

# Advantages of Precision Resistance Networks for use in Sensitive Applications



**Where the World Goes  
for Precision Measurement and Control**

# Advantages of Network vs. Discrete Resistors

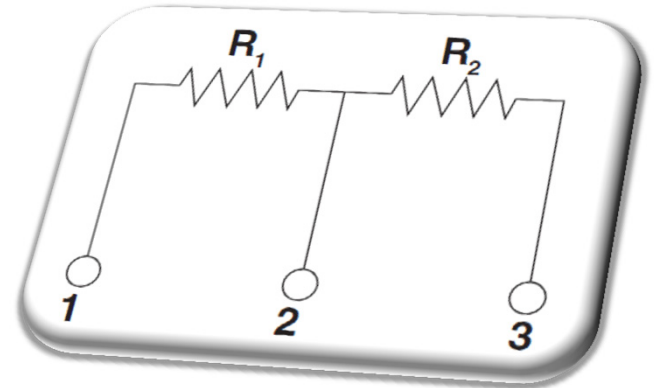
- Space Saving Features
- Lot Uniformity
- Tracking Features
- Existing Reliable Technologies “Known Good Die”
- Long Term Stability Advantages
- Cost Savings

## Space Saving Benefits of Networks

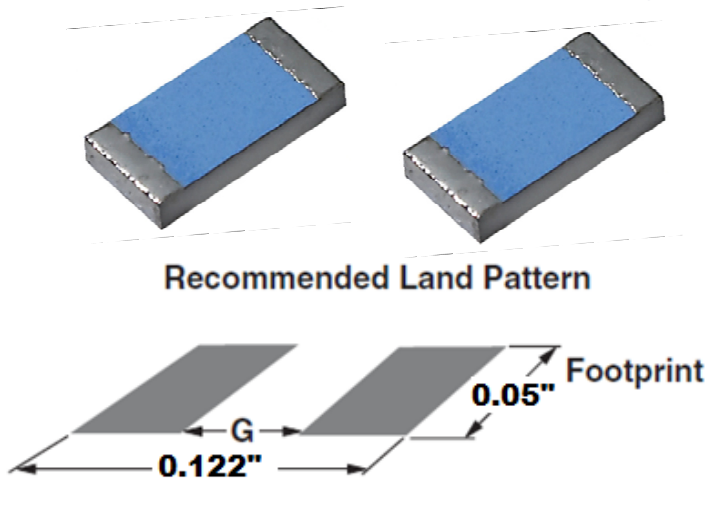
- Can combine multiple terminals in a common node
- Reduces redundant features (substrate, molding..etc)
- Reduces complexity of PCB or hybrid design



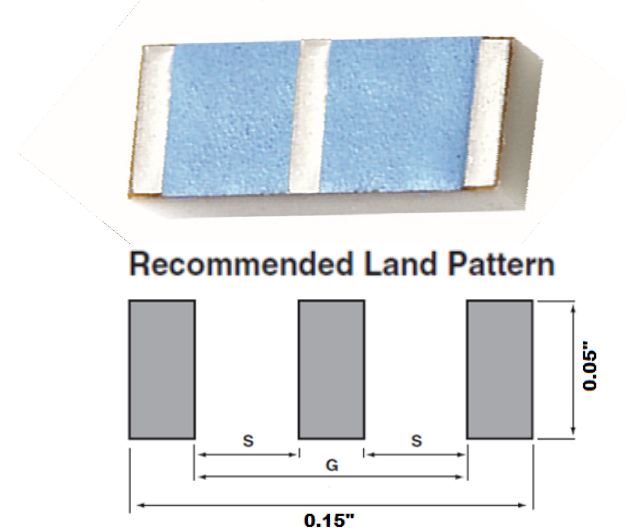
VS



## Space Saving Benefits of Networks cont. (building a divider)



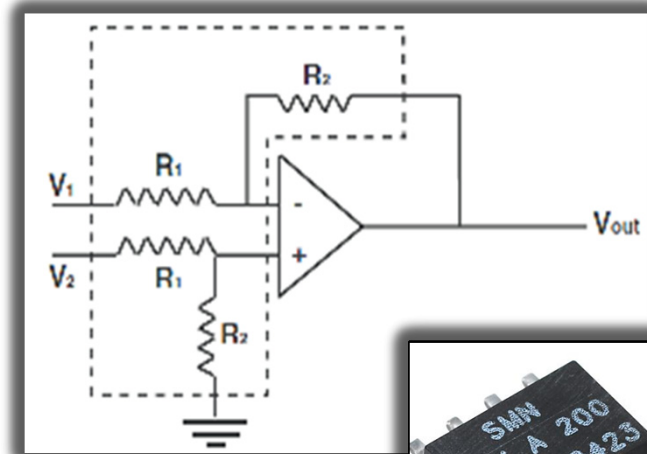
- **Two 0805** chip resistors
- Total Mounting Area (not counting traces) = **0.0122 inches<sup>2</sup>**



