Embedded Thin Film Resistors

IPC Designers Council
Orange County Chapter

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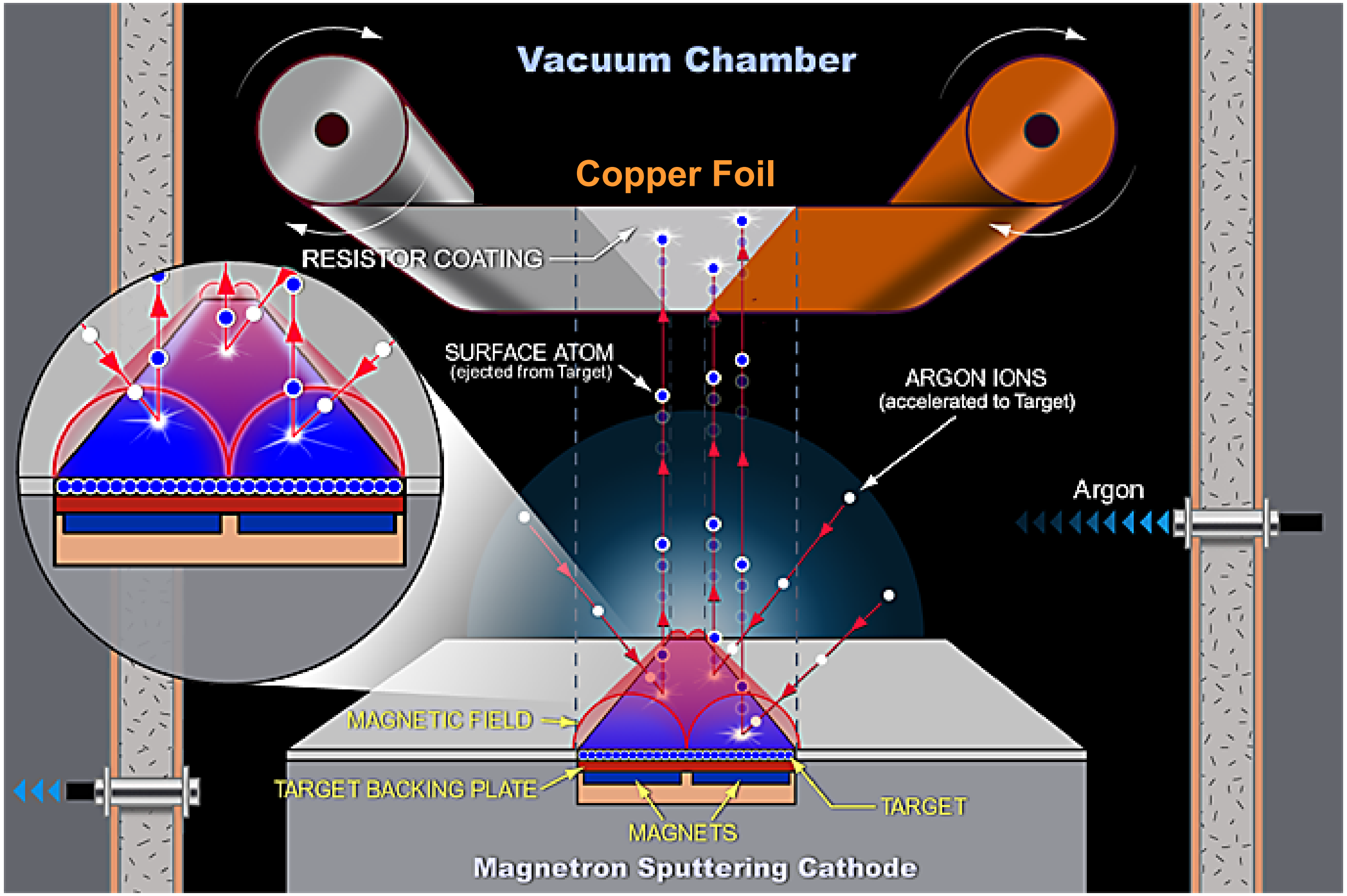
Agenda

- Overview of TCR® Thin Film Embedded Resistors
- Design tools and design considerations including power handling
- Applications showing advantages and reliability
- TCR-HF for low insertion loss

