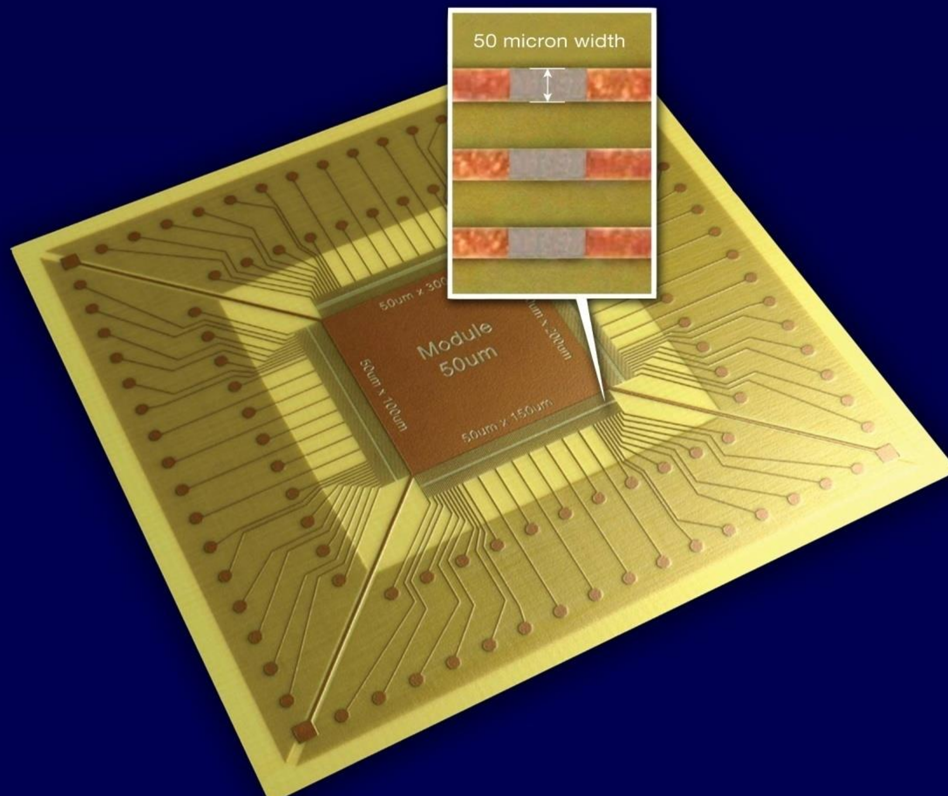
Ohmega Technologies, Inc.



OhmegaPly® Design

Ohmega
Ohmega Technologies, Inc.

Table of Contents

Ohmega Products

- OhmegaPly® RCM® & Laminate (Resistor Conductor Material)
  - Standard material available in 25Ω/□, 40Ω/□, 50Ω/□, 100Ω/□ and 250Ω/□

- OhmegaPly® ORBIT® (Ohmega Resistor Built in Trace)
  - Lower resistivity material available in 10Ω/□ ideal for low value termination applications. Increased power handling capabilities also facilitate design of very low profile/flexible heaters.

- OhmegaPly® MTR® (Micro Trace Resistor®)
  - Enhanced alloy allowing for precise planar resistor definition below 100um widths. Developed for use in High Density Interconnect (HDI) technologies.

- OhmegaPly® RF
  - Low profile/low insertion loss copper available for PTFE and other low loss substrates. Extensively used in RF and microwave circuits beyond 50GHz.

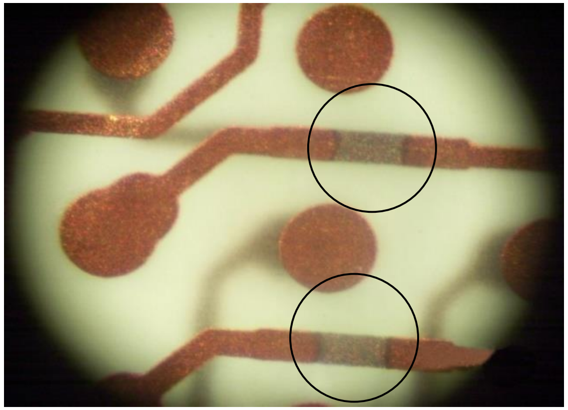
- OhmegaPly® FaradFlex®
  - A patented combined product of OhmegaPly® RCM® and Oak-Mitsui FaradFlex capacitance dielectric material for production of embedded RC networks.

Ohmega Products

OhmegaPly® RCM®

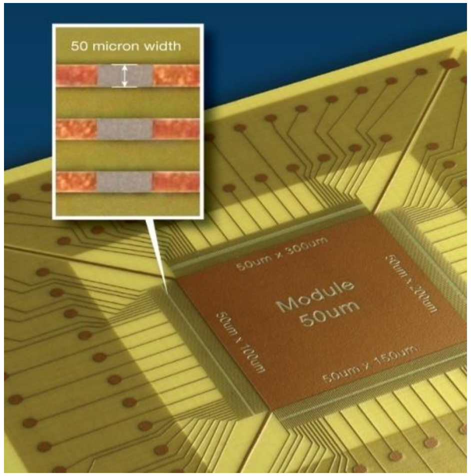
Streamlining MEMS microphone miniaturization

OhmegaPly® ORBIT®



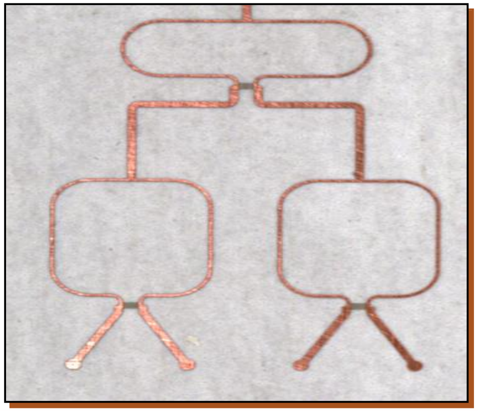
Ohmega Resistor Built in Trace

OhmegaPly® MTR®



Enhanced for precision processing

OhmegaPly® RF

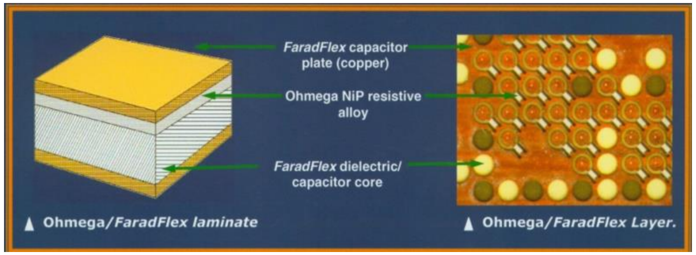


Improved RF and Microwave performance

OhmegaFlex®

Flexible heaters

Ohmega® / FaradFlex®



Integrated resistive and capacitive core

OhmegaPly® Material Overview

OhmegaPly® is a thin film NiP metal alloy Electrodeposited-On-Copper referred to as Resistor Conductor Material, RCM. The RCM is laminated to a dielectric material then subtractively processed to produce planar resistors. Because of its thin film nature, it can be buried within layers of a PWB without increasing the thickness of the board or occupying any surface space like discrete surface mount resistors.

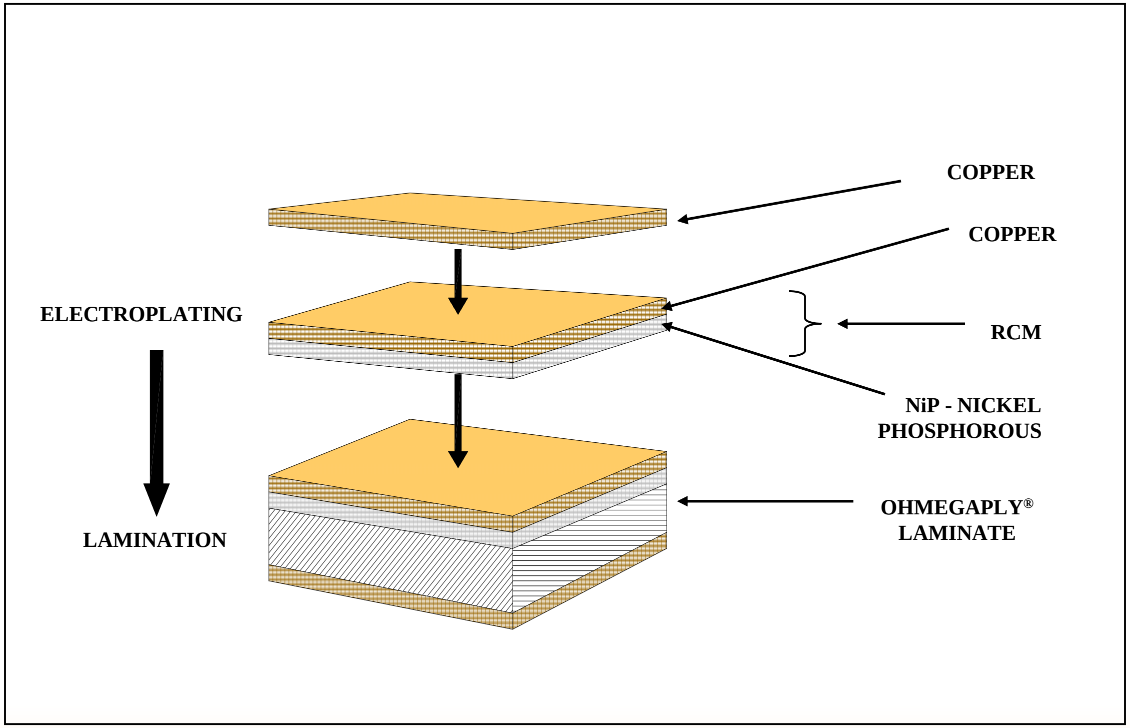


Image 1: OhmegaPly® material construction

OhmegaPly® Basic Design Concept

The resistance of an OhmegaPly® resistor:

$$R = R_S \frac{Length\ of\ Resistor}{Width\ of\ Resistor}$$

Equation.1

Where R_s is the sheet resistance of the RCM material designated as ohms per square, OPS. The resistance value can be determined by material resistance and geometry of the resistor according to the formula above.

