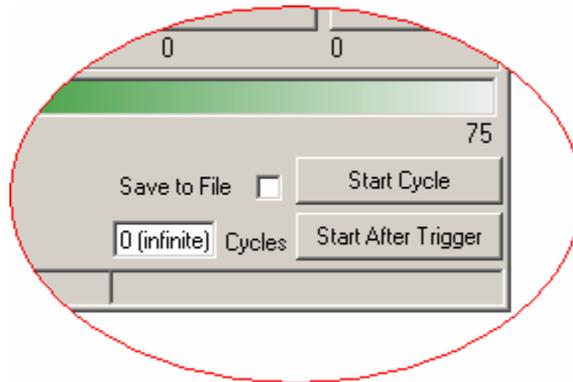
#### Status Log

The status log (5) can be expanded or collapsed similar to the log for the main window of TTAComm. Unlike the main log, the last line is still shown when collapsed, serving as a real time status update to the user during a calibration.

## **Data Acquisition**

### **Cycles**

A cycle is defined as a complete run through all active channels acquiring both temperature and flow data. At the end of every cycle, the external voltage is sampled and displayed for the user. As seen in Figure 10, the default is to cycle indefinitely until stopped by the user. Entering 0 cycles, or any non-numeric character will cause the TTA to cycle continuously. Entering any valid integer sets the number of cycles that will be run when the Start Cycle button is clicked or the Start After Trigger button is clicked and the trigger is received.



**Figure 10: Data Acquisition Options**

### **Data Format**

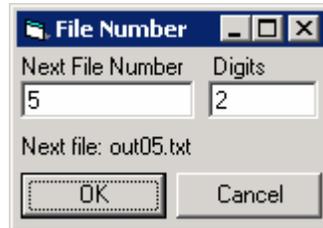
There are two methods by which the user can retrieve data from the TTA, displayed in TTAComm or through an output file.

#### **GUI Display**

As the TTA cycles through the attached cells, the data for each cell is updated and will be displayed until the next time the cell is cycled. Temperature and flow data will be displayed both as a number and through the coloration of the block corresponding to a specific cell. This output method is constantly running even when file output is being used.

### File Output

File output can be obtained by checking the Save to File check box prior to starting a cycle. The file for output can be chosen through the File menu, or if not chosen, the user will be prompted when the TTA cycle is started. After choosing the file, the user will be prompted with the window seen in Figure 11. Once the file number and digits to be used are set, TTA Comm will automatically store the data from each sequential run in a new file and increment the file number. If the number of runs exceeds that allowed by the chosen number of digits, TTA Comm will wrap back to 0 and overwrite the old files.



**Figure 11: File Number**

The output will be a text file with data formatted as space delimited values. Each line in the file represents one complete cycle through each cell in the array, as illustrated below.

$$c_1 t_{1,1} T_{1,1} V_{1,1} c_2 t_{2,1} T_{2,1} V_{2,1} \dots c_c t_{c,1} T_{c,1} V_{c,1} \dots c_{16} t_{16,1} T_{16,1} V_{16,1} E_1$$
$$c_1 t_{1,2} T_{1,2} V_{1,2} c_2 t_{2,2} T_{2,2} V_{2,2} \dots c_c t_{c,2} T_{c,2} V_{c,2} \dots c_{16} t_{16,2} T_{16,2} V_{16,2} E_2$$
$$c_1 t_{1,n} T_{1,n} V_{1,n} c_2 t_{2,n} T_{2,n} V_{2,n} \dots c_c t_{c,n} T_{c,n} V_{c,n} \dots c_{16} t_{16,n} T_{16,n} V_{16,n} E_n$$

$c_x$  represents the number of the  $x^{\text{th}}$  cell it will not vary with acquisition cycle.  
 $t_{x,y}$  represents the time that the  $x^{\text{th}}$  cell started heating in the  $y^{\text{th}}$  cycle of data acquisition.

$T_{x,y}$  represents the temperature of the  $x^{\text{th}}$  cell in the  $y^{\text{th}}$  cycle of data acquisition.

$V_{x,y}$  represents the flow rate of the  $x^{\text{th}}$  cell in the  $y^{\text{th}}$  cycle of data acquisition.

