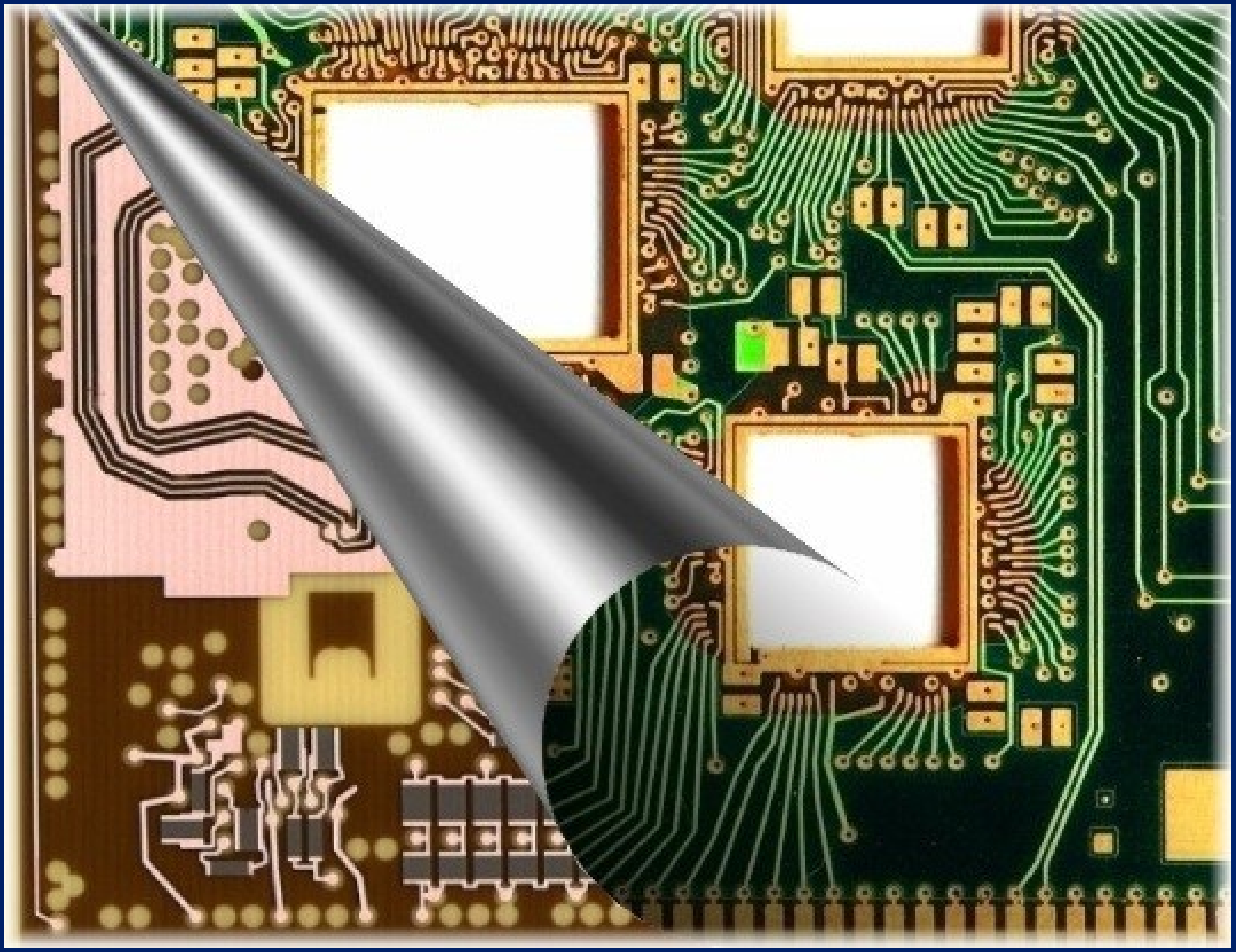
Ωhmega Technologies, Inc.



ΩhmegaPly® Design

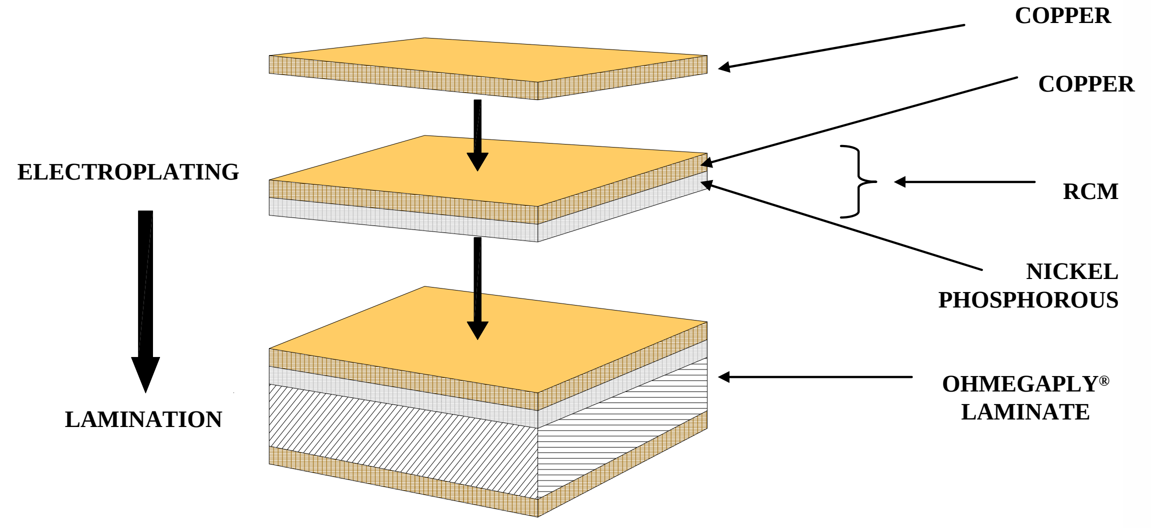
Ohmega Technologies, Inc.

OhmegaPly® Embedded Resistor Technology

1. Electrodeposited thin film resistive material for planar resistor
2. Standard subtractive PCB processing
3. Surface or embedded resistors
4. Mature technology (30+ years)
5. Field Proven, Excellent Long Term Reliability
6. Performance Enhancing, Cost Effective Resistor Technology in High Speed/High Density Circuit Designs

OhmegaPly® Manufacturing Overview

OhmegaPly® is a thin film Electrodeposited-On-Copper NiP metal alloy (RESISTOR-CONDUCTOR MATERIAL) that is laminated to a dielectric material and subtractively processed to produce planar resistors. Because of its thin film nature, it can be buried within layers without increasing the thickness of the board or occupying any surface space like discrete resistors.



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OhmegaPly® Sheet Resistivity Vs. % Tolerance

Sheet Resistivity	Material Tolerance
10 Ω/□	3%
25 Ω/□	5%
50 Ω/□	5%
100 Ω/□	5%
250 Ω/□	10%

OhmegaPly® Laminate Recommended Copper Type

TOCIII

PTFE

Rogers Duroid®

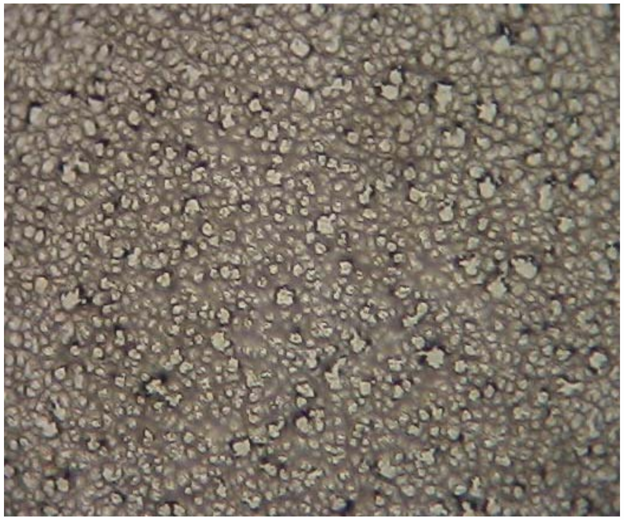
Arlon CLTE

Ohmega/Faradflex ®

BC24

BC16

Flex



1R25 with TOCIII COPPER FOIL at 200X

PT

Hi T_g Epoxy

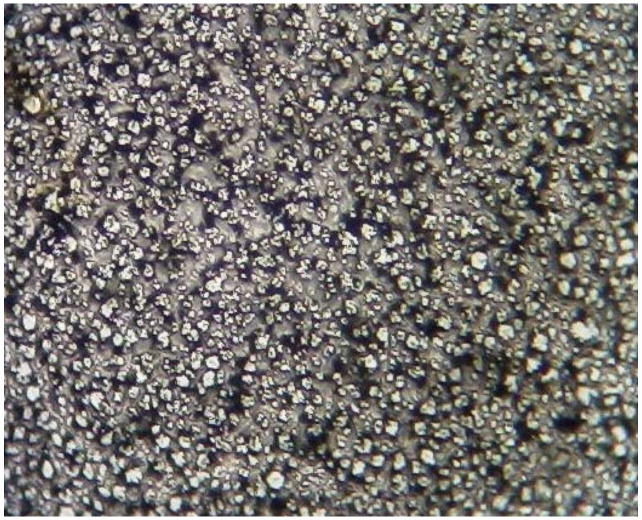
Polyimide

Lead-Free

Rogers 4003

Ceramic-Filled

LCP (Rogers Ultralam 3850)



1R25 with PT COPPER FOIL at 200X

DFF

Ohmega/Faradflex ®

BC12

BC8

1R25 with DFF COPPER FOIL at 200X

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Advantages of OhmegaPly®

A. Electrical Advantages

1. Improved line impedance matching,
2. Shorter signal paths and reduced series inductance,
3. Eliminate the inductive reactance of the SMT device,
4. Reduced cross talk, noise and EMI

B. PCB Design Advantages

1. Increase active component density & reduced form factors,
2. Improved wireability due to elimination of via.
3. Improved reliability due to elimination of solder joints.

C. Improved Reliability

1. Low RTC of <50 PPM
2. Life testing: 100,000 hours = +2% at 110° C
3. Stable over wide frequency range: tested beyond to 20+ GHz.
4. Lead-free compatible

D. Economic Advantages

1. Elimination of discrete resistors
2. Improved assembly yield
3. Board densification and/or size reduction

Advantages of OhmegaPly®

D. Economic Advantages

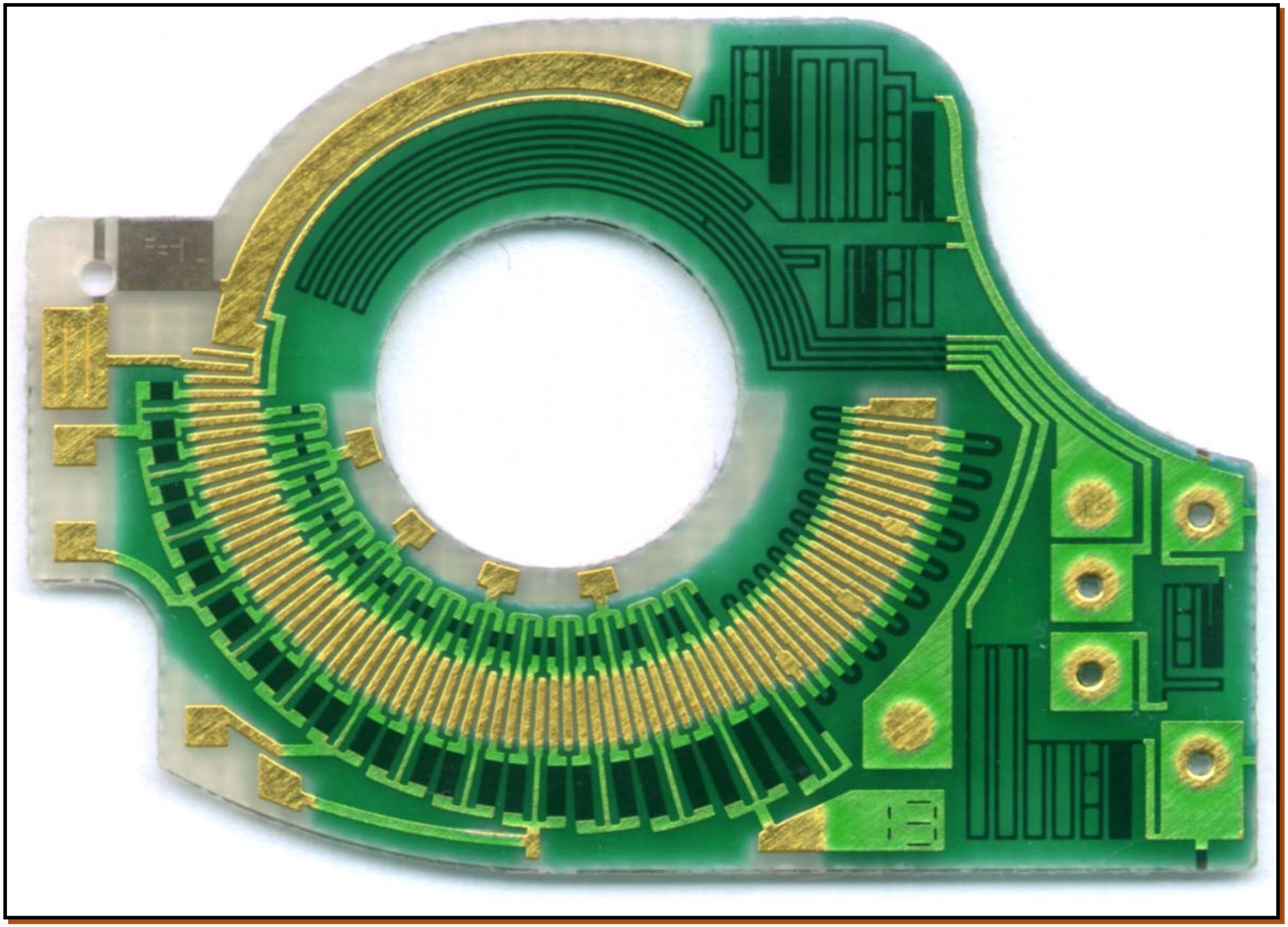
4. Board simplification (double sided SMT to single sided SMT; potential layer and via count reduction)
5. Deliver tested board to the assemblers

E. Minimal Risk

1. Over 30 years of use
2. Predictable
   - Design: Know how to achieve target with simple formula (L/W x Rs)
   - Process: Know how to characterize and compensate
   - Linear relationship: increase 10% resistor length equal to 10% increase in resistance value
   - Yield: process capability and tolerance drive yields
3. Proven long term reliability

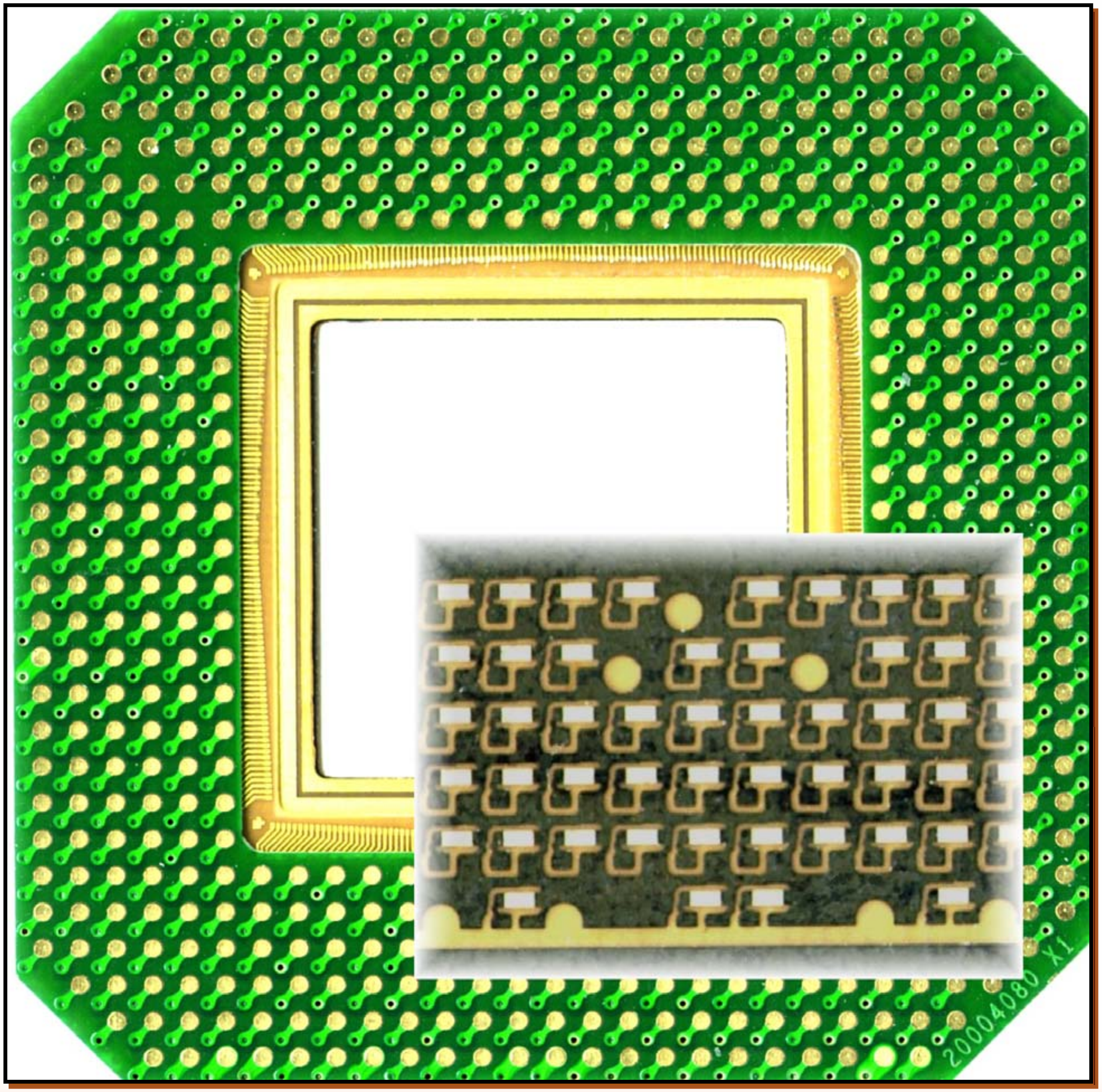
Typical OhmegaPly® Applications

Actual Designs Used Over the Past 30 Years



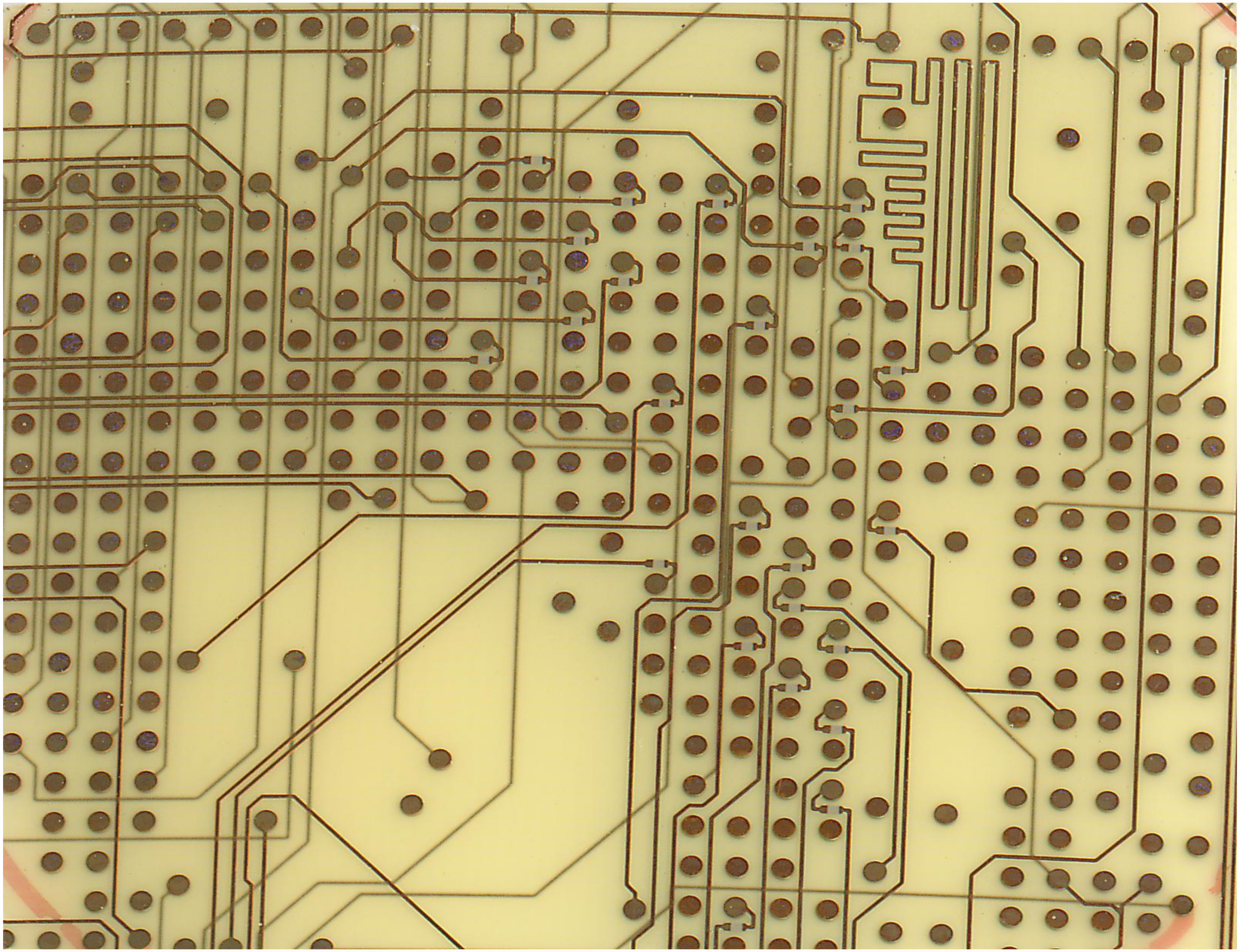
Surface resistor application –Potentiometer (35 mm SLR camera).

Typical OhmegaPly® Applications



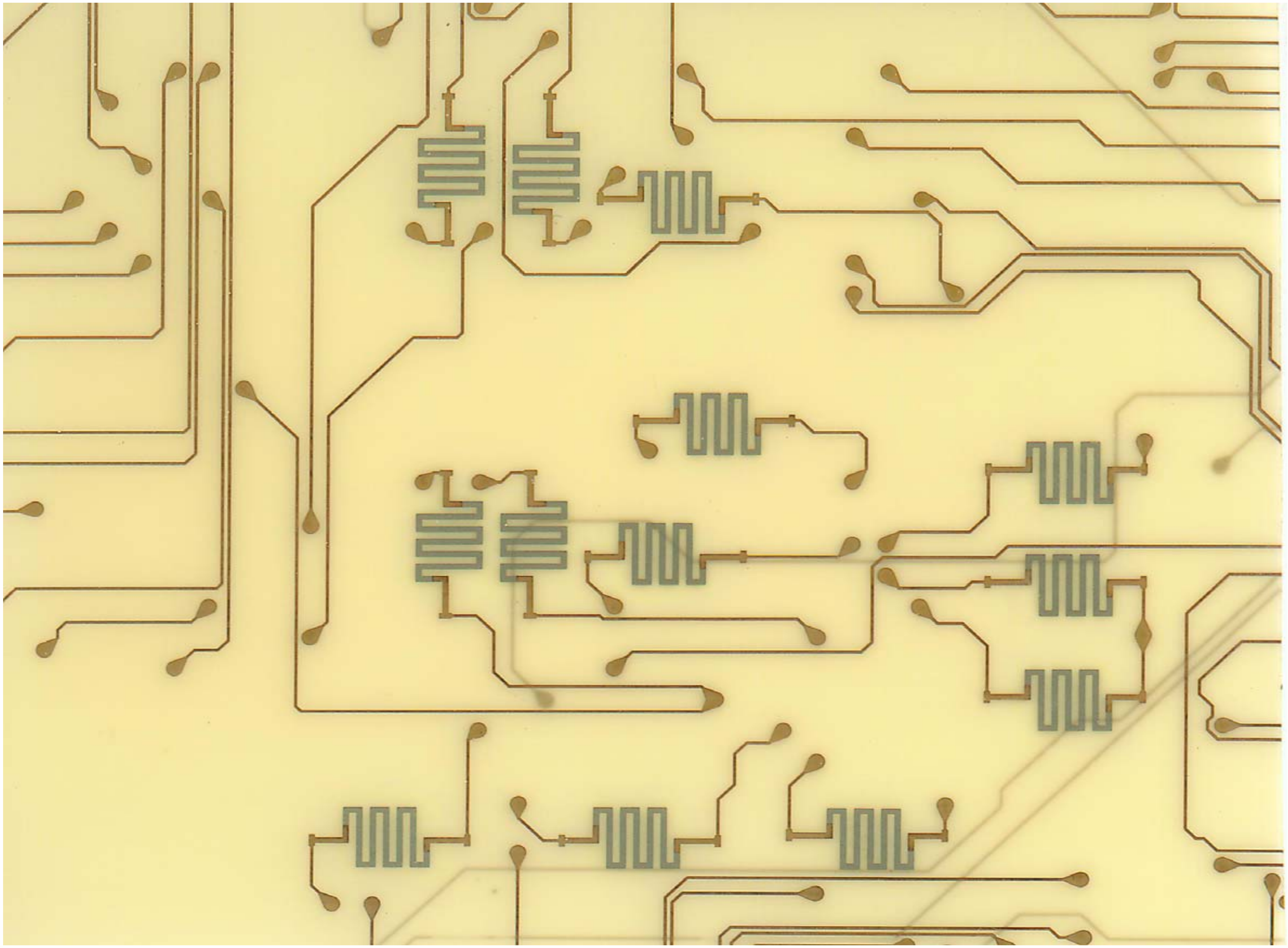
Interposer board.

Typical OhmegaPly® Applications



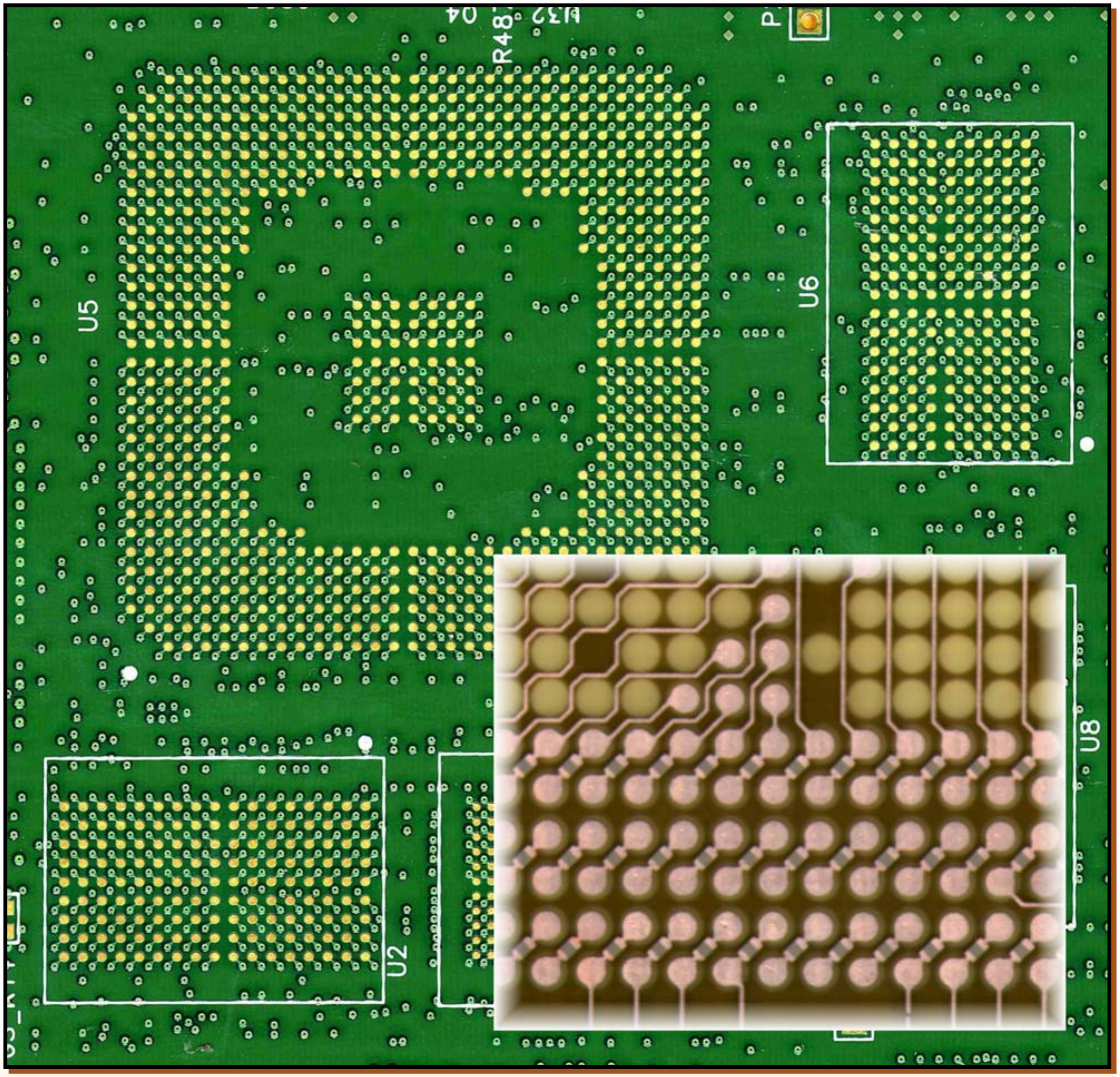
Series termination resistors in a BGA package.