$$R = R_S \times N$$

Equation.2

Where N is the ratio of length to width or number of squares ($N = L/W$)

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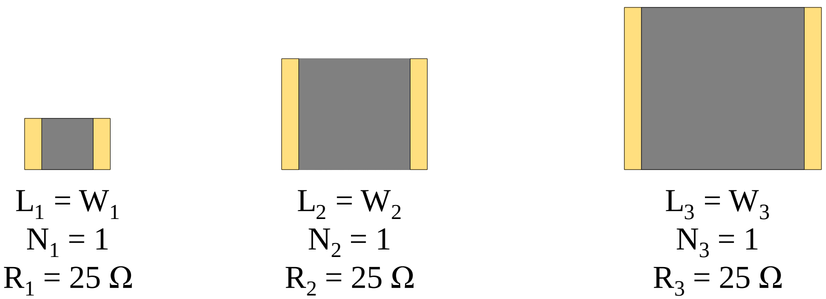
OhmegaPly® Basic Design Concept

For a given sheet resistivity

- Resistance of a square area equals the bulk sheet resistivity of the material.
- One square of 25 Ω/□ material will equal 25 Ω regardless of the size of the square.



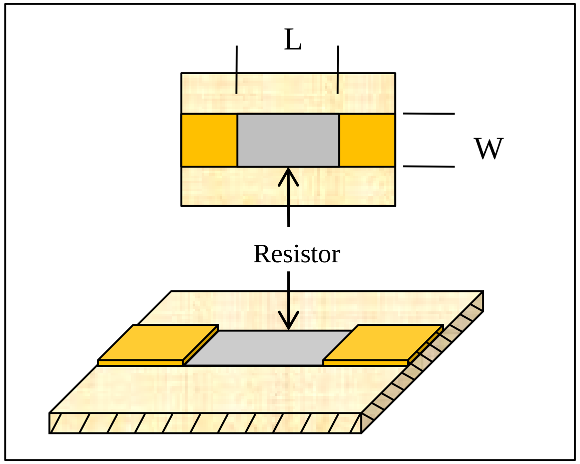


Image 2: Material characteristic

- To create different resistor values with a given sheet resistivity simply adjust the length to width ratio or number of squares.
  - For example, to create a 50Ω resistor using R_s of 25Ω/□ material adjust the length to twice the width:

$$R = R_s \left(\frac{L}{W}\right) = R_s \left(\frac{2W}{W}\right) = 2\,R_s$$

OhmegaPly® Basic Design Concept

Basic Resistor Patterns

1. Bar Type

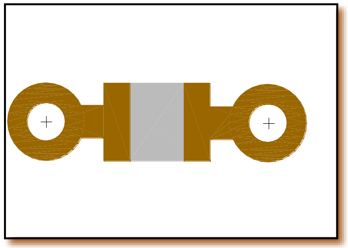


Image 3: Partial Squares (N < 1)

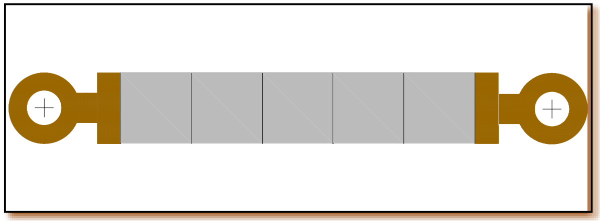


Image 4: Multiple Squares (N ≥ 1)

2. Meander or Serpentine Type

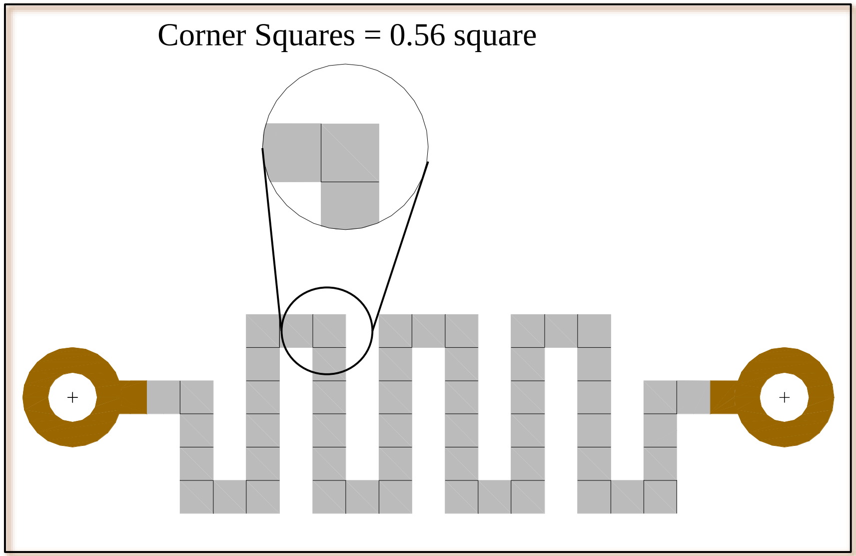


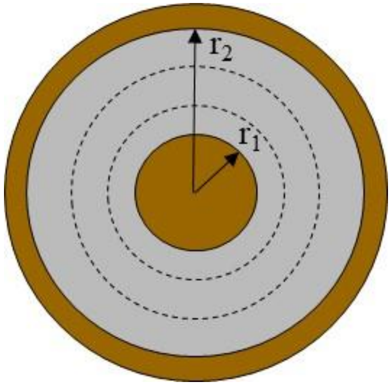
Image 5: Meander/Serpentine type

Due to a change in current density at right-angles, corner squares only add roughly half of their expected resistance. Corner squares are equivalent to 0.56 square.

OhmegaPly® Basic Design Concept

Basic Resistor Patterns

3. Circular Resistor



The length of resistor = dr

The width of resistor = 2πr

Resistance:

$$dR = R_s \frac{Length}{Width} = R_s \frac{dr}{2\pi r}$$

Where R_s = Sheet Resistance (Ω/□)

The sum of these elements from r_1 to r_2 is the total resistance:

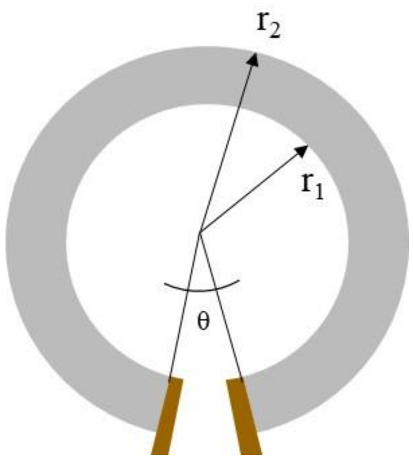
$$R = \int dR = \int_{r_1}^{r_2} R_s \frac{dr}{2\pi r}$$

$$\boxed{R = \frac{R_s}{2\pi} \ln \frac{r_2}{r_1}}$$

OhmegaPly® Basic Design Concept

Basic Resistor Patterns

4. Arc Resistor



$$R(\Omega) = R_s \frac{R_l}{R_w}$$

Where:

$$R_l \approx \pi(r_2 + r_1) \times \left(\frac{360 - \theta}{360}\right)$$

$$R_w = (r_2 - r_1)$$

Therefore:

$$R(\Omega) = R_s \frac{\pi(r_2 + r_1)}{(r_2 - r_1)} \left(\frac{360 - \theta}{360}\right)$$

Ohmega Design Spreadsheet Tool

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.