- **One 1505** size Divider
- Total Mounting Area = **0.0075 inches<sup>2</sup>**
- **~39% space savings**

## Lot Uniformity

- Resistors that meet a performance specification may not be identical
- Single Lot Date Codes are only applicable to a single line item!
- Various constructions of MIL-PRF-55342– May all be the same Part #
  - Tantalum Nitride
  - Ruthenium Oxide
  - Nickel Chromium



**Only a network or an SCD will guarantee uniform construction**

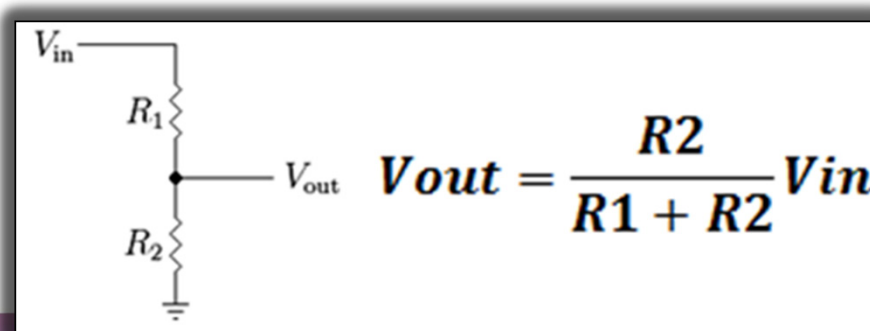
# Tracking Benefits of Network Resistors

## Temperature Coefficient (TCR)

- Defines drift with varying ambient temperature
- Ideally both resistors have identical TCR
- Relevant primarily in low power applications

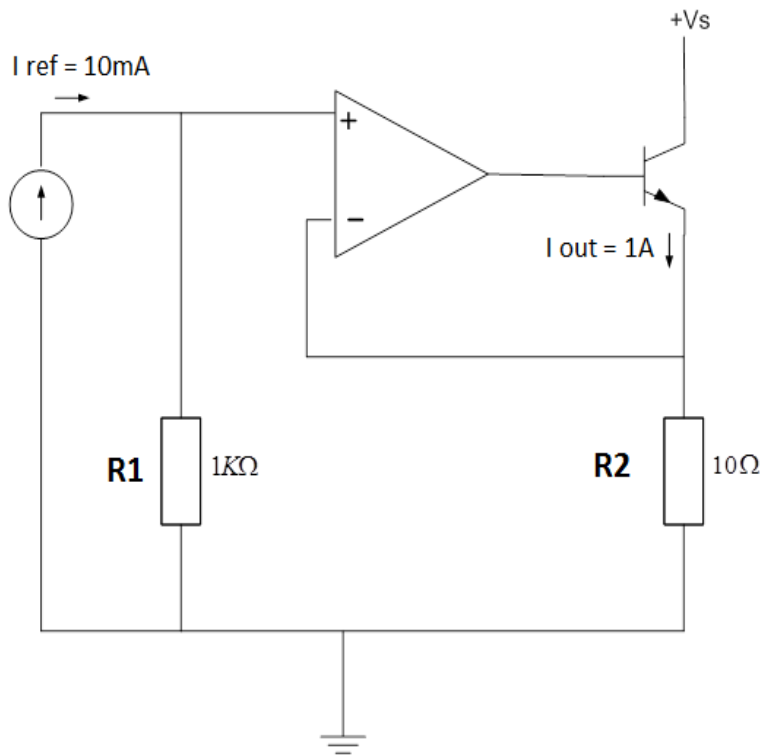
## Power Coefficient (PCR)

- Defines drift with applied power
- Best performance may not require matched but not identical PCR
- Relevant in power applications and also non-unity gain ratio's



# Tracking Benefits of Network Resistors cont.

## Perfectly Matched Discrete Resistors



Suppose  $\Theta_j = 9^\circ\text{C} / \text{W}$   
 TCR Tracking =  $0 \text{ ppm}/^\circ\text{C}$  (perfect)  
 Absolute TCR =  $5 \text{ ppm}/^\circ\text{C}$

Then:



$P = 10\text{W}$   
 $\Delta T = +90^\circ\text{C}$   
 $\Delta R = 450\text{ppm}$

$P = 10\text{mW}$   
 $\Delta T = +0.09^\circ\text{C}$   
 $\Delta R = 0.45\text{ppm}$

The ratio is not maintained  
 despite perfect tracking!

