Embedded Thin Film Resistors

An Update on Current Applications & Design

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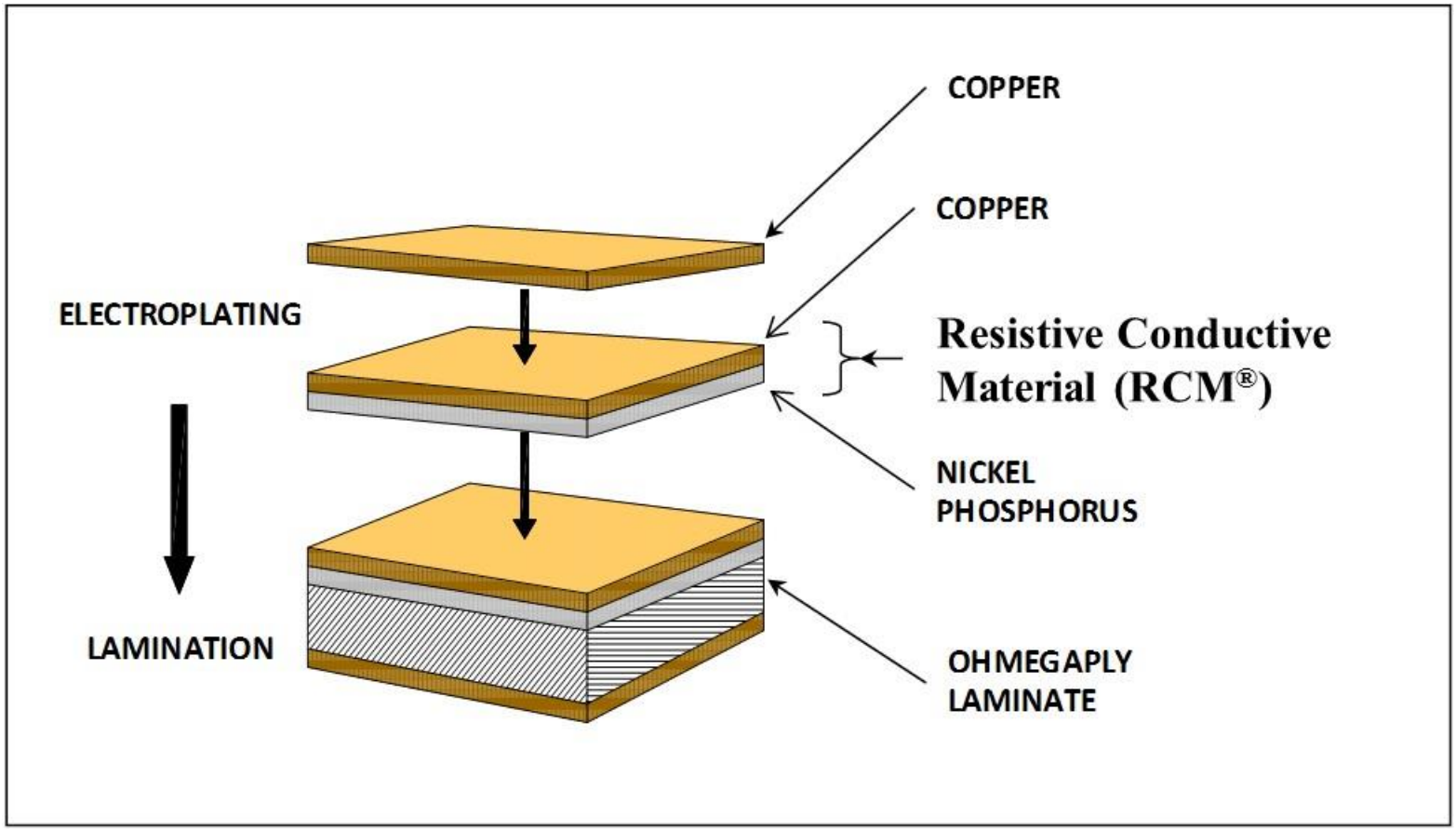
NiP Thin Film Resistive Material

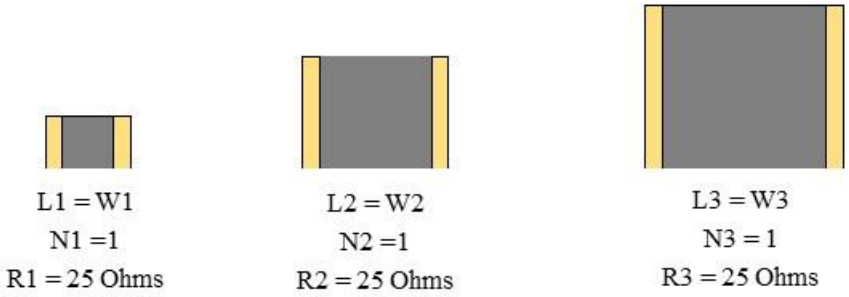


NiP Sheet Resistivity Offerings

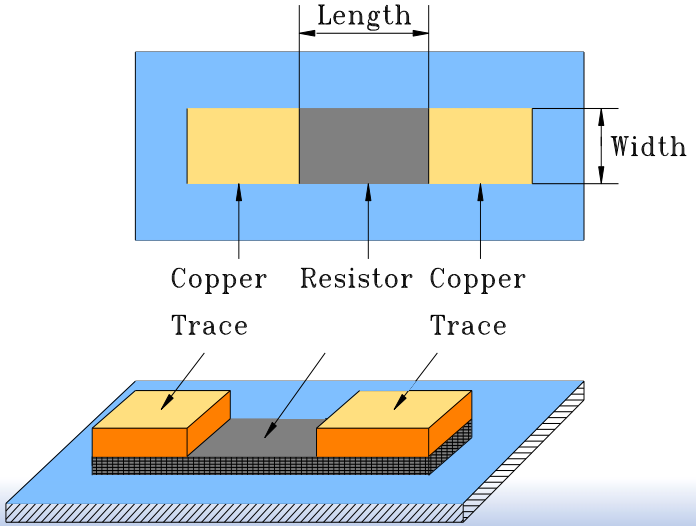
Sheet Resistivity (Ω/□)	Material Tolerance (%)	Typical Applications
10	3	Series termination, impedance matching, planar heaters
25	5	Series/parallel termination resistors, power dividers, filters
40	5	
50	5	
100	5	Pull-up/pull-down resistors
250	10	High ohmic applications

Basic Design Overview

- Sheet resistivity, stated in Ohms per square is dimensionless
  - A square area of resistive material equals the sheet resistivity of material

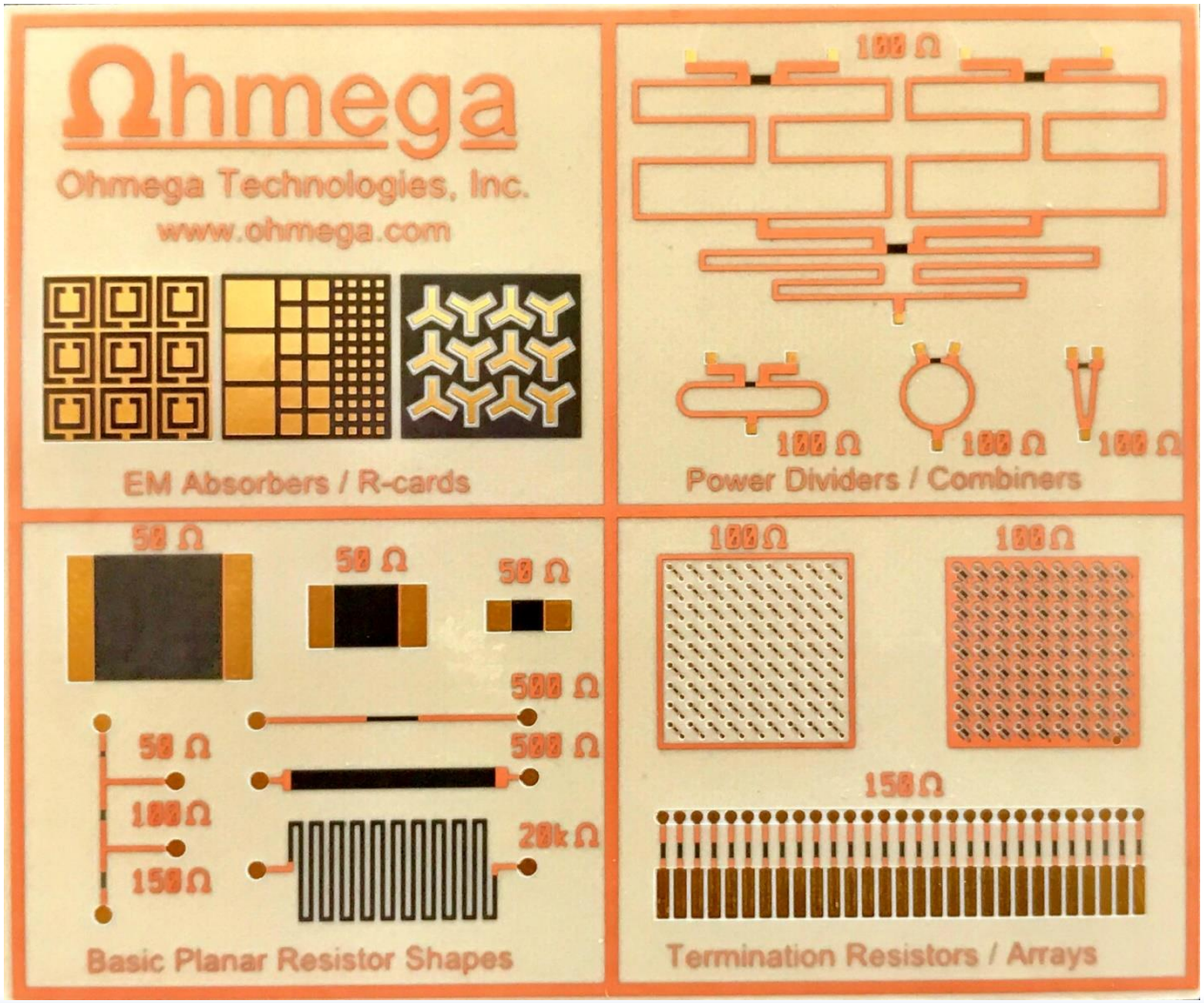


  - 25 ohms per square $(\frac{\Omega}{\square})$ sheet resistance
- Resistor value = sheet resistivity X ratio of element length to width
  - $R = R_s \times \frac{L}{W}$; where $\frac{L}{W} = number\ of\ squares\ N$
- For example:
  - Sheet resistivity (R_s) = 25 Ω/□
  - Length = 0.030” (30 mils)
  - Width = 0.015” (15 mil)
  - $R = 25\frac{\Omega}{\square} \times \frac{30\ mils}{15\ mils}\square$
  - $R = 50\Omega$