Typical OhmegaPly® Applications



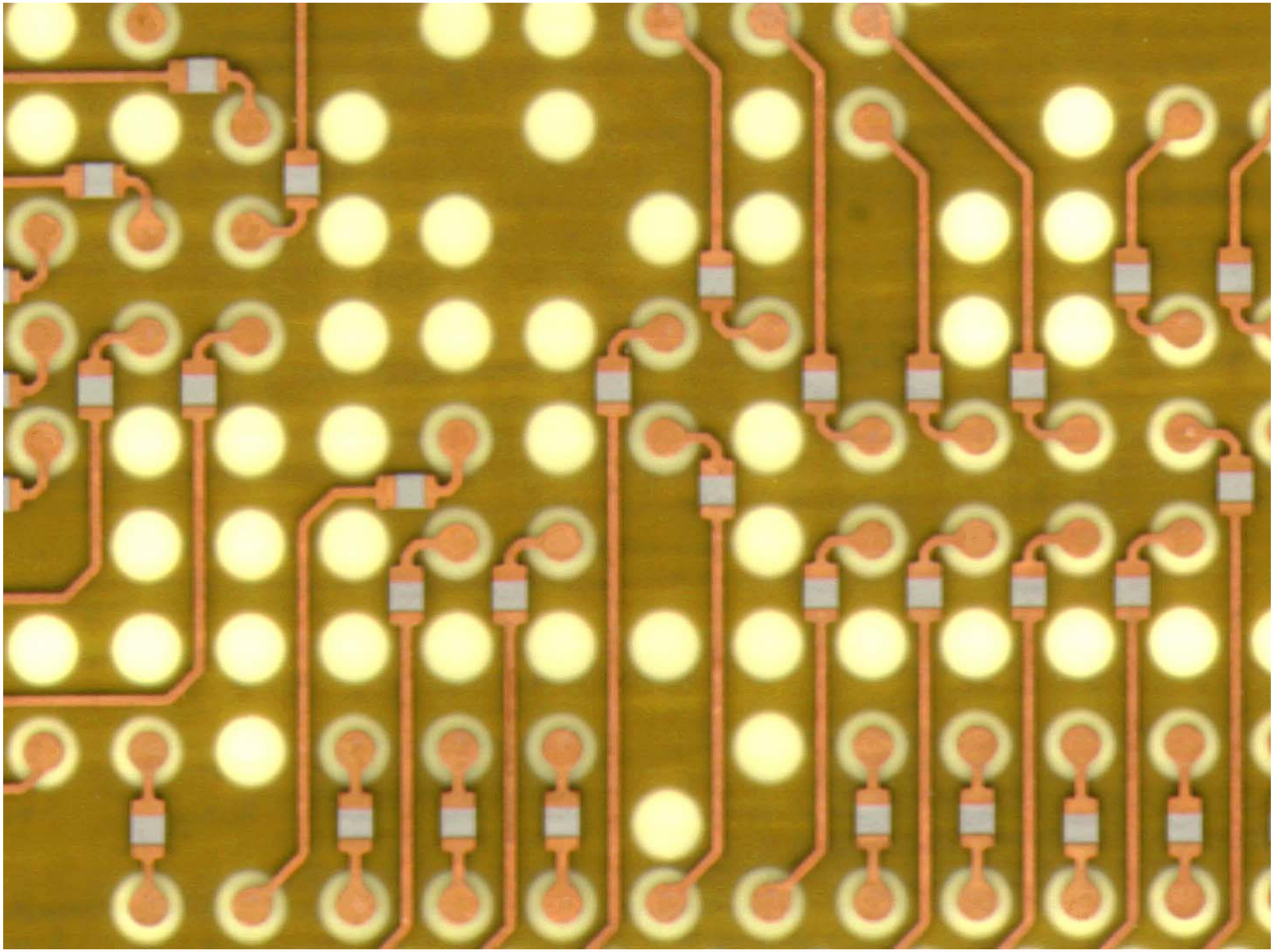
Pull-up resistors in an avionic application

Typical OhmegaPly® Applications



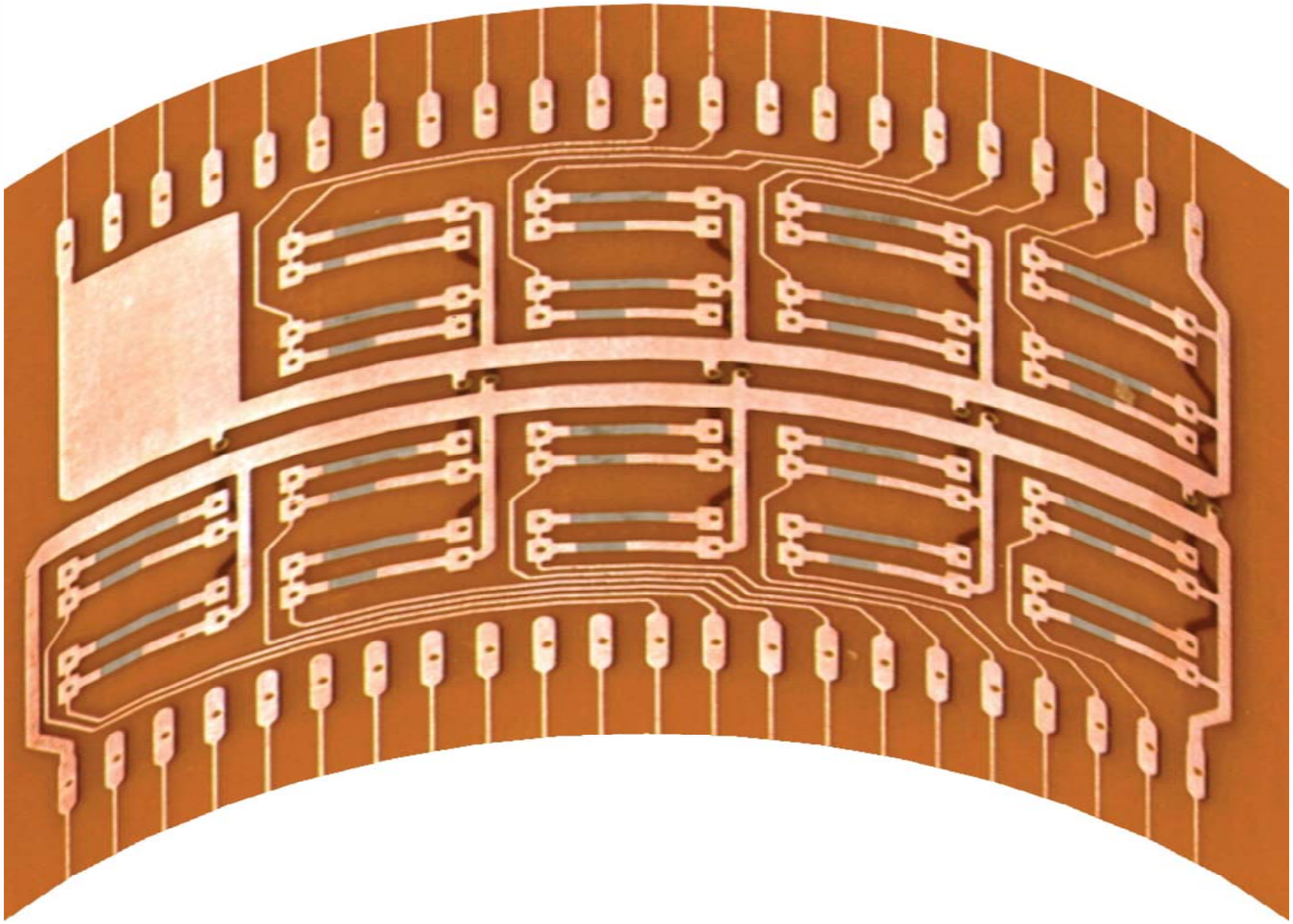
HDI board.

Typical OhmegaPly® Applications



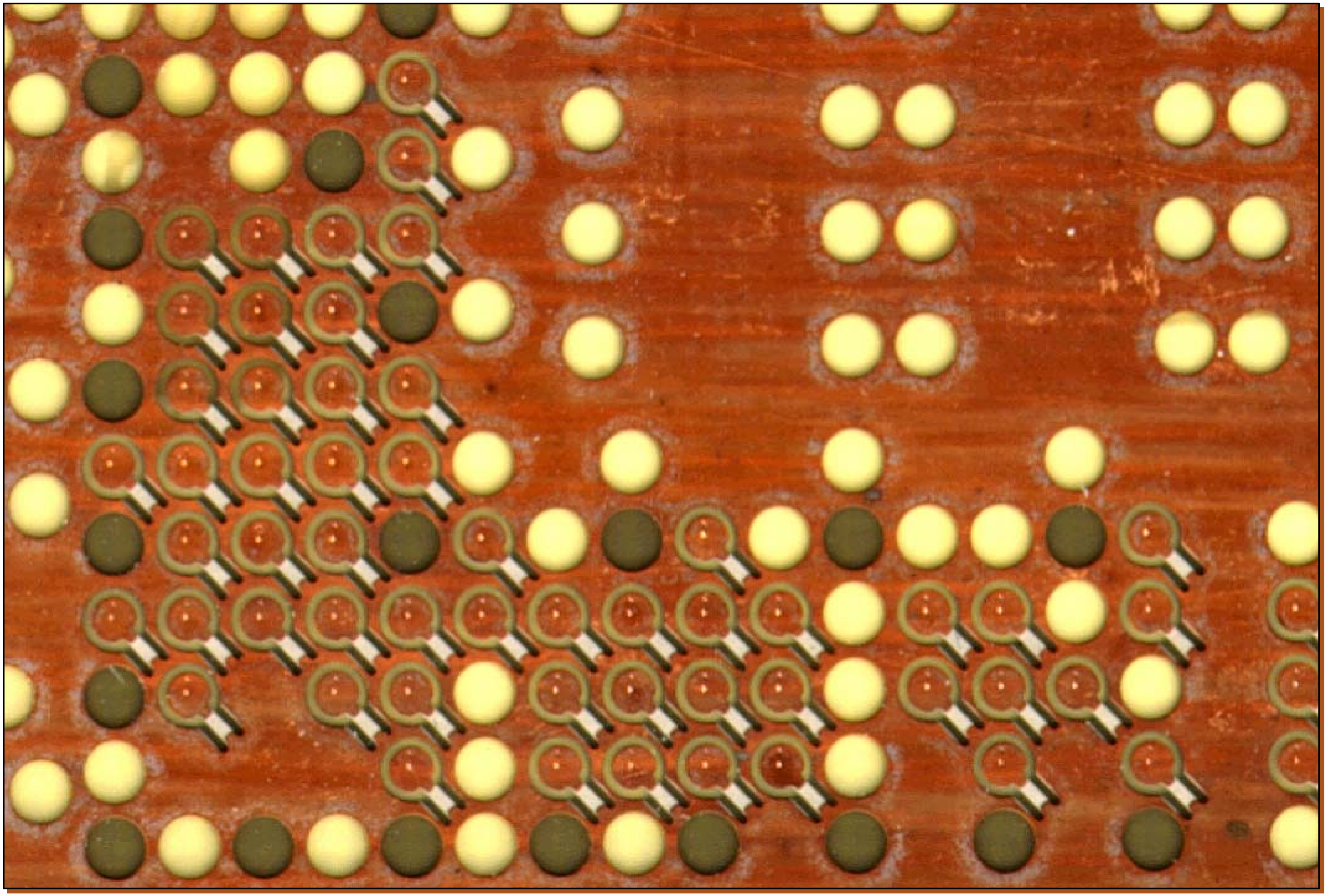
Series termination resistors for telecom switching card

Typical OhmegaPly® Applications



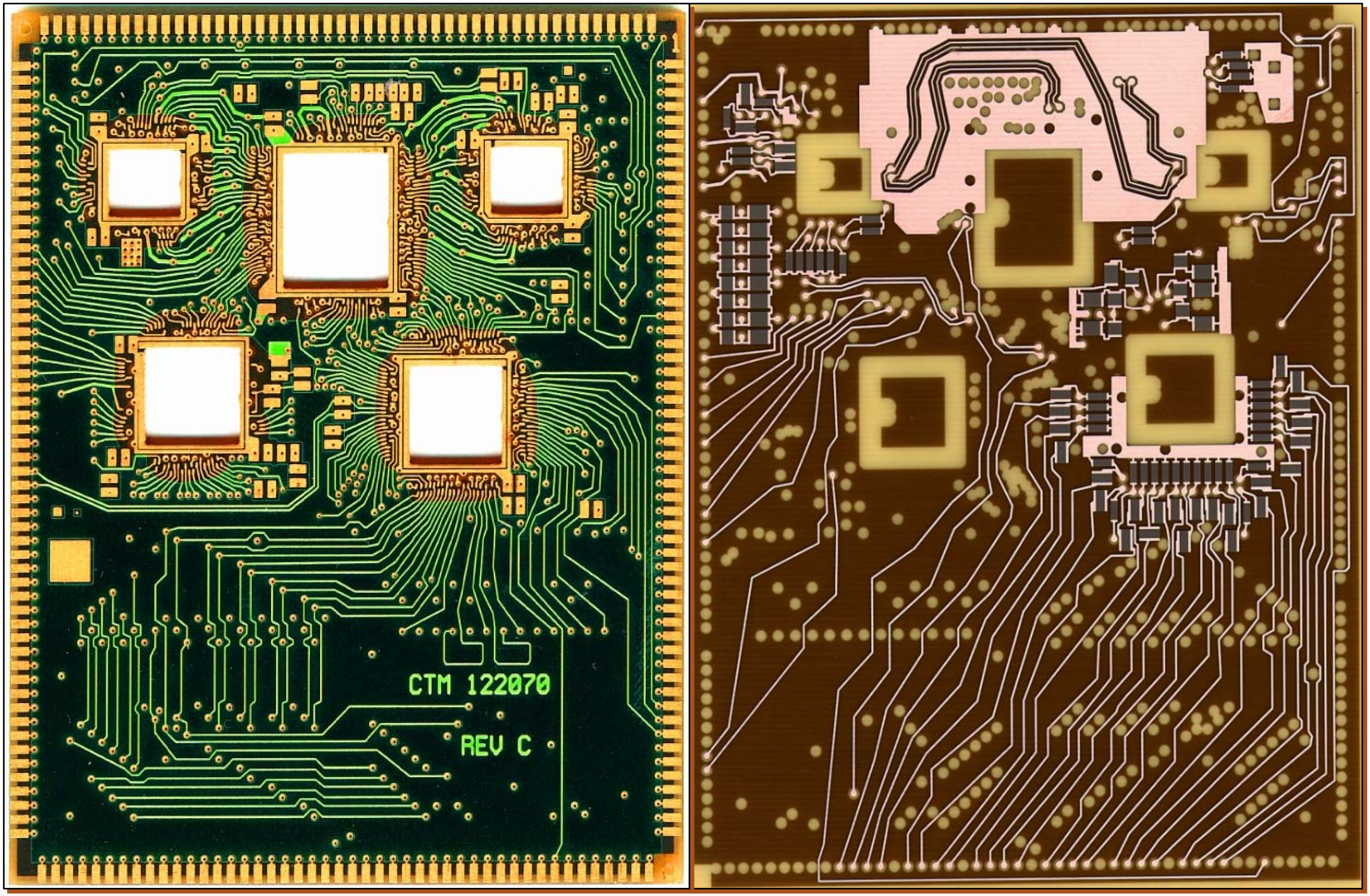
OhmegaPly® Resistors in Flex Circuit

Typical OhmegaPly® Applications



▲ *Parallel termination resistors in a BGA package.*

Typical Ohmega-Ply ® Applications



▲ *Buried resistor application – 2” X 3” Probe Card.*

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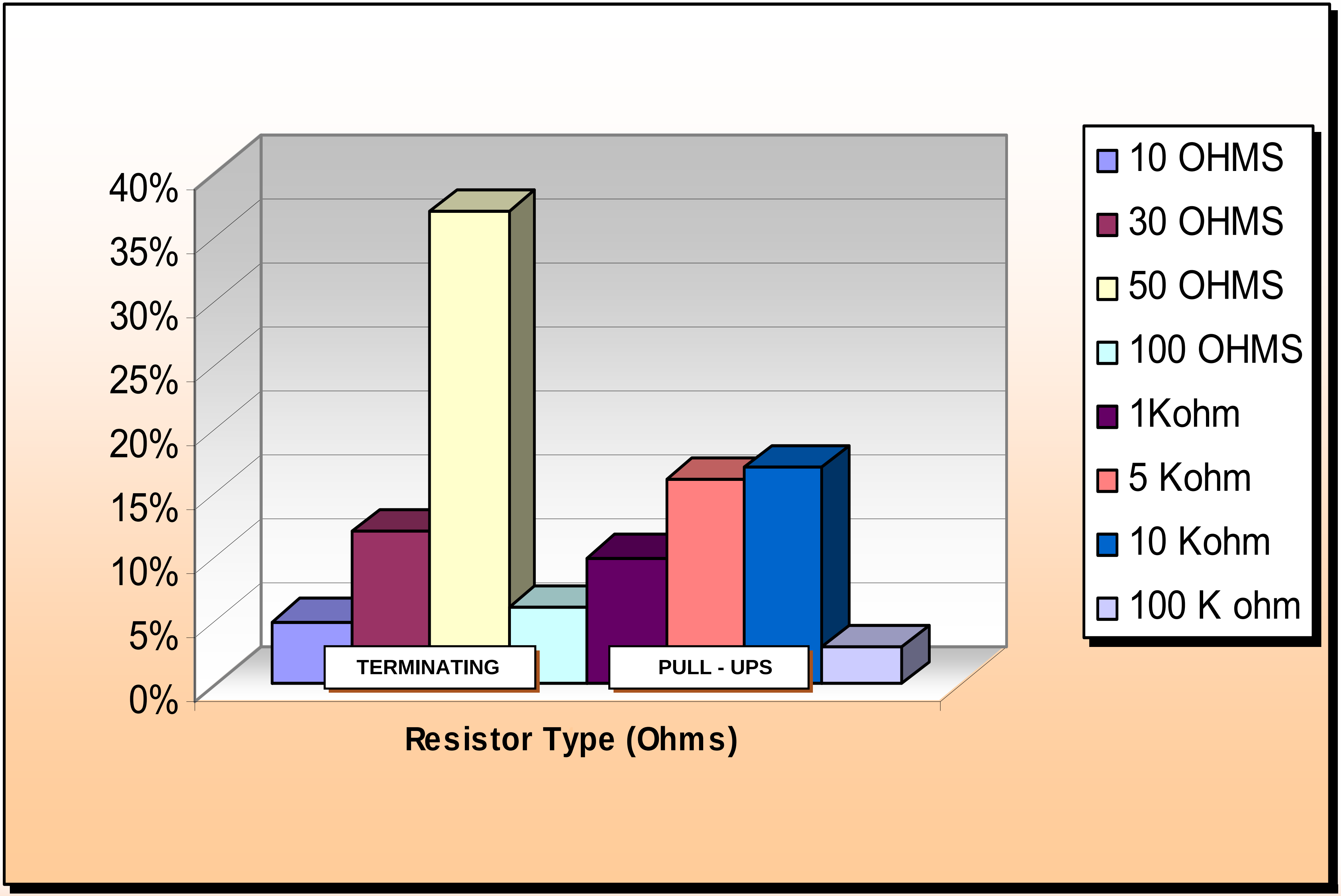
Distribution of Ohmega-Ply® Resistor Values



OhmegaPly® Basic Design Overview

A. Explanation of Ohms-Per-Square

The resistance of a OhmegaPly® resistor:

$$R = R_S \frac{Length\ of\ Resistor}{Width\ of\ Resistor}$$ Equation.1

Where R_S is the sheet resistance (in ohms per square) of the PRT material. The resistance value of the resistor can be determined by sheet resistance and geometry of the resistor according to the formula above.

$$R = R_S \times N$$ Equation.2

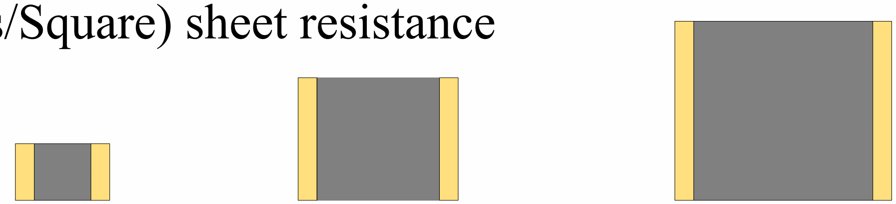
Where N is the number of squares ($N = L/W$)

OhmegaPly® Basic Design Overview

Sheet resistivity (stated in Ohms per square) is dimensionless

- A square area of resistive material = sheet resistivity of resistive material

  E.g., a 25 Ω/(Ohms/Square) sheet resistance



L1 = W1 N1 = 1 R1 = 25 Ohms

L2 = W2 N2 = 2 R2 = 25 Ohms

L3 =W3 N3 =3 R3 = 25 Ohms

- Resistor value = sheet resistivity x ratio of element length to width (R =Rs x L/W)

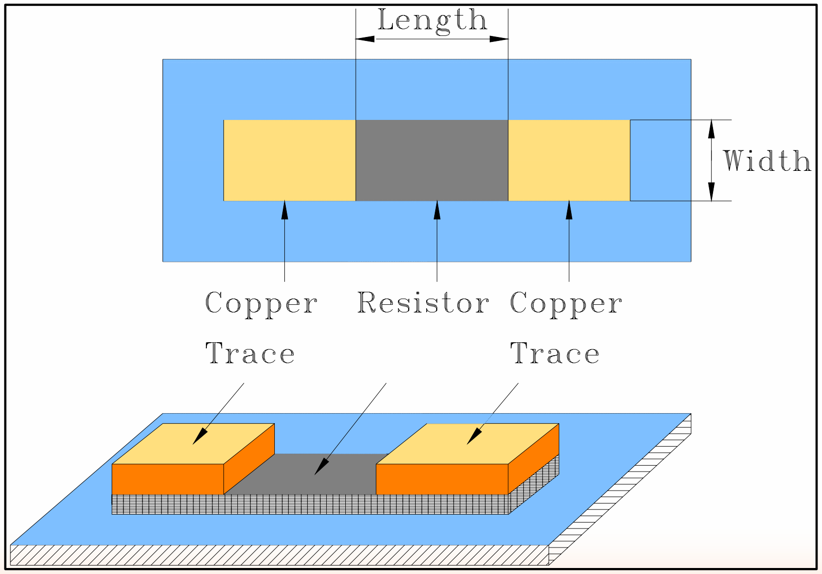
  E.g., a 25 Ω/ sheet resistivity

  Length = 0.030” (30 mils)

  Width = 0.015 “ (15mils)

  Resistor value = 25 Ω/ x (30mils/15mils)

  = 25 Ω/ x 2 squares = 50 ohms



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Determine and Recommend Resistor Sizes Under Spreadsheet Program

A - DESIGN SPECIFICATION

Please enter the resistance value **(*R*)** in Ohm**,** power rating ***(P)*** in milliWatt, and *maximum* tolerance **(*t*)** in percent for each desired resistor (**R_1, R_2, R_3, R_4 & R_5**) in table 1 below, and exit the cell to allow the program performs the calculations.

	R_1	R_2	R_3	R_4	R_5
Resistance Value ***(R)*** in Ohm	10	25	50	100	250
Power Rating ***(P)*** in mW	20	62	65	125	250
Maximum Tolerance ***(t)*** in %	7	11	15	15	20

Table 1. For designer to enter the resistance, power rating and percent tolerance values of desired resistors

B - RECOMMENDED MINIMUM WIDTH AND LENGTH OF DESIRED RESISTORS

Sheet Resistivities (Ohm/Sq.)	R_1			R_2			R_3			R_4			R_5		
	W_1 (Mil)	L_2 (Mil)		W_2 (Mil)	L_2 (Mil)		W_3 (Mil)	L_3 (Mil)		W_4 (Mil)	L_4 (Mil)		W_5 (Mil)	L_5 (Mil)	
10	35.0	35.0	*t**	12.0	30.0	*t**	7.0	35.0	*t**	7.0	70.0	*P**	7.0	175.0	*P**
25	123.0	49.2	*t**	23.0	23.0	*t**	11.0	22.0	*t**	13.0	52.0	*P**	13.0	130.0	*P**
50	210.0	42.0	*t**	35.0	17.5	*t**	16.0	16.0	*P**	20.0	40.0	*P**	19.0	95.0	*P**
100	385.0	38.5	*t**	58.0	14.5	*t**	28.0	14.0	*P**	35.0	35.0	*P**	32.0	80.0	*P**
250	607.0	24.3	*P**	770.0	77.0	*t**	84.0	16.8	*t**	59.0	23.6	*P**	53.0	53.0	*P**

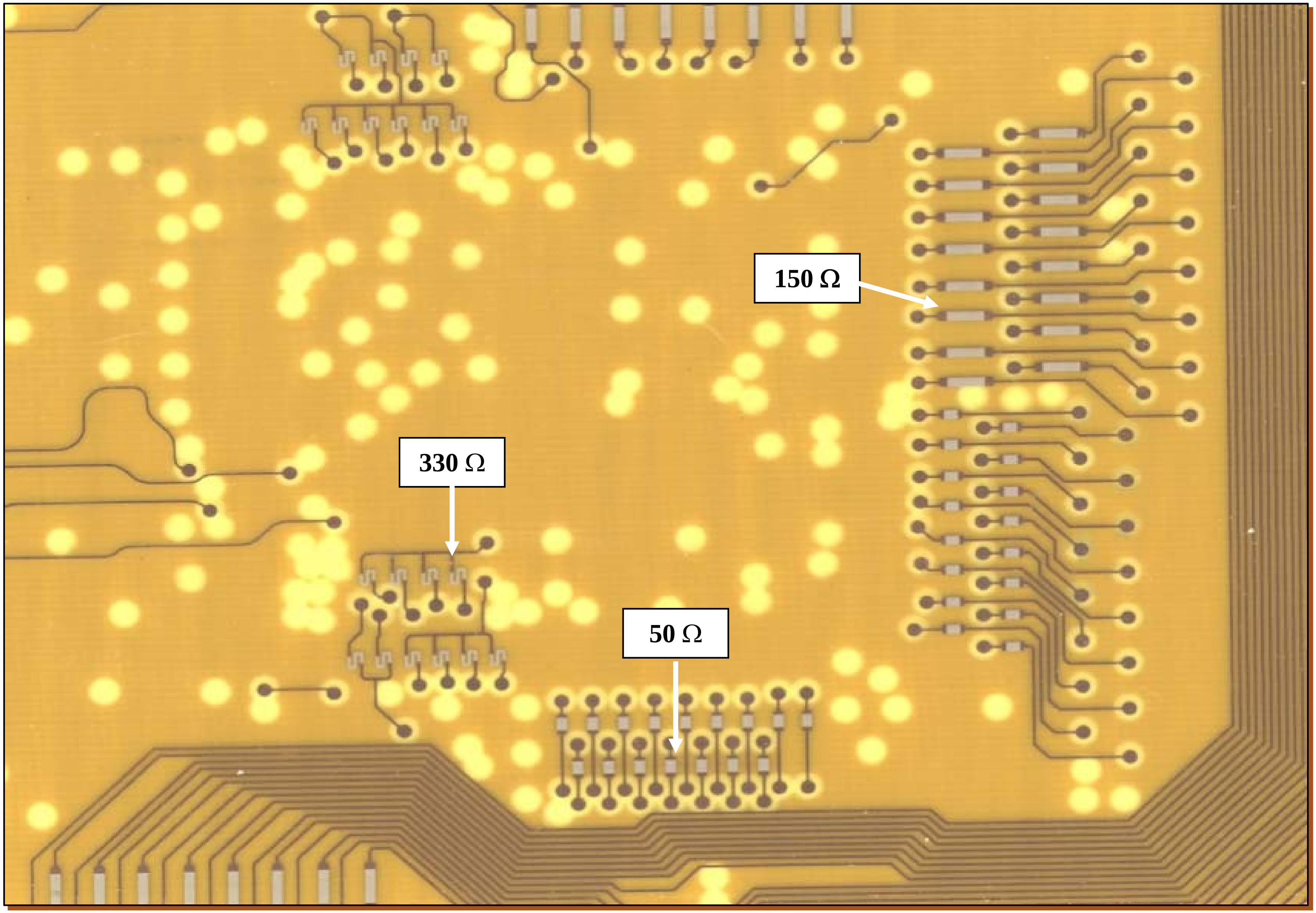
Table 2. The recommended minimum width and length for each desired resistor which is calculated by the program base on the given values by the designer in table 1.

C - RECOMMENDED RESISTOR FOOTPRINTS

R_s	R_1	R_2	R_3	R_4	R_5
10	Bar Type	Bar Type	Bar Type	Bar Type	Serpentine
25	Partial Square	Bar Type	Bar Type	Bar Type	Bar Type
50	Partial Square	Partial Square	Bar Type	Bar Type	Bar Type
100	Partial Square	Partial Square	Partial Square	Bar Type	Bar Type
250	Partial Square	Partial Square	Partial Square	Partial Square	Bar Type

Table 3. The recommended resistor footprints for different type of sheet resistivities

Ohms Per Square

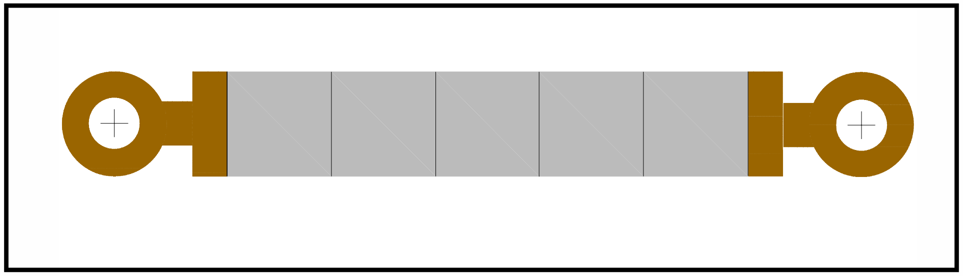


Termination and pull-up resistors in an ATM switching card.