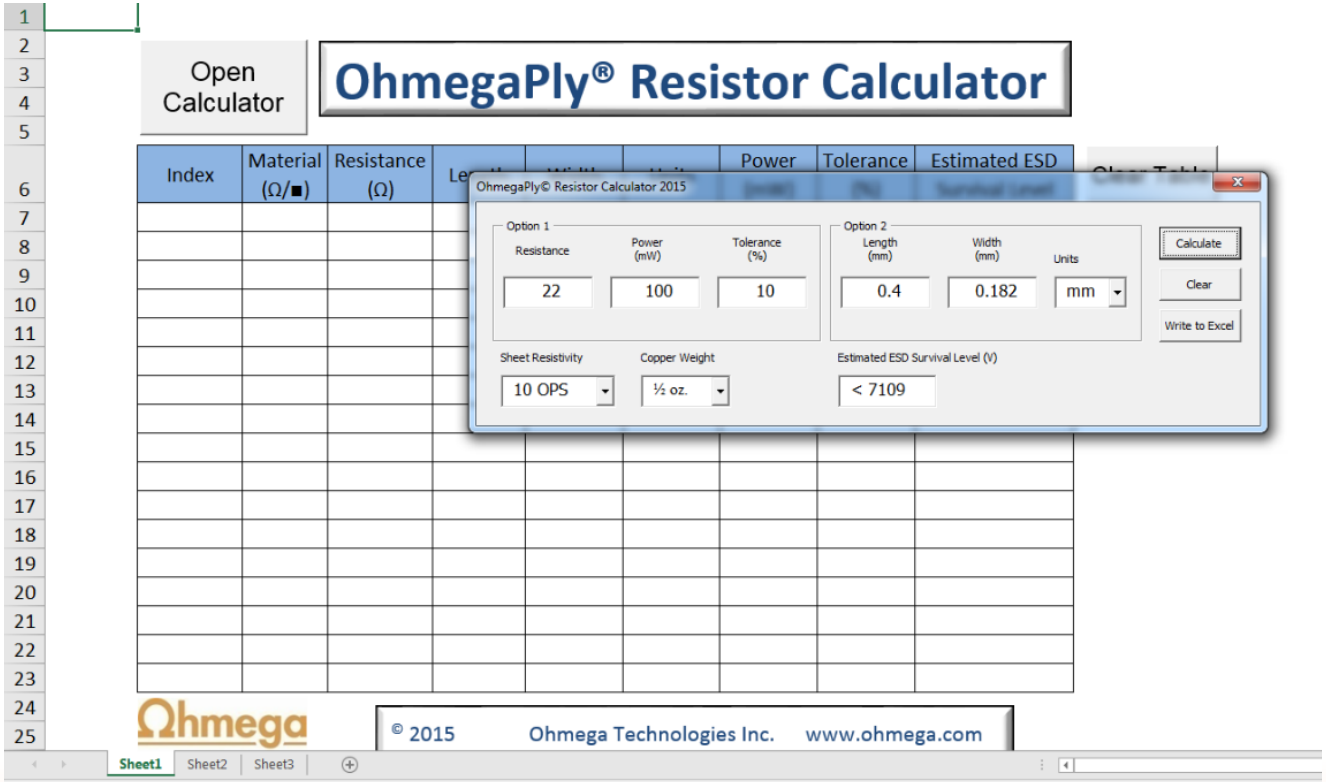


Image 8: Ohmega design spreadsheet tool

OhmegaPly® Technical Specifications

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OHMEGAPLY® RCM TECHNICAL SPECIFICATIONS								
Sheet Resistivity	10 Ω/□	25 Ω/□	40 Ω/□	50 Ω/□	100 Ω/□	250 Ω/□	Unit	Remark and Condition
Material Tolerance	+/-5	+/-5	+/-5	+/-5	+/-5	+/-10	%	Sheet Resistivity
Resistance Temperature Characteristic (RTC)	20	50	75	75	100	100	PPM/°C	MIL-STD-202-304 -55°C to 125°C
Maximum Power	0.175	0.100	0.090	0.085	0.070	0.060	W	Values shown for 20 mil x 10 mil (LxW) resistors. Significant improvements can be achieved with changes in resistor design and PCB stack-up. Please contact for more information.
ESD *	8000	3500	2500	1900	1100	800	V	Values shown for 20 mil x 10 mil (LxW) resistors. Significant improvements can be achieved with changes in resistor design and PCB stack-up. Please contact for more information.
Short Time Overload	0.0	0.0	0.0	0.0	0.0	0.0	Δ R%	MIL-R-10509 Method 4.6.6 2.5 x rated power, 5 sec
Load Life Cycling Test	<0.3(1)	<5	--	<5	<5	<0.5(1)	Δ R%	MIL-STD-202-108I 70C, 1.5 hrs On/Off Cycle, 10000 hrs
Current Noise Index	< -16	< -15	< -15	< -15	< -15	< -15	dB	MIL-STD-202-308
Humidity Test	0.5	1.0	1.0	1.0	1.5	2.5	Δ R%	MIL-STD-202-103A 40°C, 95% RH, 240 hrs
Thermal Shock	0.1	0.1	0.5	0.5	0.5	1.5	Δ R%	MIL-STD-202-107B -65°C to 125°C, < 5 min transition, 25 ccl
Hot Oil	--	0.1	0.3	0.3	0.5	0.75	Δ R%	IPC-TM-650 METHOD 2.4.6 260°C, T_0 = 20°C
Solder Float	0.2	0.5	0.8	0.8	1.0	0.5	Δ R%	MIL-STD-202-210D 260°C, 20 sec
Capacitance	~0.0	~1.0	~1.0	~1.0	~1.0	~1.0	pF	Extracted at 5Hz
Inductance	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	nH	Extracted at 5Hz

* ESD survival levels estimated on ANSI/ESDA/JEDEC JS-001-2012 Human Body Model – Component Level standard. Direct discharge across resistor elements constructed with minimal complexity. Please contact for more details.

(1) Result after 1000 hours

OhmegaPly RCM is RoHS and REACH SVHC Compliant

OhmegaPly® Technical Specifications

OhmegaPly® Power Dissipation vs. Area of Resistor (Power Density)

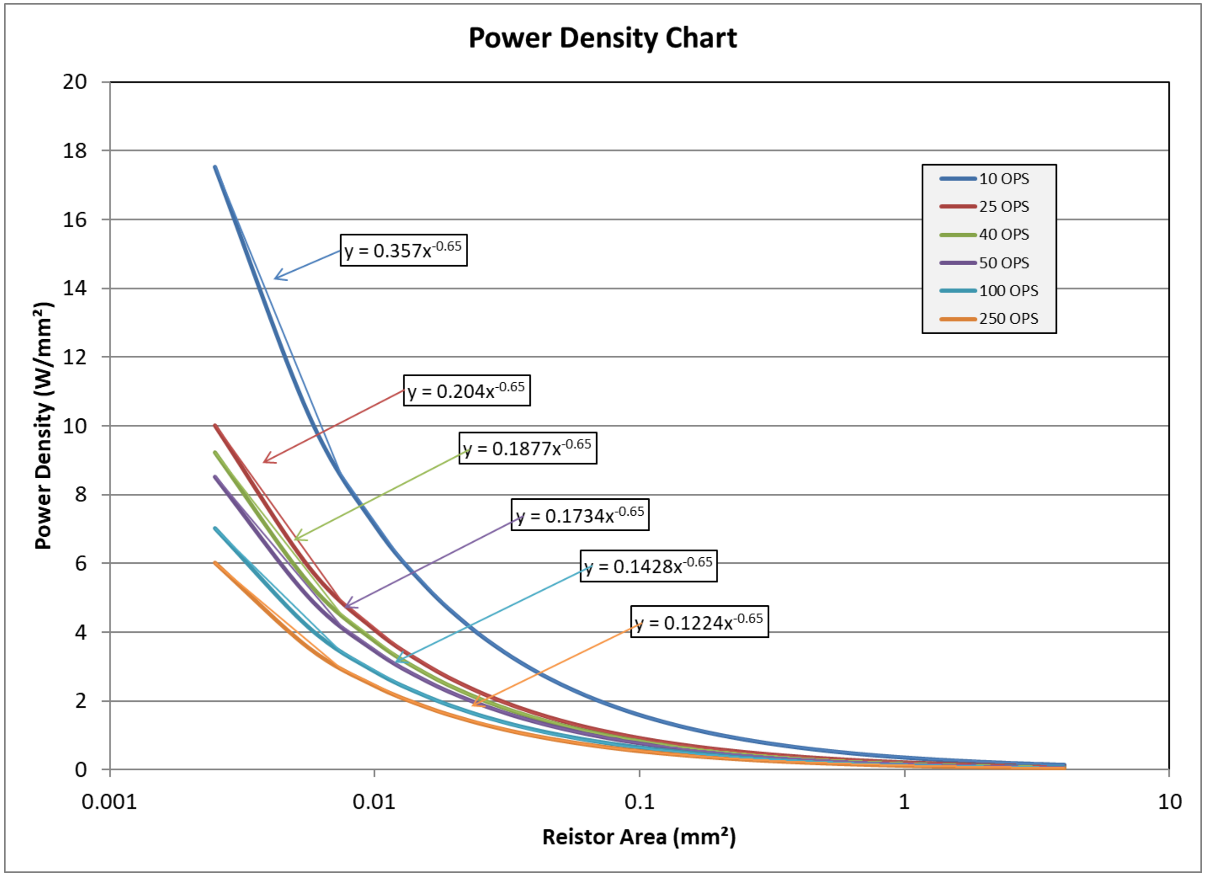


Chart 1: Power density curves

The power density is defined as the dissipated power divided by the resistor area. The power density of a resistor increases as the resistor area decreases.

Maximum power dissipation depends on the ambient temperature, resistor element size, and laminate/circuit board thermal properties. Dissipation improves with the use of natural heat sinks such as ground and power planes.

Typical power dissipation for most PRT resistor designs operating at an ambient of less than 70 °C is approximately 1/10 to 1/8 watt.