Ohms Per Square

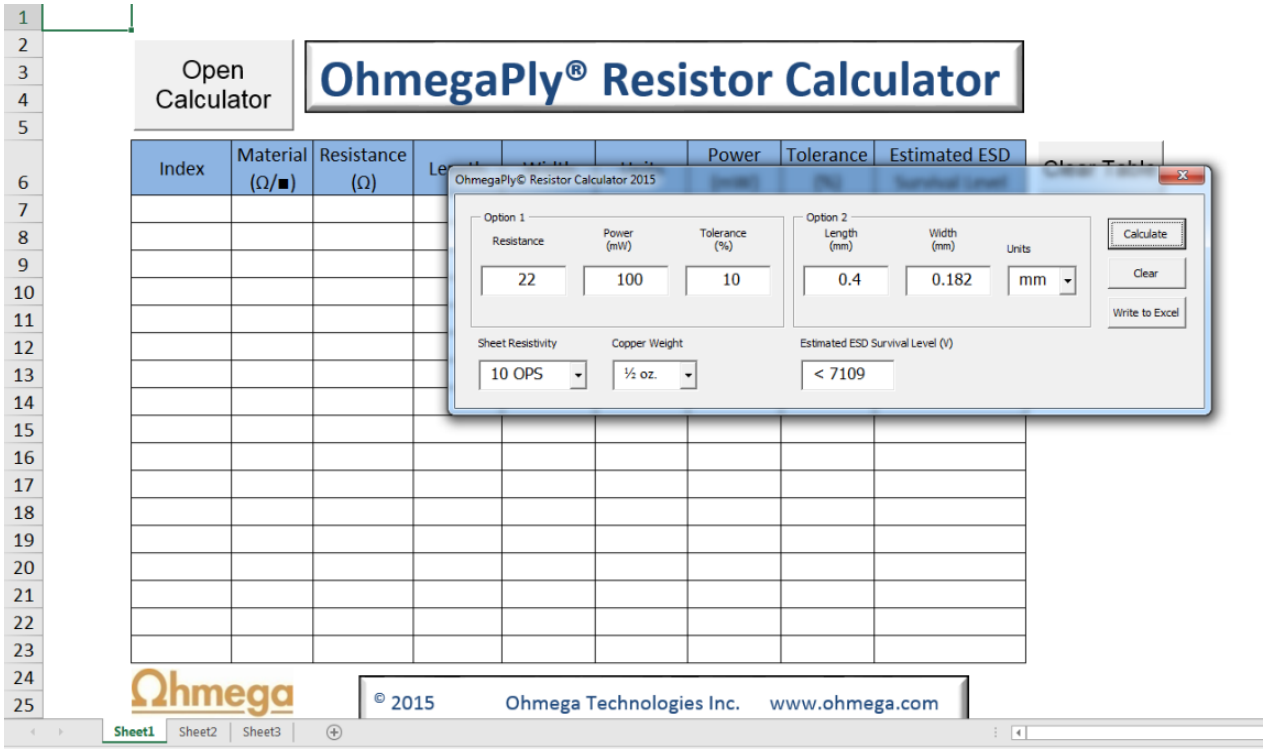
- Sample Circuit



Example Resistor Calculator

The tool provides the option of selecting resistance, power and tolerance to suggest resistor dimensions. Alternatively, resistor dimensions can be input to calculate resistance, power and tolerance.

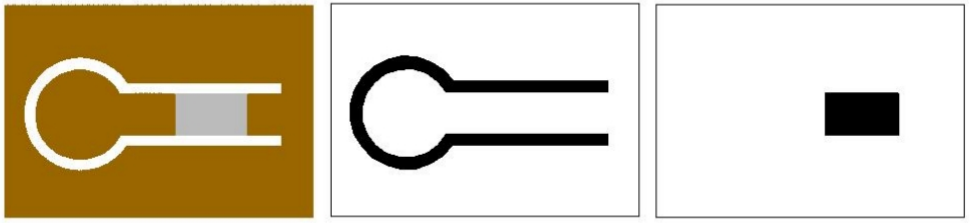
- The resistance values are accurate to the dimensions.
- The calculator power and tolerance values are approximate. There are many factors in the construction of the PCB that effect the power capability and tolerance.



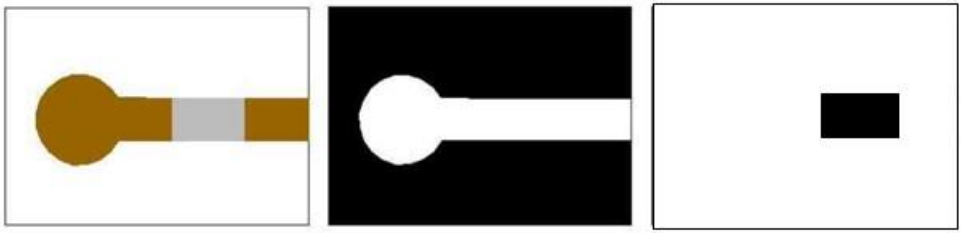
Two Print Artwork PCB Processing

Artwork layout

- NiP resistor processing consists of two prints:
  - 1st print – COMPOSITE image of conductors and resistors
  - 2nd print – RESISTOR DEFINE image of resistor elements



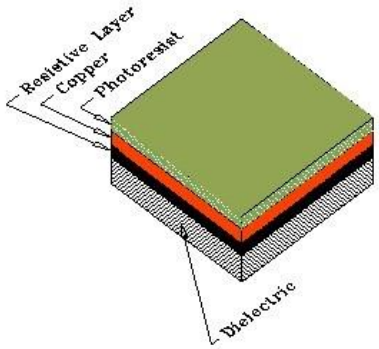
Composite (negative film) resistor define commonly used for voltage or ground plane with most of the copper preserved.



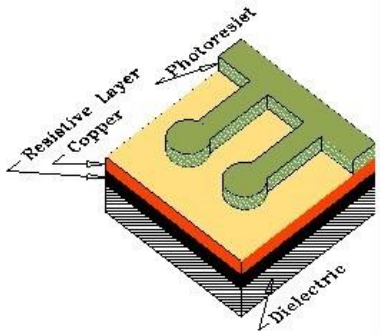
Composite (negative film) conductor protect commonly used for signal plane

PCB Processing of NiP Resistive Conductive Material

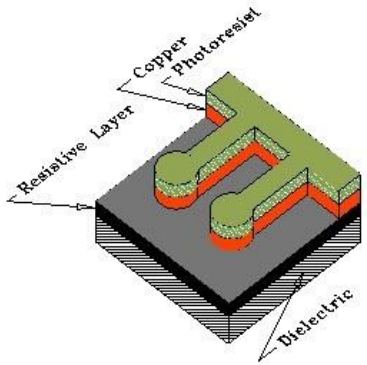
- **STEP 1**: Apply Photoresist to Laminate



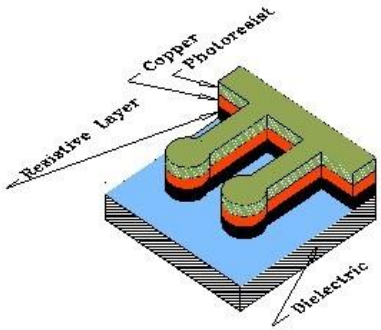
- **STEP 2**: Print and Develop Composite Image



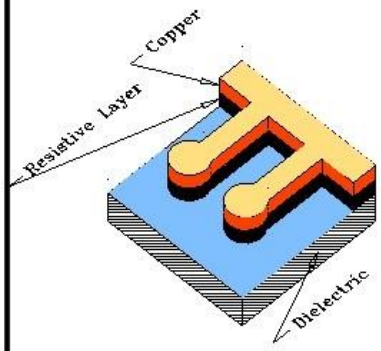
- **STEP 3**: Etch Unwanted Copper Using Any Conventional Etchant (1st etch)



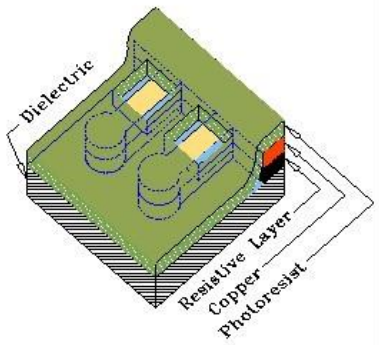
- **STEP 4**: Etch Unwanted Resistive Material with Copper Sulfate Solution (2nd etching process)



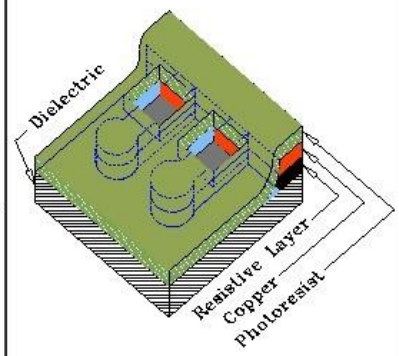
- **STEP 5**: Strip Photoresist



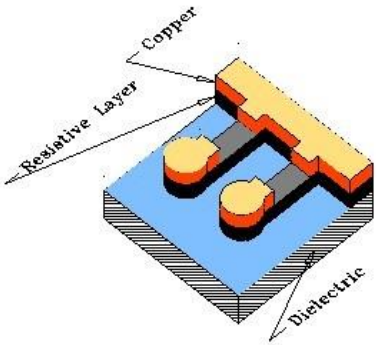
- **STEP 6**: Apply Photoresist, Print and Develop Conductor Protect Image (2nd print)



- **STEP 7**: Etch Away Copper Over the Designed Resistor Using a Selective Alkaline Etchant (3rd etch)



- **STEP 8**: Strip Photoresist



Why use Embedded Resistors?

