



SANTA BARBARA AUTOMATION

Thermal Transient 2012 Installation and Operating Manual

Rev: 12-167 Nov. 10, 2012

For the latest version of this document, please visit:

<http://santabarbaraautomation.com/PDF/Thermal%20Transient%202012%20Manual.pdf>

For the latest version of Thermal Response software, please visit:

<http://santabarbaraautomation.com/Downloads.html>

**2705A De La Vina Street
Santa Barbara, California 93105
Telephone (805) 682-0900
support@santabarbaraautomation.com
www.santabarbaraautomation.com**

TABLE OF CONTENTS

Installation.....	3
Hardware Overview	3
Hardware Installation	4
Software Installation.....	5
Application Settings	6
Test Parameters File	6
Start Up	7
Testing Limits and Options	12
Configuring Test Limits for Safety.....	12
Resistance Measurement	13
Current Pulse Stabilization and Accuracy	14
Analysis Parameters.....	16
Testing Parts	17
Automation View.....	18
Test Results	20
Part Counters	23
Measurement Data Files	24
Thermal 2012 Extended Automation Interface	25
Hardware Connections	25
Test Options.....	28
Test Timing.....	31
Diagnostic Tools	34
APPENDIX A: Data Analysis Computations.....	36
APPENDIX B: Specifications	38

Installation

Hardware Overview



Front Panel

Power on switch: this switch is illuminated when power is applied.

Trans LED: active when the thermal transient instrument is sending data

Rec LED: active when the thermal transient instrument is receiving data

Error LED: active when an internal error is detected

Test On LED: active during a thermal transient test



Rear Panel

NOTE: If your system has one of the automation options, please refer to automation section below. The rear panel will have additional connections.

Power inlet : **Please verify the correct voltage before turning the equipment on.**

Volt/Ohm Input: One pair of the Kelvin connections to a multimeter when used.

4-Wire Ohm Sense : The second pair of Kelvin connections to a multimeter when used.

Current Out/Measure In: Electrical connections to the test chamber and part under test.

Serial Port: RS232 communications to the computer.

Remote Switch: Optional test start switch when the equipment is used manually.

Interlock: Mandatory connection to the door closure sensor that indicates a test may safely be performed.

Hardware Installation

NOTE: If your system has one of the automation options, please refer to automation section below. You must provide a properly connected interlock signal in order to run tests.

1. Connect a high quality shielded serial interface cable to the 9-pin SERIAL PORT connector on the back of the Thermal Transient Test System. Connect the other end to a serial port on the computer.
2. Plug the measurement cable into the rear of the thermal transient enclosure. Connect the 15-pin “D” connector to the connector labeled “Current Out/Measure In”. Connect the banana plugs from the measurement cable to the banana jacks labeled “Interlock”. When the chamber door is open the Thermal Transient Test System is electrically disconnected from the chamber. The interlock status is noted on the main screen of the application. Additionally, an LED is visible inside the rear of the Thermal Transient enclosure to indicate when the chamber door is closed.
3. Connect the other end of the measurement cable to the rear of the test chamber. Place the Interlock, Sense and Current banana plugs into the proper banana jacks on the rear of the test chamber. Polarity must be observed for the banana plugs, the side of the banana plug with the tab is the negative side and should be connected to the black banana jack.
4. If the optional external multimeter is used (Agilent 34401A or Keithley 2010), connect it to an available serial port (such as COM2) using the supplied serial cable. If you have received the multimeter along with the system from Santa Barbara Automation, it is already configured for serial port operation. Otherwise, configure it for use with RS232 interface (usually the default factory setting is GPIB, see the owner’s manual for details.)
Agilent 34401: RS-232, 9600, 8, N, 1, DTR/DSR handshaking; **must use Agilent cable**,
Keithley K2010: RS-232, 19200, 8, N, 1, Xon/Xoff handshaking; normal RS-232 cable.
5. Connect the optional operator switch (banana plug, when used) to the REMOTE SWITCH connector on the Thermal Transient Tester. You may also start the test by clicking on the test button of the measurement screen in the thermal transient software application. *The button is only active when the test chamber door is closed.*
6. Verify that the mains voltage is proper (as shown in a small window on the modular AC inlet), connect the power cord to the modular AC inlet and plug it into an AC outlet.



Figure 1A: Thermal Transient enclosure rear



Figure 1B: Thermal Transient with Extended Automation Option Rear



Figure 1C: Agilent 34401A Multimeter Rear



Figure 1D: Keithley 2010 Multimeter Rear

Software Installation

This program may be installed on 32-bit Microsoft XP Professional (Service Pack 3 required), or 32 or 64 bit Vista (SP2 required) or Windows 7 (SP1 required) or Windows 8. To install the Thermal Transient application, your computer must have the following resources:

- A Pentium 4, dual core 2.0GHz or better processor,
- A minimum of 2 Gigabytes of RAM (4GB recommended).
- 50 Megabytes of free disk space for installation, 100MB for data storage.
- 1024x768 or higher resolution display, 1600x900 recommended, 1920x1080 or 1920x1200 is required for Automation view.
- One high-speed serial port (16550 UART) for Thermal response hardware
- An optional second serial port for the multimeter connection.
- Thermal response firmware version v48 or later, v52 or later required for all features
- You must have Administrator privileges for the program installation and updates.

IMPORTANT

If you already have Thermal2012 installed, use the update installer instead of the full installer – doing so will preserve all program settings. If you are updating an installation of Thermal Response 2010 or earlier, you *must* uninstall the previous version before proceeding. For earlier versions of the Thermal Response program the directory is C:\Program Files\Thermal4 (or C:\Program Files (x86)\Thermal4 for 64-bit operating systems). Use the Windows Add/Remove Programs application in the Control Panel to uninstall the application. Please remember to back up the testparameters.ini file if necessary.

1. Insert the Thermal Transient install disk into the CD drive, or download and unpack the setup file.
2. Run Thermal2012setup.exe (or Thermal2012Update.exe if upgrading). Follow the instructions that appear on the display. Select “Viewer Only” installation only if there is no hardware present – this will remove the hardware control panel from the view; it can

always be re-enabled later if desired by deleting Thermal2012ViewerOnly.txt located in the install folder.

Unless instructed otherwise, the installer will place Thermal 2012 application in “C:\Program Files\Thermal2012” on 32-bit systems or in “C:\Program Files (x86)\Thermal2012” on 64-bit operating systems. This directory also contains the configuration files: testparameters.ini, settings.xml, and application logs in the Log\ subdirectory. Thermal2012 does not store any information in the user profile directory. You will need administrator privileges when you start the application for the first time. Do NOT use “Run as Administrator”.

This completes the program installation. ***If you do not have the Thermal Transient test hardware and plan to use the software for viewing and processing previously acquired data, no further configuration is required. Please refer to the “Quickstart Guide – Without Hardware” for additional information.***

Application Settings

The Thermal Response 2012 application stores most settings including test current and duration in the settings.xml file located in the program directory. This means that all settings are saved when the application exits, and then they are restored upon startup, and this includes test current and pulse duration. **The operator must verify test parameters before testing in order to prevent part functioning due to excessive test current or duration. This is critical to avoid testing with excessive current or pulse duration that may result in inaccurate test results or may compromise operator safety.**

When the application is launched in viewer mode (for example, when an xml-tr4 file is double-clicked in Windows Explorer), the settings are stored in a separate file, settings_view.xml. These files are not interchangeable; settings_view.xml may be deleted any time to force the viewer to re-read the main settings.xml. This allows the viewer mode to maintain persistent analysis settings (such as bridgewire parameters) while avoiding corruption of the main settings.xml file.

Test Parameters File

Next you should examine, and if necessary, edit the test parameter file: testparameters.ini. This file contains the test parameters referenced by part type and is unique to each type of initiator tested. The file is located in the program folder indicated above. The installer provides a sample file that may be used to create additional part types. Without properly configured part numbers in this file, you must manually enter all test parameters.

The test parameter file uses similar formats to the testparameters.ini file on all Santa Barbara Automation Final Electrical Test equipment. Only a responsible supervisor or engineer who is knowledgeable and understands test parameters should maintain the Testparameters.ini file.

CAUTION

The settings in the testparameters.ini file provide consistent means of testing and allow the operator to identify initiators by part number (ref. Fig 17). Incorrect settings, such as higher current or longer pulse width, may detonate parts. Proper maintenance of this file and the data within are critical to the safe use of the Thermal Transient Test System. **Do not allow untrained operators access to this file.**

Start Up

To start the Thermal Transient Tester and the Thermal Transient program:

1. Verify that no initiators are within the test chamber.
2. Turn on the power switch on the front of the Thermal Transient Tester and confirm that the POWER light is lit on the front panel and that the error indicator if not lit.
3. Double-click the Thermal2012 icon on the Windows desktop.



Thermal 2012 desktop icon

The Thermal transient software may operate in either online or offline modes. In the offline mode the user may view, print and analyze previously acquired waveforms; in the online mode parts may also be tested and new data may be acquired, and previously stored waveforms may be opened. The Thermal Transient software may be used on any computer in the offline mode – no hardware connection is required.

If the Thermal Transient Test System is connected to COM1 and no external multimeter is used, select the “Go Online Now” option. If a different serial port is used or an external multimeter is connected select “Go Offline” and verify that the communication settings are configured properly (see below for details). If the software will always be used in Offline mode, then select “Always Stay Offline” to disable the dialog box. You may select “Switch Hardware View Off” option under the “Equipment Menu” to hide the hardware window.

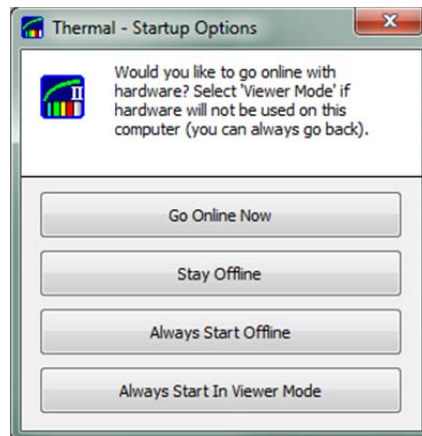


Figure 2: Startup Online/Offline selection

4. If you connected the serial interface cable to a port other than COM1, you will receive a message either saying the port cannot be opened or the Thermal Transient Test System could not be initialized. To change the serial port settings, use the Options menu on the hardware window while offline, then select the serial port where the interface cable is connected and select the proper settings, then click the OK button.

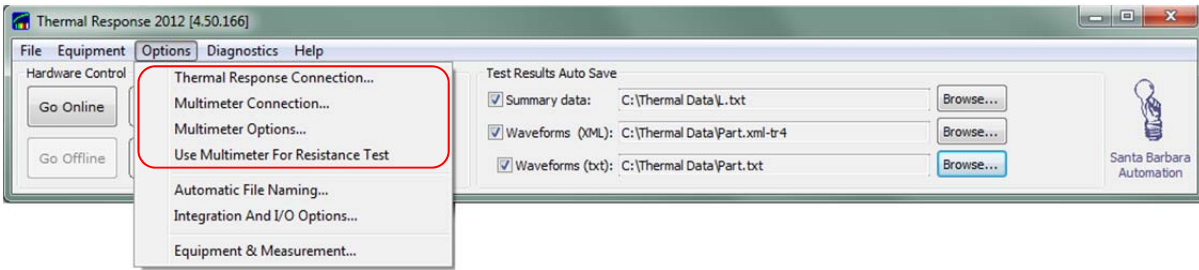


Figure 3: Options Menu

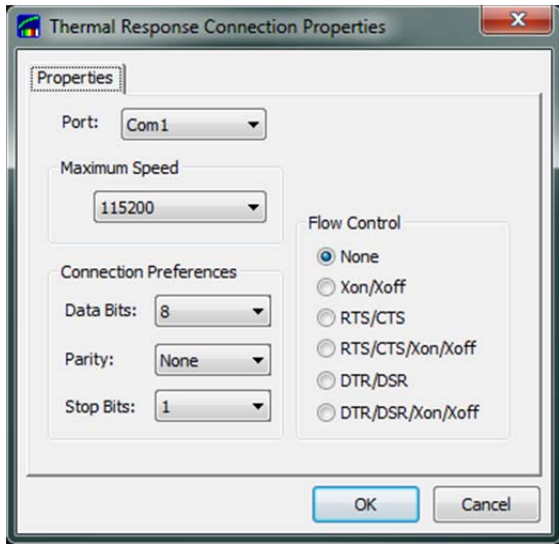


Figure 4A: Port Setup for Thermal Response

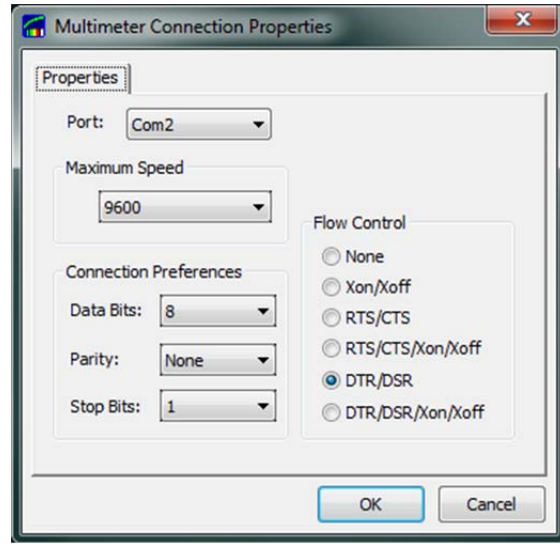


Figure 4B: Port Setup for Agilent 34401 Multimeter

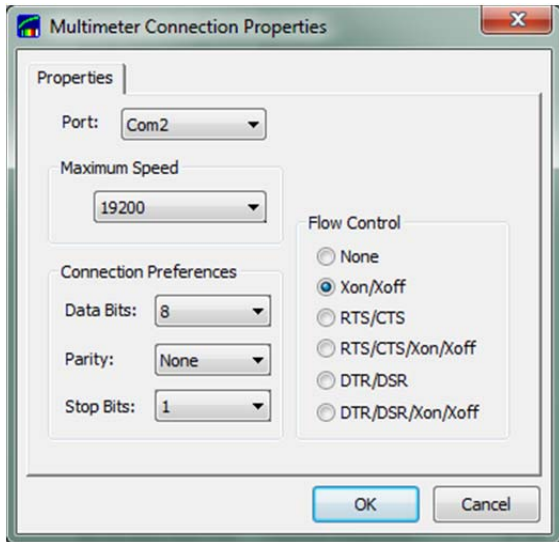


Figure 4C: Port Setup for Keithley 2010 Multimeter

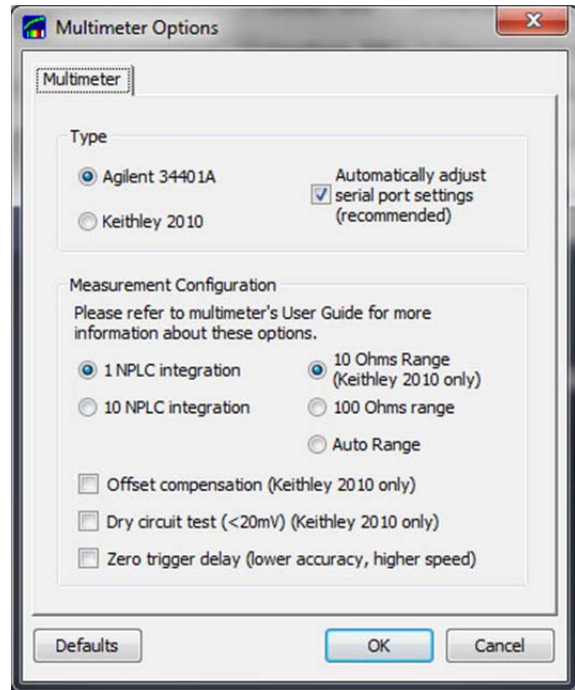


Figure 5: Multimeter Options

5. If an external multimeter (Agilent 34401A or Keithley 2010) is used, click Options on the menu bar and select Use Multimeter for Resistance Test. The application will remember this setting and will attempt to initialize the multimeter each time the application is placed online. To change the settings you must be offline.

