



SANTA BARBARA AUTOMATION

Thermal Transient 2017 Installation and Operating Manual

Standard and Automation Interface

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For the latest version of this document, please visit:

www.santabarbaraautomation.com/PDF/Thermal%20Transient%20manual%202017.pdf

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

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

**1304 Brookfield Court
High Point, NC 27262
Telephone (805) 682-8206
descon@silcom.com**

www.santabarbaraautomation.com

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A brief overview of thermal transient testing

In simple terms a thermal transient test is the application of a heating current to a part under test while monitoring the change in resistance with time.

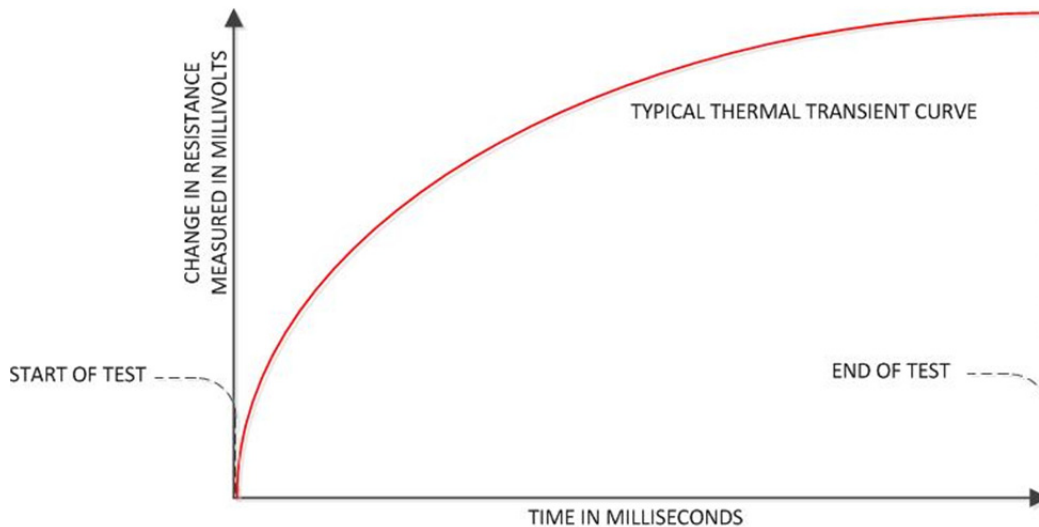


Figure 1: Typical thermal transient curve

When test parameters are properly selected a typical initiator will produce the curve above. The change in resistance over time, as measured in millivolts, is larger at the beginning and smaller at the end. The difference between the voltage measured 100 microseconds after the start and the voltage at the end is the thermal transient value. The positive slope results from the positive temperature coefficient of the bridgewire.

Initially both the bridgewire and powder are at ambient temperatures. When current is applied, the bridgewire becomes warmer and the powder acts as a heat sink depending on the quality of the bond between the bridgewire and powder. The thermal transient value will increase if powder is absent or if the quality of the bond is compromised due to improper mix, granulation or fractures.

Both the numeric value of thermal transient as well as the waveform may be used for test criteria. Production problems with bridgewire welding, powder preparation and powder application are reflected in the waveform shape and may be included in pass/fail criteria. Calculated values for thermal conductivity (γ) may also be evaluated and offer independence from the test current when properly configured.

Some process defects can create excessive movement in the bridgewire that is reflected as steps in the waveform. This movement may be detected by placing pass/fail boundaries on the allowable slope of the waveform within a specified range of time.

The features included with the Thermal 2017 application provide powerful analysis tools both for design and production. Many users, especially those testing for thermal transient only, may not need the advanced options and can choose to use the default configuration provided with the download. For those installations that require qualification of parts based on slopes and γ , the new process and filter windows will be needed.

Please carefully review the information presented in this manual in order to understand the concepts presented and tools provided before attempting to change any settings.

New features in Thermal 2017

- Display of gamma and theta waveforms.
- Pass/fail analysis based on gamma.
- Three independent slope calculations with pass/fail analysis.
- Processing and filter windows for uniform analysis compatibility.
- Ability to process older data to conform to newer parameters.

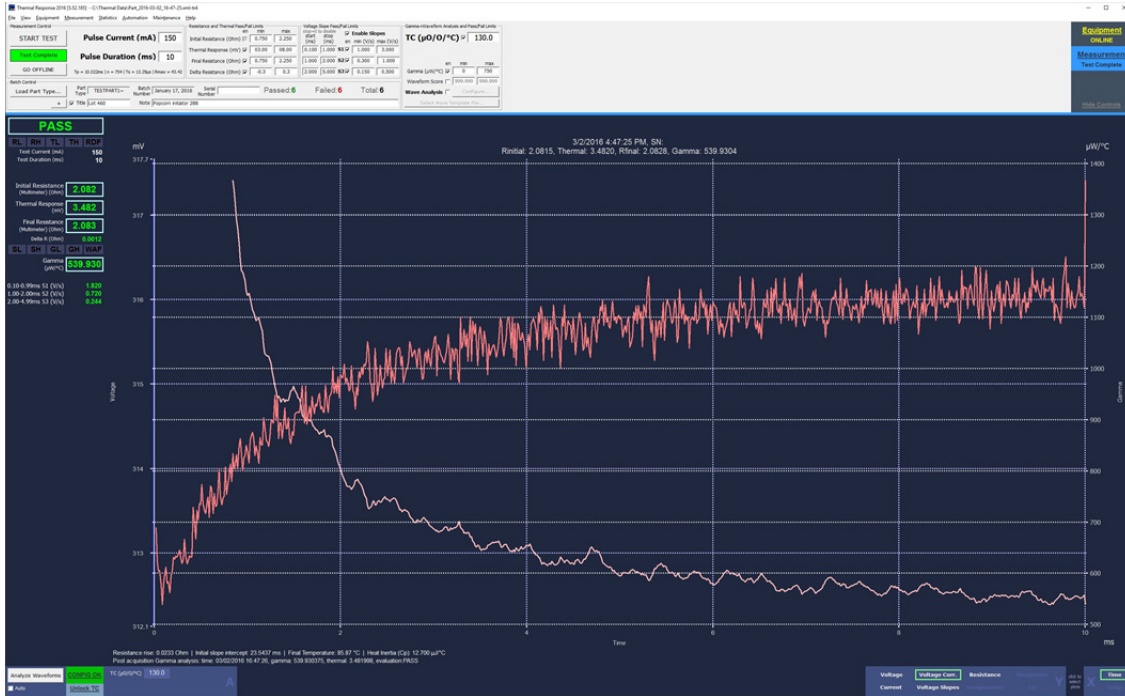


Figure 2: Thermal 2017 display showing thermal transient, gamma, and numeric analysis

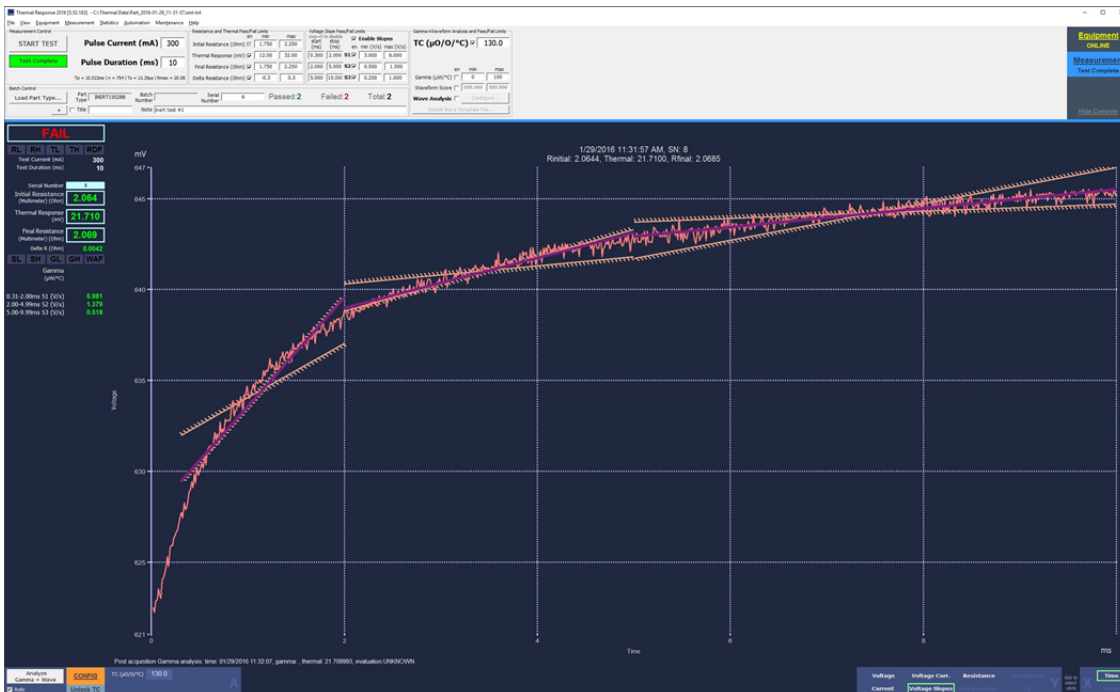


Figure 3: Thermal 2017 display showing slopes and analysis

Before starting to test with the Thermal Transient equipment:

- Complete the hardware assembly and installation.
- Install the Thermal Transient software application.
- Determine the testing parameters to be used for each part type.
- Enter the test parameters into the testparameters.ini file.
- Properly configure the thermal transient software for connections to the thermal electronics cabinet and the digital multimeter (when used).
- *Select any options based on your test requirements and part types.*

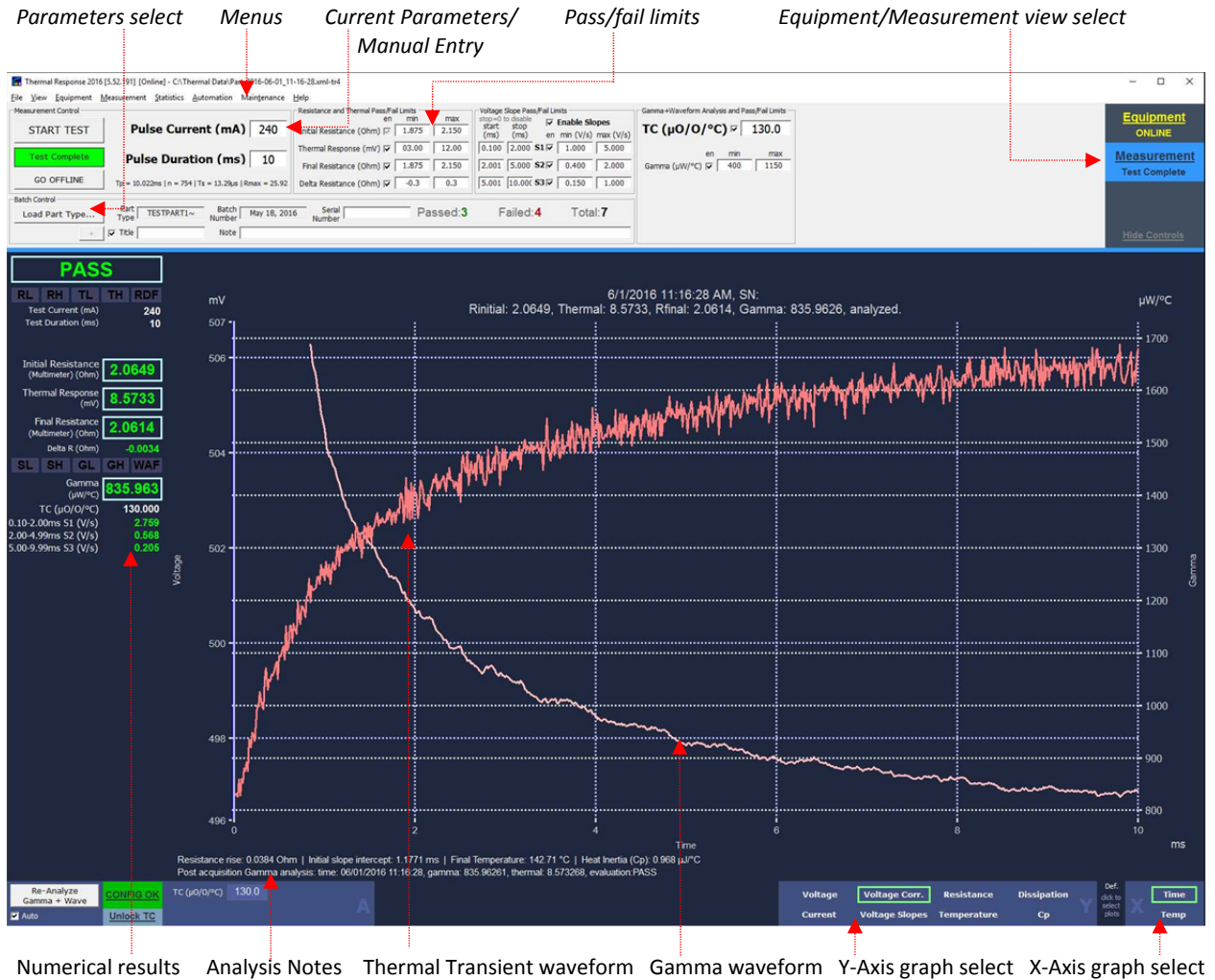


Figure 4: Definition of features

Note that the X-Axis selector is only available after a full analysis. Click on Re-Analyze Gamma + Wave at the lower left of the screen or select the Auto option just beneath.

Installation

Hardware Installation

1. Connect a high quality shielded serial interface cable from the 9-pin SERIAL PORT connector on the back of the Thermal Transient Test System to a serial port on the computer.
2. Connect the test chamber cable to the CURRENT OUT/MEASURE IN connector on the back of the Thermal Transient electronics cabinet. This is a 15 pin 'D' connector.
3. Connect the other end of the test chamber cable to the test chamber. On the test chamber this is a pair of dual banana plugs. Note the side of the banana plug with the tab is the negative side and should be connected to the black banana jack. Polarity must be preserved for these connections.
4. Connect the test chamber door interlock switch cable (dual banana plug) to the INTERLOCK connector on the Thermal Transient Test System. When the test 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.
5. Connect the 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. *These buttons are 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.
7. If either the Agilent 34401A or Keithley 2010 optional external multimeter is used connect to an available serial port such as COM2 with 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 2010: RS-232, 19200, 8, N, 1, Xon/Xoff handshaking.
8. If the optional Keysight 34461A is used an open Ethernet port on the computer is required. Connect an Ethernet cable from the computer to the Keysight 34461A multimeter.

This completes the hardware installation.

Software Installation

This program may be installed on 32 or 64 bit Microsoft Windows 7 Professional (Service Pack 1 required), Windows 8.1, or Windows 10. To install the Thermal Transient application, your computer must have the following resources:

- A dual core or higher 2.0GHz or better processor.
- A minimum of 2 GB of system memory (4GB recommended).
- 50 Megabytes of free disk space for installation, 100MB for data storage.
- 1440x900 or higher resolution display for acquisition, 1280x720 for viewing only, 1920x1080 or 1920x1200 is required for Automation view. 1920x1080 or higher is recommended.
- One high-speed serial port (16550 UART) for the Thermal response hardware (USB adapters not recommended)
- A second high speed serial port or Ethernet port if the optional multimeter is used.
- Thermal response firmware version 51, 53, 54 or later.
- *You must have Administrator privileges for the program installation and updates.*

IMPORTANT

If you have a recent version (Thermal 2016) of the thermal application 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 2012 or earlier, you must uninstall the previous version before proceeding. For earlier versions of the Thermal Response program the directory is C:\Program Files\Thermal 2012 (or C:\Program Files (x86)\Thermal 2012 for 64-bit operating systems), similar for Thermal 2010. Use the Windows Add/Remove Programs application in the Control Panel to uninstall the application.

Please remember to back up the testparameters.ini file before uninstalling if you intend to reuse the parameters. Please do *not* copy the settings.xml file from an earlier version of Thermal. The configuration files provided with Thermal 2017 contain the proper default value sets for the new gamma analysis and pass/fail functionality.

1. Insert the Thermal Transient install DVD into the drive or download the setup file.
2. To install the Thermal Response 2017 application, please unzip, if necessary, and install the Thermal Response release 2017 software by running Thermal2017setup.exe (or Thermal2017Update.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.

Unless instructed otherwise, the installer will place the Thermal 2017 application in “C:\Program Files\Thermal2017” on 32-bit systems or in “C:\Program Files (x86)\Thermal2017” on 64-bit operating systems. This directory also contains the configuration files: testparameters.ini, settings.xml, and application logs in the \Log subdirectory. Thermal 2017 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” to run the application on regular basis.

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.***

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 Thermal 2017 program folder indicated above and is also accessible via File->Edit Testparameters.ini menu. The installer provides a sample file that may be used to create additional part types. It is highly recommended to configure this file for all common part types in order to avoid errors while manually entering the parameters.

The test parameter file uses similar formats to the testparameters.ini file on all Santa Barbara Automation Final Electrical Test equipment and may be edited by Notepad or a similar program. Only a responsible supervisor or engineer who is knowledgeable and fully understands testing parameters should maintain the Testparameters.ini file. We suggest maintaining backup copies of this file.

CAUTION

The settings in the testparameters.ini file provide a consistent means of testing and allow the operator to identify initiators by part number. Incorrect settings, such as higher current or longer pulse width, may damage the part or cause parts to function. 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 personnel 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 illuminated on the front panel.
3. Double-click the Thermal 2017 icon on the Windows desktop.



Figure 5 : 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, 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 if no external multimeter is used, select the “Go Online” 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” option under the “Equipment Menu” to disable the dialog box.

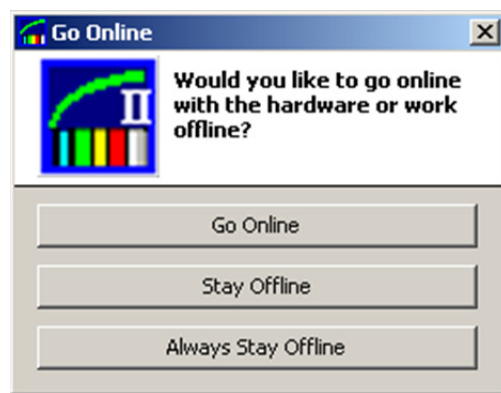


Figure 6 : Online/Offline selection

4. If you connected the serial interface cable to a port other than COM1, an error message will be received either saying the port cannot be opened or the Thermal Transient Test System could not be initialized. To change the serial port settings while offline, select Thermal Response connection or Multimeter connection under the Equipment menu, then select the serial port where the interface cable is connected and configure the proper settings. When

finished click the OK button.