- Density improvement – free up board area or reduce board size with elimination of discrete resistors
- Improve reliability in harsh environments by reducing number of solder joints
- Reduce parasitic inductance associated with surface mount chip resistors
- Eliminate vias and shorten critical signal path lengths by incorporating termination/impedance matching resistors directly into traces
- Placement of a termination resistor very close to the drive line
- Very small element sizes with subtractive PCB print/etch
- EMI improvement and improved fidelity in conjunction with a planar capacitor as an RC filter (example: MEMs microphone modules)
- Embedded or integral heaters at board level
- Many domestic and international board shops with established processing capability.

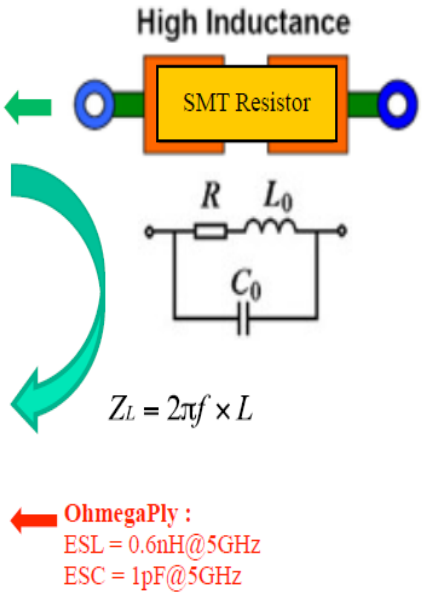
Performance Benefit of NiP Planer Resistor

- Reduction in parasitics compared to surface mount components.
  - Reduce metal-to-metal transitions associated with chip resistors
  - Reduce vias on critical nets

Typical parasitic inductance for a 0402 SMT resistor with 2 vias :

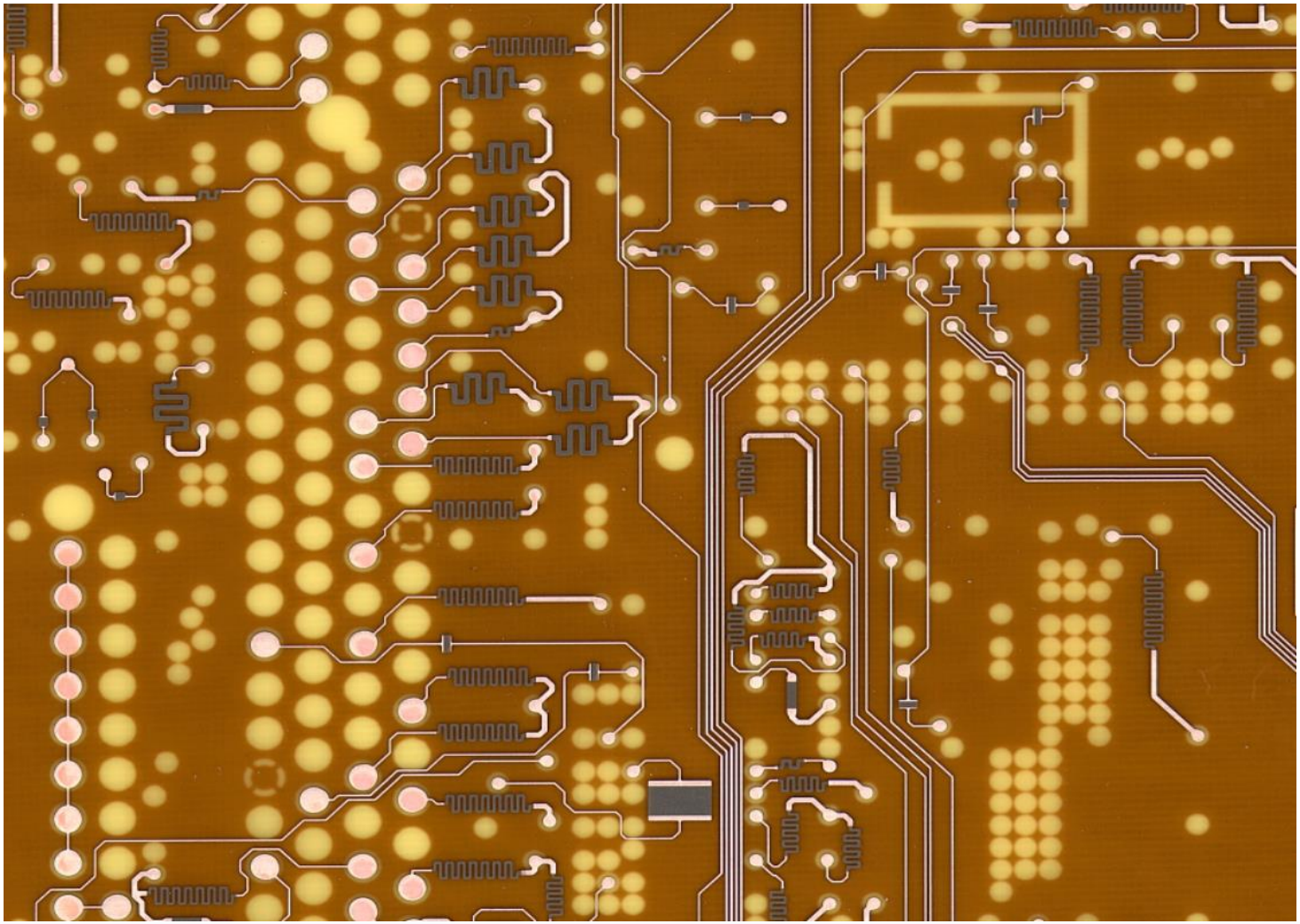
Item	Dimension	ESL (nH)
One SMT Resistor	0402	0.7
Two vias	h = 0.1in , d = 0.01in	4.76
Two traces	0.05in, 50ohms, FR-4	0.83
Total		**6.29**

Frequency (MHz)	Inductive Reactance of OhmegaPly-R (ohms)	Inductive Reactance of SMT-R (ohms)
500	**1.89**	19.76
1000	**3.77**	39.52
5000	**18.85**	197.6