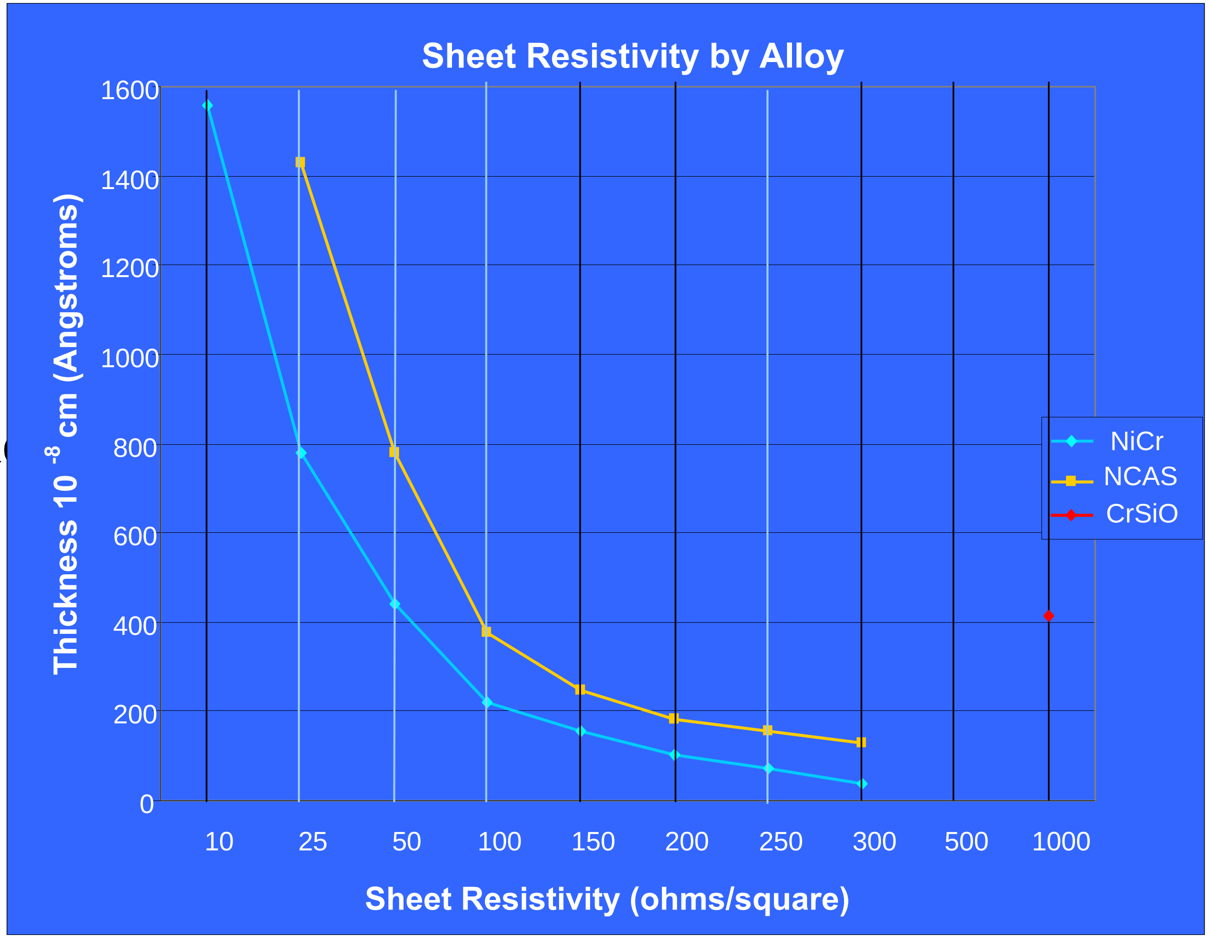
Vacuum Metallization Schematic



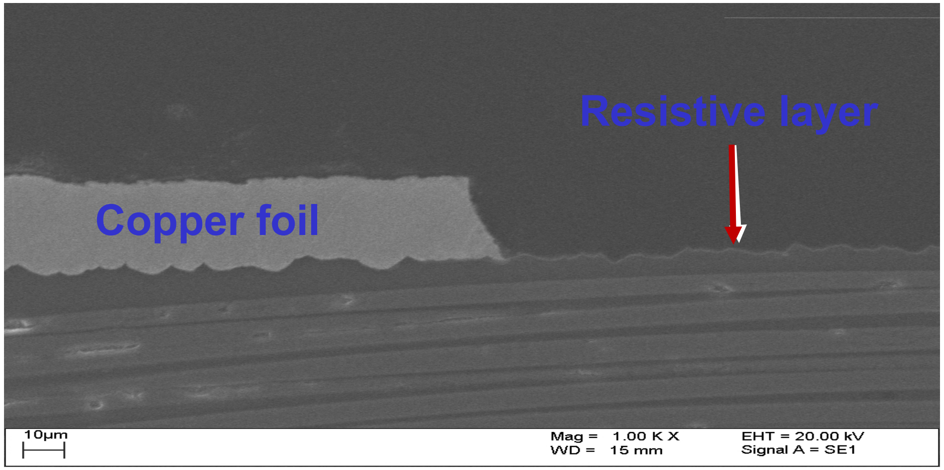
Sheet Resistance by Alloy Thickness

Contributing factors to sheet resistivity and to thickness ratios

- Resistive Alloy
- Copper Surface Profil

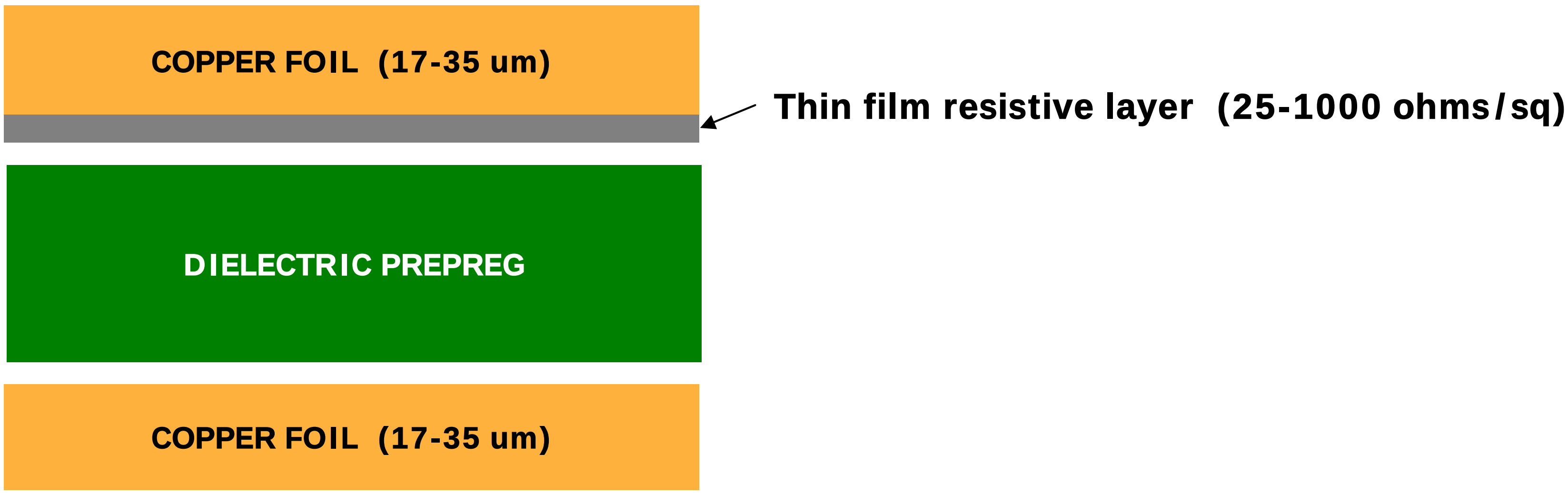


Cross-section of Resistive Foil on Laminate



- Alloy: NiCr
- Sheet Resistivity: 25 Ohms/square
- Copper Weight: 18 micron

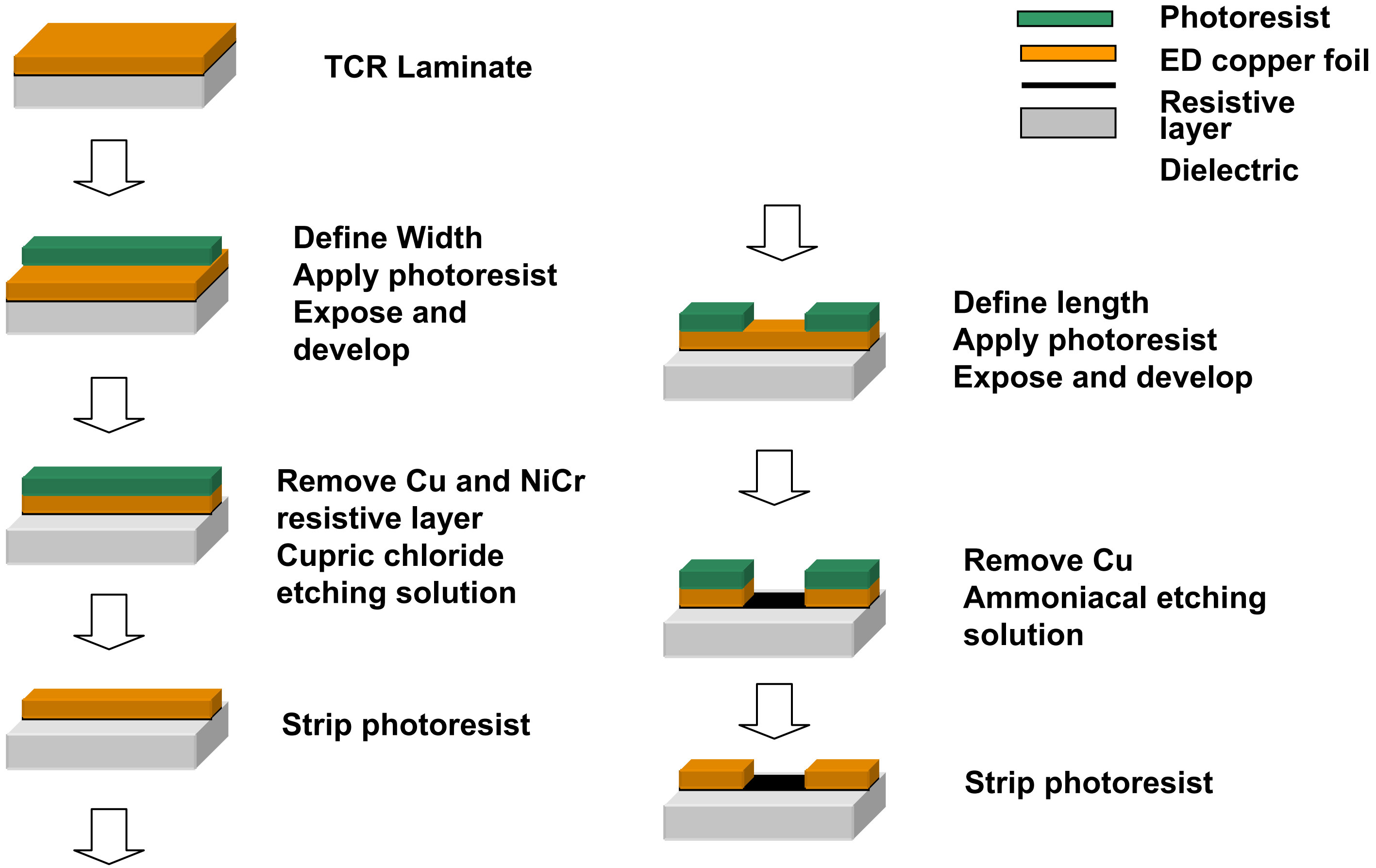
Ticer TCR® Thin Film Resistor Foil



Construction

- Resistive coated copper or laminate form
- Resistive Layer <1 micron thick
- Common dielectrics, glass styles & thickness

Thin Film Embedded Resistors PCB Processing



Availability of TCR®
Laminates and PWB Manufactures

- **US Laminates w/ TCR**
  - Arlon
    - CLTE, CLTE-XT,
    - 25N, 92ML, 85N
  - Rogers
    - 4003C &4350B, 4360,
    - 6202 PR, 6002PR
  - Isola
    - 406, 408HR, 370HR
  - Nelco
    - 4000-6, -13SI, -29,
    - N7000-2HT
    - Meteorwave
  - Taconic
    - TSM 29&30, TSM DS,
    - TSM DS 3, and FR35A2
  - DuPont
    - Pyralux® APR
  - 3M:
    - ECM

- **US PWB Manufactures**
  - Advanced Circuit Int'l
  - Brigitflex, Inc
  - Compunetics
  - i3 Electronics
  - Electrotek Corporation
  - FTG
  - Hallmark Circuits Inc.
  - Hughes Circuits
  - KCA
  - Marcel Electronics Int'l
  - Printed Circuits Inc
  - Sanmina CM & O
  - Speedy and Metro Circuits
  - Streamline
  - Triangle Labs
  - TTM Staf & SA
  - Unicircuit
  - Viasystems ANA, NJO,
    - OR
  - NetVia Group

- **WW PWB Manufacturers**
  - Cimulec
  - Ciretec
  - Daeduck
  - Fastprint
  - KCC
  - OK Print
  - Optiprint
  - Sanmina Singapore
  - Simmtech
  - Somacis
  - Stevenage
  - Suntak
  - Tripod
  - Wrekin Circuits Ltd

Resistor Calculator Example

Ticer Resistive Foils TCR® Designer's Guide

Variables: Resistor Value, Power Dissipation, Tolerance, & Etch Tolerance **Calculates**: Baseline Resistor Width & Length

METRIC (microns)

A-Input Resistor Specifications (Table 1)

Step 1: For each resistor enter the resistor value (R) in ohms, its power dissipations (P) in mWatts, and the maximum allowable tolerance ***(t)*** in percentage (%). Note: Tolerances below 5% will output a value less than the TCR® material tolerance.