$E_y$  represents the external voltage at the end of the  $y^{\text{th}}$  cycle of data acquisition

### **Sample Run**

Figure 12 shows TTA Comm after running a 16 cell array for three cycles with only the first two cells active. The results of the most recent cycle can be seen in the coloration of the blocks and the numerical data below them. Flow rates are in meters per second while Temperature is in degrees Celcius. The sequence of events can be seen in the status log at the bottom of the program.

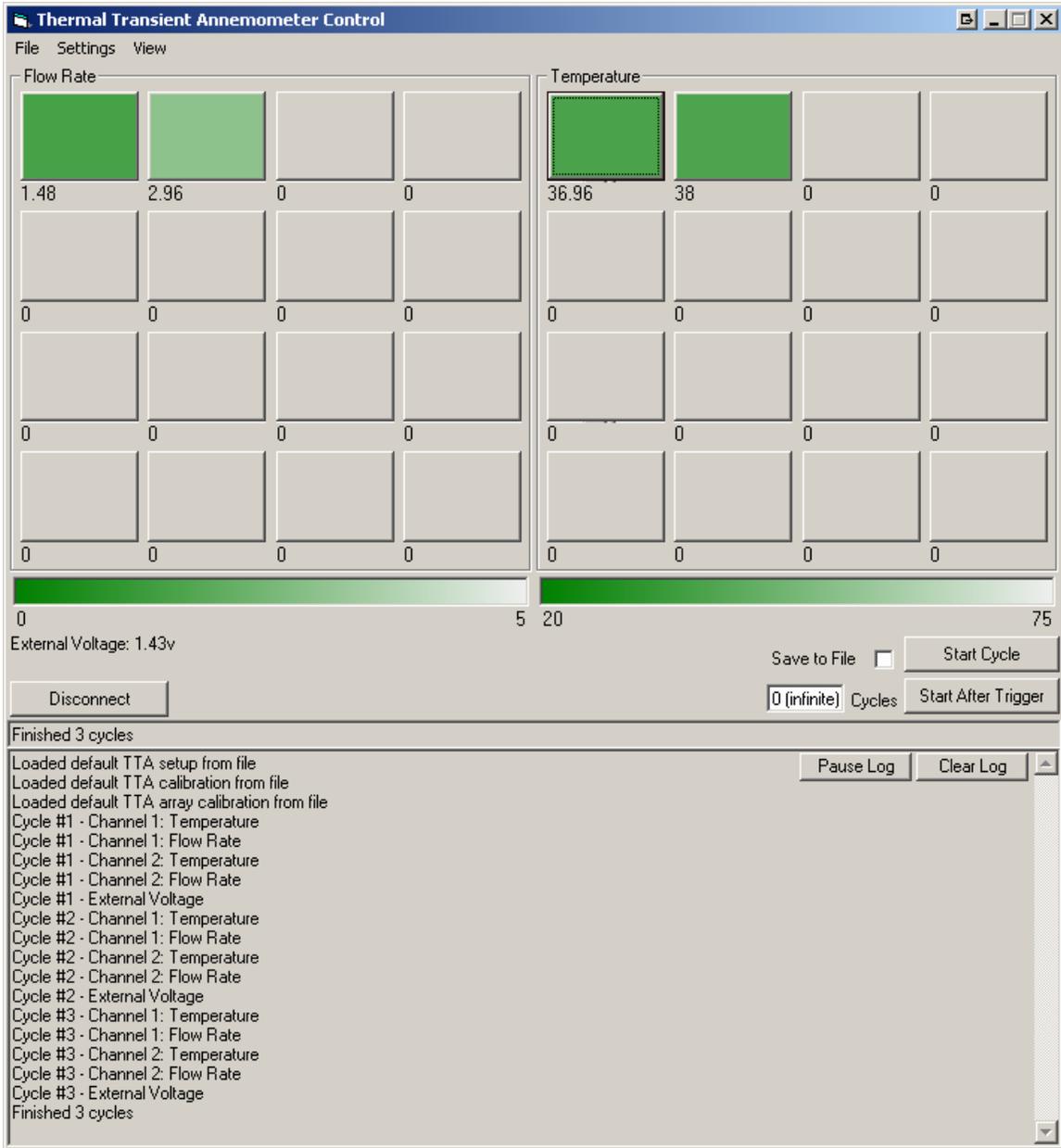


Figure 12: TTA Comm after three cycles