TIM Thermal Measurement Services

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TEA

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Introduction

- Need for making proper thermal measurements following a reasonably standardized approach has become paramount
- Thermal Interface Material (TIM) conductivity measurements are among the least understood
- Measurements can be either standards-based or application-based methods.
- Standards-based is primarily for determining TIM bulk conductivity.
- Application-based is focused on actual thermal management design implementation.
- This presentation will deal with both approaches - describing how the measurements are made, what data is important, and how to get the desired results.

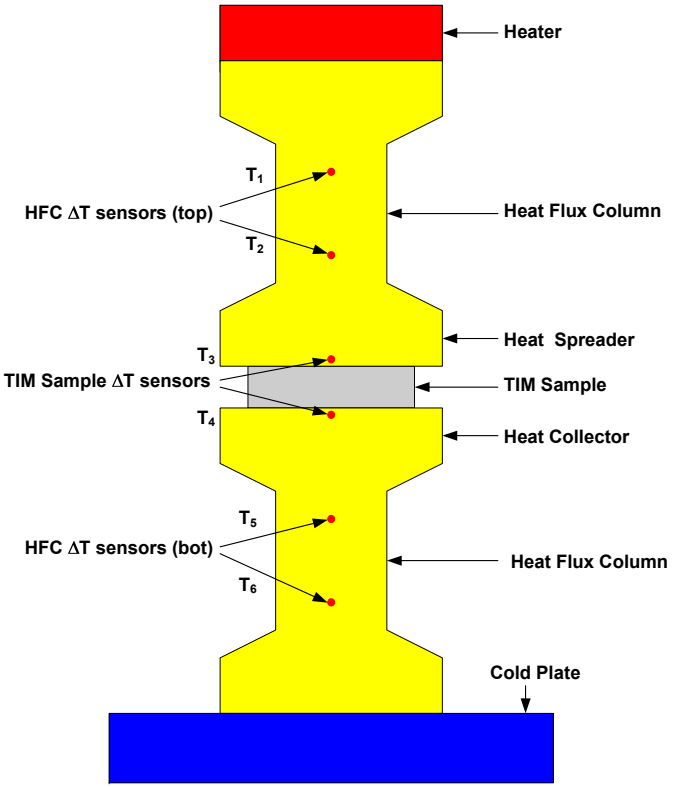
Measurement Types

- **Standards Based**
  - Documents issued by standards bodies detailing measurement setup and conditions for specific situations (ASTM D5470 is most often cited)
  - Produces a material-centric Bulk Thermal Conductivity
- **Application Based**
  - Specific to a single or general class of thermal management applications
  - Produces a thermo-mechanical-centric thermal resistance

Standards Based

Steady-State Method Implementation

- ASTM D5470 approach
- Measures heat flux above and below sample
- Uses embedded sensors for temperature differential across sample
- Addresses heat loss across stackup



Standards Based

"A Data Point in Space"

$$k = \left[\frac{1}{\frac{\Delta T}{Q}} \right] x \frac{L}{A}$$

Where:

L ➔ Thickness of the test sample

A ➔ Area of the heat flow through the test sample

ΔT ➔ Temperature differential across test sample

Q ➔ Heat fluk flow through the test sample area

L ➔ Thermal conductivity

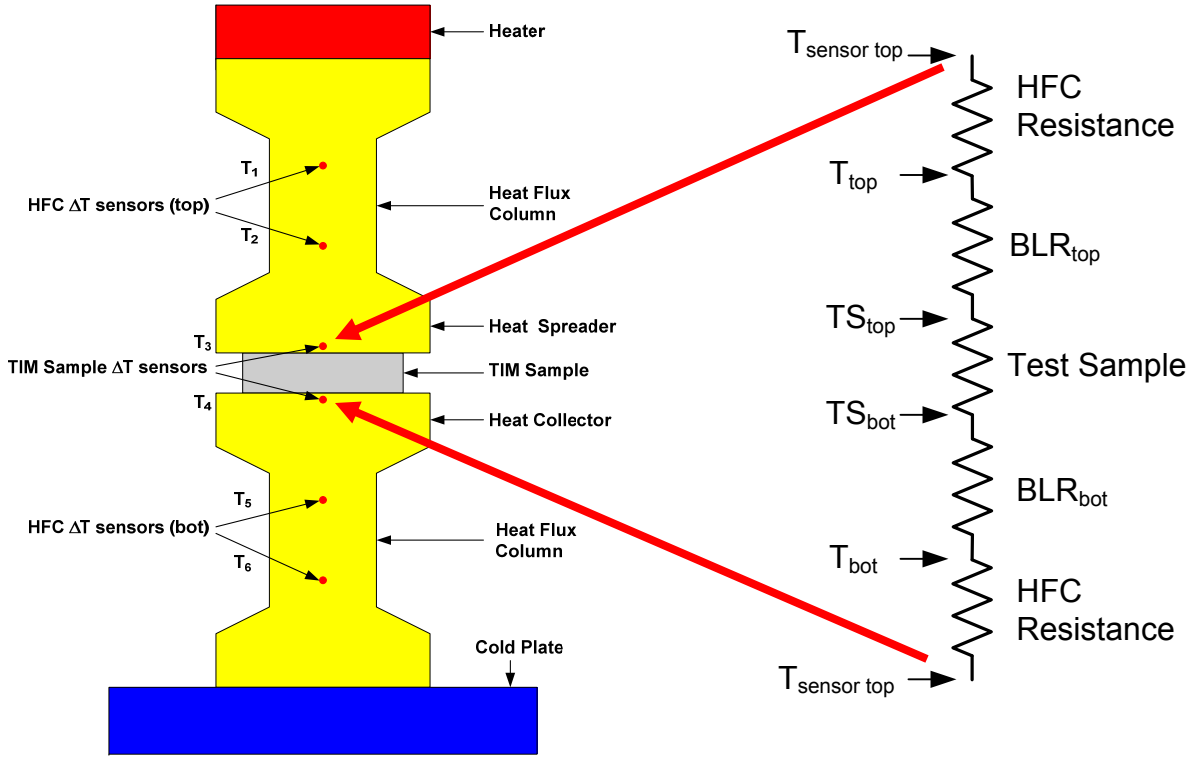
Natural tendency is to make a single measurement, apply the data to the equation at left, and calculate *k*.

This would generate a "data point in space" that is meaningless.

In this case, the k value would not necessarily be the true TIM bulk conductivity.

Standards Based

Measured Elements



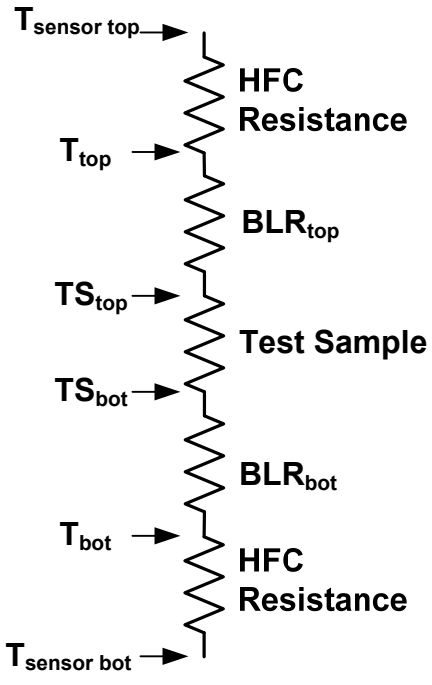
BLR ➔ Bound Line Resistance

TS ➔ Test Sample

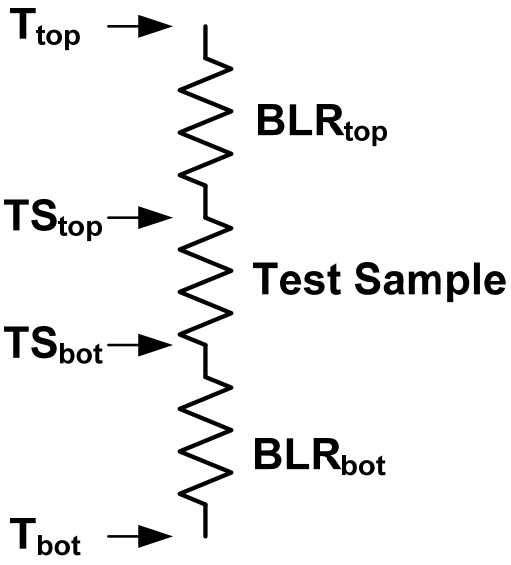
HFC Resistance ➔ HFC material between sensor and platen

