Extreme Temperature Automotive Testing

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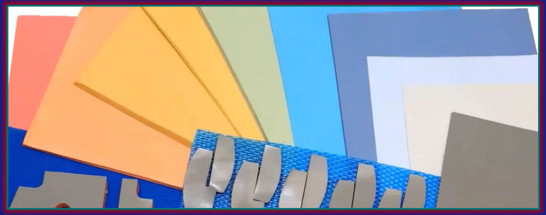
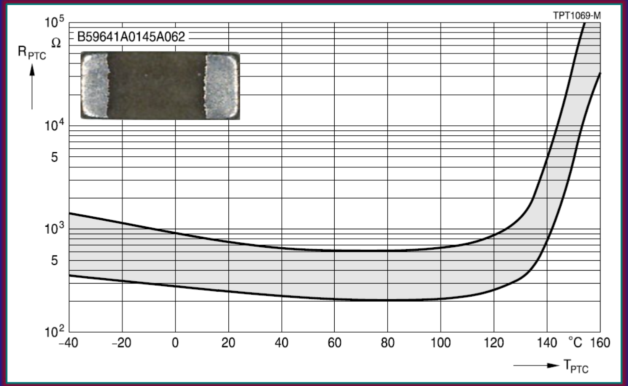
TestConX™
Mesa, Arizona • March 2-5, 2025

The Problem

- Automotive Manufacturers Often Require Extreme Temperature Testing of Very Small Devices





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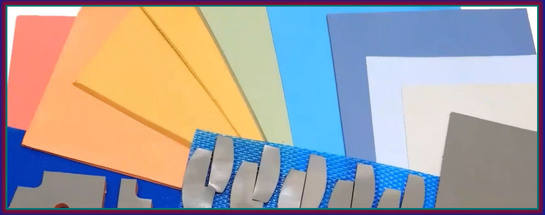
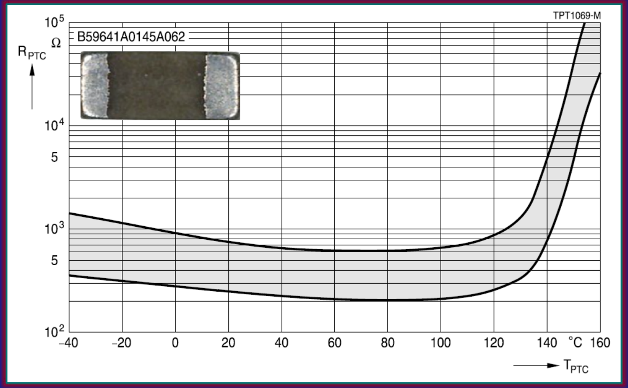
  - Industry Wide, handlers have difficulty with 150°C
  - At hot, Integrated Circuit (IC) Junction Temps can be 30°C off





The Problem

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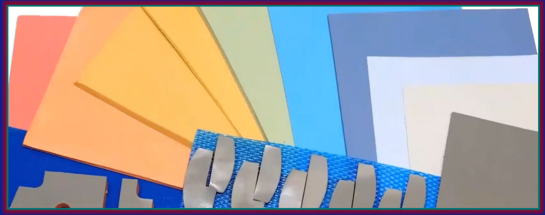
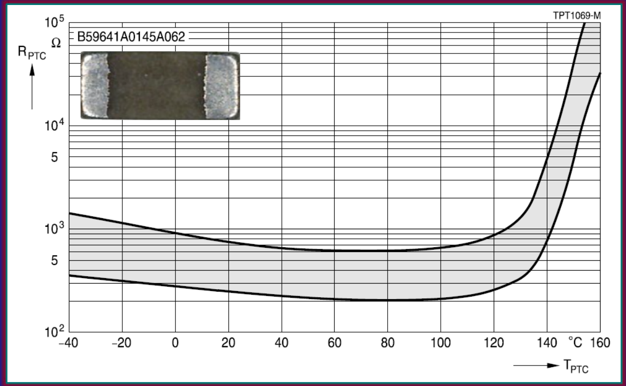
  - Industry Wide, handlers have difficulty with 150°C
  - At hot, Integrated Circuit (IC) Junction Temps can be 30°C off
  - Cold at -40°C is also tricky





Extreme Temperature Automotive Testing

Passive

- Passive Thermal Regulation
- Thermal Zoning
- Materials and Components
- Knowing the Junction Temp
- Active Thermal Regulation
- Other Considerations

Passive Thermal Regulation

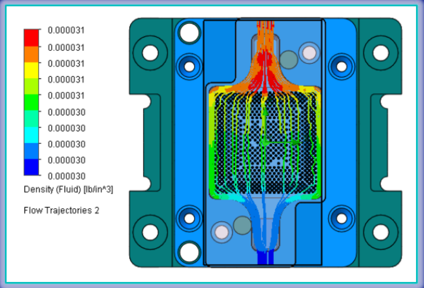
Passive

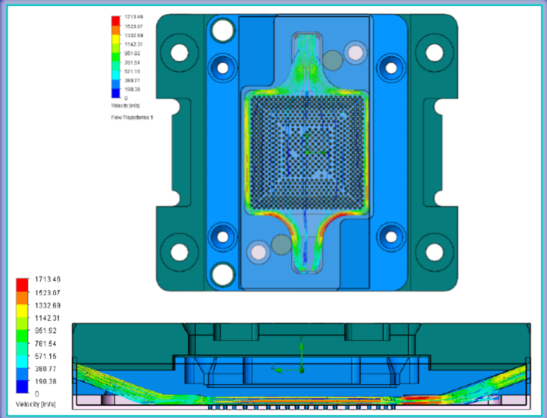
- Socket and PCB design based upon the abilities of the handler
- Purge Covers and Heat Shields
- Wafer Sort (WS) probing
- Using Daughter boards to minimize heat sink from Device Under Test (DUT) area to ambient temperature
- Controlling heat exchanges between thermal zones

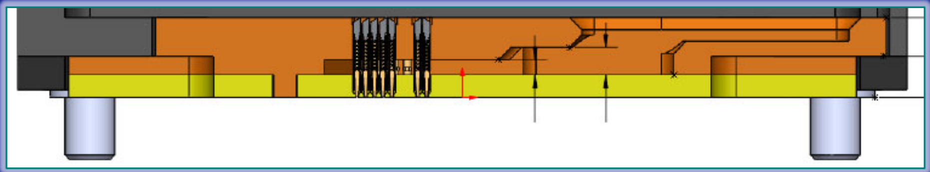
Passive

Socket and Printed Circuit Board (PCB) design

- Socket and PCB design based upon the abilities of the handler
- Cohu provided Computational Fluid Dynamics (CFD) Analysis



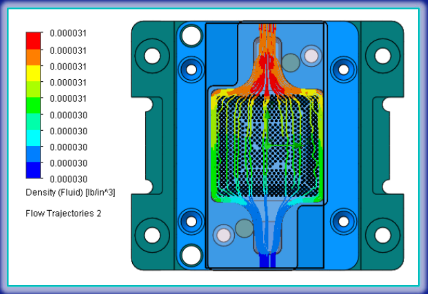


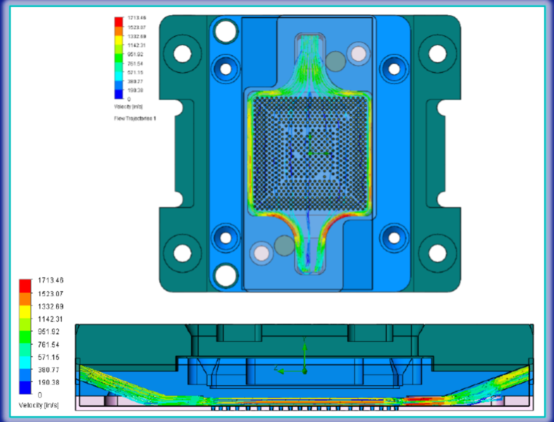


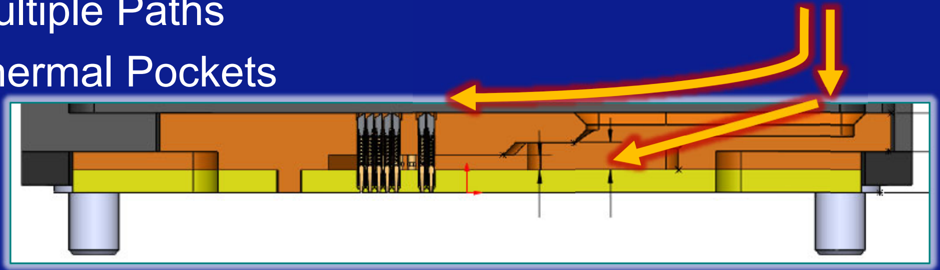
Passive

Socket and Printed Circuit Board (PCB) design

- Socket and PCB design based upon the abilities of the handler
- Cohu provided Computational Fluid Dynamics (CFD) Analysis
  - Cohu simulated best socket design to achieve DUT junction temp
- Rasco Handler Provides Airflow through socket
  - Warms / Cools pogos directly without DUT disrupting airflow
- CFD Analysis Looks for:
  - Flow Velocity
  - Density
  - Multiple Paths
  - Thermal Pockets







Passive

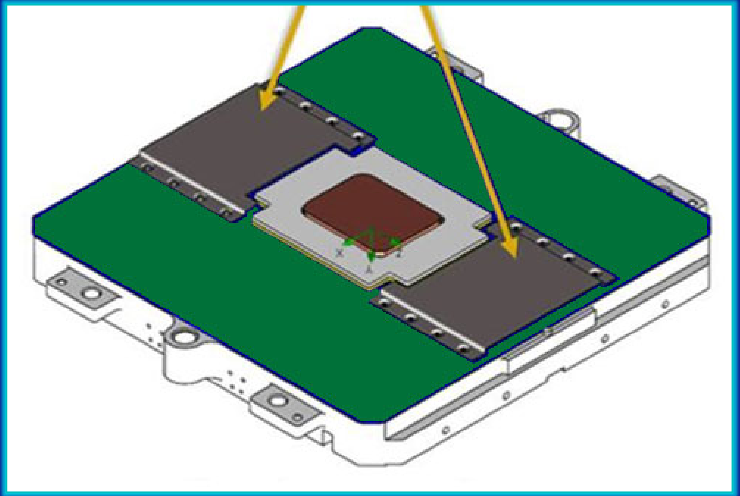
Purge Covers and Heat Shields

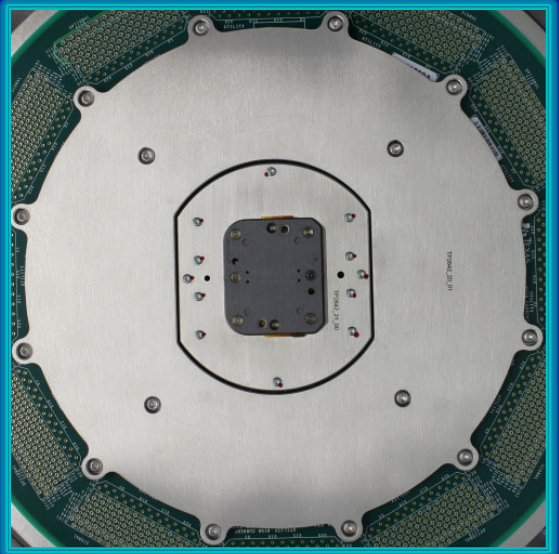
- Heat Shields Protect DUT/Sensitive Components from Heat
- Reliability (REL) / Characterization (CHAR) handtest Heat Shield
  - Protect Room Temp HW, Non-Nelco 4800-20 FR4
  - Using 5oz copper
- Purge Covers keep the DUT / Sensitive Components from Icing