Figure 7 : Options Menu

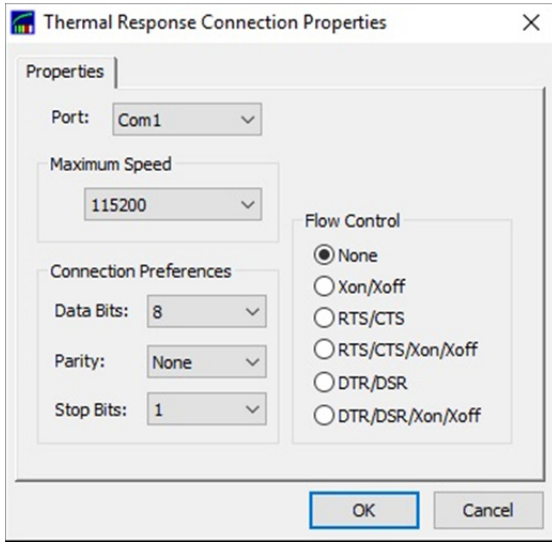


Figure 9 : Port Setup for Thermal Response

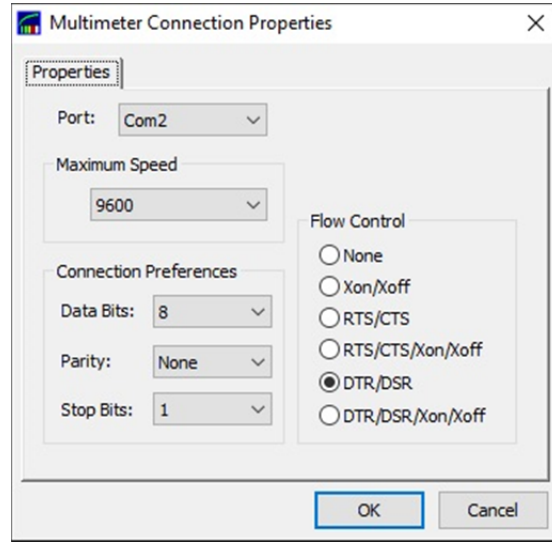


Figure 8: Port Setup for Agilent 34401A Multimeter

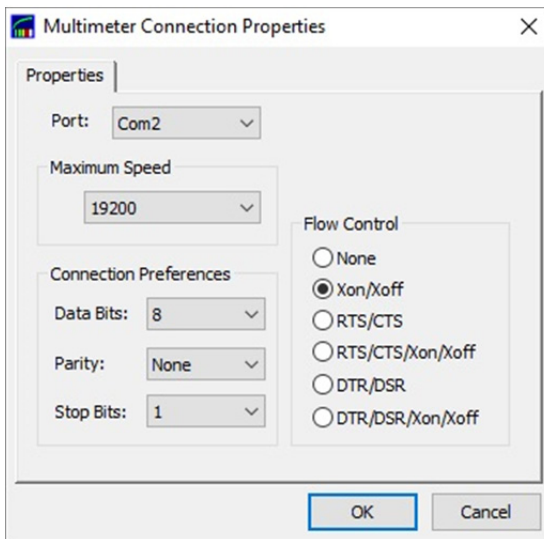


Figure 10 : Port Setup for Keithley 2010 Multimeter

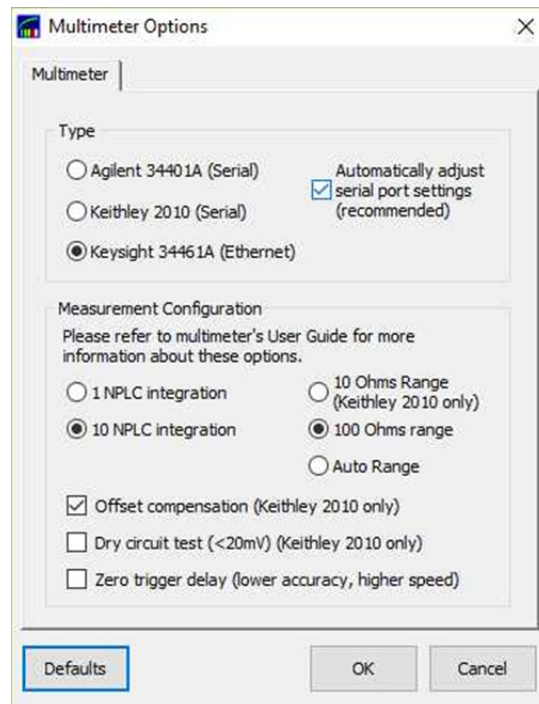


Figure 11 : Multimeter Options

- When using the Keysight 34461A multimeter an Ethernet cable is required. If the computer is connected to a network then a second network interface card (NIC) will also be necessary. Connect the Ethernet cable from the second Ethernet port to the back of the Keysight 34461A as shown below.

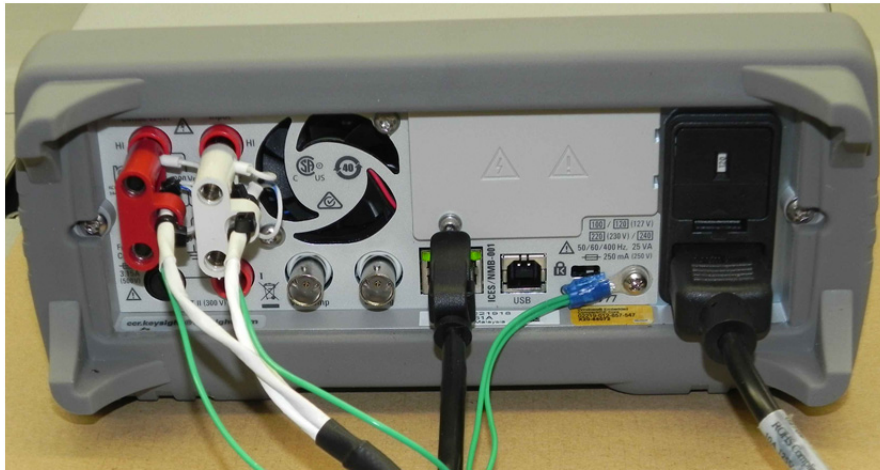
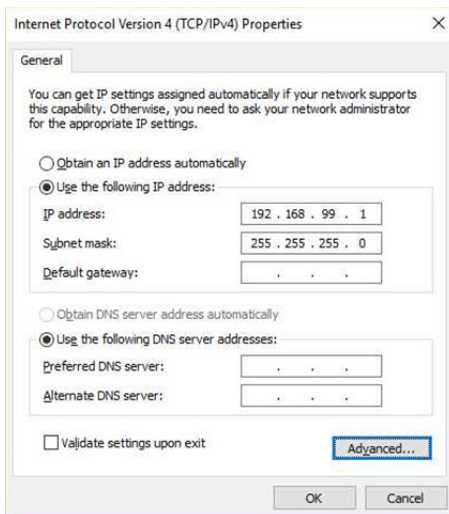


Figure 12: Keysight 34461A connections



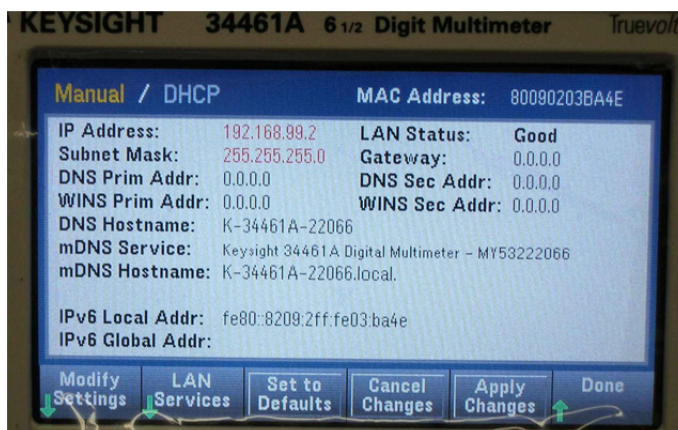
Configure the Ethernet port of the computer with the settings shown.

For Windows 7: Control Panel, Network and Internet, Network and Sharing Center: select properties for the network connections.

For Windows 10: Settings, Network and Internet, Change Adapter Properties, Properties.

Note the computer IP Address of: 192.168.99.1

Figure 13: Computer IP settings for Keysight 34461A



Plug the Ethernet cable in.
 Press shift > display (utility)
 Press I/O Config
 LAN > on (status = good)
 Select: LAN settings
 Select: modify settings
 DHCP = manual
 Set IP address = 192.168.99.2
 Set Subnet mask = 255.255.255.0

Apply settings when finished, then select done.

Figure 14: Keysight 34461A IP settings

- When the external multimeter (Keysight 34401A, 34461A or Keithley 2010) is used, click Equipment 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 15 : 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.

- When the initialization is successful, the display will briefly flash green for the Thermal and multimeter status and then change to the Measurement view:

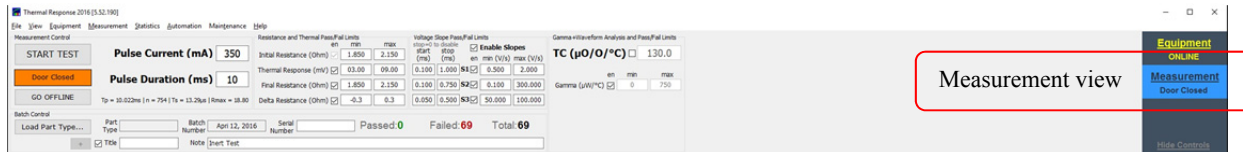


Figure 16: Thermal Transient System online

If an external multimeter is connected, a “beep” will be heard from the multimeter. You may change to the Equipment view at the right of the screen.

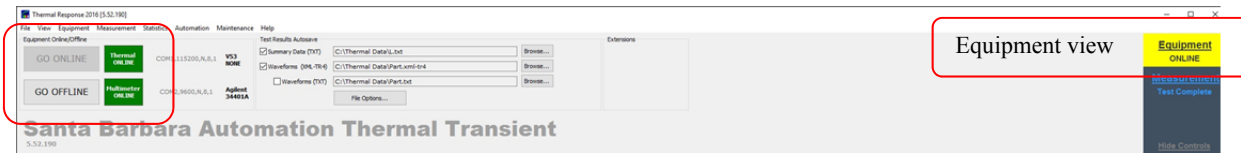


Figure 17: Thermal Transient and Multimeter Equipment view online

- With power applied to the Thermal Transient electronics cabinet and the software application online, the TRANS and REC lights on the electronics cabinet front panel will blink. The TEST ON light should not be lit.
- Open and close the door on the test chamber. Confirm that the door (interlock) status is displayed correctly in the Measurement window. Note that 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.**
- Select the output data destination folders, by selecting the Equipment view and using the browse buttons to choose the file save locations. The default data storage location is “C:\Thermal Data”. Change back to the Measurement view by selecting “Measurement” to view the interlock status and test parameters.

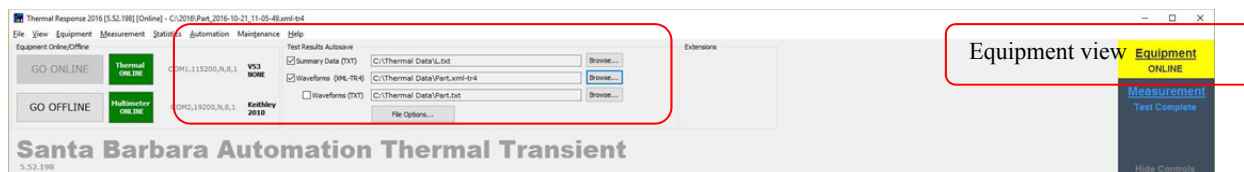


Figure 18: Auto-Save Configuration

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 either xml or xml-tr4 are compatible with the Thermal application; however, xml-tr4 is preferred.

Please refer to “Test Results” section below for more information on file formats.

1. Additional configuration settings can be found in Automatic File Naming under “File” on the menu bar and then “File Options”.

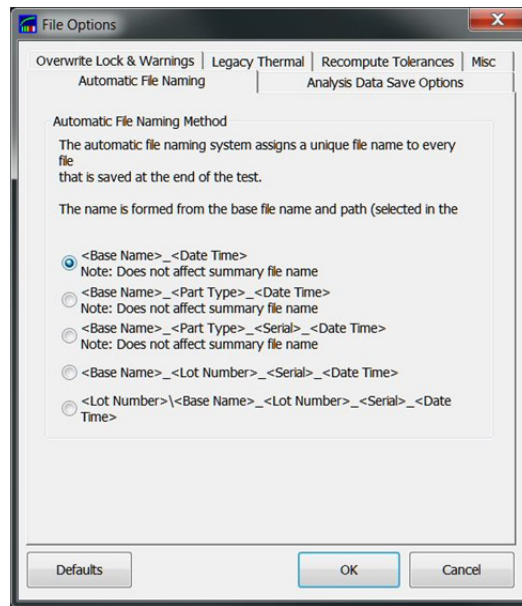


Figure 19: Automatic Naming Properties and Auto-generated File Names

The file Options window also contains selections for Analysis Data Save Options, Overwrite Lock & Warnings, Legacy Thermal, Recompute Tolerances and Misc. These are described later under Advanced Options.

A number of additional options specifying the behavior of settings, batch information, and other similar options may be found under the Automation menu by selecting “Integration and I/O Options”.

Under Integration and I/O Options the “Auto Title” tab contains settings pertaining to the experiment notes. The software application can auto-fill these fields if desired, and can also automatically clear them. Please note that by default these fields will persist even after a software restart.

Also under Integration Options the “Data Persistence” tab contains additional options for clearing lot/batch information, clearing the auto-analyze option and auto-discarding of count totals for parts that did not progress past the initial resistance stage (often indicating poor electrical contacts, not a genuine part failure).

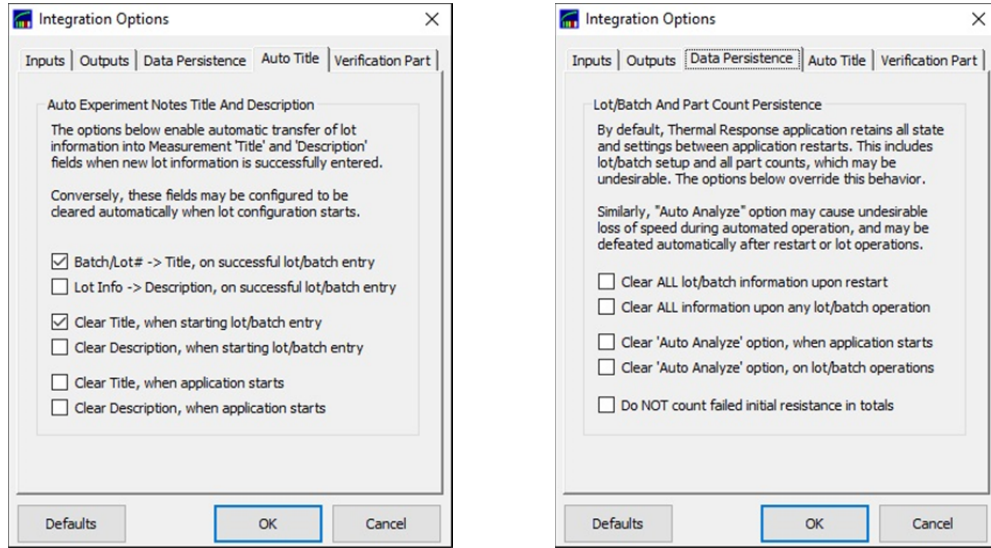


Figure 20: Experiment Notes and Data Persistence Options

- The Thermal 2017 application has additional features listed under “Automation” at the top of the screen.



Figure 21: Automation and Integration Options

The optional Automation version of the equipment is used for higher speed production testing with more than one part tested per test cycle, or for comparative testing when in the manual mode. It provides histograms of the test results that are color-coded for pass/fail results.



Figure 22 : Automation View Screen

This completes the initial configuration and startup.

Basic System Configuration

Testing Limits and Options

IMPORTANT

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

Set Maximum Test Current 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 1 amp and optional 2 amps for high-current versions could 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 any user selected test current. To enable a limit on the test current:

1. Click **Equipment** on the menu bar then select **Acquisition Options**.
2. Under **Thermal Response** select the box marked **Enable Test Current Limit**. Enter the maximum safe test current (milliamps). If the user inputs a test current that exceeds the set limit, a warning will be displayed and the test will be aborted (figure 23).

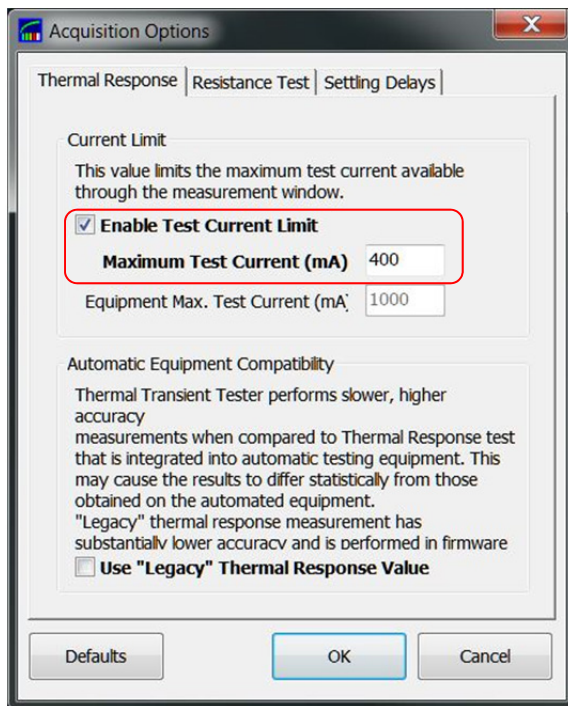


Figure 24: Test Current Limit

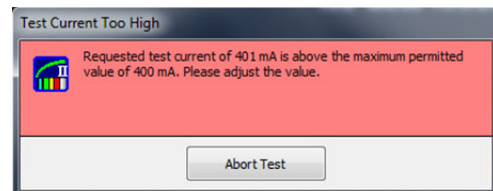


Figure 23: Test Current Limit Warning

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 no multimeter is present, or if “Options, Use Multimeter for Resistance Test” is not checked, the thermal transient circuitry will be used to measure resistance.

The resistance measurement settings are located under “Equipment”, “Acquisition Options”. The test current used by the thermal transient circuitry for resistance may be configured selecting the **Resistance Test** tab. Typically, the resistance test current is from 1mA to 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 found in the main Measurement view window.

A normal test sequence involves 1) the initial resistance measurement, 2) the thermal transient test, and 3) the final resistance measurement. Please note that the test will be aborted if the initial resistance is outside of the initial resistance limits, which may indicate a defective part, a missing part, or poor electrical contact.

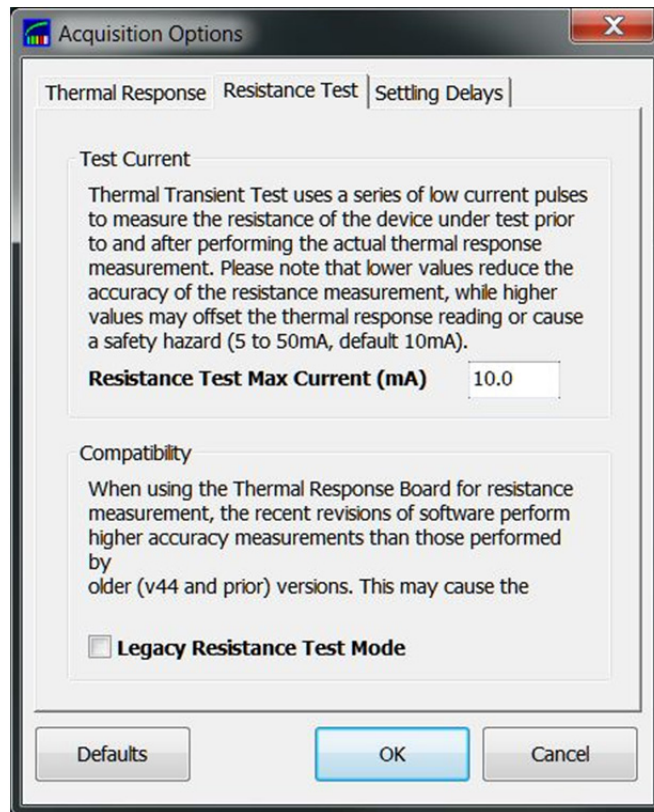


Figure 25 : Thermal Response Based Resistance Test Configuration

Current Pulse Stabilization and Accuracy

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

Please follow these instructions during the initial setup, or when defining new part types, or for equipment configuration changes (such as changes in test fixtures, wiring, etc.). All parameters referenced in this section are located under the “Equipment”, “Acquisition Options...” menu.

Acquisition parameters are transferred to the thermal transient circuitry prior to each test. When changing between different current values, such as when using the thermal transient board for resistance test (from 10mA to the value selected for thermal test and back to 10mA), the internal reference takes several few seconds to settle. The time allowed for settling may be adjusted with the “Current Setpoint Delay” parameter. Values of 3000ms to 5000ms are typical, where longer times provide slightly greater accuracy. The delay is applied each time the current changes, which is twice per test if a multimeter is not used for resistance test, otherwise the delay is applied only when the actual thermal transient test current changes.