OhmegaPly® Temperature Rise vs. Power Dissipation

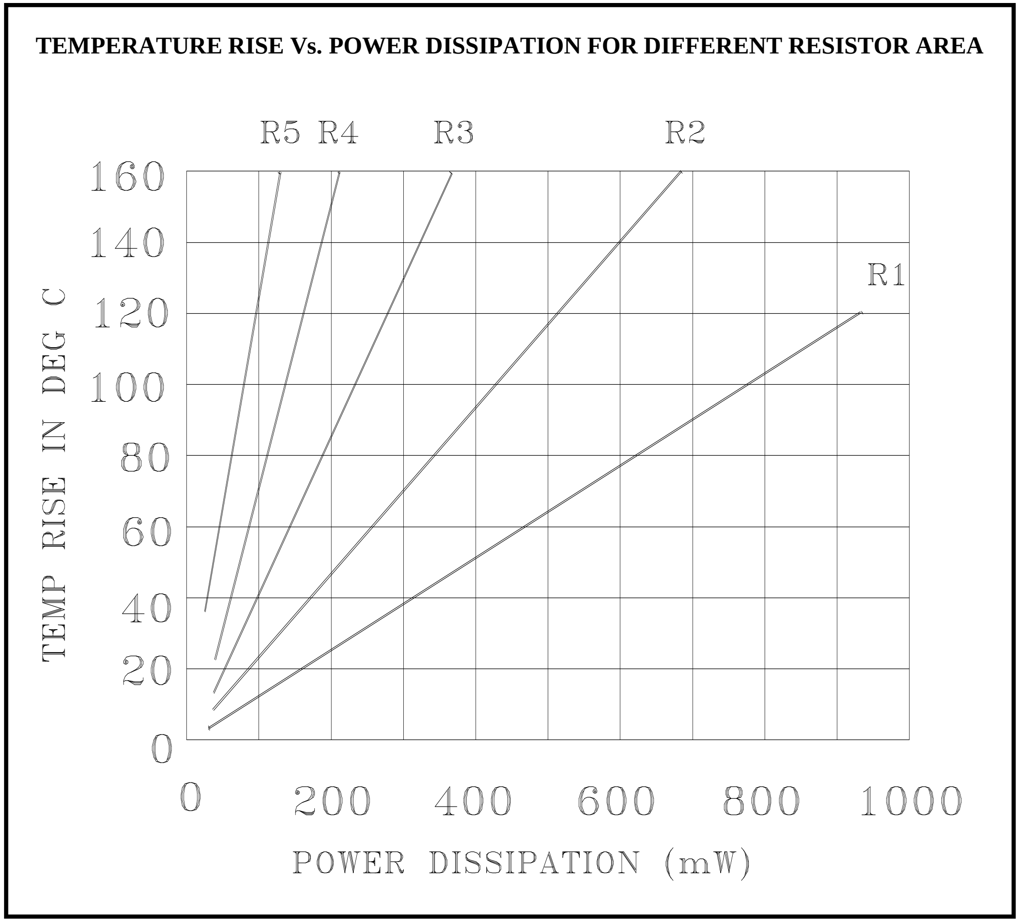


Chart 2: Relationship between Temperature, Power and Resistor Area

Controlling the resistor operating temperature prolongs the working life of the resistor improving the long term stability. The chart on the left shows the relationship between resistor size, operating temperature and power dissipation.

R1 = 25Ω area of R1 = 0.500 x 0.500 = 0.2500 in^2
R2 = 25Ω area of R2 = 0.250 x 0.250 = 0.0625 in^2
R3 = 25Ω area of R3 = 0.125 x 0.125 = 0.0156 in^2
R4 = 25Ω area of R4 = 0.063 x 0.063 = 0.0039 in^2
R5 = 25Ω area of R5 = 0.031 x 0.031 = 0.0010 in^2

The experimental data indicates larger resistors are capable of dissipating more power. In designs where power and reliability are critical it is recommended to design the resistor as large as possible.

OhmegaPly® Technical Specifications

OhmegaPly® Substrate Effects on Temperature Rise

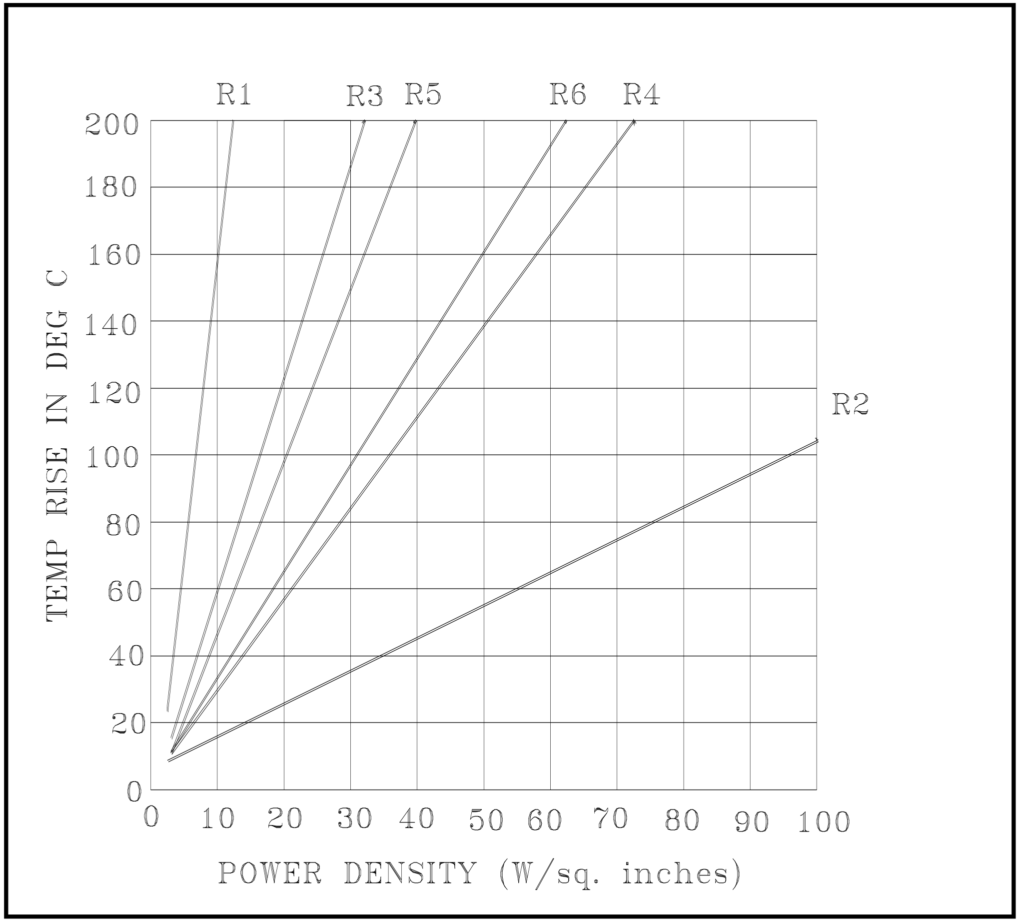


Chart 3: Heat sinking effect on power density

For buried resistors the physical and thermal characteristics of the substrate directly effect the heat dissipation. The thickness of the substrate and cladding can have a dramatic effect on resistor operating temperature and therefore power handling capability. When comparing R1 and R2 in the graph shown to the left it can be seen that the addition of cladding significantly decreased the temperature of R2.

	Core Thickness	Cladding
R1 = 250Ω	0.0025	NO
R2 = 250Ω	0.0025	YES
R3 = 250Ω	0.025	NO
R4 = 250Ω	0.025	YES
R5 = 250Ω	0.062	NO
R6 = 250Ω	0.062	YES

OhmegaPly® Technical Specifications

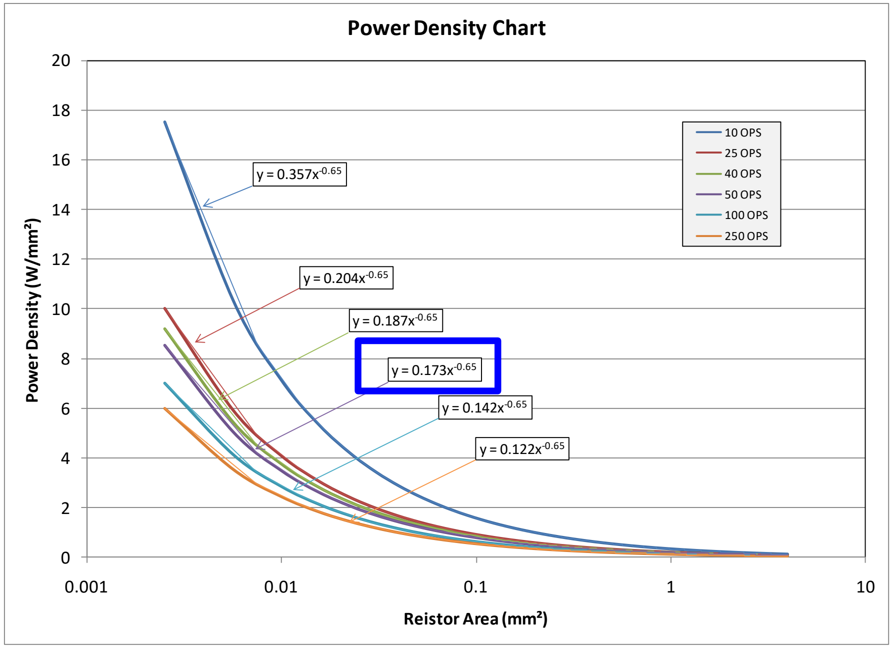
1. Design Resistor
   - Determine desired resistance, power and tolerance.
   - Select material (sheet resistivity).
   - Calculate resistor area.
2. Determine operating power using Power Density Curves
   - For example: 50Ω/□, Area = 0.129mm² (0.254mm x .508mm)

     $P(w) = 0.173*(0.129)^{(1-0.65)}$

     $P(w) = 0.084\ W \sim \frac{1}{12}\ W$
3. Calculate operating voltage/current

$$V = \sqrt{P * R}$$

$$I = \sqrt{\frac{P}{R}}$$



$$\text{Power Density} = \frac{\text{Power}}{\text{Area}} = \frac{y}{x} = ax^{b}$$

Where

x = Resistor Area (mm²)
a = Specific material power scalar
b = Specific material power exponent

Power (W) = Power Density (W/mm²) * Area (mm²)

$$P = y = ax^{(1+b)}$$

Minimum resistor area based on power requirements

$$x = e^{\left[\frac{1}{(1+b)} * \ln\left(\frac{P}{a}\right)\right]}$$

Max ESD Levels vs. Resistor Width

The ESD tolerance is a function of the cross sectional area of the resistor. The experimental data to the right shows this relationship. As the resistors widths become smaller the ESD levels that can be tolerated also decrease. If the application will be in an environment exposed to ESD type transients and space constraints are lenient it would be better to select a lower sheet resistivity for design.