Standards Based

Measured Elements Simplified

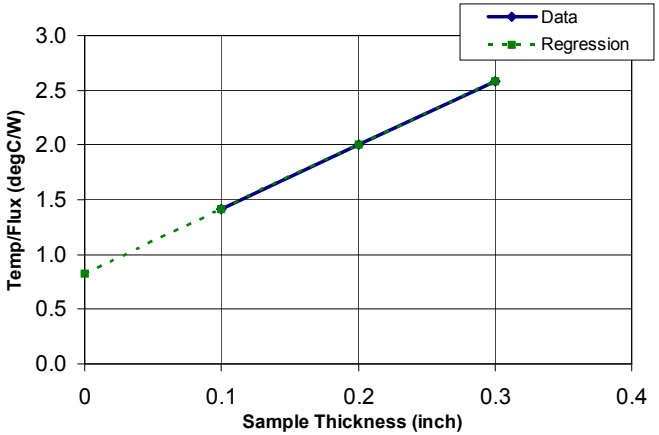


HFC Resistance is copper-based and can be ignored.



Standards Based

Extracting TIM Bulk Conductivity



$$k = \left[\frac{1}{\frac{\Delta T}{Q} - Y_0} \right] x \frac{L}{A}$$

L = sample thickness

A = sample X-Y area

ΔT = temperature across sample

Q = heat flux through sample

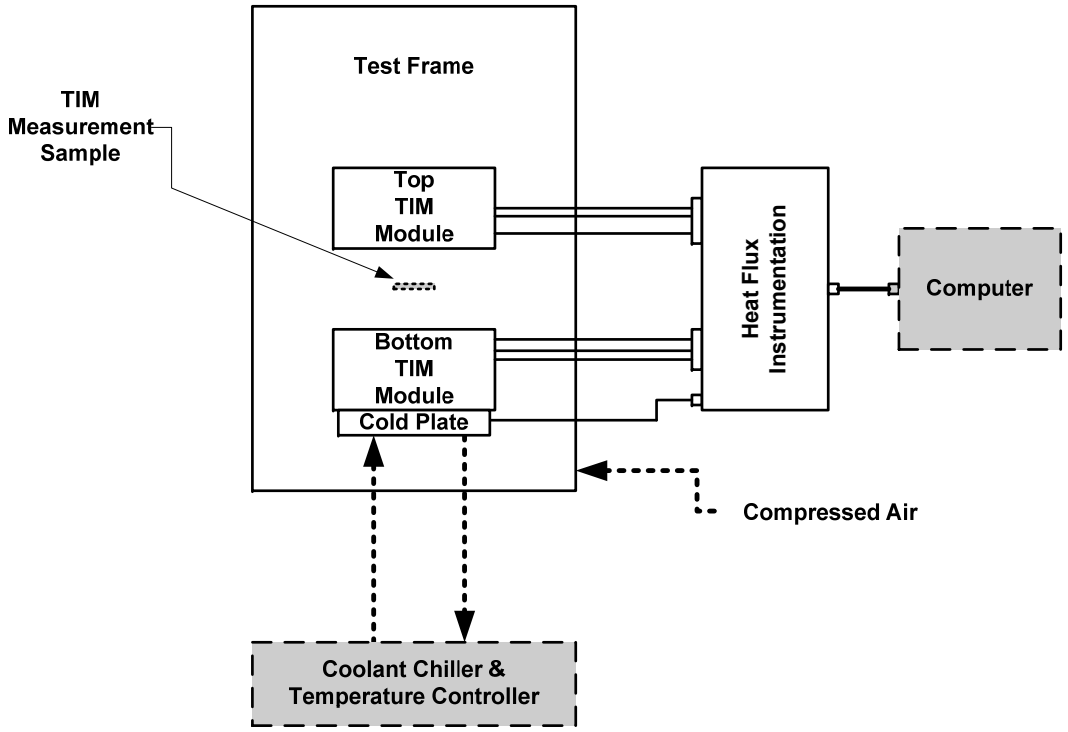
Yo = Y-axis intercept

k = thermal conductivity

- Measure at least 3 samples each at 3 different thicknesses