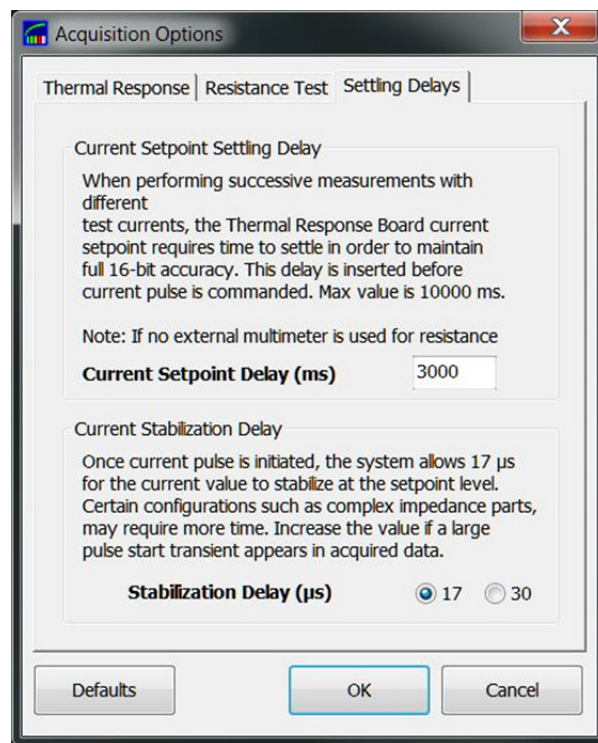


Figure 26 : Settling and Stabilization Delays

Another critical delay value is applied just after the actual test current is placed through the part. During the initial current rise, the length of time required to achieve stability is typically less than 20 μ s and should not be greater than 50 μ s. This time is a function of the requested current, 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, 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 by selecting “Equipment”, “Acquisition Options” and “Settling Delays”. The Stabilization Delay selection will delay ADC sampling during the first few microseconds 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 the stabilization delay is 17 μ s. To determine if the 30 μ s 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 30 μ s. Please see page 20 details.

In earlier versions of the thermal transient application the “Pulse Settling Offset” was used to adjust the time after the start of current to obtain the best waveform stability for subsequent calculations. Note that this value did not pertain to the acquisition of data, but to the subsequent analysis that produces the actual Thermal Response result.

Thermal 2017 is a very significant upgrade and provides enhanced tools for analysis, including the conversion of older test data to conform to newer parameters. The introduction of pass/fail analysis based on gamma and slopes mean that each facility can, and should, optimize the configuration for their specific test hardware and environment.

In brief, thermal transient testing (as used for the past 3 decades) is relatively immune to variation introduced by settling times and other hardware-related issues. **The results for gamma (and related) values are, however, quite sensitive to equipment misconfiguration and absolutely require properly adjusted settings.** In many ways gamma is preferred as a pass/fail criteria since it is somewhat independent of test current. To take advantage of the new analysis features a new set of tools has been introduced and changes made to earlier Options windows.

Advanced System Configuration

Thermal 2017 Configuration Options

The introduction of gamma as a pass/fail parameter is a powerful tool when properly configured. Configuration is required due to the large numbers of legacy products still active in the field, some of which are infrequently calibrated. Additionally, gamma is a calculated measurement and is highly dependent on accurate settings for temperature coefficient (alpha) and proper sampling settings for the initial and final curve fit (P_A and P_B).

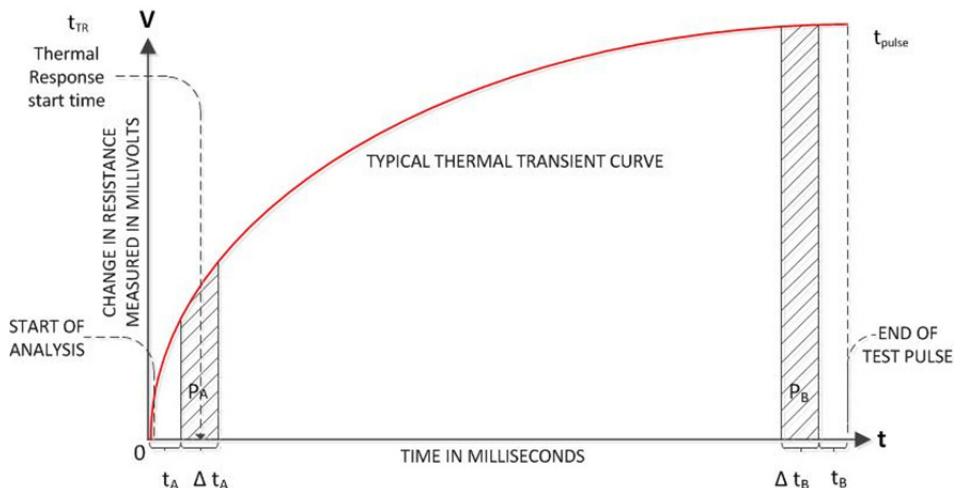


Figure 27 : Thermal Response Computation Overview

It is important that the values for P_A and P_B are not set too low or too high as both of those curve fits measure slope and value by applying a linear regression fit to the data. Too low of a value will reduce the accuracy of computation because of noise; too high a value will shift the samples too far away from the industry standard 100 microsecond point or the end of the pulse.

The initial fit (P_A) is critical due to the fast rise times involved and the need to maintain accuracy at 100 microseconds. The final fit (P_B) is more forgiving and a larger number of samples may be used due to the slower rate of change near the end of the pulse.

Thermal 2017 differs from previous software versions and provides more comprehensive tools for system configuration and also for viewing and analyzing older measurements. We recommend the following process for configuring your equipment.

Configuration Tools and Setup Sequence

The objective for the thermal transient test system is to achieve consistent thermal transient and gamma measurements that will provide accurate and repeatable test results across different part types and production locations. This will allow the user to establish meaningful pass/fail criteria for all parts.

Because every system, setup, part, and test environment is different, layers of adjustable parameters are provided to calibrate out or to compute out those differences in order to give consistent test results.

A logical process may be followed to optimize the system performance;

1. Calibrate your hardware on a regular basis to increase the consistency of acquired data.
2. Use high quality 4-wire (Kelvin) connections and shielded wiring to the test fixture.
3. Adjust the current pulse stabilization after installation to mitigate the effects of inductance, capacitance and other electrical artifacts (see above).
4. Adjust the parameters for P_A and P_B , allowing for some safety margin.

Following this process will result in consistently acquired data, proper calculation of P_A and P_B and therefore consistent thermal transient and gamma results. Failure to follow this process will likely result in relatively consistent thermal transient values but highly inconsistent and perhaps totally unusable gamma values.

The reason for this is because the thermal result is not significantly dependent on an accurate value for the slope of P_A and P_B , but gamma and other thermodynamic results are. Essentially, thermal transient uses the slopes to do somewhat better than straight averaging, whereas gamma requires accurate fits.

Consequently, in order to obtain usable gamma values, both the hardware must be set up properly and also the test parameters for the part under test must be configured to ensure repeatable and reliable fits.

Advanced configuration 3-step process

Hardware compensation, P_A and P_B adjustment

1. **Hardware compensation.** Perform a test on several typical parts and view the results. If your test environment has longer cables, highly capacitive cables or unusual part characteristics (ferrite suppression, internal capacitors, etc.) the leading edge of the waveform may take longer to settle. After reviewing several different parts select a typical igniter waveform. Using the graphing tools expand the starting edge of the waveform and note the time required for stabilization, typically between 17 and 30 microseconds. Under Equipment, Acquisition Options, select Settling Delays and click on the time noted, either 17us or 30us, where shorter is preferred.

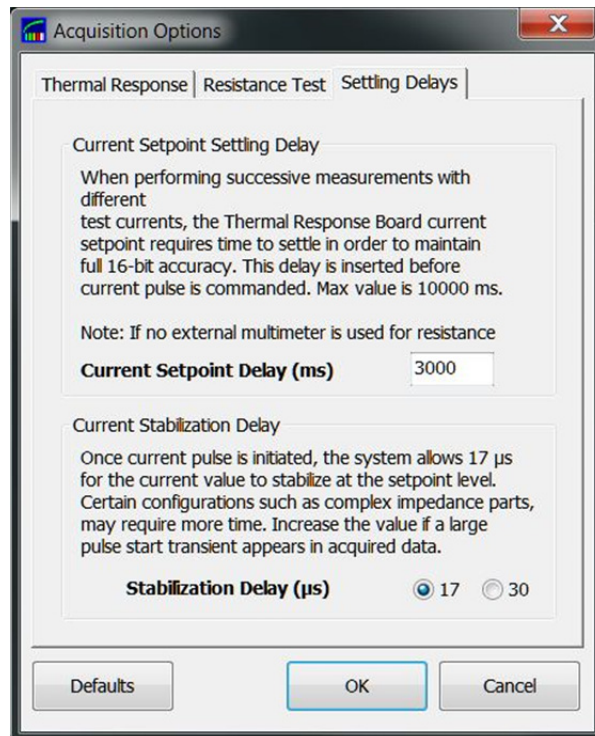


Figure 28 : Acquisition Options, Settling Delays

This same window may be used to set the delay imposed when using the thermal transient circuit board to perform resistance measurements as noted on page 18 of this manual. The following illustrations show examples of determining the current stabilization delay.

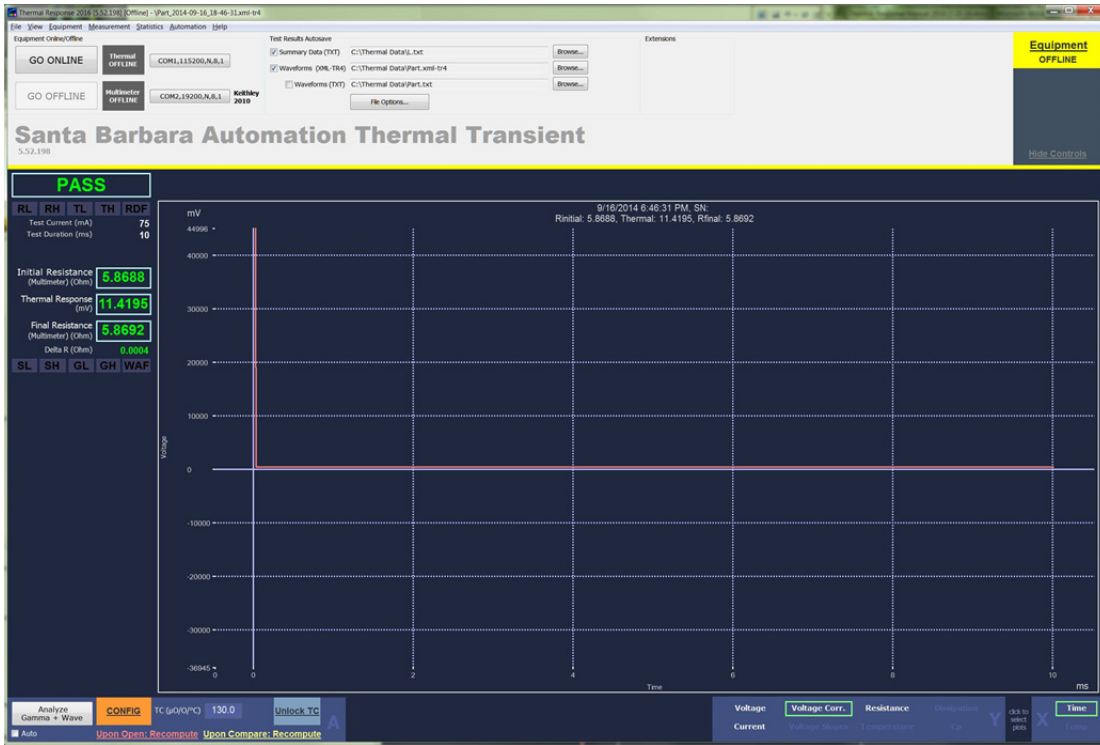


Figure 29 : Settling Time for a Typical Waveform

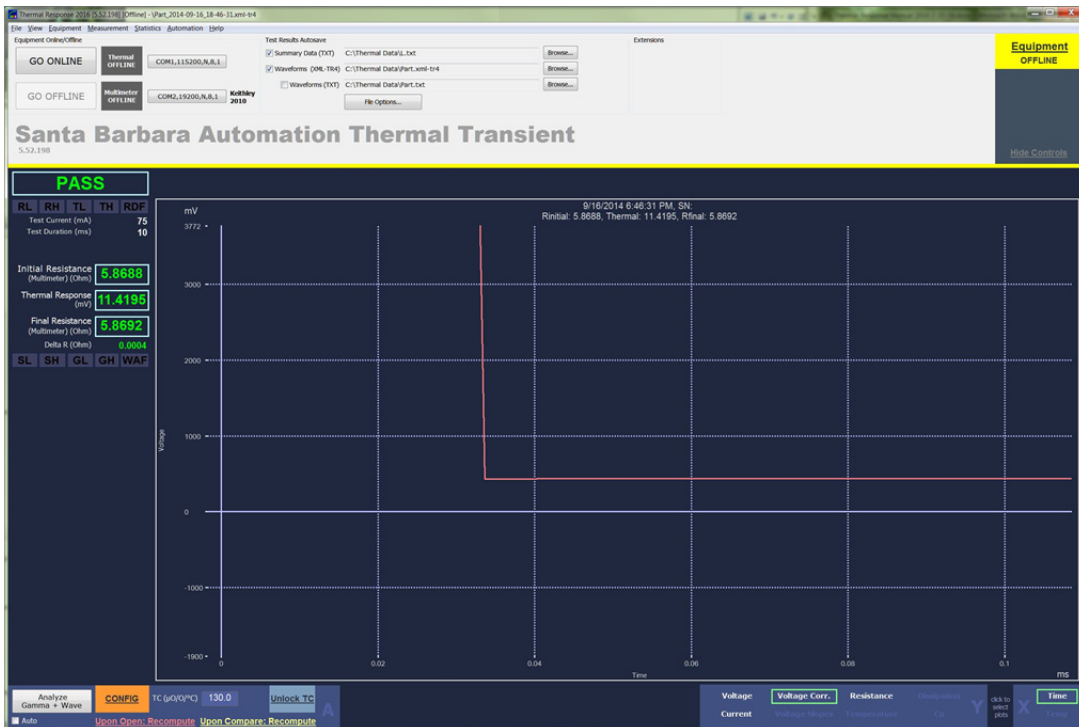


Figure 30 : Expanded View to Examine Settling Time

For the test environment and waveform above set the stabilization time to 30us.

- P_A and P_B adjustment.** In general, only the settings for the number of samples for P_A and the number of samples for P_B should need to be adjusted. The settings for the Start of Pulse and Power/Dissipation Start point are industry standard values of 100 microseconds after the beginning of the test and normally should never be changed.

Under Measurement, Processing Options, review and if necessary change the entries in the Processing Options window. *Note that the entries listed under System are the settings to be used for a new measurement, while those listed under Measurement are those saved with prior test results.* The distinction is very important.

The System entries are specific to each individual test site and test environment. The system entries may be adjusted to provide the most accurate results as well as compatibility between test sites. After a test has been performed the System parameters that were used during the new test are archived along with the test results. When the results of a prior test are opened the parameters used at the time of the test will show under the Measurement section.

For those companies with large databases of previous test results (XML or XML-tr4) it is useful to review those earlier tests to understand how production variables may have changed over time. The entries in the Measurement section provide these tools.

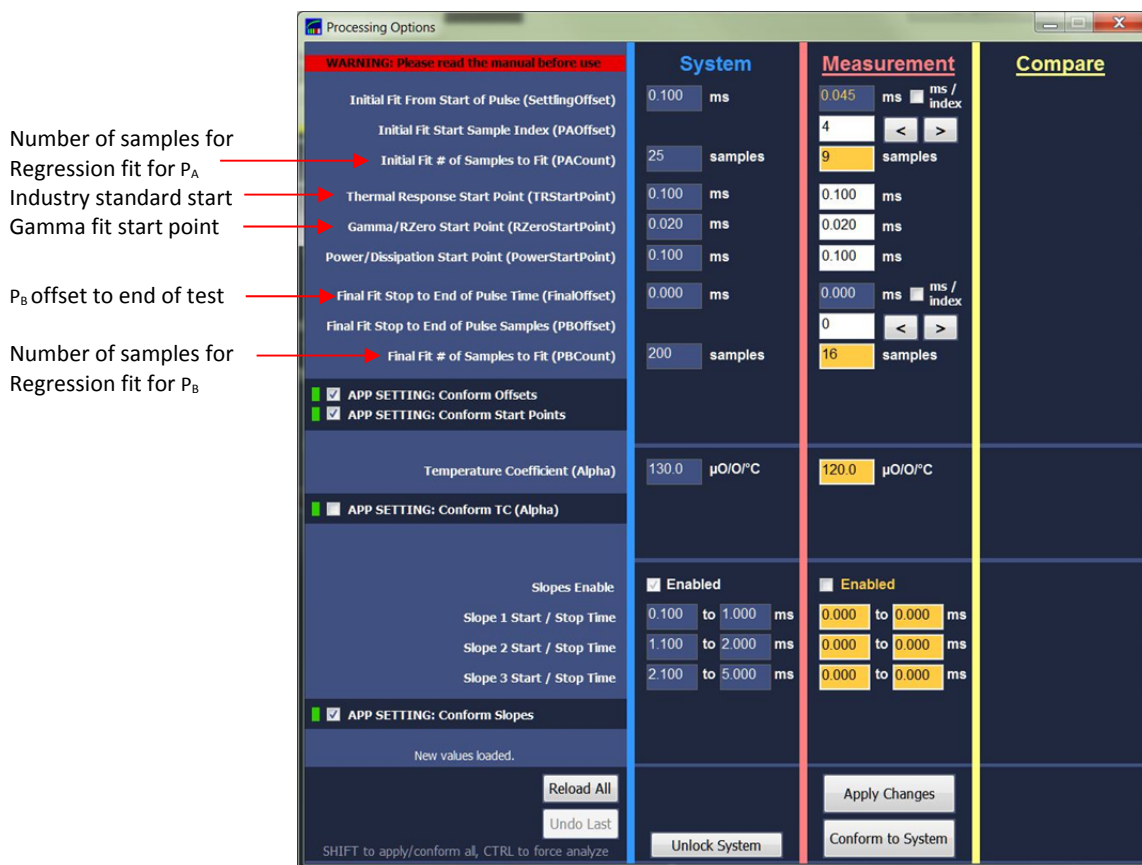


Figure 31 : Processing Options Window with Typical Entries

The image above reflects settings to be applied to a new test (System) as well as the settings when a much older test was viewed (Measurement). Please refer to Figure 25 on page 17 for a graphical definition of P_A and P_B .

To change the *System Processing Options* click on “Unlock System” at the bottom of the window. The entry areas will turn white when unlocked. When the changes are complete click on “Apply Changes to System Values” to save them. *System changes should only be made after reviewing prior tests and optimizing the settings with changes under the Measurement section, which does not modify the System settings.*

- The Settling Offset normally does not require adjustment and should be left at 0.100ms.
- The P_A Offset (under System) is not available for new acquisitions.
- The P_A Count is the number of samples used in the initial regression fit and is critical.
- The T_R StartPoint is the industry standard 100us after the start of the test.
- The $RZero$ StartPoint defines the first stable sample used for gamma calculations.
- The P_B Offset (under System) is the time from the end of P_B Count to the pulse end.
- The P_B Count is the number of samples used in the end of pulse regression fit.

The parameters for P_A are adjustable in order to ensure that only well-settled waveforms are used in computations. This mitigates the effects of wiring and fixture inductance, capacitance and other electrical artifacts. The duration of the P_A/P_B fits ensures a sufficient number of samples for accurate computation.

The first step in any configuration is to verify that the pulse settling is fast enough for the selected values (as noted on pages 21 and 22). During this process inspect the waveforms received to verify that there are no low or high frequency oscillations or noise introduced by nearby machinery that could affect both P_A and P_B . For example; by testing with a normal 10ms test pulse and a 100ms pulse with lower current on production parts.