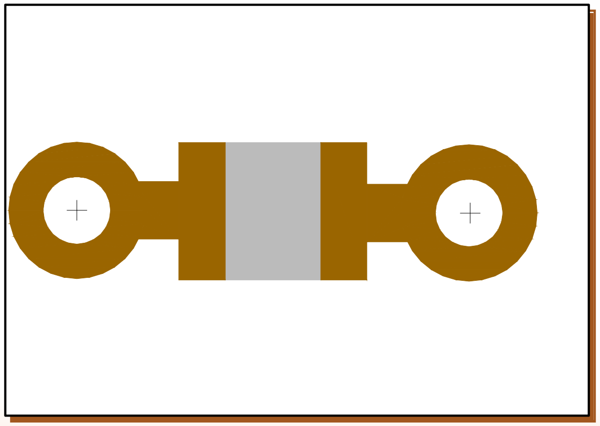
Basic Resistor Pattern

1. Bar Type

a. Multiple Squares (N ≥ 1)



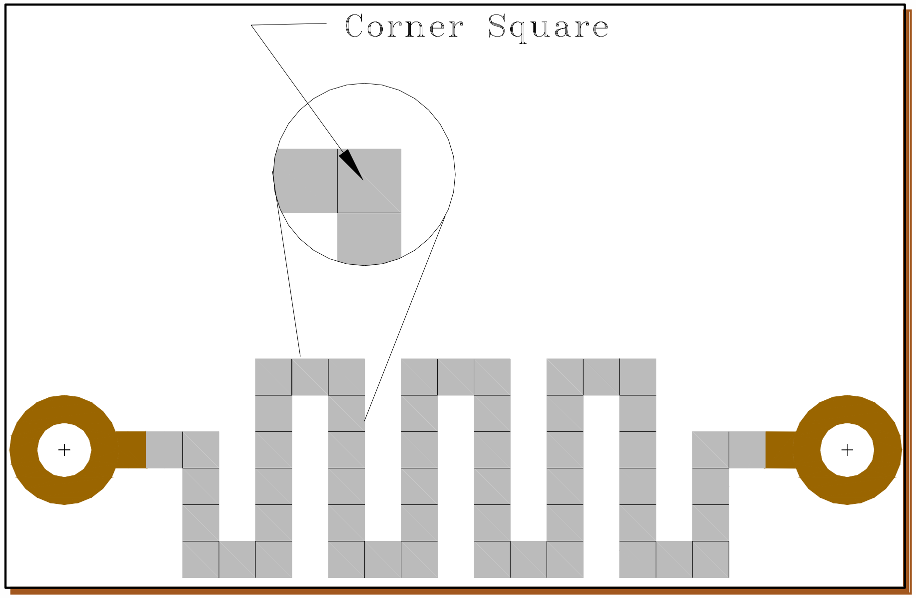
b. Partial Squares (N < 1)



OhmegaPly® Basic Design Overview

2. Meander Type

Basically, a meander resistor can be considered as a bar resistor with the exception of the corner squares (right-angle bends). Due to the change in current density at right-angle path, the effective number of square is ***0.56.***



e.g., sheet resistance (R_S) = 100 Ω/□
No. of squares = 37
No. of corner squares = 16
Total No. of effective squares = 37 + (16 x 0.56)
= 45.9
≅ 46
Resistance value = 46 x 100
= 4.6 KΩ

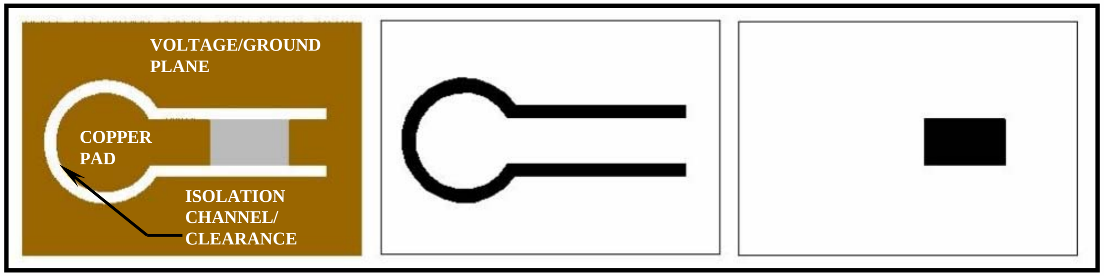
PCB processing of OhmegaPly®

Artwork layout

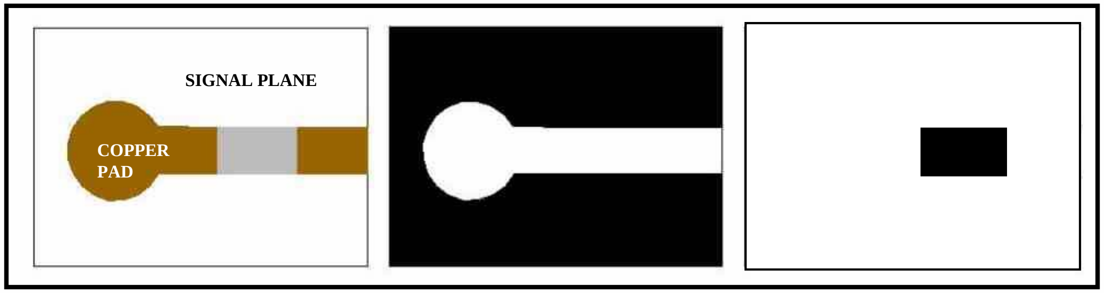
PRT resistors processing consists of two prints:

1st print – COMPOSITE image of conductors and resistors

2nd print – RESISTOR DEFINE image of resistor elements, which is commonly used for voltage or ground plane with most of the copper preserved or CONDUCTOR PROTECT image of conductor, commonly used for signal plane



▲ *Composite (negative film) resistor define*



▲ *Composite (negative film) conductor protect*

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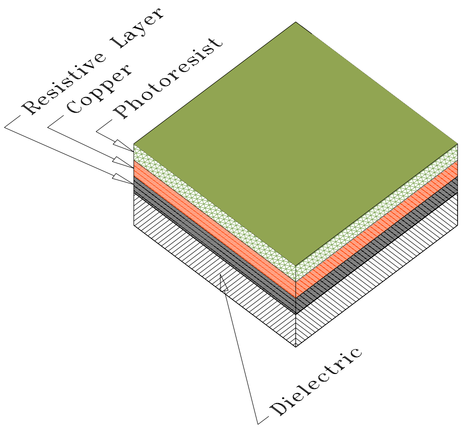
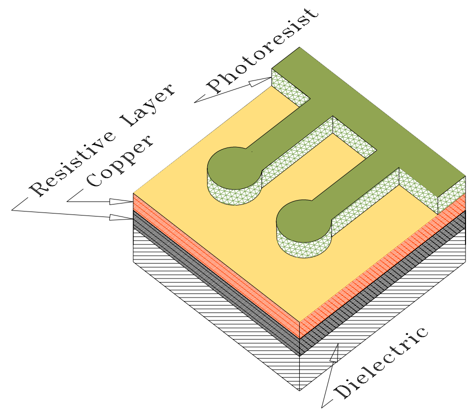
PCB processing of OhmegaPly®

A. Step-By-Step Processes and Required Chemistries.

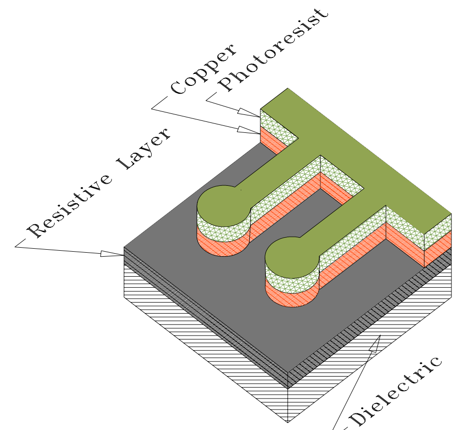
- **STEP 1**: Apply Photoresist to Laminate



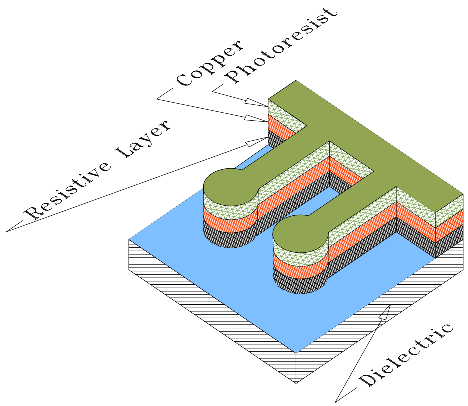
- **STEP 2**: Print and Develop Composite Image



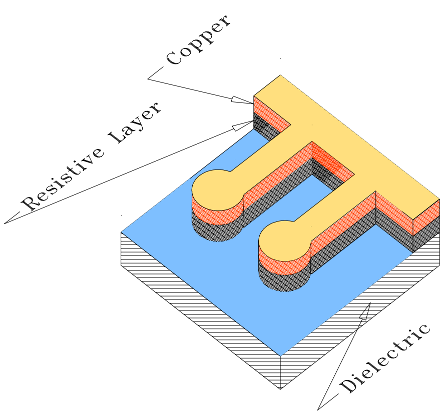
- **STEP 3**: Etch Unwanted Copper Using Any Conventional Etchant (1st etch)



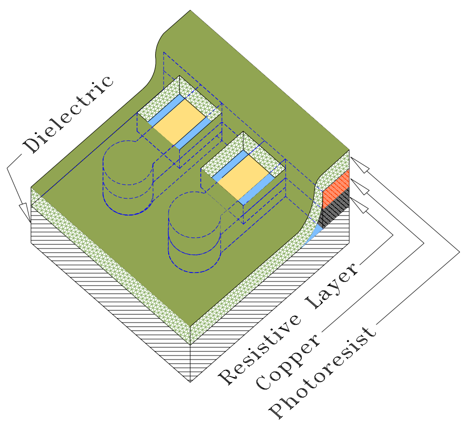
- **STEP 4**: Etch Unwanted Resistive Material with Copper Sulfate Solution (2nd etching process)



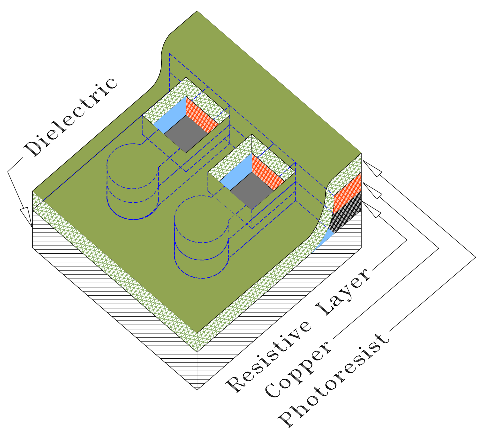
- **STEP 5**: Strip Photoresist



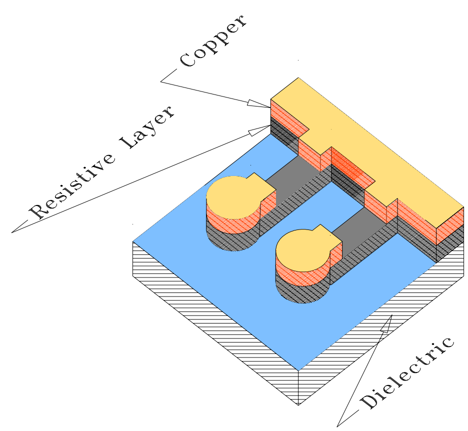
- **STEP 6**: Apply Photoresist, Print and Develop Conductor Protect Image (2nd print)



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

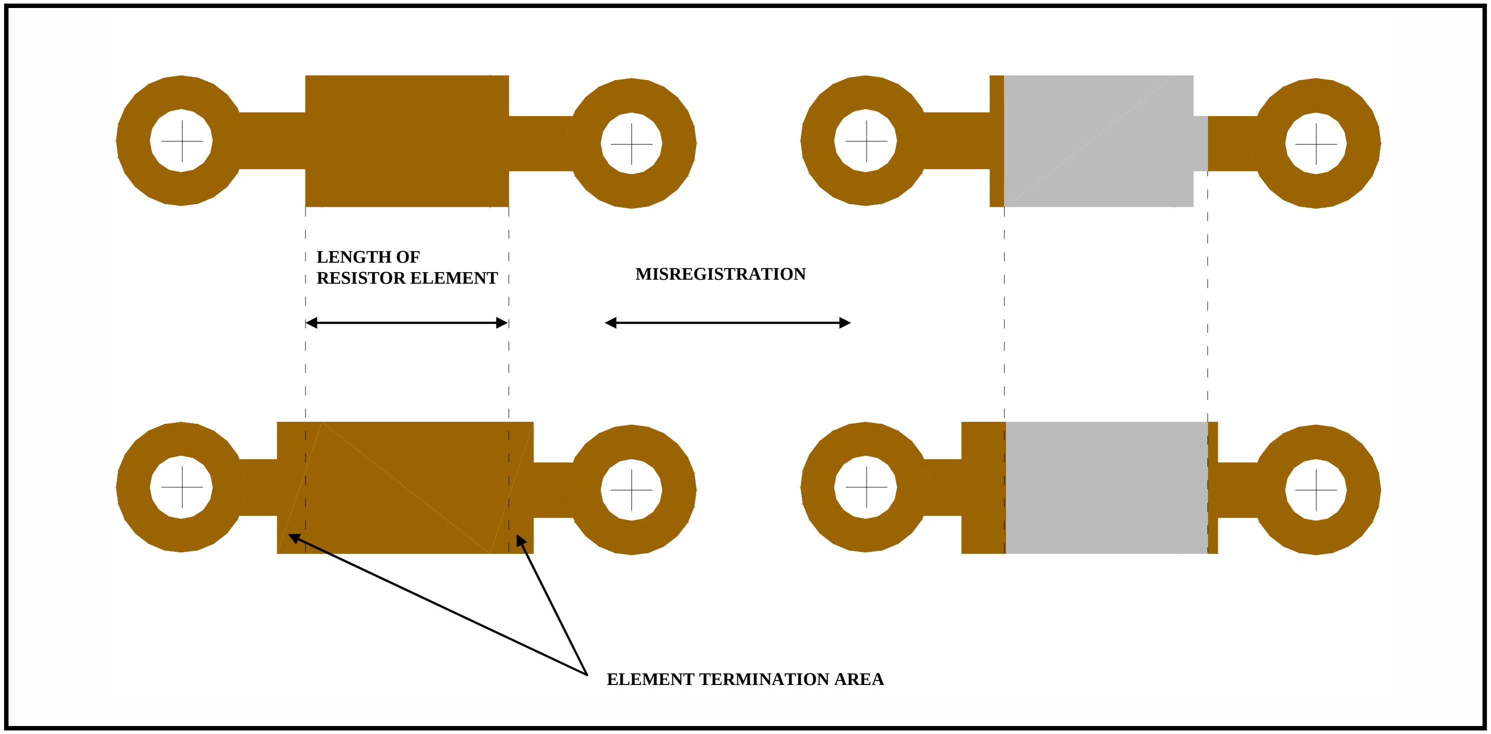


- **STEP 8**: Strip Photoresist



Design Element Termination and Overlap Area

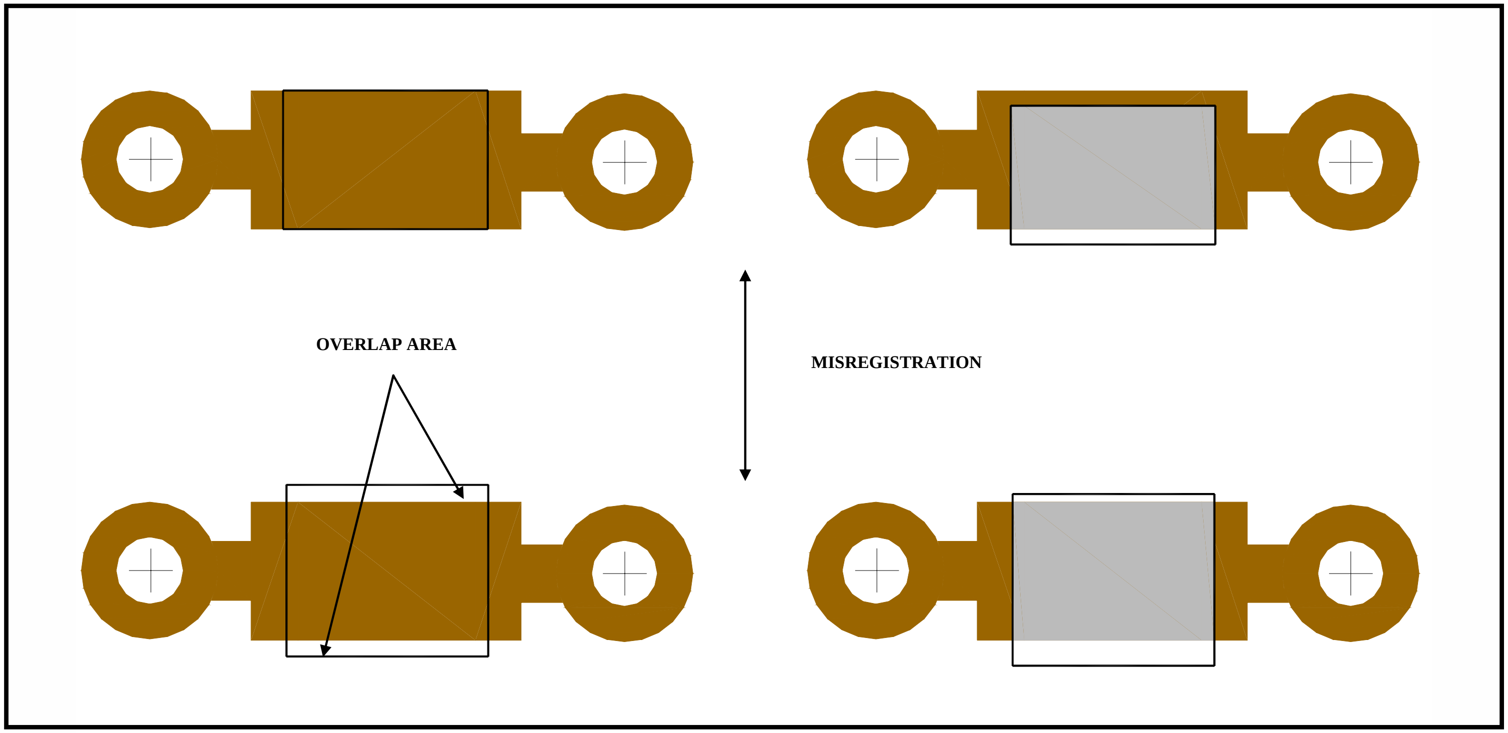
1. **Element Termination Area** – design element length longer (5-10 mils) so that any misregistration or misalignment of artwork can be compensated.



▲ *Composite - 1st print*

PCB processing of OhmegaPly®

2. **Overlap Area** – design the overlap area (5 to 10 mils beyond resistor's width) so that any misregistration or misalignment of artwork in image printing process can be compensated as is shown in figure above.



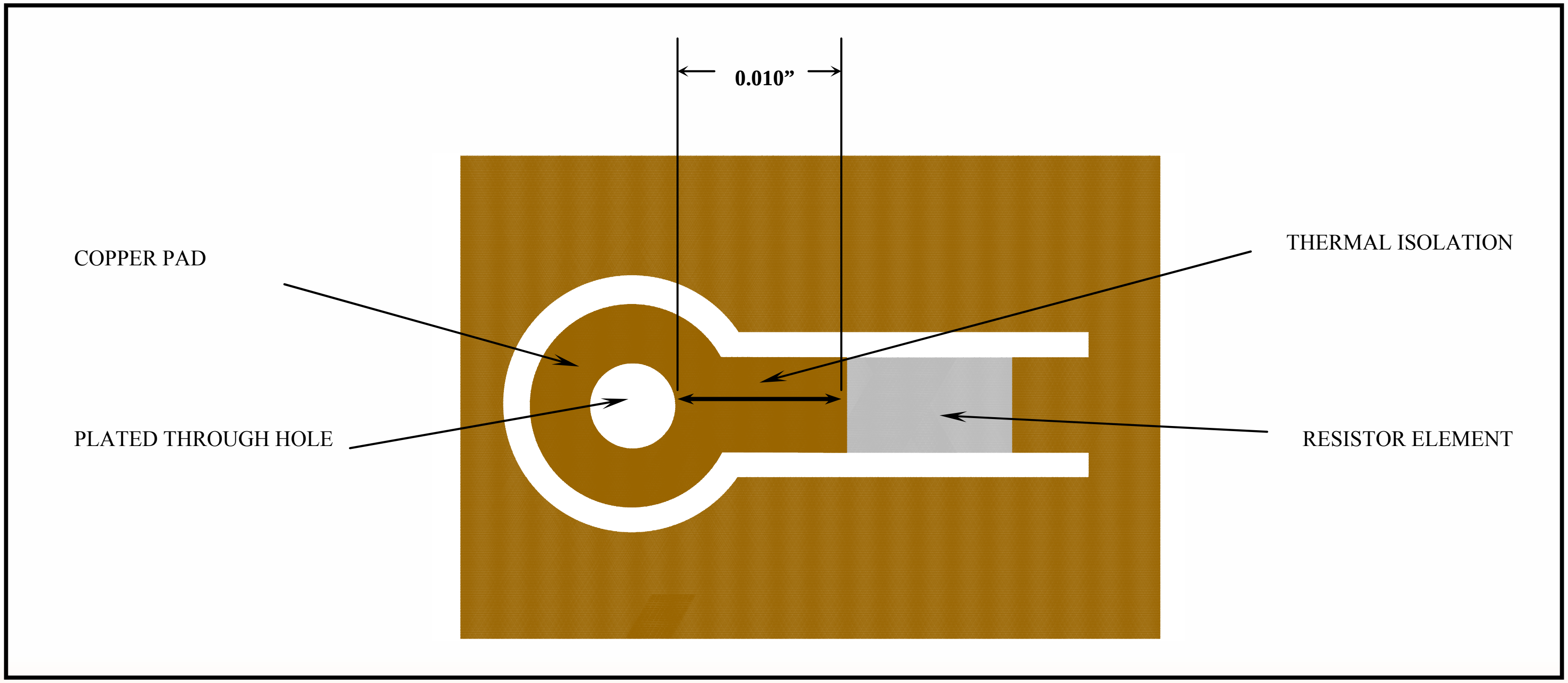
▲ *Resistor defined – 2nd print*

Thermal/Mechanical Isolation

The primary purpose of thermal or mechanical isolation is to reduce stress from the flow of heat from a plated through via or surface mount pad during soldering, process, reflow, hot air, etc

Secondarily, it also acts as a mechanical isolation preventing resistance change during via drilling and/or x,y and z axis dimensional movement of the PCB.

The recommended thermal isolation distance from the plated through hole to the resistor element is 10 mils, and laser drill microvias the minimum distance is 5 mils.



▲ *Thermal/mechanical isolation*

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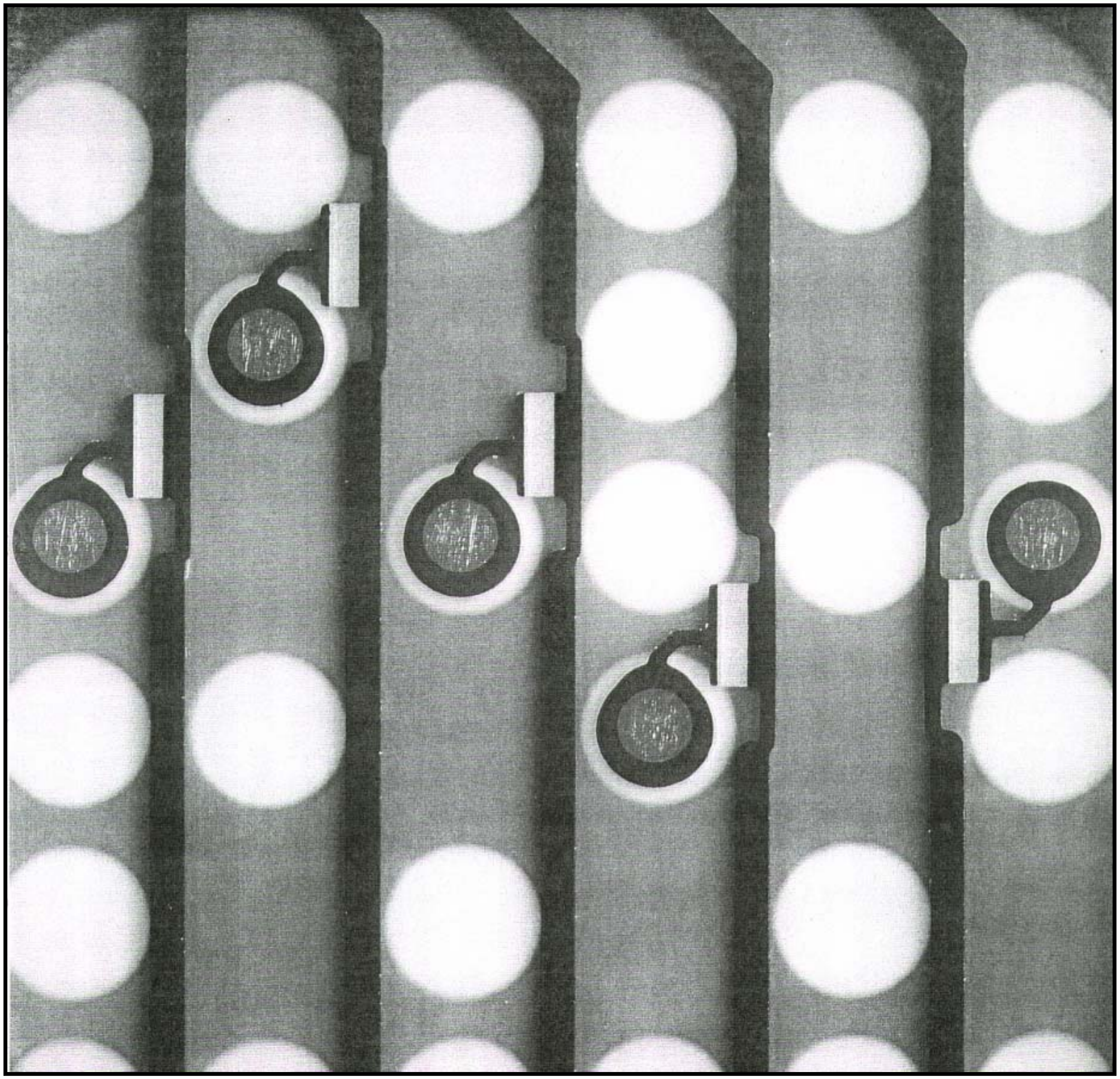
Thermal/Mechanical Isolation



▲ *A server backplane showing thermal/mechanical isolation of OhmegaPly® resistors*

OhmegaPly® Thin Film Subtractive Versus Thick Film Additive Technologies

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Reoccurring CAD problems in embedded passive designs have to do with the difference between thick film ***additive*** and thin film ***subtractive*** technologies. Resistor elements and terminations are determined by different techniques for additive than for subtractive processes.

Type of Resistor	Element Footprint Creation	
	First Print	**Second Print**
Additive (print and silkscreen)	Length (etch)	Width (screen paste)
Subtractive (two print and etching)	Width (etch)	Length (etch element)

CAD/CAM operators in companies who switch from one technology to another must make artwork adjustments because the compensation for dimensional stability and registration tolerances are different.

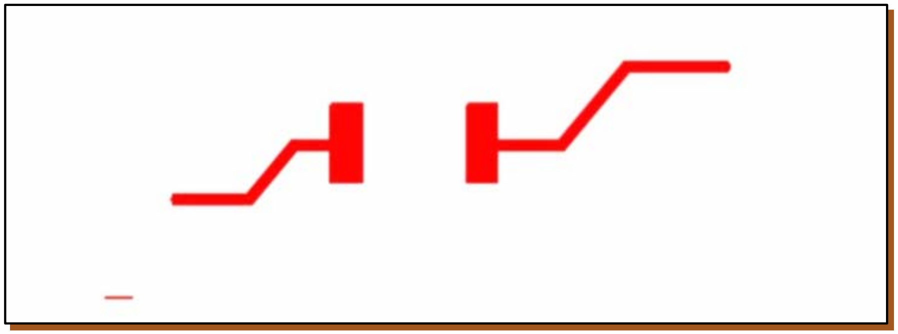
DRC programs may not support embedded component technologies and errors may escape detection. Most common is the lack of overlap of the second print image to the first print image.

Resistor Design Method Graphic Layout

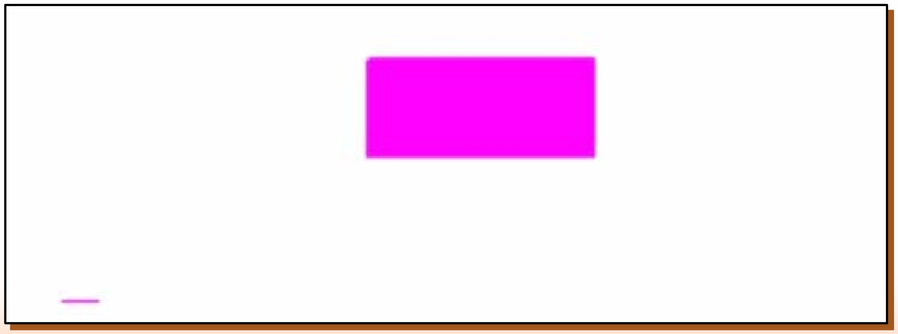
OhmegaPly is a subtractive technology where the manufacturing starts with a laminate with a thin film resistance material under the copper.

The first production film is a Gerber, extended Gerber or ODB++ document with the pad and trace layer merged with the resistor body layer.

This picture shows the pad/trace for a resistor.