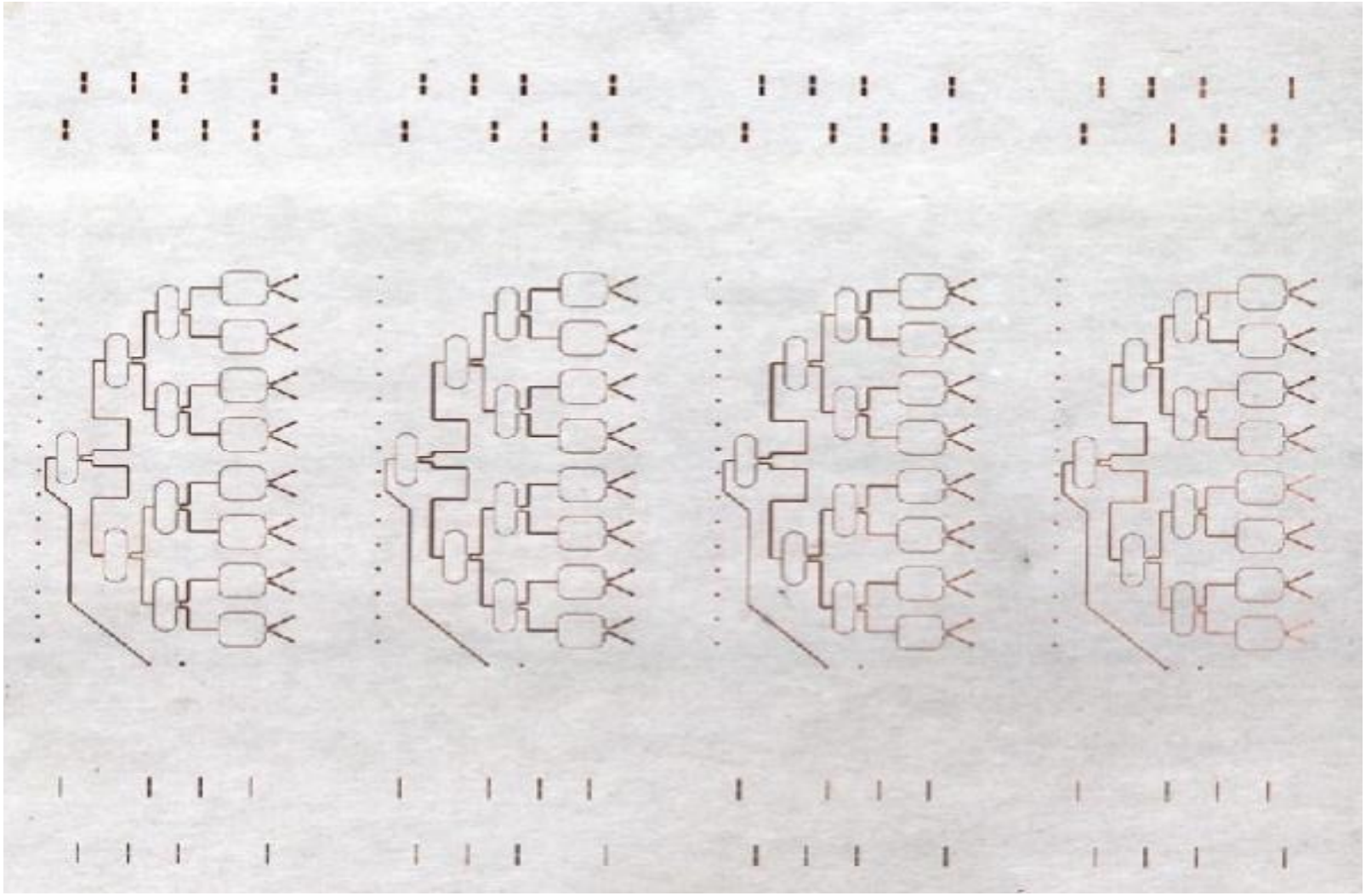


Example Applications

- Pull-up/down and termination resistors military/aerospace board



NiP Resistors in Microwave Applications



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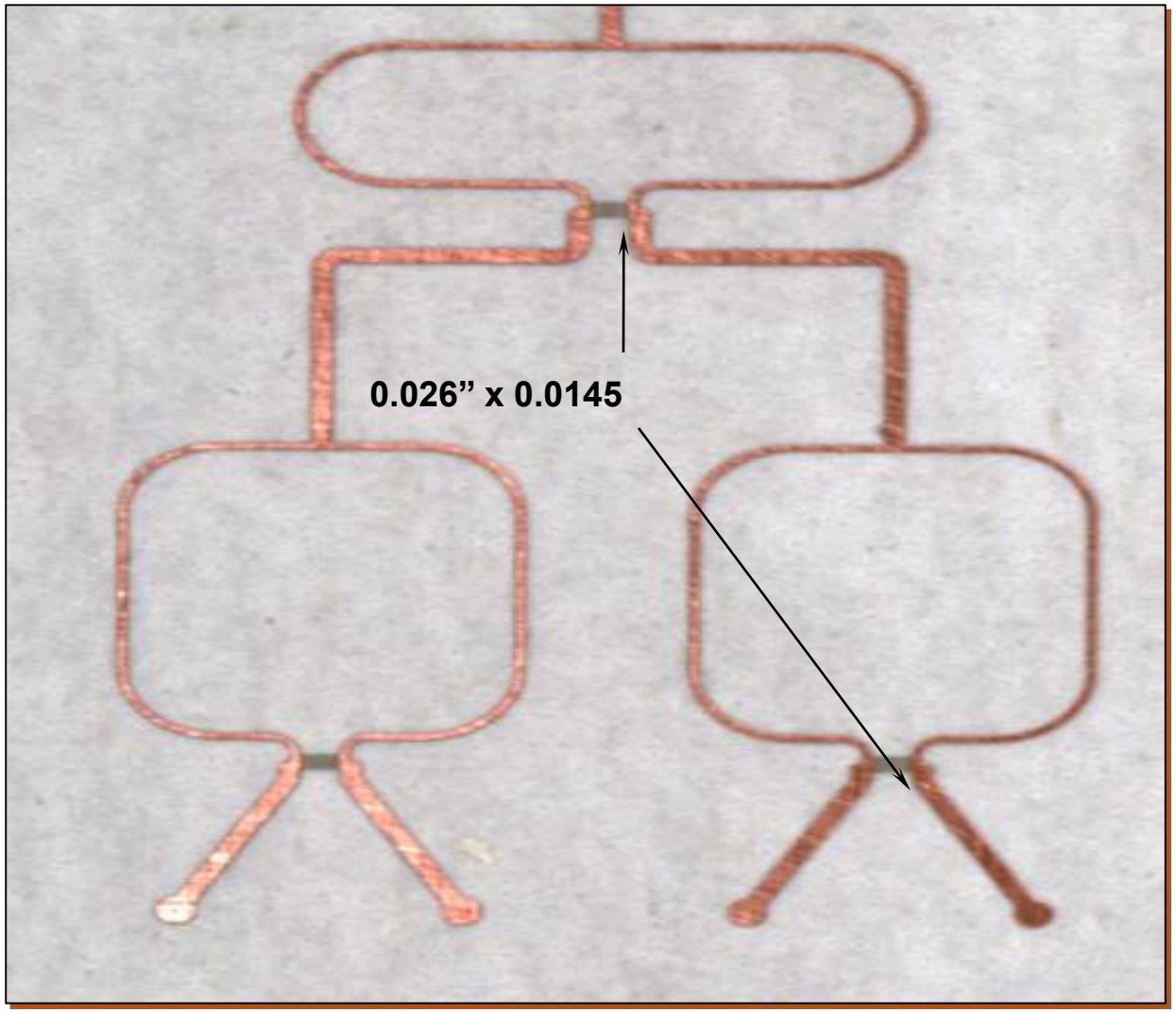
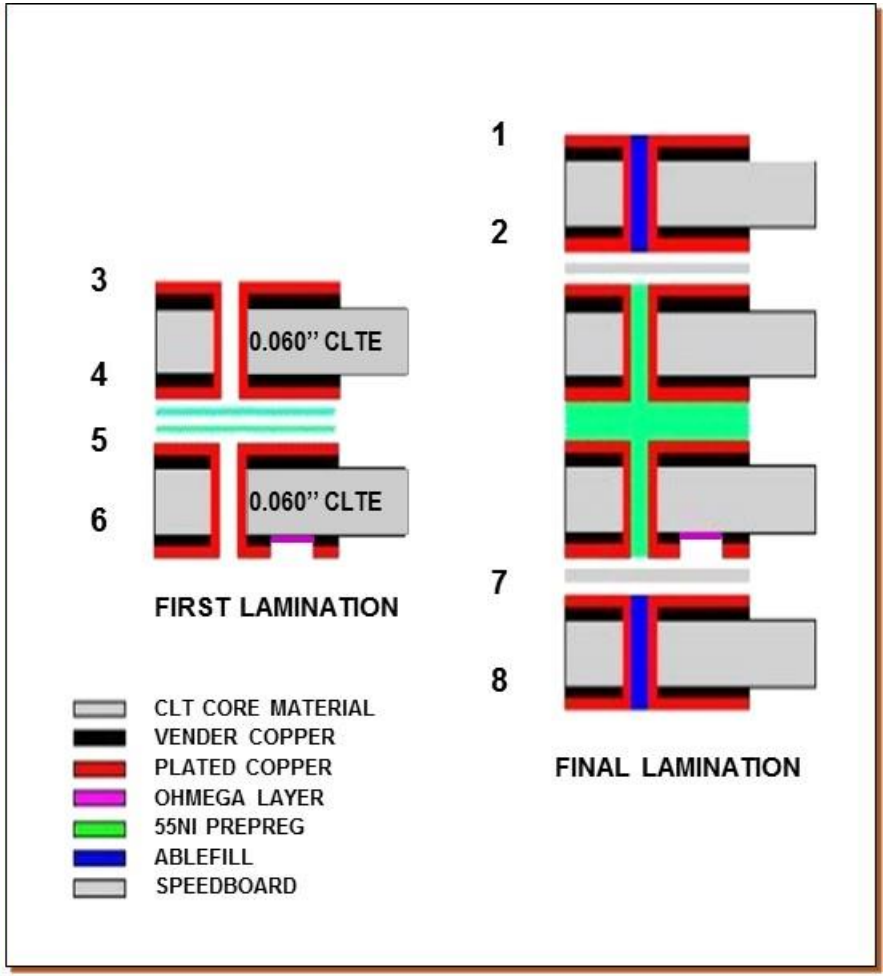


Enlargement of a four-up array 16-way power divider with 50 Ω/sq NiP resistors

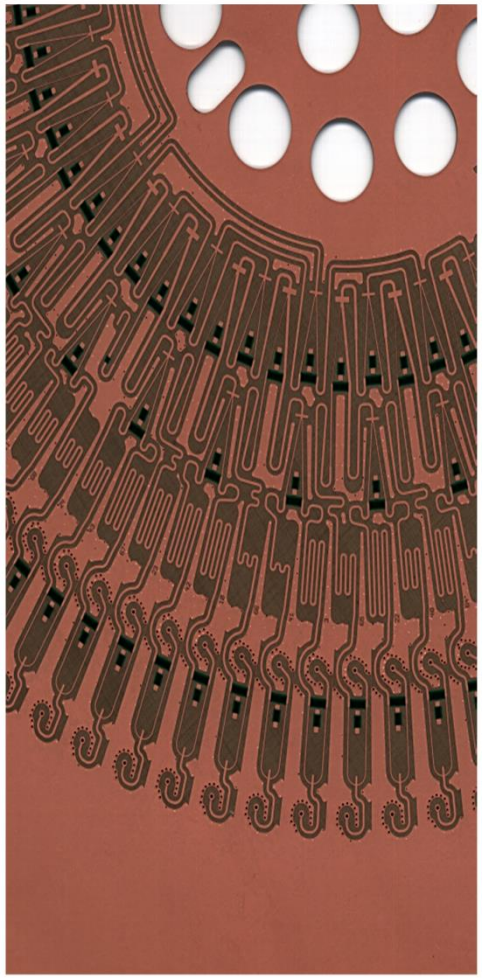
NiP Resistor Designs in Space Applications