WS Probing Heat Shield

Passive

- Covers part or entire WS board with a Metal Cover
- Protects DUT board from the Chuck's Radiant Heat
- Top-Side Components benefit most





Passive

Daughter Boards

- Using Daughter boards to minimize heat sink from DUT area to ambient temperature
- Want Daughter Board size of Handler Chamber
- Breaks the Ground (GND) planes from topside, Direct Ambient contact
- Minimizes Heat Sink effect

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Passive

Minimizing/Controlling Heat Exchanges

- Control heat exchanges between thermal zones
- Refrigerators and Ovens are Very Well Insulated
- Convection → Purge
- Radiation → Heat Shields
- Conduction → Insulation
- Improperly Design DUT Board
  - Heating an IC is like cooking an egg with a laser

Extreme Temperature Automotive Testing

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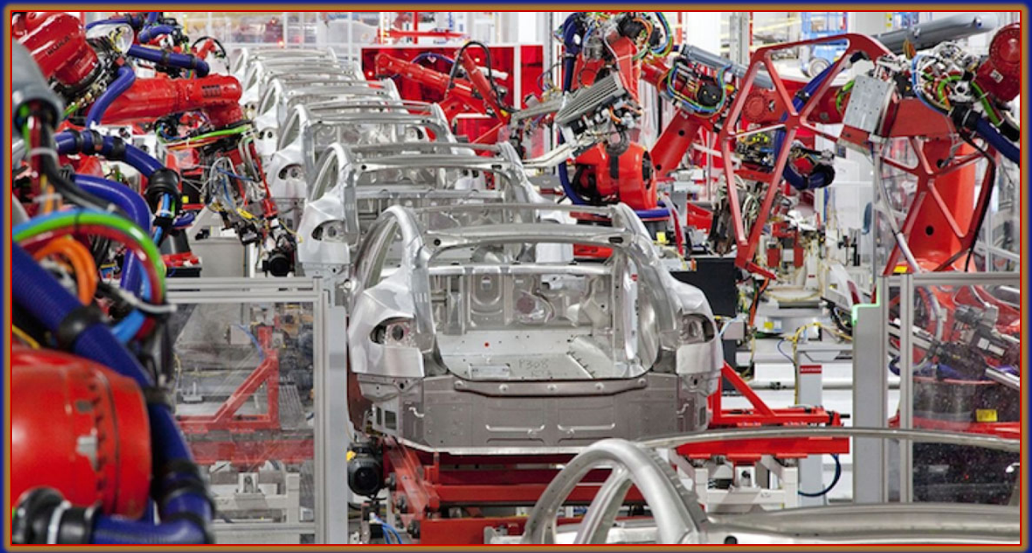
- Thermal Zoning
- Materials and Components
- Knowing the Junction Temp
- Active Thermal Regulation
- Other Considerations



Thermal Zoning

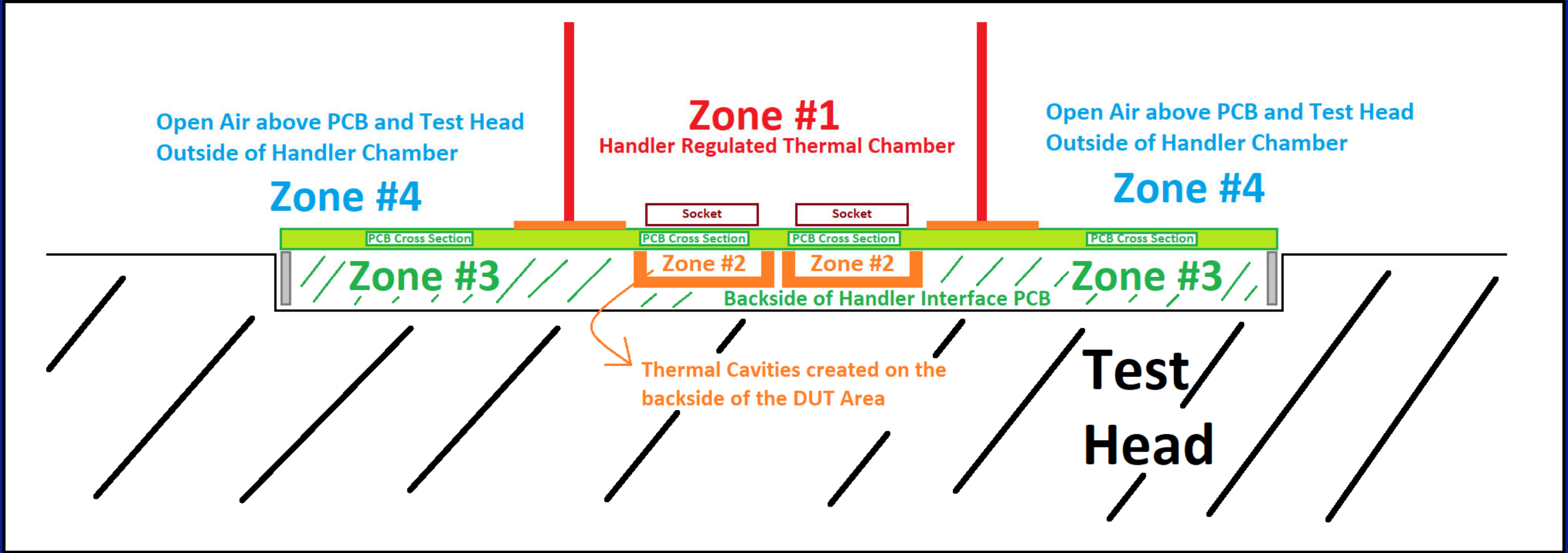
Zones

- Thermal Zoning (Zones 1 – 4)
- Zone 1 Handler Chamber
- Zone 2 Backside DUT area
- Zone 3 Between DUT Board and Tester
- Zone 4 Top of the Board

Thermal Zoning (Zones 1 – 4)

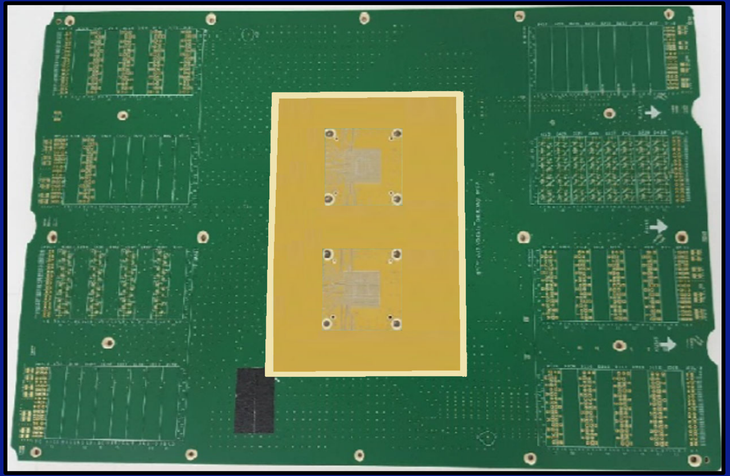
Zones

- Zone 1: DUT area top rated to **170˚C**
- Zone 2: DUT area bottom **125˚C**
- Zone 3: Outside DUT area bottom **85˚C**
- Zone 4: Outside DUT area top **65˚C**

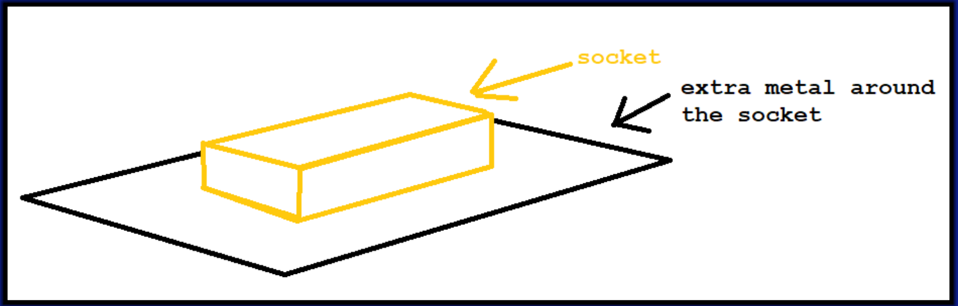


Zones

Zone 1



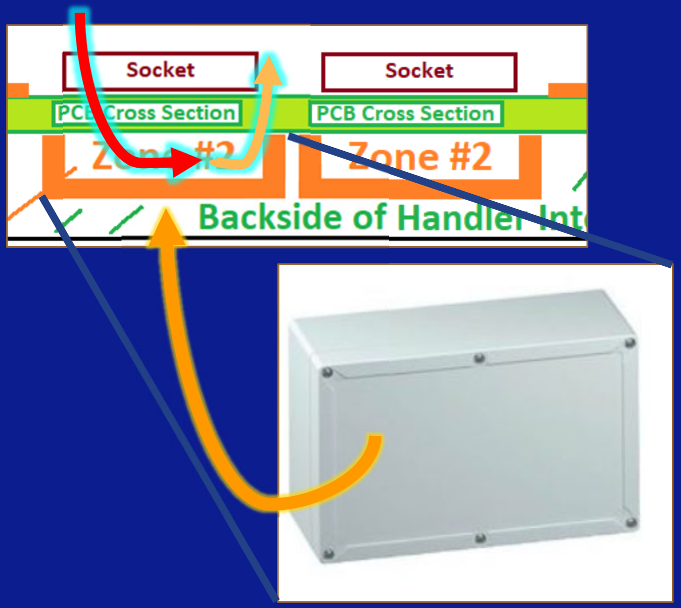
- Thermal ballast
  - Similar to Bench Design
  - Heated Metal Acts as Thermal Ballast
  - Bench Heats a Big Slab of Metal for Oven Ballast
  - Floating, Not Grounded
  - Top layer, no solder mask, gold plated
  - Extra Plate of Metal on the socket flush with the DIB.
- Topside Caps & Resistance Temperature Detectors (RTD's)
  - Inside the socket cavity
- Components should be rated for 170˚C



Zone 2

Zones

- Backside DUT area covers
  - Prevents **cool down** at hot from backside purge
- Active/Passive air flow Zone 2
  - Prevents Zone 2 (and 1) Cool Down
  - Airflow from Zone 1
- Components should be rated for 125˚C
  - 110˚C may be ok if no active air flow from zone 1
  - Needs a Temp sensor to verify zone temperature
  - May get hotter than 125˚C with good air flow
  - Avoid 85˚C relays



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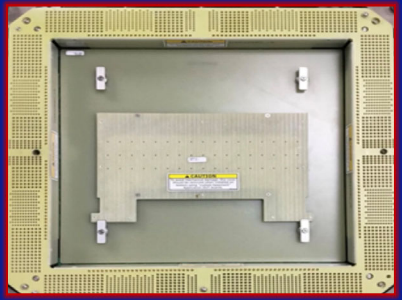
Zones

Zone 3

- Eagle Clean Dry Air (CDA) purging “The Shower Head”
- Between the Test Head & Underbelly of DUT Board
- Purging cools down hot testing
- And helps keep cold testing dry & Warmer
- Components should be rated for **85 ˚C**