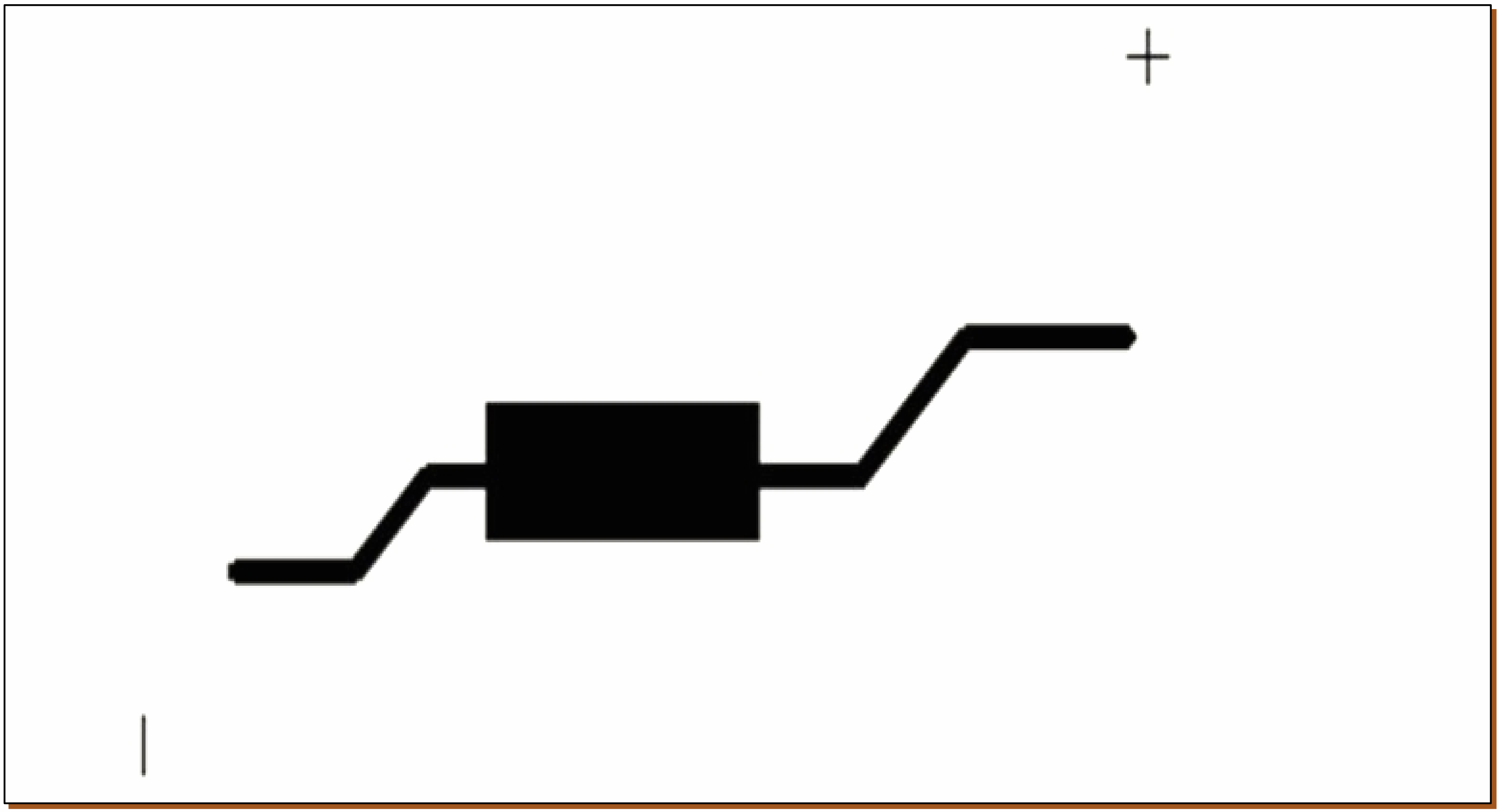


This picture shows the resistor body layer.



Resistor Design Method Graphic Layout

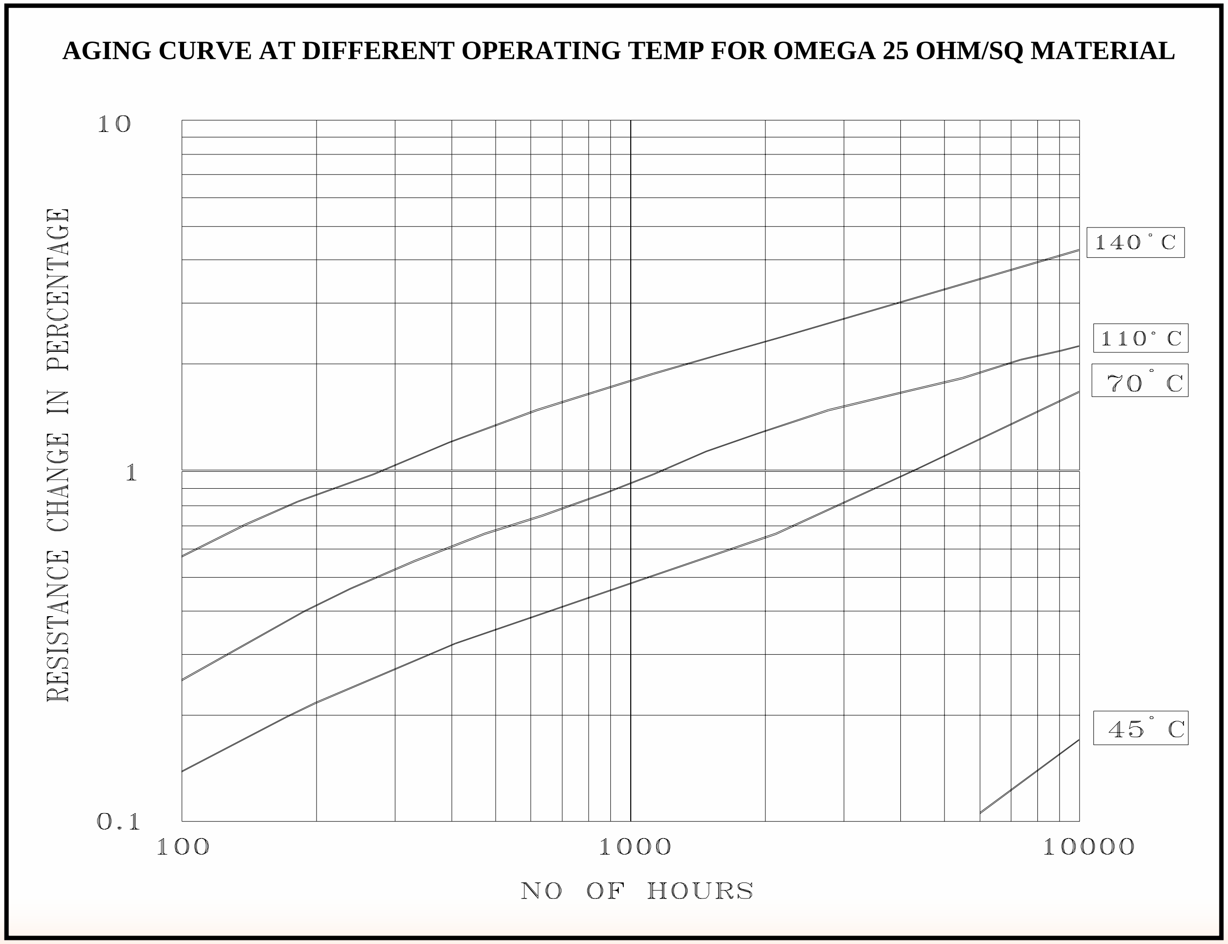
The combined Gerber film result.



Design Parameters for Optimum Long Term Stability

As a Function for Resistor Operating Temperature

Long-term reliability is a function of operating temperature. Like most electronic components, operating temperature (ambient temperature + temperature rise) is one of the most important factors that determine power rating of the component. As more power is dissipated through the resistors, the temperature of the resistor film increases which makes it more susceptible to thermal oxidation. Stability is measured by the change of resistance with aging. The figure below illustrates the relationship between different operating temperatures and change of resistance with respect to time.



Because the resistor film is a part of laminate, the physical and thermal characteristics of the substrate become major considerations. The heat dissipation of resistor films depends on:

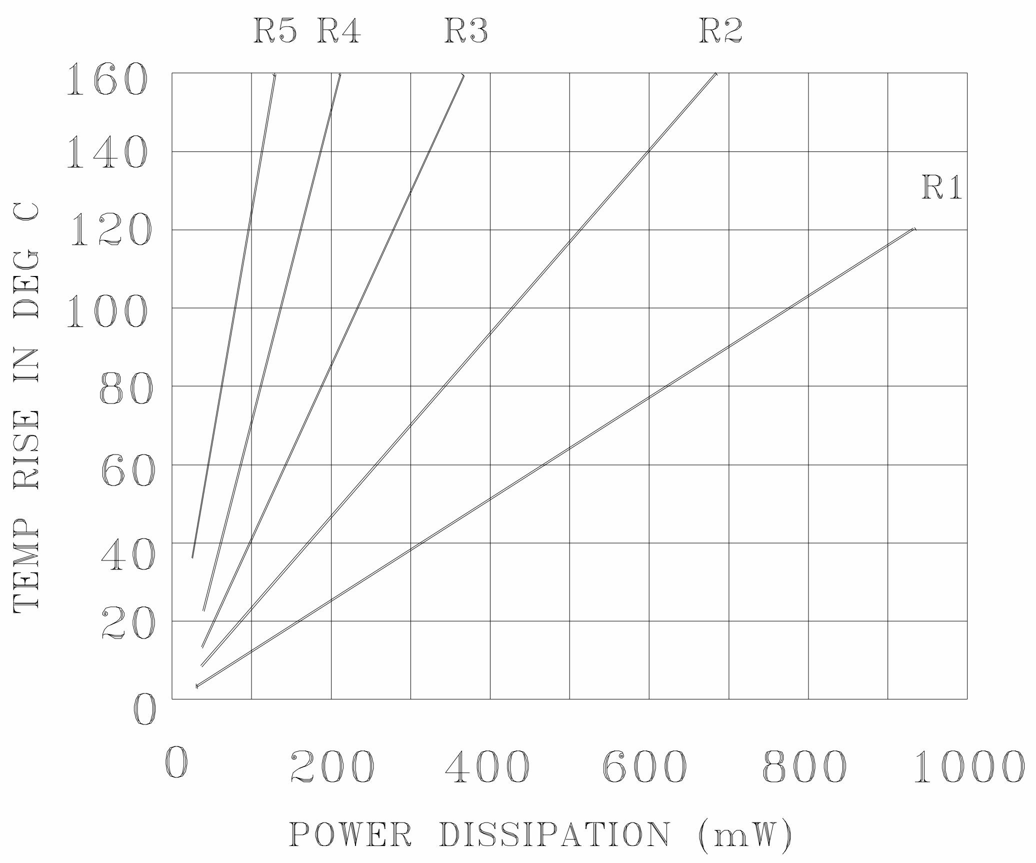
1. The size (area) of the resistor
2. The circuit thickness and material type
3. The circuit configuration (clad/unclad)
4. ambient temperature
5. The thermal conductivity of the substrate
6. Additional system cooling (e.g. air-cooling, other heat sinking, etc.)

Design Parameters for Optimum Long Term Stability

1. Size (area) of Resistor

The power density is defined as the total power dissipated divided by the effective surface area. The power density of resistor element increases as element area decrease, all other conditions illustrate that for the same power input, the temperature rise depends on the area of the resistor.

TEMPERATURE RISE Vs. POWER DISSIPATION FOR DIFFERENT RESISTOR AREA

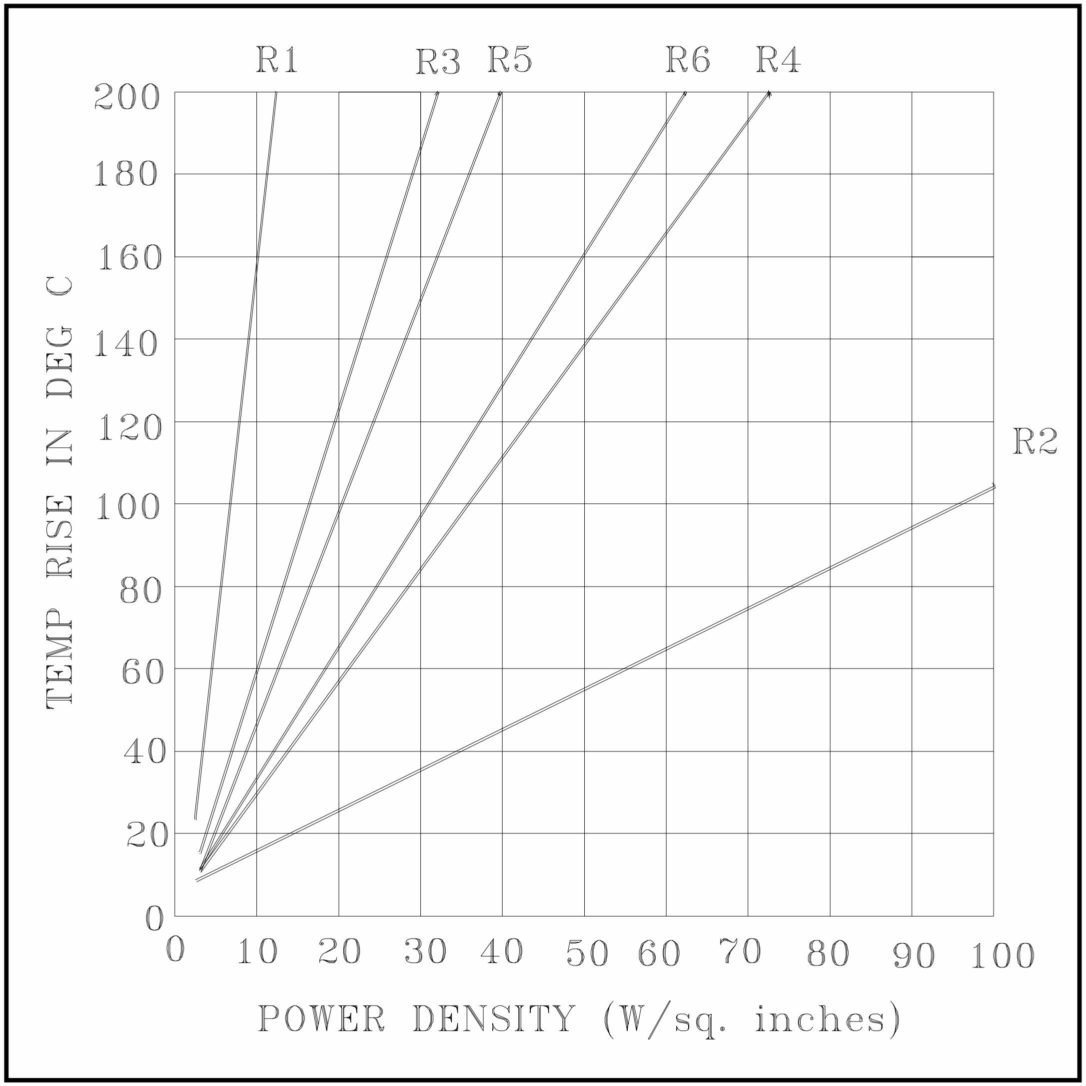


R1 = 25Ω area of R1 = 0.500 x 0.500 = 0.2500 in^2
R2 = 25Ωarea of R2 = 0.250 x 0.250 = 0.0625 in^2
R3 = 25Ωarea of R3 = 0.125 x 0.125 = 0.0156 in^2
R4 = 25Ωarea of R4 = 0.063 x 0.063 = 0.0039 in^2
R5 = 25Ωarea of R5 = 0.031 x 0.031 = 0.0010 in^2

For the same power input, the temperature rise of R5 (smallest area) is the highest. In other words, the resistors with larger area can dissipate more power than a smaller on provided that all conditions remains the same. If space available, design the resistor as large as possible.

Design Parameters for Optimum Long Term Stability

2. The Substrate Thickness & Configuration (clad/unclad)

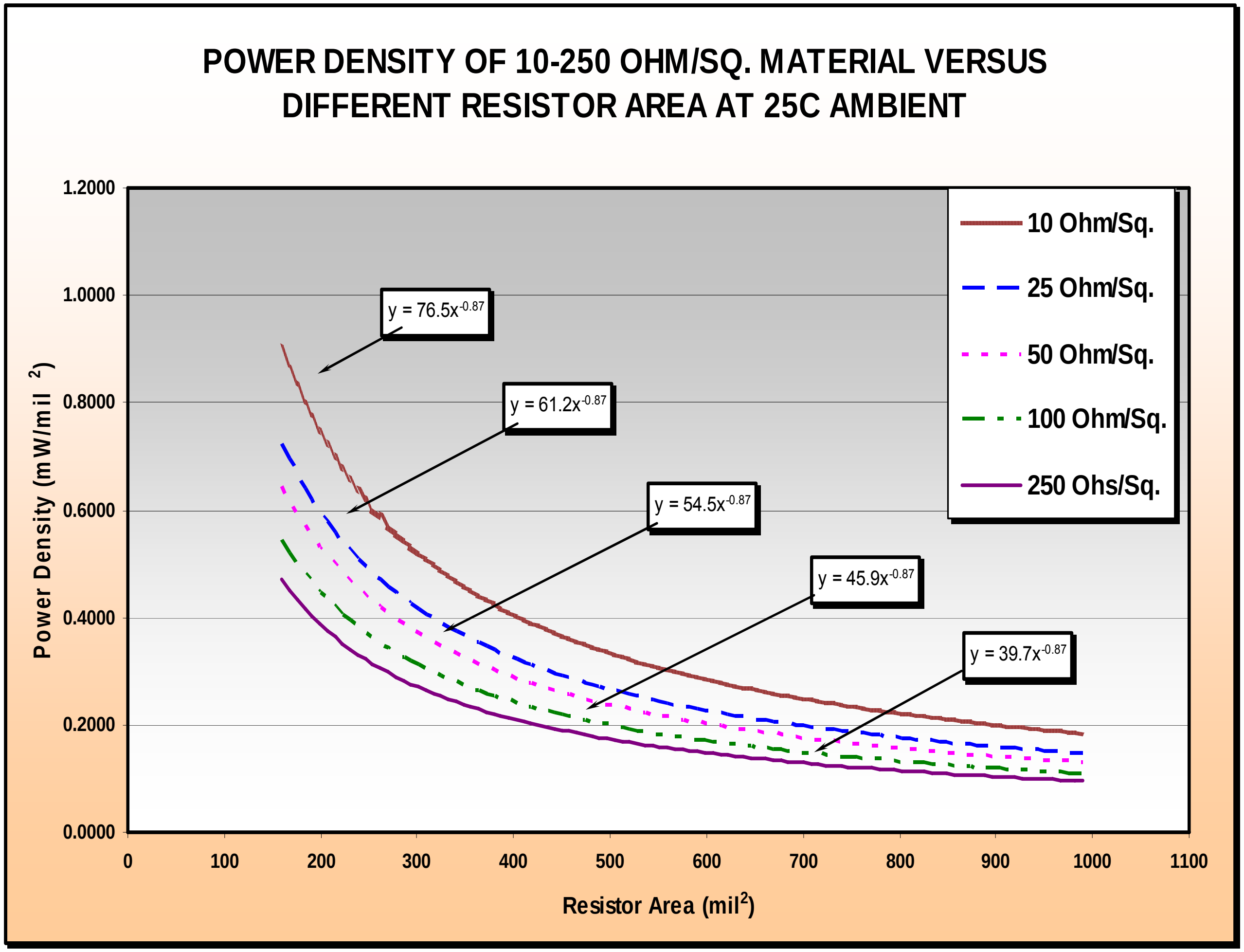


Because the resistor is buried within the layers, the physical and thermal characteristics of the substrate directly affect the manner of heat dissipation from the substrate e.g. the thickness of the substrate and cladding (heat sinking effect). As shown in the above graph the temperature rise in the resistor (R1) is improved significantly when copper cladding (R2) is used

	Core Thickness	Cladding
R1 = 250Ω	0.0025 in	1R25/0 (unclad)
R2 = 250Ω	0.0025 in	1R25/1 (clad)
R3 = 250Ω	0.025 in	1R25/0 (unclad)
R4 = 250Ω	0.025 in	1R25/1 (clad)
R5 = 250Ω	0.062 in	1R25/0 (unclad)
R6 = 250Ω	0.062 in1	R25/1 (clad)

Design Parameters for Optimum Long Term Stability

3. OhmegaPly® Power Dissipation vs. Area of Element



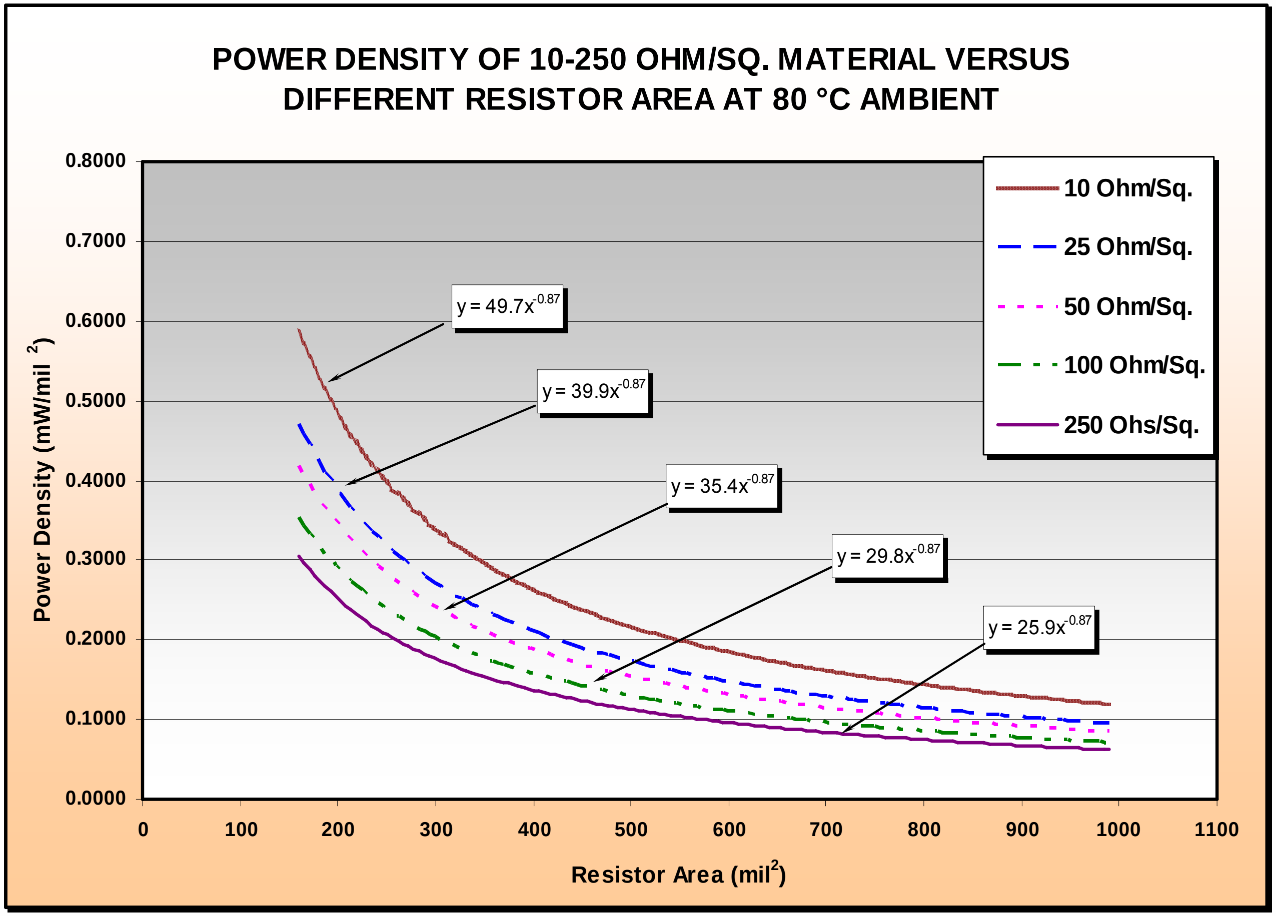
▲ *The recommended power dissipation of small resistor area (less than 1100 mil²) at 25 °C ambient*

For resistor area larger than 1100 mil², the recommended power dissipation at 25 °C ambient is as follows:

10 Ω/☐ 0.187+ MilliWatts/mil²
25 Ω/☐ 0.150+ MilliWatts/mil²
50 Ω/☐ 0.138+ MilliWatts/mil²
100 Ω/☐ 0.100+ MilliWatts/mil²
250 Ω/☐ 0.090+ MilliWatts/mil²

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.

Design Parameters for Optimum Long Term Stability



▲ *The recommended power dissipation of small resistor area (less than 1,100 mil^2) at 80 °C ambient*

For resistor area larger than 1100 mil^2, the recommended power dissipation at 80 °C ambient is as follows:

10 Ω/☐ 0.122+ MilliWatts/mil^2
25 Ω/☐ 0.098+ MilliWatts/mil^2
50 Ω/☐ 0.090+ MilliWatts/mil^2
100 Ω/☐ 0.065+ MilliWatts/mil^2
250 Ω/☐ 0.059+ MilliWatts/mil^2

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.

Tolerance, How Important Is It?

Excerpts from paper by Wally Doeling, Sequent Computer, 1998:

For high speed designs and short rise times, the ohmegaPly® resistor tolerance is not as nearly as important as the elimination of the inductive reactance of the SMT chip component, vias and trace.

- Frequency is key driver requiring improved signal integrity,
  1. 100 MHz to 20 GHz.
  2. Rise times less than 1.0 ns.

- The actual tolerance is a combination of
  1. The initial mismatch of the device value and line impedance,
  2. The device tolerance (percentage), and
  3. The series inductance and inductive reactance of the device.

Resistor Type	Series Inductance
1/4 watt axial	2.5 nH
1/8 watt axial	1.0 nH
1/8 watt 1206	0.9 nH
Ωhmega-Ply®	<0.4 nH

Rise time	Inductive Reactance
1.0 ns	2.8 ohms (1206)
0.5 ns	5.6 ohms (1206)
0.25 ns	11.3 ohms (1206)

- For these applications, a 10% ohmegaPly® resistor is better than a 1-% SMT tolerance.

Manual Resistor Design

Design Demonstration

1. Part lists for demo

R1 & R2 are partial square resistors.

R3 & R4 are multiple squares resistors used in analog, digital and RF applications.

R5, R6 & R7 are series terminating resistors.

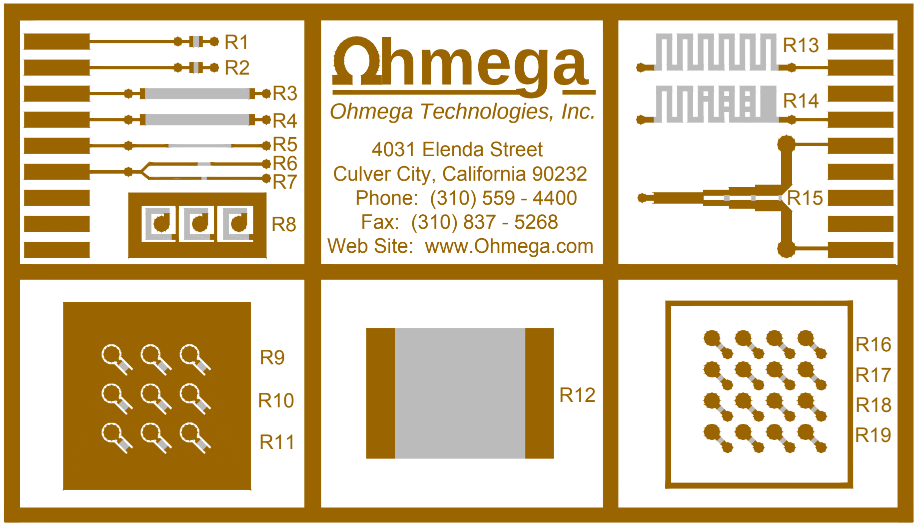
R8's are higher value resistors used in digital applications with limited "real estate". Referred to as "**Wraparound**" resistors

R9, R10 & R11 are parallel terminating resistors under BGA package for high-speed logic applications.

R12 is used as heating element.

R13 & R14 are higher value meander resistors. R17 also contains a ladder network for trimming to tight tolerances (1%) as required in some digital and analog applications.

R15 is a power divider for microwave applications.



The resistance value and recommended power dissipation are listed below. Individual resistors can be tested to the suggested powers.