Table 1

	R_1	R_2	R_3	R_4	R_5	R_6
Resistor Value (Ohms)	100	1000	10000	15000	67000	100000
Power Dissipation (mWatts)	60	60	60	60	60	60
Tolerance (%)	10	10	10	15	15	20

B-Input Width and Length Etch Tolerances. Available from PWB Fabricator. (Table 2)

Step 2: Width and Length Etch Tolerances (E) based on PWB fabricator data is input. Note: Default value = 12.7 um for 1/2 oz. copper

Table 2

	E (um)
Width Etch Tolerance	12.7
Length Etch Tolerance	12.7

C-Recoumended Length (L) and Width (W) of resistors by corresponding sheet resistivity (Table 3)

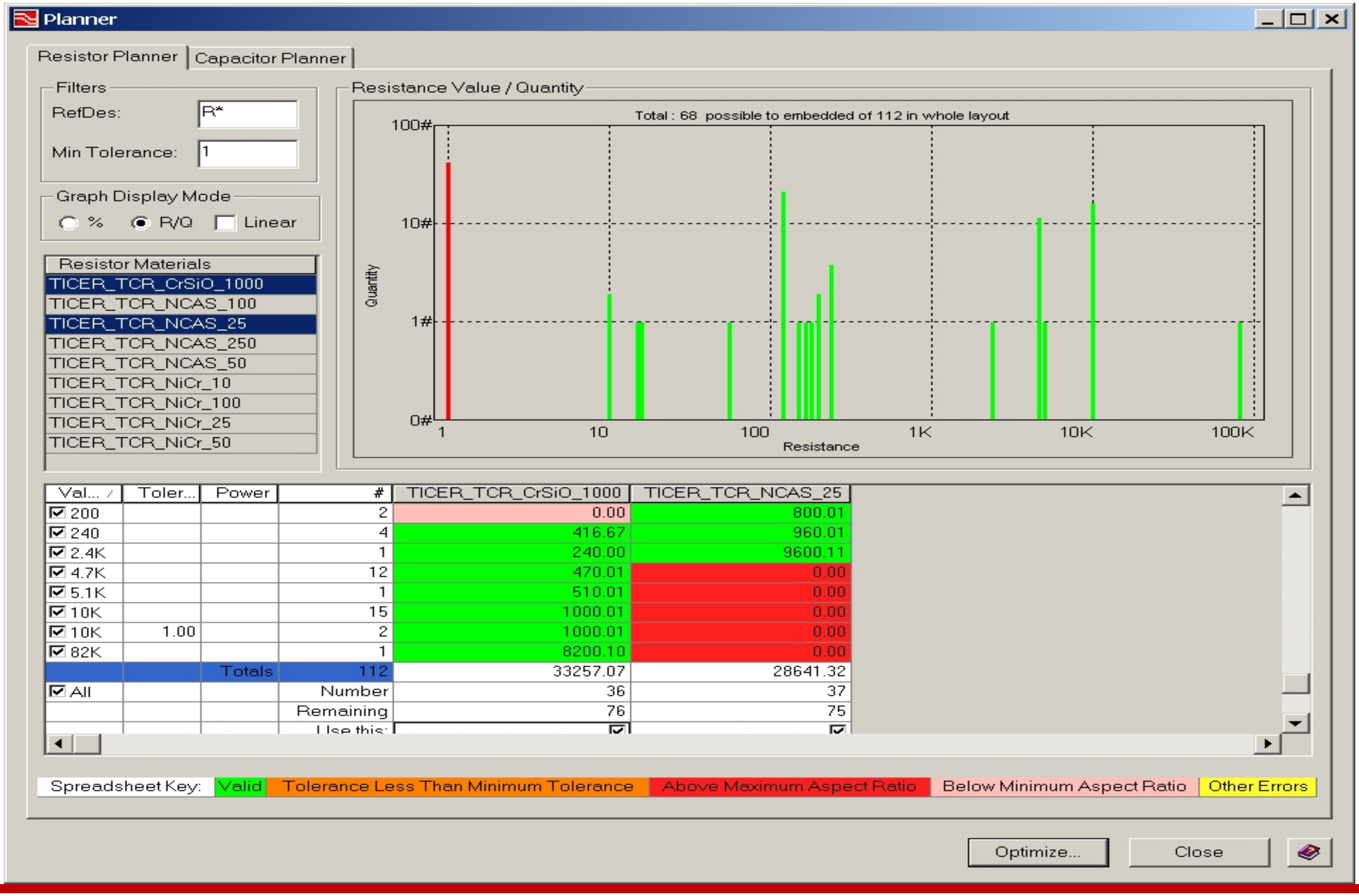
Step 3: Length and Width of the resistors are calculated for the different sheet resistivities.
Review for acceptability for each sheet resistivity against design rules

Table 3

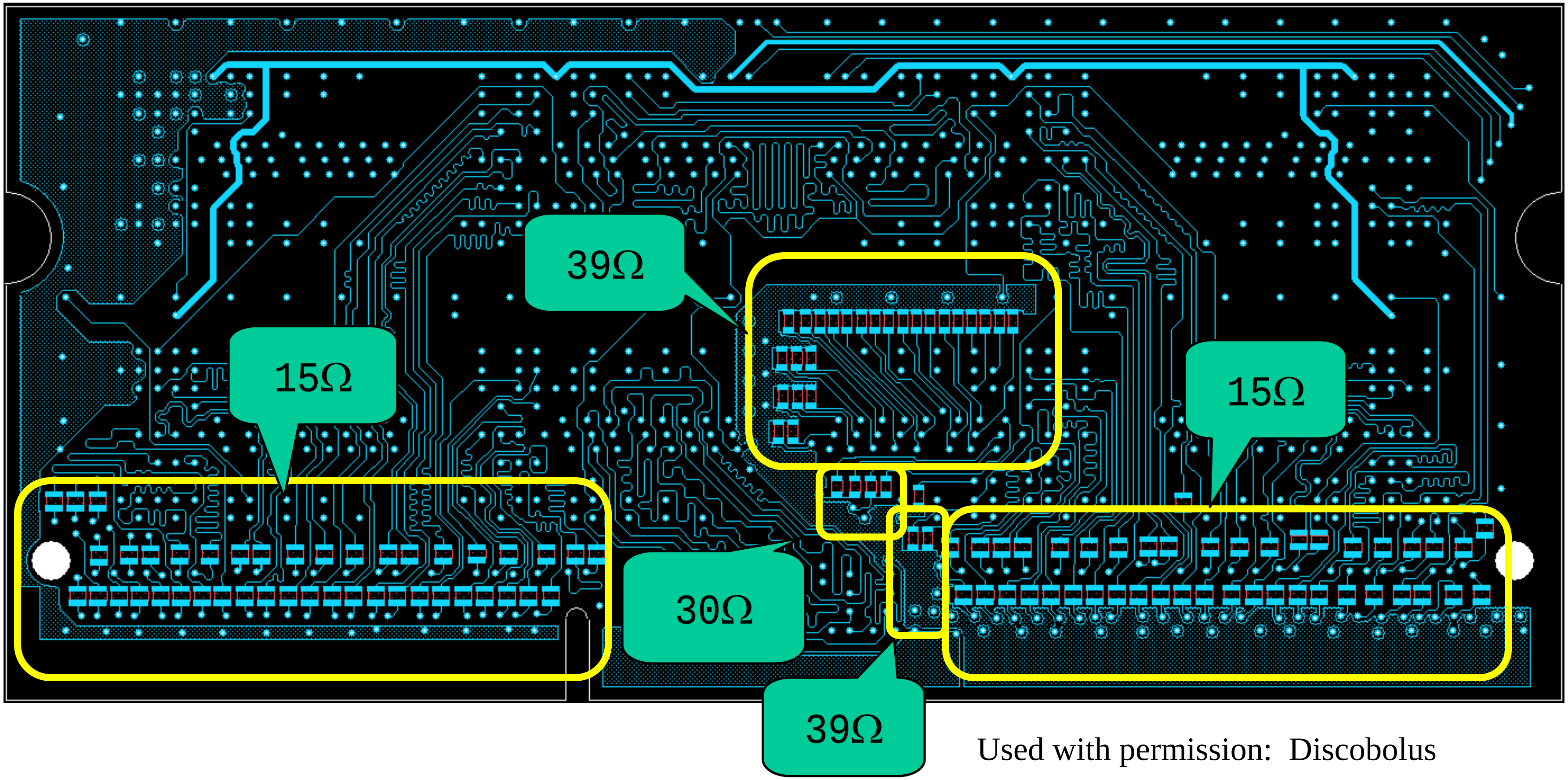
Sheet Resistivity	*R1*			*R2*			*R3*			*R4*			*R5*			*R6*	
	W1	*L1*		*W2*	*L2*		*W3*	*L3*		*W4*	*L4*		*W5*	*L5*		*W6*	*L6*
Ohms/Square (OPS)	*(um)*			*(um)*			*(um)*			*(um)*			*(um)*			*(um)*	
25	311	1245	*t**	255	10210	*t**	250	99857	*t**	126	75571	*t**	126	337116	*t**	84	336508
50	374	747	*t**	261	5229	*t**	250	50053	*t**	126	37849	*t**	126	168621	*t**	84	168296
100	531	581	*P**	274	2739	*t**	252	25151	*t**	127	18987	*t**	126	84373	*t**	84	84190
250	872	349	*t**	311	1245	*t**	255	10210	*t**	128	7670	*t**	126	33825	*t**	84	33726
1000	2739	274	*t**	498	498	*t**	274	2739	*t**	134	2012	*t**	128	8551	*t**	85	8495