# Tracking Benefits of Network Resistors cont.

## The Network Solution



Two Resistors in the Same Package or on the Same Substrate Experience More Uniform Thermal Conditions:

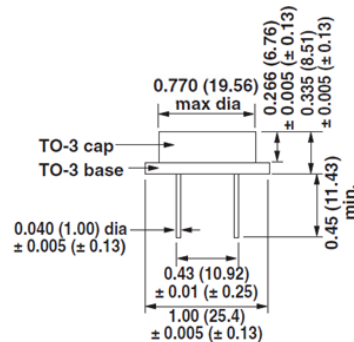
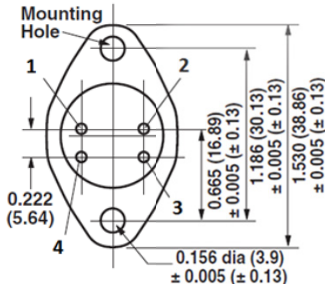
$$\Delta T_{R1} \approx \Delta T_{R2}$$

and thereby:

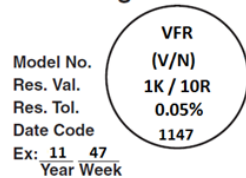
$$\Delta R_1 \approx \Delta R_2$$



The ratio is maintained!



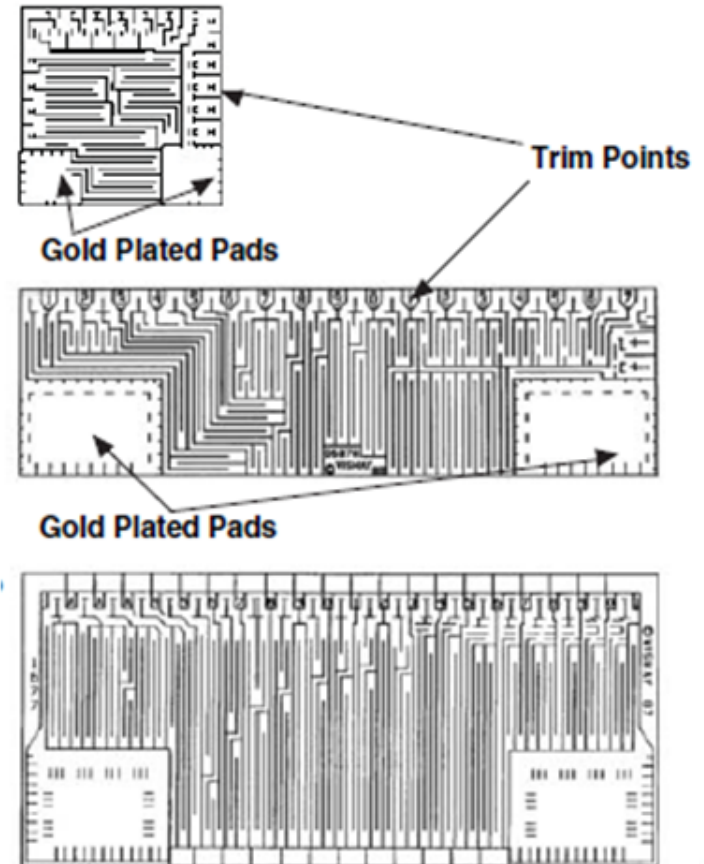
### Standard Marking Arrangement





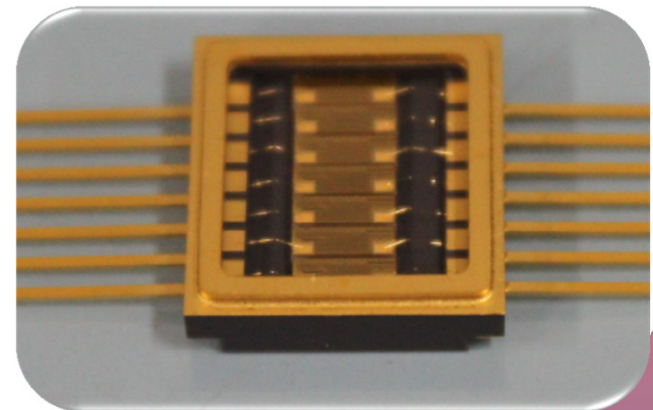
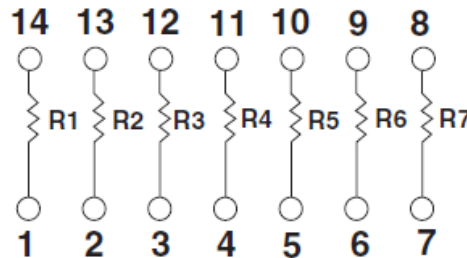
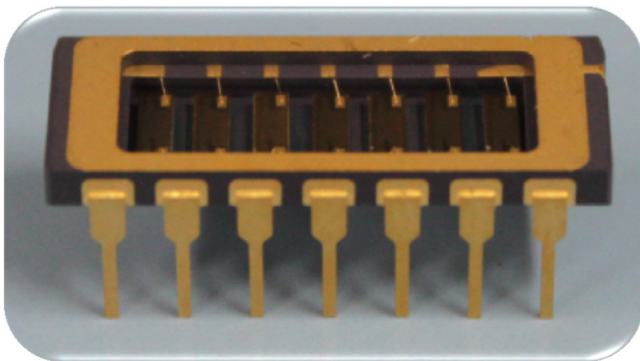
## “Known Good Die”