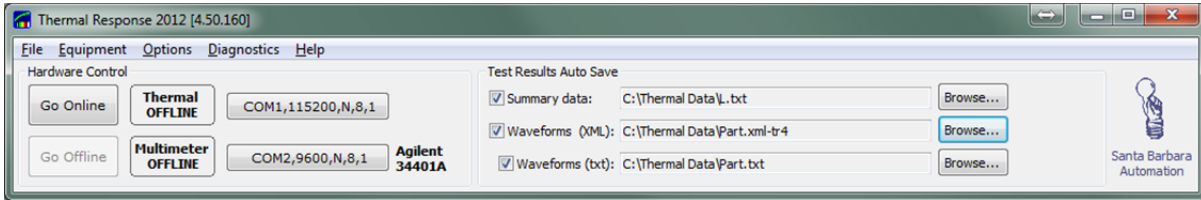


Figure 6: Hardware Control Window

Once the COM port and multimeter are configured, select “Go Online” on the menu bar. This will initiate communications with the Thermal System.

6. When the initialization is successful, the Thermal Response Board status display will change to ONLINE with a green background:

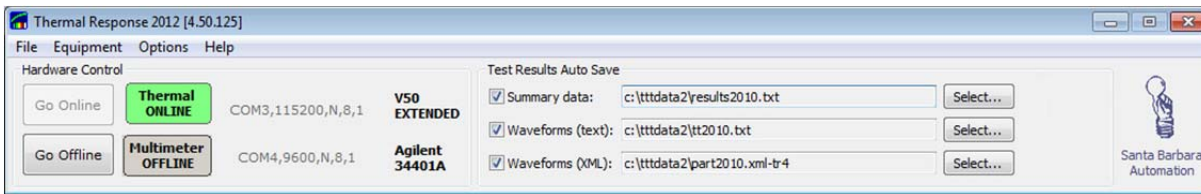


Figure 7A: Thermal Transient System online indicator

If an external multimeter is connected, the Multimeter status display will also change to ONLINE with a green background:

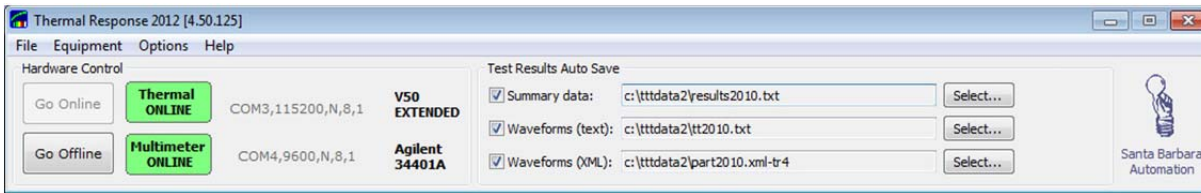


Figure 7B: Thermal Transient and Multimeter online indicators

7. With power applied to the Thermal Transient Test System and the software application online, the TRANS and REC lights on the Test System front panel will blink and the TEST ON light should not be lit.
8. Open and close the door on the test chamber. Confirm that the door (interlock) status is displayed correctly in the Measurement window. For the automation option 24VDC must be supplied to the Machine Ready input to enable testing. This input is the equivalent of the interlock for the manual system and indicates that safe conditions exist to perform tests. *Do not use the equipment without a functional safety interlock*
9. Select the output data destination folders, if necessary, under the Test Results Auto Save section on the main window by clicking on the selection buttons. Additional configuration settings can be found in Automatic File Naming under the Options menu and under the Equipment menu. The default data storage location is “C:\Thermal Data”.

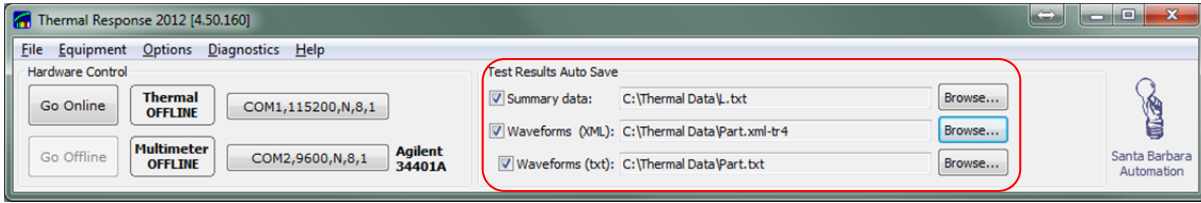


Figure 8: Auto-Save Configuration

Note that an extension of xml-tr4 will automatically associate any saved waveform files with the Thermal Transient program and is recommended. Waveform files with xml or xml-tr4 are also compatible with the Thermal application; however, xml-tr4 is preferred. Please refer to “Test Results” section below for more information on file formats.

10. Select the file naming features found under Options, Automatic Naming Properties:

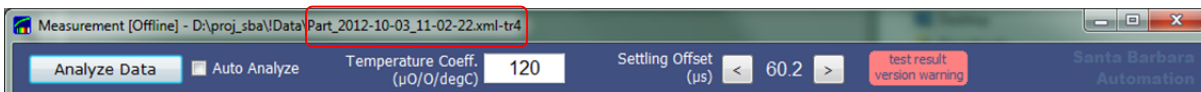
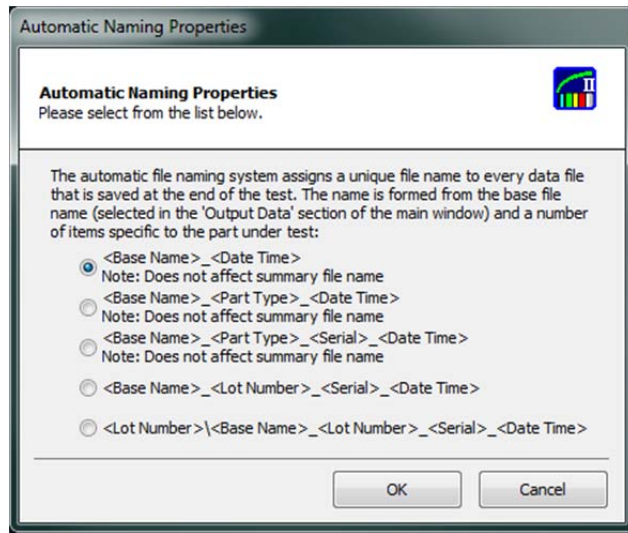


Figure 9: Automatic Naming Properties and Auto-generated File Name

- 1.1. A number of additional options specifying behavior of settings, batch information, and other similar options may be found under the “Integration Options” menu.

The “Auto Title” page (Fig 10, left) contains settings pertaining to the experiment notes (ref. Fig. 19). The software can auto-fill these field if desired, and can also automatically clear them. Please note that by default these fields will persist even after software restart.

The “Data Persistence” page (Fig 10, right) contains additional options for clearing lot/batch information, auto-analyze checkbox and auto-discarding of test that did not progress past the initial resistance stage (often indicating poor contacts, not a genuine failure).

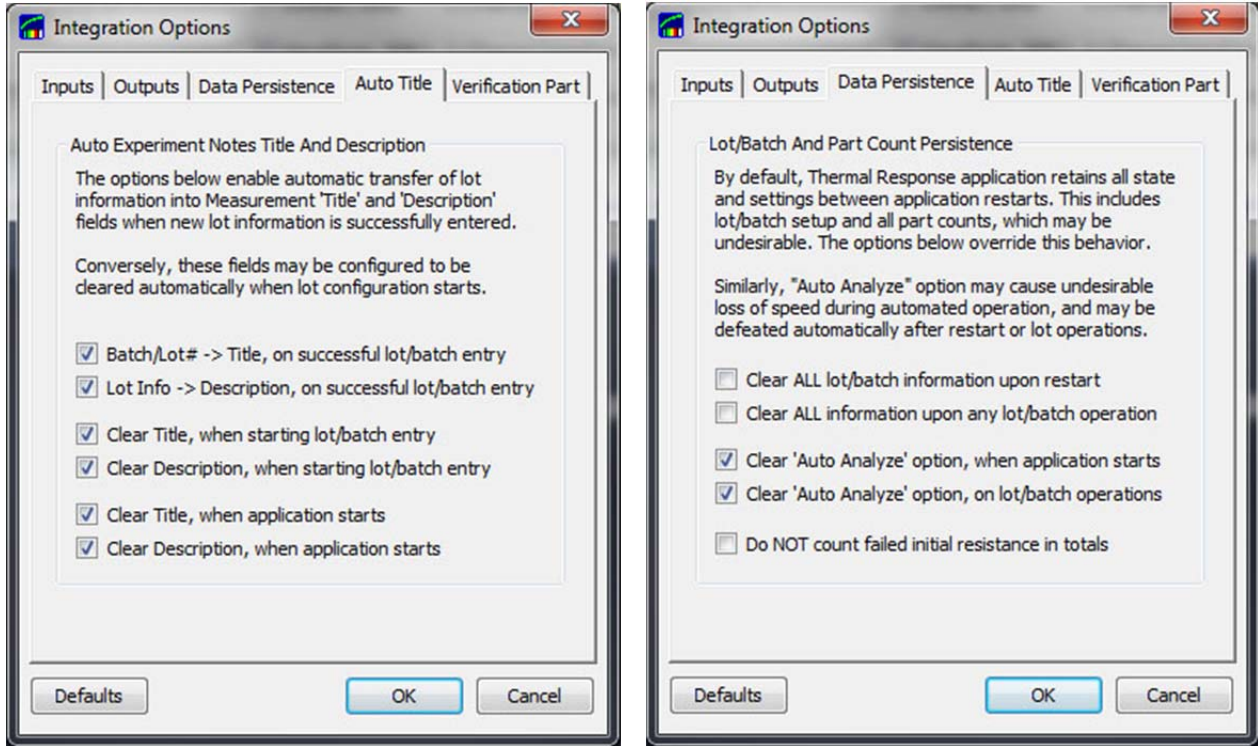


Figure 10: Experiment Notes and Lot Configuration Management Options

12. The Thermal2012 application has additional features when purchased with the optional automation hardware. Please refer to the [“Thermal 2012 Extended Automation Interface”](#) below for additional steps required for proper equipment operation.

13. In addition to the normal operator view, the software is able to operate in the Automation View. Please refer to the following chapter for more details. The Automation View has no effect on how the test is performed, but it does present the data in a way suitable for testing larger quantities of parts. The Automation view may be enabled via the “Equipment” menu.

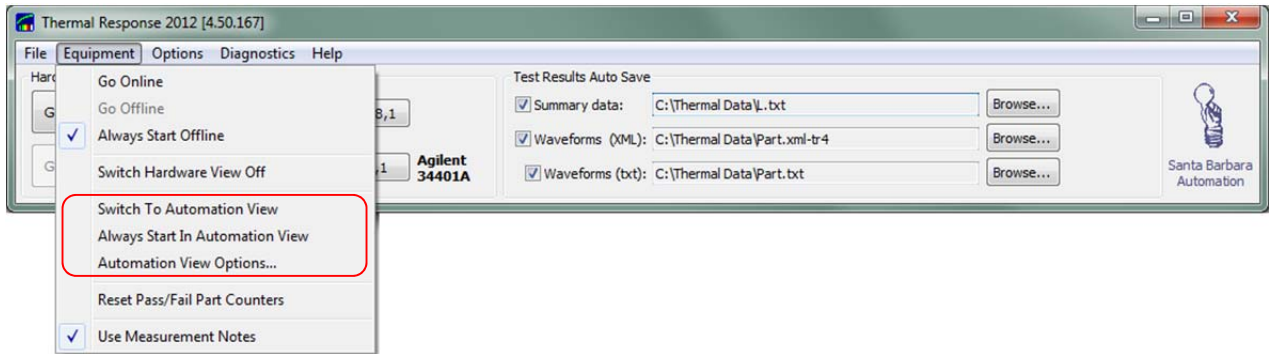


Figure 11: Equipment View Selection

This completes the initial configuration and startup.

Testing Limits and Options

IMPORTANT

The proper configuration of test and processing parameters is absolutely essential to obtaining consistent and accurate measurements. Improper configurations may produce unusable data and/or may damage parts and compromise operator safety.

Configuring Test Limits for Safety

CAUTION

The Thermal Transient software may be limited to a maximum upper current limit. Depending on the individual part type, the standard equipment capabilities of 999mA and optional 1999mA for high-current versions may cause a part to function should excessive test current be specified. The maximum current applied during a Thermal Transient test should be limited to a safe value regardless of the user entered test current. To enable a limit on the test current:

1. Click **Options** on the menu bar then select **Equipment and Measurement**.
2. In the **Equipment and Measurement Options** menu under the Thermal Response tab select the box marked **Enable Test Current Limit**. Enter the maximum safe test current (milliamps). If the user inputs test current that exceeds the set limit, a warning will be displayed and the test will be aborted.