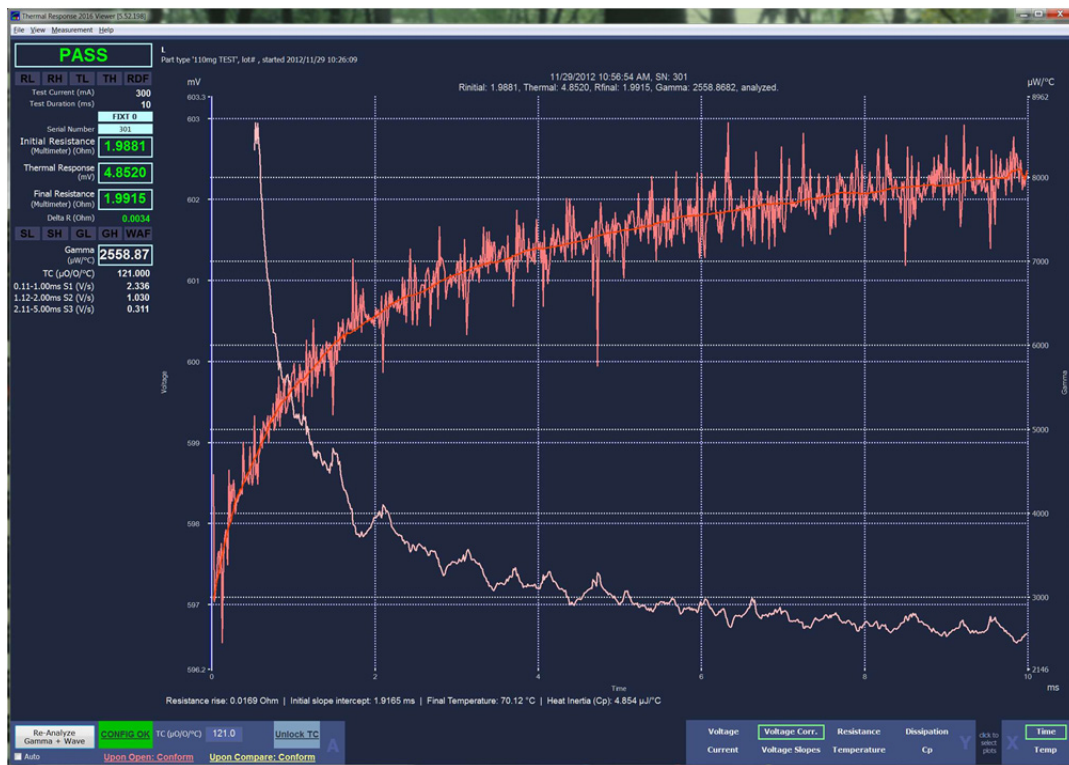


Figure 32 : Severe noise introduced by nearby equipment

For the test result shown in Figure 32 above note the thermal response of 4.8520 and gamma value of 2558. The initial fit from the start of the pulse was set to .050ms, P_A was set to a value of 10, P_B to a value of 25. This particular test was conducted on an index table test system with a nearby electrically noisy vibratory feed bowl and track as well as unshielded wiring to motors and controls. The wiring to the test position contacts was also unshielded.

When reviewing the effects of different settings on earlier tests first open a test and also the Processing Options window. On the main Thermal 2017 window click on “Re-Analyze Gamma + Wave” to display slope and gamma from the time of test. To review potential changes to P_A and P_B you may change the values in the Processing Options window under “Measurement” and then click on “Apply Changes”. For example, note the differences in Figures 32 and 33.

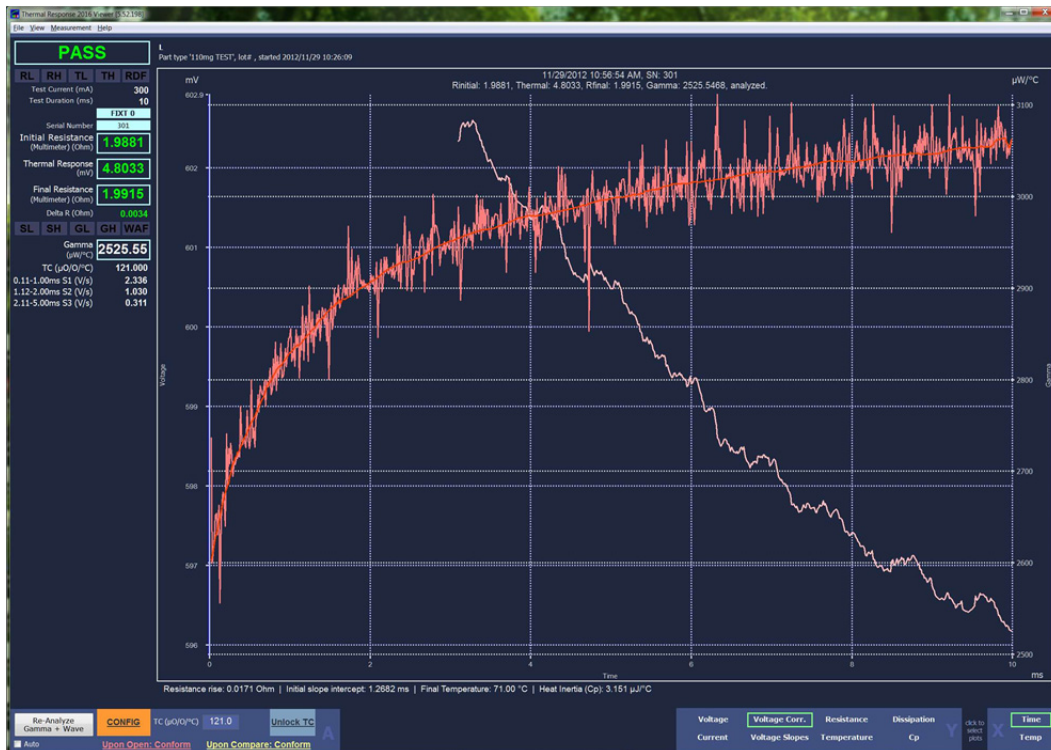


Figure 33 : Noisy Waveform with modified P_A and P_B

Above is the waveform as in Figure 32, but with P_A set to a value of 25, P_B to a value of 200. Thermal response has changed from 4.8520 to 4.8033 and gamma has changed from 2558 to 2525. This does not change System settings and you may safely try different “what if” scenarios.

Clearly, a first step would be to improve the test environment by adding appropriate noise filters and shielding before attempting to optimize the thermal transient application. Once this is complete, review several measurements to determine the best settings for accuracy and consistency among parts. When satisfied you may enter the new settings into the System section after clicking on “Unlock System”. You may then apply any updates to the System settings by clicking on “Apply Changes to System Values”.

Only qualified personnel should be allowed to make System changes, as this may affect future test results.

Another example; for a longer duration test with a very low value thermal response part.

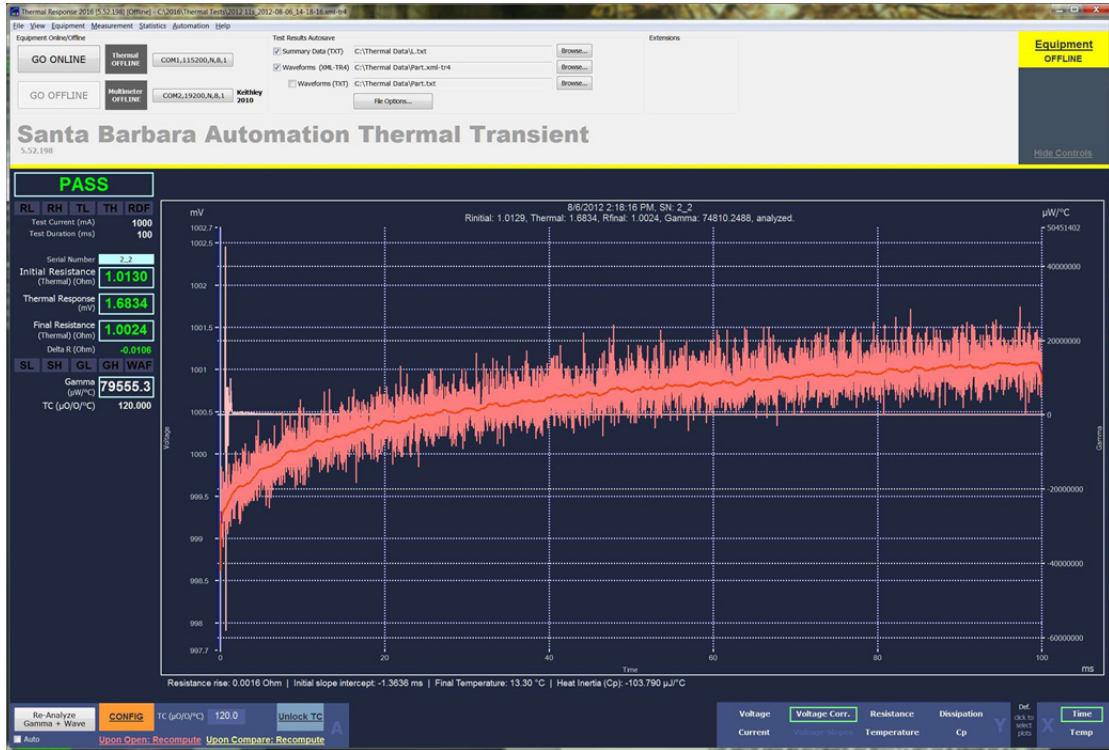


Figure 34 : Noisy Environment with $P_A = 10$, $P_B = 25$

For the above test note the thermal response of 1.6834 and gamma value of 79,555. P_A was set to a value of 10 and P_B to a value of 25.

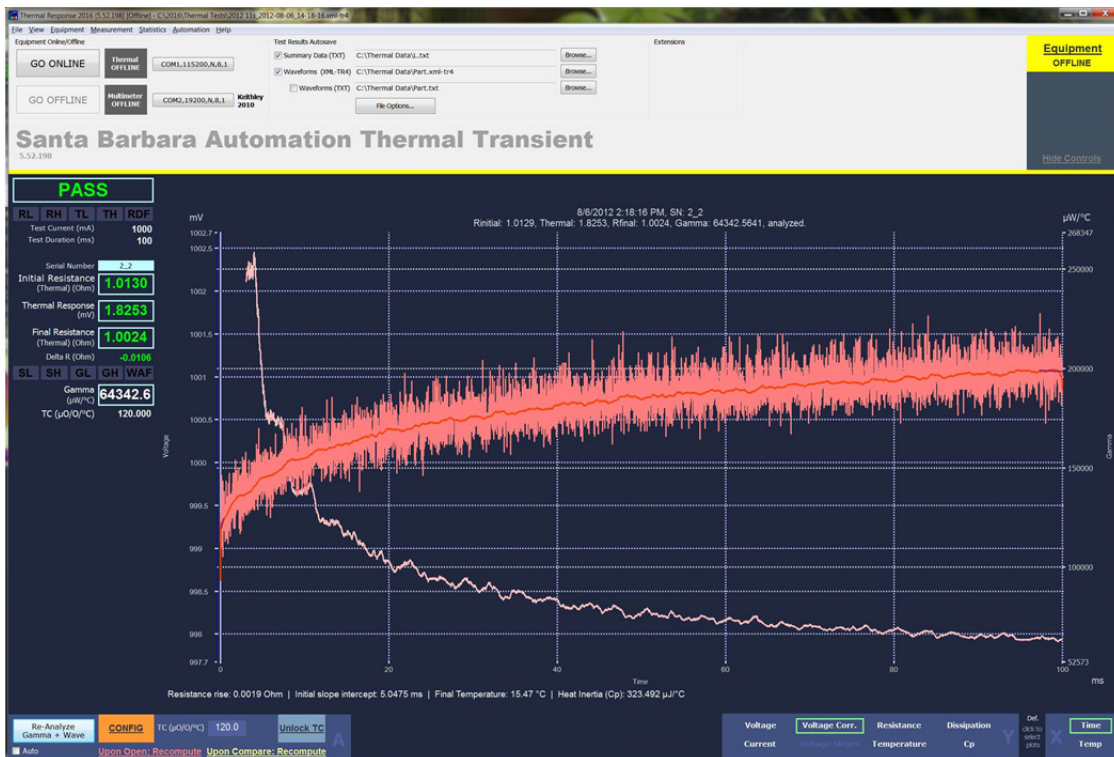


Figure 35 : Noisy Environment with $P_A = 25$, $P_B = 200$

Figure 35 above is the same test as in Figure 34 with P_A changed to a value of 25 and P_B to a value of 200. Note the change in thermal response measurement from 1.6834 to 1.8253 and gamma from 79,555 to 64,342. No other changes were made.

To continue the analysis hold the shift key down and click on Voltage Corrected. A new set of lines (purple) will appear on the graph near the beginning and end of the measurement. These represent the average values computed for P_A and P_B . The red line is the average for the overall curve and the beige line is the gamma curve with the gamma scale at the right side of the graph. Expand the start of the waveform and examine the slope of P_A as shown below in Figure 36.

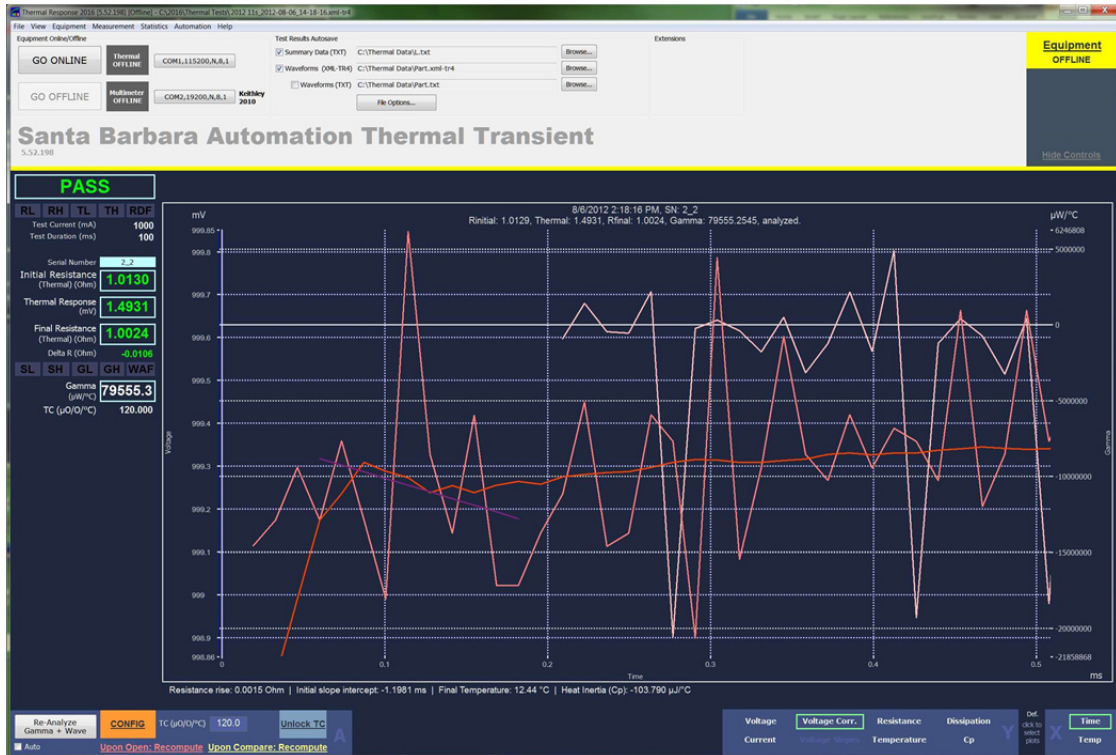


Figure 36 : Settling and P_A review

For Figure 36 with a P_A value of 10 the initial P_A slope is negative. Because this can result from bridgewire movement and other manufacturing defects it will be necessary to run tests on several parts to determine if it is characteristic of the part, is due to a unique part or is a consequence of the test environment and noise. In this case the low thermal transient reading of 1.493mV suggests that it is a combination of the part and noise in the environment.

If, after additional review, the results of testing a statistically significant number of parts are similar, then for consistent and accurate measurements larger values of P_A and P_B are suggested.

Review the proposed changes by entering new trial values in the Measurement section of the Process Options window and then click on “Apply Changes”. Once again expand the start of the waveform and examine the slope of P_A as shown below. Measurement changes are not saved to the System setting unless “Unlock System” is clicked and new values are entered.

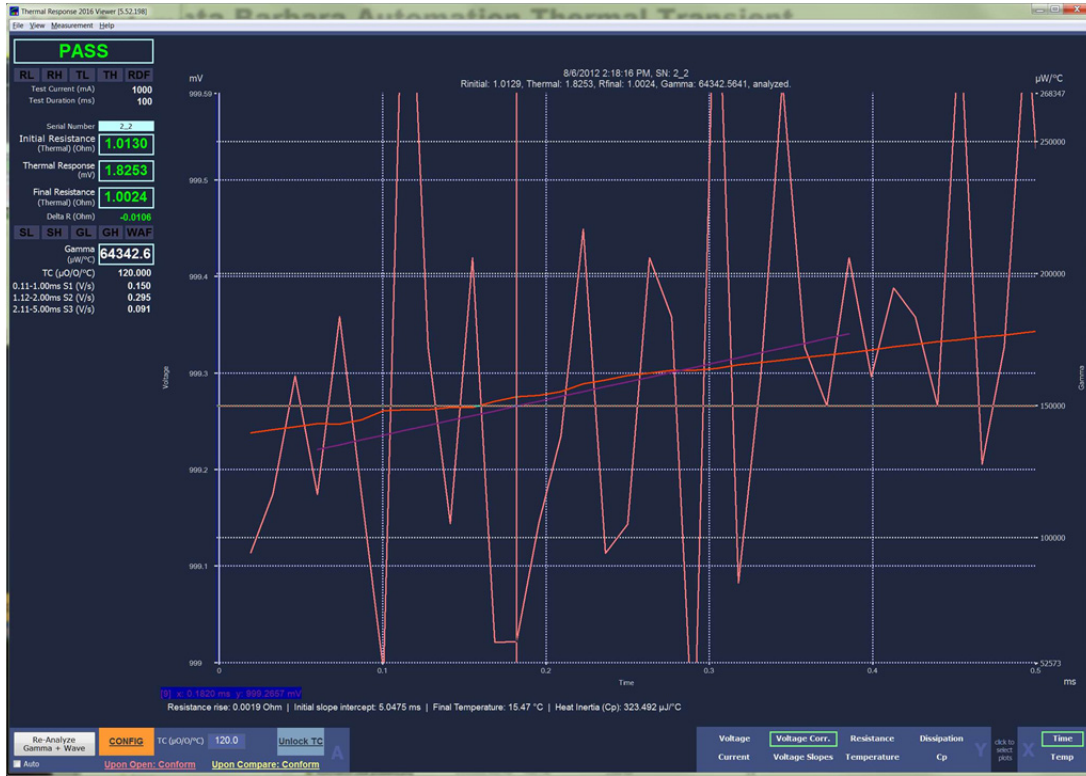


Figure 37 : Settling and P_A review after changes

After changing P_A to a value of 25 and P_B to a value of 200 the initial slope of P_A is now positive, as would be expected if the temperature coefficient of the wire is positive and the testing parameters are properly configured. Figures 32, 33, 34, 35 and 36 are all for the same archived file. As this illustrates, for some part types and test environments the effects on production test and yield are significant and justify the time to properly evaluate and select the best configuration parameters.

These examples are not intended to define the settings for any specific site, but are provided as examples of the evaluation process leading to the selection of parameters that will provide accuracy and consistency. These are also examples of problematic test environments.