ESD sensitivity levels determined by ANSI/ESDA/JEDEC JS-001-2012 Human Body Model – Component Level Standard.

- Recommended limits based on ESD levels directly coupling across resistor elements.
- Information intended to assist system level designers to incorporate proper level of ESD protection.

Resistor Width (mm)	10Ω/□ Max ESD (kV)	25Ω/□ Max ESD (kV)	40Ω/□ Max ESD (kV)	50Ω/□ Max ESD (kV)	100Ω/□ Max ESD (kV)	250Ω/□ Max ESD (kV)
0.050	2.7	1.0	0.7	0.6	0.3	0.3
0.075	3.5	1.4	1.0	0.8	0.4	0.3
0.100	4.4	1.7	1.2	0.9	0.5	0.4
0.125	5.2	2.0	1.4	1.1	0.6	0.5
0.150	6.0	2.3	1.6	1.3	0.7	0.6
0.175	6.9	2.6	1.9	1.4	0.7	0.6
0.200	7.7	2.9	2.1	1.6	0.8	0.7
0.225	8.6	3.2	2.3	1.8	0.9	0.8
0.250	9.4	3.5	2.5	2.0	1.0	0.9
0.275	10.2	3.9	2.8	2.1	1.1	1.0
0.300	11.1	4.2	3.0	2.3	1.2	1.0

Table 2: ESD tolerance versus resistor width.

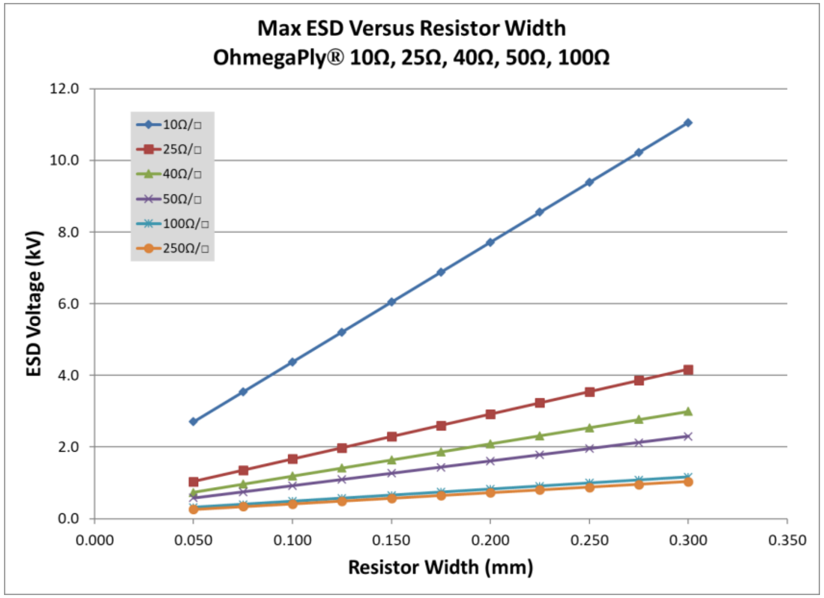


Chart 5: ESD tolerance versus resistor width.

Insertion Loss of OhmegaPly on Rogers PTFE Substrate

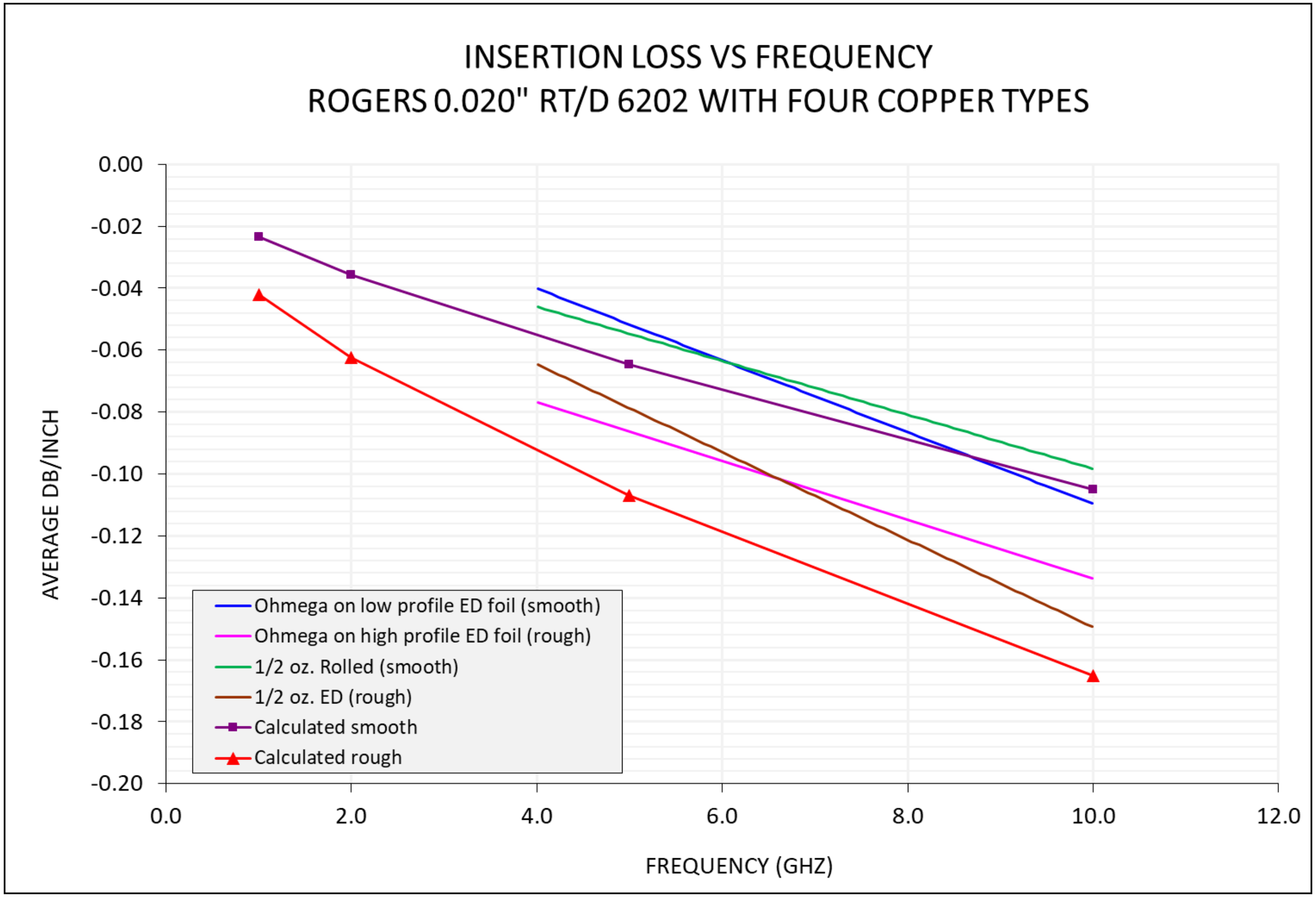


Chart 6: Insertion Loss comparisons of Ohmega on Rogers PTFE substrate.