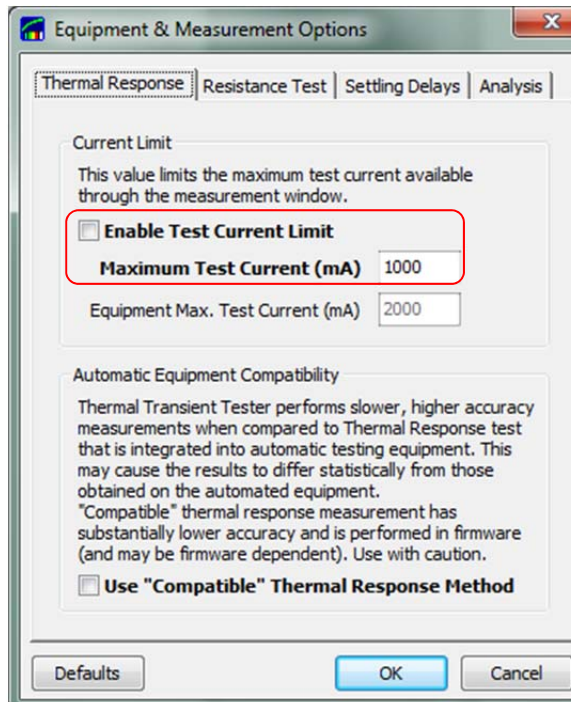


Figure 12A: Test Current Limit

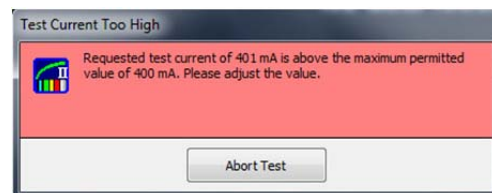


Figure 12B: Test Current Limit Warning

Resistance Measurement

The thermal transient hardware is capable of high precision resistance measurements for the range of values typically found in pyrotechnic parts. For critical testing, faster testing, or when maximum accuracy is desired, an external multimeter is recommended.

When an external multimeter is used, the resistance measurement settings are located under “Options, Multimeter Options...” (ref. Fig. 5). If no multimeter is present, or if “Options, Use Multimeter for Resistance Test” is not checked, the thermal response circuitry will be used to measure resistance.

Thermal response resistance measurement settings are found under “Options, Measurement Options, Resistance Test”. For resistance measurement a typical test current value is 10mA; where higher values will generally produce more accurate readings. The thermal transient hardware performs multiple measurements to compensate for DC offsets caused by calibration errors and/or thermocouple effects unless the “Legacy Resistance Test Mode” is selected. Pass/fail limits for resistance tests are in the Measurement window (Fig. 16).

A normal test sequence involves the initial resistance measurement, the thermal transient test, and the final resistance measurement. The test will be aborted if the initial resistance is outside of the initial resistance limits, which may indicate a defective/missing part, poor electrical connections to the part, or improper connections to the multimeter.

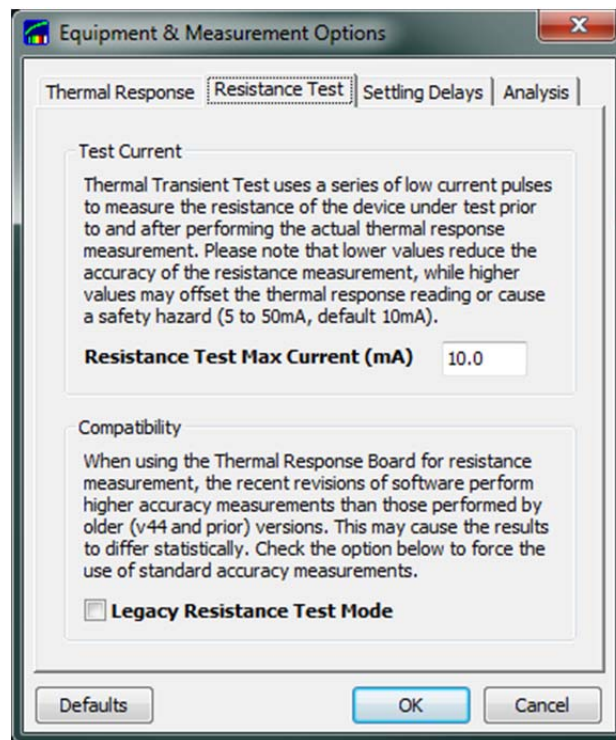


Figure 13: Thermal Response Based Resistance Test Configuration

Current Pulse Stabilization and Accuracy

For accurate measurement, the characteristics of the current source are critical. The current pulse and associated voltage drop across the bridgewire are also used for establishing the initial values of bridgewire resistance and temperature, which in turn affect the rest of thermodynamic results.

Please follow these instructions during both the initial setup and when setting up new part types or for equipment configuration changes (such as changes in test fixtures, wiring, etc.)

All parameters referenced below in this section are located under “Options, Test & Measurement Options...” menu on the hardware control window.

1. The selected testing parameters are transferred to the thermal transient circuitry prior to each test. When changing from one current value, such as when using the thermal transient board for resistance test (from 10mA to the value selected for thermal test), the internal reference takes several few seconds to settle to 16-bit accuracy. This settling delay may be adjusted with the “Current Setpoint Delay” parameter (Fig. 14, top). Values of 3000ms to 5000ms are typical, where longer times provide slightly greater accuracy. The delay is applied when the current setpoint changes, and is, for example, twice per test if a multimeter is not used for resistance test.

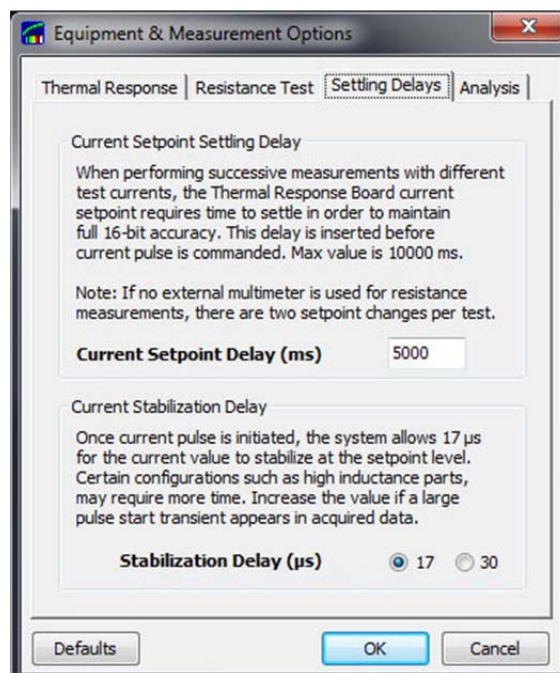


Figure 14: Settling and Stabilization Delays

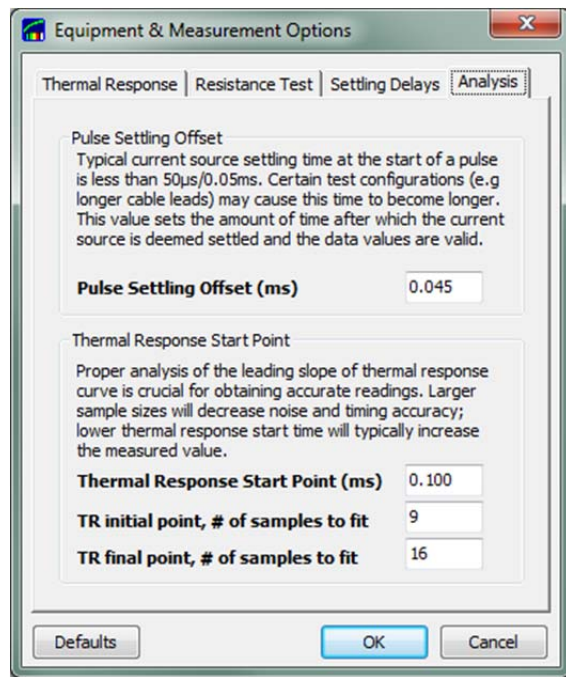
2. A different case occurs during each thermal transient test, when higher current is placed through the part under test. During the initial current rise the length of time required to achieve stability is typically less than 20 μ s and is no greater than 50 μ s. This time is a function of the requested current and the characteristics of the part under test and wiring to the test chamber, and to a lesser degree, the test fixture. Igniters with higher values of inductance or capacitance or longer test wiring may require longer settling times.

For those cases that require longer settling times the application may be adjusted for best accuracy with the “Stabilization Delay” parameter under the “Settling Delays” tab. The selection will disable ADC sampling during the first few samples to avoid inaccuracies or possible analog to digital converter saturation. Please note that V52 or later firmware is required for this feature to work.

The default value for stabilization delay is 17µs. To determine if the 30µs value should be used, acquire a waveform using typical pulse settings. If a large overshoot is observed on the first visible sample, the value may be adjusted to 30µs.

3. “Pulse Settling Offset” is the time after the start of current before the waveform is considered stable and may be used for calculations. This value does not pertain to data acquisition, but to the subsequent analysis that produces the actual Thermal Response result.

It is important that this value is not set too low or too high. Too low of a value will reduce the accuracy of computation because some unstable samples may be included; too high of a value will deprive the software of sufficient number of samples at or near the 100 microsecond point and will increase noise. Values of 0.040ms to 0.060ms are nominal, with 0.045ms the default. The actual effective value will be adjusted to the next available data sample at the time of acquisition/analysis.



Typical conversion sample timing for test pulses of 100ms or less (in µs) :

#	V52+	older firmware
1	7.0	19.3
2	20.3	32.8
3	33.6	46.4
4	46.9	60.0
5	60.2	73.6
6	73.5	87.1
7	86.8	100.6
8	100.1	114.2
9	113.2	127.8
10	126.7	141.3
11	140.0	154.9
12	153.3	168.5
13	166.6	182.0
14	179.9	195.6
15	193.1	209.1

Figure 15: Analysis Parameters and Sample Timing

One related, but independent value, is the “settling offset” found in the measurement window. It modifies the settling value used for thermodynamic analysis, which includes temperature and initial resistance. The separate analysis settling offset allows for consistent analysis of data acquired with different settings. It may need to be adjusted to ensure that the correct slope is used for extrapolation of temperature and resistance to time 0.

Analysis Parameters

The thermal transient test result (the Thermal Transient value in mV) is computed using two linear regression fits on the corrected voltage curve. From the physics perspective, the corrected voltage is essentially equivalent to resistance because it is calculated as follows:

$$R_n = V_n / I_n$$

$$V_{corr_n} = R_n * I_{test}$$

Note that the calculation is done on sample-by-sample basis and that the hardware acquires the current and voltage samples time simultaneously using two separate analog-to-digital converters that are synchronized to the same clock. This allows the system to effectively reject current noise as well current source absolute errors to first order.

The final “Thermal Response” result is the difference in the corrected voltage value calculated from the point defined by “Thermal Response Start Point” to the end of the pulse. *The result is highly sensitive to the start point position.* “Thermal Response Start Point” should be set to 0.1ms, the industry standard.

Two linear regression fits are applied (to decrease noise) as shown on the figure. The two “# of samples to fit” parameters control how many samples are used for the fit. Larger values will reduce noise but also will, particularly for the initial value, reduce the accuracy of the initial slope. The default value of 9 samples combined with the settling offset of 0.045ms (see table on Fig 15, above) centers the fit exactly at the 0.1ms mark.

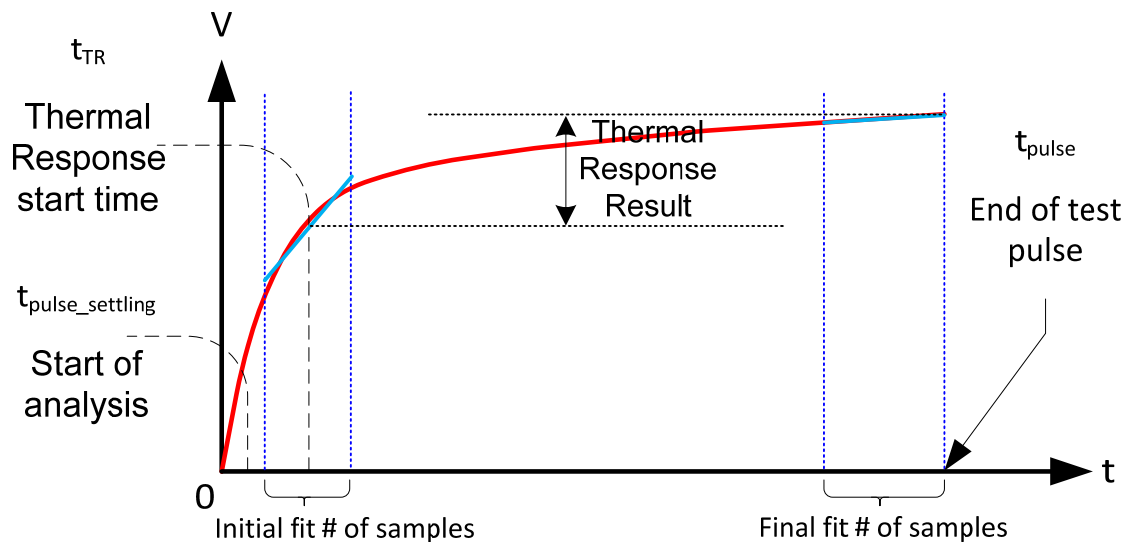


Figure 16: Thermal Response Computation Overview

Please note that test pulses *longer than 105 to 109 ms* (depending on the hardware) have different sampling rates (2x or 3x slower, see specifications or the real-time spec on the measurement window for exact values). This means that the effective averaging interval for the regression fits is greater, even though the same number of samples is used. The start time remains unchanged. This will usually cause slightly lower thermal response results.

Testing Parts

Please note that the Thermal Transient application must be **online** in order to run a test and **offline** to change settings such as use of the multimeter. To run a thermal transient test:

Either: a) Select a part type from testparameters.ini (if configured) by clicking on the box next to the **Part type** on the **Measurement Window**, or b) Configure the test parameters (test current and duration) directly. The part number and testing parameters listed in the Part Number drop down menu must be present and properly configured in the Testparameters.ini file to appear in the menu.



Figure 17: Select Testing Parameters from Testparameters.ini

1. Decide how and where the test results should be saved under **Test Results Auto Save**.
2. Connect the initiator to the test connector and close the test chamber door.
3. Verify testing parameters such test current and pulse duration in the measurement window (Fig. 18A).
4. Enter or verify test notes, if desired (Fig. 18B). The notes will be saved along with the measurement.
5. Either press the operator switch or click the program's **Start Test** button.

CAUTION

Always wait until the test is completed before opening the test chamber door. The test will stop automatically if the chamber door is opened. Never attempt to bypass the interlock switch as this is an unsafe condition.