Sampling rates vary depending on when the thermal product was produced. Older hardware was limited to about 40us/sample, while the current version is about 13.3us/sample. Newer versions are planned that will be much faster. In addition, sampling rates will vary when longer test pulses are selected. Pulse times greater than 105ms to 109ms (depending on hardware) will have sampling rates of 2x slower, and pulse times above 210ms will have sample rates that are 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.*

While evaluating the waveforms for P_A and P_B values and slope it is easy to expand the leading edge of the waveform and look at the settling time. Press “C” to show the cursors on screen. Expand the scale, move the cursor to the first sample point, and note the time at the bottom of

the screen. For the part shown in Figures 32 – 36 the signal is stable within 19.3 microseconds after the test start. Consequently, the Stabilization Delay may be set to 17us.



Figure 38 : Review of Rise Time after P_A and P_B changes



Figure 39 : Filter Options

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 labeled **Batch Control** next to the **Part Type** in the **Measurement View window**, or b) Configure the test parameters (test current and duration) manually. Note that the part number and test 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.

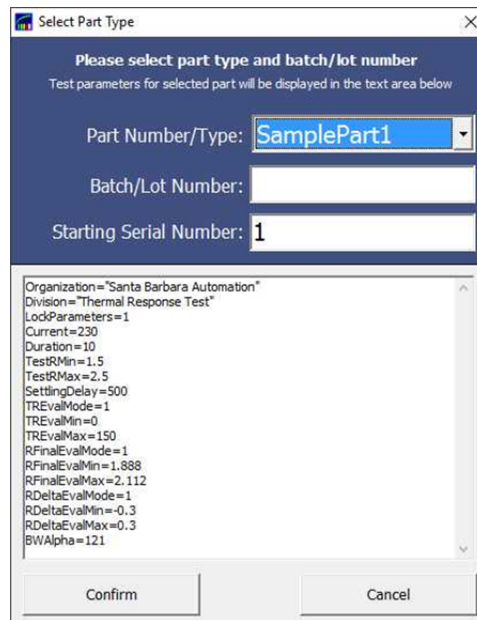


Figure 40: Select Testing Parameters from Testparameters.ini

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. Select the part number to be tested by clicking on Load Part Type or by entering the test parameters manually.
4. Verify testing parameters such test current and pulse duration in the measurement window.
5. Enter or verify the test notes, if desired. The notes will be saved along with the measurement.
6. To start a test press the operator switch or click the program's **Start Test** button.
7. To avoid retesting the same part the chamber door must be opened and closed between each test.

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.

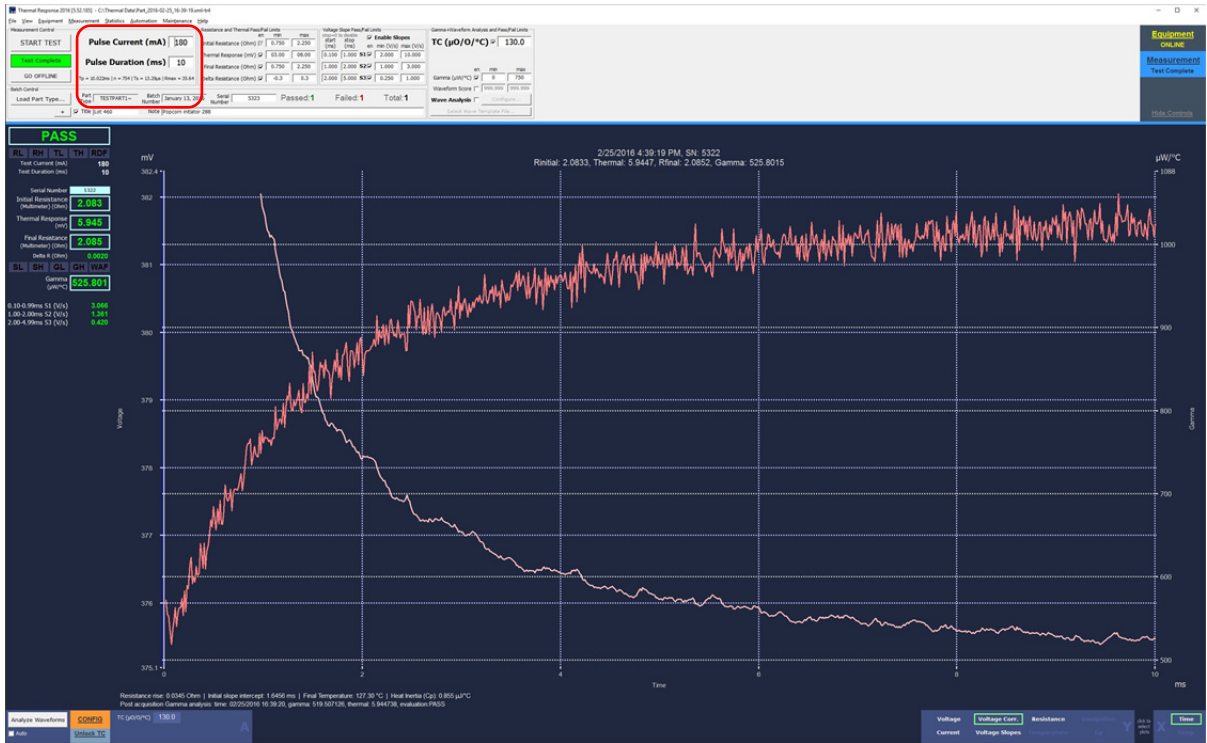


Figure 41: Test Configuration Area

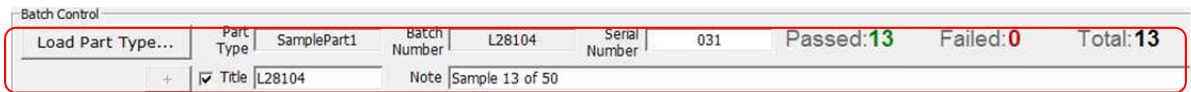


Figure 42: Measurement Notes

When testing multiple parts, or when operating under PLC control, the Automation view provides a streamlined interface suitable for display of the test history and two test positions.



Figure 43: Automation View

Basic Test Results

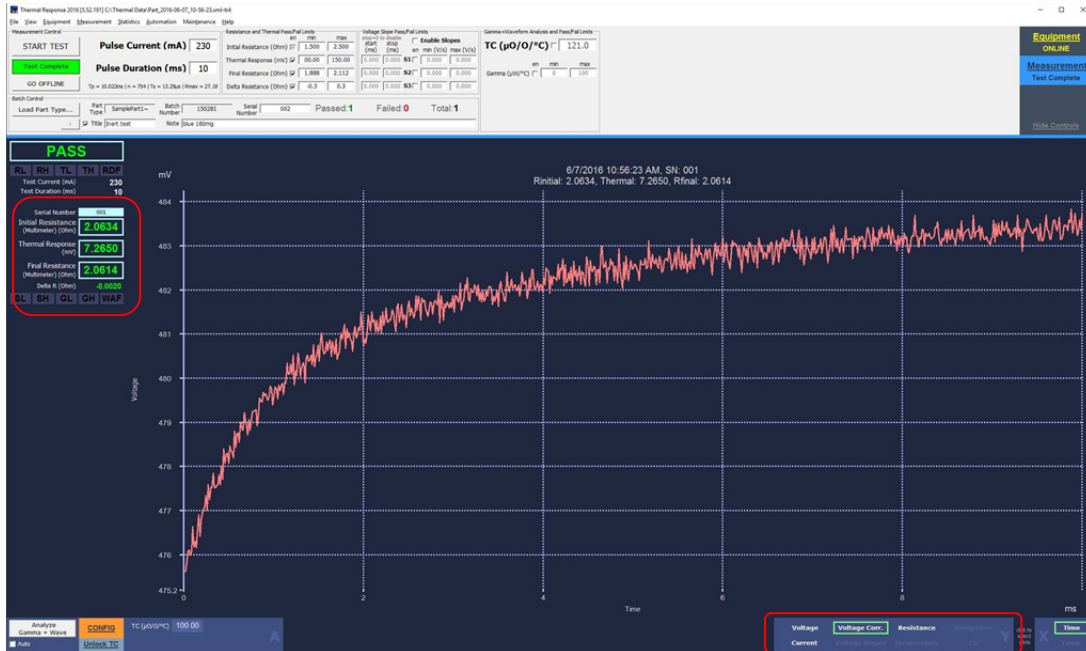


Figure 44: Thermal Transient Test Measurement

The primary display of the basic 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, color coded green for passing results and red for failing.

For the Thermal Transient system the testing 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 230mA. Note that the initial portion of the curve (between 0 and 1 millisecond) reflects a much faster rate of rise than later portions of the curve. Accurate measurement of voltage and current at 100us is critical to precision measurement of thermal transient values.

The viewer will display the selected test results in both 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 when 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 with the Thermal 2017 application the following keyboard and/or mouse operations may be used for adjusting the viewing area of the graph (click on the graph to enable keyboard focus):

Keyboard Shortcuts

Keyboard Entry	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 45: 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” box. Note that the Settling Offset in microseconds 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 left corner of the axis selection control area (Fig. 26). 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 if the analysis is performed, otherwise only the current, voltage and timing data will be exported.

Advanced Testing

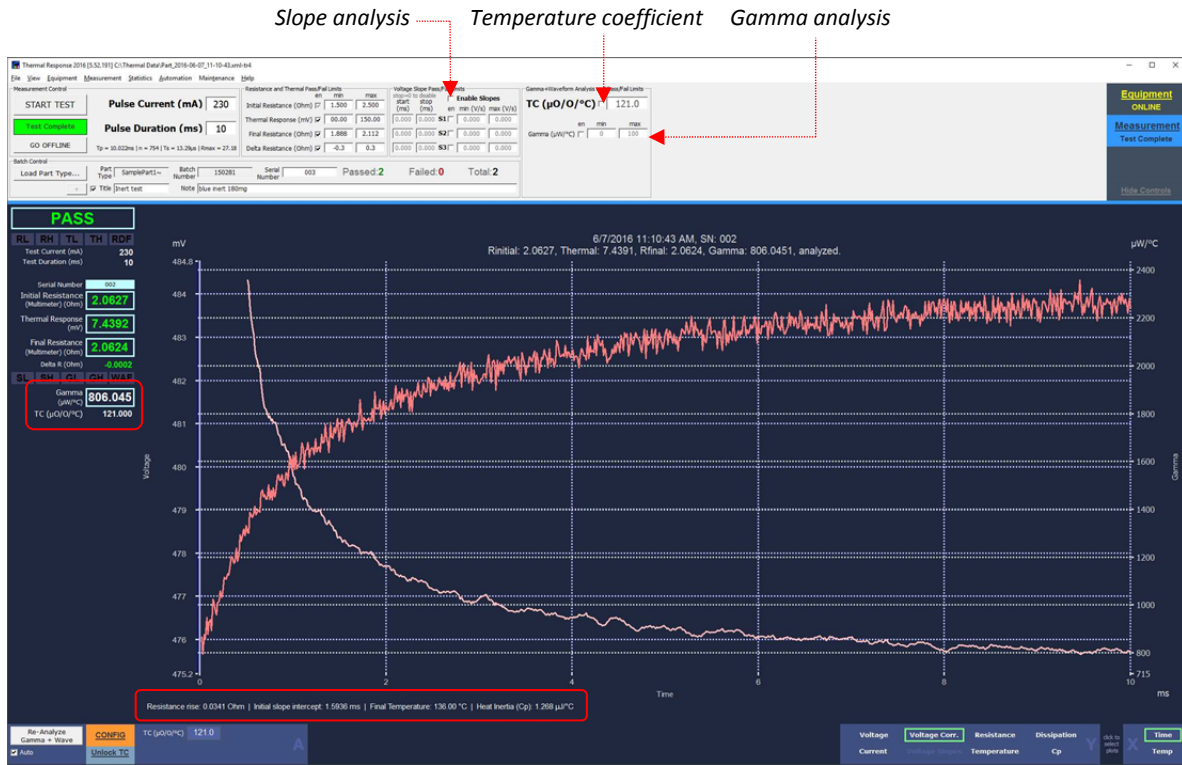


Figure 46: Analyzed Measurement with gamma waveform

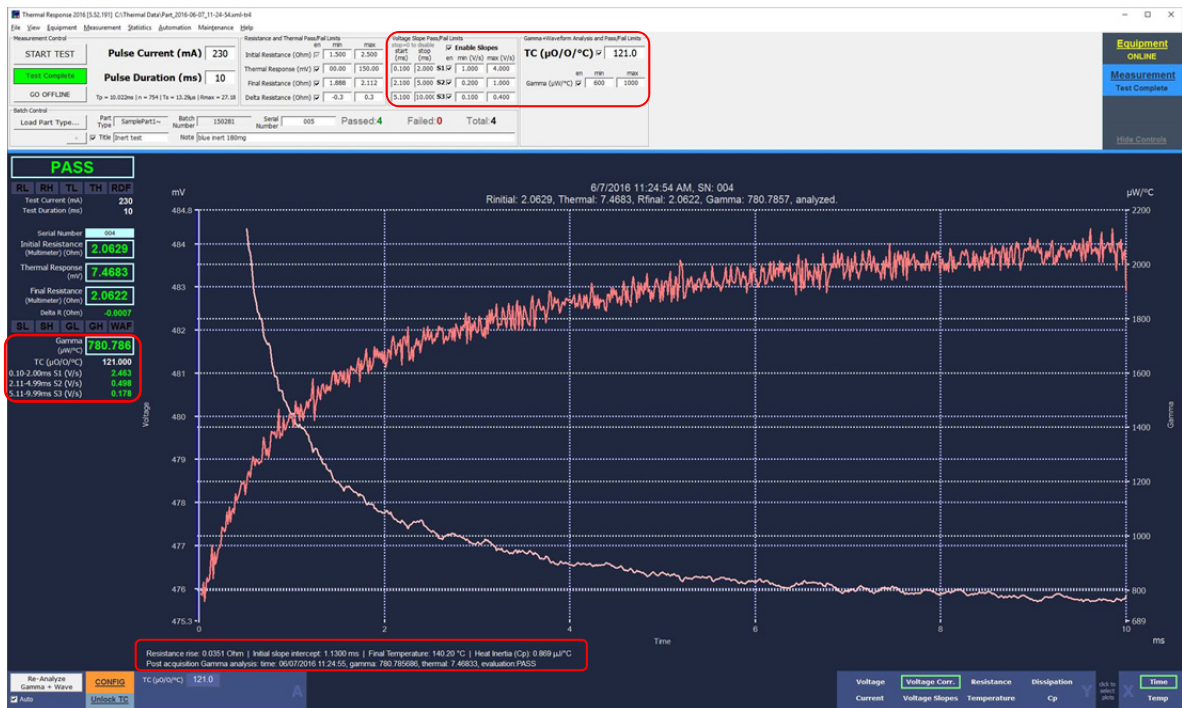


Figure 47: Analyzed Measurement with pass/fail on slopes and gamma enabled

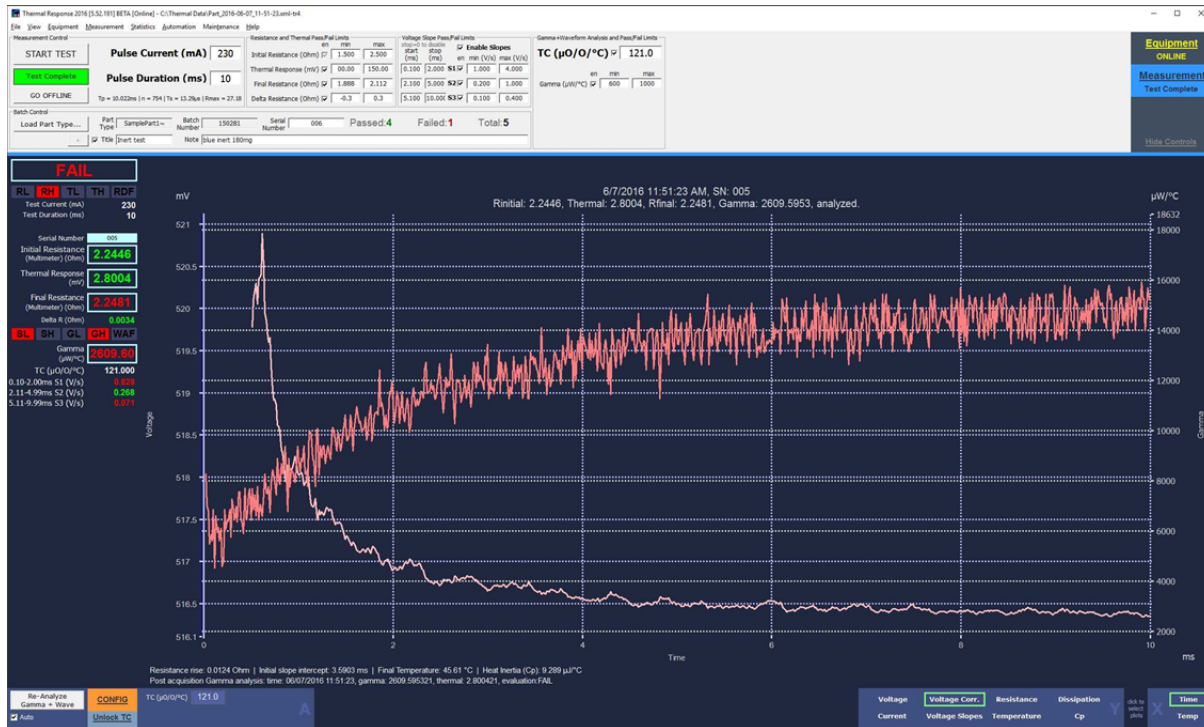


Figure 48: Failing Test Results Screen

In the example above the part passed the initial resistance test but failed the final resistance test. More specifically, the part passed for initial resistance, thermal transient and delta R but failed for final resistance, gamma, slope one and slope three tests.

The Thermal 2017 application will display abbreviations for reject categories beneath the pass/fail window. The 5 categories are noted as:

- SL = Slope Low
- SH = Slope High
- GL = Gamma Low
- GH = Gamma High
- WAF = Waveform Anomaly Fail (future).

Measurement Data Files

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

1. **Summary Date (TXT):** The **Text Summary**, normally called the results file, archives test results in a form suitable for statistical analysis of test data. The initial file is written when the first test is performed and is appended to afterwards. Data is stored one test per line in comma separated values (CSV) format. For example (presented here in 3 lines due to page width limitations):

```
Date, Time, Serial, FixtureID, PartType, LotNumber, TestCurrent, PartEvaluation, InitialR,
2017-03-02, 14-25-14, , -3, TESTPART1~, 0, 310.00, PASS, 2.00134,
InitialREval, Thermal, ThermalEval, FinalR, FinalREval, DeltaR, DeltaREval, Gamma, GammaEval,
PASS, 3.19704, PASS, 1.00208, PASS, 0.00074, PASS, 1139.58781, PASS,
Slope1, Slope1Eval, Slope2, Slope2Eval, Slope3, Slope3Eval, LogTitle, LogText
0.01183, UNKNOWN, 0.01459, UNKNOWN, -0.00303, UNKNOWN, , Default Part Configuration
```

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

2. **Waveforms (XML-TR4):** 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 are not associated with the thermal software and may only be opened after the thermal application is open.
3. **Waveforms (TXT) 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 into the application and then clicking “**Export Analysis Data As Text**” under the **File** menu.

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

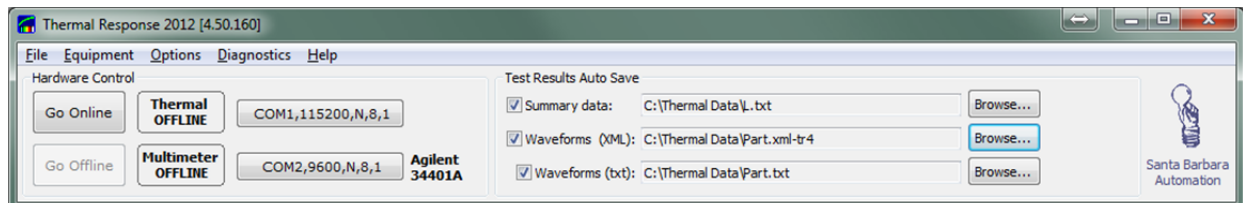


Figure 49: Output data save selection screen

Select the type and location of the data you wish to save prior to running a test by using the Browse buttons. Choose file names that will allow the series of tests and data to be easily identified at later dates. Since large groups of data may be useful for determining production equipment performance we suggest periodically archiving the data, which reduce the number of files in the save location.