Purge option for the tester configured with HCMUX

	ASM4267	ASM4268	ASM4434	ASM4714	ASM4724
ETS364 new testers		Yes			Yes
ETS364 Old testers (pre-September 2010)	Yes	Yes			Yes
ETS364B new testers		Yes			Yes
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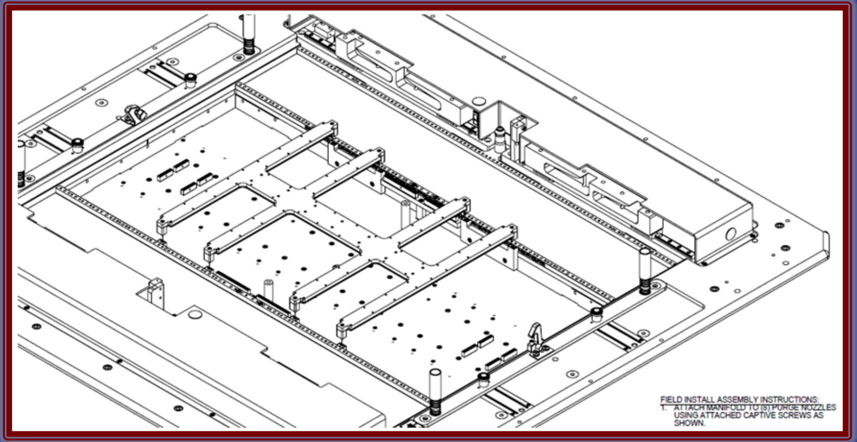

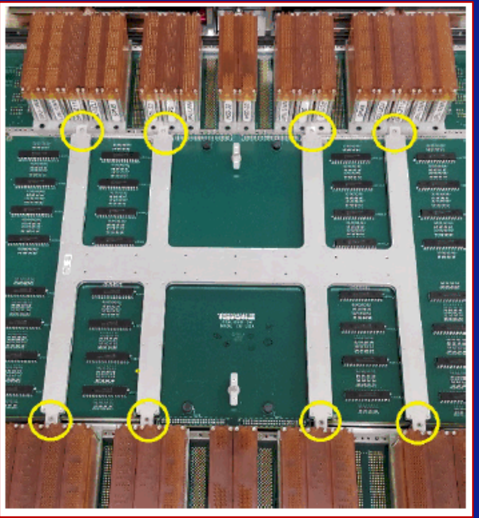

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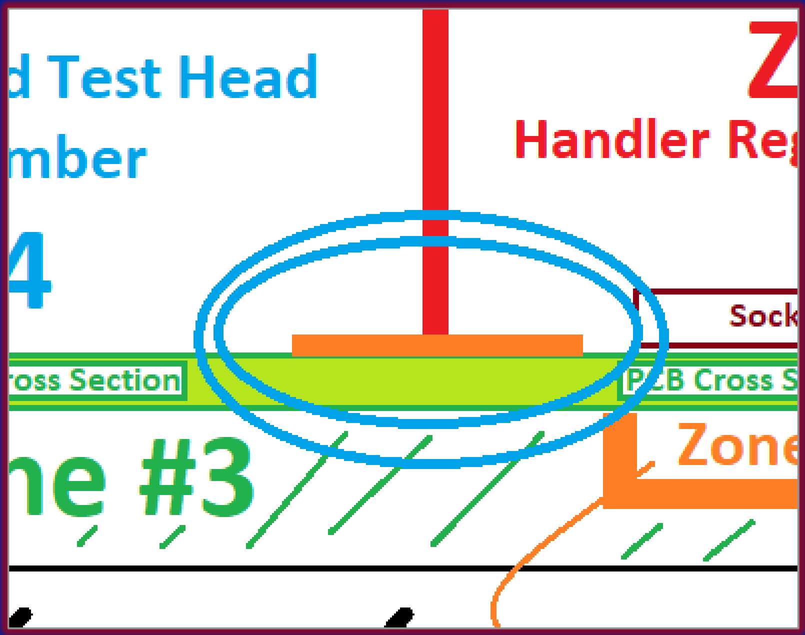
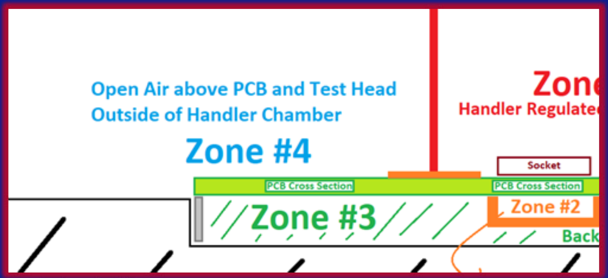
Zone 4

- Sharpest Thermal Gradient
- Purge Shield
  - Recommended Rasco Option
  - Prevents Icing at Cold on Topside of DUT Board
- Typically **Zone 4** is 'unregulated'
  - Open to Test Floor Ambient
  - May be restrictions on Placement
  - Comps Rate for ~**65˚C**





Mat Comp

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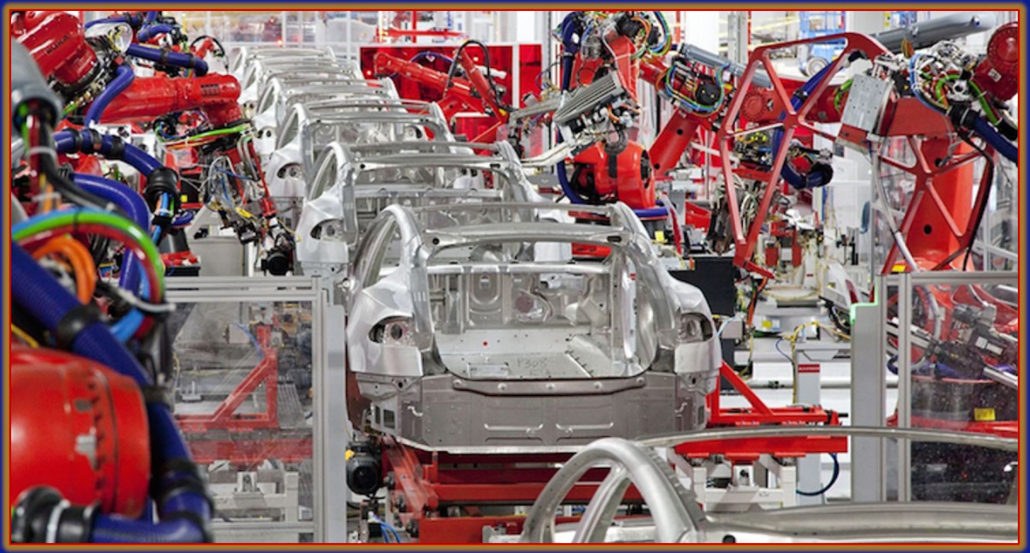


Mat Comp

Materials and Components

- Nelco 4800-20
- Socket Design
- Thermal Interface Materials (TIM's)
- Relays
- Caps
- Resistors

Mat Comp

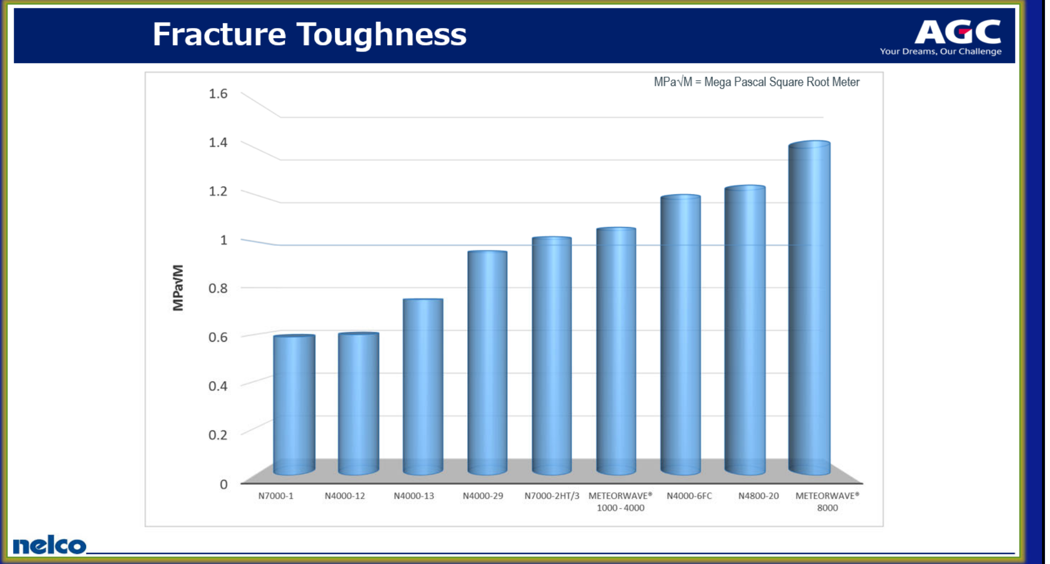
Nelco 4800-20

- Max Operating Temp (MOT) 150˚C
  - Recently Approved @ UL
- High Tg - 200˚C
- Z-axis Coefficient of Thermal Expansion (CTE) = 27 Part Per Million (PPM) / ˚C
- Behaves like regular FR4
- Superior Fracture Toughness

N4800-20 & N4800-20 SI

High-Speed Multifunctional Epoxy Laminate & Prepreg

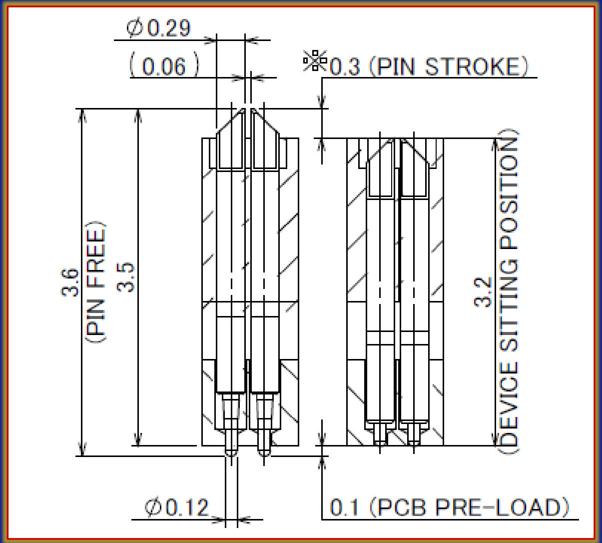
Mechanical Properties	N4800-20	N4800-20 SI®	U.S. Units	N4800-20	N4800-20



Socket Design – Pogo Pins

Mat Comp

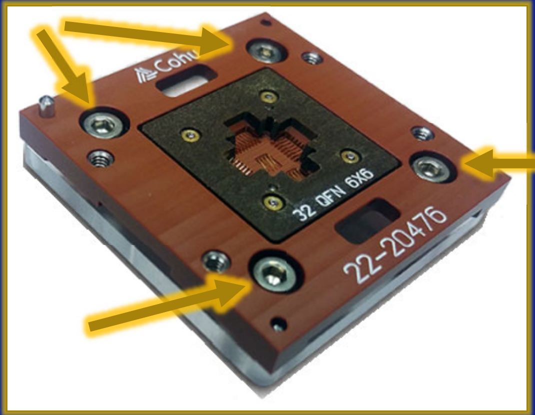
- Increased Stroke
  - Between DUT and Socket Top Plate
  - Compensate for Temp Warpage & Misalignment
- Insert scrub to avoid DUT flank



Mat Comp

Socket Design Continued

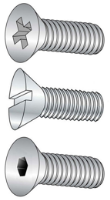
- Thermal Insulators not Thermal Conductors
  - Topside Polyimide (PI) Material
  - Avoid thermal shorts between zones 1 & 2
    - Helps prevent cooling Zone 1 DUT area
  - PEEK Mounting Screws
    - Polyetheretherketone semicrystalline thermoplastic
    - Strong, good price



PEEK Flat Head Screws

The optimal balance of chemical, mechanical and thermal properties

- Excellent strength, and stiffness up to 500°F (260°C)
- Low coefficient of friction and high wear resistance
- Chemically resistant to common chemicals
- Low out gassing, low particle generation and inherent purity
- Unique physical, thermal & electrical properties
- PEEK flat head screw features and benefits



PEEK flat head screws (chemically known as Polyetheretherketone) offer a unique combination of properties for some of the most extreme applications. PEEK is classified as semicrystalline thermoplastic and high purity polymer, offering excellent mechanical strength and chemical resistance at high temperatures. PEEK flat head screws offer a high strength alternative to PTFE fluoropolymers.