Resistor No.	No. of Square	Nominal Resistance (Ohm)	Power Dissipation (mW)
1, 2	0.5	12.5	173
3, 4	10.0	250	1552
5	24.0	600	523
6	5.0	125	120
7	2.0	50	75
8	12.2	305	654
9, 10, 11	1.8	43.75	138
12	1.0	25	5786
13	83.0	2075	2327
14	51.5	1287.5	1790
15	0.8	20	340
16,17,18,19	1.0	25	141

Manual Resistor Design

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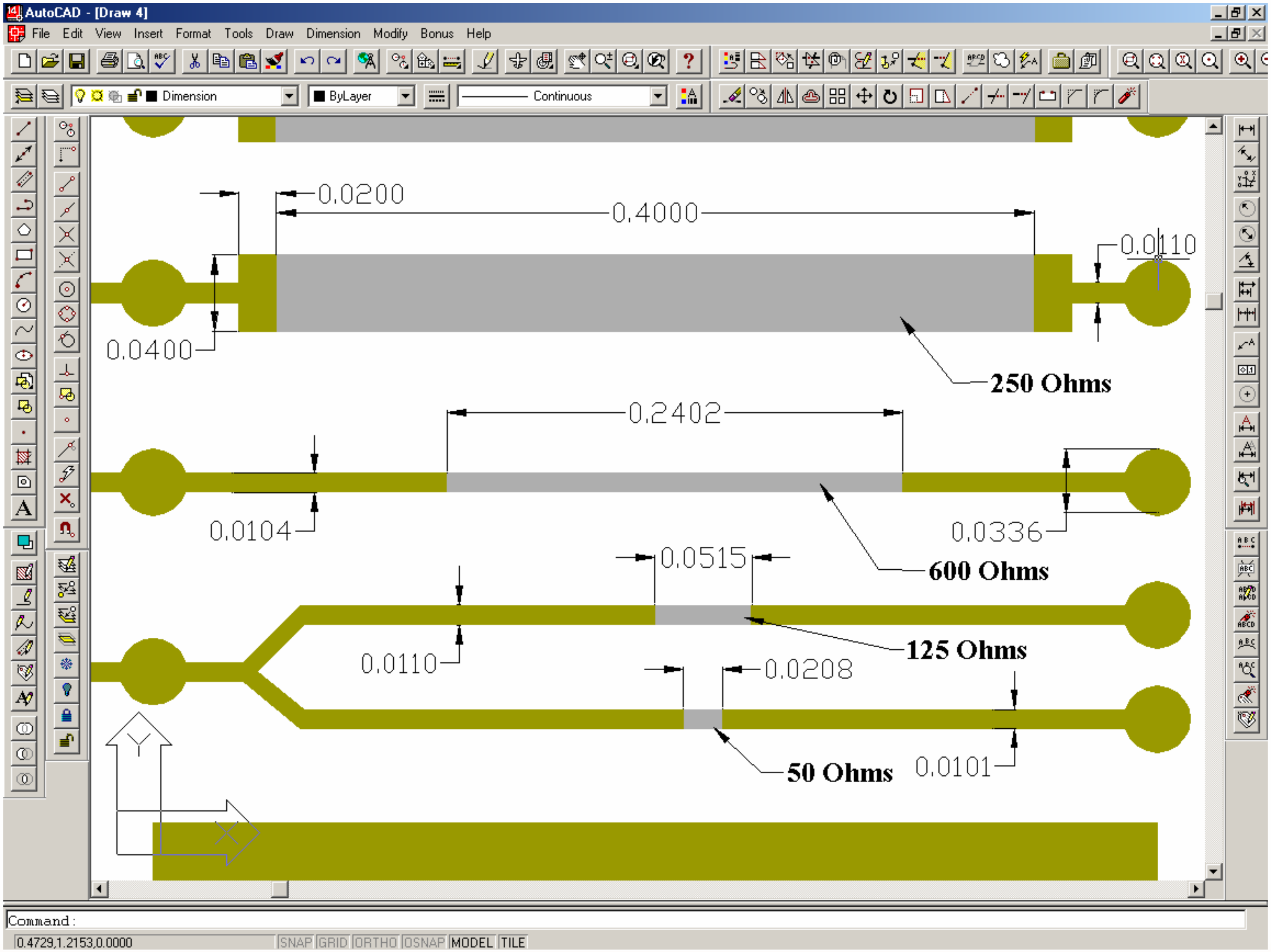
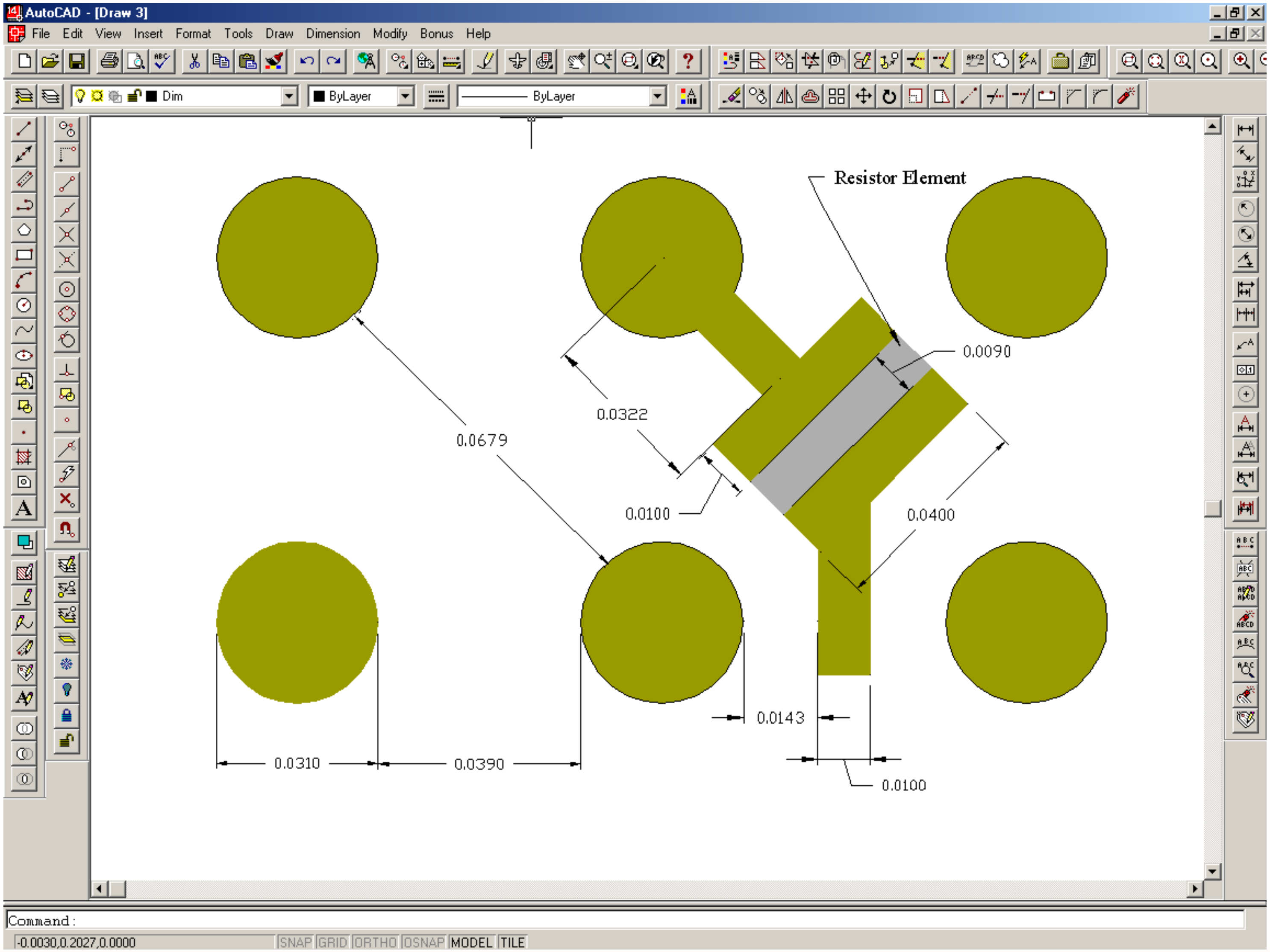
1. Resistor Footprints from Spreadsheet in AutoCAD



▲ *50, 125, 250 & 600 ohms resistor design*

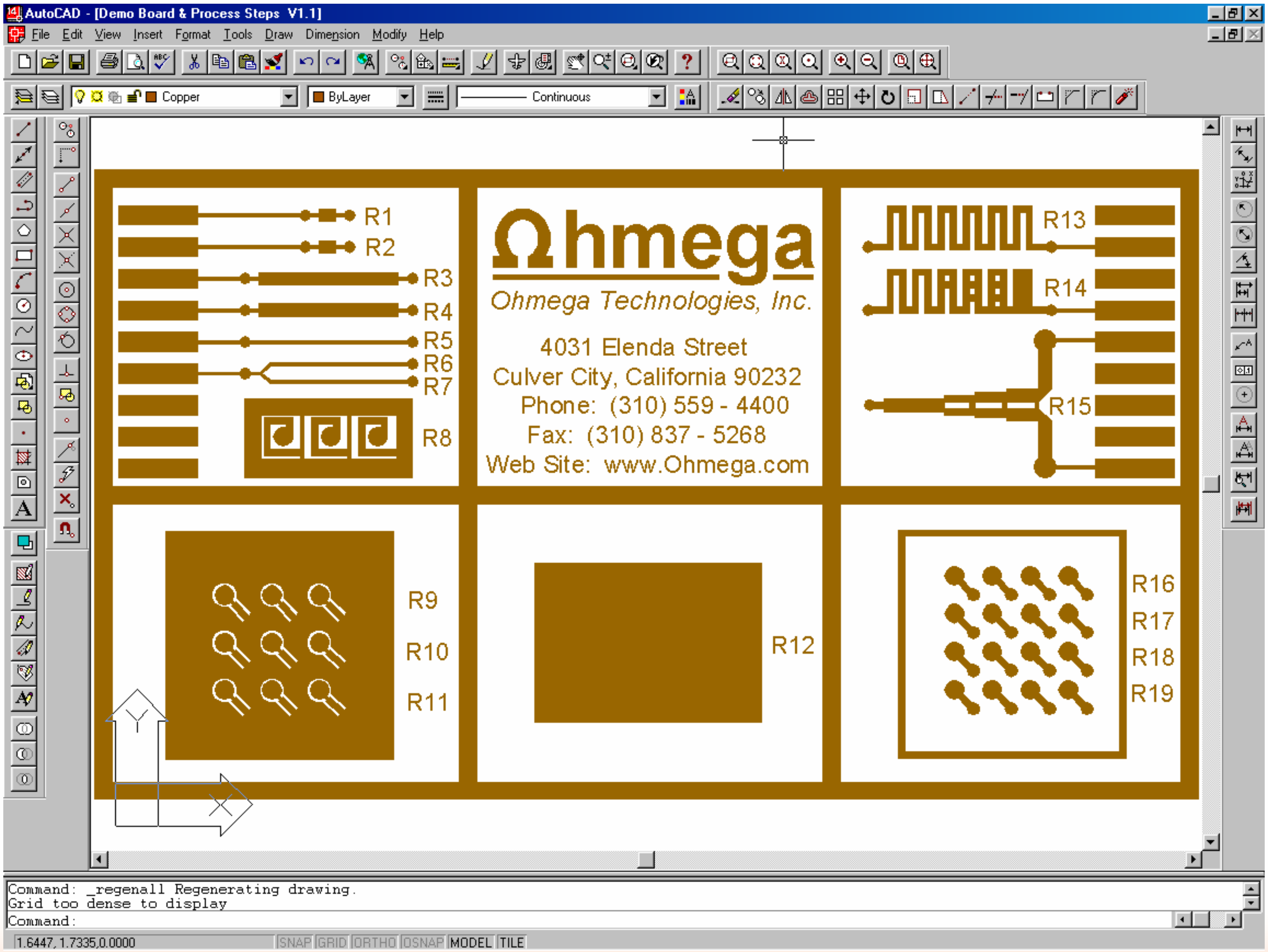
Manual Resistor Design

2. Manual Design Rule Check (DRC)



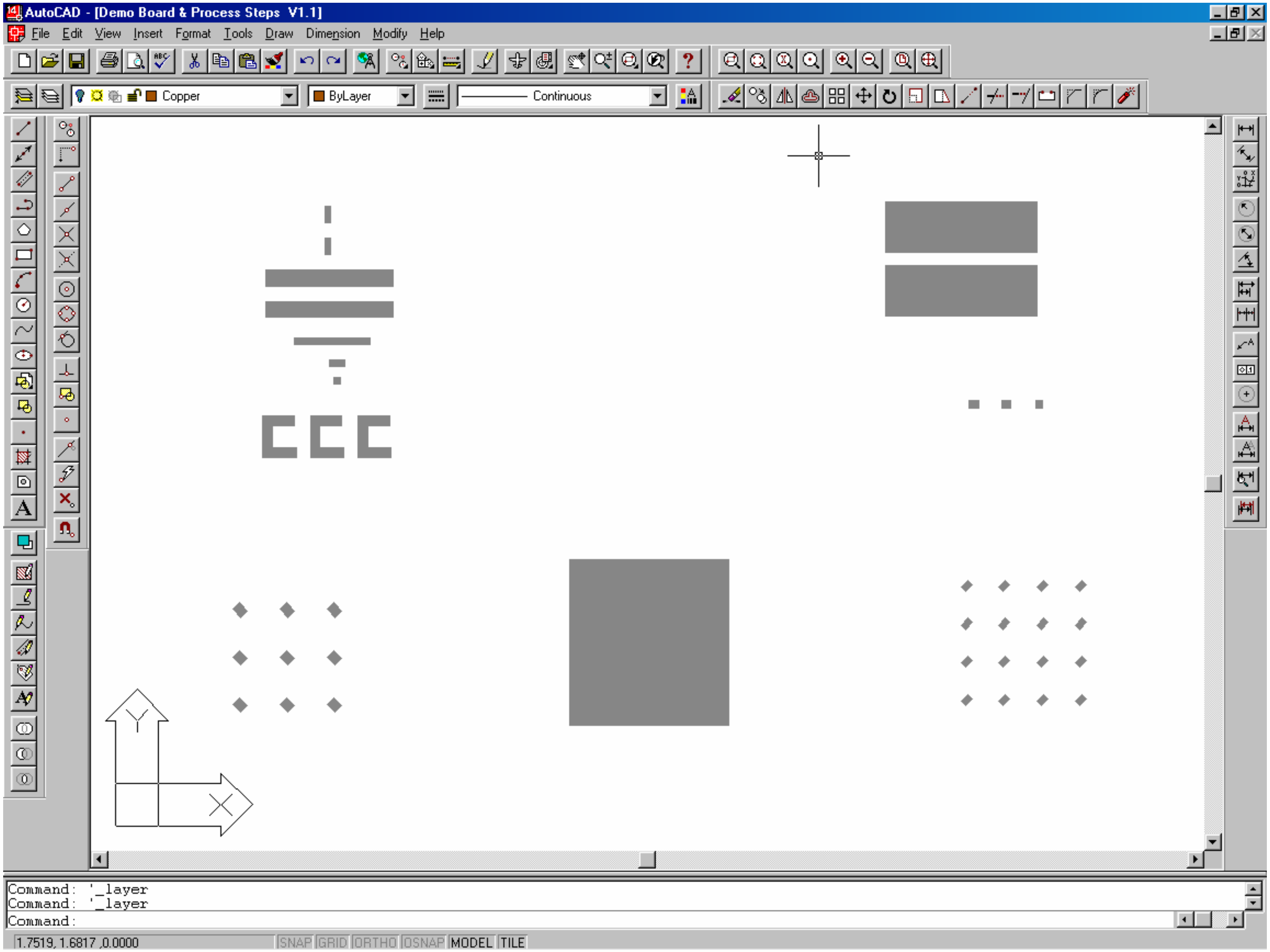
▲ *12 ohms resistor design*

3. AutoCAD PCB Layout



▲ *Composite image of conductors and resistors*

Manual Resistor Design



▲ *Figure 16 – Resistor define - image of resistor elements*

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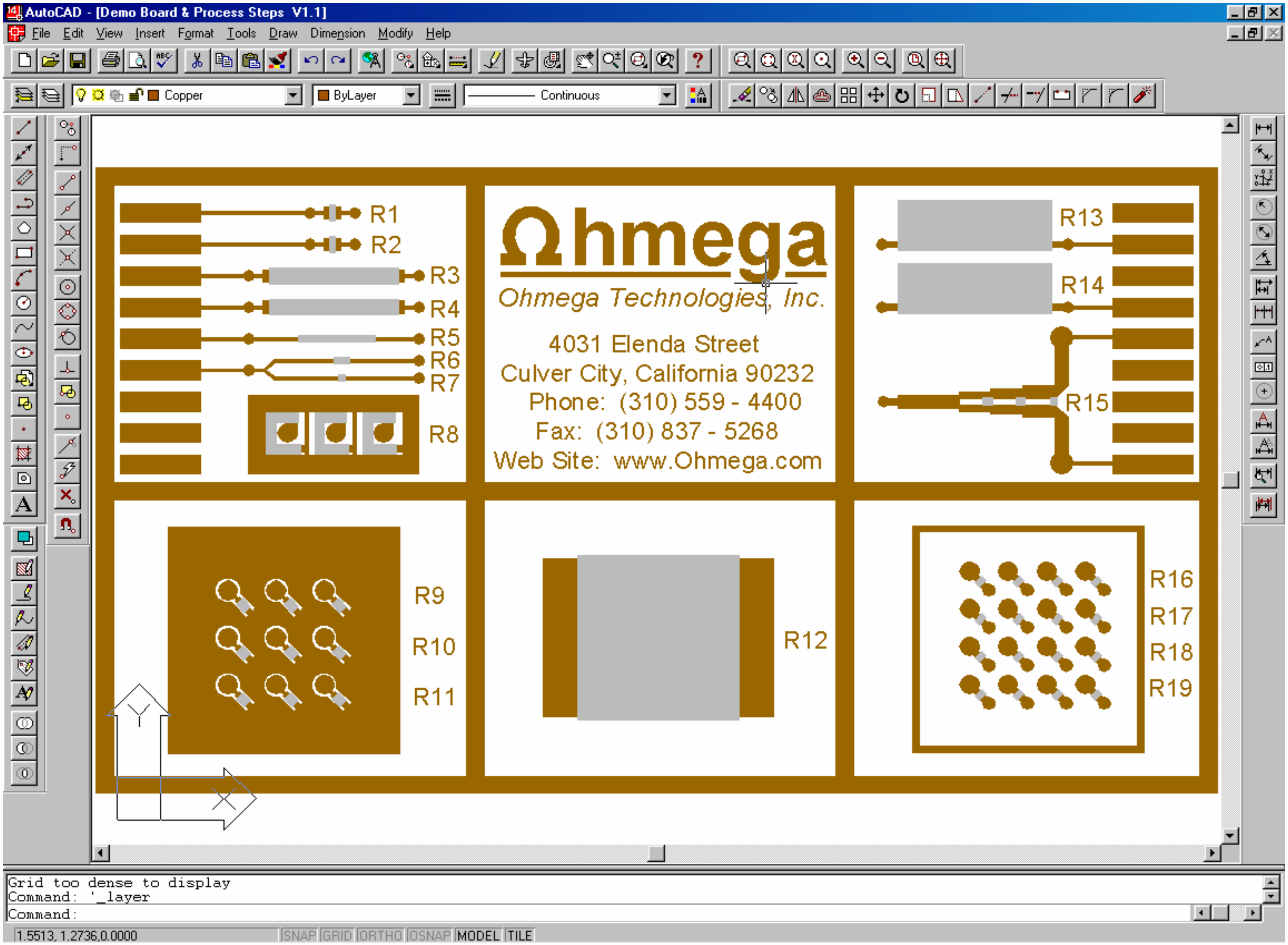
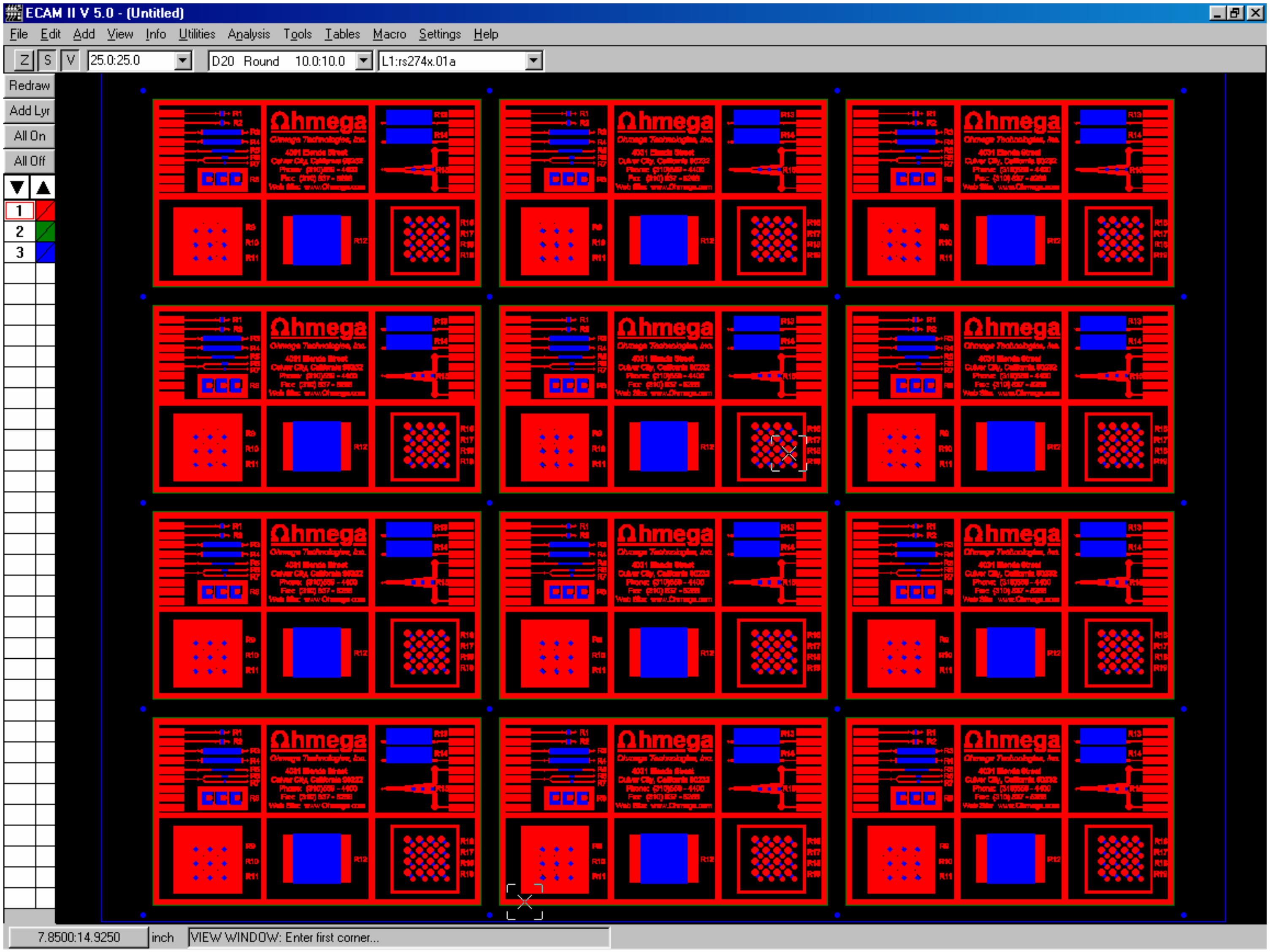
Manual Resistor Design



▲ *Resistor define overlay the composite image of conductors and resistors*

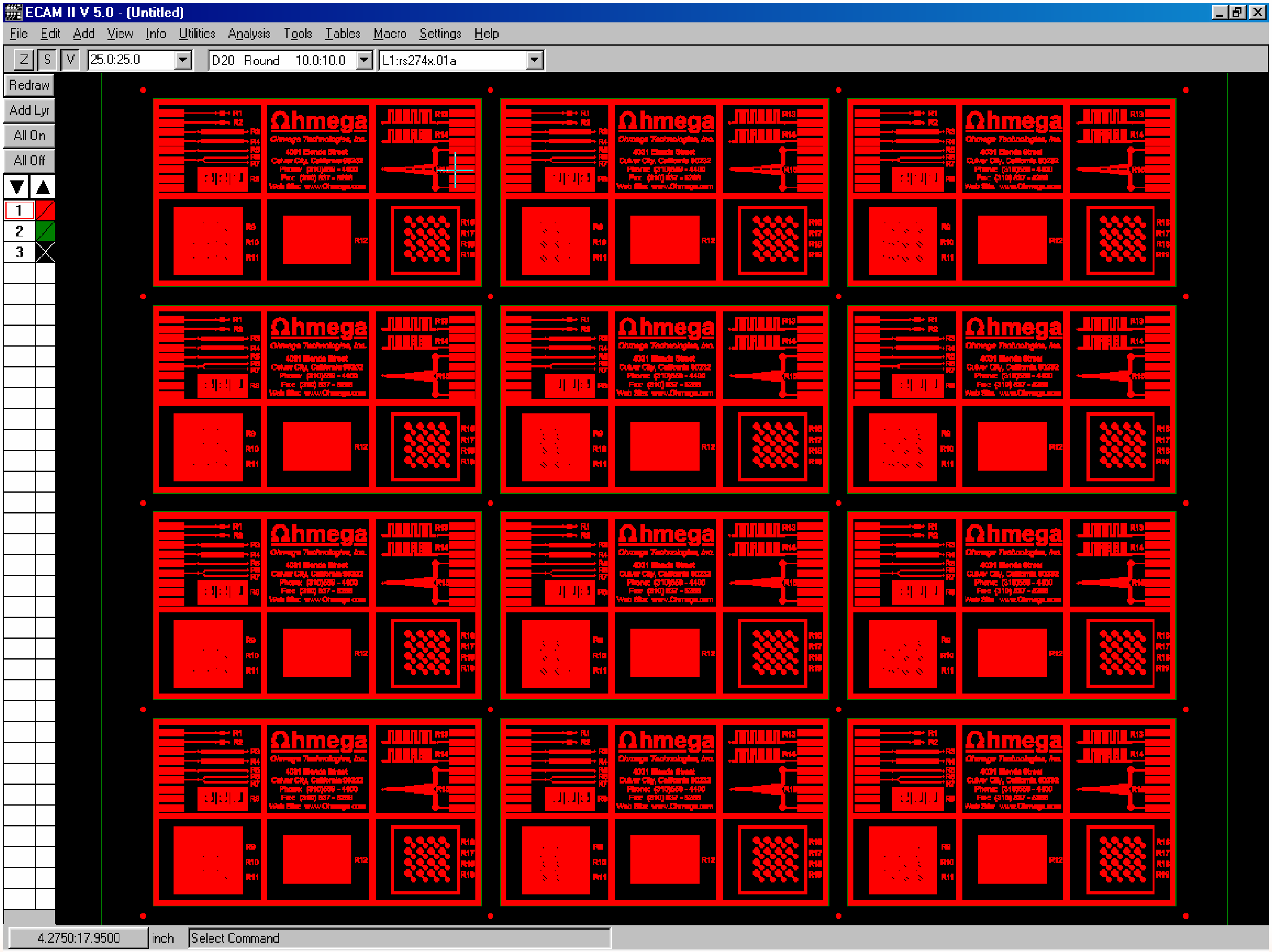
Manual Resistor Design

4. CAM Layout



▲ *ECAM Panelized PCB - copper + resistor*

Manual Resistor Design



- *ECAM Panelized PCB - copper*

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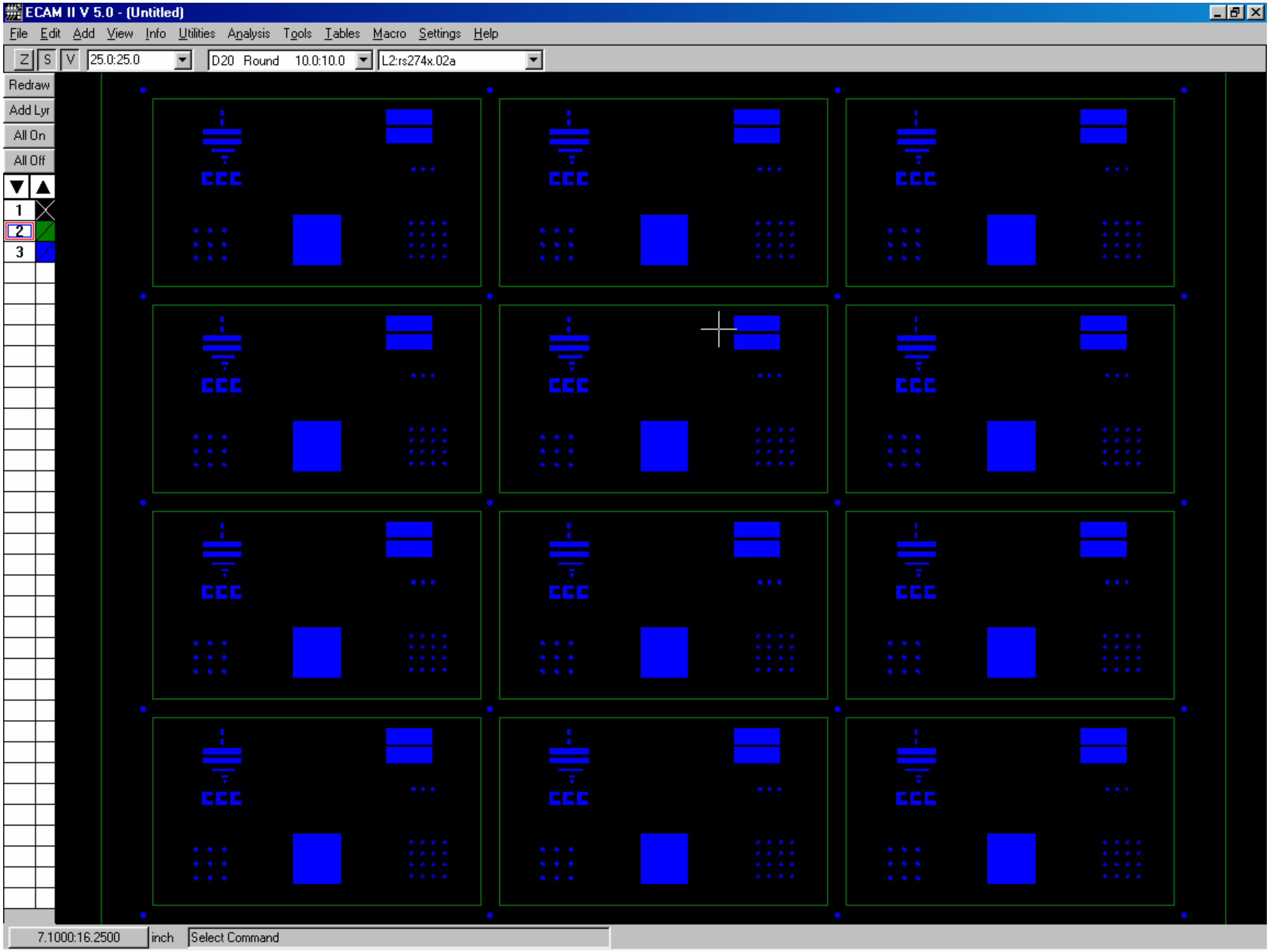
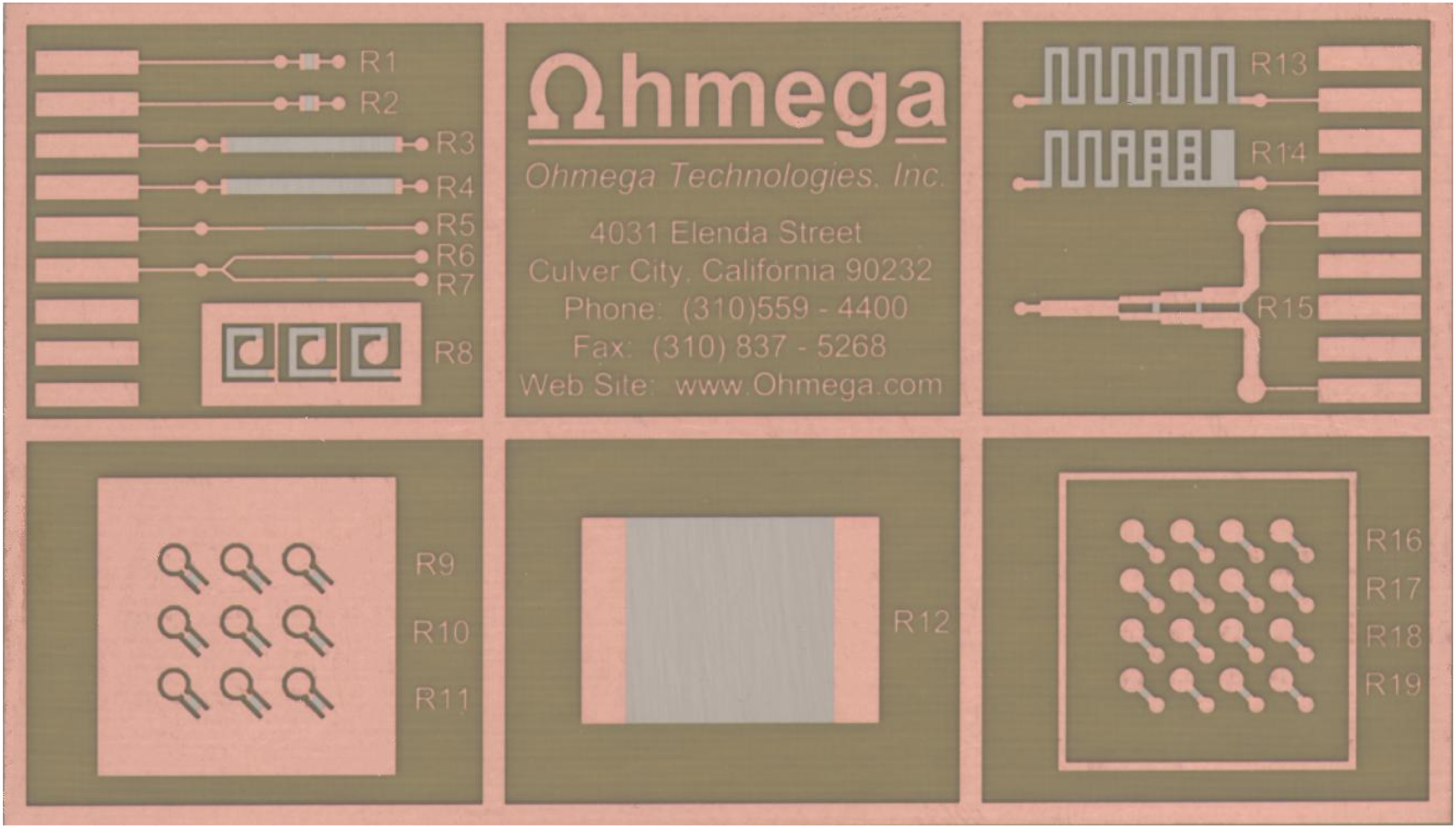
Manual Resistor Design