Thermal 2017 Automation Interface Supplement

The Thermal Transient Automation Interface must be used with version 50, 51, 54 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 250mA
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. *The Machine Ready input should only be active when a test may safely be run. A test chamber door interlock is such an example. Without this input you may not run a test.*

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 50: Thermal Transient Automation Interface rear panel

Please note the connectors and LEDs on the rear panel of the Thermal Transient instrument. The 10-pin connector is for the output signals and the smaller 4-pin connector is for the input signals. The 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.

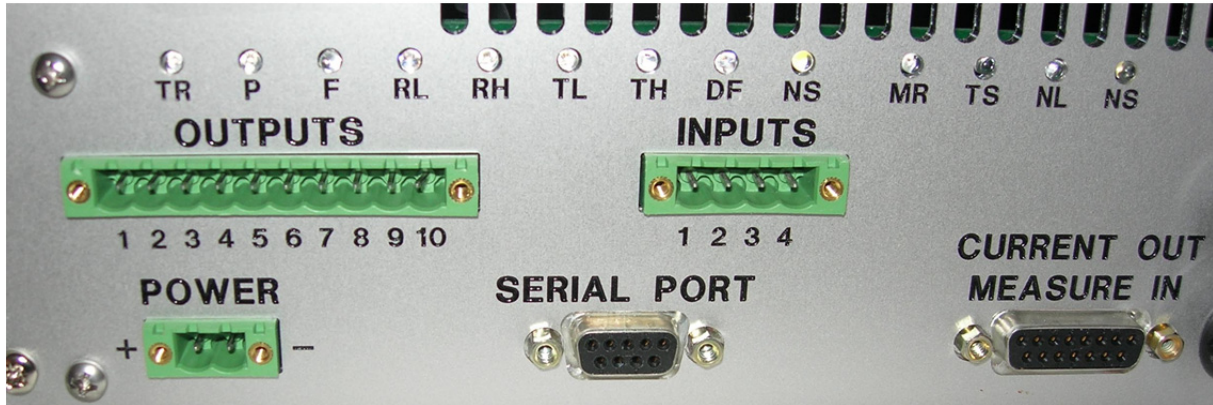


Figure 51: Automation LEDs, power supply and interface connections

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 the Thermal instrument 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 low resistance.
5. **Resistance High** – output, this line is high when the part fails for high resistance.
6. **Thermal Transient Low** – output, this line is high when the part fails for low thermal.
7. **Thermal Transient High** – output, this line is high when the part fails for high 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 to 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	NS
Thermal Ready	Pass	Fail	Resistance Low	Resistance High	Thermal Low	Thermal High	Delta Fail	Nest Select

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.*

Test Options

When using the automation version of Thermal2017 and the correct hardware the user has numerous integration options that change the manner in which the equipment functions.

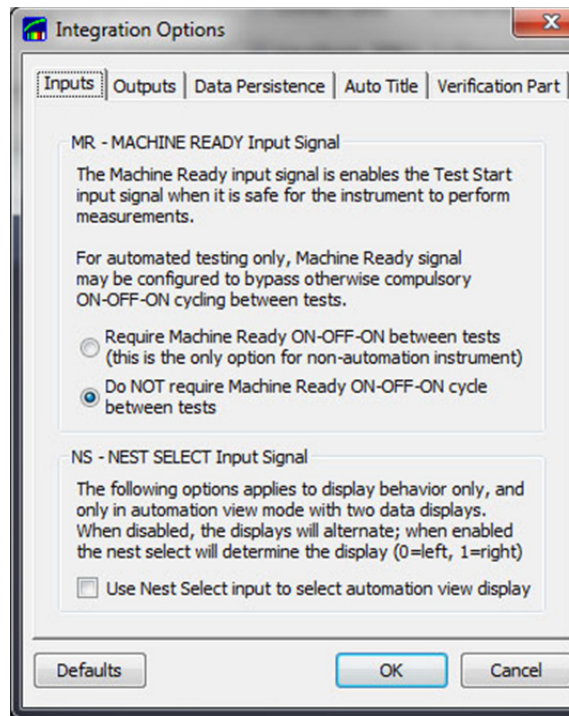


Figure 52: Machine Ready and Nest Select

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 to 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.

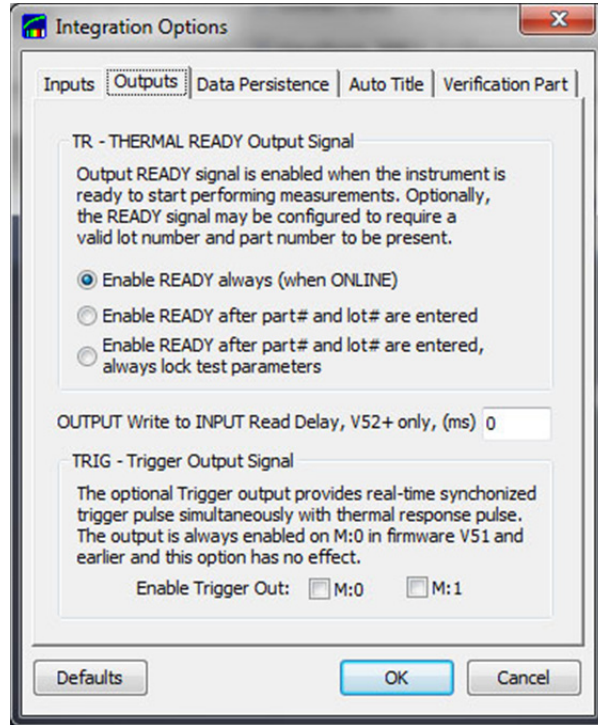


Figure 53: Integration Options, Outputs

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 new part development and for quality assurance test, the parameters may be frequently changed by entering values manually. In this case, and only when safe conditions allow, it may be preferable to have the equipment always online.

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

When the optional hardware is available and is selected, the trigger signal is active during a test and will allow external equipment, such as an oscilloscope, to capture waveforms independently. The 5 volt 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 multiple bridgewire initiators.

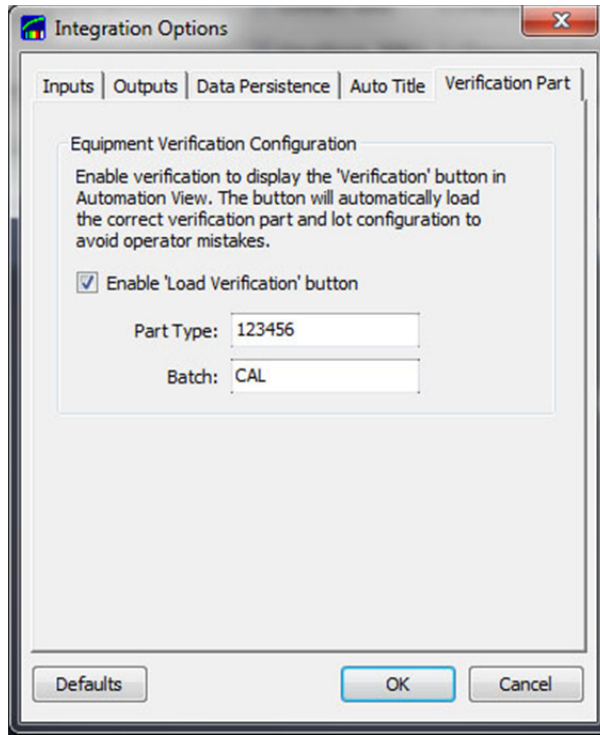


Figure 54: Integration Options, Verification Part

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/validation module, such as provided by Santa Barbara Automation, may be given a unique part type and name. When enabled this feature will enable the “Verif. Load” button on the Automation view screen *only*, to load the test parameters associated with the verification part.

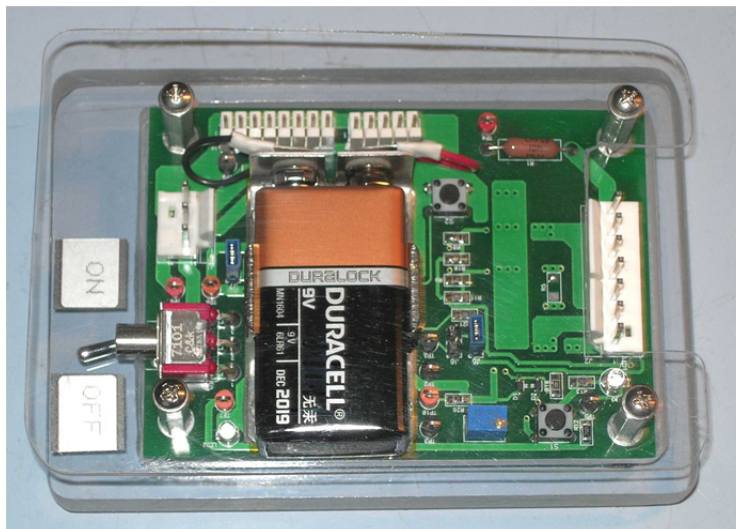
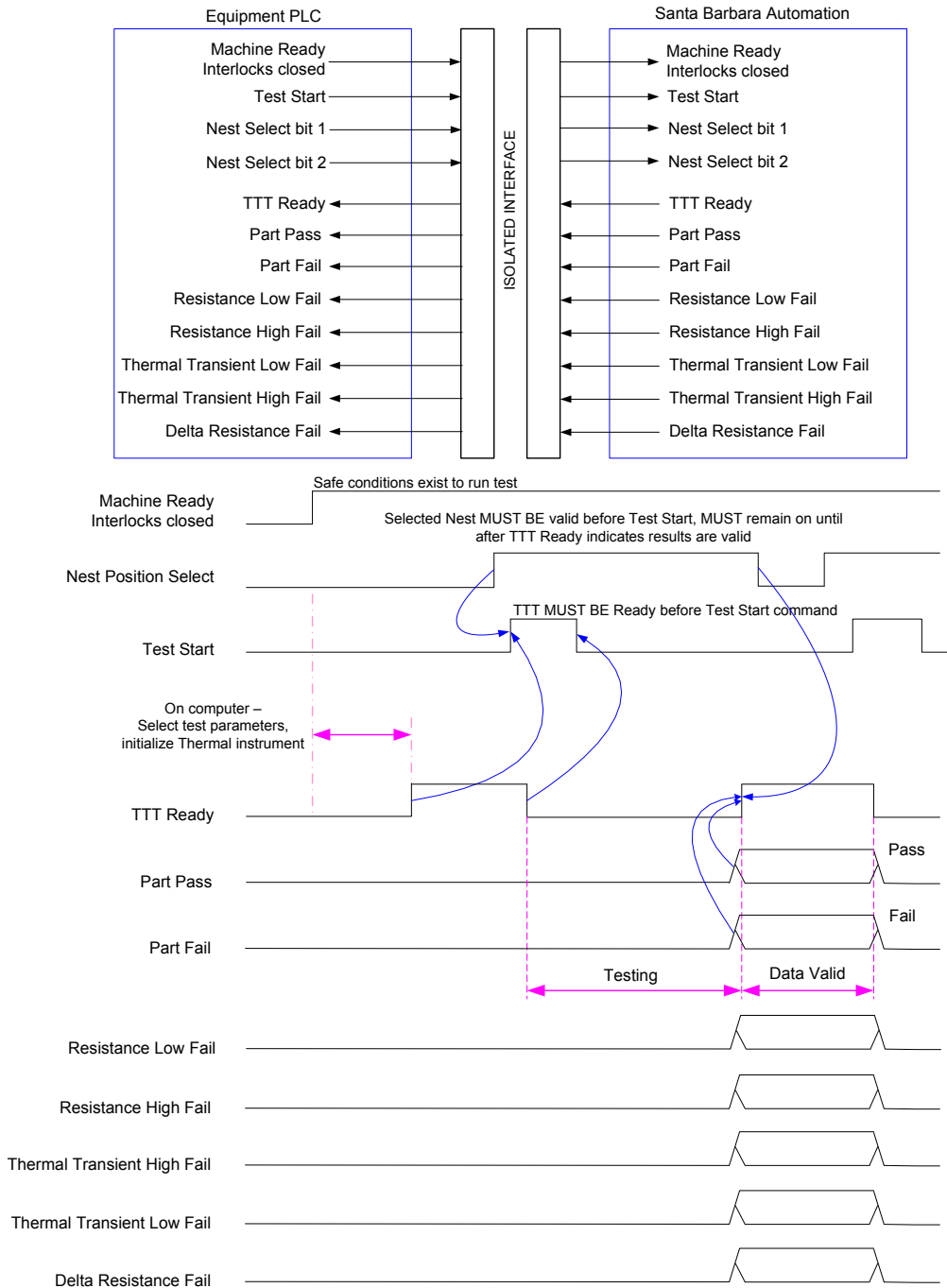


Figure 55: Solid State Single Channel Test Certification module

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.

Equipment PLC - Santa Barbara Automation Interface

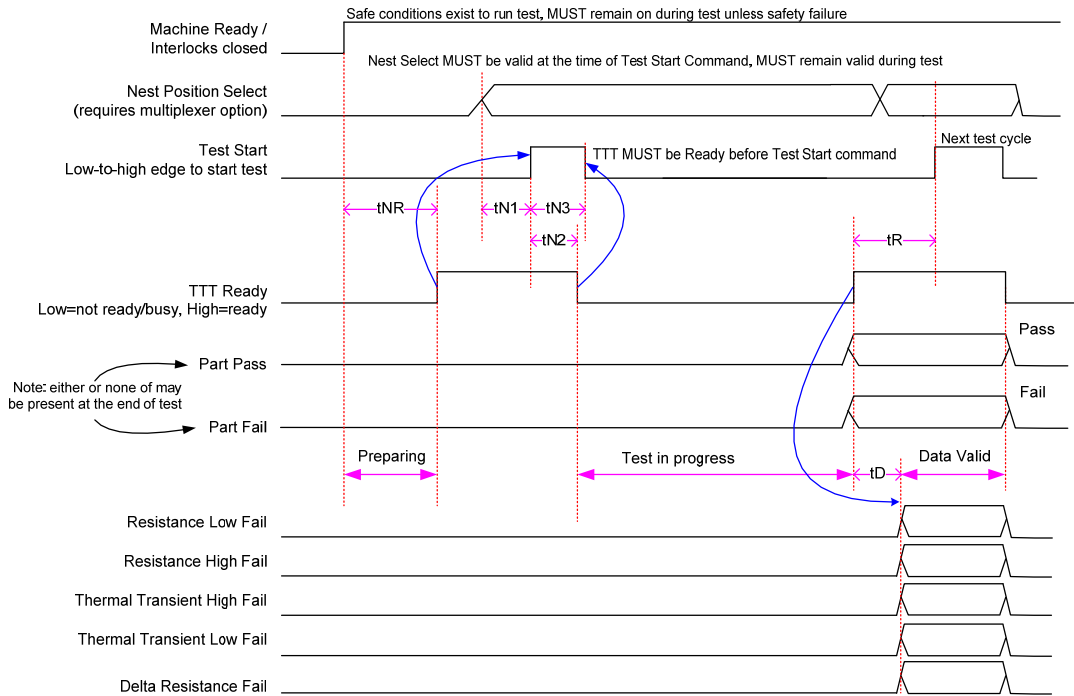


NOTES:

1. Machine Ready (safe) signal is required before any testing.
2. TTT Ready must be valid before Test Start.
3. Nest Selects must be valid before Test Start and remain valid until TTT Ready indicates the test is complete.
4. Must use compatible multiplexer circuit board to be able to use multiple Nest Select.
5. TTT Ready output will go low to indicate test in progress.
6. Test Start input may return Low once the test is in progress.
7. TTT Ready output will return High when the test is complete and data is valid.
8. Part Pass and Part Fail are high, only one line active. Data is valid until next Test Start command.
9. Fail category outputs are high, only one line active. Data is valid until next Test Start command.
10. All lines are 24V DC, active high, sourcing outputs, sinking inputs.
11. +24VDC to be supplied from outside machine power.
12. Loss of Machine Ready input stops test, data archive.

Figure 56: Timing diagram for Automation interface inputs and outputs

TTT Automated Test Timing – “Machine Ready Cycle NOT Required” Configuration



Automation Thermal I/O Signals and timing when not using Machine Ready cycle logic

TIMING SPECIFICATION:

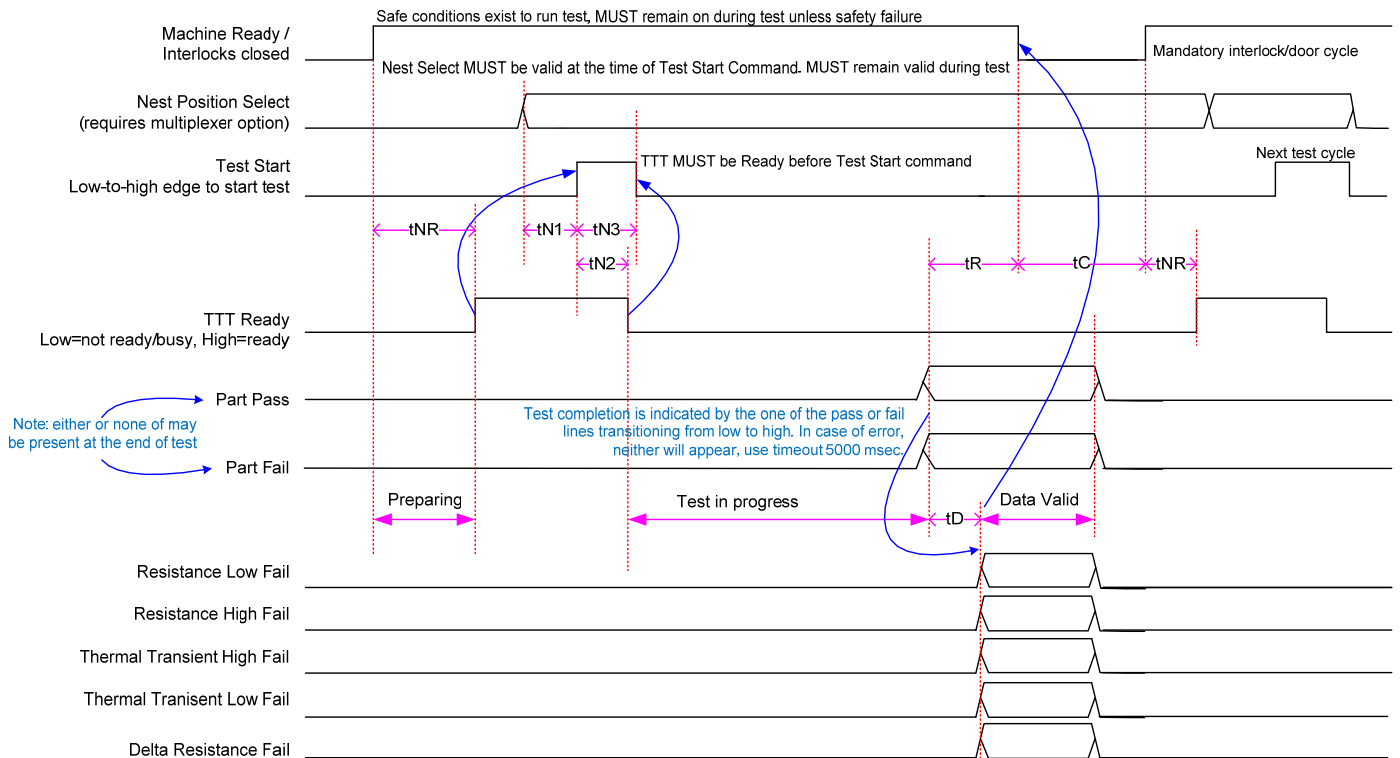
- t_{NR} : Time to TTT ready after Machine ready. 10msec min, any length max because may require lot configuration from user
- t_{N1} : Time Nest Select must be ready before test start: 50 msec min.
- t_{N2} : Test start delay: 200 msec max, set timeout to 1000 msec.
- t_{N3} : Test start and Nest select 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 57: Automation I/O Signals & timing when not using Machine Ready cycle logic

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



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.
- t_C : Interlock cycle time: 300 msec minimum.