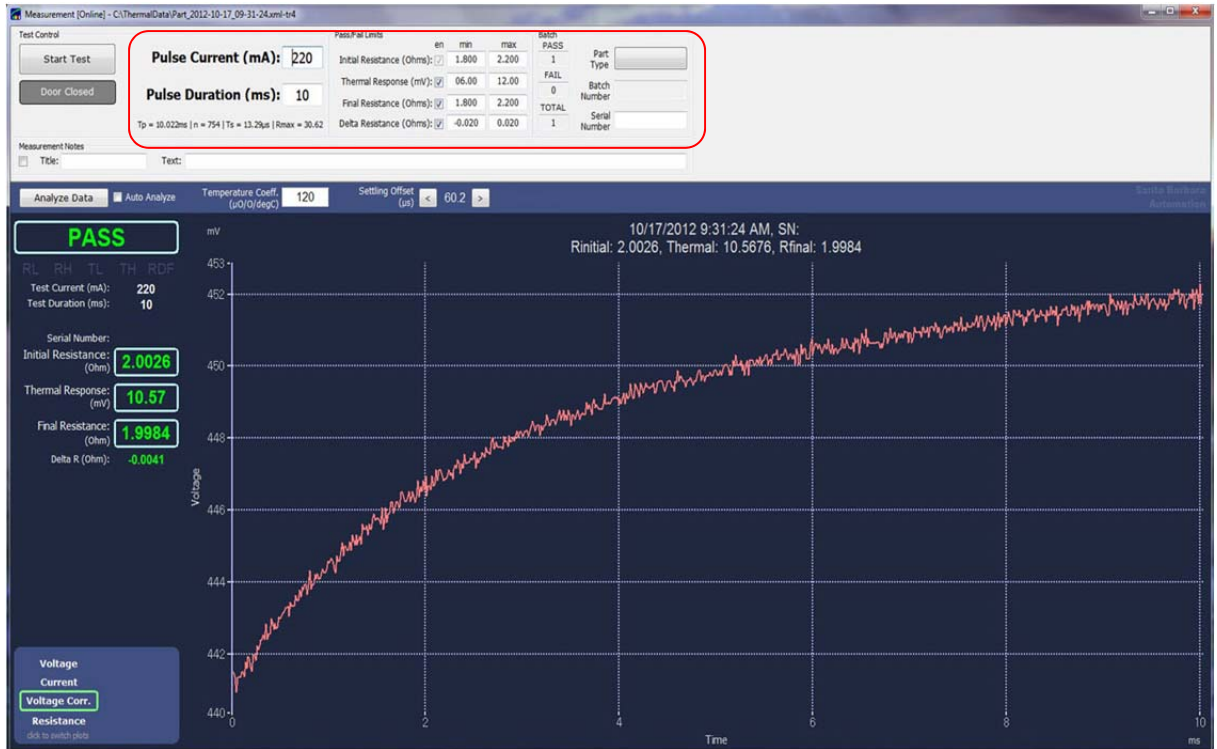


Figure 18A: Test Configuration Area

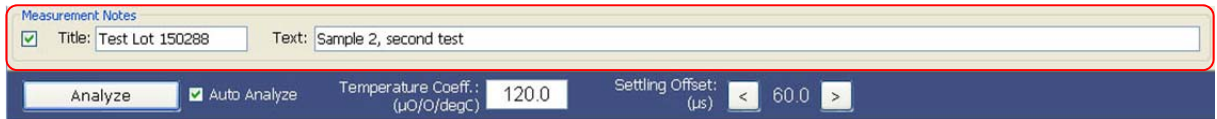


Figure 18B: Test Measurement Notes

Automation View

In addition to the normal operator view depicted above, the software is able to operate in Automation View. While it is optimized for use with the optional automation interface hardware the hardware is not required in order to use Automation View. Please refer to Fig. 19A/B/C. The Automation view is enabled via the “Equipment” menu and may be set up to always open upon startup (except when viewing existing measurements by double-clicking in Windows Explorer).

The automation view does not allow the operator to directly change test parameters such as test current or pulse duration or pass/fail limits. The operator will be able to load predefined part types *only* by using the “Change Lot/Batch” button. The Automation view does not change how the tests are performed, but it does change the way the data is presented to the operator, and is suitable for testing larger quantities of parts and/or production environments.

Password protection is available for the “Full View” button (switches back to normal view) and the “Manual Test” button. These are configured under “Equipment, Automation View Options...”

The “Verif. Load” button does one-click loading of the verification part type, which may be configured under “Options, Integration Options, Verification Part”, (also see Fig. 30).

Automation view also provides access to additional part counters, including failures per category.

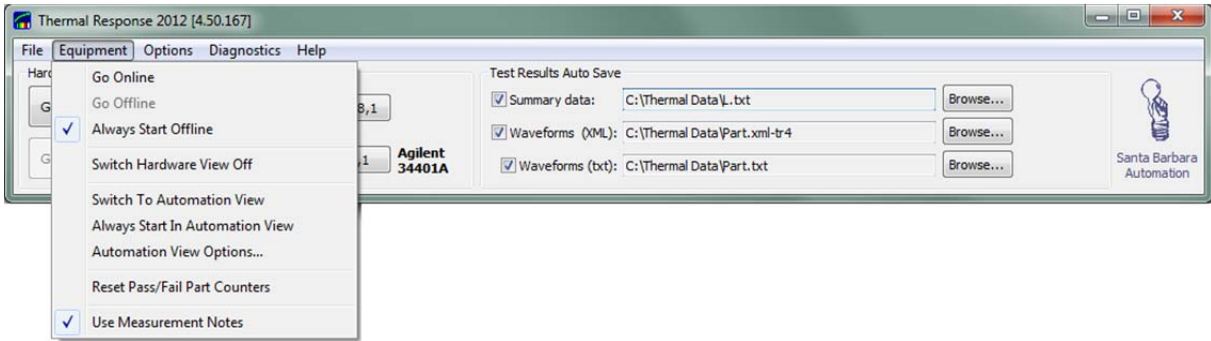


Figure 19A: Equipment Menu with View Options

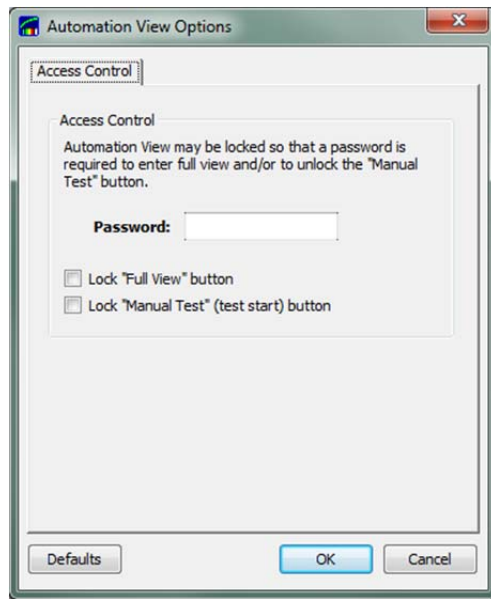


Figure 19B: Automation View Options



Figure 19C: Automation View

Test Results

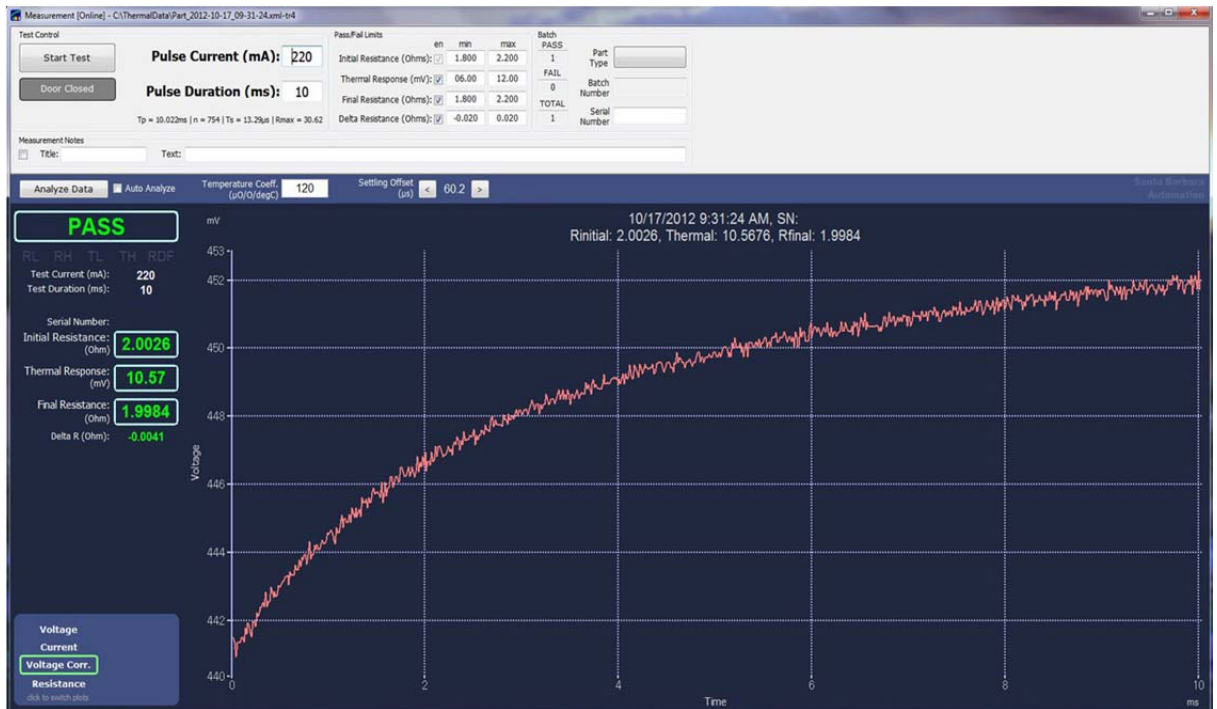


Figure 20: Thermal Transient Test Measurement

The primary display of the Thermal Transient test is a graphical window as shown above. The vertical axis shown in this display is the corrected voltage across the bridgewire and the horizontal axis is test time. A numerical display of the test results is provided on the left side of the screen.

For the Thermal Transient system the test is conducted in three parts;

1. The initial bridgewire resistance is measured.
2. The Thermal Transient test is conducted.
3. The final bridgewire resistance is measured.

When the test has been successfully completed the test results are uploaded to the host computer and displayed on the screen. You may select several viewing options, including:

1. The voltage across the bridgewire.
2. The constant current through the bridgewire during the test.
3. The voltage across the bridgewire as corrected for correlated current noise.
4. The bridgewire resistance during the test.

The waveform above represents the heating curve and resistance change resulting from a test current of 240mA. Note that the initial portion of the curve (between 0 and 2 milliseconds) reflects a much faster rate of rise than later portions of the curve. Accurate measurement of the 100us voltage and current is critical to measurement of thermal transient values.

The viewer will display the selected test results in numerical and graphical form. You may view the acquired voltage, acquired current, voltage corrected or calculated resistance

waveforms. Click the waveform name to select it. The corrected voltage graph is shown after the application starts. The menu at the top of the window allows additional options such as comparisons between separate tests.

When viewing the graphical display on the Thermal Transient software application the following keyboard and/or mouse operation may be used for adjusting the viewing area of the graph (click on the graph to enable keyboard focus):

Keyboard Command	Action
A	Autoscale to view all data
C	Cursor on/off
Tab	Second cursor/toggle cursor
Left/Right arrow key	Move cursor on selected curve
Shift + Left/Right arrow key	Fast move cursor on selected curve
Up/down arrow key	Next/previous curve
f	Cursors floating/locked
Control + arrow key	Scroll and pan
Control + shift + arrow key	Fast scroll and pan
Control + left mouse button held down	Define start of zoom window, move to define window
Control + left mouse button up	Zoom to defined window
Control + left mouse button up	Abort zoom operation
i	Copy bitmap to the clipboard
l	Legend on/off
o	Original scale
t	Zoom out one step
y	Toggle active y-axis
z	Start keyboard zoom
Arrow key	Move zoom rectangle
Alt + arrow key	Size zoom rectangle
Enter	Zoom
Esc	Abort zoom operation

Figure 21: Graph Navigation

If the temperature coefficient of the bridgewire material (in microohms/ohm/°C) is known, the data may be analyzed using the built-in first order thermodynamic model. Enter the temperature coefficient and click on the “Analyze” button. When analysis is complete, the application will enable additional X and Y axis choices for analysis results. To automatically analyze all acquired data, check the “Auto Analyze” box. Note that the Settling Offset in microseconds (red box above) is only used for thermodynamics analysis and will not affect other results. Complete description of the analysis calculations may be found in Appendix A.

Analysis results may be plotted against time or temperature, as indicated by the X-axis selector in the lower right corner of the axis selection control area (Fig. 20). The following data is available:

- Temperature: computed from resistance, smoothed by adaptive regression filter.
- Cp: amount of energy required to raise the temperature one degree C.
- Dissipation: includes total dissipation, initial Cp derived dissipation (light red curve) and the difference (dark red curve).

Analysis data may be exported via the File menu (“Export Analysis Data as Text...”), in comma delimited text format suitable for processing in third party applications such as Excel or Matlab. Please note that thermodynamics results are exported only after the analysis is performed, otherwise only the current, voltage and timing data will be exported.