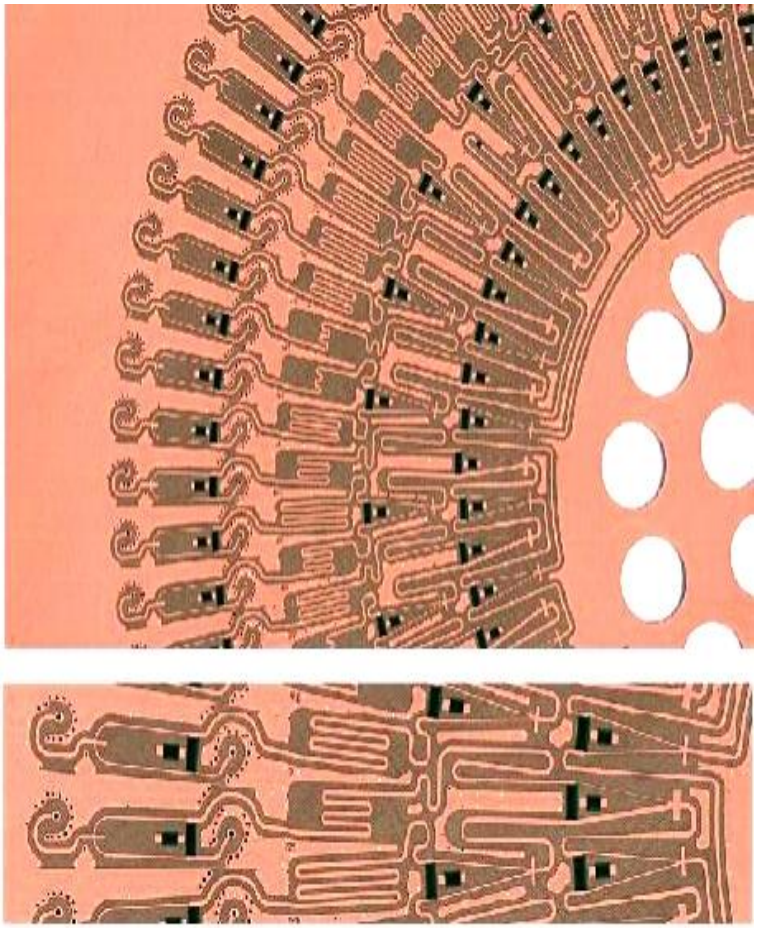
NiP resistors in microwave application for Globalstar antenna.



Layer stack up.

Globalstar Antenna – NiP Resistor Inner Layer





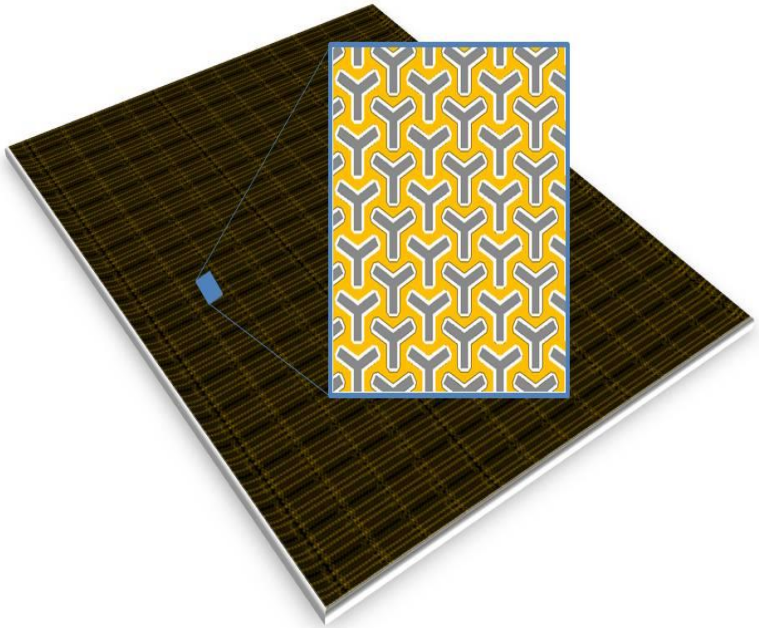
NiP Resistor Designs in Military/Aerospace Applications

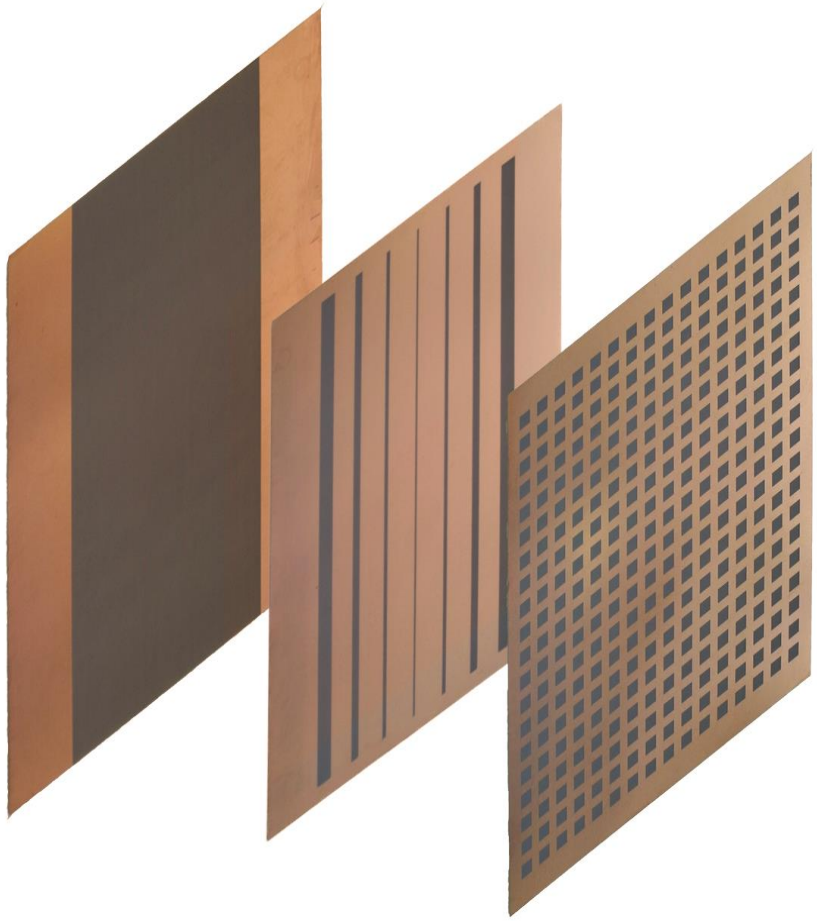
Active Phased Array Antenna

NiP Resistive Material in R-Cards and Absorbers

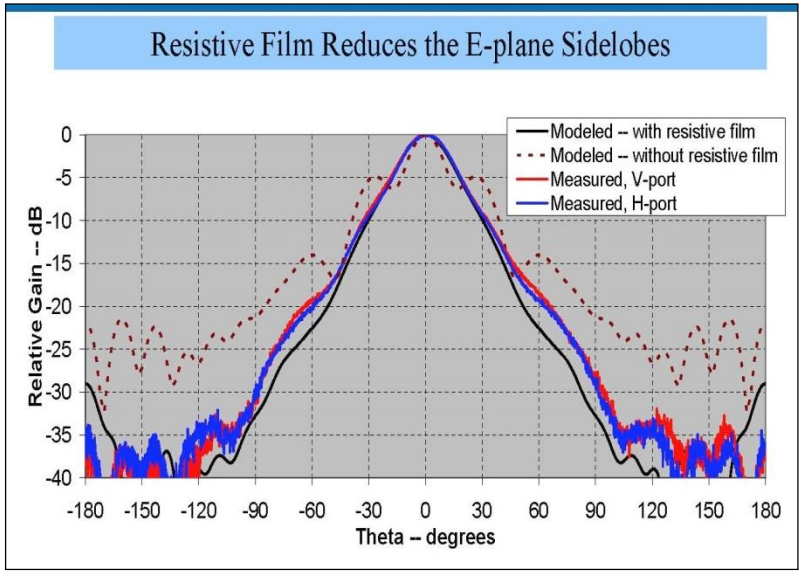
- Can be laminated to a variety of substrate materials with different permittivities
- Create repetitive, planar patterns using standard photolithography techniques (subtractive print/etch)
- Cost reduction
- Weight savings (reduced thicknesses)
- Increased bandwidth and improved performance covering wider angles of incidence

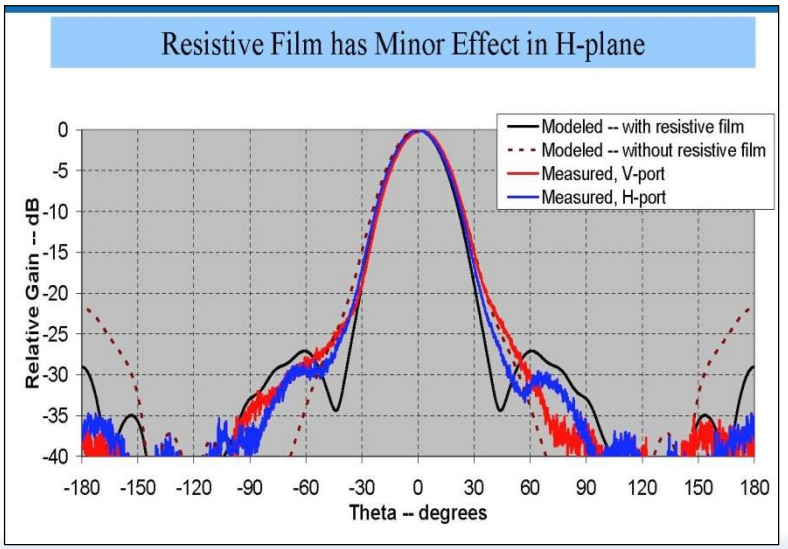
NiP Resistors in RF Electromagnetic Absorbers and R-cards