- Resistor Networks May Be Constructed Using Existing Reliable Technologies
- Keeping the same materials and processes
- Qualification by similarity
- Expanding the utility gained from a successful qualification program



## “Known Good Die” cont.

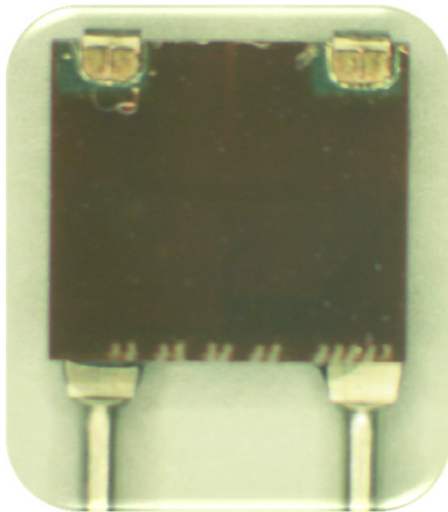
- Hermetically Sealed
- 14 pin Through-hole DIP
- Qualified in accordance with MIL-PRF-83401 char C schematic A
- 5ppm/°C TCR Tracking
- Hermetically Sealed
- 14 pin Surface Mount Flat Pack
- 0.5 ppm/°C TCR Tracking
- Any Schematic



## “Known Good Die” cont.

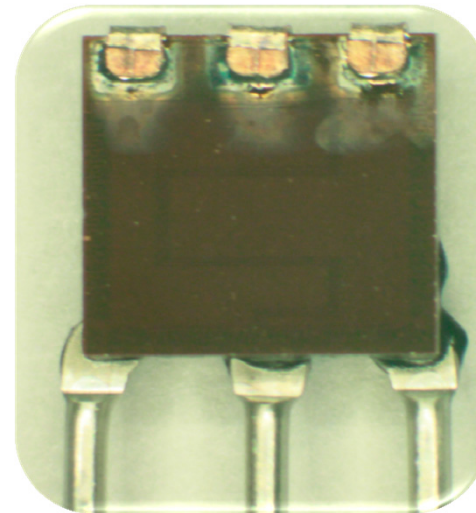
### Discrete Component

- Qualified in accordance with MIL-PRF-55182/9
- 4ppm/C TCR Tracking (two 2ppm/C discretetes)



### Integrated Divider

- Same case size
- 0.5 ppm/C TCR Tracking
- Any combination of values

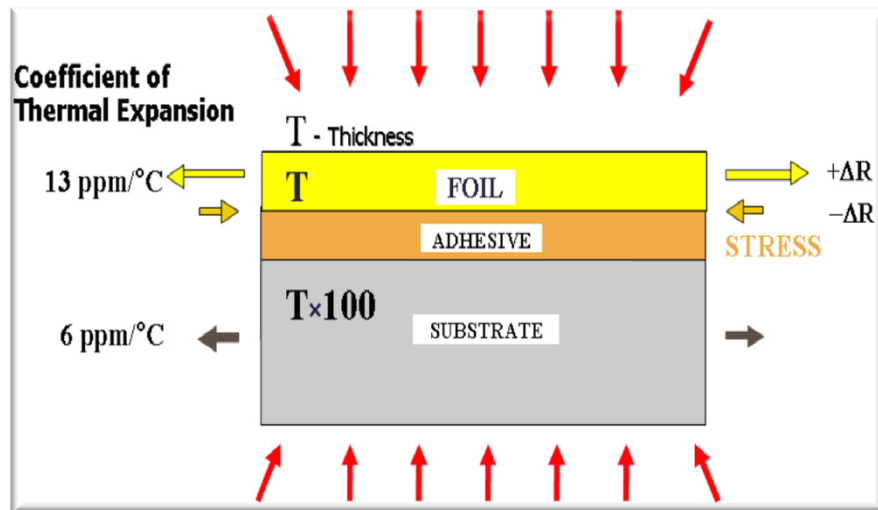


# New Network Technologies

## Hybrid Network Resistors with lower TCR

- New process developed for wire-bonding ultra low TCR resistors
- For use with commonly available gold and aluminum wire bonding processes
- Several compensation techniques to achieve lowest possible equivalent TCR