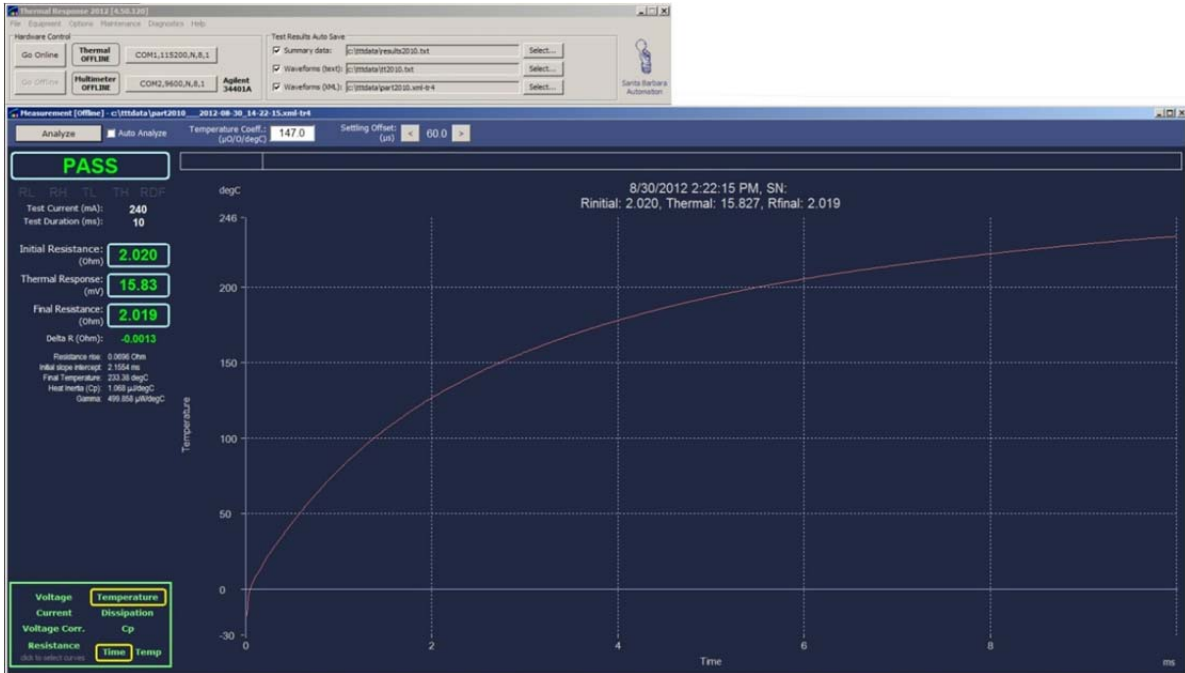


Figure 22: Analyzed Measurement

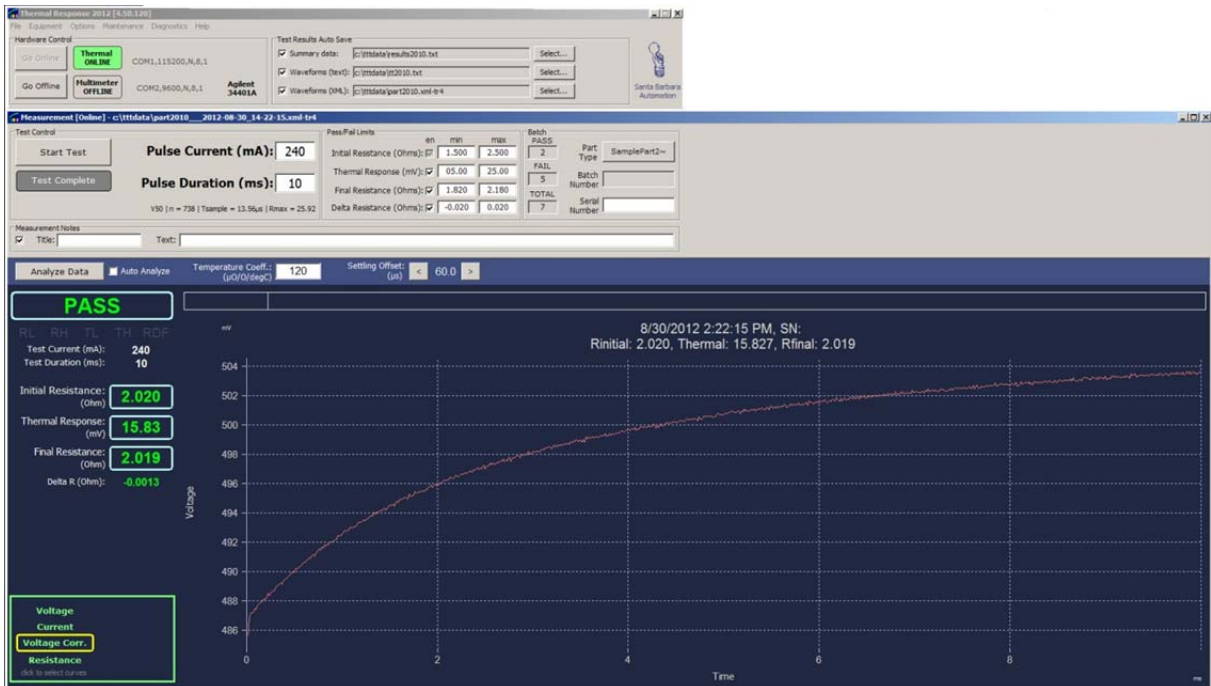


Figure 23A: Good Test Results Screen

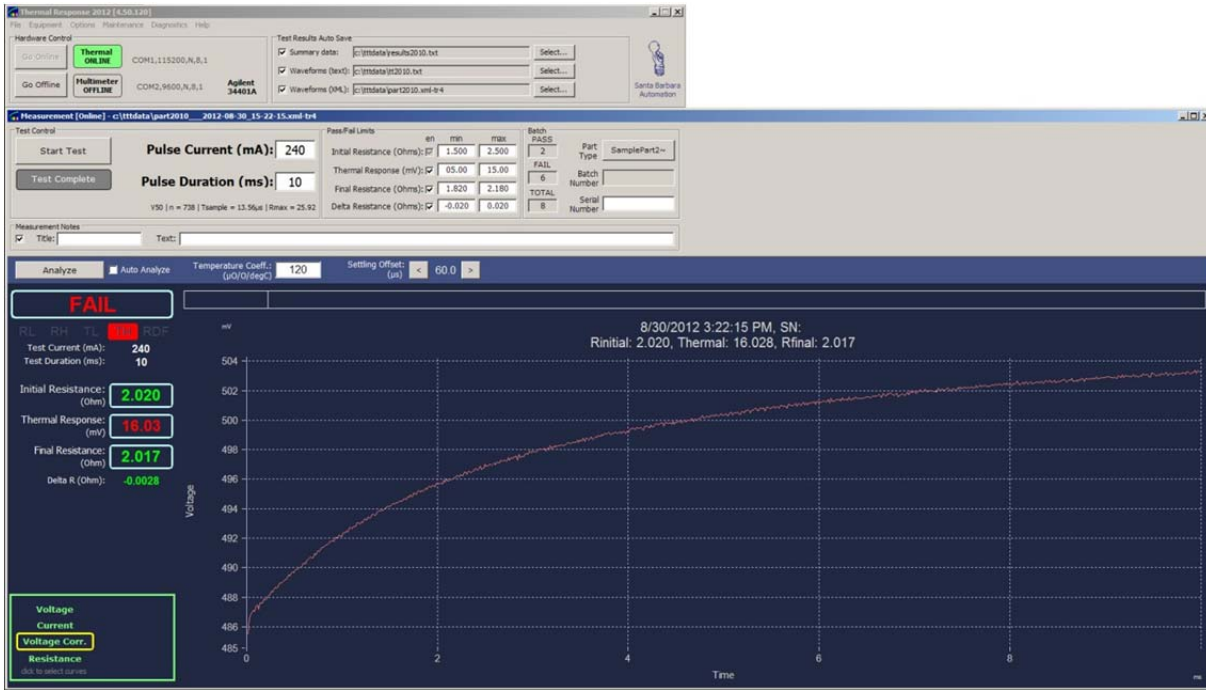


Figure 23B: Failing Test Results Screen

The Thermal2012 application will display reject categories for failing parts beneath the pass/fail window, where the above screen reflects a thermal high failure. The 5 categories are noted as: RH = resistance high, RL = resistance low, TH = thermal high, TL = thermal low and DF = delta resistance fail.

Part Counters

Each test result may be subjected to up to four separate evaluations: initial resistance, thermal response, final resistance, delta resistance; the limits are entered in the measurement windows (Fig. 18A). The initial resistance evaluation is mandatory and may not be disabled; other evaluations may be disabled by unchecking the appropriate checkbox. Note that initial resistance failure will cause all subsequent tests to be aborted. Thermal response failure will not abort final resistance. The software has the following part counters:

- **Parts Failed:** Total number of parts tested and failed. This counter is incremented when a test is performed and at least one of the evaluations fail, with one exception: initial resistance failures may be excluded by checking “Do not count failed initial resistance in totals” under “Options, Integration Options, Data Persistence”. Separate counters of parts per failure type are also visible in Automation view.
- **Parts Passed:** Total number of parts tested and passed. This counter is incremented when a test is performed, initial resistance is passed, and at least one of the subsequent evaluations is enabled and passed.
- **Parts Tested:** Total number of parts tested. This counter is incremented each time a test is performed, with the same exception as “Parts Failed” for the initial resistance.

The counters are reset every time new a batch is configured (Fig. 17), or as specified under “Options, Integration Options, Data Persistence”, or manually by clicking the “Equipment, Reset Part Pass/Fail Counters” menu item. The counters may be configured to persist after software is restarted.

Measurement Data Files

Test results are archived in as many as three different formats:

1. **Text Summary:** The **Text Summary**, normally called the results file, archives test results in a form suitable for statistical analysis of test data. The data is stored one test per line in comma separated values (CSV) format. For example (presented here in 2 lines due to page width limitations):

```
Date, Time, Serial, FixtureID, PartType, LotNumber, TestCurrent, PartEvaluation, InitialR,
2012-10-02, 11-23-52, 12, -3, SamplePart2-, , 240.00, FAIL, 2.05160,
InitialREval, Thermal, Thermal Eval, FinalR, FinalREval, DeltaR, DeltaREval, LogTitle, LogText
PASS, 17.65404, FAIL, 2.04926, PASS, -0.00234, PASS, Sample Test, Inert test
```

Select the “Summary data” checkbox to enable the **Text Summary** output.

2. **XML Waveform:** The **XML Waveform** file contains all the settings, test results, waveforms and all other information associated with a measurement. When selected, the **XML Waveform** files may be generated automatically after every measurement. You may also view the test results offline for analysis, troubleshooting and comparison to other waveforms. Using the XML-TR4 extension will automatically associate the waveform files with the thermal application and is the recommended archival format for the waveform data. Most early versions of Thermal XML files may be opened from within the new application. Files saved with a plain XML extension under the new application may only be opened from within the program.
3. **Text Waveform:** The **Waveforms (text)** file contains all waveform data along with the test results and test settings in a comma separated format. It is suitable for further data analysis in Excel or a similar program.

Note: It is not necessary to save all the test data in the **Text Waveform format** at the time of acquisition since any **XML Waveform** file can be converted to a text waveform by loading it in into the application and then clicking **Export Analysis Data As Text** under the **File** menu.

Note: Text Waveform contains all analysis data only when data was analyzed by clicking the “Analyze” button or by checking “Auto Analyze” and running a test.

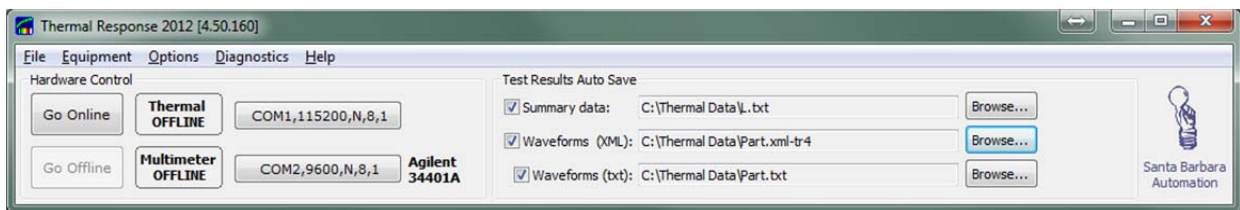


Figure 24: Output data save selection screen

Select the type and location of the data you wish to save prior to running a test. Choose files names that will allow the series of tests and data to be easily identified at a later date. Since large groups of data may be useful for determining production equipment performance we suggest periodically archiving the data. This also serves to reduce the number of files in the save location.

Thermal 2012 Extended Automation Interface

The Thermal Transient Automation Interface must be used with version 50 or later firmware and the proper hardware. This option allows handshaking with a programmable logic controller (PLC) or other equipment using several input and output lines for automatic testing. The interface is designed for 24VDC logic.

Hardware Connections

You must supply a source of +24VDC to the rear panel connector labeled Power as follows:

1. +24VDC at 200mA
2. 24V return

A minimum of 2 input connections (Machine Ready and Test Start) and 3 output connections (Thermal Transient Ready, Pass and Fail) are necessary to allow the Thermal Transient equipment to operate in the automatic mode. You must supply +24VDC to the Machine Ready input to enable the internal safety circuitry and allow a test to run. This is true for both manual and automatic modes. *This input should only be active when a test may safely be run. A test chamber door interlock is such an example.*

From the Thermal Transient equipment to the PLC (24V sourcing logic, active high outputs) the available outputs are:

1. TR - Thermal Transient Ready
2. P - Pass
3. F - Fail
4. RL - Resistance Low Fail
5. RH - Resistance High Fail
6. TL - Thermal Low Fail
7. TH - Thermal High Fail
8. DF - Delta Resistance Fail
9. NS - Nest Select

Inputs from the PLC to the Thermal Transient equipment (24V sinking logic, active high inputs):

10. MR - Machine Ready (Safety interlocks are closed – *MUST be present to run*)
11. TS - Test Start request
12. NL - New Lot request
13. NS - Nest Select



Figure 25: Thermal Transient rear panel

Please note the connectors and LEDs on the rear panel of the Thermal Transient instrument. The larger 10-pin connector is for the output signals and the smaller 4-pin connector is for the input signals. A separate 2-pin connector is for +24VDC and DC return. It is important that the proper voltage and polarity be observed for handshaking with your equipment.

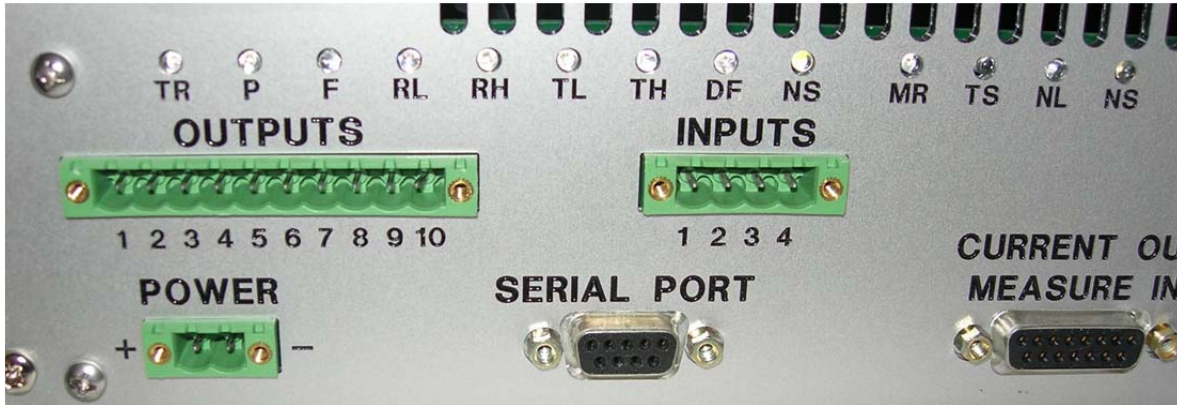


Figure 26: LEDs, power supply and interface connections

Connect a source of +24VDC power to the POWER connector. Note that the positive side is on the left.