OhmegaPly® Technical Specifications

Insertion Loss of OhmegaPly on Arlon CLTE Substrate

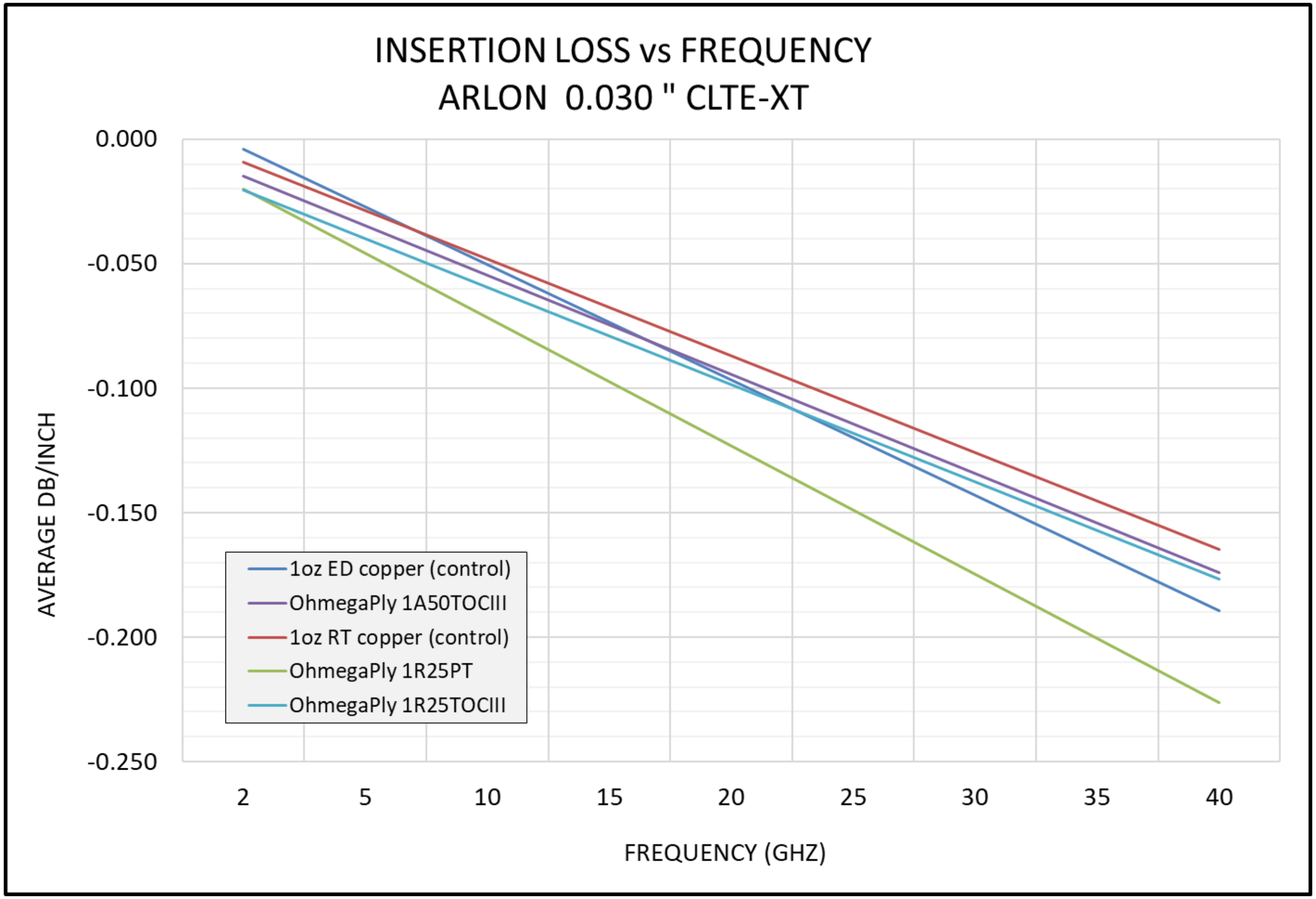


Chart 7: Insertion Loss comparisons of Ohmega on Alron CLTE substrate.

Embedded Resistor Design Flow

Identify candidate components for embedding from BOM → Termination/matching, pull-up/pull-down

* Avoid resistors > 10kΩ or precision tolerance 1%

↓

Specify or create package/footprint technology type → Ensure attributes identify Embedded Passive Technology (EPT), Embedded Resistor (ER) or Buried Resistor (BR)

↓

Design resistor geometries in PCB Component Library → Resistor geometries driven by power and tolerance requirements

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Example BOM Component Selection

Design Name PC3-SODIMM_XXXX_XX_XX_XXXXXXXXX.brd					
		Bill of Material Report (Condensed)			
SYM_NAME	**COMP_DEVICE_TYPE**	**COMP_VALUE**	**COMP_CLASS**	**QUANTITY**	**REFDES**
FBGA78_10X11_5	DDR3_BGA_82_128MX8_M	DDR3_BGA_82_128MX8_M	IC	8	U1;U2;U7;U9;U11;U12;U17;U19
MLP8_2X3FULL_CROSS	EEPROM_TEMP_MLP_9_MCP98242	MCP98242	IC	1	U3
SMC0402	CAP_0402_3.3PF	3.3pF	DISCRETE	1	C65
SMC0402	CAP_0402_22UF	.22UF	DISCRETE	1	C78
SMC0402	CAP_0402_100NF	.1UF	DISCRETE	1	C119
SMR0402	CAP_0402_1.1UF	.1UF	DISCRETE	64	C1;C4;C5;C6;C7;C9;C16;C22;C26;C31;C34;C35;C38;C40;C41;C44;C46;C47;C48;C50;C51;C52;C53;C56;C57;C59;C61;C62;C63;C66;C67;C68;C69;C70;C71;C72;C73;C74;C75;C76;C77;C81;C82;C83;C84;C85;C87;C88;C89;C90;C91;C93;C94;C96;C97;C99;C102;C103;C104;C105;C106;C113;C114;C128
SMR0402	CAP_0402_.22UF	.22UF	DISCRETE	10	C33;C42;C43;C54;C55;C64;C98;C107;C108;C109
SMR0402	RES_0402_240OHM_1%	240Ohm	DISCRETE	8	R4;R6;R7;R8;R11;R13;R15;R16
SSOP8_65MM	SPD_SSOP8_65MM__SPD	SPD	IC	1	U4
		EMBEDDED RESISTORS			
BR15L3	RES_0402_15OHM	15Ohm	EMBEDDED	88	R47;R48;R49;R50;R51;R52;R53;R54;R55;R56;R57;R58;R59;R60;R61;R62;R63;R64;R65;R66;R67;R68;R73;R74;R75;R76;R77;R78;R79;R80;R81;R82;R83;R84;R85;R86;R87;R88;R89;R90;R91;R92;R93;R94;R95;R96;R97;R98;R99;R100;R101;R102;R103;R104;R105;R106;R107;R108;R109;R110;R111;R112;R113;R114;R115;R116;R117;R118;R119;R120;R121;R122;R123;R124;R125;R126;R127;R128;R129;R130;R131;R132;R133;R134;R135;R136;R137;R139
BR30L3	ER30	30Ohm	EMBEDDED	2	R45;R46
BR39L3	ER39	39Ohm	EMBEDDED	27	R17;R18;R19;R20;R21;R22;R23;R24;R25;R26;R27;R28;R29;R30;R31;R32;R33;R34;R35;R36;R37;R38;R39;R41;R43;R140;R141

Table 3: Example BOM - embedded resistor designation

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Example Naming Convention

You place buried resistors in schematic capture just as you do any other part. When a buried resistor is placed on the board, you will see the resistor value (in ohms) below the shape. In the example below, an 8 ohm resistor was placed and was given the reference designator BR3 after compiling was completed.

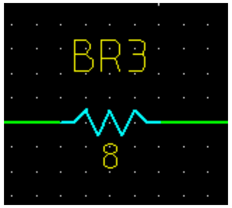
Schematic and PDB Libraries - BR100_1/4W_25MAT

- BR → Buried Resistor
- 100 → Value (in ohms)
- 1/4W → Power Rating
- 25MAT → Ohmega Material (in ohms)

2D Cell Library - BR100A

- BR → Buried Resistor
- 100 → Unique #
- A → Ohmega Material

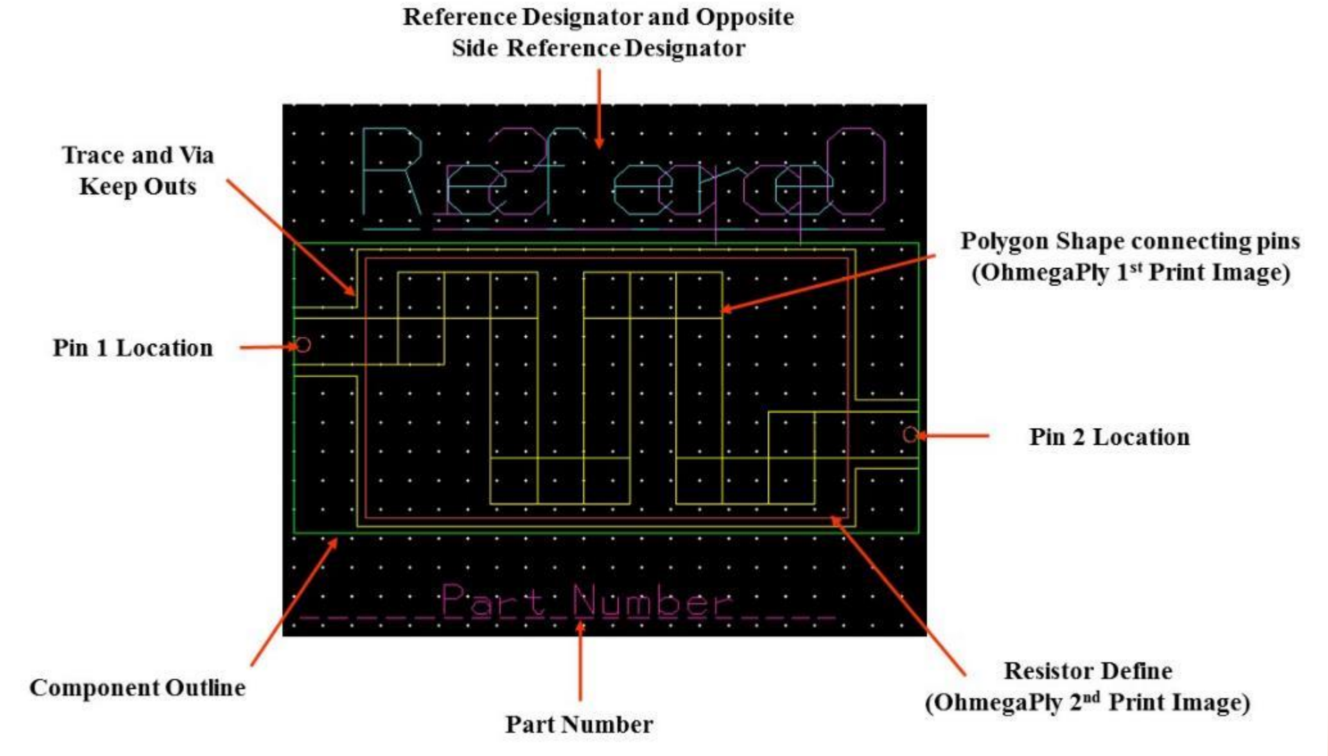
A = 25 ohm material
B = 50 ohm material
C = 100 ohm material
D = 250 ohm material