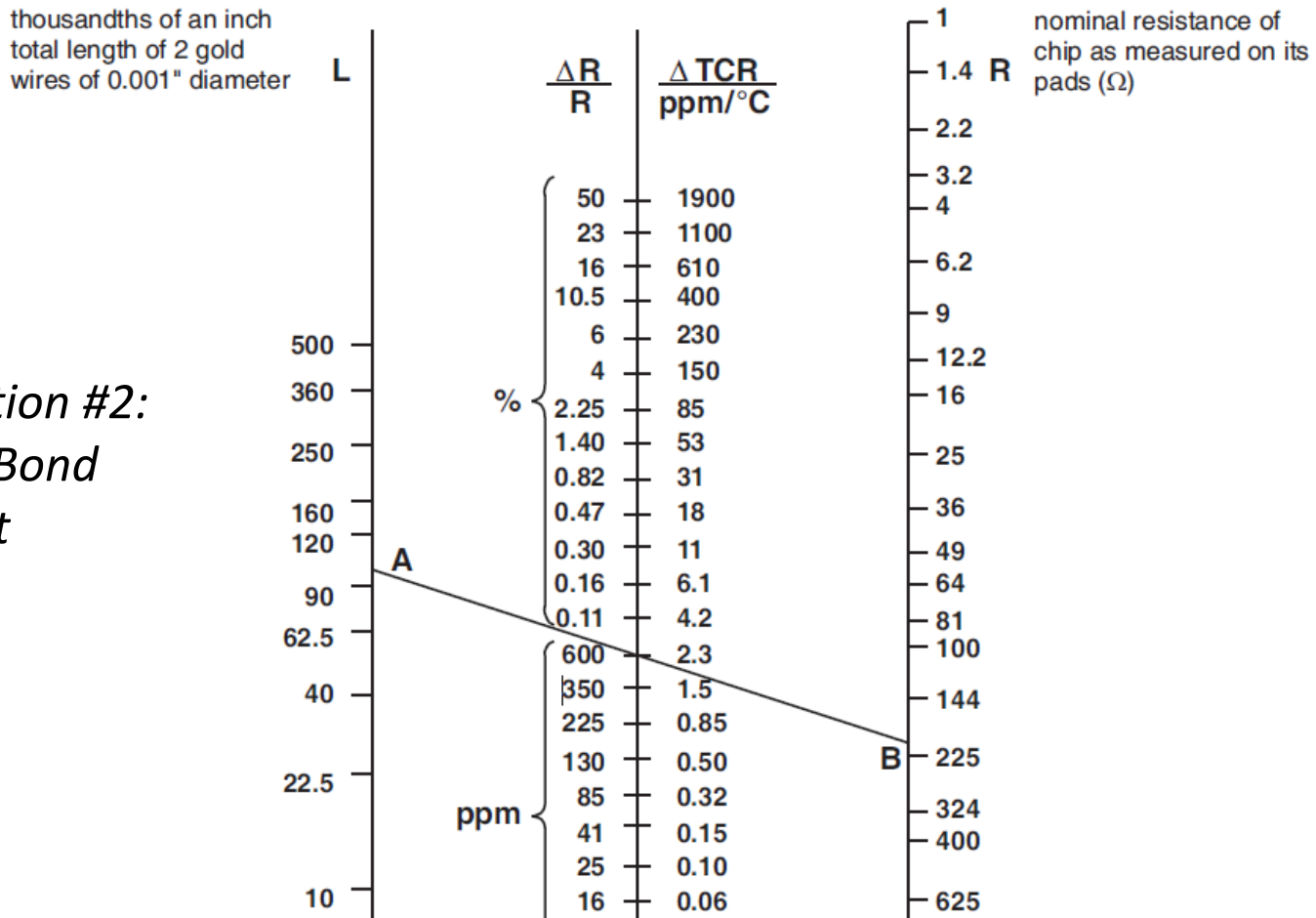
### Compensation #1: Foil Construction



# New Network Technologies

## Hybrid Network Resistors with lower TCR

*Compensation #2:  
Gold Wire Bond  
Adjustment*



# New Network Technologies

## Hybrid Network Resistors with lower TCR

What's New about this Technology?