Connect the inputs and outputs to the I/O connector as follows:

Outputs

1. **Thermal Transient Ready** – output, this line is high when Thermal Transient is ready to test.
2. **Fail** – output, this line is high when the part is found to be defective for any reason.
3. **Pass** – output, this line is high when the part passes the test.
4. **Resistance Low** – output, this line is high when the part fails for high resistance.
5. **Resistance High** – output, this line is high when the part fails for low resistance.
6. **Thermal Transient Low** – output, this line is high when the part fails for high thermal.
7. **Thermal Transient High** – output, this line is high when the part fails for low thermal.
8. **Delta Resistance** – output, this line is high when the part fails for high delta resistance.
9. **Nest Select** - output, when an external multiplexer is used to select a second test position.
10. **24VDC return**. Typically from the external nest select multiplexer circuitry.

Inputs

11. **Machine Ready** – input, +24V must be supplied to allow electrical connections to the test position. *If +24V is not present all wiring to the test chamber is isolated by internal relays.*
12. **Test Start request** – input, +24V is supplied when a thermal transient test is desired.
13. **New Lot request** – input, +24V is supplied when a Lot of parts is finished and you wish to start a new Lot. This will terminate testing and force the operator to enter the parameters for the new Lot.
14. **Nest Select** – input, selects an alternate test position when an external multiplexer is used.

The LEDs on the rear panel will assist with troubleshooting your connections. Due to limited space their labels are abbreviated as follows:

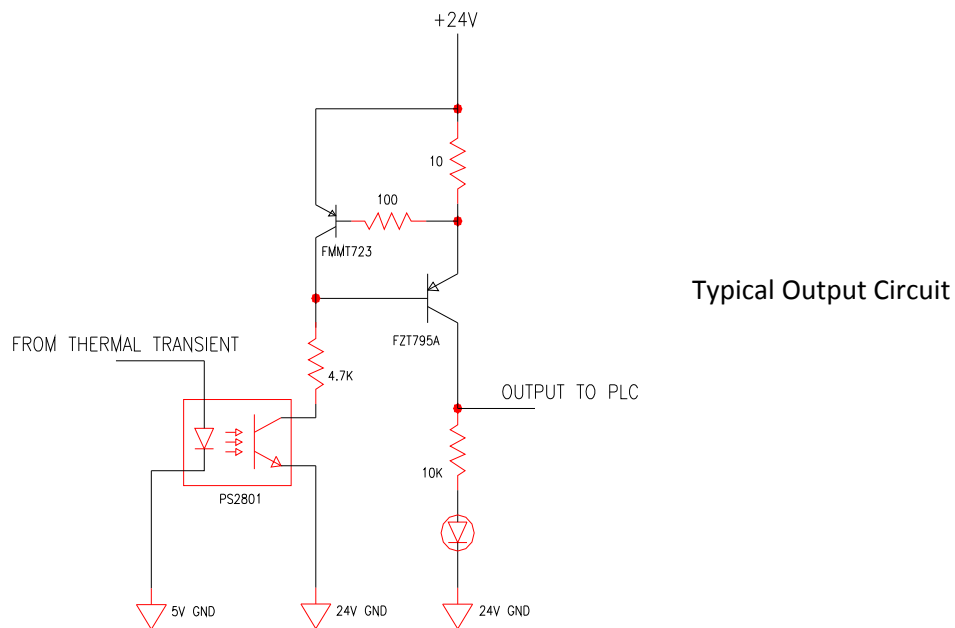
INPUTS

MR	TS	NL	NS
Machine Ready	Test Start	New Lot	Nest Select

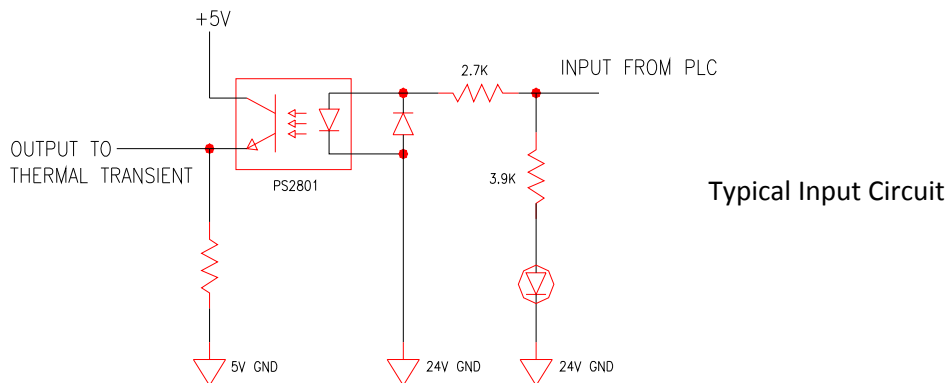
OUTPUTS

TR	P	F	RL	RH	TL	TH	DF
Thermal Ready	Pass	Fail	Resistance Low	Resistance High	Thermal Low	Thermal High	Delta Fail

For operator safety the electrical connections within the Thermal Transient enclosure are disconnected from the output terminals unless the Machine Ready input is supplied with +24VDC, indicating that all guards and shields are in place and a test may be safely conducted. *Note that a test may not be performed without this input being active.*



Typical Output Circuit



Typical Input Circuit

Figure 27: Typical circuitry for outputs and inputs

Test Options

When using the automation version of Thermal2012 and the correct hardware the user has numerous integration options that change the manner in which the equipment functions.

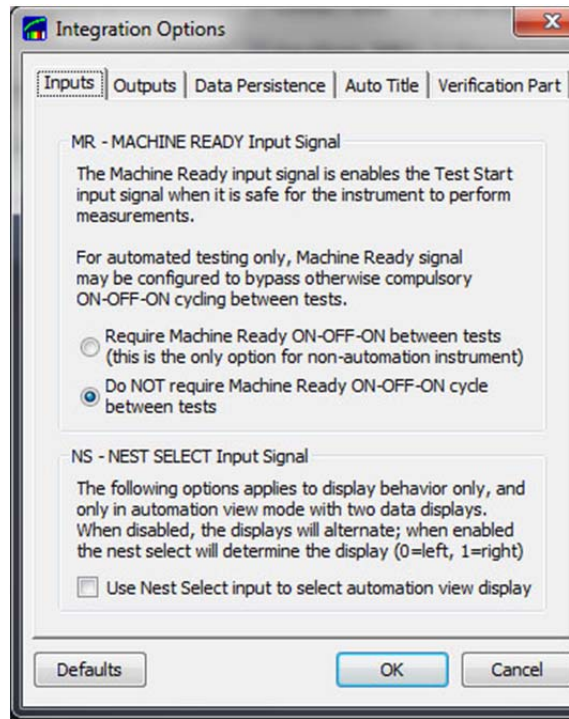


Figure 28: Machine Ready and Nest Select

The manual test version of the thermal equipment requires that the test chamber door be opened and closed between each test to avoid double testing a part. *The automation version of the Thermal Transient Test System MUST have the Machine Ready input active to enable testing.* Without this input all electrical connections to the test station are disconnected. If your automation equipment provides reliable, safe, testing conditions select the option that does not require a Machine Ready cycle between each test. Otherwise, provide a state change for the MR signal to enable the next test and indicate that safe conditions exist for testing.

The “Use Nest Select” display option may be used with or without the automation option. When the “Use Nest Select input to select automaton view display” is checked the graphical test results for each test are associated with the nest position on the display, either Nest 0 or Nest 1.

The Outputs section of the Integration Options menu provides different options for when the equipment is placed online, for inserting a delay between output write and input read operations and for the trigger signal option.

The testing parameters and Lot information should always be selected prior to performing production tests. For manual testing, such as during development and for quality assurance test, the parameters may be frequently changed by entering values manually. In this case it may be preferable to have the equipment always online.

To provide compatibility with some types of faster automation equipment a delay between the output write and the input read may be selected.

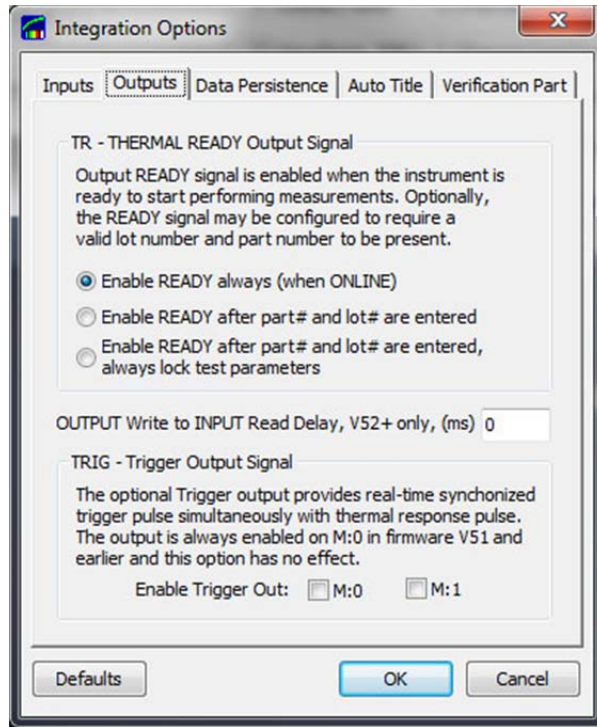


Figure 29: Integration Options, Outputs

When the proper hardware is available and selected, the trigger signal is active during a test and will allow external equipment, such as an oscilloscope, to capture waveforms independently. The signal rise and fall quite accurately represent the test pulse current. Alternately, another option will allow these signals to be used to select test positions for initiators with multiple bridgewires.

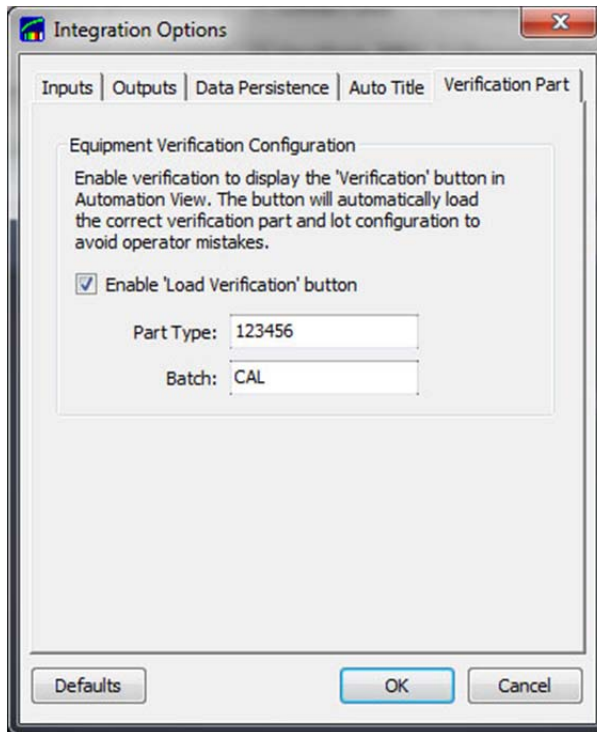


Figure 30: Integration Options, Verification Part

A test certification part may be used to verify machine performance and reduce the risk of shipping defective product. To simplify this process the test certification part, such as those provided by Santa Barbara Automation, may be given a unique part type and name. When enabled this feature will enable the verification part button on the Automation view screen *only*, to load the test parameters associated with the verification part. Please refer to the Automation View section for more information.



Figure 31: Single Channel Test Certification module

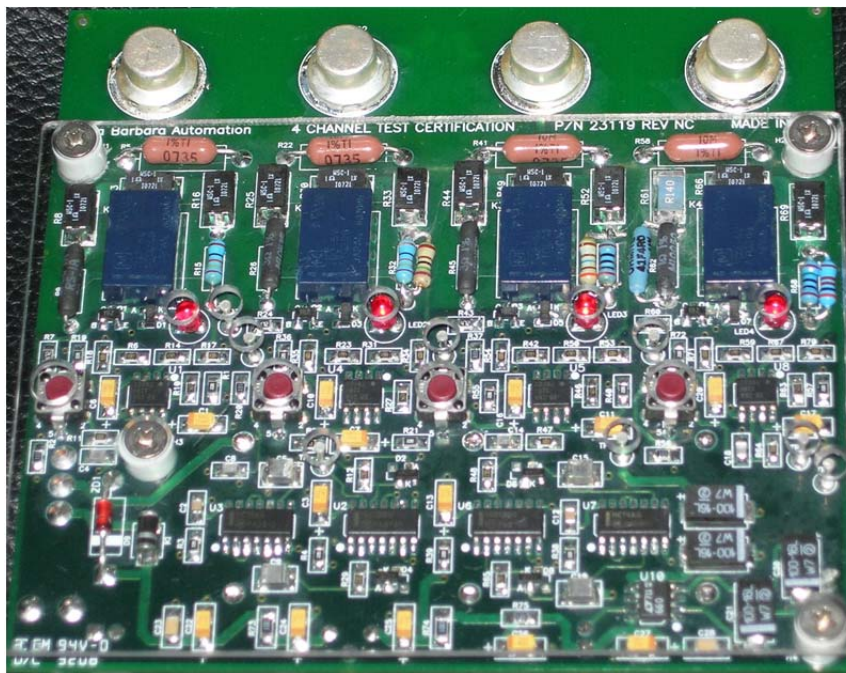
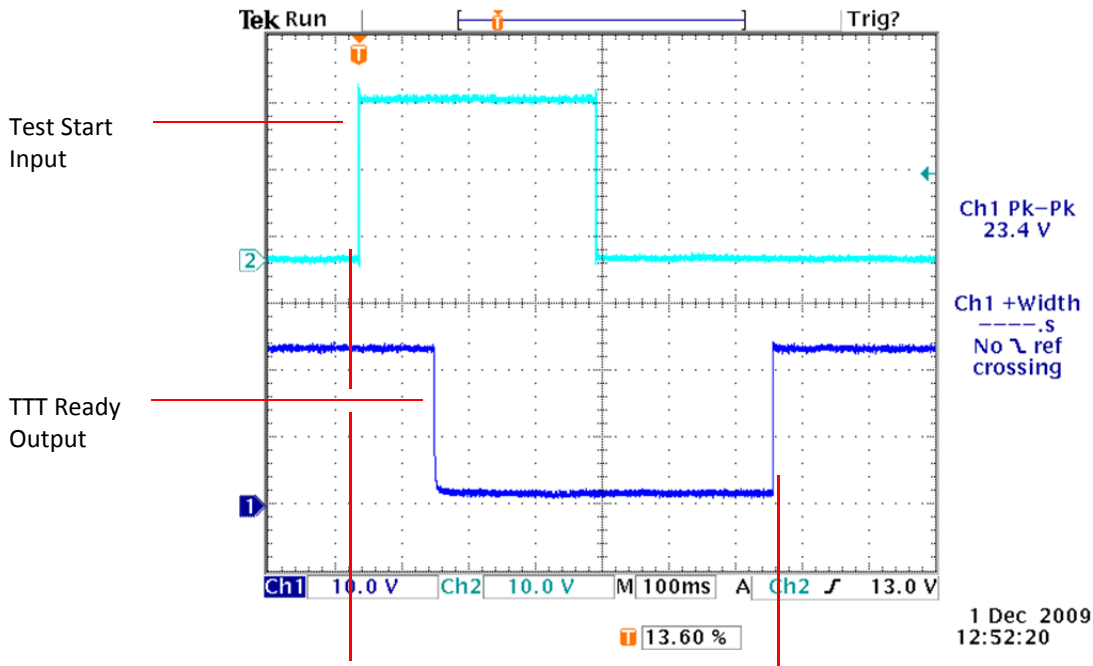


Figure 32: Four Channel Test Certification module

Many versions of certification modules are available, with from one to as many as 20 channels for fast, reliable equipment validation. Different resistance and thermal standards may be specified as required for each installation.