Example Buried Resistor Make-Up

Process will vary tool-to-tool but the concept is the same.

- Create layer specific pins.
- Create embedded resistor shape. Include trace and via keep-out, part and reference designators and component outline.
- On a separate layer create the resistor define (OhmegaPly 2nd Print Image). This will be used for the selective etch finishing the resistor and defining the length.



OhmegaPly® Process Considerations

Resistor Element Termination and Overlap Areas

Image 11: Element Termination Area – Defined in 1st Print. Design element length 0.005” to 0.010” longer to compensate for potential misregistration of artwork during imaging to prevent resistance errors.

Image 12: Overlap Area – Defined in 2nd Print. Design an overlap area of 0.005” to 0.010” beyond resistor’s width to compensate for potential misregistration of artwork during imaging to prevent short circuits.

To avoid potential loss of time and materials associated with reruns it is safer to adjust for 0.005” to 0.010” of overlap and termination area if space permits. In addition, further adjustments maybe necessary to compensate for etch factors.

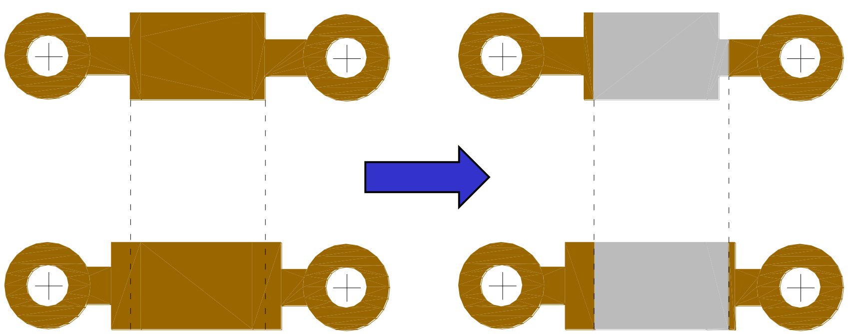


Image 11: Resistor termination adjustment

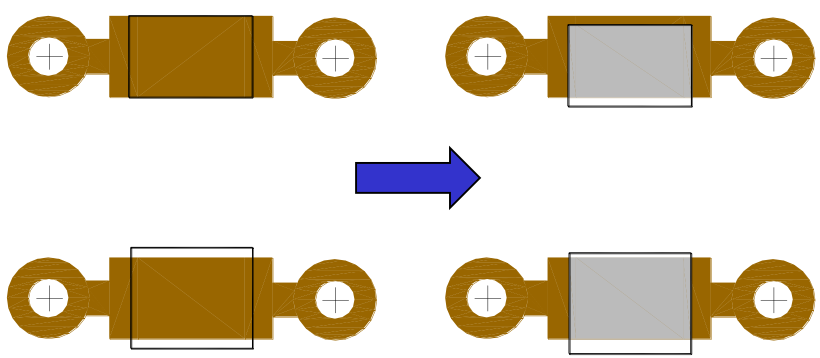


Image 12: Resistor overlap adjustment

OhmegaPly® Process Considerations

Thermal/Mechanical Isolation

In order to avoid unexpected changes in resistance caused by Z expansion from thermal excursions and mechanical stresses created by the plated through hole process it is recommended to create an offset of the resistor from the via. Offsets should also be exercised where resistors are connected to solder pads on the surface.

The recommended offset is 0.010” and 0.005” for laser drilled microvias.

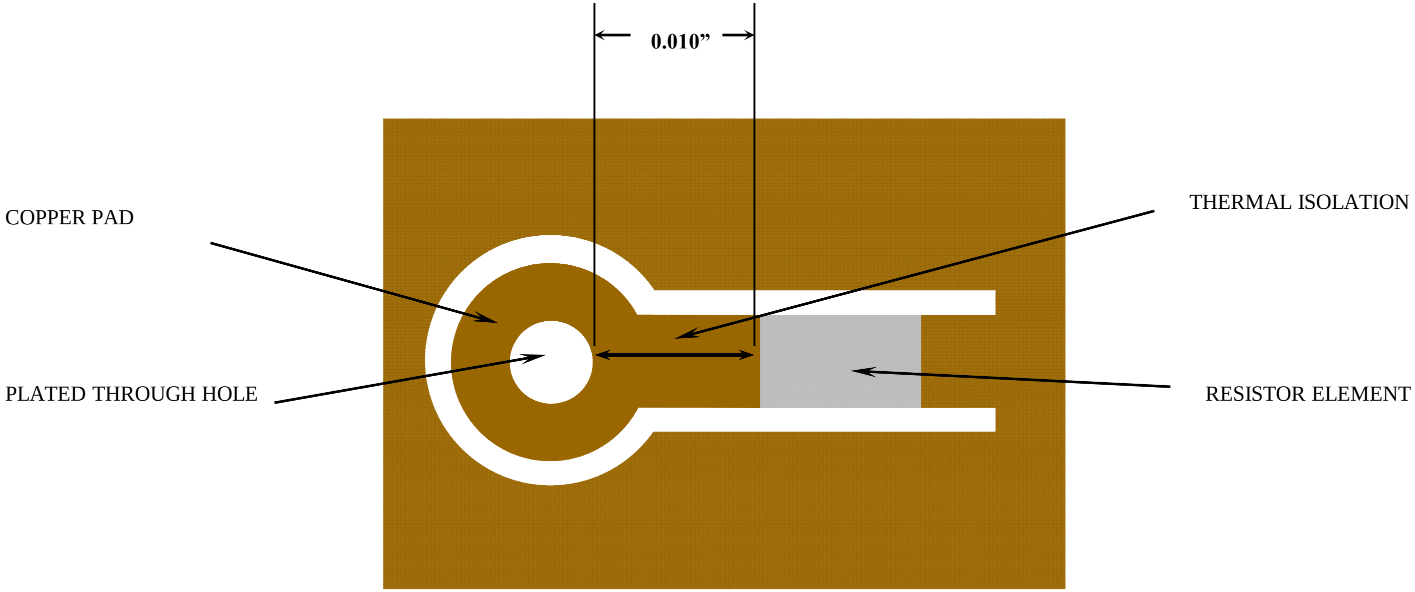
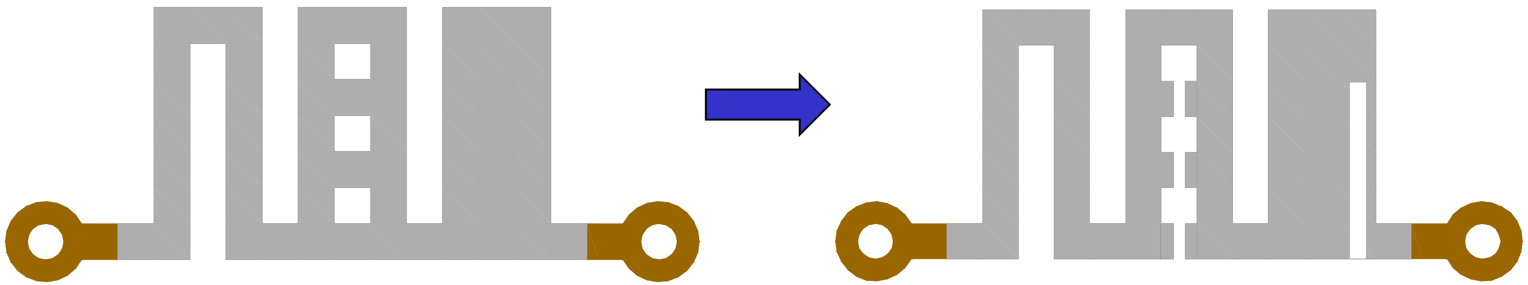


Image 13: Resistor recommended thermal/mechanical isolation.

Examples of Resistor Trimming

Resistors can be laser trimmed to achieve 1% tolerances.