M6-1.00 Dia./Thread,

Thermal Interface Materials

Mat Comp

- Parker Therm-a-Gap TIMs materials
  - Excellent for transferring heat
  - From Positive Temperature Coefficient (PTC) thermistor to socket cavity
  - Helps condition the temperature of the DUT area
  - Conducts heat well
  - Non-Electrically-Conductive Material
  - Silicone Oil inside is also non-electrically-conductive

THERM-A-GAP™ Gap Filler Pads

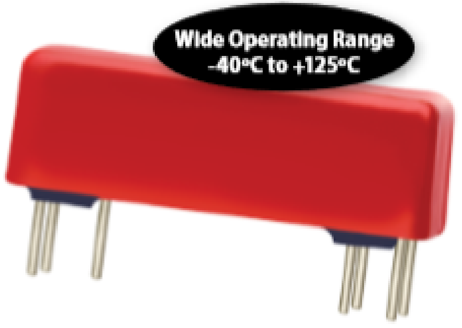
Typical Properties	HCS10	569	570	579	580	Test Method
Color	Orange / Gray Carrier	Gray	Blue	Pink	Yellow	Visual
Carrier Options Supported (standard): G = Woven glass carrier - no PSA A = Aluminum foil carrier - with acrylic PSA Supported (custom): PN = PEN film carrier KT = Thermally enhanced polyimide carrier	HCS10A or HCS10G	A569, G569 or 569PN	A570 or G570	A579, G579, 579PN, 579KT, or 579	A580, G580, or 580	–

Mat Comp

Relays, Caps and Resistors

- New Relays, Caps & Resistors
  - Good, Reliable, High Temp, High Perf
  - Ok Cost
  - Be aware of Best Practices

2970 SERIES REED RELAYS

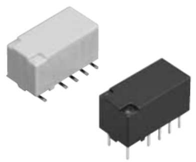


2970 Serie
Ideally suited
2970 series o
testing envir
tive or Coto's

2970 Serie
- Coaxial shi
- High Insul
- Hermetical
- Epoxy coat
- Wide opera
- RoHS com

Panasonic
ideas for life

Small size, controlled 7.5A inrush current possible



3. **Outstanding surge resistance.**
   Surge breakdown voltage between open contacts:
   1,500 V 10×160µ sec. (FCC part 68)
   Surge breakdown voltage between contact and coil:
   2,500 V 2×10µ sec. (Bellcore)
4. **Nominal operating power: High sensitivity of 140mW**

NIPPON CHEMI-CON

CONDUCTIVE POLYMER HYBRID ALUMINUM ELECTROLYTIC CAPACITORS Surface Mount

HXE Upgrade! Series

- High reliability is realized by hybrid electrolyte
- Endurance with ripple current : 2,000 to 4,000 hours at 135℃
- Rated voltage range : 16 to 63Vdc, Capacitance range : 22 to 470µF
- For high temperature and high reliability applications. (Automotive equipment, Base station equipment, etc.)
- RoHS2 Compliant
- Halogen Free
- AEC-Q200 compliant : Please contact Chemi-Con for more details, test data, information.

HXE
↑ Higher temperature
HXC

◆SPECIFICATIONS

Items	Characteristics
Category Temperature Range	-55 to +135℃

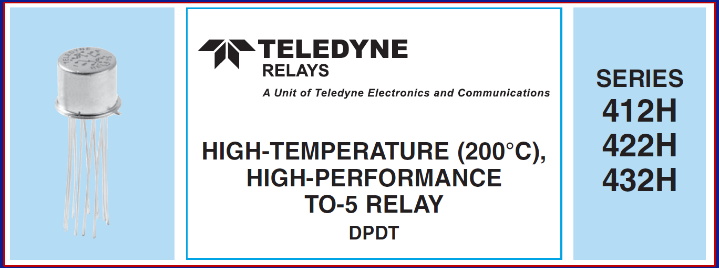
TestConX™

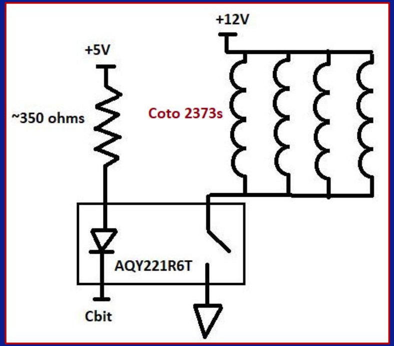
Extreme Temperature Automotive Testing

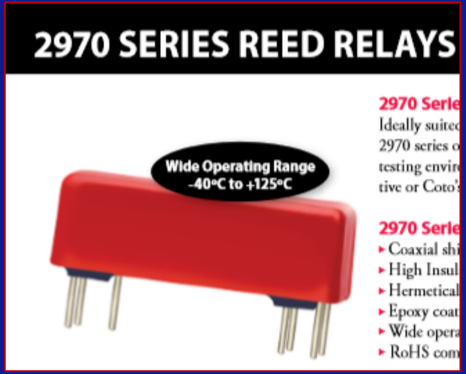
Mat Comp

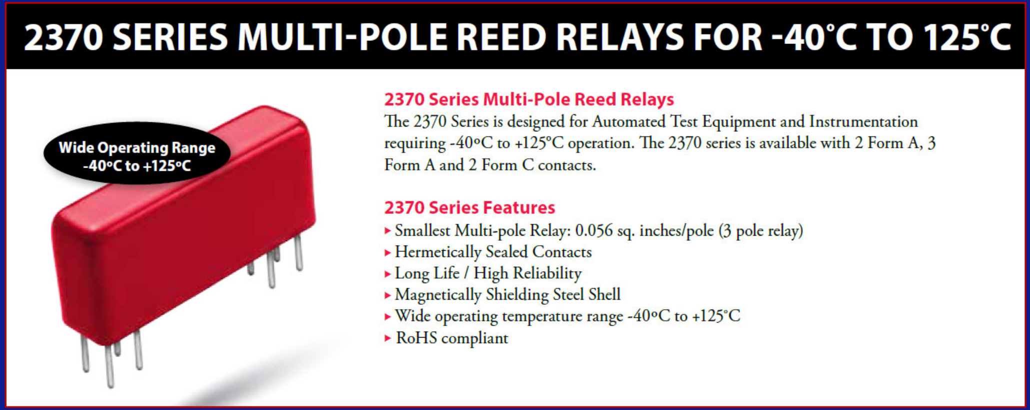
Relays – Mechanical High Temp

- Improved Max Operating Temp
  - Coto2370 & 2970 series 125˚C
  - Teledyne 400H series 200 ˚C
- Other Considerations
  - Using Coil Pulldown Relays
  - Over-Driving mechs for better Temp Performance
  - ie. 4.5V relay with 5V rail





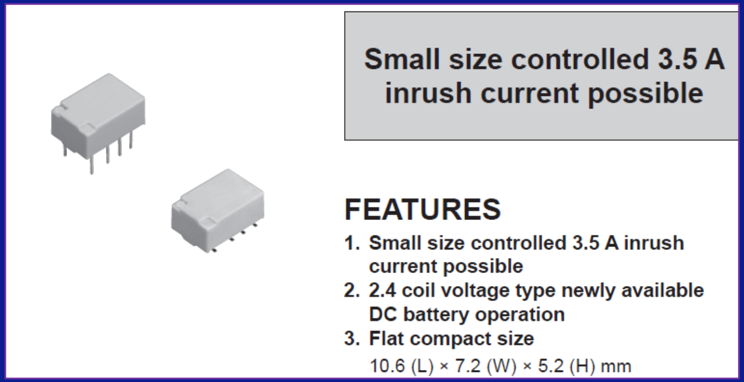




Mat Comp

Relays – Mechanicals: Small, High Current

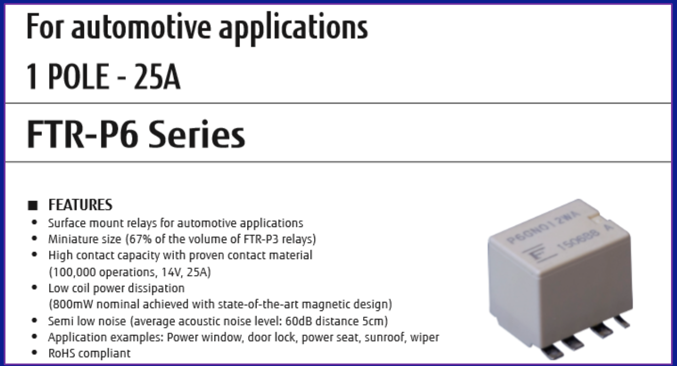
- New Small Size, Higher Current TX2, AGN mechs
  - TX2 – 7.5A Inrush per side 2 Form C
  - AGQ20TA4H – 3.5A Inrush per side 2 Form C (4.5V at +5V)
  - Pickering Series 120 – 4x4mm, 125˚C possible
- Fujitsu small, high current Auto relays
  - FTR-G1, FTR-P3
  - FTR-P6 (1 Form C, 25A, surface mount)
- Other Considerations
  - Contact Metal Type
  - Cleaning Cycles
  - MSL level
  - Surface Mount
  - Sockets hard to find
- Also Consider
  - Panasonic ALQ1F & ALZN1F 105˚C mech relays



Small size controlled 3.5 A inrush current possible

FEATURES

1. Small size controlled 3.5 A inrush current possible
2. 2.4 coil voltage type newly available DC battery operation
3. Flat compact size
   10.6 (L) × 7.2 (W) × 5.2 (H) mm



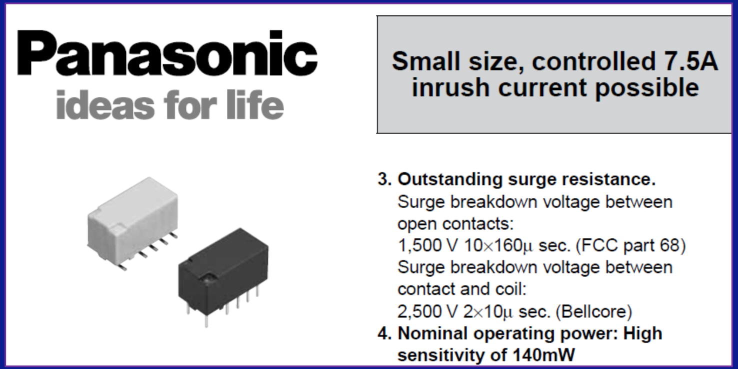
For automotive applications

1 POLE - 25A

FTR-P6 Series

■ FEATURES

- Surface mount relays for automotive applications
- Miniature size (67% of the volume of FTR-P3 relays)
- High contact capacity with proven contact material (100,000 operations, 14V, 25A)
- Low coil power dissipation (800mW nominal achieved with state-of-the-art magnetic design)
- Semi low noise (average acoustic noise level: 60dB distance 5cm)
- Application examples: Power window, door lock, power seat, sunroof, wiper
- RoHS compliant



Panasonic
ideas for life

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4. Nominal operating power: High sensitivity of 140mW