$\pm 2$  ppm/ $^{\circ}\text{C}$  Absolute TCR

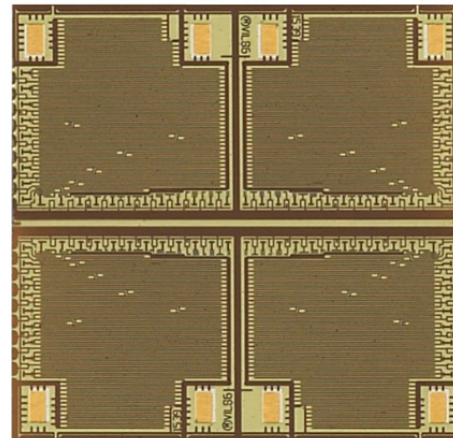
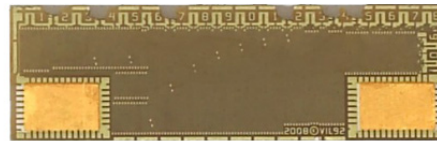
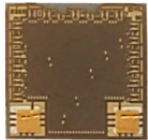
$\pm 0.5$  ppm/ $^{\circ}\text{C}$  TCR Tracking

Multiple Sizes & Configurations

Gold or Aluminum wire bondable

Operation up to  $+240^{\circ}\text{C}$

Recently qualified new materials allow for improved specifications over existing hybrid die.



# Load Life & Long Term Drift Tracking

- Purpose:
  - To analyze the drift trend of discrete versus network components
  - Compare statistical deviation of parts within one lot
- Compare like resistive elements under similar conditions
  - MIL-PRF-83401 and MIL-PRF-55182 Foil Resistor Elements
  - 1000 hours of load life QPL maintenance Data
  - Full Rated Power, 75% duty cycle

# Load Life & Long Term Drift Tracking

## Data Summary

Long term stability of resistance ratios are improved when a specific technology is packed in a network configuration

Load Life Test Results after 1,000 hours		Network Resistors MIL-PRF-83401 style
Date Code	Qty of Resistors	Average 1 $\sigma$ Lot Deviations (ppm)
0714*	10 Networks of 7 Isolated Resistors	4.50745
0741	10 Networks of 7 Isolated Resistors	12.193
0814	10 Networks of 7 Isolated Resistors	9.3634
1014	10 Networks of 7 Isolated Resistors	4.9174
	280	<b>7.745313</b>
	Total Qty	<b>Weighted Average Standard Deviation</b>

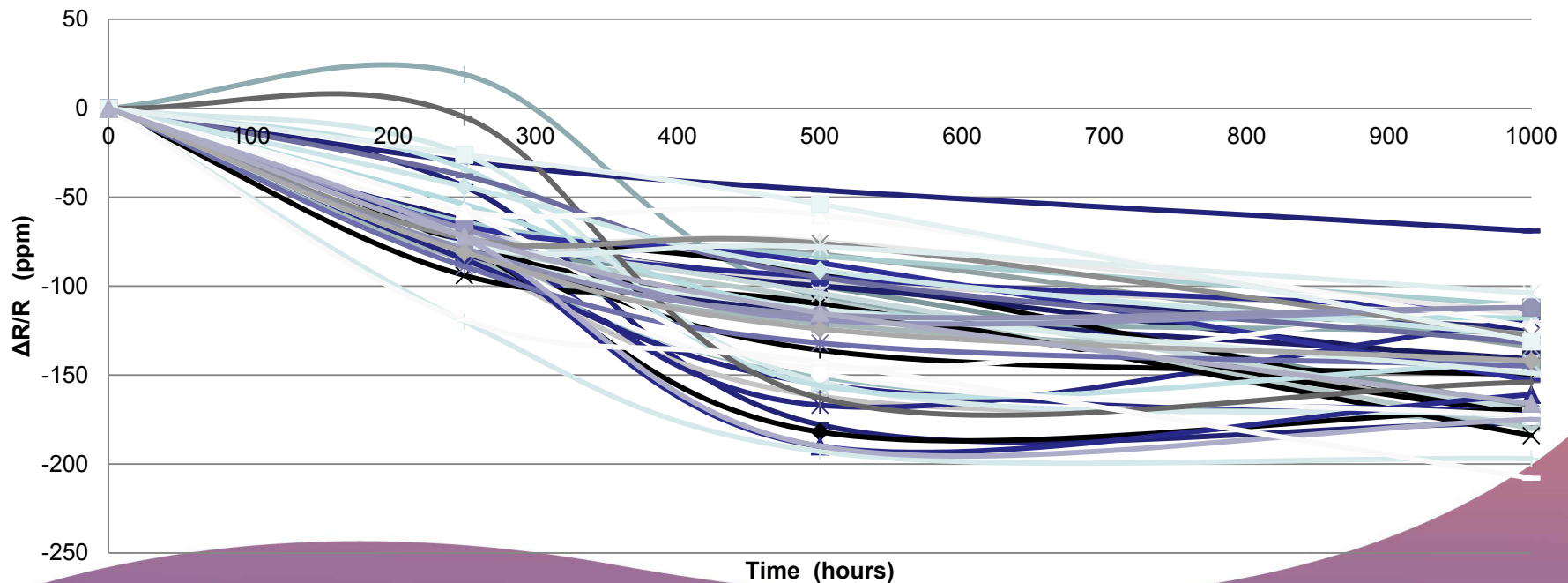
Load Life Test Results after 1,000 hours		Discrete Resistors MIL-PRF-55182 style
Date Code	Qty of Resistors	1 $\sigma$ Lot Deviation (ppm)
0606	48	35.09
0736	48	34.419
0828	48	29.921
0910*	48	28.684
0937	24	24.571
1001	24	11.869
	240	<b>29.2668</b>
	Total Qty	<b>Weighted Average Standard Deviation</b>