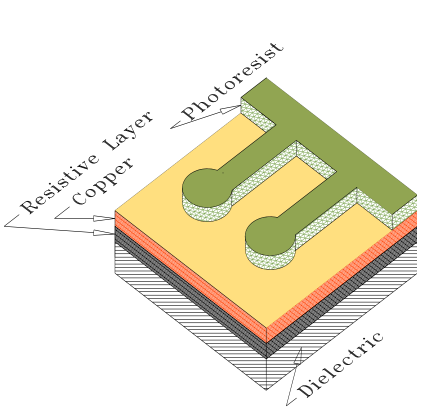
The top figures are designed without special modification for trimming except to provide enough area to handle power dissipation and current if cross-section is reduced by a conventional trim cut



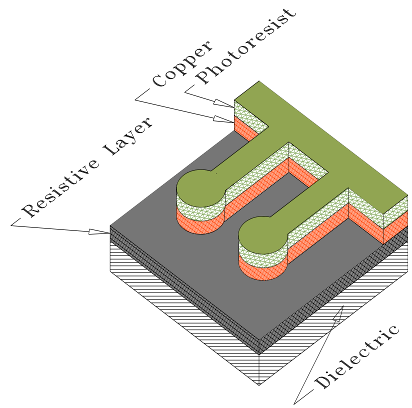
The bottom figures are designed with segments that can be trimmed without reducing cross-section of primary current path

General OhmegaPly® Fabrication Process

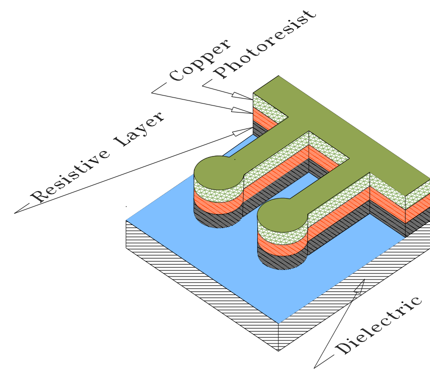
Step-By-Step Processes and Required Chemistries.



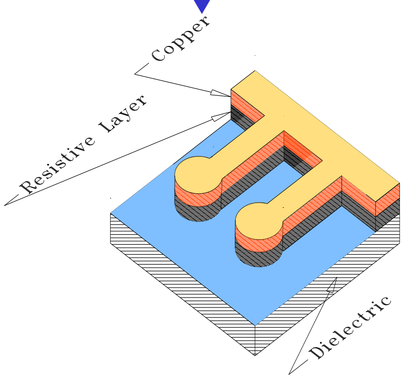
Step 1: 1st Print. Image and develop resistor widths.



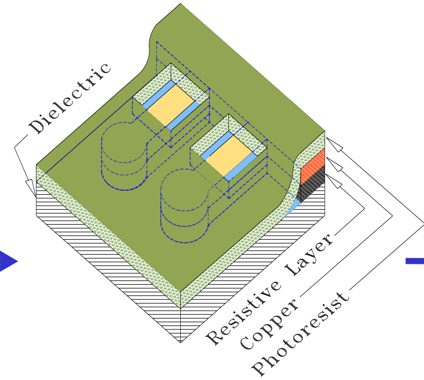
Step 2: 1st etch using any conventional copper etchant.



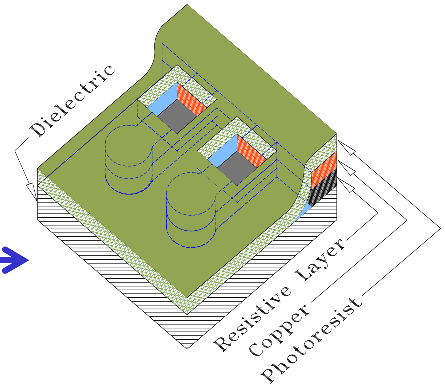
Step 3: 2nd etch to remove resistive material with $CuSO_4$



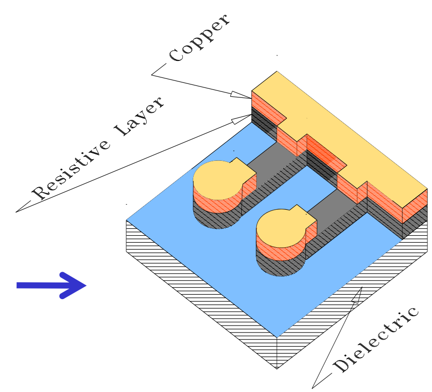
Step 4: Strip photoresist.



Step 5: 2nd Print. Image and develop resistor lengths.

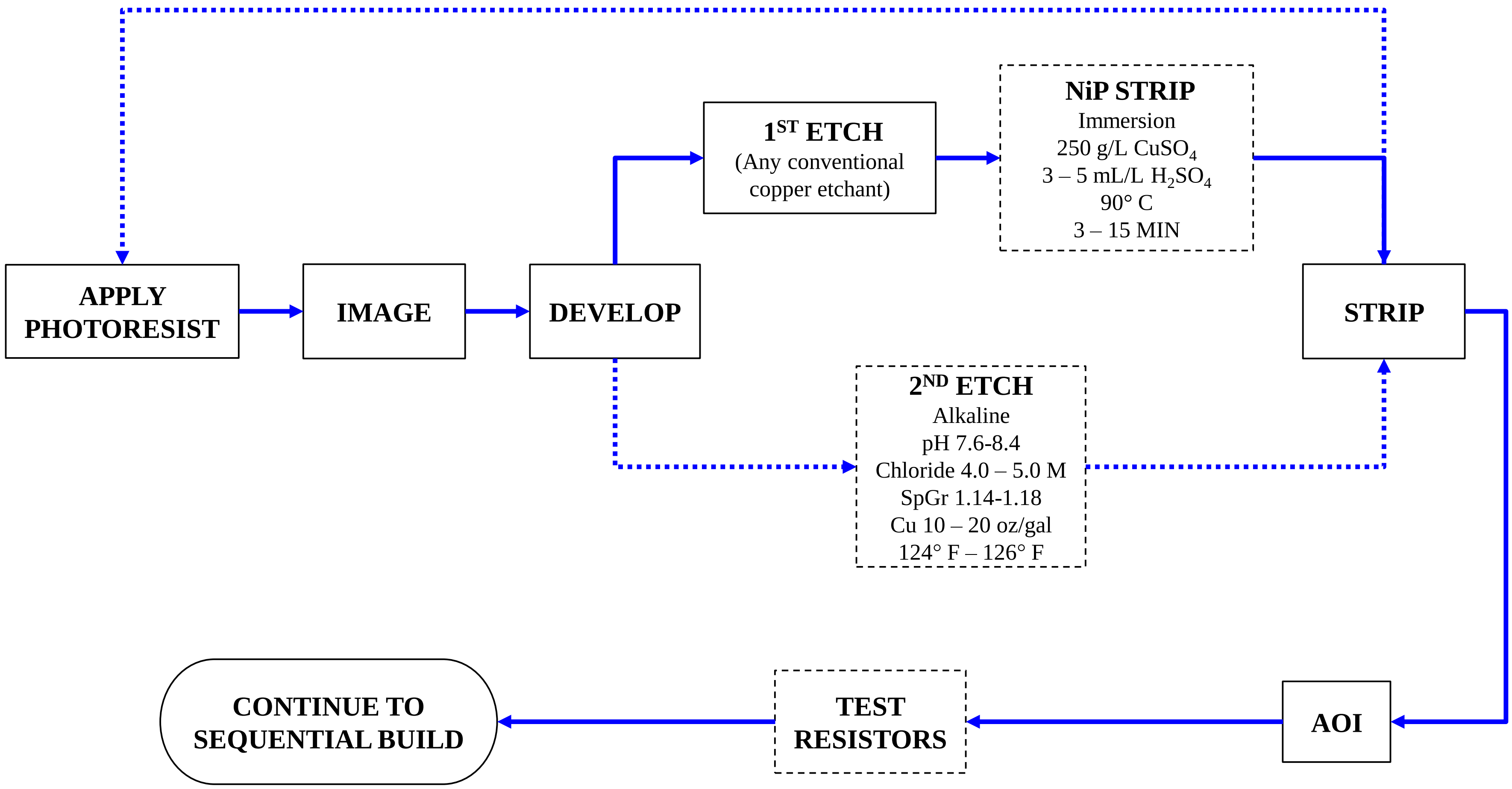


Step 6: 3rd etch. Planar resistors fully defined.



Step 7: Strip photoresist.

General OhmegaPly® Inner Layer Etch Process



Resistor Electrical Test Recommendations

- 100% electrical test should be performed on both the inner-layers and the finished bare board. Special probes enable inner-layer testing through double treat or black oxide coatings.

- Ensure the measurement current does not exceed the rated current carrying capacity of the resistor.

- AOI is not a substitute for inner layer electrical test.

- Custom software may be required to program the tester. Net lists downloaded to the tester must include all resistor locations or test points and all resistor min/max values.

- One of three methods are:
  1. A CAD generated net list in a format that includes resistors.
  2. A CAD generated net list with a secondary resistor file to merge at CAM station.
  3. Gerber extraction net list at the CAM station.

- Standard electrical test equipment is utilized:
  1. Universal bare board tester (bed-of-nails with fixture).
  2. Flying probe tester (fixtureless).
  3. Custom built tester.
  4. Manual measurement system.

- The resistance measurement accuracy depends on the instrument accuracy, contact resistance, probes and leads.

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