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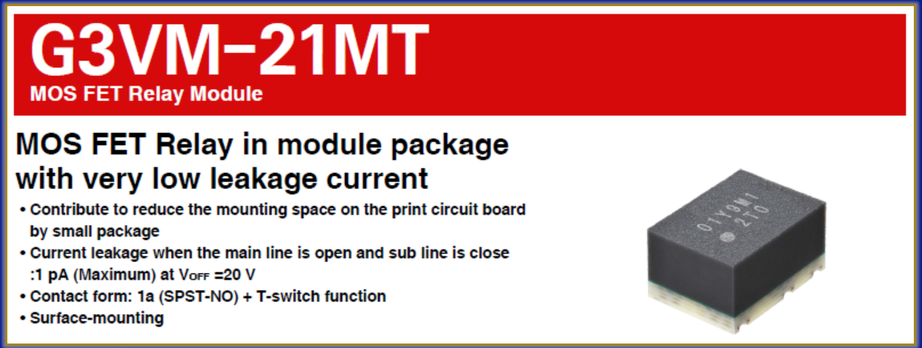
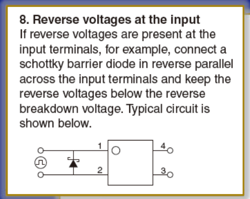
Relays – Photomos, Capacitor Coupled (CC) & T-Switch

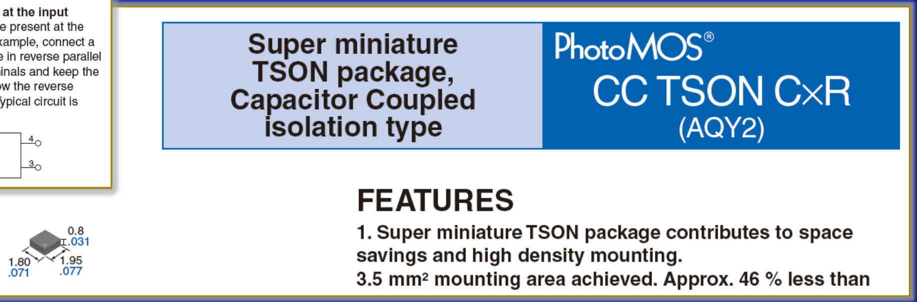
Mat Comp

- Improved Thermal Rating
  - 110˚C mini-Omrons, G3VM-31QR, G3VM-21MT
    - Nice for Zone 2
  - 105˚C AQY2C1R2 (Cap Coupled Panasonics)
- Driving All Photomos Hard
  - Better Hot Perf, hi Forward I
  - Lower Drain-Source On Resistance (RDSon)
  - Longer Toff, Shorter Ton
  - Lower Life, Worse Cap, Higher Leakage
- Other Considerations
  - CC Photomos powered like an IC
  - Needs protection diode
  - CCmos have very low drive I requirements


G3VM-31QR
MOS FET Relays S-VSON 4-pin, High-current and Low-ON-resistance Type
World's smallest * class New S-VSON Package
• Load voltage 30 V.
• Continuous load current 1.5 A max.
* As of November 2016 Survey by OMRON.
RoHS Compliant
NEW
Note: The actual product is marked differently from the image shown here.


G3VM−21MT
MOS FET Relay Module
MOS FET Relay in module package with very low leakage current
• Contribute to reduce the mounting space on the print circuit board by small package
• Current leakage when the main line is open and sub line is close :1 pA (Maximum) at V_{OFF} =20 V
• Contact form: 1a (SPST-NO) + T-switch function
• Surface-mounting


8. Reverse voltages at the input
If reverse voltages are present at the input terminals, for example, connect a schottky barrier diode in reverse parallel across the input terminals and keep the reverse voltages below the reverse breakdown voltage. Typical circuit is shown below.



Super miniature TSON package, Capacitor Coupled isolation type
PhotoMOS®
CC TSON C×R
(AQY2)
FEATURES
1. Super miniature TSON package contributes to space savings and high density mounting.
3.5 mm² mounting area achieved. Approx. 46 % less than

TestConX™

Extreme Temperature Automotive Testing

29 2025

Mat Comp

Caps

- High Temp Caps
  - Upgrade Hardwired, Backside DUT caps to 150˚C X8R
  - Upgrade Topside Caps to Kemet 175 & 200˚C series
  - COG class 1 ultra-stable, high precision capacitors
    - Less dielectric loss, more temp stable, bigger, fewer options

Surface Mount Multilayer Ceramic Chip Capacitors (SMD MLCCs)

Electronic Components KEMET CHARGED.

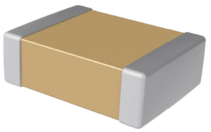
High Temperature 200°C, C0G Dielectric, 10 – 200 VDC (Industrial Grade)

Overview

KEMET's High Temperature surface mount C0G Multilayer Ceramic Capacitors (MLCCs) are constructed of a robust and proprietary C0G/NP0 base metal electrode (BME) dielectric system that offers industry-leading performance at extreme temperatures up to 200°C. These devices are specifically designed to withstand the demands of harsh industrial environments such as down-hole oil exploration and automotive/avionics engine compartment circuitry.

KEMET's High Temperature C0G capacitors are temperature compensating and are well suited for resonant circuit applications or those where Q and stability of capacitance characteristics are required. They exhibit no change in capacitance with respect to time and voltage and boast a negligible change in capacitance with reference to ambient temperature. Capacitance change is limited to ± 30ppm/°C from −55°C to +200°C. In addition, these capacitors exhibit temperatures up to 200°C. They also exhibit low ESR at high frequencies and offer greater volumetric efficiency over competitive high temperature precious metal electrode (PME) and BME ceramic capacitor devices.

These devices are Lead (Pb)-Free, RoHS and REACH compliant without the need of any exemptions.



Surface Mount Multilayer Ceramic Chip Capacitors (SMD MLCCs)

Electronic Components KEMET CHARGED.

High Temperature 150°C, Ultra-Stable X8R Dielectric, 10 – 100 VDC (Commercial & Automotive Grade)

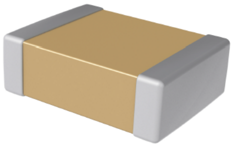
Overview

KEMET's Ultra-Stable X8R dielectric features a 150°C maximum operating temperature, offering the latest in high temperature dielectric technology and reliability for extreme temperature applications. It offers the same temperature capability as conventional X8R, but without the capacitance loss due to applied DC voltage. Ultra-Stable X8R exhibits no change in capacitance with respect to voltage and boasts a minimal change in capacitance with reference to ambient temperature. It is a suitable replacement for higher capacitance and larger footprint devices that fail to offer capacitance stability. Capacitance change with respect to temperature is limited to ±15% from −55°C to +150°C.

Driven by the demand for a more robust and reliable

In addition to commercial grade, automotive grade devices are available and meet the demanding Automotive Electronics Council's AEC–Q200 qualification requirements.

Click to activate...



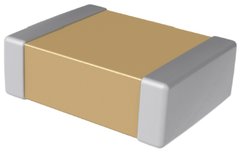
Surface Mount Multilayer Ceramic Chip Capacitors (SMD MLCCs)

Electronic Components KEMET CHARGED.

High Temperature 175ºC, X7R Dielectric, 16 – 200 VDC (Industrial Grade)

Overview

KEMET's High Temperature X7R Dielectric capacitors are formulated and designed for extreme temperature applications. Constructed of a robust and proprietary base metal electrode (BME) dielectric system, these devices are capable of reliable operation in temperatures up to 175°C. Providing an attractive combination of performance and robustness in general high temperature applications, High Temperature X7R dielectric capacitors are well suited for high temperature bypass and decoupling applications or frequency discriminating circuits where Q and stability of capacitance characteristics are not



Mat Comp

Bulk Caps

- Bulk Caps
  - Alum Elect. Low Equivalent Series Resistance (ESR), Conductive Polymer Hybrid
  - 125˚C, small, High Power Density
  - HXE series now rated to 135°C

NIPPON CHEMI-CON

CONDUCTIVE POLYMER HYBRID ALUMINUM ELECTROLYTIC CAPACITORS

Surface Mount

HXE Series *Upgrade!*

- High reliability is realized by hybrid electrolyte
- Endurance with ripple current : 2,000 to 4,000 hours at 135℃
- Rated voltage range : 16 to 63Vdc, Capacitance range : 22 to 470µF
- For high temperature and high reliability applications.
  (Automotive equipment, Base station equipment, etc.)
- RoHS2 Compliant
- Halogen Free
- AEC-Q200 compliant : Please contact Chemi-Con for more details, test data, information.

HXE

Higher temperature

HXC

◆SPECIFICATIONS

Items	Characteristics
Category Temperature Range	-55 to +135℃

NIPPON CHEMI-CON

Engineering Bulletin

Introductory

No.830I/May.2014

Conductive Polymer Hybrid Aluminum Electrolytic Capacitors

HXA Series

- High reliability and high voltage are realized by hybrid electrolyte
- Endurance with ripple current : 4,000 hours at 125℃
- Rated voltage range : 16 to 80Vdc, Capacitance range : 10 to 470µF
- For high temperature and high reliability applications.
  (Automotive equipment, Base station equipment, etc.)

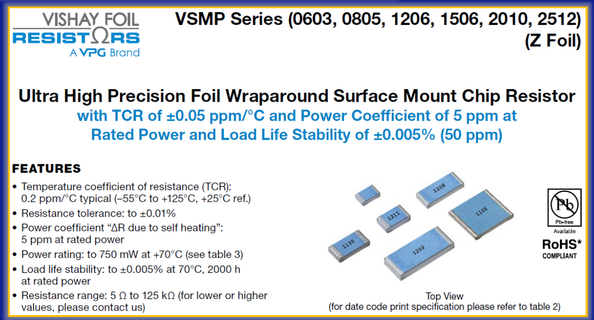
◆ SPECIFICATIONS

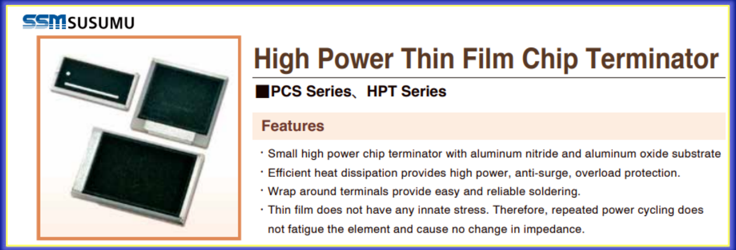
Items	Characteristics
Category Temperature Range	-55 to +125℃

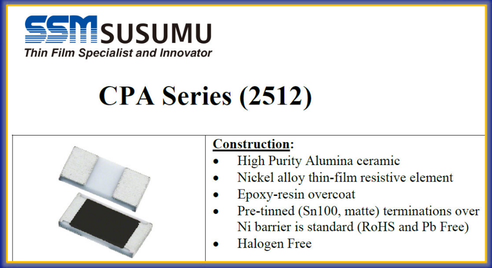
Mat Comp

Resistors

- Higher Power Rating per Form Factor
- PCAN very high power density
  - 0805 PCAN is a **1W** resistor
  - Check Power Curves vs. P70 ratings
- PHP, ERJ, PATT high power density
  - Larger Ohm range than PCAN
- P70 ratings
  - Running at Rated Wattage will increase Res Temp by 70˚C
- Vishay Z-Foil – 0.01%, 0.2ppm/ ˚C
- Susumu CPA – 16W 2512's
- Susumu 2.5W 0603
  - Terminator HPT1608-50-T1
  - 50Ω, Needs a plane tie