NiP Resistors in RF Electromagnetic Absorbers and R-cards

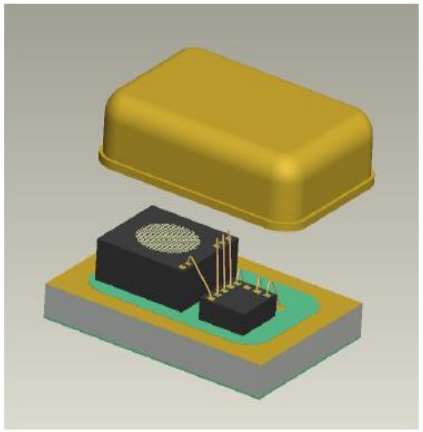


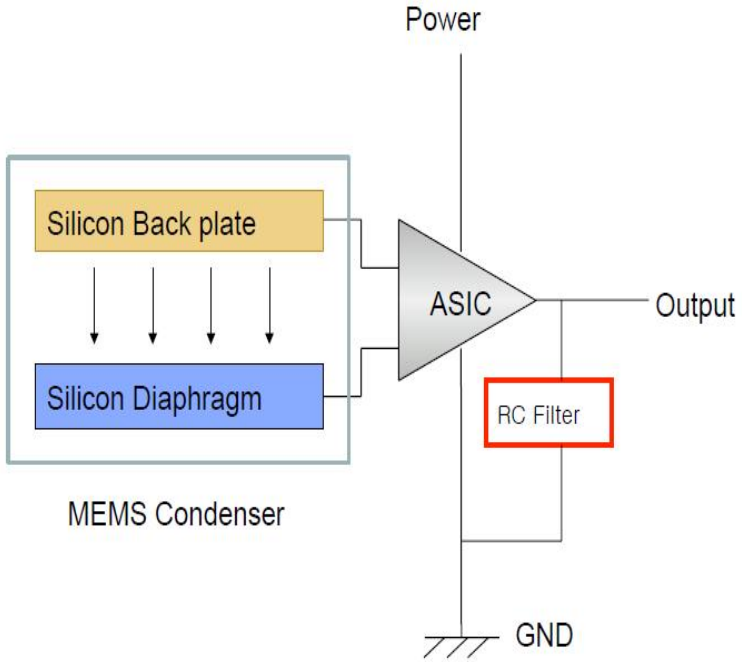


NiP Resistive Conductive Material in Sensors

- Increased PCB density (small element sizes)
- Reduced PCB thickness (eliminate SMT-R)
- Reduced assembly (resistor built into PCB)
- Improved Reliability (elimination of solder joints)
- Improved electrical performance (reduced EMI)
- Cost savings (replacement of discrete SMT-R)

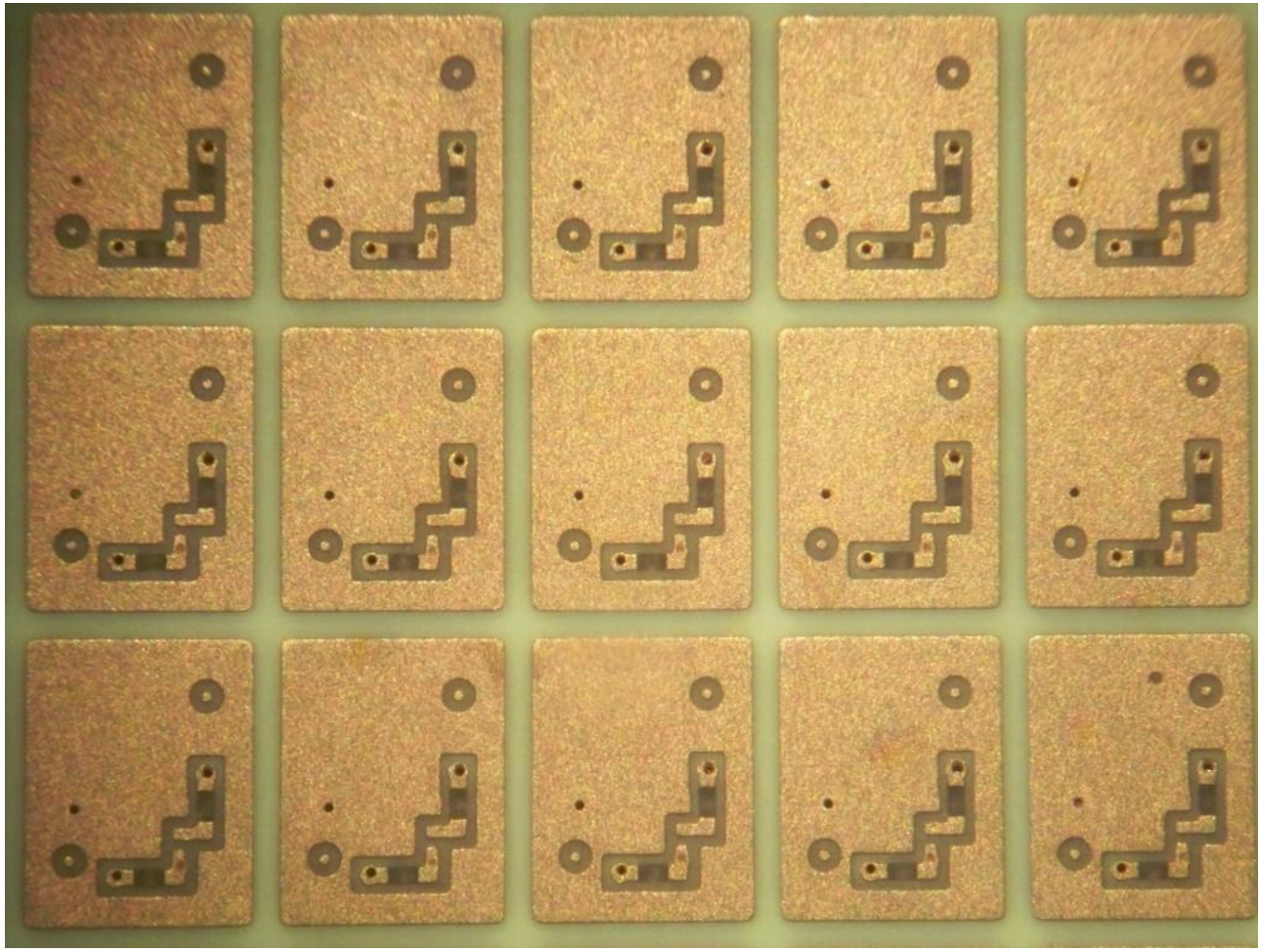
NiP Resistors in MEMs Microphone Sensor





EMC@217Hz &1KHz improved 20dBV from 500 to 2800MHz

NiP Resistors in MEMs Microphone Sensor



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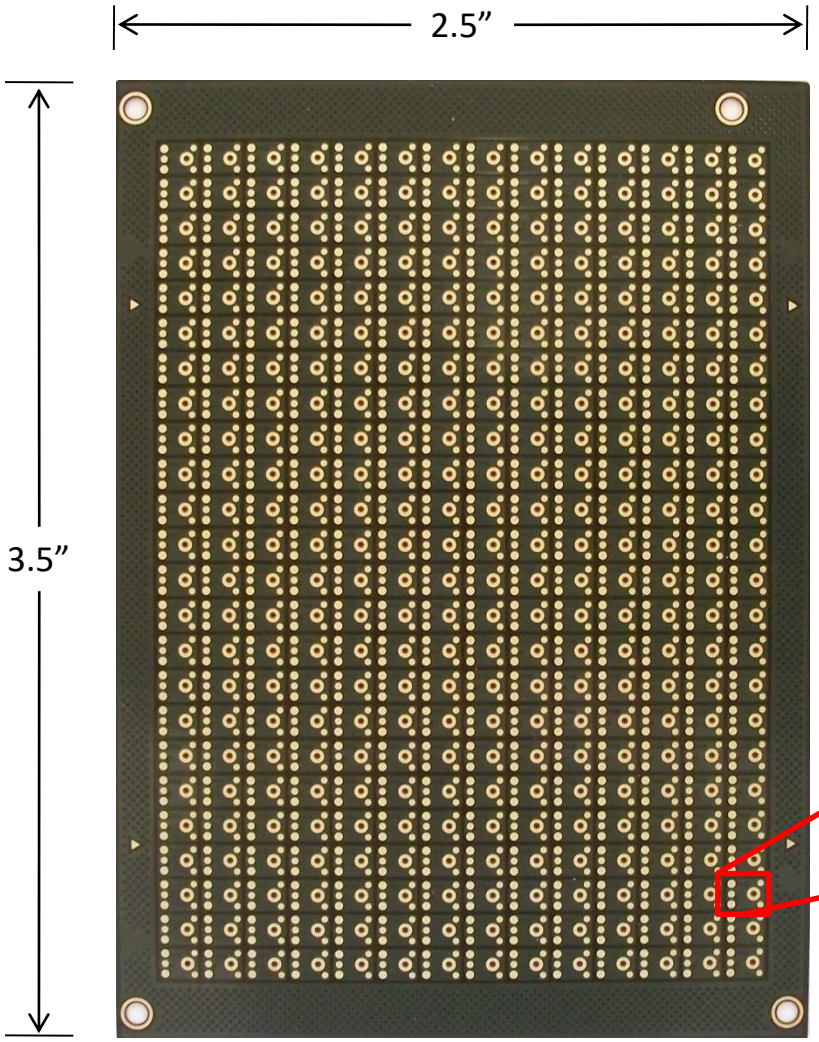