Smaller deviation between resistors in a lot



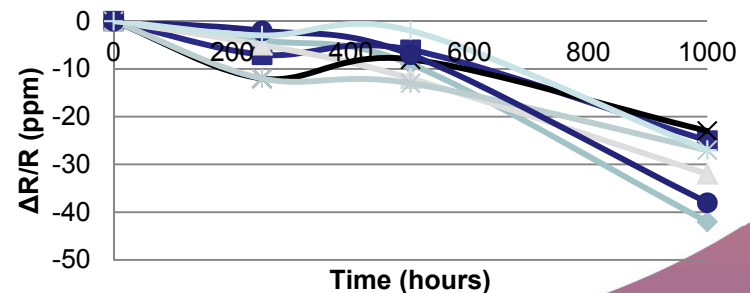
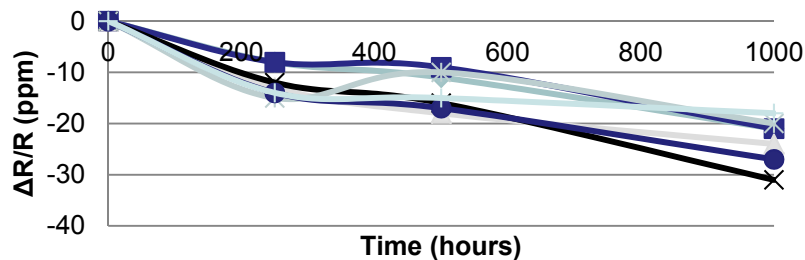
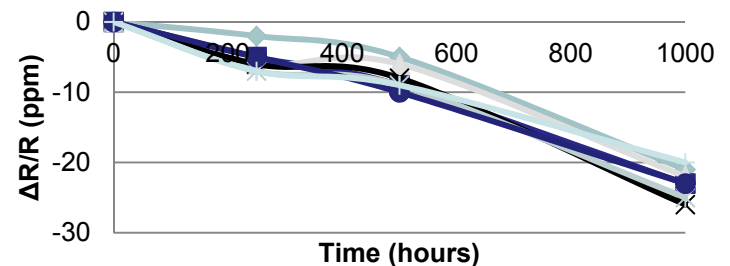
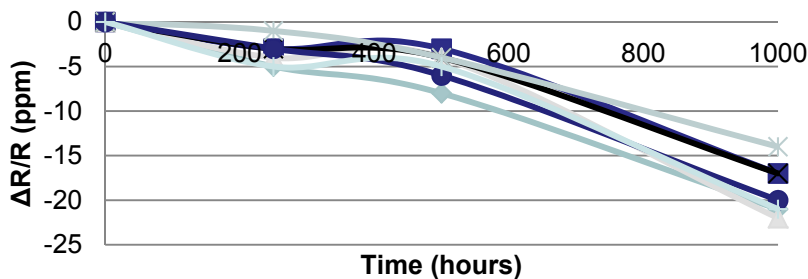
# Load Life & Long Term Drift Tracking MIL-PRF-55182/9 Discrete Typical Results

- Date Code 0910  $\sigma = 28.684\text{ppm}$
- 48 pieces tested over 1000 hours
- Resistors manufactured in a single lot tend to drift together



# Load Life & Long Term Drift Tracking MIL-PRF-83401 Network Typical Results

- Date Code 0714      Average:  $\sigma=4.5075$  ppm
- Four 7-resistor networks shown (28 resistors total)
- Resistors manufactured in a single lot tend to drift together
- Resistors within a package drift together\*\*