- ECAM Panelized PCB - resistor

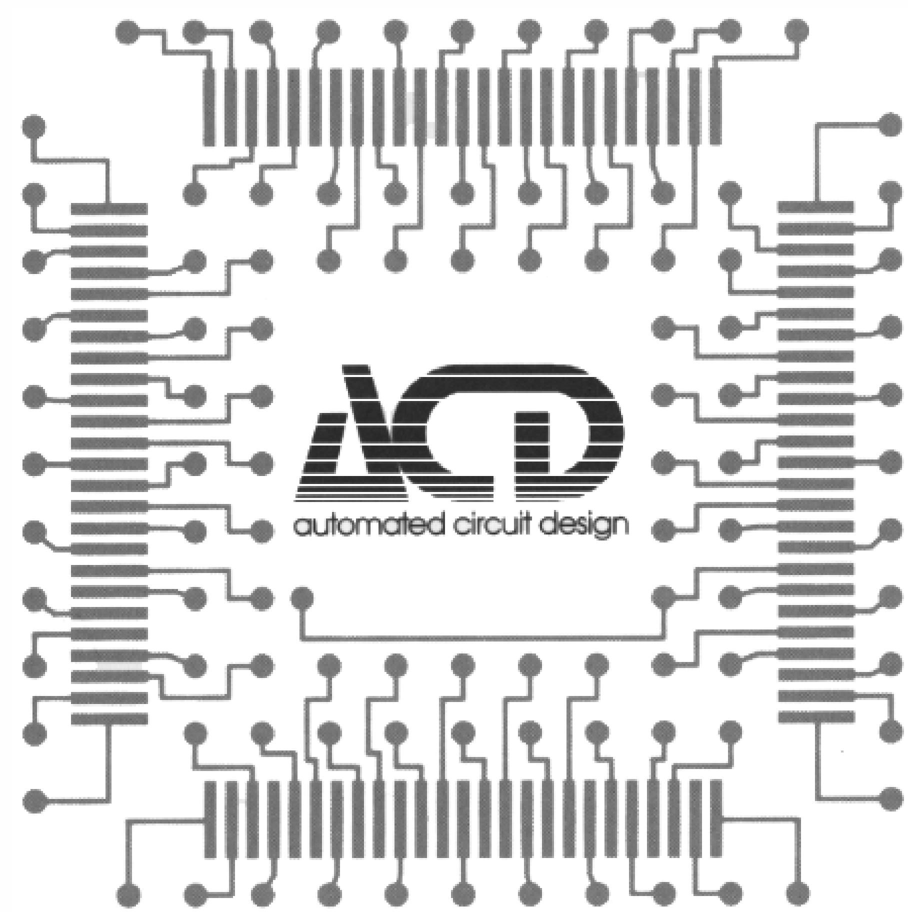
Manual Resistor Design



▲ *Finished resistors*

Designing a VeriBest PCB using Ohmega Buried Resistors

- Make-up of a Buried Resistor
- Library Naming Conventions
- Placing Buried Resistors in a Schematic
- Setting Up VeriBest to Handle Buried Components
    - Setting up Job Parameters
    - Setting up Pin Table
    - Setting up Pin Correspondence Table
- Placement and Routing Procedures for Buried Components
    - Recommended Placement Procedure
    - Pushing Components
    - Recommended Routing Procedure
- Outputting Gerber Data
    - Composite (Trace) layer
    - Resistor Define layer
    - Reference layer
- Other Notes of Importance



Make-up of a Buried Resistor

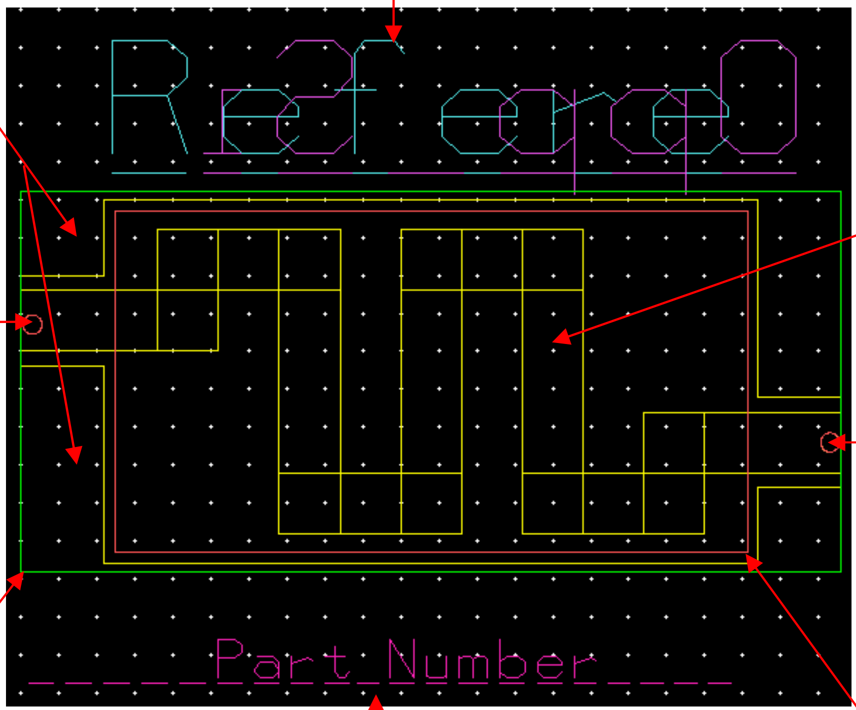
Size, Number of Characters, and Positional Location of Reference Designator and Opposite Side Reference Designator

Trace and Via Keep Outs

Trace connecting the pins as a Polygon Shape

Pin 1 Location

Pin 2 Location



(green outline) Component Outline

Size, Number of Characters, and Positional Location of Part Number

(orange outline) Resistor Define shape created as a Resistor Shape

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Library Naming Conventions

The following naming conventions were used to build the Schematic, PDB, and Cell Libraries

Schematic and PDB Libraries -

BR100_1/4W_25MAT

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

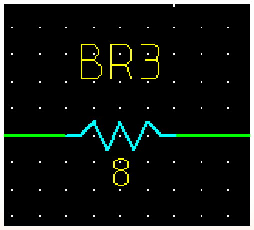
2D Cell Library - (see Buried Resistor Library spreadsheet for cross reference)

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

Placing Buried Resistors in a Schematic

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 to the right, an 8 ohm resistor was placed and was given the reference designator BR3 after compiling was completed.



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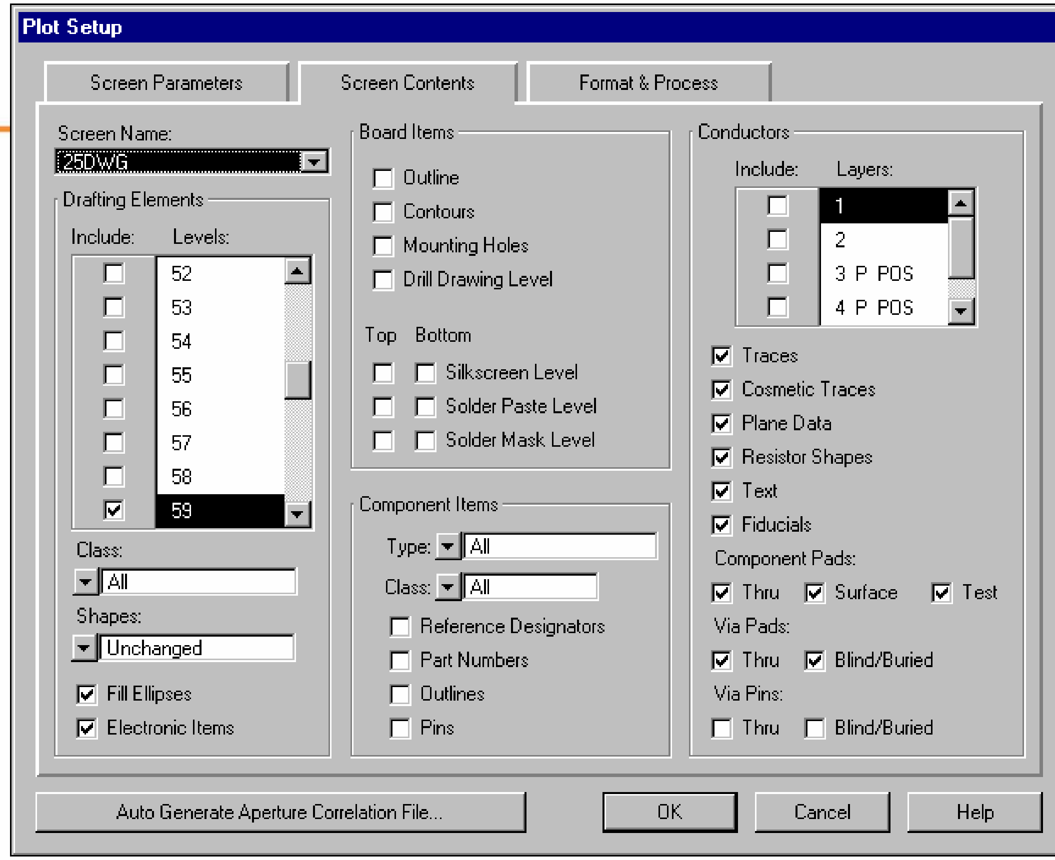
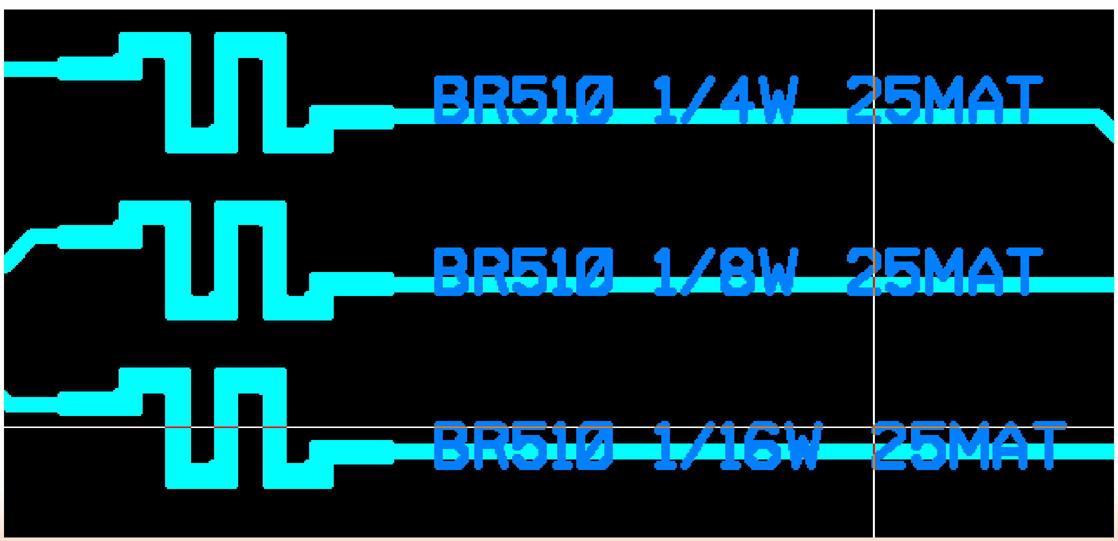
3) Reference layer

The Reference layer is simply a layer that can be referenced to show which Buried Resistors are in which where.



<u>Drafting Element</u> -

- Turn on the level on which your references reside.
- If you have a board title and or targets layer for your board, you can turn them on here.



Example of Gerber results using these settings

Composite (Trace) Layer and Reference Layer are turned on.

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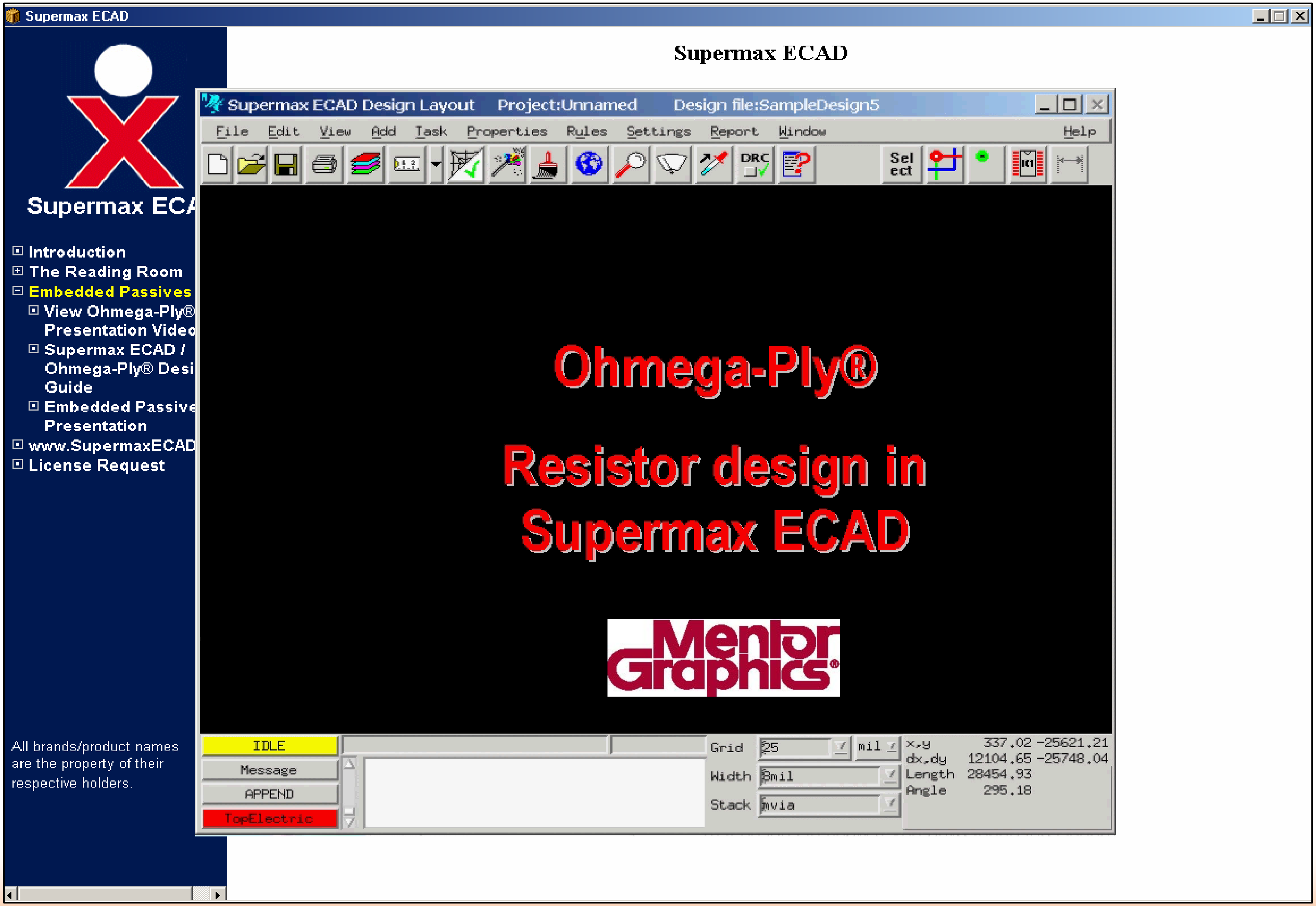
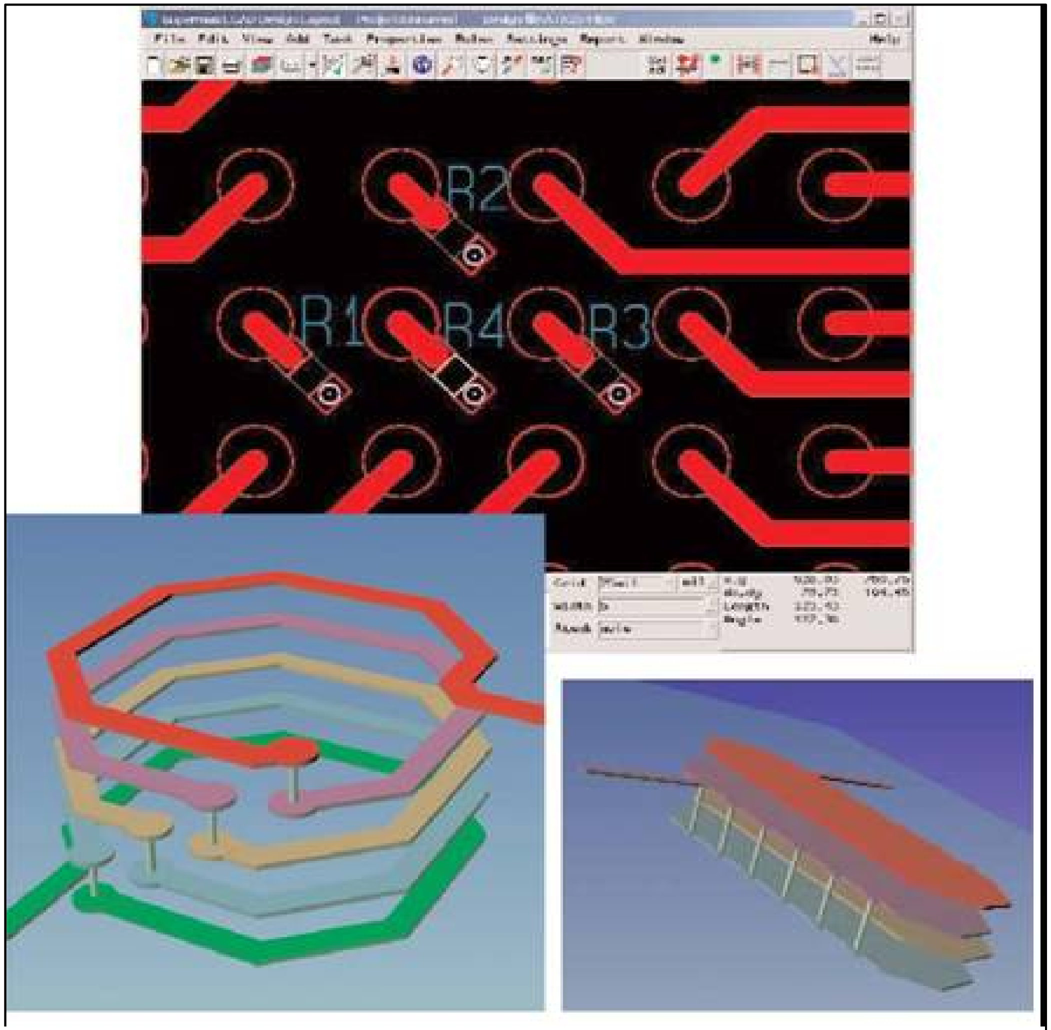
Parametric Design in Supermax® ECAD of Mentor Graphics



Parametric Design in Supermax® ECAD of Mentor Graphics

Supermax ECAD provides an effective platform for the design of embedded passive components – resistors, capacitors, inductors and transformers.



Advanced capabilities for embedding passive components

- Create and place embedded components on any layer
- Edit components online
- Automatic synthesis of resistors and capacitors
- Resistor types: L-shape, serpentine, tophat and rectangle
- Automatic generation of all production documents
- Firmly integrated with common schematic environments such as Mentor Graphics® Design Architect® and DxDesigner™
- Integrated with analysis tools and virtual prototyping environments
- Read and write standard formats such as GDS

Design Rule Check (DRC)

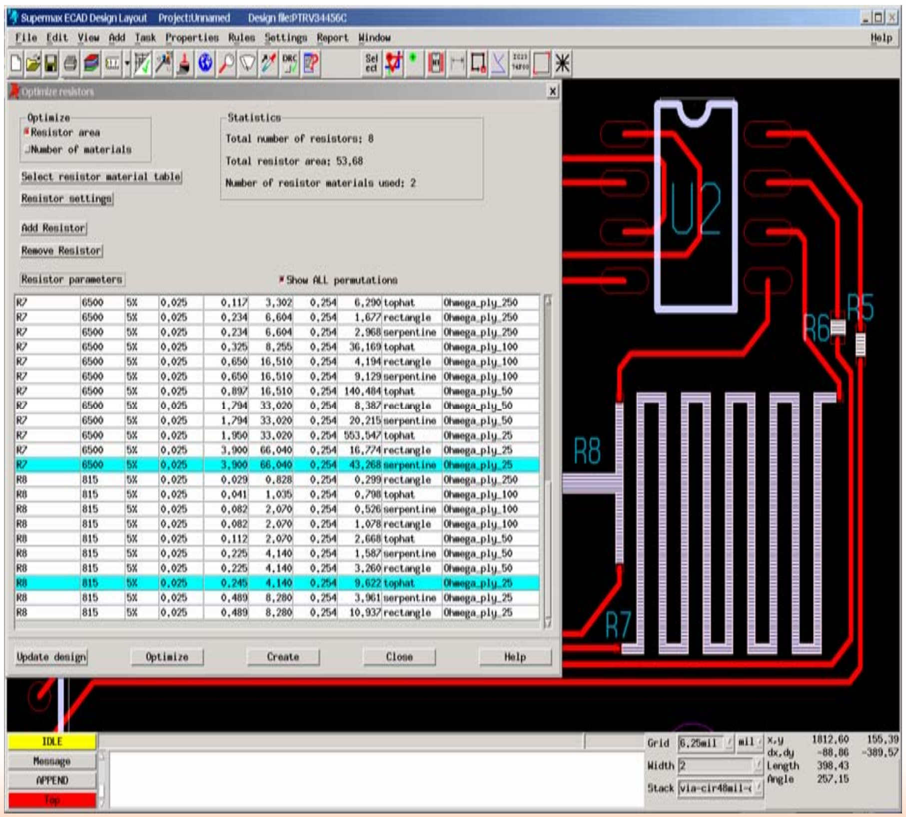
Since embedded passives are not standard discrete compo-nents but are, in fact, DC short circuits, DRC functions need to recognize the difference between a DC short circuit and an AC short circuit. With Supermax ECAD, design specifica-tions are met with an extensive rules set and online DRC of electrical and manufacturing rules. In addition, Supermax ECAD has online verification of signal integrity rules, clear-ance rules, trace resistance, impedance and propagation delays.

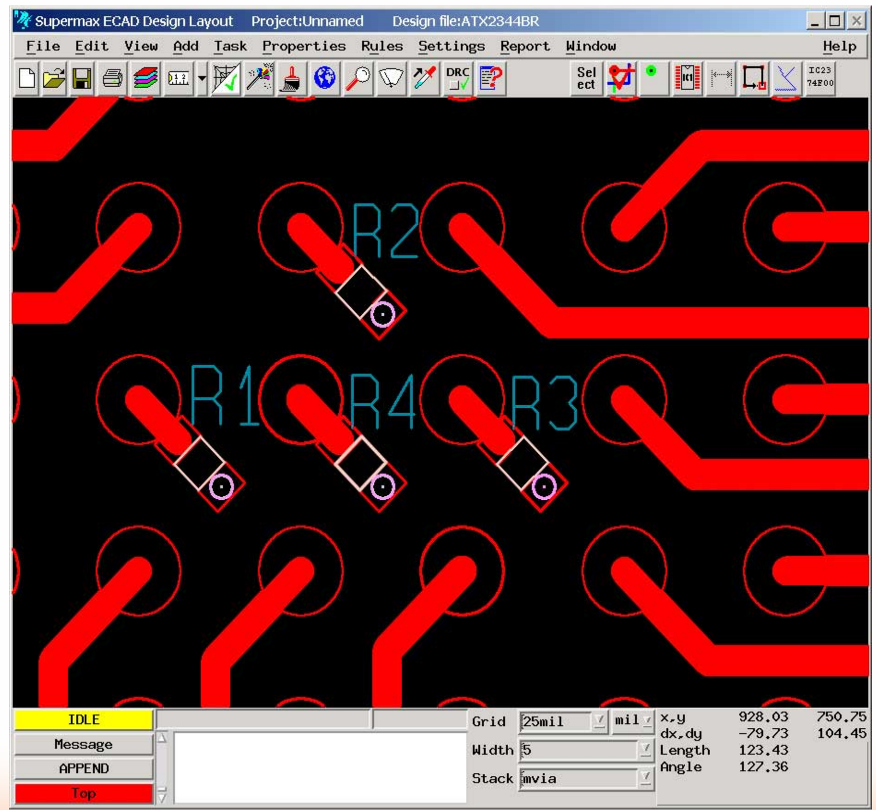
Parametric Design in Supermax® ECAD of Mentor Graphics

With Supermax ECAD, the design process is even faster than with conventional discrete components as no library is required. Resistors are automatically synthesized from component values usually available as properties from the schematic.

The synthesis takes nominal value, trimable range, tolerance, power rating, aspect ratio and geometry into account. The generated resistors can be interactively edited with dynamic feed back of the resulting resistance.