- Either each sample has the same area or the data has to be normalized against area
- Plot normalized ΔT/q against thickness
- Y-axis intercept (Y_0) is the total Bond Line Resistance (BLR)
- Then use the modified equation to compute k

Standards Based

Steady-State Measurement Setup



Standards Based

Steady-State Measurement Setup

Test Frame with integrated Cold Plate, sample thickness measurement, pneumatic force capability, and Heat Flux Columns

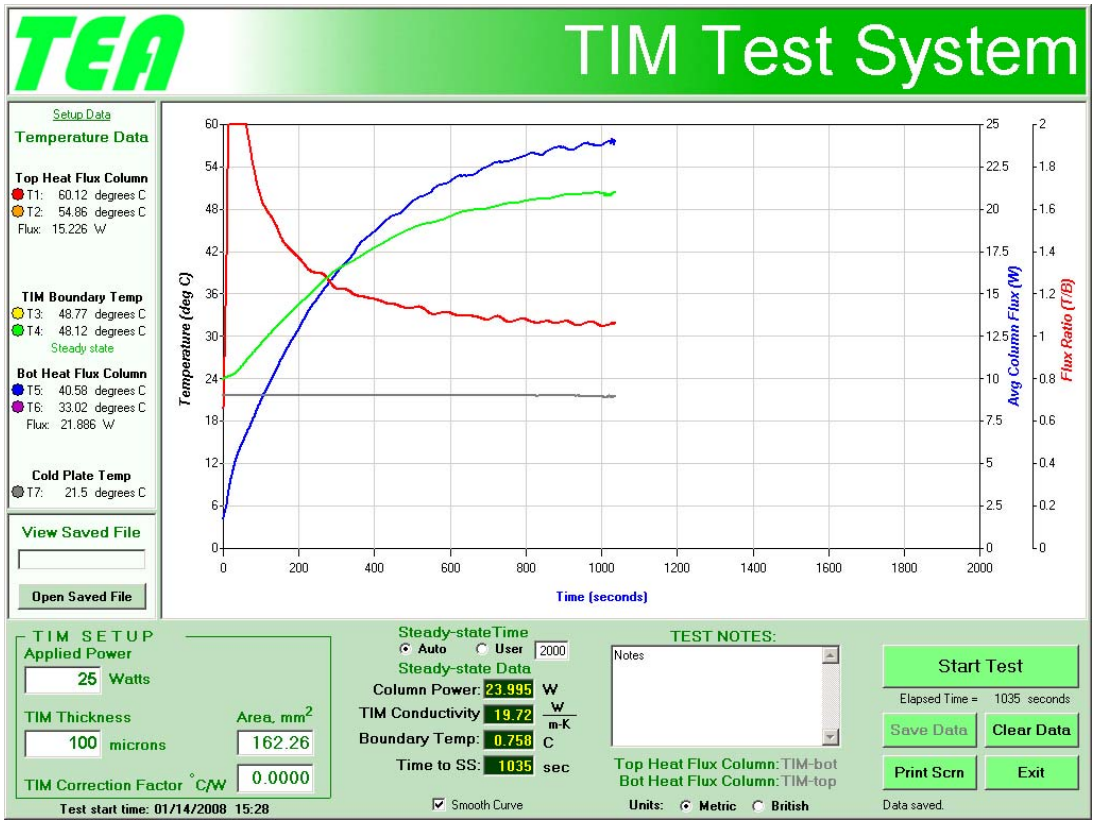
Instrumentation unit for controlling heat source, measuring temperatures and interfacing to customer computer