Consumer Electronics

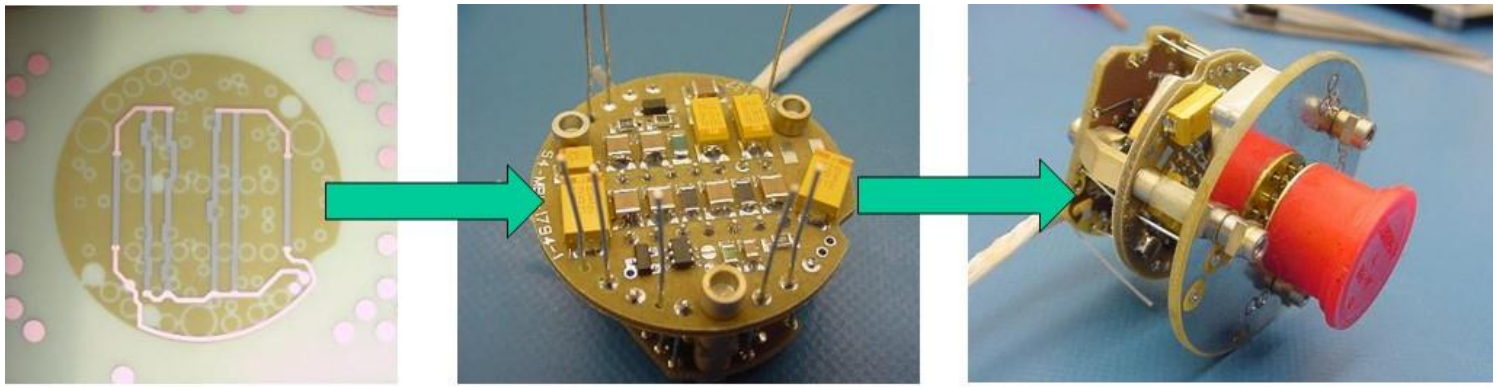
MEMs Microphones

Embedded Thin Film Heater Applications

- Aerospace & Defense
  - SAL (semi-active laser) activation guided munitions
  - XRF Spectrometer & Control board (Mars Beagle 2 lander)
  - Satellite solar array deployment mechanism
- Biomedical Electronics
  - Bioassay
  - Drug vaporization for subcutaneous injections
  - Heat therapy for dry eye
- PCB Temperature Control
- IC Testing/Burn-In

Aerospace & Defense - NiP Heater Beyond Earth

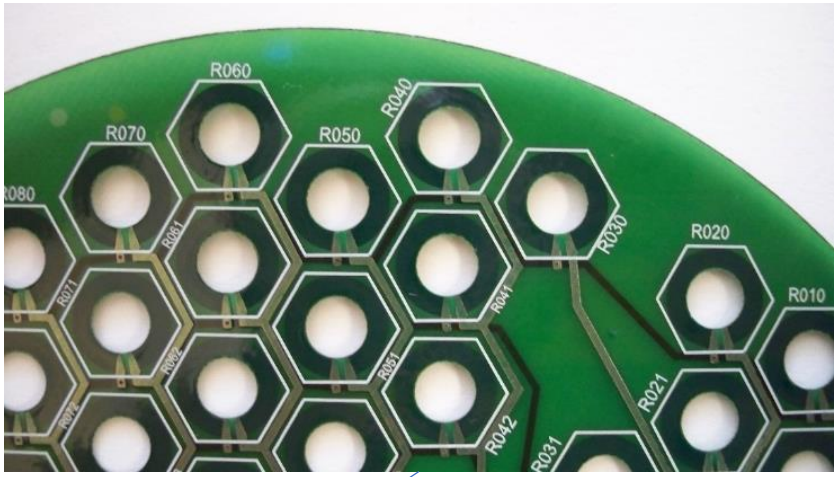
- Application shows a heater used to bring the X-Ray Spectrometer (XRS) biasing and pre-amplification electronics to -50 degrees Celsius in the Mars Beagle 2 Lander.

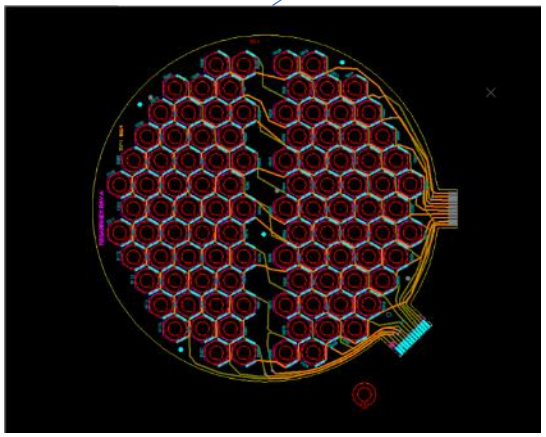


Inner Layer Heater | Assembled board | Assembled XRS unit

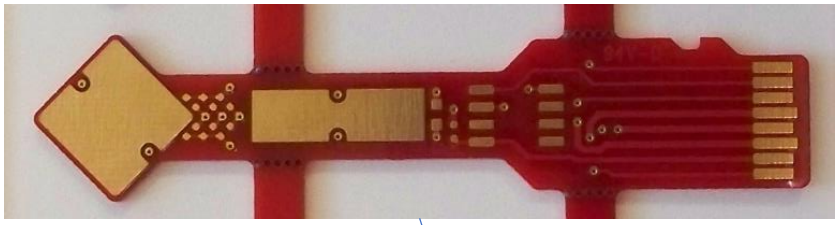
Images Courtesy of the University of Leicester Space Research Centre and the Beagle2 Consortium.