TestConX™

Extreme Temperature Automotive Testing

J Temp

Extreme Temperature Automotive Testing

- Passive Thermal Regulation
- Thermal Zoning
- Materials and Components
- Knowing the Junction Temp
- Active Thermal Regulation
- Other Considerations

J Temp

Knowing the Junction Temp

- How far off is the Elephant Air Temp?
- Triple current to the diode equation
- Average Voltage vs. Junction Temp
- Thermal Gradient Across the Junction
- Bench to Tester (BTT) Correlation on Individual Devices
- RTD in package
- Experiments – multiple pins, Electrostatic Discharge (ESD) diodes while operating

J Temp

Elephant Air

- How far off is the Elephant Air Temp?
- Forced Air is about 40˚C off at 150˚C set point
  - Takes 185 - 190˚C to get a 150˚C junction
- Forced Air is about 25˚C off at -40˚C
  - Takes -60 to -65˚C to get a -40˚C junction
- How about with a Thermal Couple
  - In the air stream
  - Very close to the DUT
  - About 15˚C off
- Thermal-stream temp can be controlled by test measurements

J Temp

Solving the Diode Equation

- Triple current to the diode equation
  - 3x Currents needed to solve all variables
  - Double, Symmetric Measurements
  - Long Test Time (TT), about 600mS
  - Must measure the 'n' factor on the bench
    - 'n' factor is temperature dependent
- Direct Measurement of DUT Temp
- Can be very accurate **(1-2˚C)**

$$I_D = I_S\left(e^{\frac{qV_D}{nkT}} - 1\right)$$

Ideal Diode Equation

Where

I_D and V_D are the diode current and voltage, respectively

q is the charge on the electron

n is the ideality factor: n = 1 for indirect semiconductors (Si, Ge, etc.)

n = 2 for direct semiconductors (GaAs, InP, etc.)

k is Boltzmann's constant

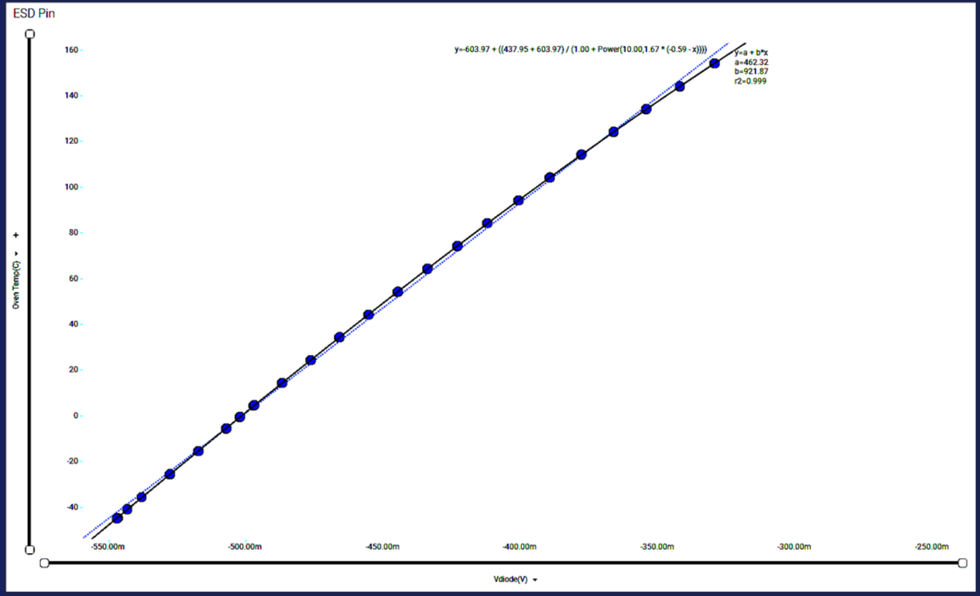
T is temperature in Kelvin

kT/q is also known as V_{th}, the thermal voltage. At 300K (room temperature), kT/q = 25.9mV

J Temp

Making V-T Curves

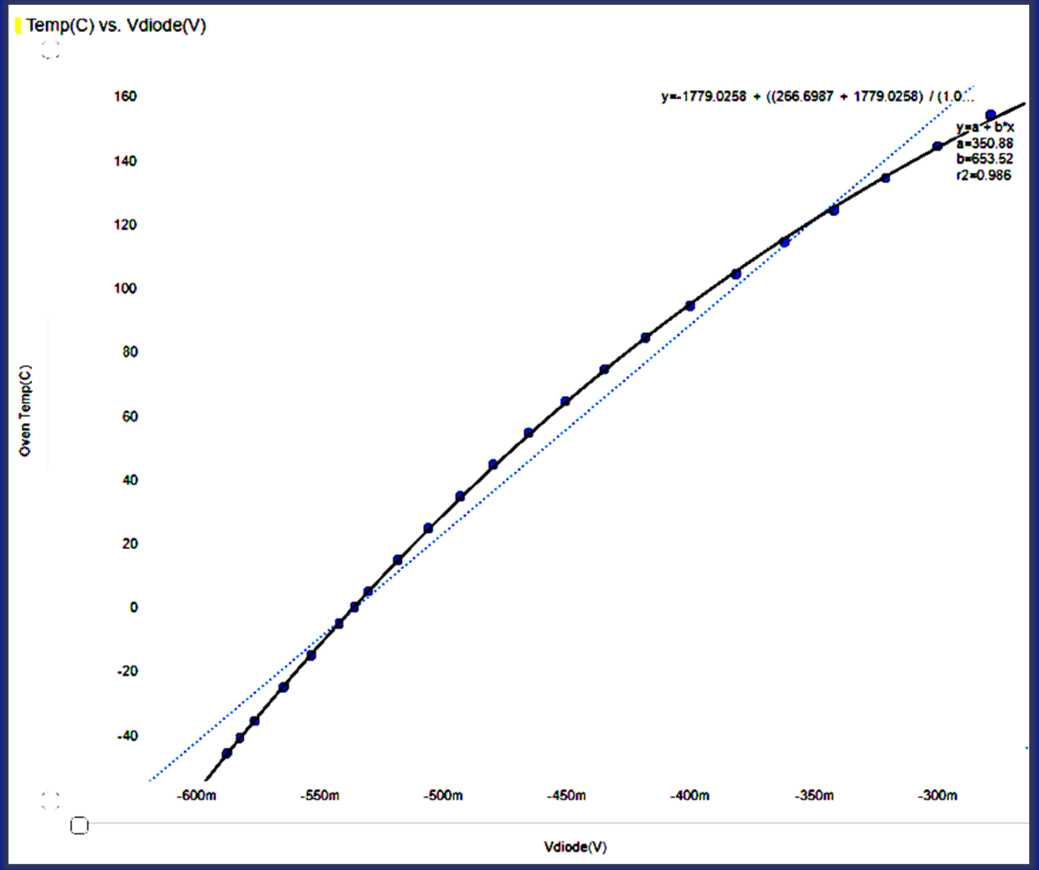
- Average Diode Voltage vs. Junction Temp
  - High Impedance ESD diode node
  - Often a Feedback (FB) pin is chosen
  - Voltage vs. Temperature 4th – 6th order best fit Using Excel
- About **+/- 2˚C** Avg Error across Dist.
- Extreme ends Breakdown
  - Due to Higher Order Effects
- But Individual IC's can be **+/- 10˚C**
- Possibly Good Enough for Production



J Temp

Making V-T Curves Continued

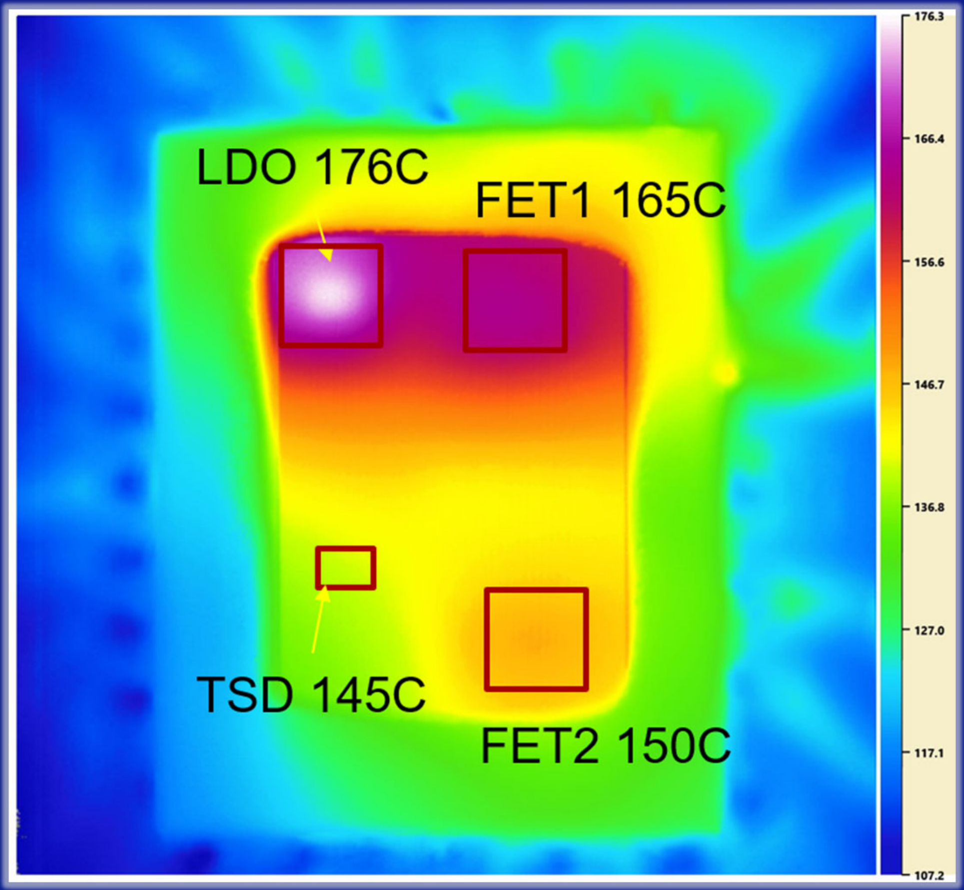
- Best ESD Diodes Have Very Little **'Extra Circuitry'**
  - High Impedance ESD diode node
  - Buffered Pin, Open Drain, FB work well
  - Active Circuitry Can Cause 'Bending Away'
- This Pin was Available for Monitoring
  - While DUT was being tested
  - Proximity to Hottest Area of IC is Critical
  - ESD diodes near the power Field Effect Transistor (FET) were +/-5°C when calibrated to exposed Silicon using a Thermal Camera



J Temp

Thermal Gradient Across the Junction

- Large Thermal Gradients
  - Statically forcing High Current (HC) causes ‘Hot Pockets’
  - High Thermal Resistance to PCB prevents equalization
  - Thermal Shutdown (TSD) circuitry too cold to work
  - 30°C+ delta across the DUT at 2A
  - Use ESD Diode near ‘Hot Pocket’
  - Use a Design For Test (DFT) request to have the TSD cell moved nearer to the power FET