TIM Measurement System Datasheet can be downloaded from

http://www.thermengr.net/Lit/TIM_Measurement_System_130203.pdf

Standards Based

Steady-State Measurement Example



Legend

Grey = Cold Plate temperature

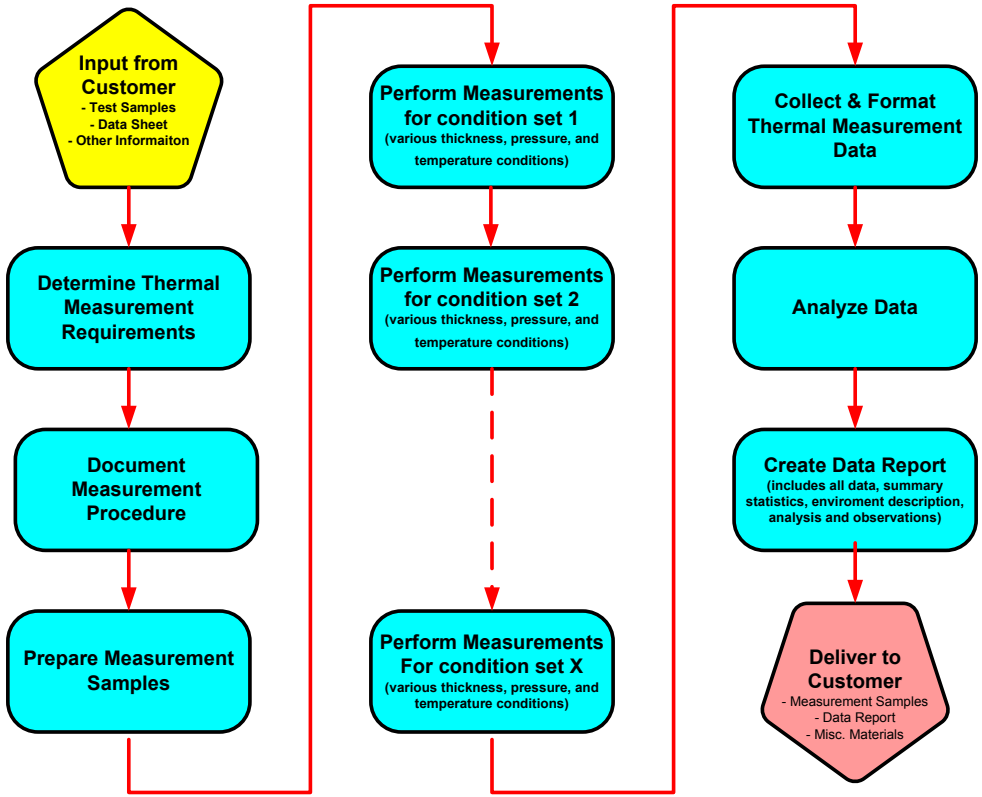
Blue = Avg column heat flux

Red = ratio of top and bottom column heat flux

Green = sample bottom temperature

Standards Based

Thermal Measurement Procedure



Each set of Measurement Conditions (i.e., thickness, pressure, temperature, etc.) requires a separate measurement run.

Standards Based

Customer-supplied Input

- Measurement requirements objectives, overview and details
- Measurement samples
- Measurement samples datasheet(s)

Standards Based

Thermal Measurement Cost Info

The information presented below is for budgetary purposes only. A formal quotation will be submitted in response to a request accompanied with specific measurement requirements including appropriate material datasheet(s) and measurement condition requirement(s).

- **Bulk Thermal Conductivity Measurements for a single set of material, thickness or pressure, and temperature conditions requires a minimum of 3 measurements for each of 3 thickness, all at the same reference temperature;**
  - **Price is $2,950**
- **Additional material, thickness or pressure, or reference temperature conditions;**
  - **Price is quoted in response to specific requirements.**

All Data Reports are delivered electronically unless otherwise requested and quoted.

Standards Based

Thermal Measurement Schedule

The schedule information provided below is based on typical times for standards-oriented measurements assuming a single material and measurement conditions.