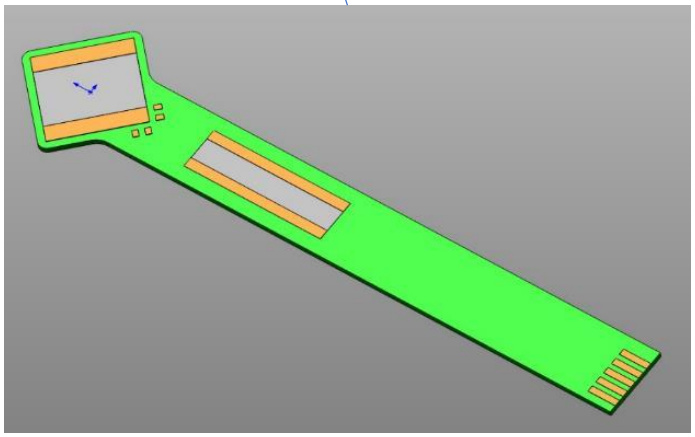
Biomedical Application Examples





Example NiP heater array

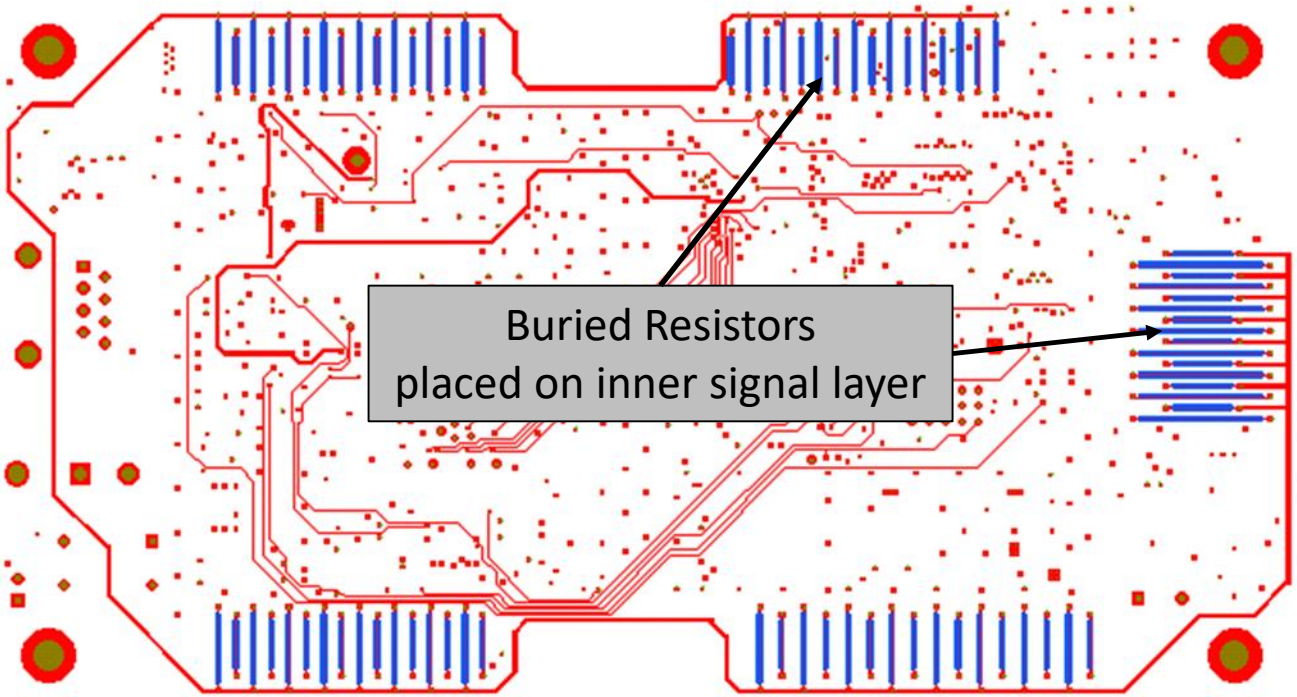




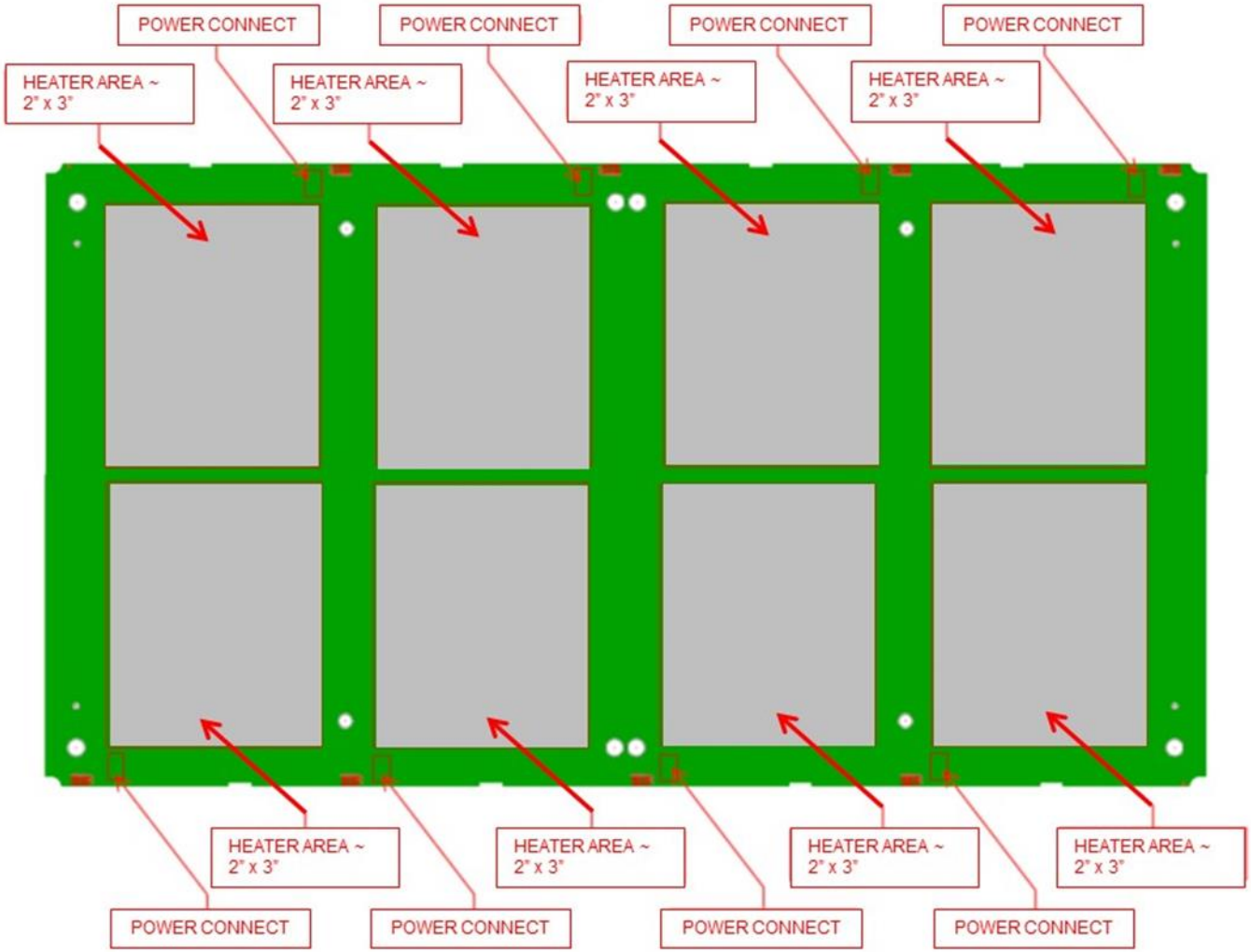
Example embedded NiP heater

PCB Temperature Control

- Resistors are not in BOM. Resistors built into the PWB and used as a PCB heater for colder climate operating environments
- Buried resistors placed under components and use a thermostat to maintain constant temperature for outdoor products



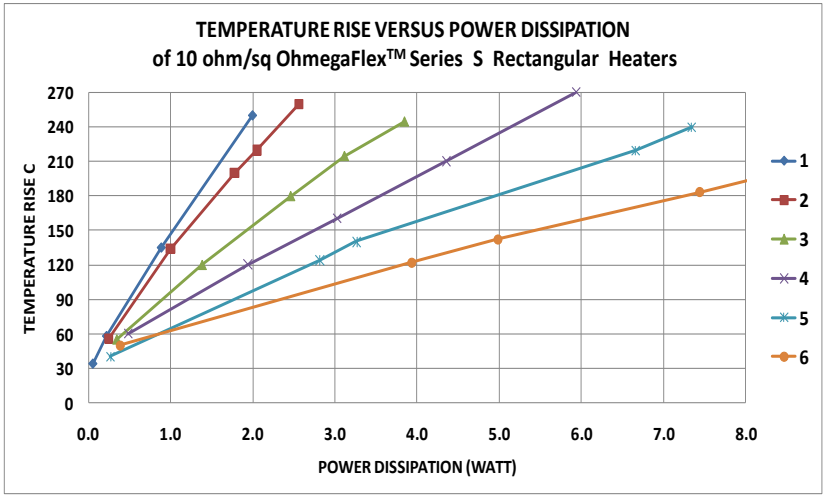
IC Testing / Burn-In



Example 10 ohm/sq embedded heater array for IC Burn-In testing at 65C

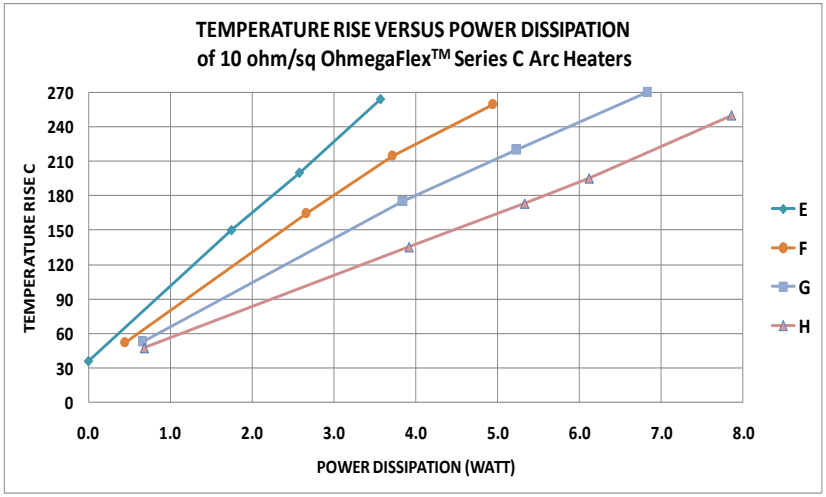
Sample Heater Boards

OhmegaFLEX rectangular heaters



Temperature versus Power measurements

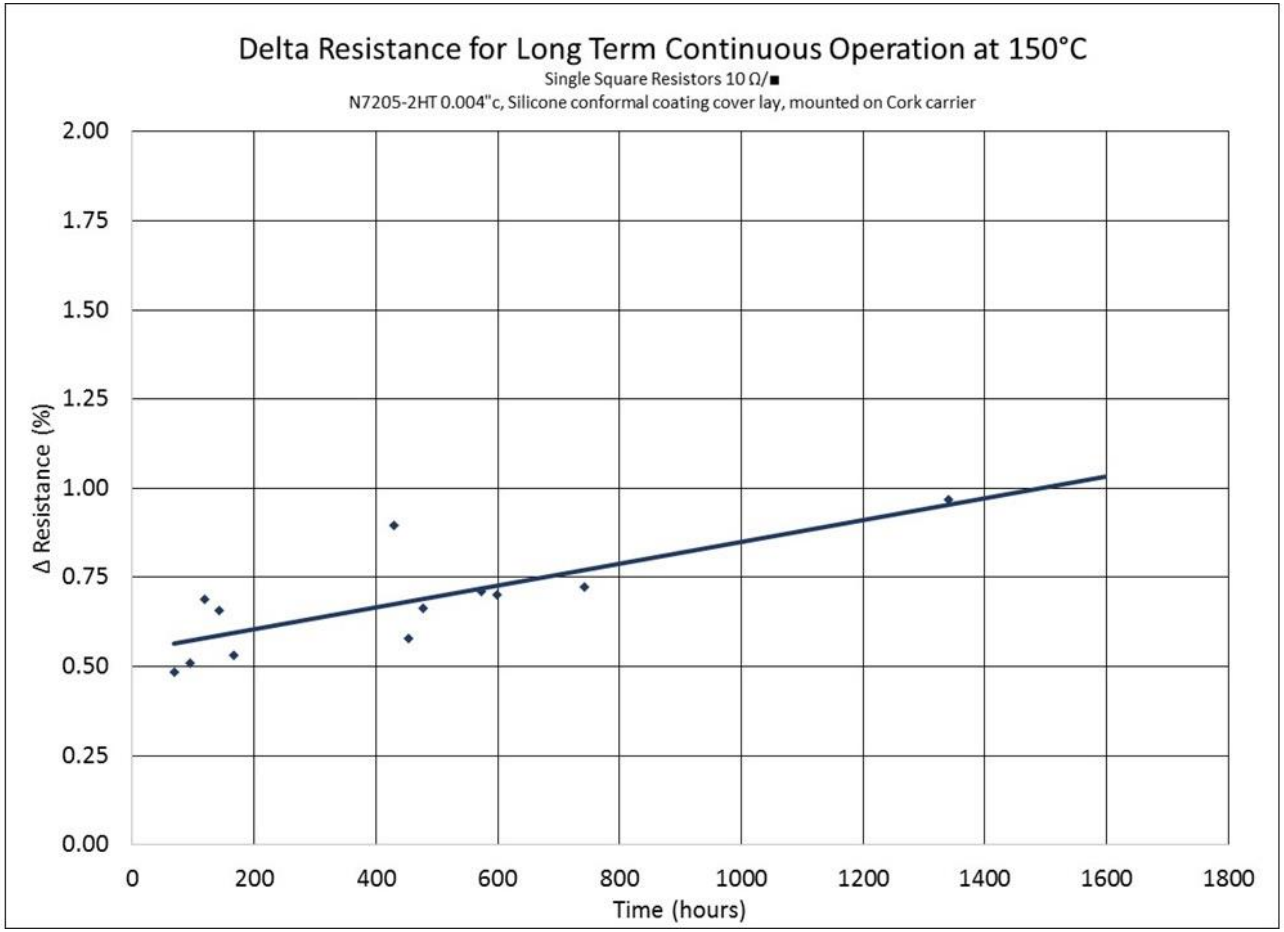
OhmegaFLEX circular heaters



Temperature versus Power measurements

NiP Resistor Reliability

- Stability over long term continuous operation



Summary

- NiP thin film resistive material used extensively in RF and MEMs designs
- Improved package densities
- Improved electrical performance
- Improved reliability
- Standard subtractive PCB processing
- Growing applications in IC packaging, IOT sensor technologies, 5G and DDR4 memory devices

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