J Temp

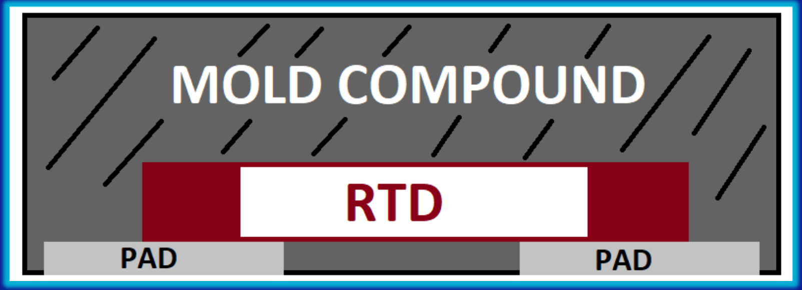
BTT Corr

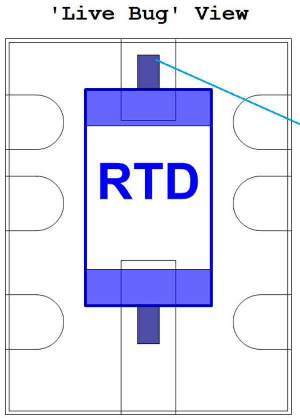
- BTT Correlation on Individual Devices
  - Testing each DUT on bench is time consuming
  - Possible to use BTT gold units as Temperature Corr Devices
  - But for REL / CHAR there can be wide Temp variation with each insertion
- Technique of Gathering bench Data
  - 5x temp sensors inside oven
  - RTD 0.5˚C measured in oven too
  - Large thermal ballast
  - Wait 1h (or overnight) for temp to settle
  - 100uA of FI to +/- 0.1uA
  - Measure FB diode Voltage with HP3458
- Accurate averages
  - 2˚C at cold, 0.25 ˚C, 2.5˚C at Hot
- Individual Parts Not very Accurate
  - +/- 10˚C

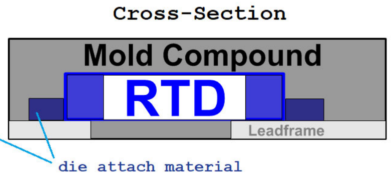
J Temp

RTD in Package

- RTD: What is it?
- An RTD is a Resistance Temperature Detector
  - 2 Terminal Temp Sensor
  - Usually made of Platinum because of linearity
- RTD in Package
  - Accurately determine junction Temp of Setup
  - Very helpful for Pre-Production CHAR / REL
    - Adjacent Strip Test Socket Correlation
  - Very helpful for Verifying Temp of Production Setup







- 0805 RTD attached to Leadframe
- Mold Compound poured around it
- Used for Temperature Calibration

TestConX™

Extreme Temperature Automotive Testing

TestConX 2025

J Temp

RTD: How Good is It?

- CHAR / REL accuracy +/- 2˚C
- Breakdown of Accuracies:
  - Distribution +/- 0.3˚C
  - RTD +/- 0.5˚C
  - Site to Site +/- 1˚C
- Much More Accurate than BTT
- But Indirect Measurement
- Note Error 2nd order fixes a 1˚C offset at hot

Nominal values

The nominal or rated value of the sensor is the target value of the sensor resistance at 0° C. The temperature coefficient α is defined

as $\alpha = \frac{R_{100} - R_0}{100 \cdot R_0}$ $[K^{-1}]$ and has the numerical value of 0.00385 K^{-1} according to DIN IEC 751.

In practice, a value multiplied by 10^6 is often entered: $TCR = 10^6 * \frac{R_{100} - R_0}{100 \cdot R_0}$ [ppm/K].
In this case, the numerical value is 3850 ppm/K.

Temperatur Characteristic Curve

The characteristic temperature curve determines the dependence of the electrical resistivity on the temperature.
The following definition of the temperature curve according to the DIN EN 60751 standard applies:

-200 bis 0°C $R(t) = R_0 (1 + A * t + B * t^2 + C * [t-100] * t^3)$

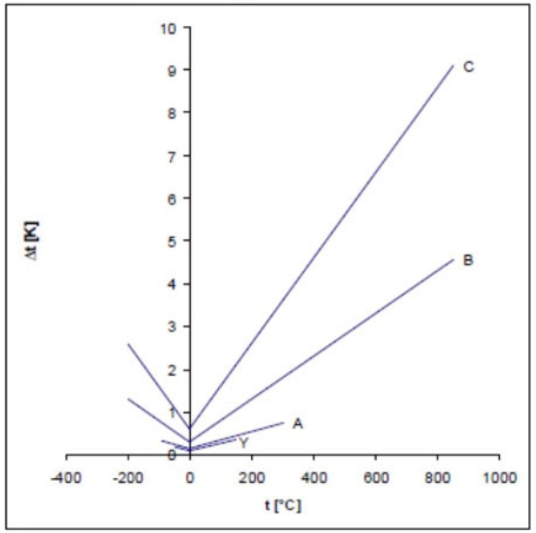
0 bis 850°C $R(t) = R_0 (1 + A * t + B * t^2)$

Platinum (3850 ppm/K):
$A = 3.9083 * 10^{-3}$ [°C^{-1}]; $B = -5.775 * 10^{-7}$ [°C^{-2}];
$C = -4.183 * 10^{-12}$ [°C^{-4}]

Platinum (3750 ppm/K):
$A = 3.8102 * 10^{-3}$ [°C^{-1}]; $B = -6.01888 * 10^{-7}$ [°C^{-2}];
$C = -6 * 10^{-12}$ [°C^{-4}]

Platinum (3770 ppm/K):
$A = 3.92 * 10^{-3}$ [°C^{-1}]; $B = -6.03 * 10^{-7}$ [°C^{-2}];

R_0 = Resistance value in ohm at 0°C;
t = temperature in accordance with ITS 90

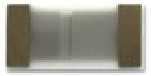


Tolerance field

J Temp

RTD as a DUT Board Temp Sensor

- Using RTDs to Measure Thermal Zone Temps
- 2 pin device, no Communication protocols!
- Easy to use, Measure Resistance convert to Temp
- Very Thin, so can fit in Socket Cavities
- Kelvin to Pad
- For Example, IST's P1K0.1206.4P.A
  - 3850ppm / ˚C
  - 1.573kΩ at 150˚C
  - 1.097kΩ at 25˚C
  - 1.000kΩ at 0˚C
  - 0.842kΩ at -40˚C

P1K0.0805.2 P.A 	24M9668 Data Sheet RoHS	IST INNOVATIVE SENSOR TECHNOLOGY RTD Sensor, Class A, 0805, 1 kohm, -60 C, +150 C RoHS Compliant: Yes	Awaiting Delivery Contact us for more availability or to purchase on backorder Check Stock & Lead	Each Delivery in 5-7 business days from our UK warehouse for in stock items	1+ $7.45 10+ $6.94 25+ $6.38 50+ $5.82 100+ $5.27

J Temp

Experiments to Try

- Multiple pins
- ESD diodes while ATE tests are running
- Streamlined Triple Current Diode Calibration
- On Board temp Sensors integrated into DUT

Extreme Temperature Automotive Testing

Active

- Passive Thermal Regulation
- Thermal Zoning
- Materials and Components
- Knowing the Junction Temp
- Active Thermal Regulation
- Other Considerations

Active Thermal Regulation

Active

- EPCOS PTC Thermistors
- Fully utilizing the handlers heating / cooling capabilities
- External Options

Active

PTC Thermistors

- EPCOS brand PTC Thermistors
  - DUT area temperature conditioning
  - Self-regulating Voltage Controlled Heating Elements
  - Sintered, doped barium titanate polycrystalline ceramic
  - Some quality questions
  - +/- 24V lines to +/- 5V lines give you about 120W
  - Many needed Top-Side Dut Area
  - Very inexpensive (10-12¢ each)
  - Available in 0402, 0603, 0805 form factors
  - You buy the Temp you want
  - TIMs material from EPCOS to Socket

perature above the Curie temperature T_C, the resistance of the PTC thermistor rises exponentially. Beyond the range of the positive temperature coefficient α the number of free charge carriers is increased by thermal activation. The resistance then decreases and exhibits a negative temperature characteristic (NTC) typical of semiconductors (see figure 2).

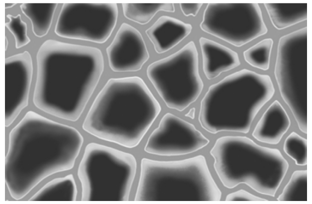
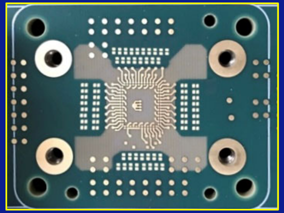


Figure 1
Schematic representation of the polycrystalline structure of a PTC thermistor.

The PTC resistance R_{PTC} is composed of individual crystal and grain boundary resistances. The grain boundary resistance is strongly temperature dependent.

$R_{PTC} = R_{grain} + R_{grainboundary}$

$R_{grain\ boundary} = f(T)$

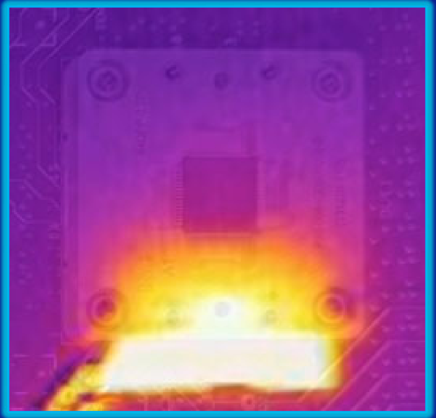


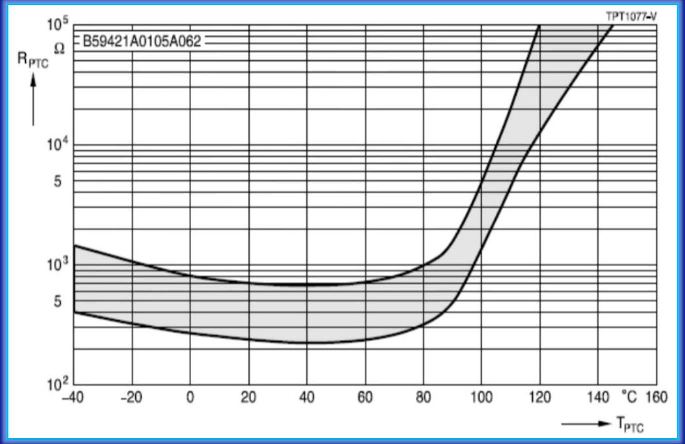
B59641A014 5A062	72R4674 Data Sheet Data Sheet RoHS	EPCOS PTC Thermistor, 470 ohm, SMD, 32 VDC, -50% to +50%, B59641 Series (0) Zero Power Resistance at 25°C 470ohm Thermistor Mounting SMD Product Range B59641 Series + See all product info	1,096 In stock Check Stock & Lead Times	Each (Supplied on Cut Tape) Available in quantity shown	1+ $0.117 25+ $0.117 50+ $0.117 100+ $0.117 250+ $0.117 More Pricing...