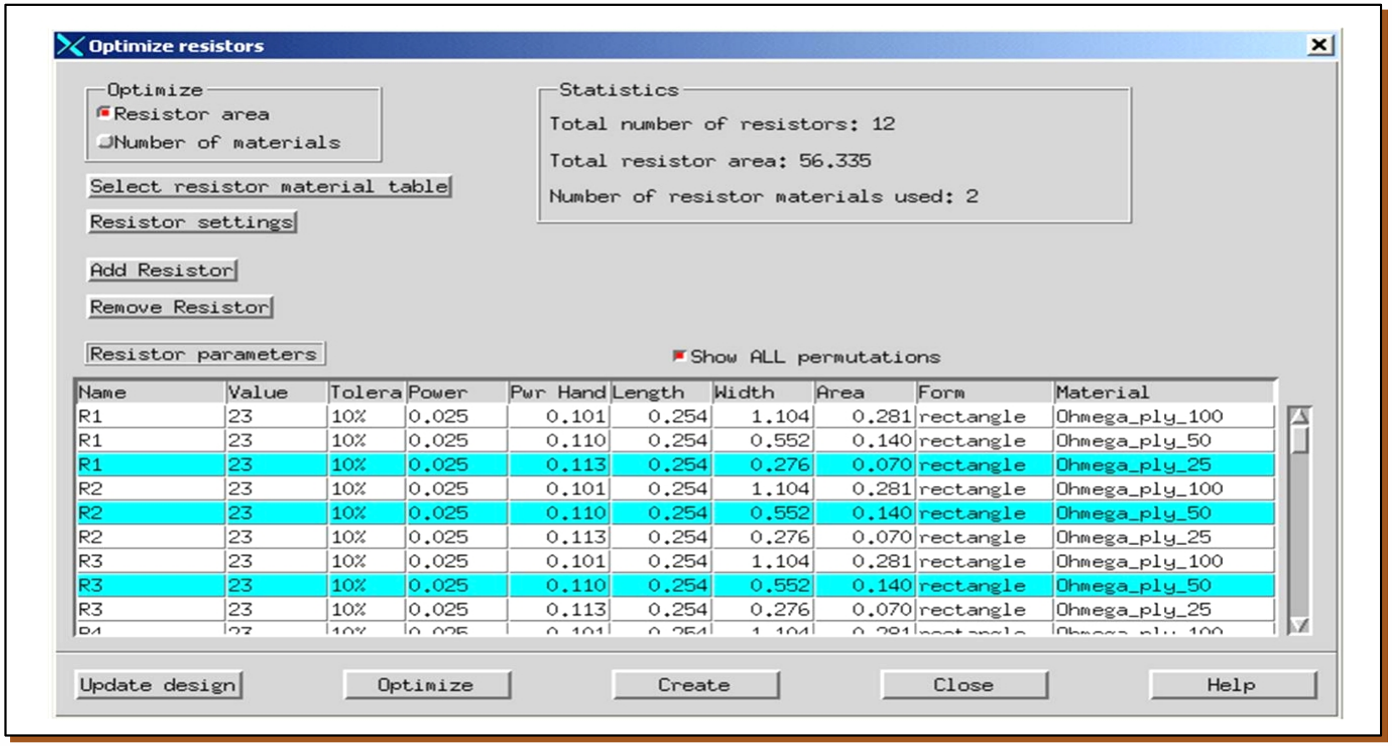
A comprehensive Design Kit is available and together with sample designs and an instructive tutorial design guide, technology introduction is made fast, flexible, and correct.





Parametric Design in Supermax® ECAD of Mentor Graphics

Once a resistor is set to be an embedded resistor, the system automatically syntheses multiple permutations of the resistor. One for each available resistance material in the set up and for each material one of each available geometry (Rectangle, top hat, serpentine).



For each resistor the resulting power handling and dimensions are shown and the designer may choose the desired permutation by clicking in the spreadsheet or use the automatic optimization functions to optimize either on total area or by the number of resistance materials needed.

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Standard CAD Layout Tools

Ohmega resistor design with standard CAD tools

Instructions available for:

1. Mentor Boardstation
2. Allegro
3. Intergraph, Classic
4. PAD Power PCB

Use in conjunction with Excel program, those methods achieves full logic-DRC resistor controlled schematic or net list level.

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Resistor Electrical Test Recommendations

Electrical testing is required to verify correct resistor values and identify out-of-tolerance resistors.

100% Electrical tests should be performed on both the innerlayers and the finished bare board.

Net list testing is required as comparative testing cannot identify nominal resistor values nor incorrect series or parallel resistor networks. AOI is not a substitute for inner layers 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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Resistor Electrical Test Recommendations

Test Parameters:

The measurement current should not exceed the rated current carrying capacity of the resistor, as high current could cause permanent damage to the resistor.

For most automated bare board test equipment, the recommended program test parameters and procedures are:

1. Input the power rating (watts) of the resistor, if this feature is supported by the test system.

2. Input the test voltages on most other standard systems,
   Continuity {opens} 10 volts (20mA limiting current).
   Isolation {shorts} 40 volts (10 Mega ohm failure).

Special probes enable innerlayer testing through double treat or black oxide coatings.

For extremely low value resistors (i.e. less than 15 ohms), contact, probe and lead resistance becomes a critical factor in determining measurement accuracy.

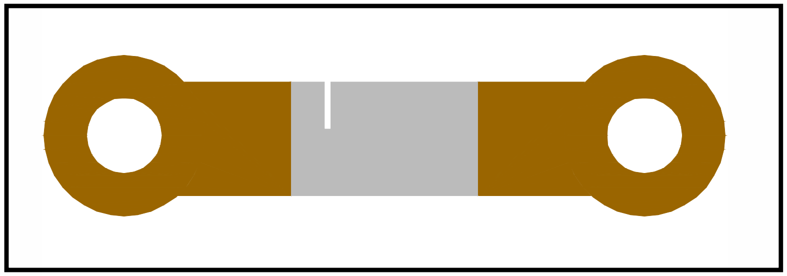
Fixtures for innerlayer testing may have to be rebuilt if the panel layout (PCB location or orientation) is changed or scaled after the first fixture is built.

First time users should contact their Test Equipment Manufacturer to determine the applicability of the their test equipment and availability of the required software

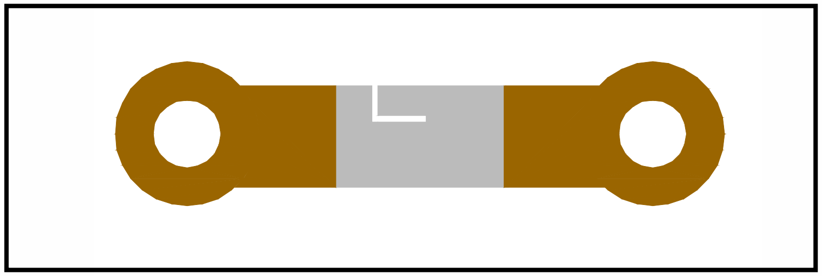
Coupons electrically tested to monitor material, process variation, but coupons are not a substitute for 100% electrical testing read boards.

Resistor Trimming

Examples of Resistor Design for trimming



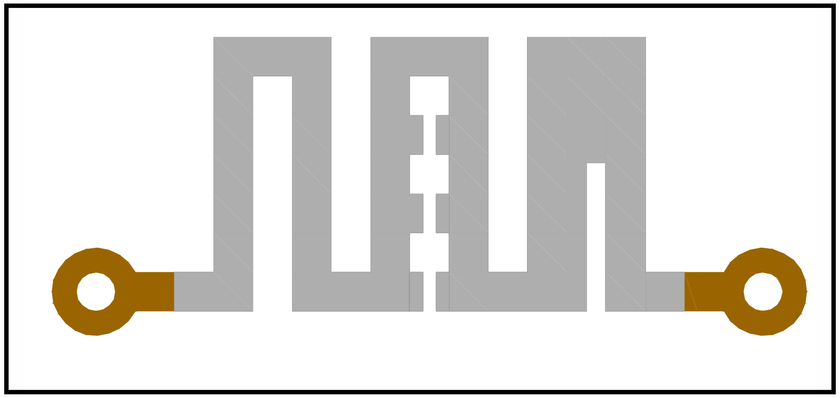
▲ *Plunge Trim*



▲ *L-cut trim*

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

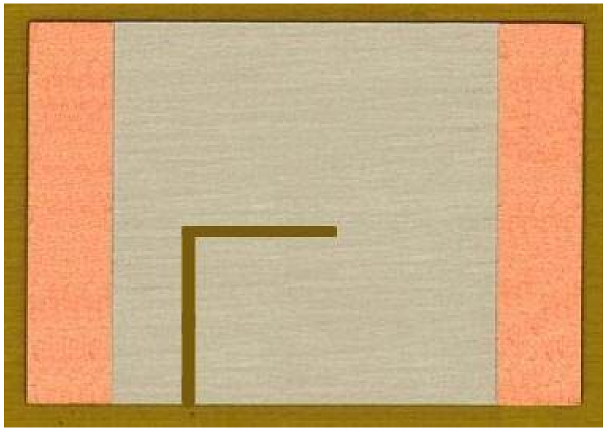
▲ *Trimmable resistor Ladder network*



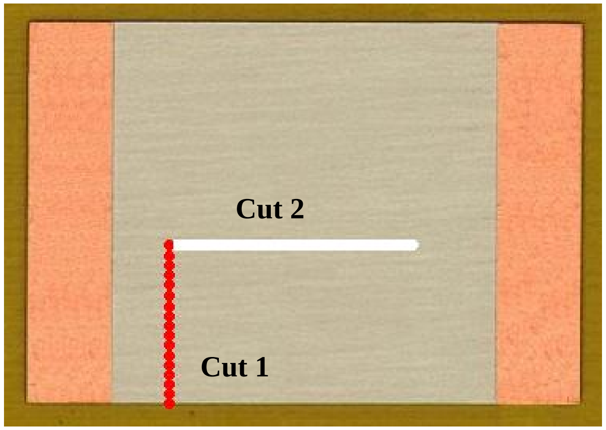
▲ *trimmed multiple square resistor*

The bottom figures are designed with segments for adjust without reducing cross-section of primary current path

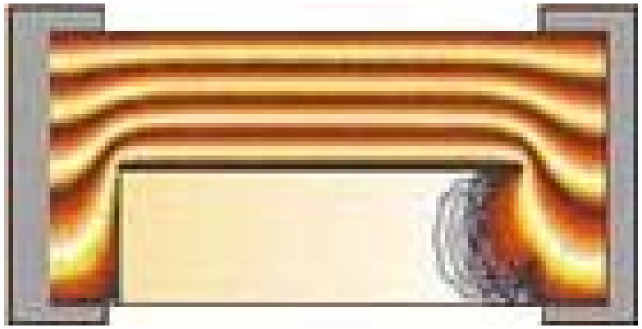
Resistor Trimming



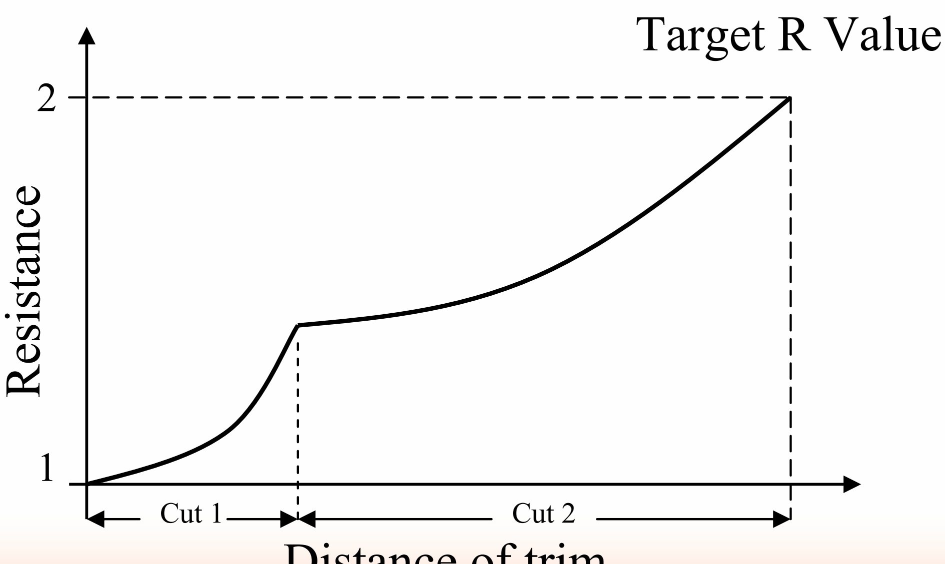
Finished Trim



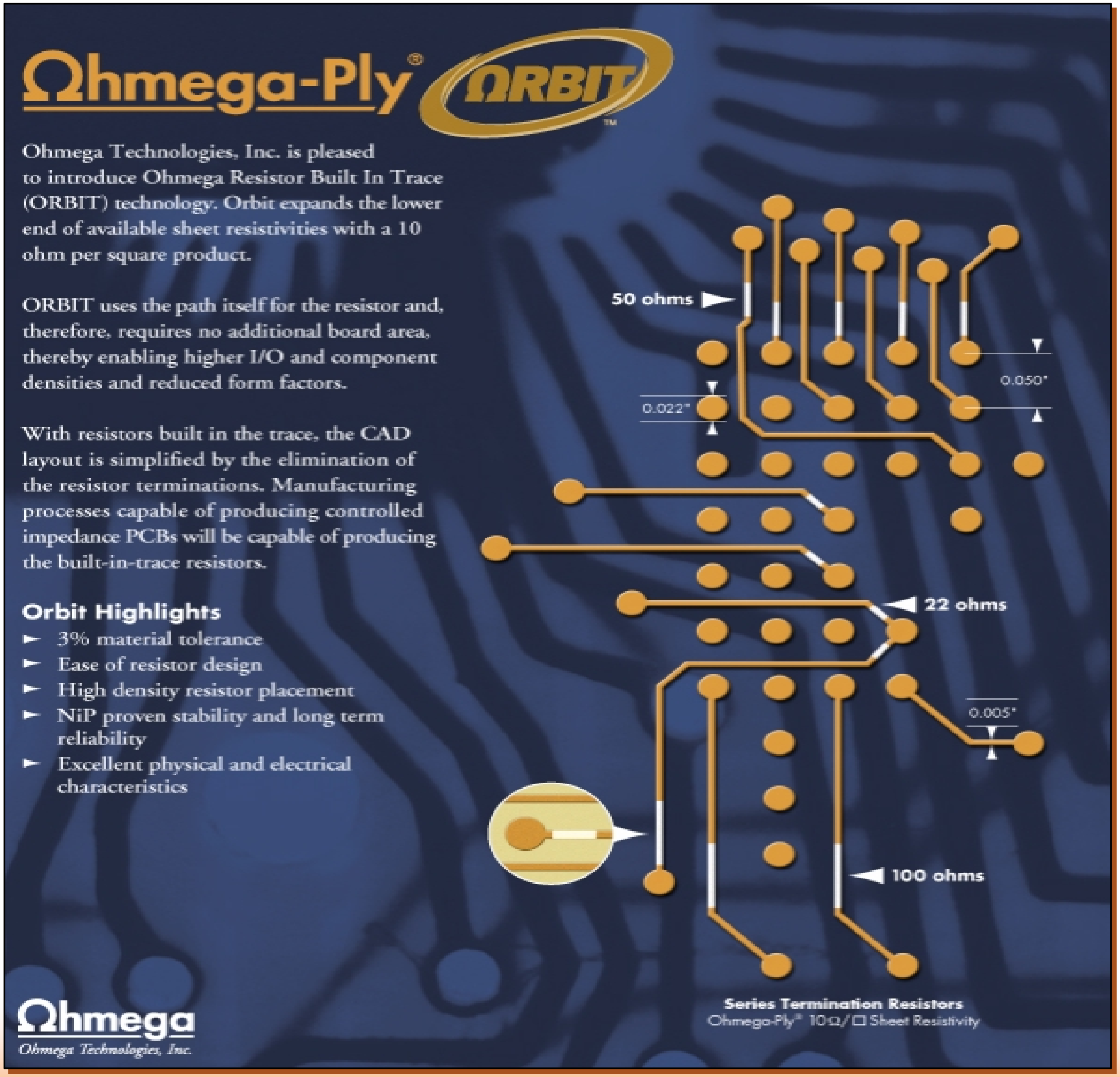
Pulsed Laser Machining



Current Flow Modeling



Ohmega Resistor Built in Trace (ORBIT ™)



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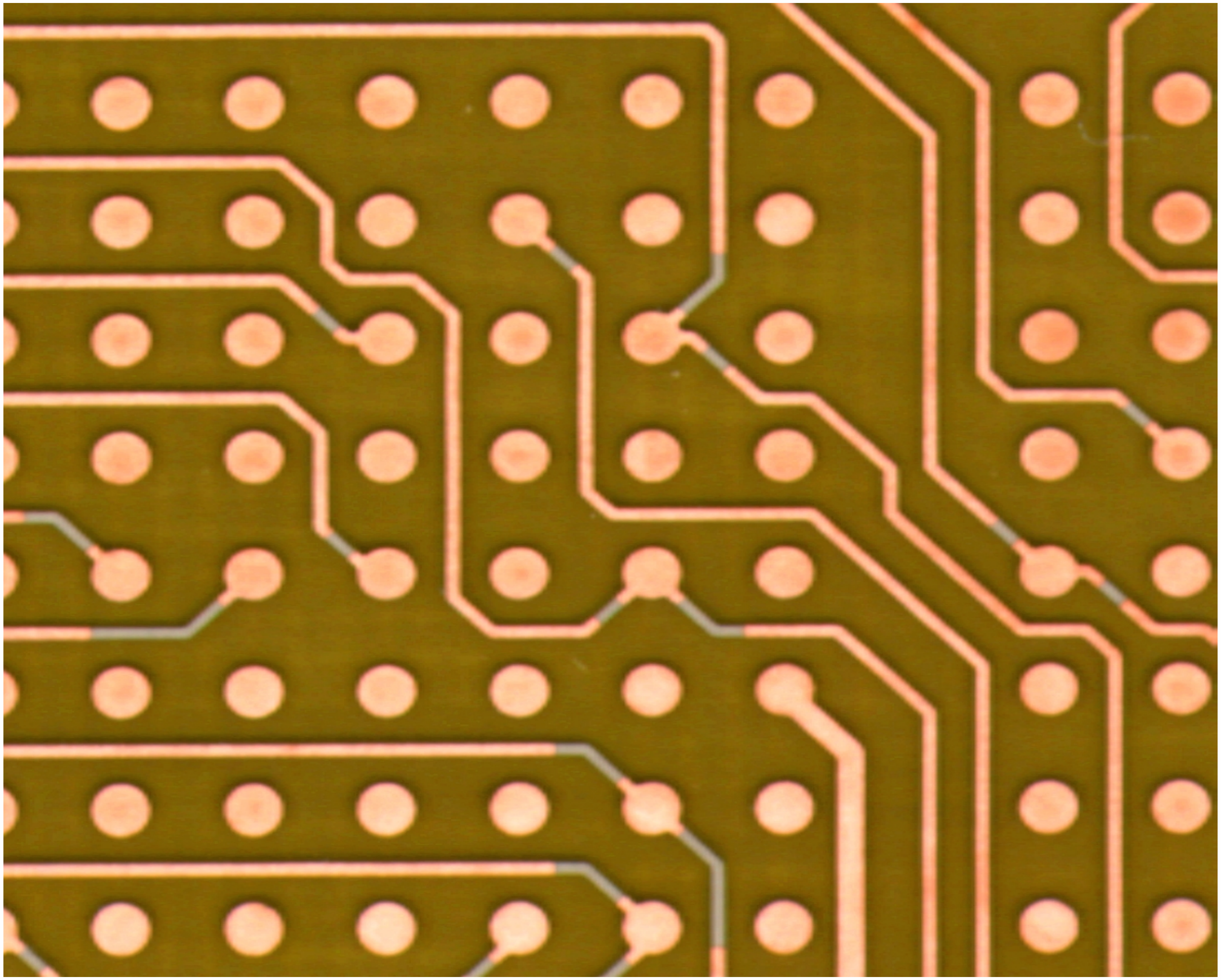
ORBIT™ Applications



ORBIT™ *as series terminating resistors.*

Ohmega®/*FaradFlex*®

Ohmega®/*FaradFlex*®

EMBEDDED RESISTANCE-CAPACITANCE TECHNOLOGY

Ohmega®/*FaradFlex*® is a combined product of the OhmegaPly® thin film resistive-conductive material (RCM) laminated to a *FaradFlex*® dielectric material and subtractively processed to produce embedded RC Networks.

▲ Ohmega/*FaradFlex* laminate ▲ Ohmega/*FaradFlex* Layer.

- Combined Laminate Product.
- Resistance and Capacitance in the same core.
- Developed to accommodate high density designs.
- Embedded Resistor and Capacitor Networks
- Improved signal integrity by better impedance matching.
- Improved signal to noise ratios.
- Standard PCB Subtractive Processing.
- Greater cost effectiveness than separate BR and BC cores.

4031 Elenda Street
Culver City, California 90232-3799
Phone: (310)559-4400
Fax: (310)837-5268
Web: http://www.ohmega.com

80 1st Street
Hoosick Falls, NY 12090
Phone: (518)686-4961
Fax: (518)686-8080
Web: http://www.faradflex.com

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OAK-MITSUI TECHNOLOGIES

Ohmega®/FaradFlex® Properties for 1R25/BC24

OAK-MITSUI TECHNOLOGIES
MITSUI KINZOKU CORPORATE GROUP

Properties	Ohmega/FaradFlex Core	Remarks and Conditions
Copper Weight, µm	35	Nominal
Sheet Resistivity, ohms / square	25	Nominal
Dielectric Thickness, µm	24	Nominal
Cp@ 1MHz, nF/in2(pF/cm2)	1.0 (155)	IPC-TM 650 2.5.5.3
Dk @1MHz	4.4	IPC-TM 650 2.5.5.3
Loss Tangent @ 1MHz	0.015	IPC-TM 650 2.5.5.3
Peel Strength, lbs/in	5.0	IPC-TM 650 2.4.9
Dielectric Strength, kV/mil	5.3	IPC-TM 650 2.5.6.3
Tensile Strength, Mpa(kpsi)	152(22.0)	ASTM D-882 A
Elongation, %	18.5	ASTM D-882 A

Comparison of OhmegaPly®/*FaradFlex*® Vs. FR4

Ohmega Technologies, Inc.

Properties	1R25/BC24 Core	Ohmega Core FR-4 (control)	Remarks and Conditions
Sheet Resistivities (ohm/square)	25	25	Nominal
Material Tolerance	+/-5%	+/-5 %	
Load Life Cycling Test Resistor Size: 0.500" X 0.050" Loaded: (Δ R%) @ 150mW Unloaded: (Δ R%)	<1.6 <1.2	<5	MIL-STD-202-108I Ambient Temp: 70C On Cycle: 1.5 hrs Off Cycle: 1.5 hrs Length Of Test: 10000 hrs
Current Noise Index in dB	<-23	<-15	MIL-STD-202-308 Voltage Applied: 5.6 Volts
Humidity Test (Δ R%)	0.5	0.5	MIL-STD-202-103A Temp: 40 °C Relative Humidity: 95% Time: 240 hrs
Characteristic (RTC) PPM/°C	-6.0	50	MIL-STD-202-304 Hot Cycle: 25°, 50°,75° 125°C Cold Cycle: 25°, 0°,-25°, -55°C
Thermal Shock (Δ R%)	0.2	-0.5	MIL-STD-202-107B No of Cycles: 16 Hot Cycle Temp: 125 °C Cold Cycle Temp: -65 °C
Solder Float (Δ R%) After 1 Cycle After 5 cycles	-0.4 -0.6	0.5	MIL-STD-202-210D Temp: 260°C Immersion: 20 Second
Power Density (mW/mil ^{2}) derated at 50%	0.45	0.15	Step-up Power Test

Synergistic Effect!

Ohmega®/*FaradFlex*® Material Availability

OhmegaPly® Sheet Resistivities (Ohm/square)	FaradFlex® Products					
	BC24	BC16	BC12	BC8	BC12TM	BC16T
10	x	x	o	o	o	o
25	x	x	x	x	o	o
50	x	x	x	x	o	o
100	x	x	o	o	o	o
250	x	x	o	o	o	o
Cp @ 1MHz/1GHz (pF/cm^2)	180/160	250/225	300/270	480/430	700/600	1700/1450

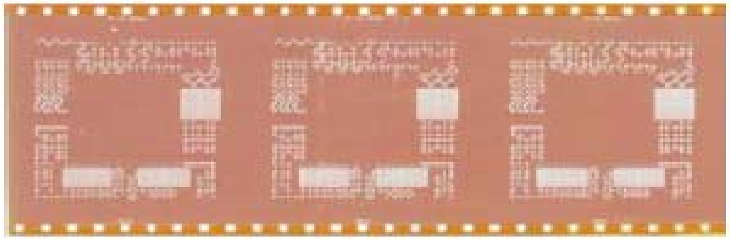
X- Current Availability

O- Available in 2008

OhmegaPly® Flex Circuit Applications

MULTILAYER FLEX TAPE APPLICATIONS

35 mm Tape BGA - 1mm Pitch
Reel to Reel Process Capability



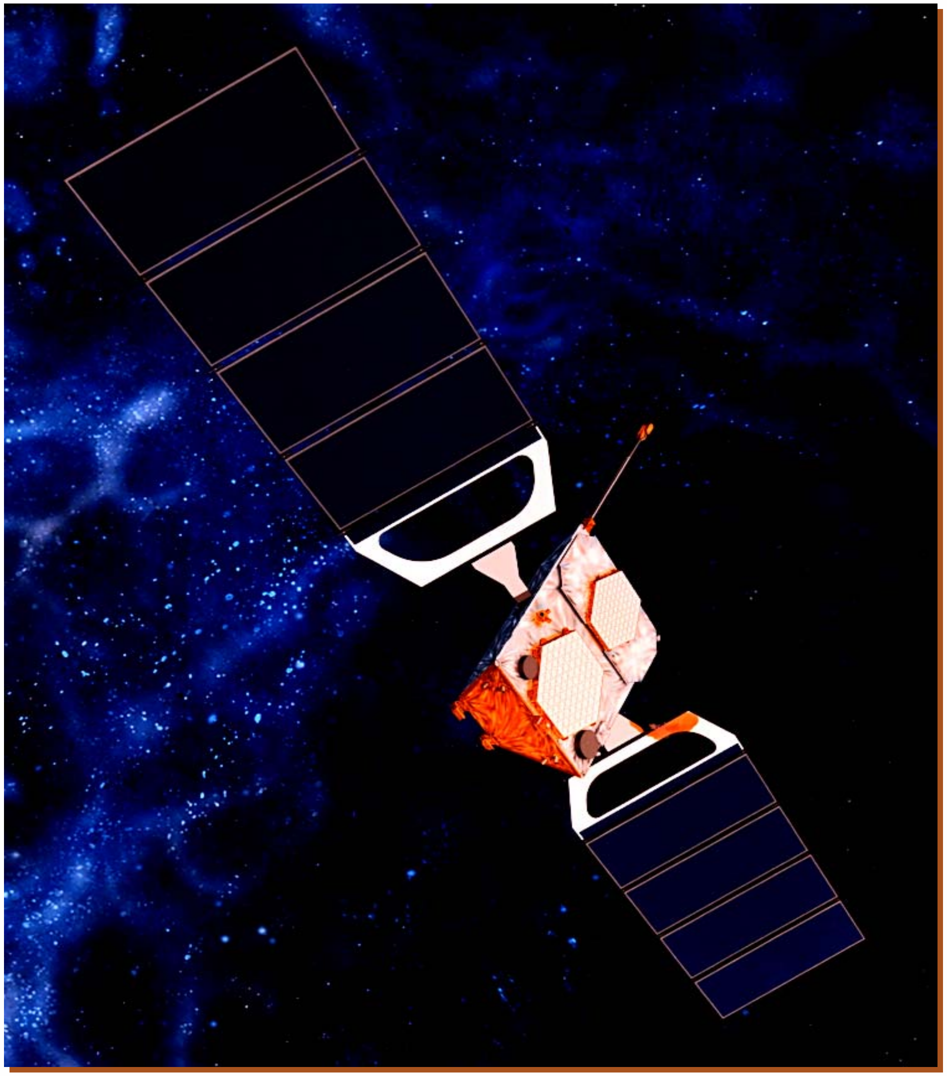
ETCHED RESISTOR TOLERANCES

Nominal Value - ohms:	25	37.5	50	75	100
Aspect ratio (# of squares):	1	1.5	2	3	4
Resistor width - mils:	8	8	8	8	8
Resistor Length - mils:	8	12	16	24	32
Mean value (ohms)	35 ohms	44 ohms	54 ohms	78 ohms	105 ohms
Percent tolerance	+/- 50%	+/- 25%	+/- 20%	+/- 15%	+/- 10%

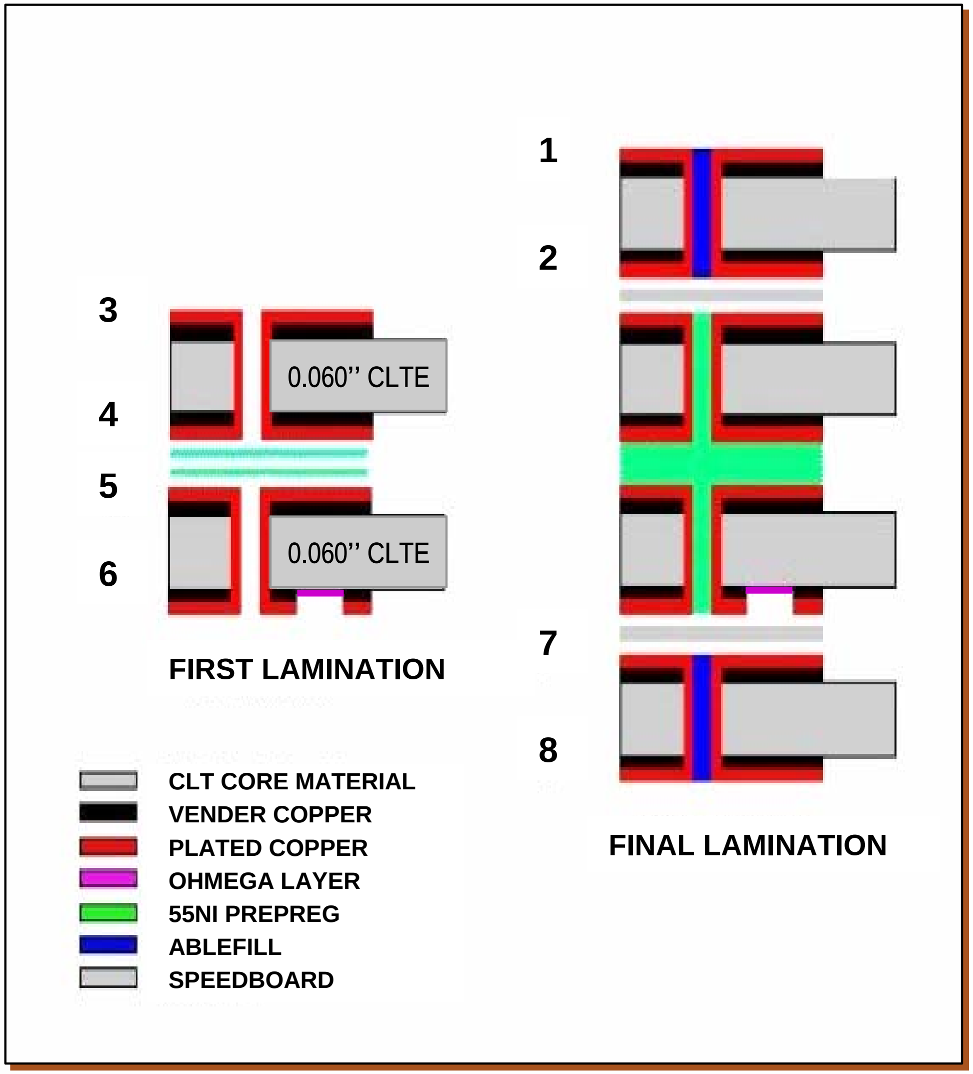
Ohmega-Ply RCM® 1/2R25 {Half ounce - 25 ohms/square} Resistive -Conductive-Material

Note: Percent tolerance decreases with resistor width and length.
Mean value can be corrected by artwork compensation.