*L and W are constrained by power dissipation ***(P)*** or tolerance ***(t)*** requirements

MG Expedition Planner Tool

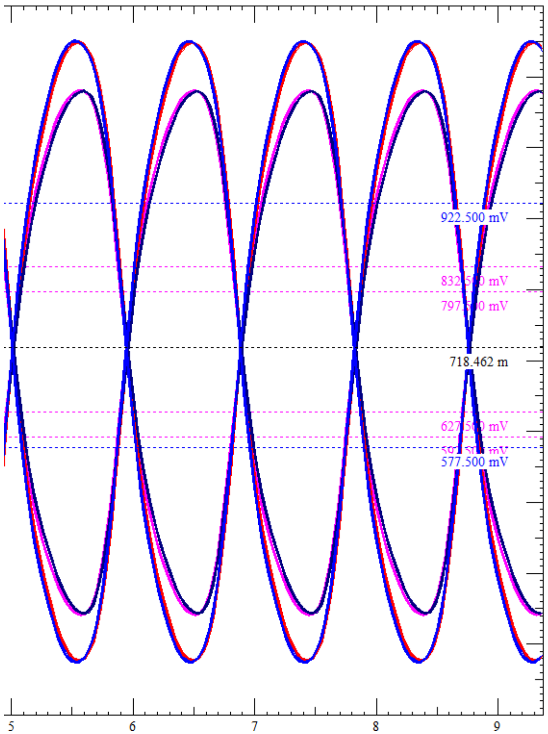


SODIMM Redesign with ER



Used with permission: Discobolus

Impact of ±33% RS Tolerance



Simple 1010 pattern
Slow & fast corners

RED = +33% (20Ω)
BLUE = -33% (10Ω)

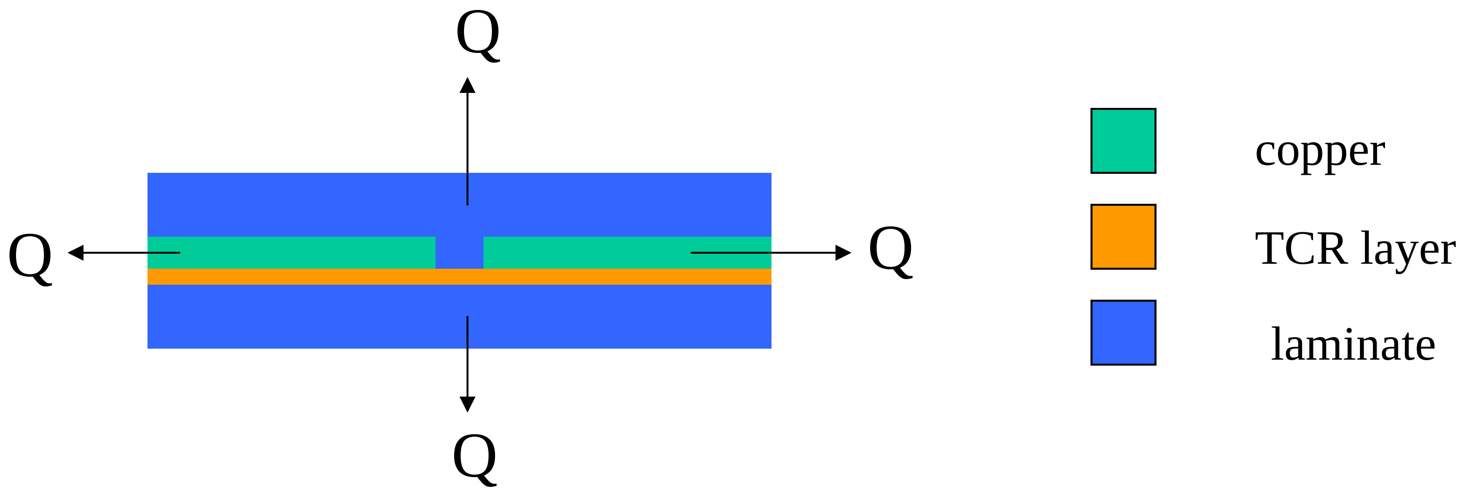
No measurable impact to timing
15% tolerance is acceptable

Courtesy of Discobolus Designs

Power Handling

- The power handling capability of a thin film embedded resistor is a thermal management issue
  - The power handling capability is a function of the resistor's size and shape, and the printed wiring board construction
  - It is the relatively low degradation temperature of organics that makes thermal management important

What influences power handling?



1. Resistor size and shape
2. Thermal conductivity & surface area of materials
3. Temperature limits of PWB materials
4. Environmental temperature

Steady State Heat Transfer

Conduction through board: $Q = k A_1 (Tr - Ts) / d$

Convection from board: $Q = UA_2 (Ts - To)$

Q = heat in watts, Tr = Resistor Temperature, k = thermal conductivity,
A_1 = resistor area, A_2 = board area, U = heat transfer coefficient
Ts = surface temperature at outer layer, To = Environmental Temperature

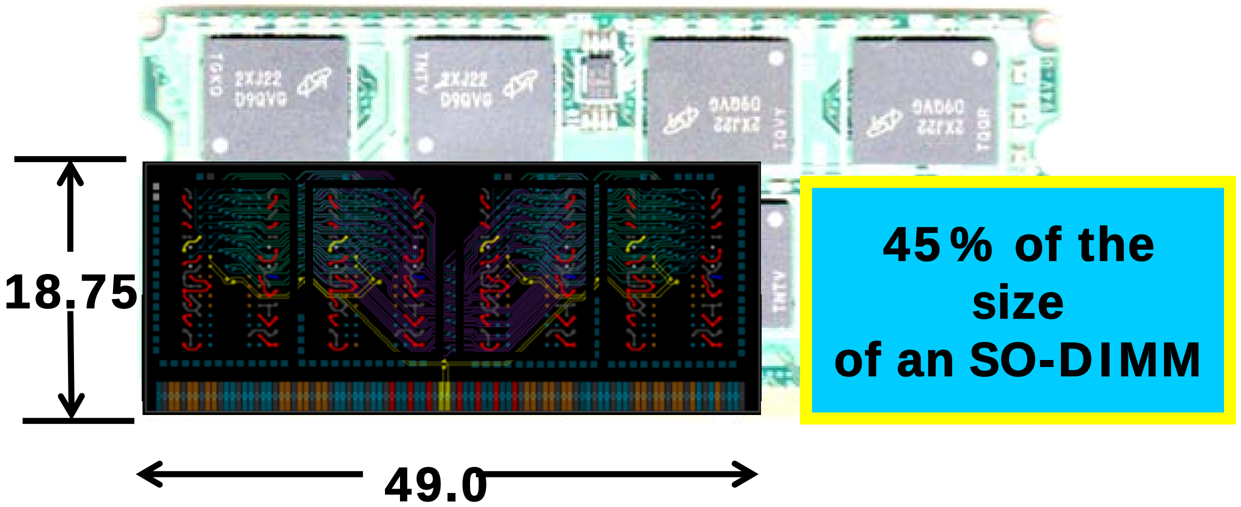
To avoid resistor failure:

Tr < Tmp of resistor material (e.g. NiCr ~ 1400 C)
Tr < Tg surrounding organics (e.g. FR4 ~ 170 C)

Therefore, the surrounding organics influence the maximum heat allowed

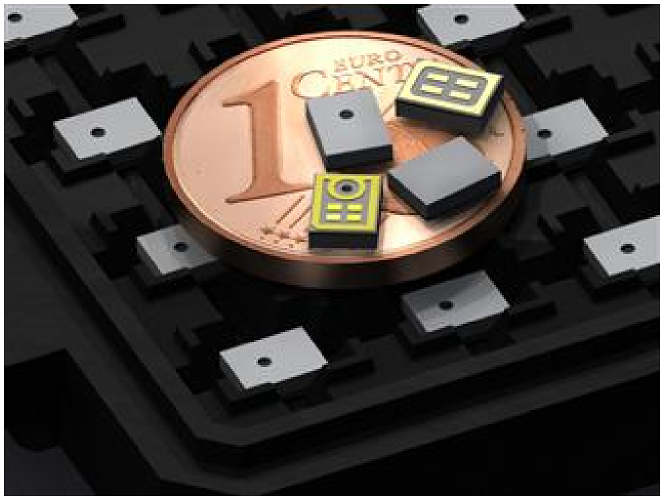
DDR3 SODIMM SMT resistors replaced w/ 25 ohm TCR ®

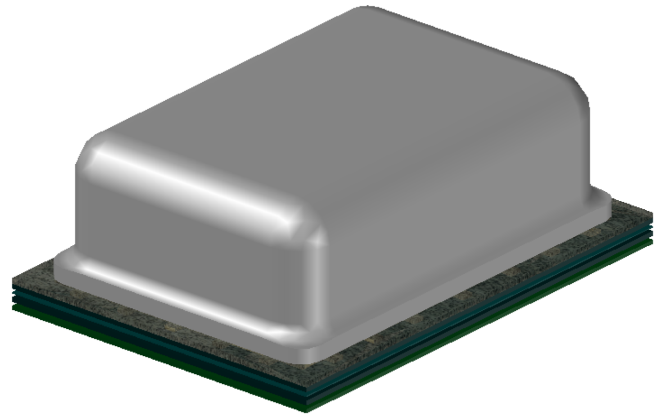
Miniaturization of Memory Modules MICRO DIMM

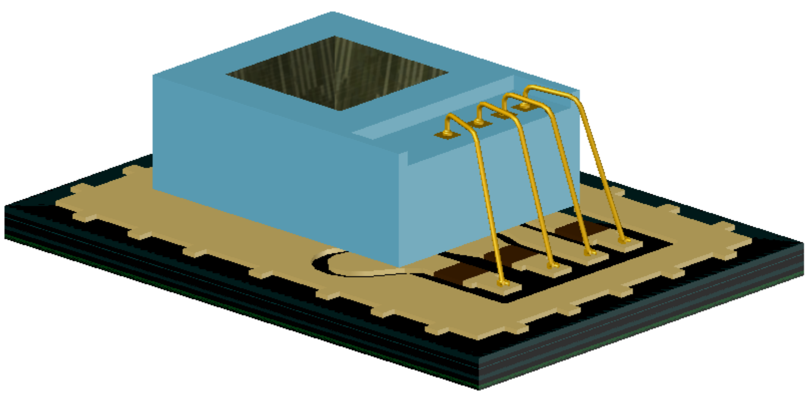


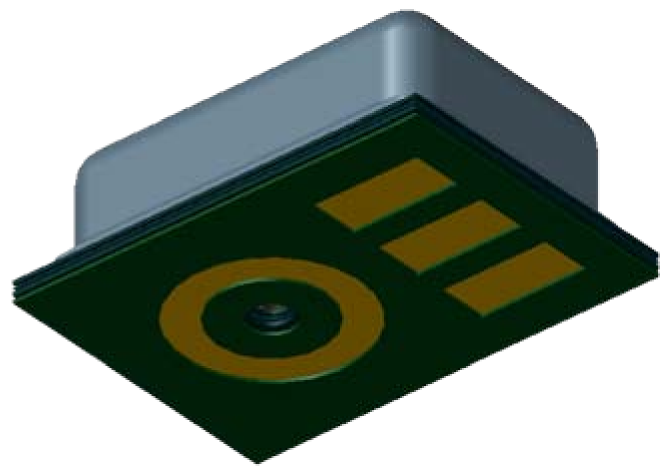
Required termination impossible with surface mount

MEMS Microphones



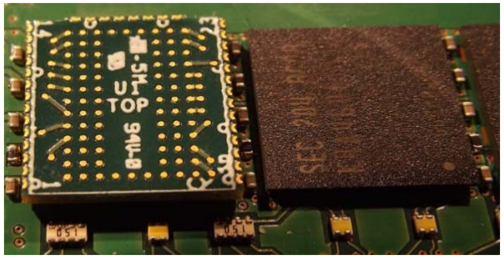




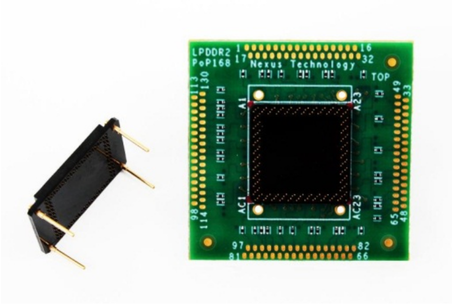


Courtesy of Amkor

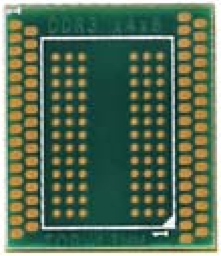
Test Instruments: Interposers



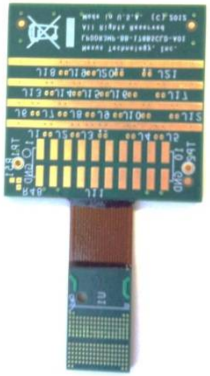
Solder Down Interposer with
Edge Style Probing