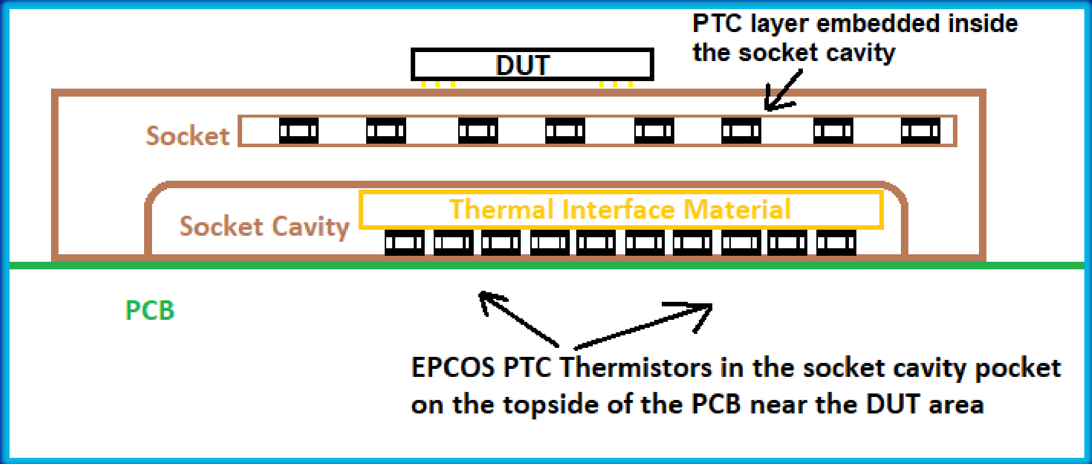
Active

PTC Thermistors

- Resistance Curve **Switches**
  - From Roughly Horizontal
  - To Roughly Vertical
- Self-Correcting Temp Reg
- Apply a Fixed Voltage
  - Temp is too high
    - Resistance goes up
    - Current goes down, Power goes down
    - Temp goes down
  - Temp is too low
    - Resistance goes down
    - Current goes up, Power goes up
    - Temp goes up
- More experiments needed







Active

Handler Options

- Fully utilizing the handlers heating / cooling capabilities
  - Many Handlers have up to +20˚C Calibration offset capability
  - This is Usually Calibrated to Force Air Temp
    - Air Temp is Device Independent
    - Air Temp is much lower than DUT Junction Temp
  - Possible to Calibrate to DUT Junction Temp Instead
  - Needs / Production Buyoff

TestConX 2025

Active

External Options

- Some External Control Systems Provide Heat Directly to the DUT
  - High Power Directly to DUT Area
  - Regulation Feedback Needed
  - Expensive
- Some Options are Mod Kits to Existing Handlers
  - Better Flow
  - Less Leakage
  - Reduced Frosting
  - Expensive

TestConX™ Extreme Temperature Automotive Testing 50 2025

Other

Extreme Temperature Automotive Testing

- Passive Thermal Regulation
- Thermal Zoning
- Materials and Components
- Knowing the Junction Temp
- Active Thermal Regulation
- Other Considerations

Other

Other Considerations

- Careful Continuity
- Setup Tests
- Checks at all temperatures

Other

Careful Continuity

- With poor Contact you cannot control resource behavior
  - Catastrophic Results
- Kelvin Checks, verify Force (F) & Sense (S) to DUT
  - esp. on power pins
- Contact Resistance
  - Cres very important at Temp
  - Helps Detect frosting
  - Helps Prevent Burn out on multiple common node pads
  - Cres before Continuity to identify Setup issues
  - Bank kelvin F to S current loop
  - APU 150k kelvin Sense High (SH) to Force Low (FL)
- Pin-to-Pin Shorts
  - Check Soft Shorts, ~1.5kohm
- Post Continuity catches ICs Damaged at Temp

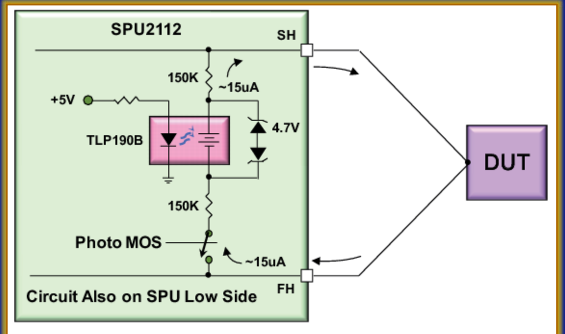
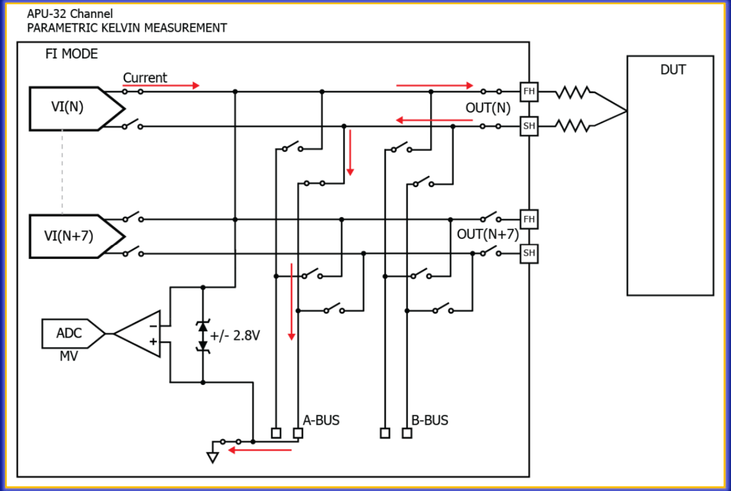


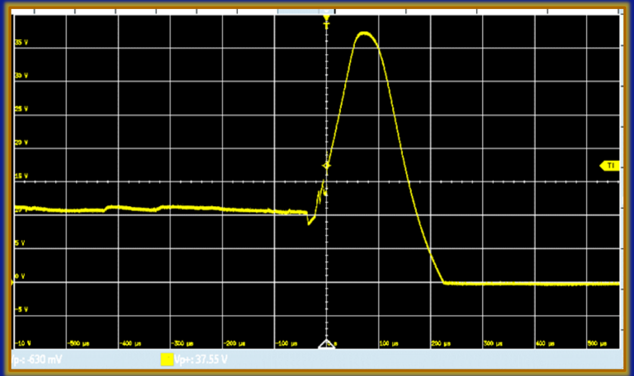
Figure 9 SPU-2112 Soft Kelvin Circuit



Other

Setup Tests

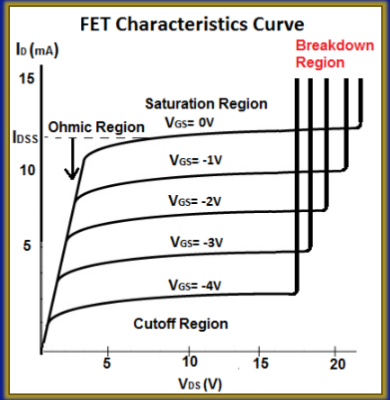
- Contact Issue at Temp Lead to Device Behavior Issues
- DUTs are More Susceptible to BAD Setup / Loosing Test Mode (TM)
- Consider Not Retesting Devices that Get Kicked out of TM
- Verify TM Before and After Potentially Damaging Tests
- For Example, Switching Regulators have Current Limit or RDSon TM's
  - If device exits TM you might force 12A into an open circuit
  - Voltage Spike exceeds Absolute Maximum (Absmax) Rating
  - Device can be killed or 'walking wounded'



Other

Check At All Temps

- Spike Check all temperatures
- Delta Quiescent Current (Iq), Junction Verification Testing (JVT), ABSMAX, Post Leakage at all temps
- Bench-to-Tester at all temps
- Full Limit Verification, Repeatability, Gage Repeatability and Reproducibility (GRR), Process Capability Index (CPK) distribution checks at All Temps
- What was a Good Idea / Nice to have at Room is Imperative at Temp



The End

- Thank You!
- Questions?

Appendix 1: Datasheets and Product Info

- Relays: TEL412H Coto2373 Coto2971 AGQ20Ts AQY221R6T CCmos TX-7.5A AQY2C1 ALZN1F FTR-G1 FTR-P3 FTR-P6 G3VM G3-Tsw ReedEMF Pickering 120
- Resistors: PCAN PATT PHP Susumu TX2575 zFoil
- RTDs & PTC Thermistors: IST_RTDs RTD_SMD PTC_APPnotes EPCOS_PTCtherm
- Caps: HXE HSE HXA X8R X7R_175deg C0G_200deg CBulk
- Misc: Therm-A-Gap Parker Thermal N4800-20 Photomos_tips Pickering Relay Guide

Appendix 2: Useful Websites

- Relay Voltage Over Temp: https://www.pickeringrelay.com/how-temperature-can-affect-reed-relay-performance/
- Extremely Low Offset Switching Considerations: https://www.ni.com/en-us/innovations/white-papers/06/switching-low-level-signals-to-a-dmm.html
- PEEK material properties & where to purchase:
  - https://www.aetnaplastics.com/products/d/Peek
  - https://www.victrex.com/en/victrex-peek
  - https://www.extreme-bolt.com/peek-screws.html
  - https://www.grainger.com/search?searchQuery=screws%20PEEK&suggestConfigId=1&searchBar=true
- Pickering US Distributor: https://products.testco-inc.com/#/app/layout/itemlisting?isRedirect=true&mfg=PICK
- Omron Photomos Relays: https://components.omron.com/us-en/products/relays/mosfet-relays
- Omron's T-Switch and other Photomos Modules: https://components.omron.com/us-en/products/relays/mosfet-relays/mosfet-relay-module_features
- Panasonic Photomos Relays: https://industry.panasonic.com/global/en/products/control/relay/photomos
- TDK Epcos PTC Thermistors: https://www.tdk-electronics.tdk.com/en/530400/products/product-catalog/sensors-and-sensor-systems/limit-temperature-sensors
- Innovative Sensor Technology RTDs: https://www.ist-ag.com/en
- Susumu High Power 50Ω Terminator and Resistor Write-Ups and CPA 16W 2512 selection on Digikey:
  - https://www.digikey.com/en/product-highlight/s/susumu/hpt-series-high-power-high-frequency-chip-terminator?_gl=1*t1cyij*_up*MQ..&gclid=2366bdb141461c31800dda172c5d69d2&gclsrc=3p.ds
  - https://www.digikey.com/en/product-highlight/s/susumu/hrg3216-series-resistor?_gl=1*1m8nlxa*_up*MQ..&gclid=2366bdb141461c31800dda172c5d69d2&gclsrc=3p.ds
  - https://www.digikey.com/en/products/filter/chip-resistor-surface-mount/52?s=N4IgjCBcoLQCxVAYygMwIYBsDOBTANCAPZQDa4AzGBRSALoC%2BDhATGSNgK5cC2n9DIA
- Vishay PCAN resistors: https://www.vishay.com/en/product/60125/
- Panasonic High Inrush Current TH Mechanical Relays: https://na.industrial.panasonic.com/products/relays-contactors/lineup/mechanical-signal-relays/series/119574
- Fujitsu Automotive Relays: https://www.fujitsu.com/sg/products/devices/components/relays/applications/automotive.html
- Technoprobe: https://www.technoprobe.com/
- Parker TIMs Materials: https://www.parker.com/us/en/divisions/chomerics-division/solutions/thermal-management.html
- Cohu Sockets & Handlers: https://www.cohu.com/interface-solutions & https://www.cohu.com/test-handlers
- Gorilla Circuits (PCB IPDs: integrated resistors & caps): https://www.gorillacircuits.com/
- Enplas Sockets: https://www.enplas.co.jp/english/business/espc/

Appendix 3: Industry Contacts

- Willie Jerrels – Enplas: Socket Designer
- Bates Micu – Technoprobe: Wafer Probe heat shield. Probe tip temp rating.
- Bob Nurmi, Doug Leys – AGC: N4800-20/SI FR4 material
- John Bahr – Panasonic: Mech & Photomos Relays among other things
- Jerry Machado – Panasonic: Thermal management & PGS materials
- Adeel Baig, Zac Hendrix– Omron: high temp relays
- Kevin Mallett – Pickering Relays
- Brian Poor – Parker Chomerics: TIMs materials
- Charlie Stretch – Fujitsu: small, high current, SMD, automotive relays
- Alan Ravizza – Innovative Sensor Technology (IST): SMD RTD temp sensors
- Kaz Morisita, Scott Madigan, Masa Yoshimoto – Susumu: high power resistors

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