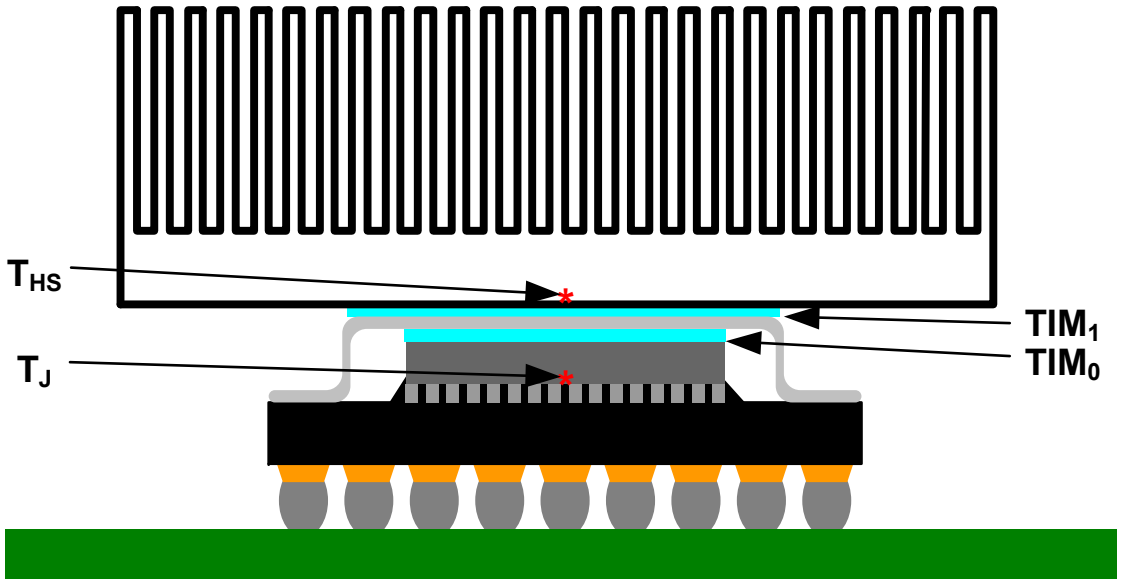
Total elapsed time is roughly 2 to 4 weeks from receipt of order, material information, and measurement samples. Shorter time is possible for additional cost.

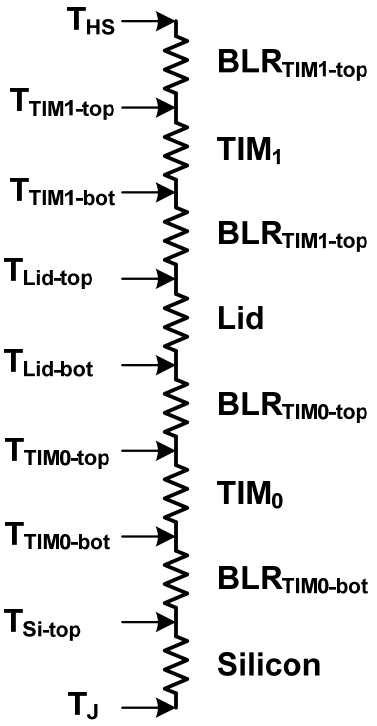
Applications-oriented Measurements

- Bulk *k* values are needed for comparison and material development purposes
- Difficult to correlate k values to the end application because of the BLR variability from application-to-application due to:
  - TIM lot variations
  - Component variations
  - Assembly issues
- Many end-users are now going to in-situ application oriented measurements