## Cost Benefits of Networks

- One resistance network of 7 resistors is often less costly than 7 discrete resistors
- In cases of multiple resistance values, fewer part numbers and inventory are required when a single network is specified
- Cost of qualifying one network may be less than the cost of generically qualifying a range of many resistances
- PCB Design may be simplified, assembly costs reduced

## Conclusions

- Resistance networks and dividers reduce the required space on PCB's and optimize usable area in hybrid cavities
- Manufacturing uniformity is guaranteed when specifying networks
- Resistance networks may be produced using existing reliable technology
- Short term drift error can be reduced by using resistance networks
- Long term drift error can be reduced by using resistance networks
- Cost Savings are realized by specifying resistance networks

## Europe

### Field Design Engineer (FDE) Territory Key:

<b>Fred Meier</b> email: fred.meier@vishaypg.com tel: +44 1506483438 mobile: +44 7801350013	<b>Franz Wenz</b> email: franz.wenz@vishaypg.com tel: +49 3328 3330 20 mobile: +49 16094 92118	<b>Laurent Wyllet</b> email: laurent.wyllet@vishaypg.com tel: +33 2387 42382 mobile: +33 685113651
--	---	---

<b>Precision Centers:</b> Contact: foil@vishaypg.com Berlin - Oberndorf, Germany Thomas Pflüger New Providence - Milano, Italy Stefano Charenton - Dordy-Croix, United Kingdom Paul Neumann Pöwertzen - Salfow, Germany Klaus Baubitz	<b>Customer Service:</b> <b>Italy</b> email: italy.customer@vishaypg.com tel: +44 (7953) 812174 <b>Spain</b> email: spain.customer@vishaypg.com tel: +49 320 131 30039 192 <b>UK</b> email: uk.customer@vishaypg.com tel: +33 237 288 601	<b>Strategic Account Manager:</b> Thomas Koch - Heilbronn, Germany email: thomas.koch@vishaypg.com tel: +49 320 131 30039 192 mobile: +49 015115102396
--	--	--



## Central and South America

### Field Design Engineer (FDE) Territory Key:

<b>Jim Hargrove</b> email: jim.hargrove@vishaypg.com tel: +1 552 225 4824 mobile: +1 810 504 9952
--



## North America

### Field Design Engineer (FDE) Territory Key:

<b>Kip Hester</b> email: kip.hester@vishaypg.com tel: +1 848 348 2054 mobile: +1 810 504 9885	<b>Ed Cernick</b> email: ed.cernick@vishaypg.com tel: +1 820 226 2148 mobile: +1 870 526 8885	<b>Don Hampton</b> email: don.hampton@vishaypg.com tel: +1 810 504 9952
--	--	---

<b>Precision Centers:</b> Contact: foil@vishaypg.com ELDOPIC, LLC - Wheelersville, PA Frank Kuznetsov Brest Components - Houston, TX Ramon Garcia LRF Resistors - Ontario, CA Rene Ehrhard	<b>Customer Service:</b> <b>Canada</b> email: canada.customer@vishaypg.com tel: +1 888 321 5314 <b>USA</b> email: usa.customer@vishaypg.com tel: +1 888 321 5314 <b>Spain</b> email: spain.customer@vishaypg.com tel: +1 888 321 5314	<b>Application Engineering:</b> Aaron Ryan - Malvern, PA email: aaron.ryan@vishaypg.com tel: +1 484 321 5311 mobile: +1 810 506 2706 <b>Strategic Account Manager:</b> John Francis - Malvern, PA email: john.francis@vishaypg.com tel: +1 484 321 5322 mobile: +1 484 844 3073
---	--	--



## Asia and Israel

### Field Design Engineer (FDE) Territory Key:

<b>Takashi Yamamoto</b> email: takashi.yamamoto@vishaypg.com tel: +81 5 5262 5573 mobile: +81 9024268870	<b>Don Taitner</b> email: don.taitner@vishaypg.com tel: +63 2 922 2481 mobile: +63 917 54 305383
---	---

<b>Precision Center:</b> Contact: foil@vishaypg.com Aoyagi Heiko, Japan Takashi Yamamoto	<b>Customer Service:</b> <b>Japan</b> email: japan.customer@vishaypg.com tel: +81 5 5262 5781 <b>India</b> email: india.customer@vishaypg.com tel: +91 98200 20000 <b>China</b> email: china.customer@vishaypg.com tel: +86 21 5288 8073	<b>Sr. Sales Manager:</b> Takashi Yamamoto - Tokyo, Japan email: takashi.yamamoto@vishaypg.com tel: +81 5 5262 5573 mobile: +81 9024268870
---	---	--



For further information please contact our  
Application Engineering department at:

[foil@vishaypg.com](mailto:foil@vishaypg.com)