NOTES:

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

Automation Thermal I/O Signals and timing when using Machine Ready cycle logic

Figure 58: Automation I/O Signals & timing when using Machine Ready cycle logic

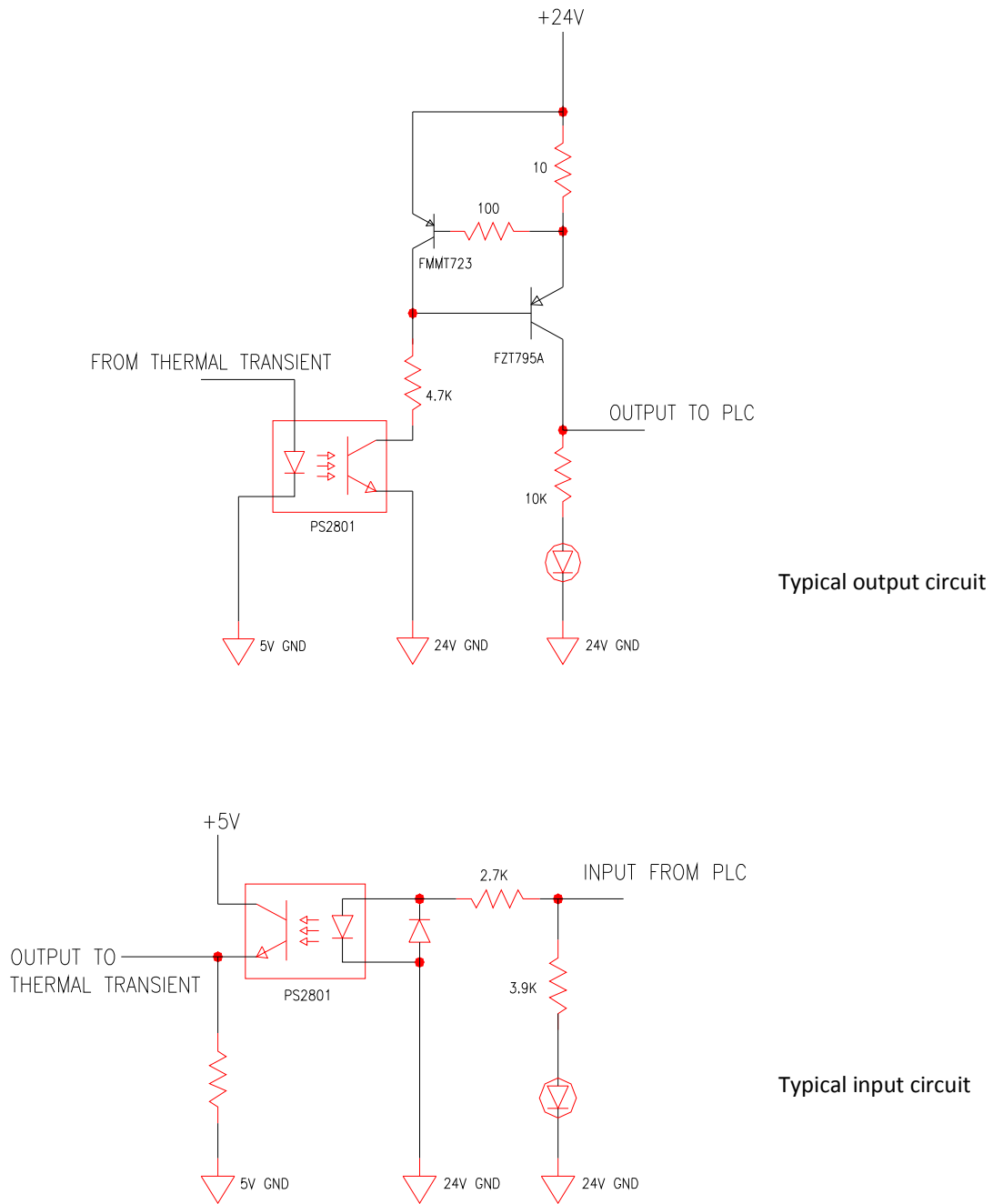


Figure 59: Typical circuitry for outputs and inputs

Diagnostic Tools

A basic diagnostic tool is included with the Thermal application for simple troubleshooting. To invoke the tool, click on Automation on 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.

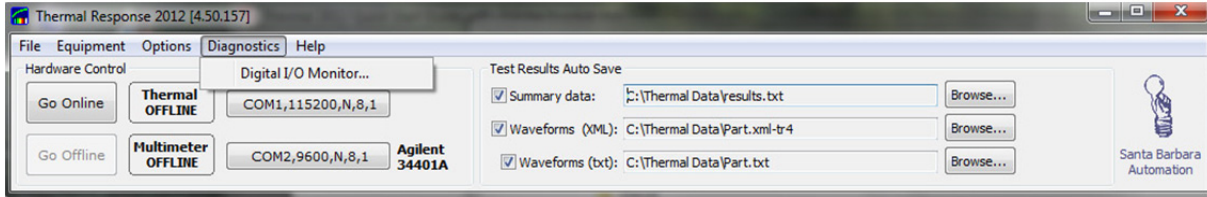


Figure 60: Diagnostics Selection on the Menu Bar

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.

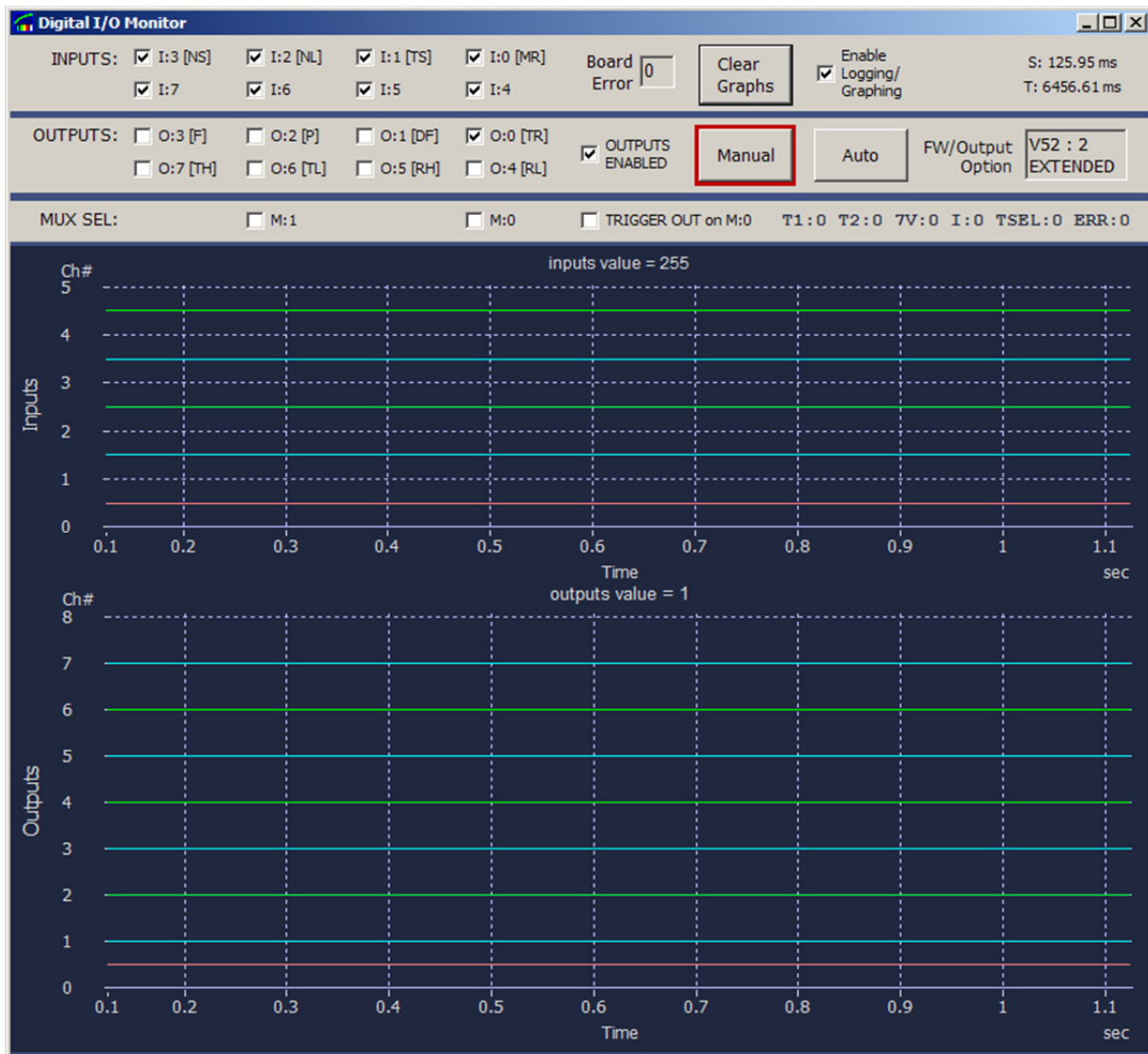


Figure 61: Diagnostics Tool

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.

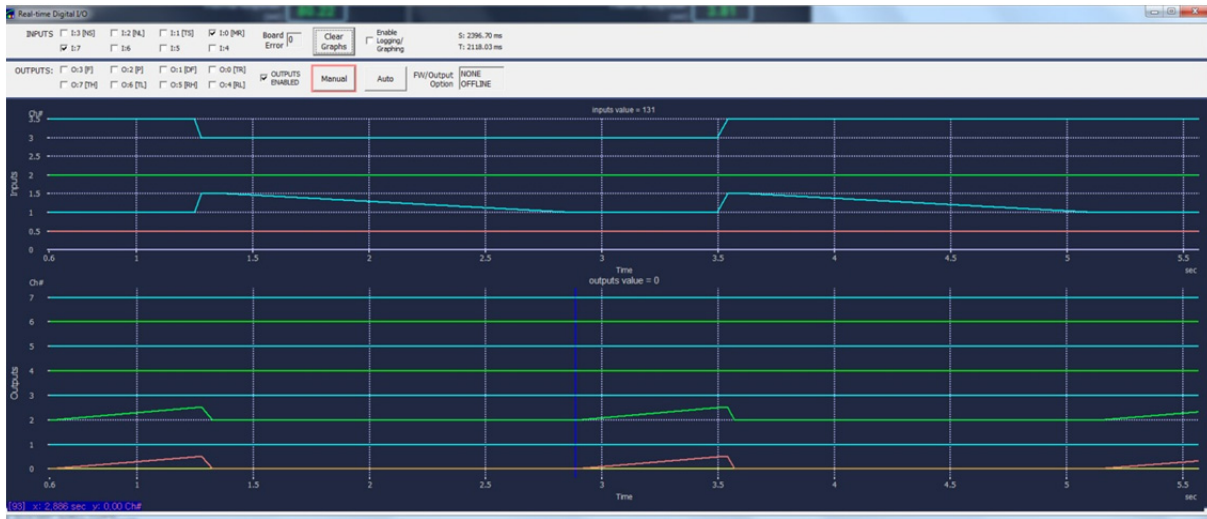


Figure 62: Diagnostics Tool Signals

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 63: Diagnostic Tool Color Codes

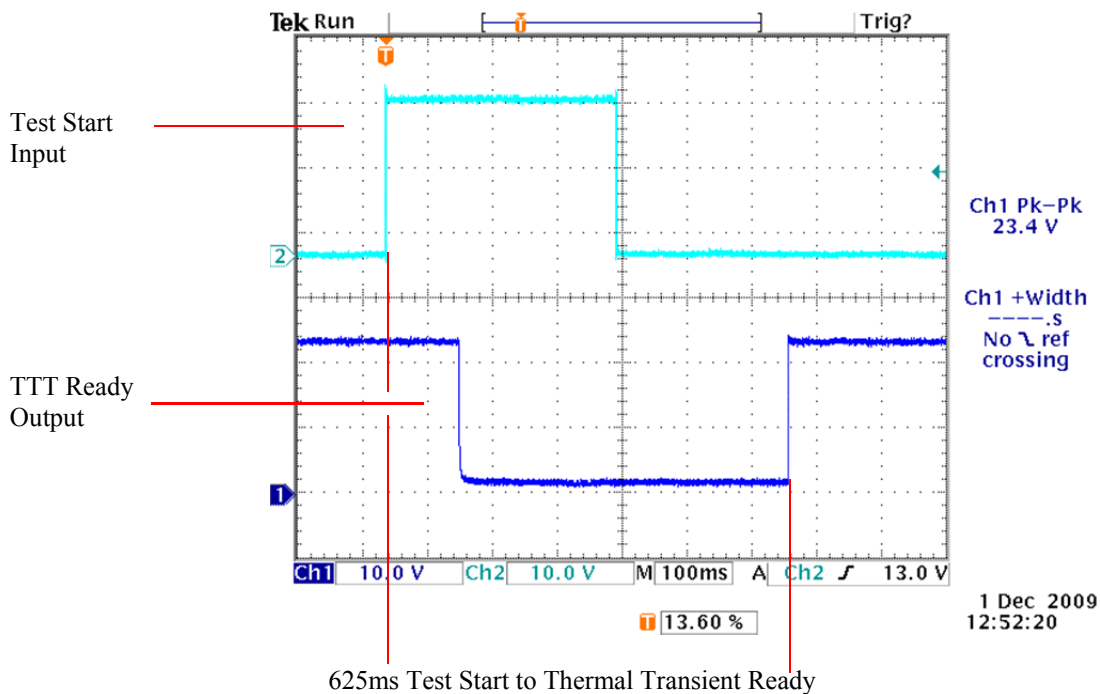


Figure 64: Overall Test Timing, Agilent 34401A, Keithley 2010, Keysight 34461A, 1PLC

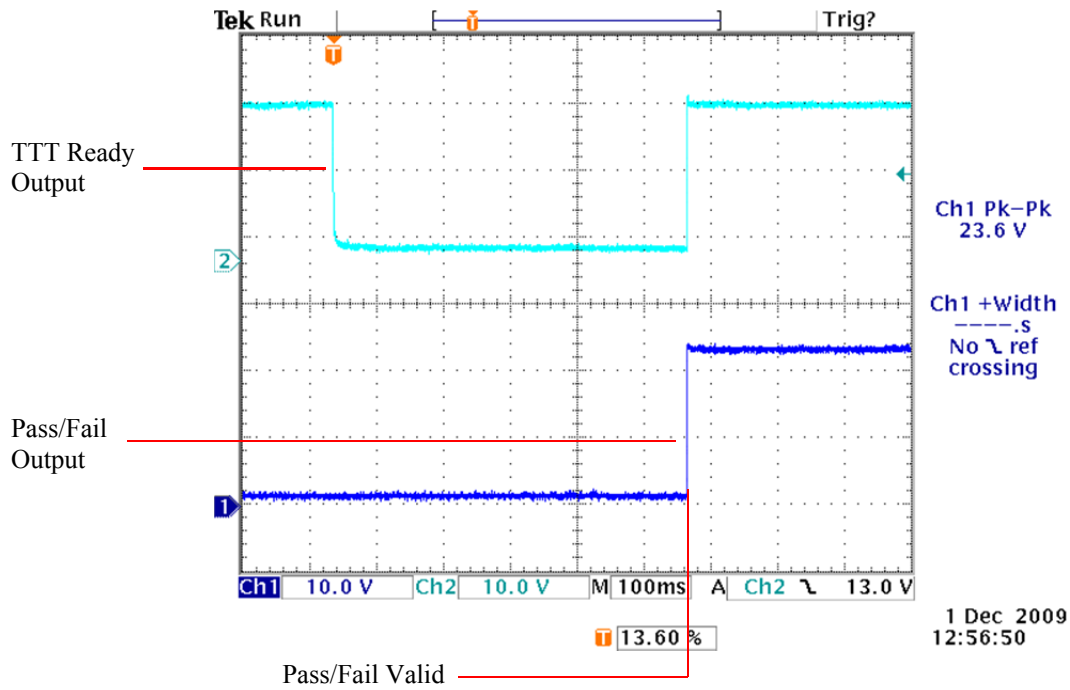


Figure 65: Pass/Fail Results Timing. Agilent 34401A, Keithley 2010, Keysight 34461A, 1PLC

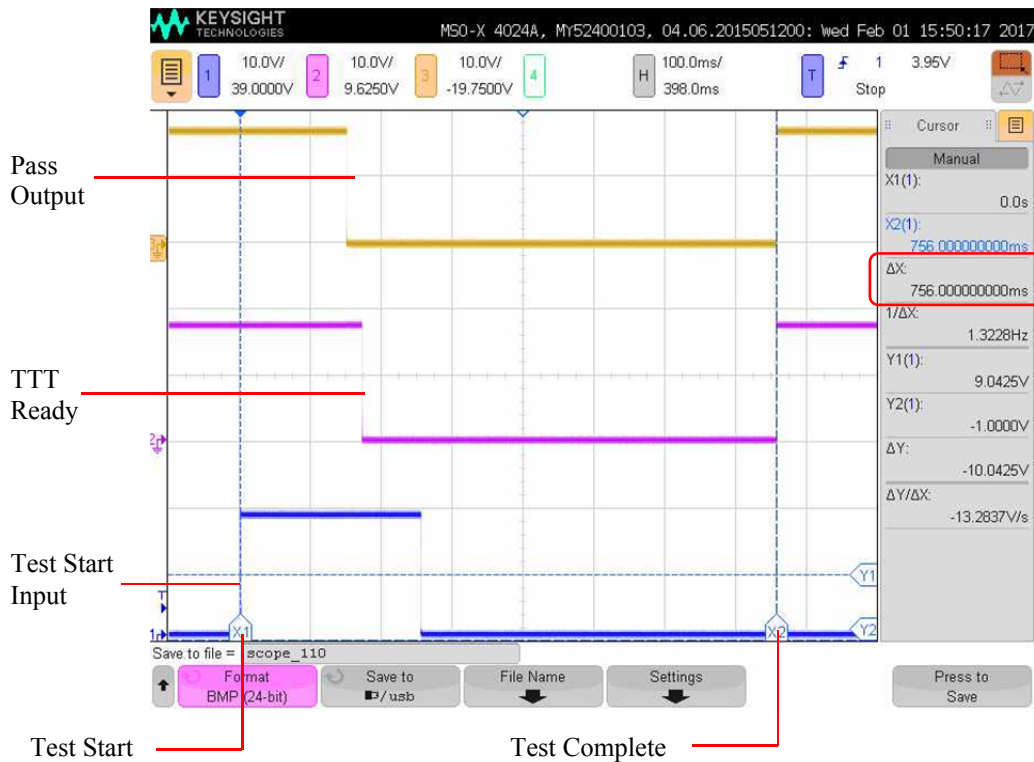


Figure 66: Pass/Fail Results Timing. Agilent 34401A, Keithley 2010, Keysight 34461A, 10PLC

Test Time Considerations

Both the Agilent 34401A and Keithley 2010 use a serial interface for communications, whereas the Keysight 34461A has Ethernet. Whether using meters with the serial or Ethernet interface the number of power line cycles used for integration will affect the overall test timing.

Under the Multimeter Options (page 11, Figure 11), Measurement Configuration, either 1 NPLC integration or 10 NPLC integration may be selected. Increased integration times (10 NPLC) will slightly increase resistance measurement accuracy, and may also be helpful in noisy environments.

With 1 NPLC the serial interface provides test start to test complete times of approximately 650 milliseconds on the Agilent 34401A and Keithley 2010, and for the Keysight 34461A with Ethernet interface about 750 milliseconds. For settings of 10 NPLC cycle times will increase to approximately 1.35 seconds. The overhead imposed for the additional averaging adds about 600 milliseconds.