Test Timing

Thermal Transient test system refreshes the inputs and outputs at approximately every 125ms, or 8 times per second. Assuming that the system is equipped with a multimeter, the hardware is capable of completing a 10ms pulse duration test in around 600ms (the total cycle may be longer because of polling delays of up to 125ms). Longer test pulses will significantly increase cycle time both due to longer pulse proper and because more time is needed for data download. Please note that for high-speed applications, Santa Barbara Automation offers a line of products capable of testing over 3000 parts per hour including transport time, or about 2 parts per second without transport time.

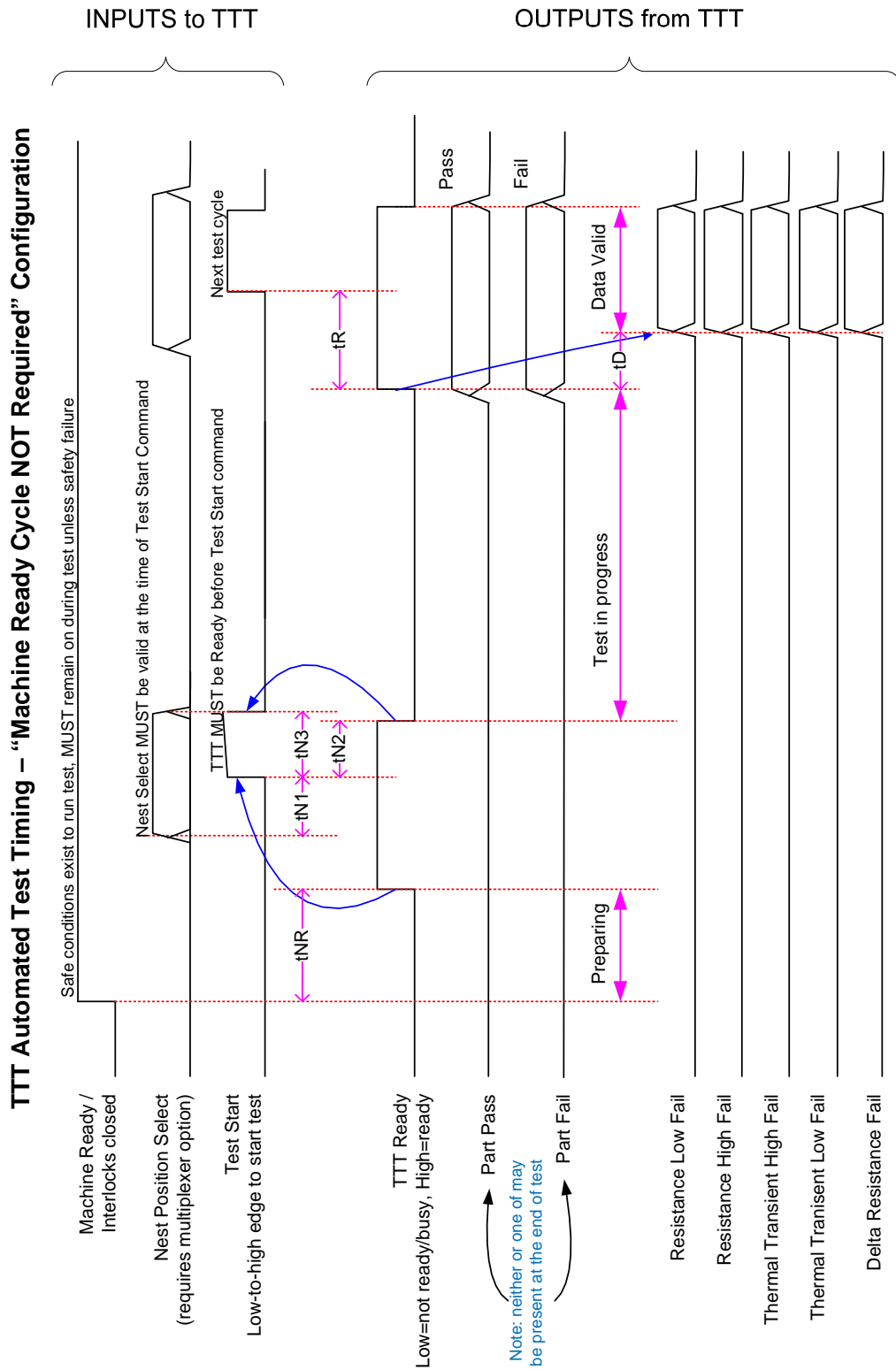


Typical test timing for 10ms test: 625ms Test Start to Thermal Transient Ready

Figure 33: Typical Test Timing

Correct implementation of handshake timing is critical for reliable and fast integrated operation. The following diagrams (Figs. 32 and 33) provide timing specifications for the Extended I/O interface. Many of the timing features follow from the fact that the thermal response hardware reads the inputs at the same time it writes the outputs from the last scan cycle (and does so about every 125ms). Please note that the Machine Ready input signal drives the relay coils for the measurement bus disconnect, and thus requires settling delays. For PLCs with relay outputs, extra care should be taken to ensure that the outputs settle before due time.

Please note that the both Pass and Fail outputs may be inactive at the completion of the test; this condition indicates equipment error and means that the measurement was aborted for some reason.



TIMING SPECIFICATION:

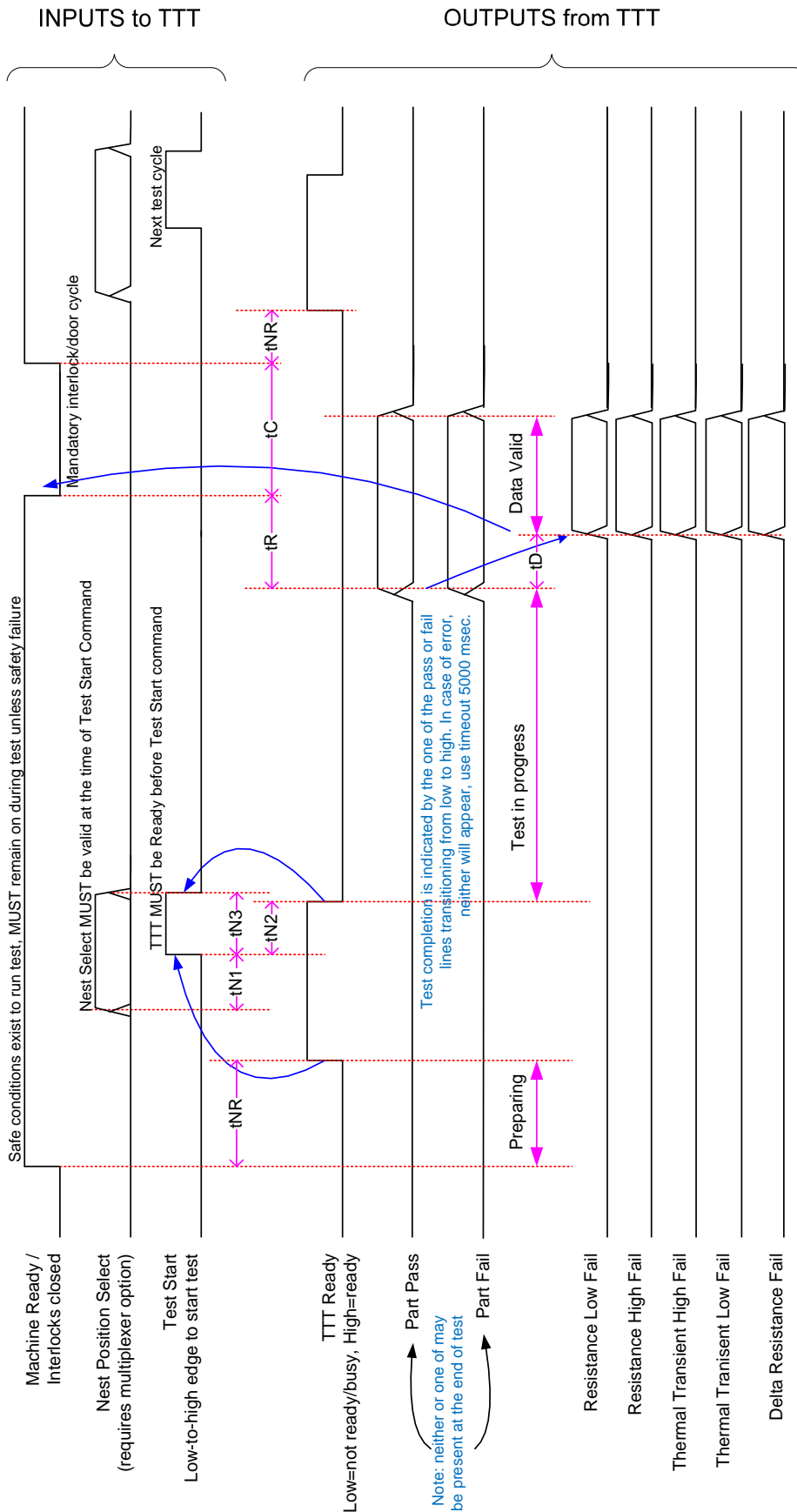
- t_{NR} : Time to TTT ready after Machine ready. 10msec min, any length max because may require lot configuration from user.
- t_{N1} : Time Nest Select must be ready before test start: 50 msec min.
- t_{N2} : Test start delay: 200 msec max, set timeout to 1000 msec.
- t_{N3} : Test start and Nest select duration: must be greater than t_{N2} .
- t_D : Test finish to Data valid delay: 20 msec + additional settling for any relays in circuit, if any.
- t_R : Test recycle time, must be greater than t_D . **WARNING:** high rate testing at high test currents may cause overheating.

NOTES:

- Part Pass and Part Fail are active high, one or neither lines active at the end of test.
- Failure category outputs are active high; all combination are possible including none or multiple simultaneous.

Figure 34: Interface Timing Specification 1 (Ready Cycle NOT Required)

TTT Automated Test Timing – “Machine Ready Cycle Required” Configuration



TIMING SPECIFICATION:

- tNR : Time to TTT ready after Machine ready. 10msec min, any length max because may require lot configuration from user.
- $tN1$: Time Nest Select must be ready before test start: 50 msec min.
- $tN2$: Test start delay: 200 msec max, set timeout to 1000 msec.
- $tN3$: Test start and Nest select duration: must be greater than $tN2$.
- tD : Test finish to Data valid delay: 20 msec + additional settling for any relays in circuit, if any.
- tR : Test recycle time, must be greater than tD . **WARNING:** high rate testing at high test currents may cause overheating.
- tC : Interlock cycle time: 300 msec minimum.

NOTES:

- Part Pass and Part Fail are active high, one or neither lines active at the end of test.
- Failure category outputs are active high; all combination are possible including none or multiple simultaneous.

Figure 35: Interface Timing Specification 1 (Ready Cycle Required)

Diagnostic Tools

A basic diagnostic tool is included with the Thermal application for simple troubleshooting. To invoke the tool, click on Diagnostics portion of the main application and select Digital I/O Monitor from the drop down menu. This tool provides a display of all input and output signals used on the thermal transient equipment and is useful for troubleshooting.

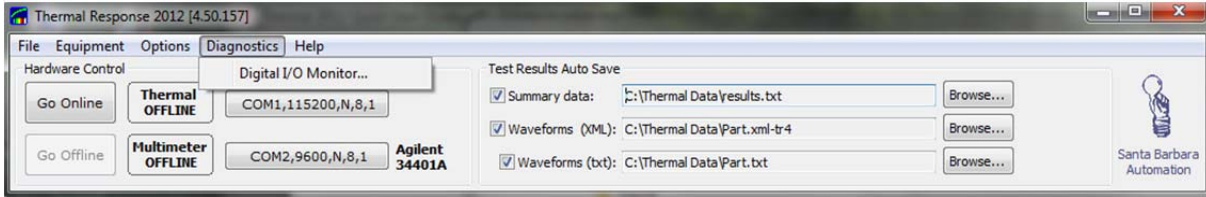


Figure 36: Diagnostics Selection on the Menu Bar

With the Thermal Transient System connected to the external equipment and power applied select Diagnostics on the menu bar and then Digital I/O to start the diagnostic graphic.