Socketed interposer for PoP packages

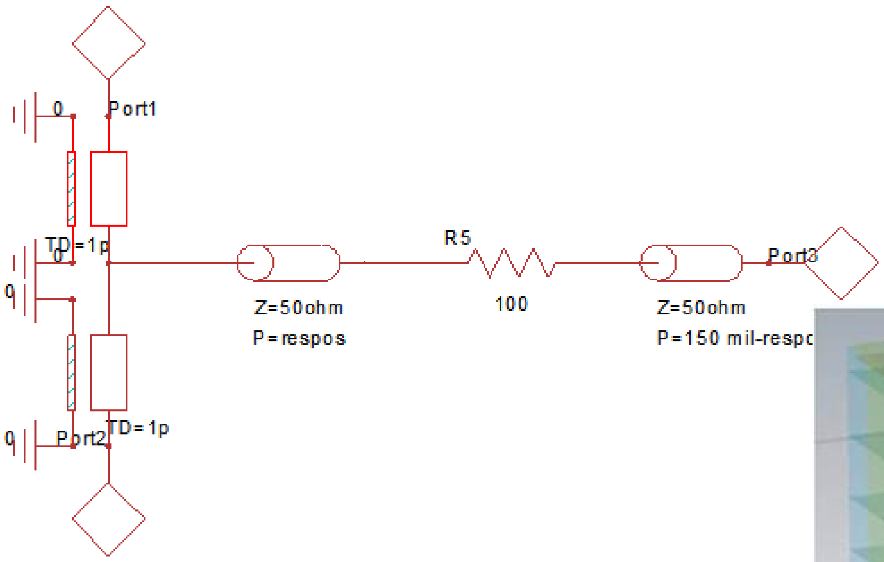


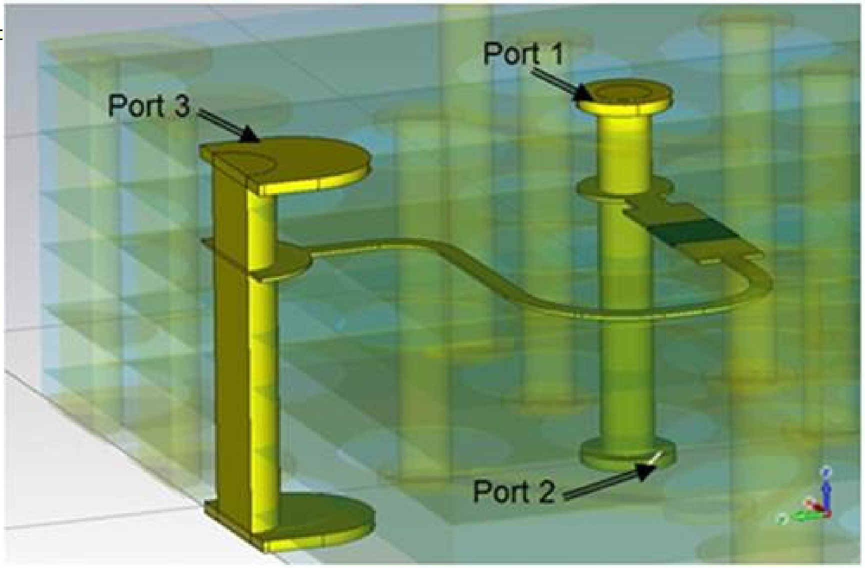
Solder Down interposer with
Probe Pads



Socketed interposer with Probe Pads

Improved Electrical Performance
Test Instruments Interposers

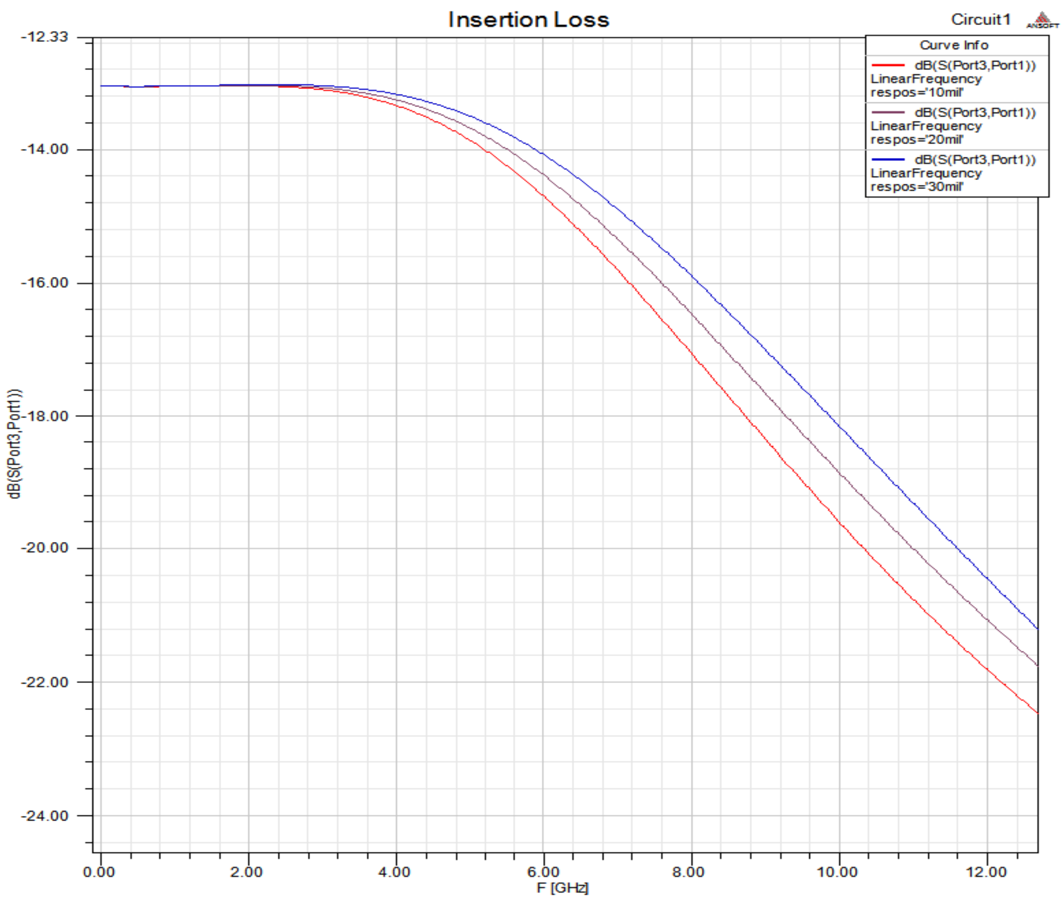




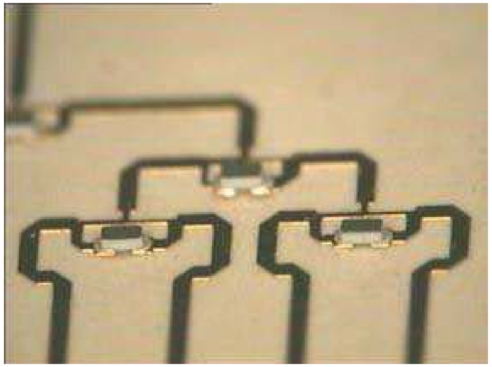
Courtesy of Textronix

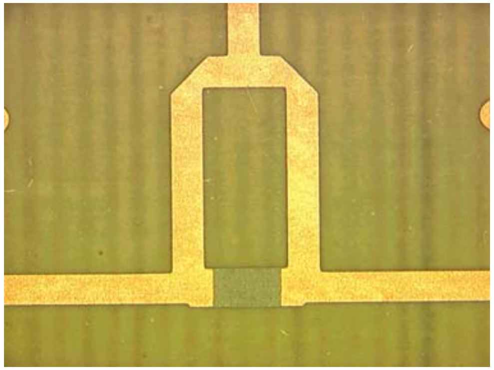
Improved Electrical Performance

- Models the insertion loss based on placement of Isolation resistor
- Resistor closer to Via has better response than the one further away



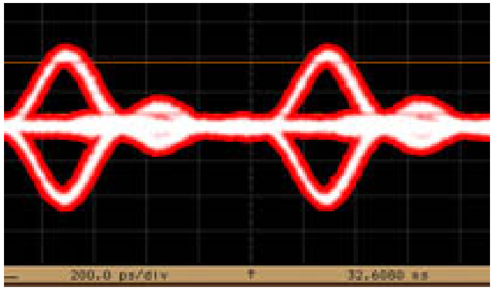
Radar-Wilkinson Divider



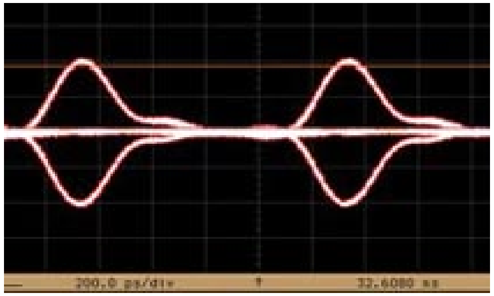


Improved Signal Performance with Embedded Resistor

50Ω SMT resistor



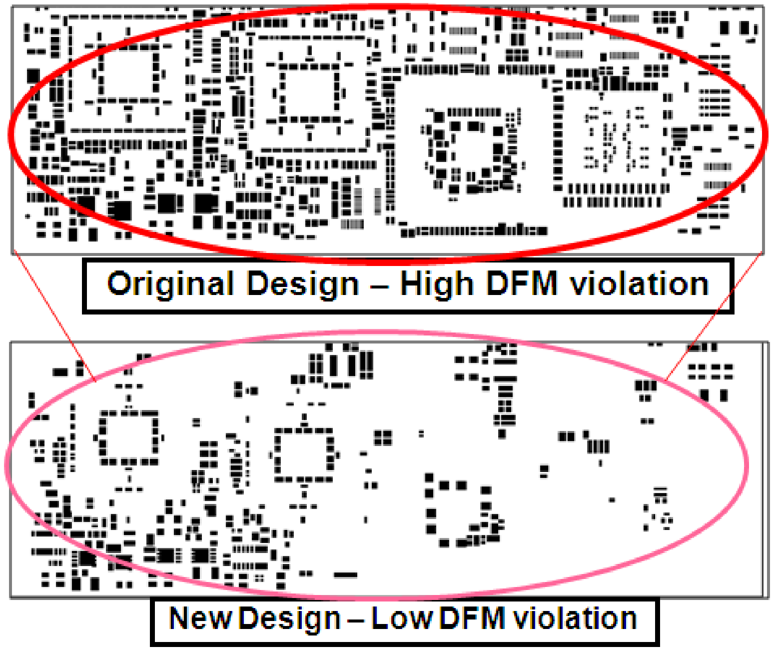
50Ω embedded resistor



Courtesy of Applied Laser Technology

Aerospace – Digital Signal PWB

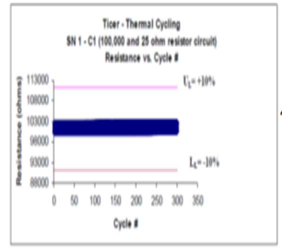
- Generated 4 different layers of embedded materials
  - 2 Resistance layers – 25Ω and 1kΩ
  - 2 Capacitance layers
- Polyimide and FR4 materials were used
- Eliminated 985 surface mount components
- Laser trimming used to achieve 1% tolerance on 1kΩ