Changing to 10 NPLC integration will increase per cycle test times as shown below.

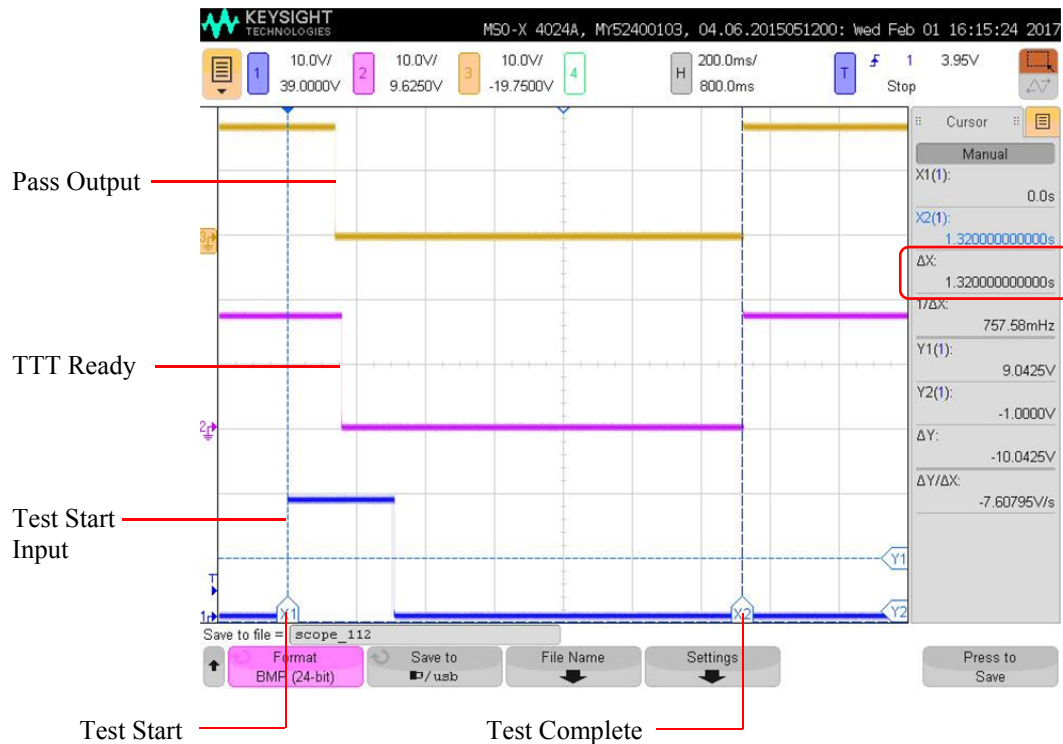


Figure 67: Pass/Fail Results Timing. Keysight 34461A, 10PLC

By comparing figures 66 and 67 the cycle time differences may be seen. Changing to 10 NPLC integration time will increase the per cycle times from about 650 to 750ms to about 1.3 seconds. If your process does not require the absolute fastest time we suggest using 10 NPLC for the slightly improved resistance accuracy.

When Parts go Bad

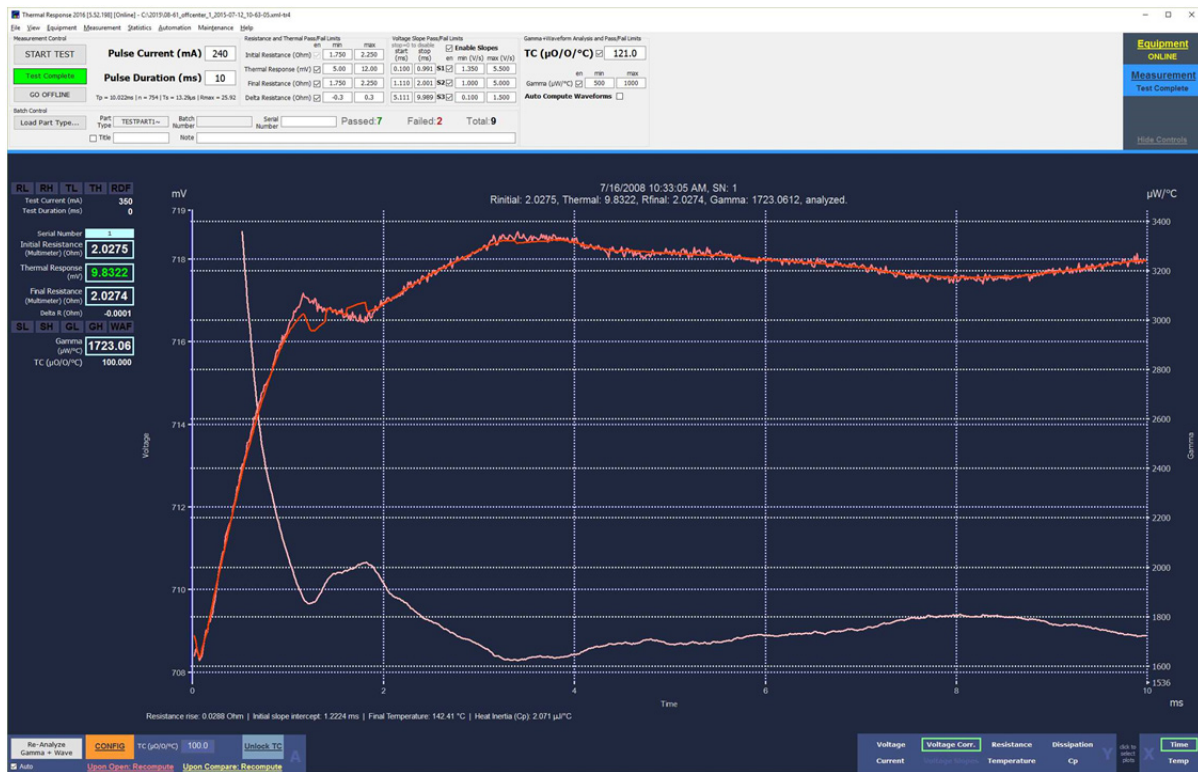


Figure 68: Passing Part with Bridgewire Movement

During startup or after maintenance unusual parts may often be found. The waveform above represents an effect called “touchdown”, where the bridge has contacted the substrate slightly beyond the weld, effectively becoming shorter. The thermal test heats the bridgewire and can cause mechanical expansion, resulting in bridgewire movement. In some cases the end welds may be compromised, others may “lift off” of the substrate near the weld, effectively becoming longer. The bridgewire may also “touch down” as shown above. Since the bridgewire is resistive these sudden changes in length show as steps or unusual shapes in the waveform. This problem may also be found for headers with poor lapping that create an uncertain last point of contact with the substrate just past the weld.

The above part passed a simple thermal transient test but would have failed if slope analysis had been enabled. Given the observed bridgewire movement the manufacturing process should be investigated.

It can be difficult to discriminate between touch down and lift off effects that shorten or lengthen the bridge and actual thermal effects. The clues that indicate mechanical movement within the header are changes in slope and the time over which the change occurs. Thermal effects typically occur over hundreds of microseconds to milliseconds in consolidated and slurry parts, and with few exceptions the slope remains positive. Where movement is involved a rapid change in slope may occur in tens to hundreds of microseconds. This can also appear as a noisy part.

Causes cover a wide range of the fabrication process, from poor header lapping that leaves a rough surface on the substrate, to worn or misaligned weld electrodes, caked powder, bridgewire tension or twist during welding, consolidation dwell times, badly mixed slurry, poor consolidation, underload or overload and more.

Slower effects may be caused by changes in the thermal coupling between wire and powder. These are also often caused by movement and can represent bridgewire heating or cooling effects that in turn represent resistance changes. Thermal 2017 is a valuable tool for investigating these causes and for improving production yields.

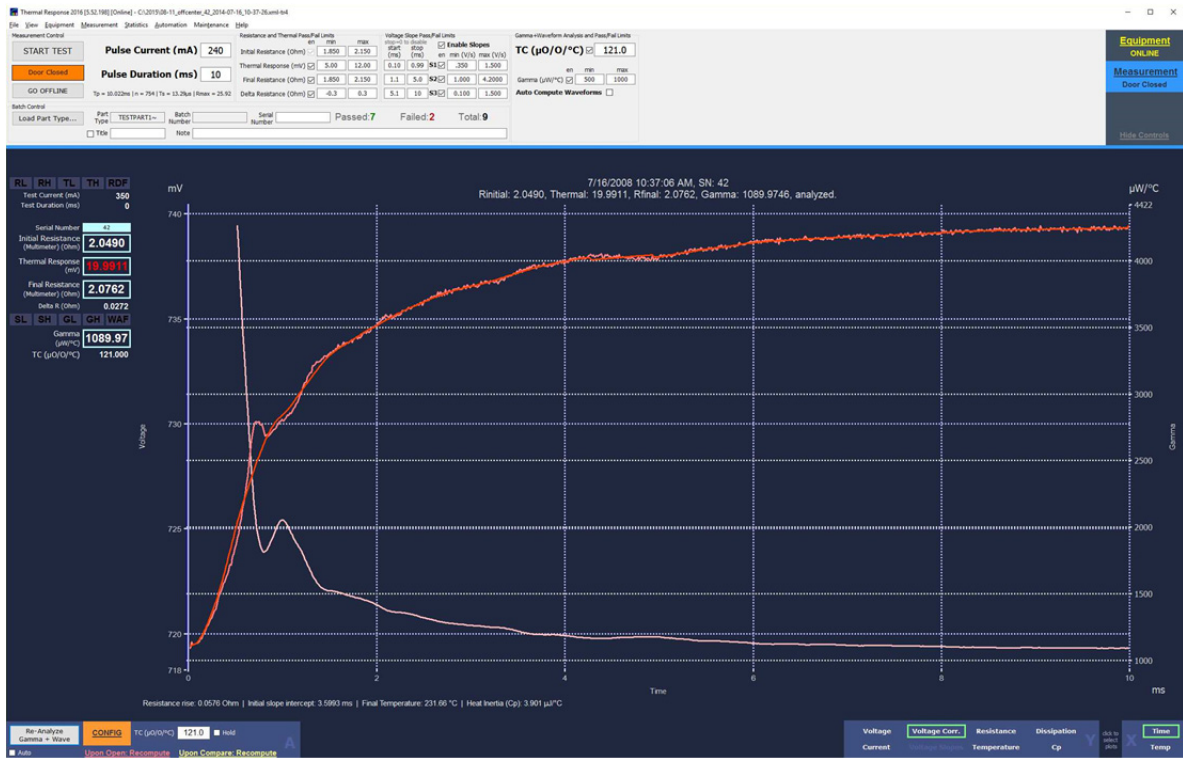


Figure 69: Reject Part with Sudden Bridgewire Movement- touch down effect

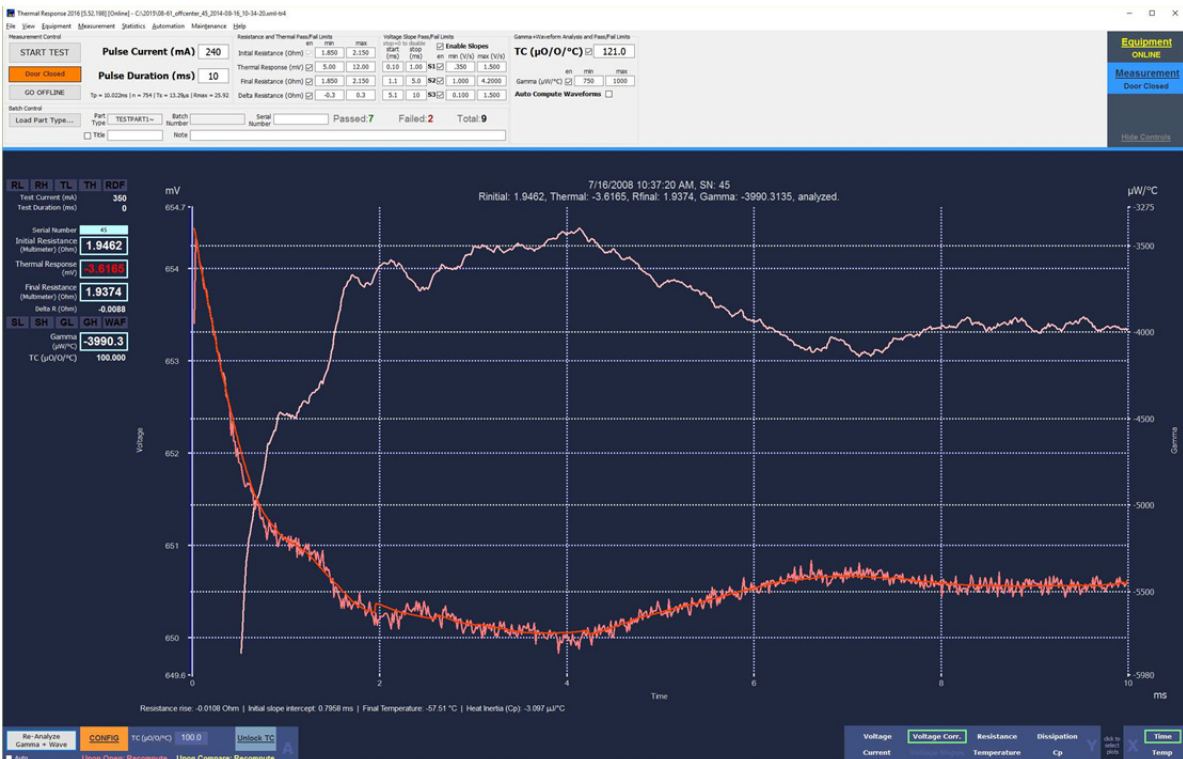


Figure 70: Worse Case- Negative Thermal Response

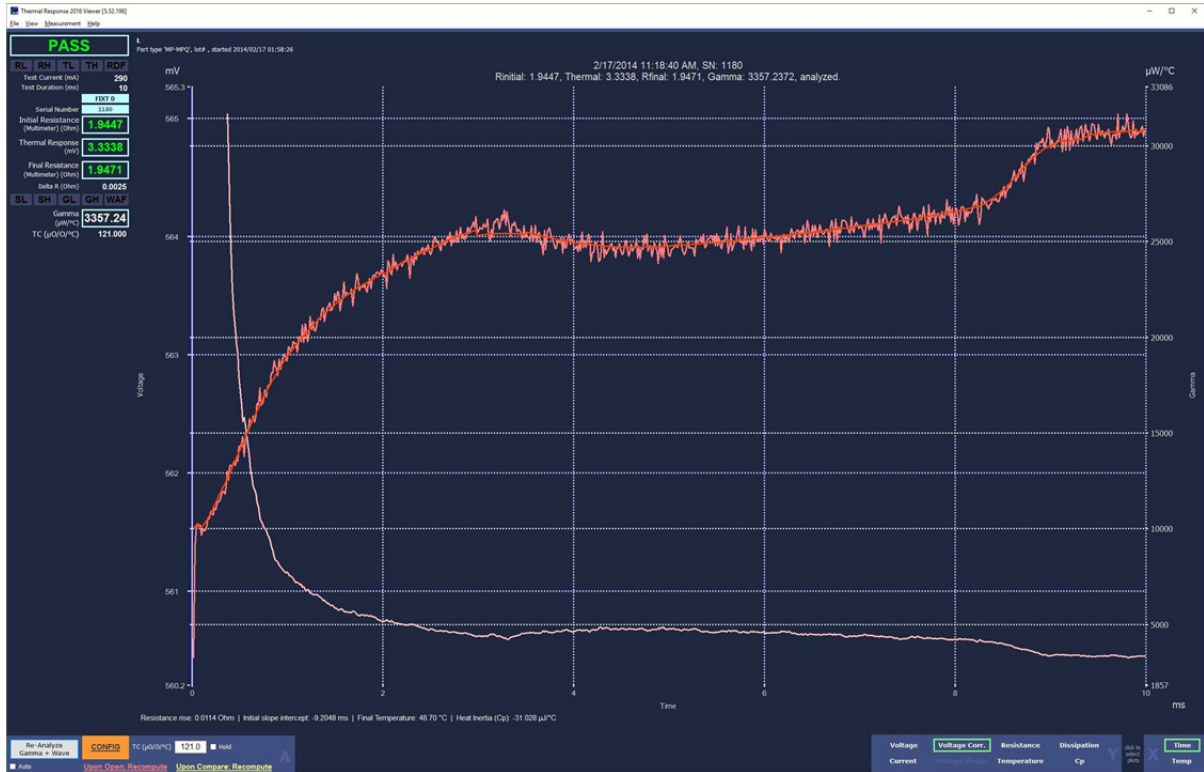


Figure 71: Bridgewire movement, slower and both up and down

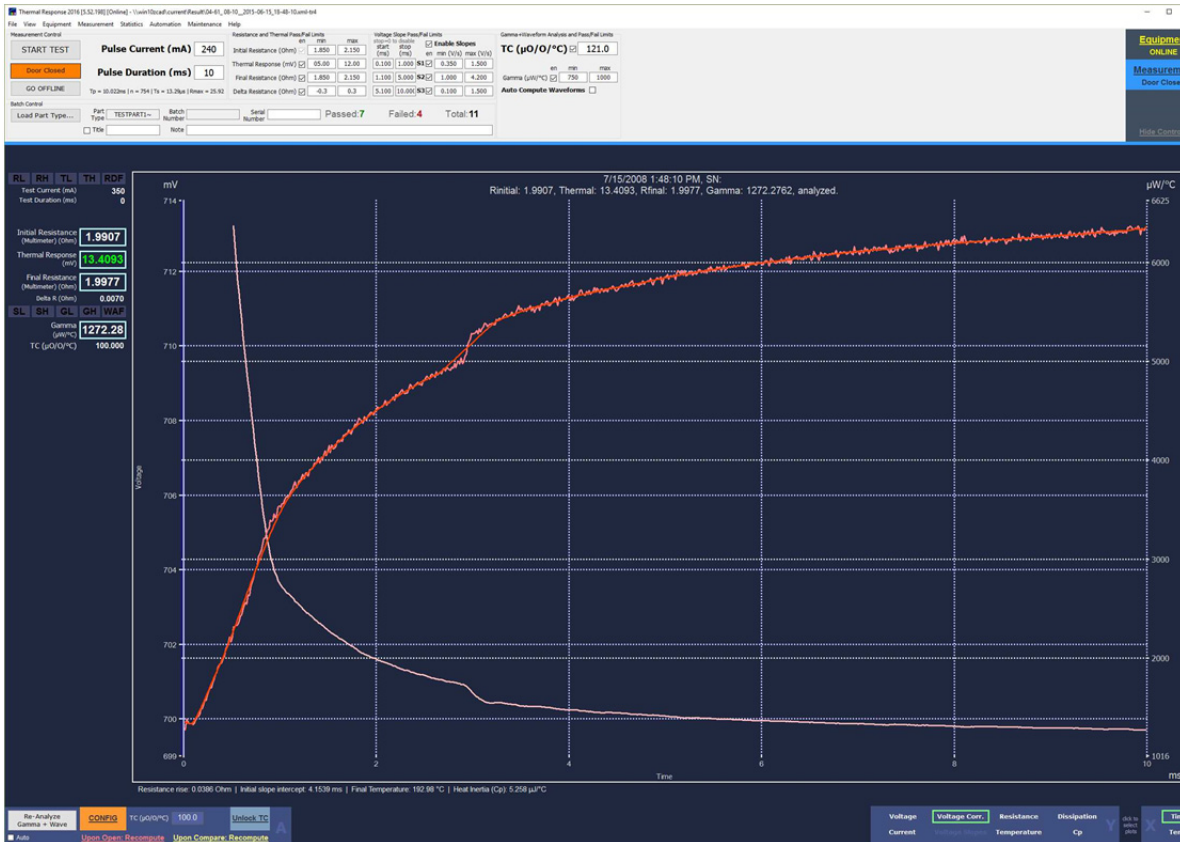


Figure 72: Bridgewire Movement, lift off