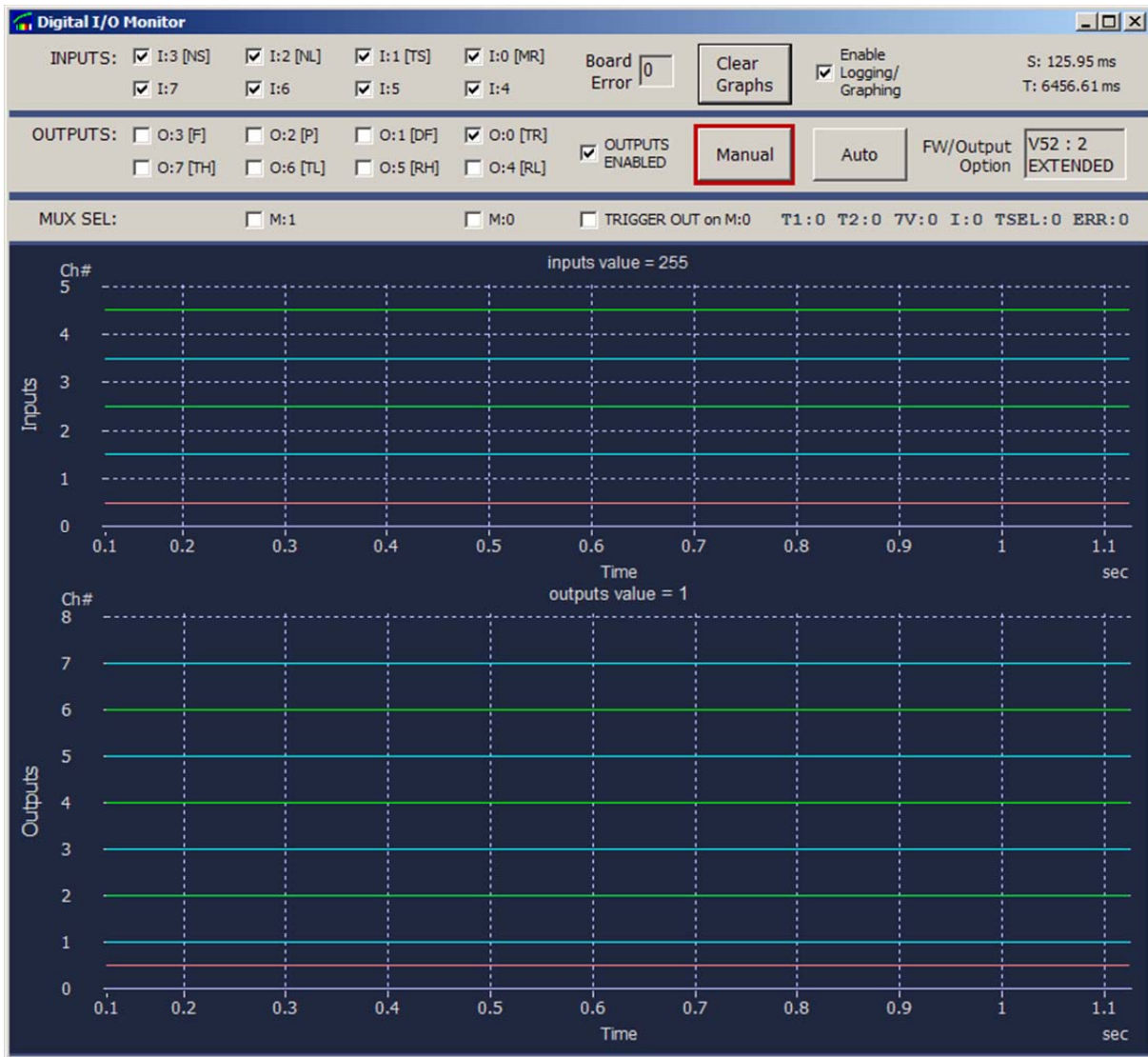


Figure 37: Diagnostics Tool

Click on Outputs Enabled, Enable Graphing and Auto and the application will start. The condition of any input or output signals (high or low) will show. Note that signal rise/fall times are not accurate.

The “y” axis on the graph corresponds to the respective bit number. For example, input 3 (I:3) is plotted on input graph at y=3 for OFF state and at y=3.5 for ON state.

The software will automatically update signal names to match the type of I/O expansion board installed (if any). Outputs will be disabled with no I/O expansion is present.

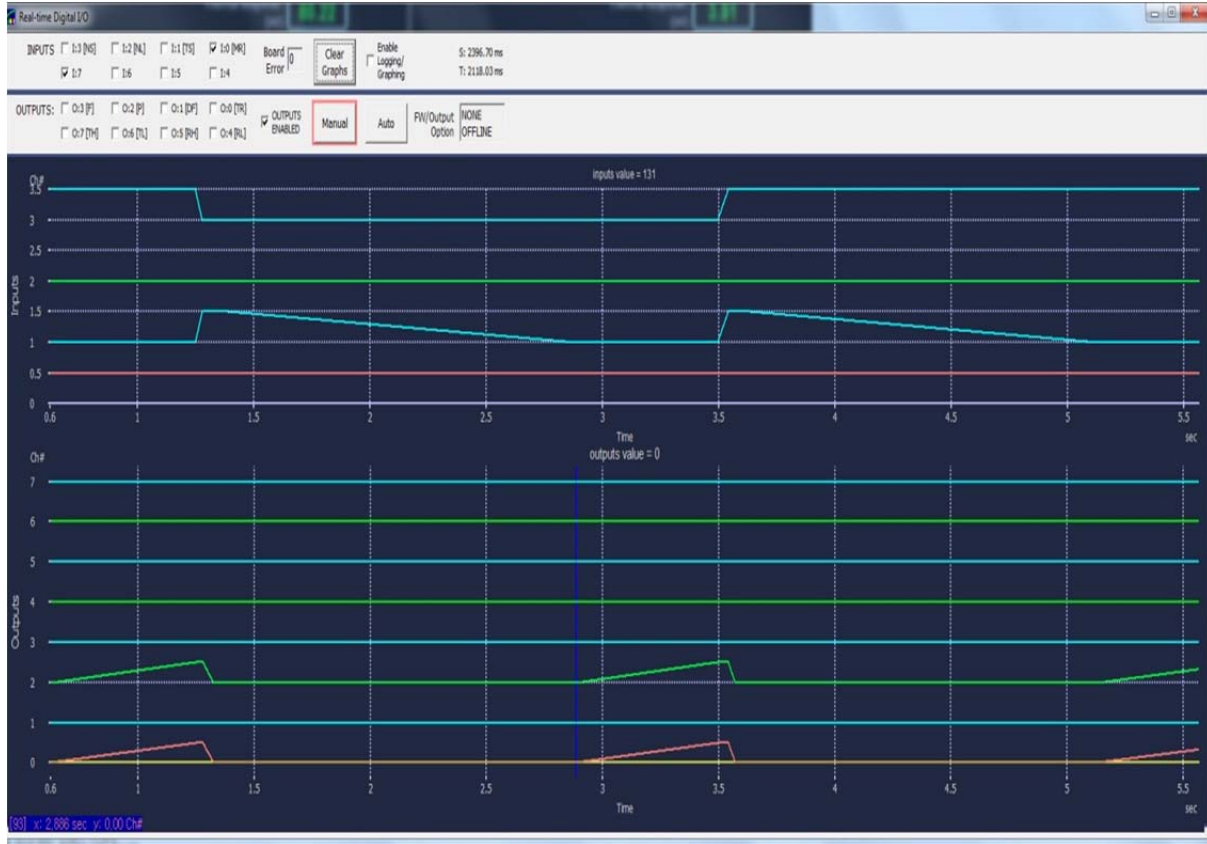


Figure 38: Diagnostics Tool Signals

CH	SIGNAL COLOR	INPUTS	OUTPUTS
7	Aqua		Thermal High Fail (active until next test)
6	Green		Thermal Low Fail (active until next test)
5	Aqua		Resistance High Fail (active until next test)
4	Green		Resistance Low Fail (active until next test)
3	Aqua	Nest Select	Part Fail (remains active until next test)
2	Green	New Lot	Part Pass (remains active until next test)
1	Aqua	Test Start	Delta Resistance Fail (active until next test)
0	Red	Interlocks/Machine Ready	Thermal Transient Ready (active until next test)

Figure 39: Diagnostics Tool Signals for Extended I/O Option

APPENDIX A: Data Analysis Computations

Applies to: Thermal Response 3.2, 3.4, 3.6, 2010, 2012.

1. Acquired Data

Symbol	Description
V_n	acquired voltage samples, sampled and quantized $V(t)$
I_n	acquired current samples, sampled and quantized $I(t)$
t_n	acquired sample times

2. Thermal Transient Computation

Symbol/Equation	Description
$R_n = V_n/I_n$	sampled bridgewire resistance
$V_{corr_n} = R_n \cdot I_{test}$	corrected voltage, I_{test} = requested test current
$P_{VA}(\), P_{IA}(\), P_{RA}(\)$	regression predictors for $V(t)$, $I(t)$ and $R(t)$ computed over $R_A = [t_A, t_A + \Delta t_A]$ ("initial" range)
$P_{VB}(\), P_{IB}(\), P_{RB}(\)$	regression predictors for $V(t)$, $I(t)$ and $R(t)$ computed over $R_B = [t_{pulse} - \Delta t_B, t_{pulse} - t_B]$ ("final" range)
$V_{TR} = P_{VB}(t_{pulse}) - P_{VA}(t_{TR})$	Thermal Response voltage
$R_0 = P_{RA}(t_{start})$	initial (cold) resistance
$\Delta R = P_{RB}(t_{pulse}) - P_{RA}(t_{start})$	total change in resistance. Note that the ΔR change in resistance does not exactly correspond to the V_{TR} change in voltage.
$P_{RA}^{-1}(\)$	inverse function of P_{RA} predictor
$\tau = P_{RA}^{-1}(P_{RB}(t_{pulse}))$	thermal response time constant

Note: $t_A, \Delta t_A, t_B, \Delta t_B, t_{TR}$ are programmable values. Please refer to the manual for test analysis timing details.

3. Heat Model Analysis

Symbol/Equation	Description
α_{BW}	bridgewire temperature resistance coefficient
$\Theta = \frac{1}{\alpha_{BW}} \cdot \frac{\Delta R}{R_0}$	final bridgewire temperature offset from ambient
$\overline{PA} = [P_{IA}(t_{AMID})]^2 \cdot P_{RA}(t_{AMID})$	average dissipated power over range R_A
$Slope(P_{RA}), Slope(P_{RB})$	P_{RA} and P_{RB} predictor slopes

(continued on next page)

$$C_p = \frac{E_A}{\Delta T_A} = \frac{\overline{P_A} \cdot \Delta t_A}{\frac{\Delta R_A}{R_0} \cdot \frac{1}{\alpha_{BW}}} = \overline{P_A} \cdot R_0 \cdot \alpha_{BW} \cdot \frac{\Delta t_A}{\Delta R_A} = \alpha_{BW} \frac{\overline{P_A} \cdot R_0}{Slope(P_{RA})}$$

C_p of the bridgewire

$$\overline{P_B} = \frac{E_B}{\Delta t_B} = \frac{C_P \Delta T_B}{\Delta t_B} = CP \frac{1}{\alpha_{BW}} \cdot \frac{\Delta R_B}{R_0} = \frac{C_P}{\alpha_{BW} \cdot R_0} \text{Slope}(P_{RB})$$

average dissipated power over range R_A

$$\gamma = \frac{\overline{P_A} - \overline{P_B}}{\Theta} \quad \text{thermal conductance in } \left[\frac{\text{Watts}}{\text{deg C}} \right]$$

$$IF_n, \quad \left(\frac{dIF}{dt} \right)_n \quad \text{filtered } I_n \text{ and } \left(\frac{dI_n}{dt} \right)_n, \text{ respectively}$$

$$RF_n, \quad \left(\frac{dRF}{dt} \right)_n \quad \text{filtered } R_n \text{ and } \left(\frac{dR_n}{dt} \right)_n, \text{ respectively}$$

$$Tn = \left(\frac{RF_n}{R_0} - 1 \right) \cdot \frac{1}{\alpha_{BW}} \quad \left(\frac{dT}{dt} \right)_n = \frac{\left(\frac{dRF_n}{dt} \right)_n}{R_0} \cdot \frac{1}{\alpha_{BW}}$$

bridgewire temperature

$$P_n = IF_n^2 \cdot RF_n \quad \text{total dissipated power}$$

$$Cp_n = \frac{E_n}{\Delta T_n} = \frac{Pn}{\frac{\Delta T_n}{\Delta t_n}} = \left(\frac{dT}{dt} \right)_n \quad \text{instant } C_p \text{ of the bridgewire}$$

$$P_{BW_n} = \frac{E_{BW_n}}{\Delta T_n} = \frac{CPn \cdot \Delta T_n}{\Delta T_n} = CP_n \cdot \left(\frac{dT}{dt_n} \right)_n \quad \text{power consumed on heating the bridgewire proper}$$

$$P_{PH_n} = P_n - P_{BW_n} \quad \text{power dissipated into the rest of the structures.}$$

APPENDIX B: Specifications

Applies to: Thermal Response 2012 with Firmware V53.

Analog Parameters

Parameter	1000mA Standard TTT	2000mA High Current TTT
Thermal Transient Test Current	10mA to 999mA	20mA to 1999mA
Resistance Test Current	5mA to 100mA	
Current setpoint DAC resolution	16 bits	
Pulse Duration	0.3ms to 860ms, 0.2ms to 3100ms with VAR option NOTE: Pulse durations >860ms are dissipation-limited at higher currents.	
Current source voltage compliance	7.0 volts	
Current source impedance	3.25 ohms	1.2 ohms
Current source noise	75 microamps peak-to-peak	150 microamps peak-to-peak
ADC resolution	16 bits, separate, time synchronous converters for voltage and current	
Voltage ADC range	1.42 volts at full scale	5 volts at full scale
Voltage resolution	43.60 microvolts / bit	152.59 microvolts / bit
Current resolution	30.45 microamps / bit	61.04 microamps / bit
Voltage accuracy	±150 microvolts	±500 microvolts
Current accuracy	±150 microamps	±300 microamps

Acquisition Timing

Parameter	1000mA/2000mA Standard TTT	Variable Acquisition Rate Option
Test Duration	0.3ms to 860ms	0.3ms to 3100ms
Max # of stored samples	8092 current+voltage pairs	
Sampling rate, 3 to 107ms pulse duration	75.2kHz / 13.29µs per sample	
Sampling rate, up to 205ms pulse duration	37.6kHz / 26.59µs per sample	75.2kHz / 13.29µs for 0 to 10 ms, 37.6kHz / 26.59µs afterwards
Sampling rate, up to 205ms pulse duration	37.6kHz / 26.59µs per sample	75.2kHz / 13.29µs for 0 to 10 ms, 37.6kHz / 26.59µs afterwards
Sampling rate, up to 400ms pulse	Same as 860ms pulse	75.2kHz / 13.29µs for 0 to 10 ms, 18.8kHz / 53.17µs afterwards
Sampling rate, up to 790/860ms pulse	9.4kHz / 106.34µs per sample 860 max duration	75.2kHz / 13.29µs for 0 to 10 ms, 9.4kHz / 106.34µs afterwards 790ms max duration at this rate
Sampling rate, up to 1570ms pulse	Not supported	75.2kHz / 13.29µs for 0 to 10 ms, 4.7kHz / 212.67µs afterwards
Sampling rate, up to 3100ms pulse	Not supported	75.2kHz / 13.29µs for 0 to 10 ms, 2.35kHz / 425.35µs afterwards

Digital Inputs/Outputs

Parameter	Standard TTT	Extended I/O
Inputs	2: Interlock, Test Start	4: Please refer to the manual.
Input Type	Contact closure	24V sinking logic, active high
Outputs	None	8: Please refer to the manual.
Output Type	N/A	24V sourcing logic, active high
Trigger output	1, 5V TTL, optional, not available with multiplexer option	
Multiplexer support	Optional, not available with trigger output	

Last Revision: Nov 07, 2012.