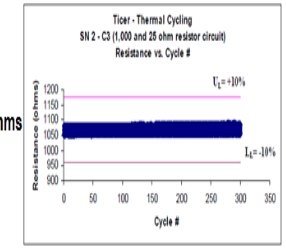
Courtesy of Honeywell

Aerospace Reliability

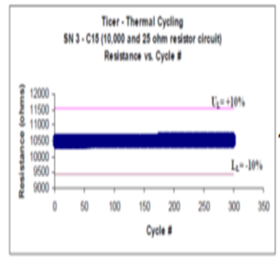
- **Testing:**
  - **Board testing from two different suppliers**
  - **Coupon were defined to be ESD protected and Non ESD protected**
  - **300 Thermal cycles to simulate life cycles, 20 years were used to validate reliability**
- **Test Parameters:**
  - **Thermal Cycling -55°C to 125°C for 300 cycles simulating 20 year life cycle**
  - **ESD controlled test**
  - **No ESD controlled test**
  - **<u>HASS and HALT (50 years) were used to validate reliability</u>**
- **Results:**
  - **Supplier selection of Ticer embedded material**



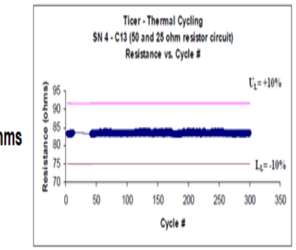
100k & 25 ohms



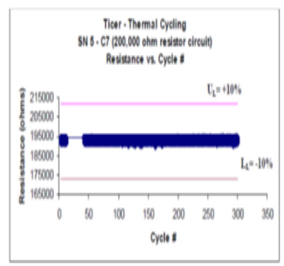
1k & 25 ohms



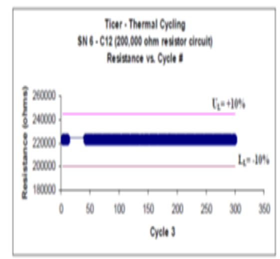
10k & 25 ohms



50 & 25 ohms



200k mixed



200k mixed

Embedded Passive Technology: Hikmat Chammas

APEX EXPO IPC 2013 INFORMATION that INSPIRES INNOVATION

Summary and Conclusion

- Product miniaturization is the standard for electronics packaging
  - Drives design complexity and producibility challenges
  - Drives significant hidden cost
  - Packaging challenges (10 lb in 2 lb container)
- These technologies will provide:
  - Yield improvement and cost reduction
  - Reduce manufacturing cycle time
  - Reduction in number of components
  - Reduction in complexity and DFM violations
- Future work aimed at implementation of HDI and EP
  - These technologies are needed to meet the increased functionality demands
  - Tools have been developed to evaluate design for technology implementation
  - Guide technology insertion evaluations for HDI and EP and implement