Application Based

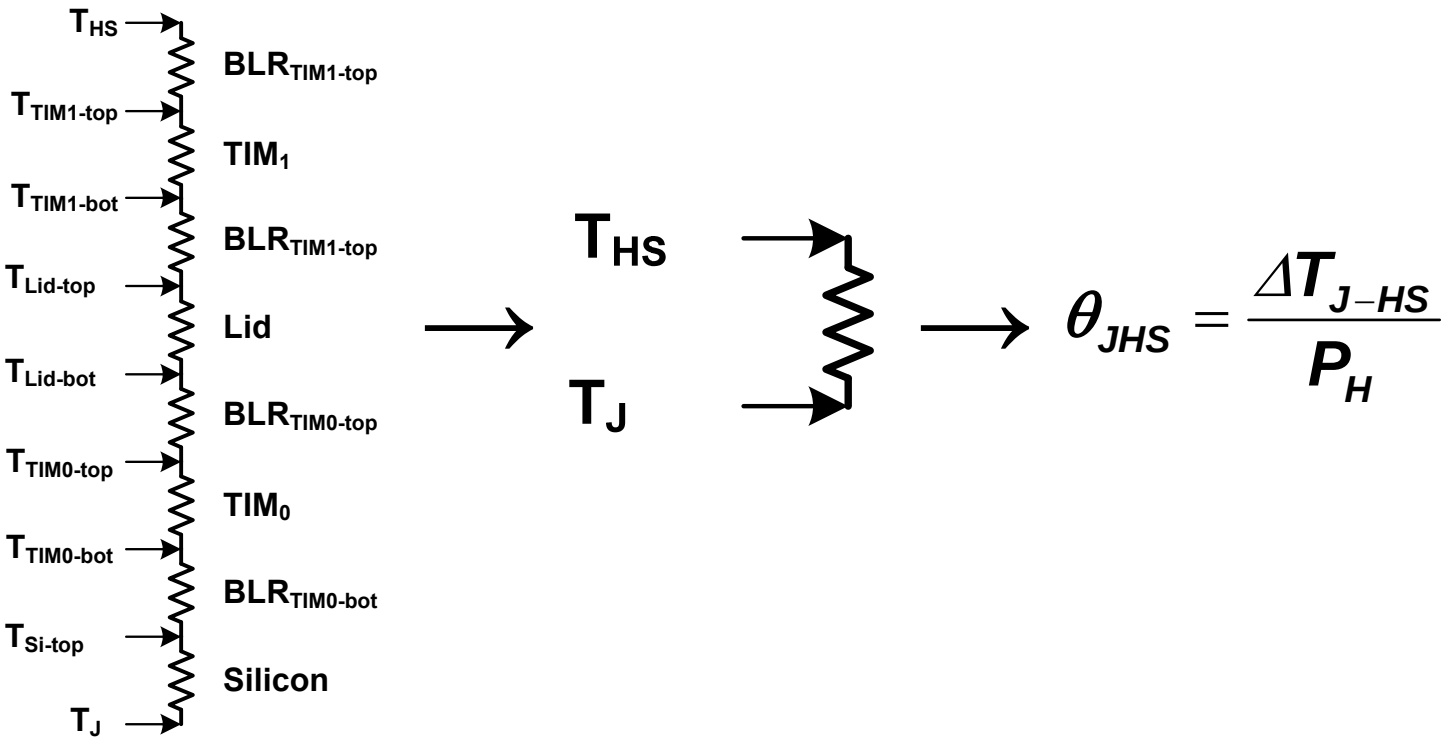
Applications-oriented Measurements





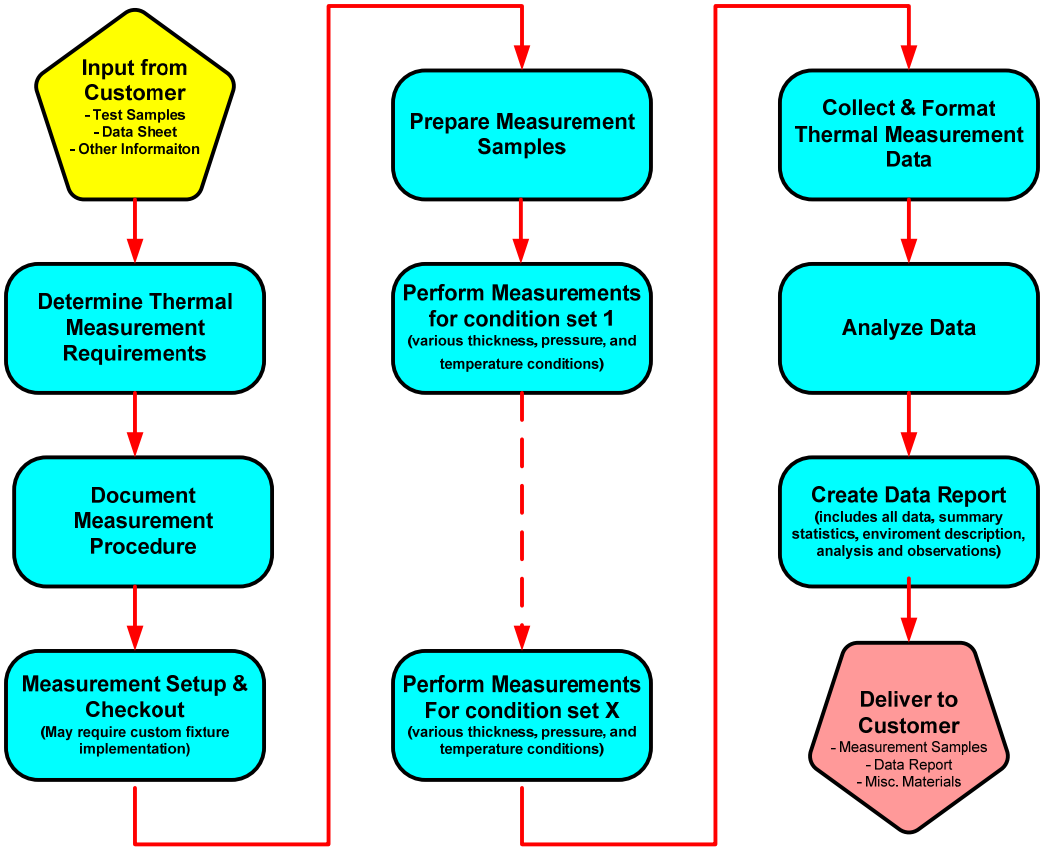
Application Based

Applications-oriented Measurements



Application Based

Thermal Measurement Procedure



Application-based measurements may require custom fixture design and implementation.

Each set of Measurement Conditions (i.e., thickness, pressure, temperature, etc.) requires a separate measurement run. Fixture(s) may also need to be modified depending on the measurement conditions.

Customer-supplied Input

- Measurement requirements objectives, overview and details
- Measurement setup requirements
  - Mechanical
  - Electrical
  - Thermal
- Measurement samples and, if appropriate, application apparatus

Application Based

Thermal Measurement Cost Info

The information presented below is for budgetary purposes only. A formal quotation will be submitted in response to a request accompanied with specific measurement requirements including appropriate device datasheets, package mechanical drawings, test fixture apparatus design.

- **Fixture Design, Layout and Fabrication**
  - Typical price range is $500 to $7,500, depending the application oriented setup – size, power level, cooling, pressure/force, electrical requirements,
- **Thermal Measurements**
  - Pricing starts at $2,475 and increases depending on apparatus setup, number of different power levels, pressure/force variations, and the number of temperature conditions required.
  - Includes Data Report in electronic form

Application Based

Thermal Measurement Schedule

The schedule information provided below is based on typical times for application-oriented measurements dependent on required environmental conditions and test matrix; this is quoted on an individual basis.

- Test fixture design and layout implementation can take up to 10 work days
- The customer is then asked to review and approve the layout; assumption is a 2-day review cycle.
- Test fixture implementation usually takes up to 10 work days
- Test apparatus setup and checkout takes up to 5 workdays
- Thermal measurements take 5 to 15 work days, depending on the measurement matrix (i.e., power levels, pressure/force, environmental, etc.) conditions required

Total elapsed time is roughly 5 to 8 weeks from receipt of order, electrical and mechanical information, and test samples. Shorter time is possible for additional cost.

Summary

- TEA offers both
  - Standards Based (ASTM DM5470 based measurement)
  - Application Based

  TIM Thermal Measurement Services.
- TEA personnel collectively have over 60 man-years of thermal measurement experience.
- TEA has been making all kinds of thermal measurements for over 50 different customer companies on a world-wide basis.
- TEA has supplied thermal measurement equipment to over 75 customers on a world-wide basis.