These enablers provide the means to meet demand for miniaturization

Courtesy of Honeywell

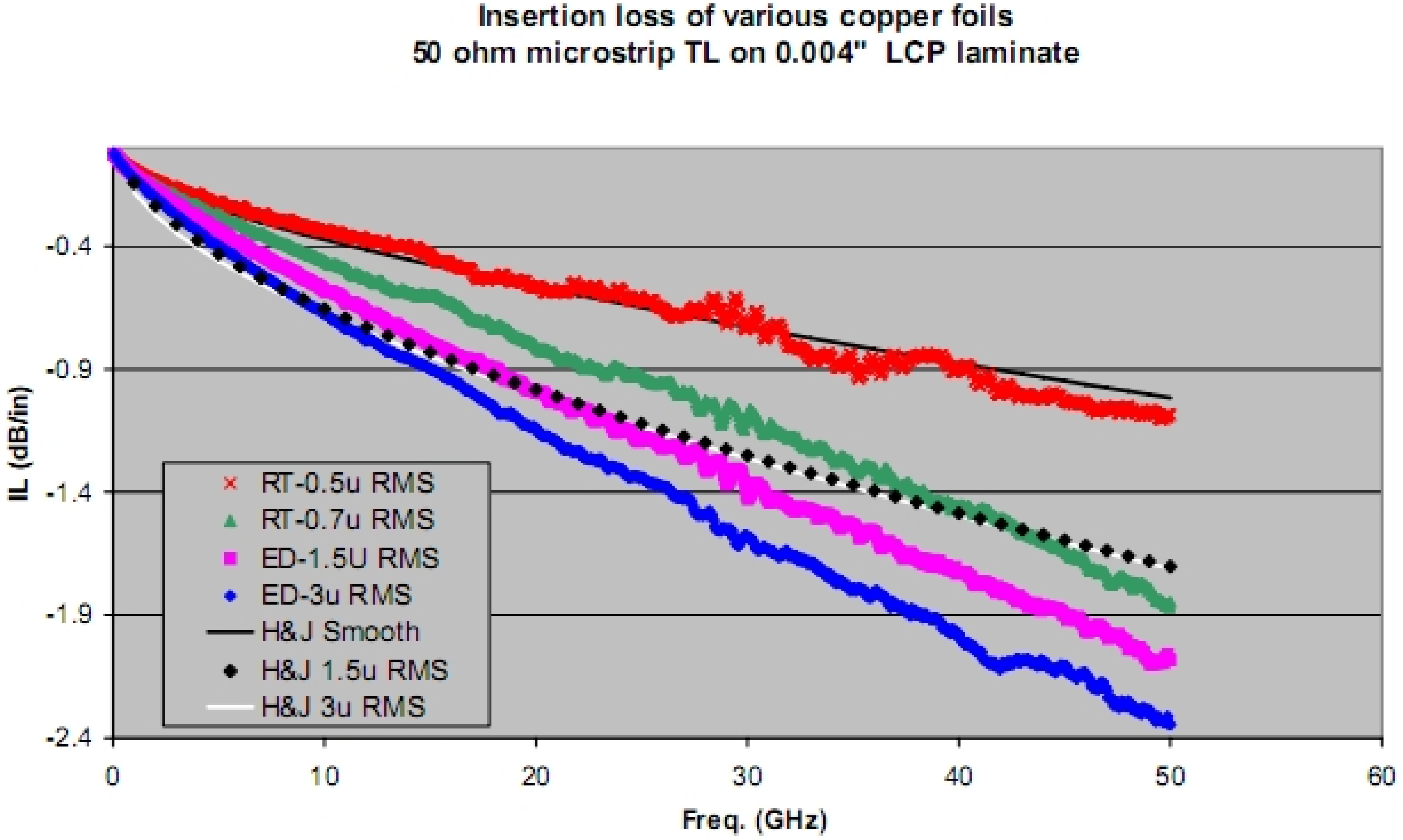
TCR-HF

Resistor Foil for Reduced Insertion Loss

Introduction

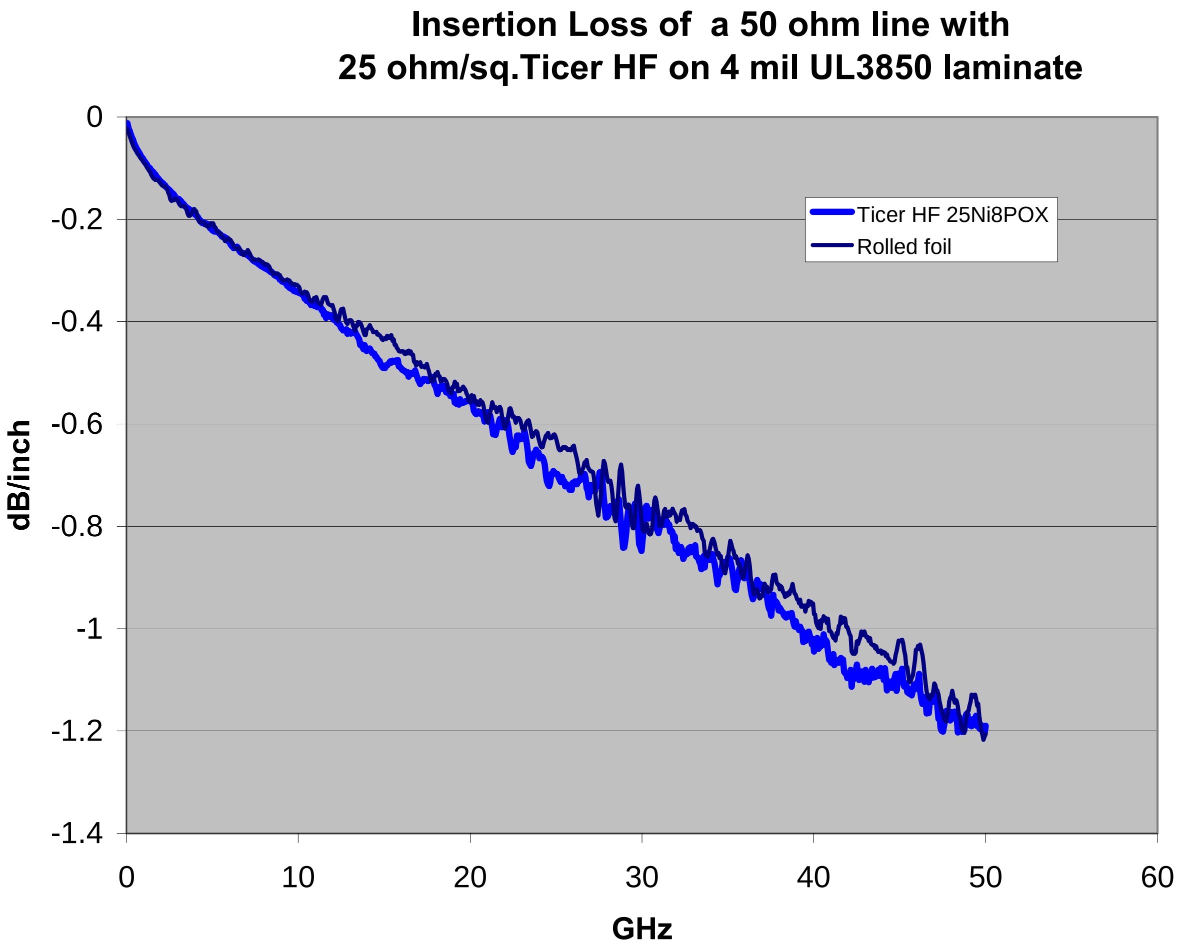
- TCR-HF is a thin film embedded resistor foil targeted for high frequency applications using PTFE laminates
- TCR-HF combines a proven nickel chrome resistive layer with a smooth copper foil conductor to reduce insertion losses

Rogers work



Effect of conductor profile….Horn, Et.Al.

Insertion Loss of TCR-HF Resistor Foil



With permission, Rogers Corp. – A. Horn

Adhesion of TCR-HF

Peel Strength (pli)

	FR-4	**CLTE XT**
TCR	3.0	**6.7**
TCR HF	2.4	**10.0**

Surface Roughness Measurement

- Wyko non-contact surface roughness

	Rq(u)	Factor
– JTCS	1.4	1.00
– TCR	0.83	.59
– **TCR-HF**	**0.48**	**.34**
– RA treated	0.4-0.5	.29 -.36

TCR-HF summary

- TCR-HF has insertion loss characteristics comparable to rolled foil
- TCR-HF peel strength is >5 pli on PTFE laminate systems

- 25 and 50 OPS available

Conclusion

- Use of embedded resistor technology frees up surface space while improving performance and reliability
- Supply chain for thin film embedded resistors is in place
- Software solutions to design embedded resistors are available
- Commercial applications are expanding

Reference

- Embedded Resistor for High Performance Memory Solutions. Memcom 2012. Bill Gervasi. Discobolus Designs
- Test Implications for SoC Designs utilizing LPDDR. Memcom 2012. Prashanth Thota. Textronix.
- Embedded Passive Technology. IPC Expo 2013. Hikmat Chammas. Honeywell International.

www.ticertechnologies.com

www.TICERTECHNOLOGIES.com

TCR

Next Generation Integrated Thin Film Resistor

Integrated thin film resistor benefits
- Increases active component density and reduces form factors.
- Improves signal routing through elimination of SMT vias.
- Improves reliability through elimination of solder joints.
- Shortens cycle times in PCB assembly.

High speed bus design benefits
- Improves line impedance matching.
- Shortens signal paths and reduces series inductance.
- Eliminates inductive reactance associated with SMT passive devices.
- Reduces EMI, crosstalk and noise.

Resistor stability during thermal excursion
- Low temperature coefficient of resistance.
- Improves resistor tolerance.
- Long term performance and reliability.

Utilizes existing PCB processes.

Uniform isotropic material properties.

Better than ± 10% resistor tolerances demonstrated after fabrication.

Laser trimmable to tolerances ±1%.

Capacity in place to meet volume needs.

OVERVIEW

TCR® thin film resistor foil was developed to meet the ever increasing challenges of packaging high speed, high density electronic devices. Integrating passive components into the circuit board using TCR foil can quickly and reliably improve electrical performance and give designers the edge they need. The TCR technology combines well characterized materials from the semiconductor industry with established copper foils and proprietary vacuum metallization technologies to provide a robust solution for both designers and printed circuit manufacturers.

TCR is offered with enhanced bonding properties, for all resin systems, with a resistive material applied to the matte side of shiny or Doubletreat (DT) using roll-to-roll vacuum deposition technology. The resistive material layer is uniform in composition and deposition thickness ensuring consistent results. Sheet resistance is isotropic and its variation within a roll and between rolls is less than ±5% for all resistance values. The resistive layer is a true thin film with thicknesses from 0.01 to 0.1 µm.

The Grade 3 foil used for TCR is the foil of choice for this application. Grade 3 copper foil exhibits excellent ductility at elevated temperatures, and like standard Grade 3 foils, withstands stresses near the edge of the plated through holes without cracking. These characteristics minimize the need for thermal and mechanical isolation in embedded resistor designs.

TCR foils are commercially available today through Ticer's manufacturing location in Chandler, Arizona. Tests by major PCB companies demonstrate consistent and reliable performance. Toolsets, including design guidelines, a resistor calculator and processing guidelines, are available to designers and fabricators via the Ticer web site.

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Requests for information can be sent to INFO@TICERTECHNOLOGIES.COM. Learn more at www.TICERTECHNOLOGIES.com

www.TICERTECHNOLOGIES.com

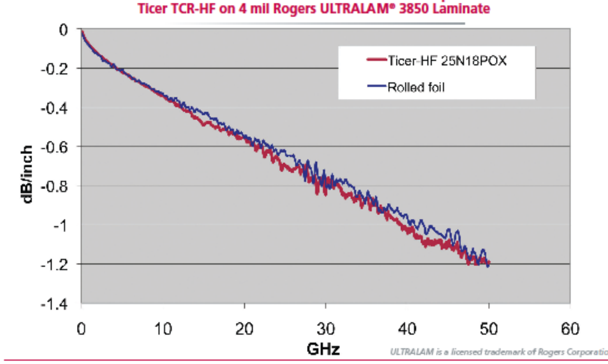
TCR-HF

High Frequency Integrated Thin Film Resistor

Features
- Smooth copper surface
- Rq roughness by Wyko: TCR-HF 0.48 µ vs. rolled foil 0.4 to 0.5 µ
- Minimal impact of resistor layer on insertion loss
- Peel strengths > 5 PLI on PTFE
- Available up to 51" width
- ½ oz foil – single side treatment

Benefits
- Great for high frequency applications
- Low insertion loss – comparable to rolled foil
- Resistance stable/reproducible after thermal excursion
- Utilizes existing PWB processes
- Use with PTFE resin systems

Insertion Loss of a 50 Ω Line with 25 Ω/sq
Ticer TCR-HF on 4 mil Rogers ULTRALAM® 3850 Laminate



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