OhmegaPly® in Microwave Applications

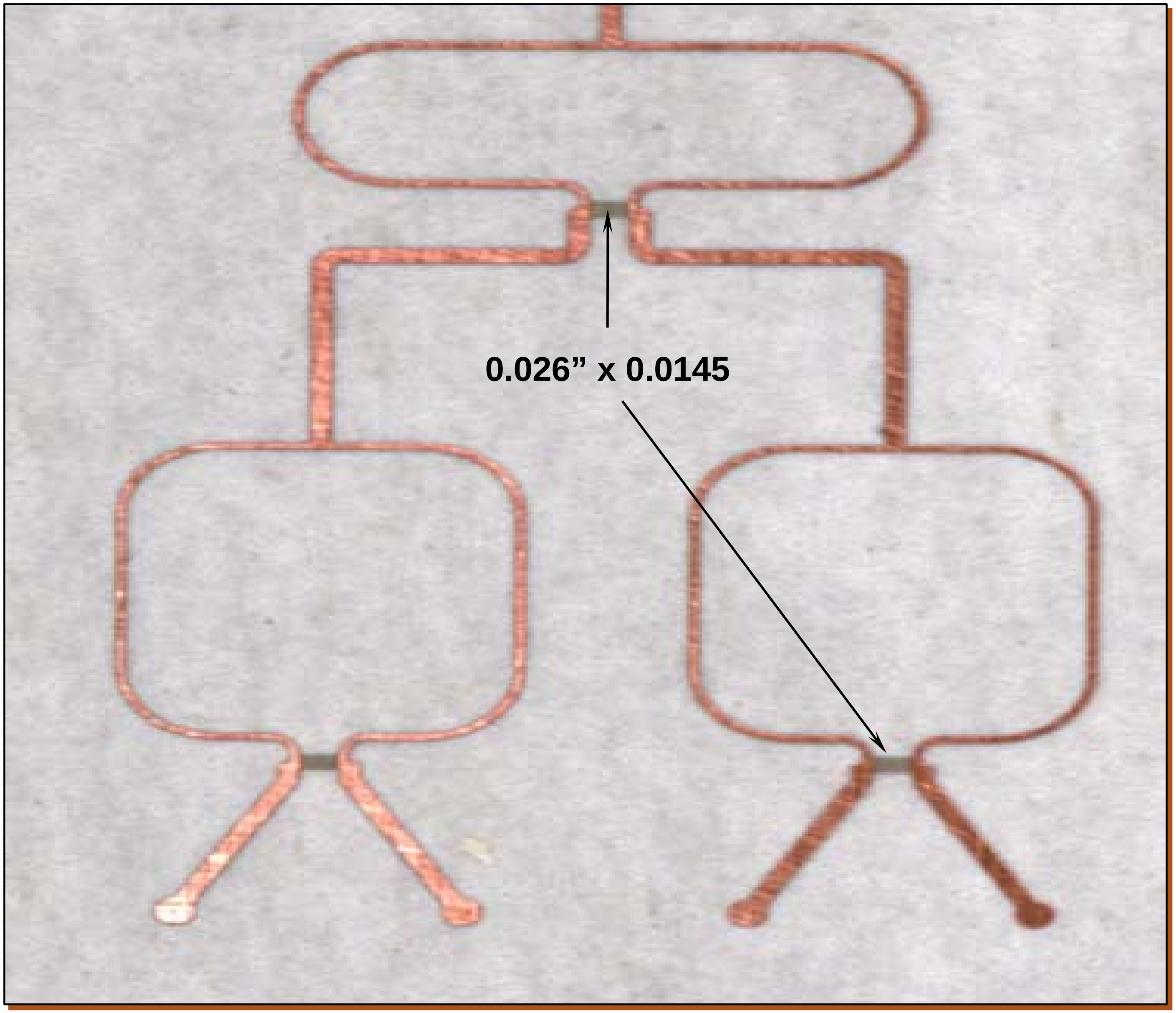


OhmegaPly® resistor in microwave application for Globalstar antenna.



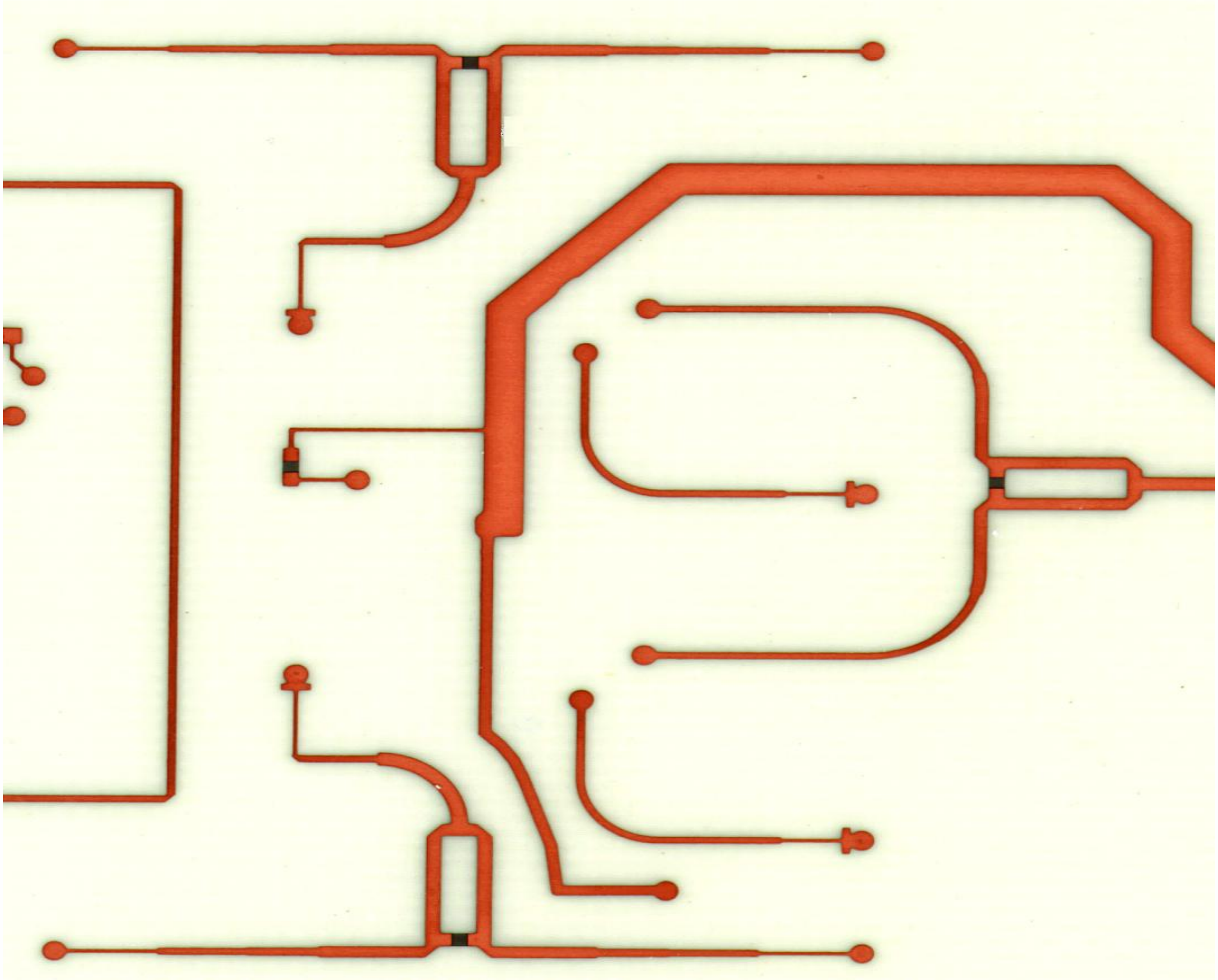
Layer stackup.

OhmegaPly® in Microwave Applications



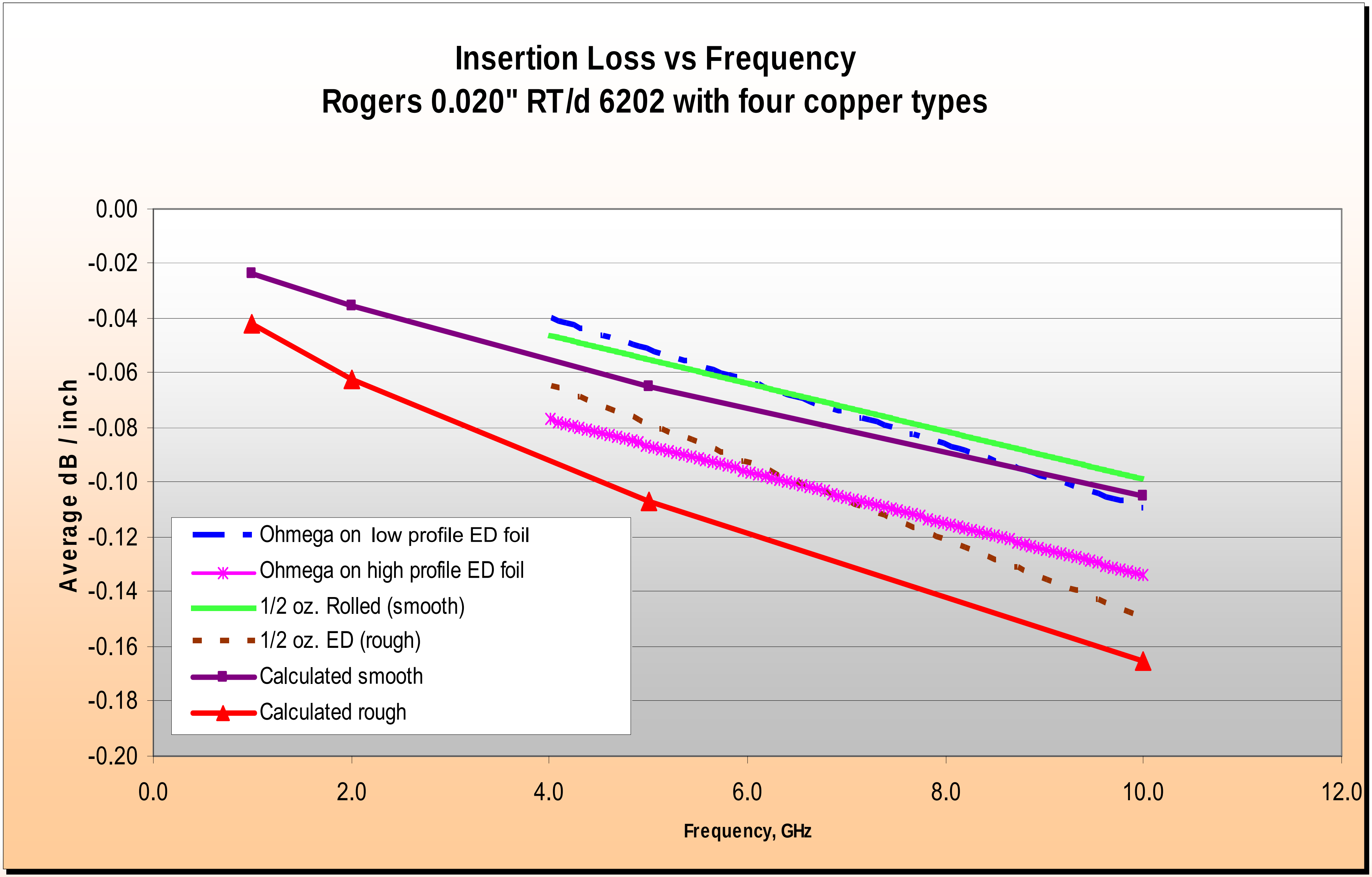
Enlargement of a four-up array 16-way power divider with 50 Ω/sq OhmegaPly® resistors

OhmegaPly® in Microwave Applications

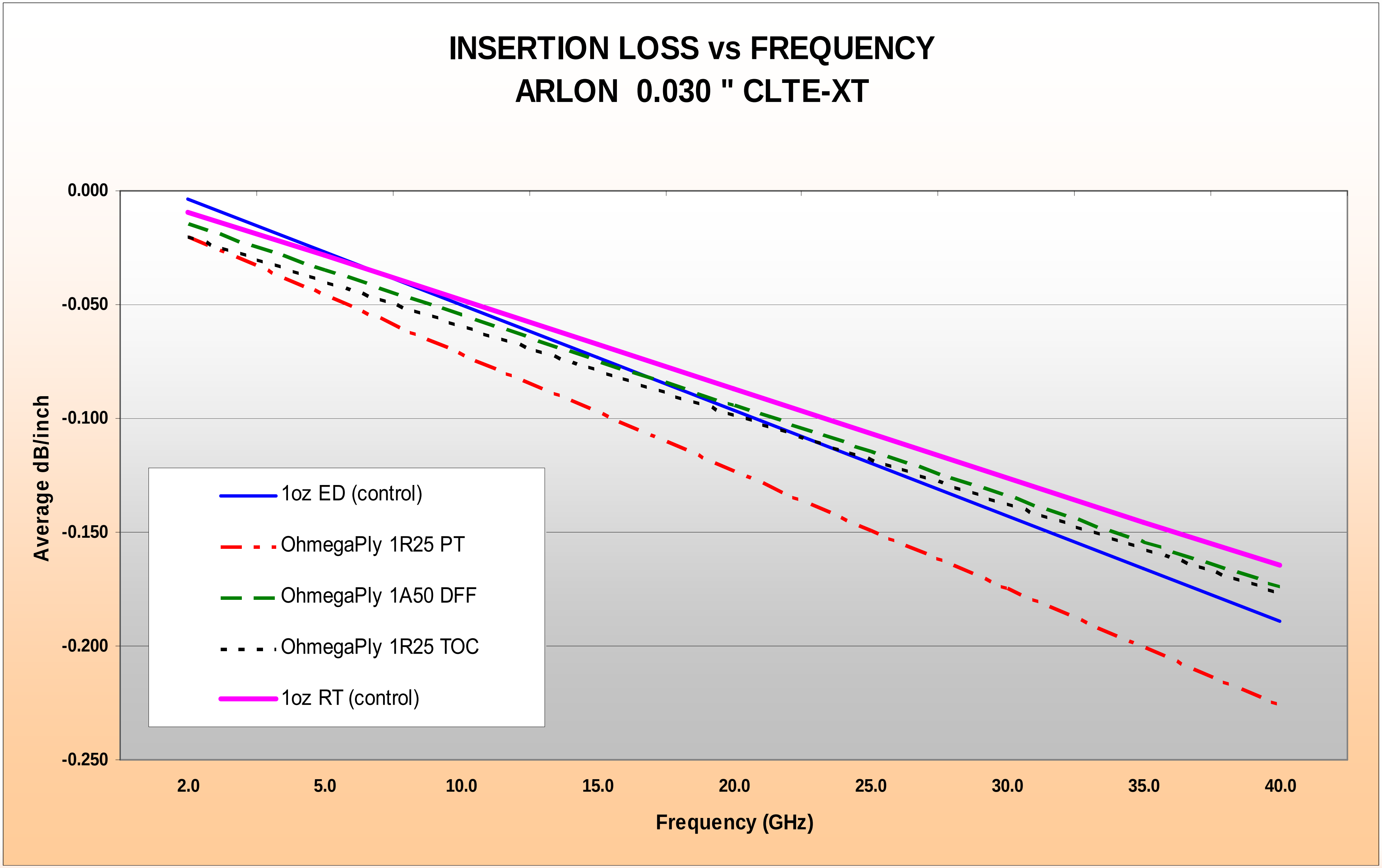


Power divider for space application

OhmegaPly® in Microwave Applications



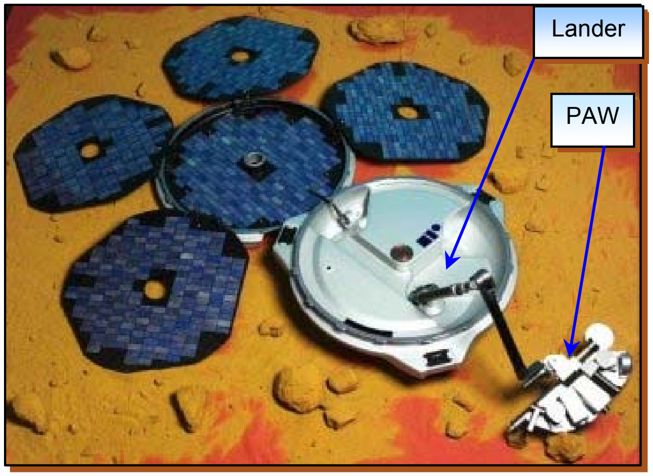
OhmegaPly® in Microwave Applications



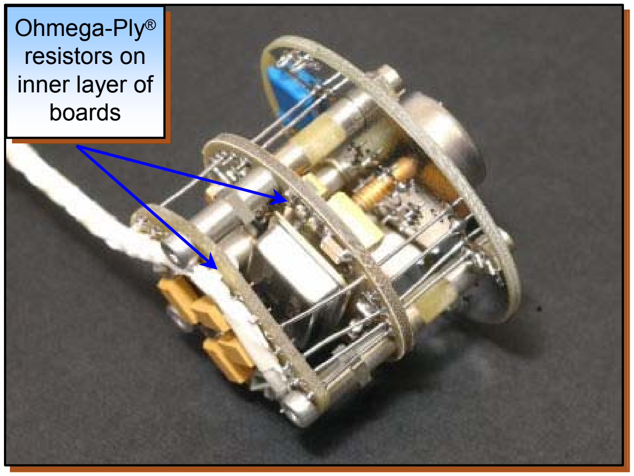
Mars Express with OhmegaPly® in Beagle 2 Lander

Ohmega Technologies, Inc.

▲ *Mars Express orbiter*

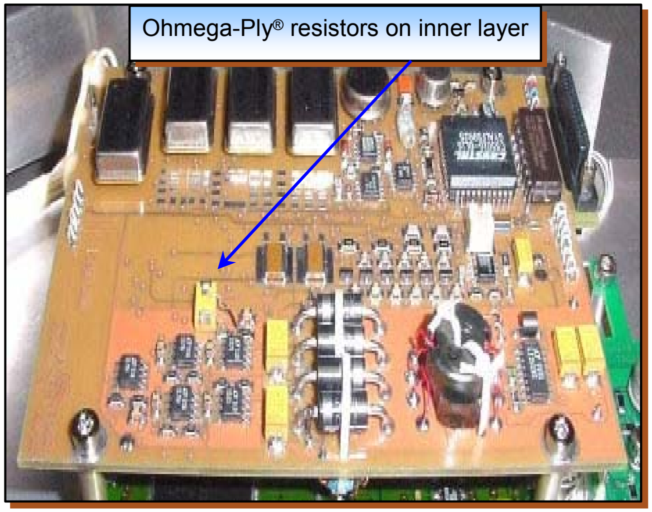


▲ *Beagle 2 Lander with instruments on its robotic arm*

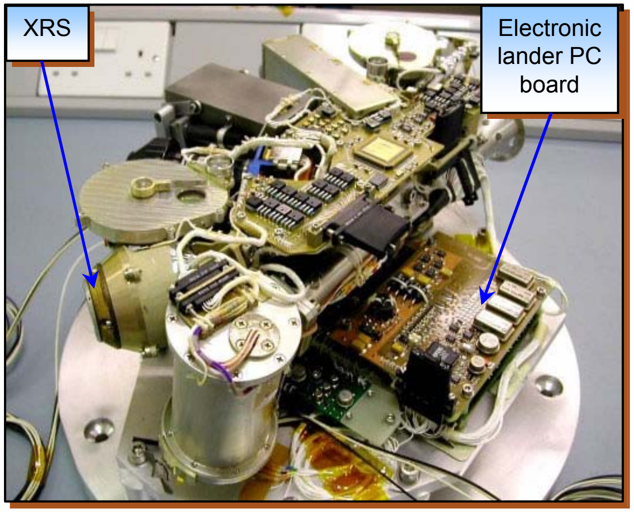


▲ *X-Ray Spectrometer (XRS) with Ohmega-Ply® resistors*

▲ *X-Ray Spectrometer with cover to measure the elements in rocks*



▲ *Ohmega-Ply® resistors in electronic lander PC board*

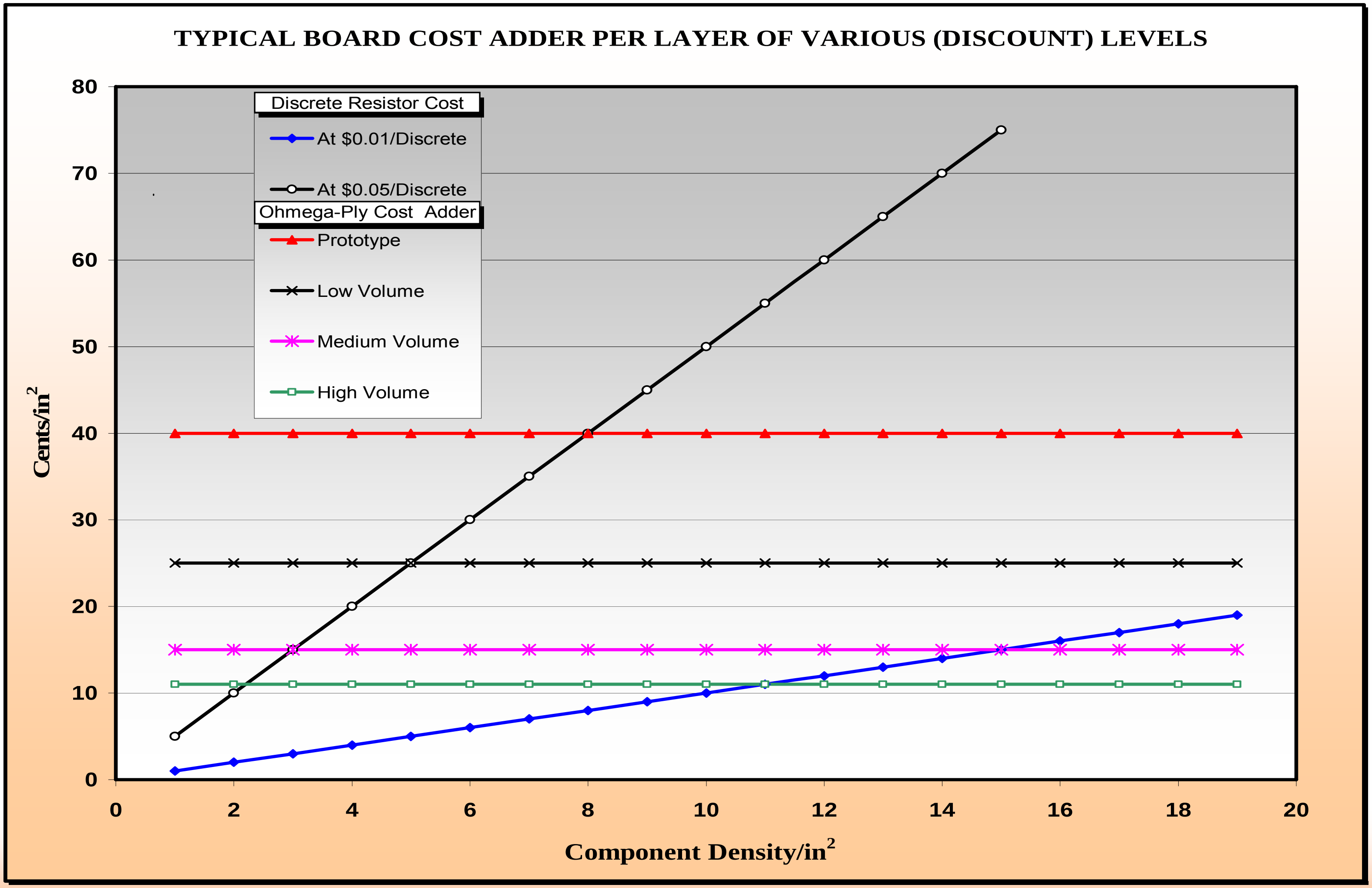


▲ *Top view of PAW (position adjustable workbench)*

Ohmega-Ply® Cost Analysis

A. Traditional Cost Model (direct replacement of discrete resistor with Ohmega-Ply)

Volume:	Prototype	Low	Medium	High
Ohmega-Ply® Material (Cents/in^2)	$0.20	$0.14	$0.10	$0.07
Board Convesion Cost Adder	$0.40	$0.25 - $0.30	$0.15 - $0.20	$0.11 - $0.15



OhmegaPly® Cost Analysis

B. Technology Tradeoff Cost Model (enhanced PCB design using OhmegaPly® to replace discrete resistors)

Following is a comparison of some board technologies (per square inch of board area). The comparison is based on an application requiring 10 resistors per square inch of board area:

Substrate type	Cost addder substrate	Total cost bare board	SMT cost (resistor)	Total cost, bare board + resistor
Standard 6-layer with SMT	---	$0.12	$0.20	$0.32
Standard 6-layer with Ohmega	$0.20	$0.32	---	$0.32
Microvia 4-layer with SMT	$0.46	$0.58	$0.20	$0.66
Sequential build 6-layer (buried vias with SMT)	$0.49	$0.61	$0.20	$0.81

Use of Ohmega-Ply® in design may:

- Reduce board area
- Reduce layer count
- Allow for discrete SMT to become single side SMT
- Improve loaded board testability
- Allow for more traditional PCB technology (through hole versus HDI)

C. Not all or nothing proposition Ohmega-Ply can be cost effective without the removal of all SMT components

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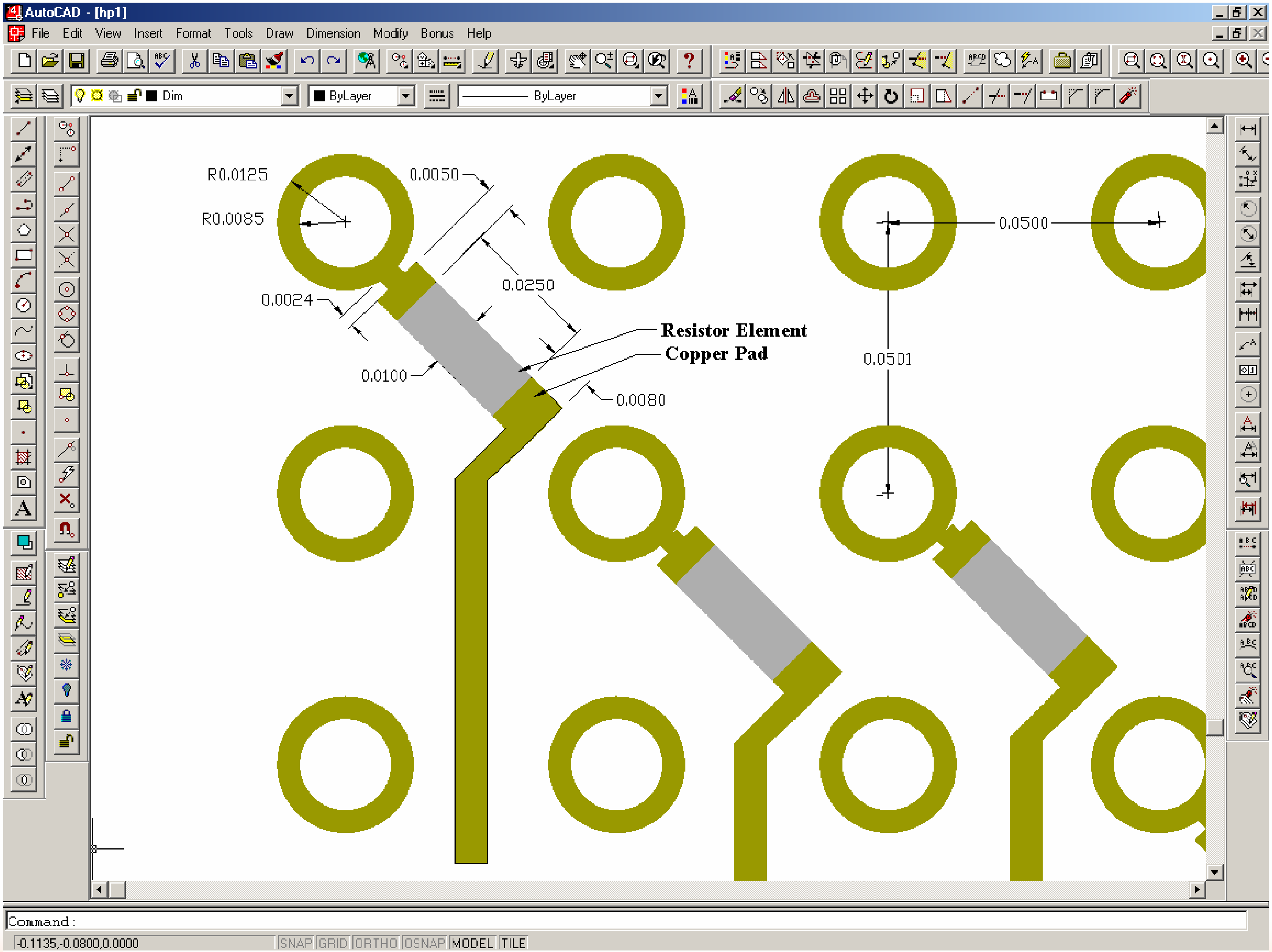
Application Library

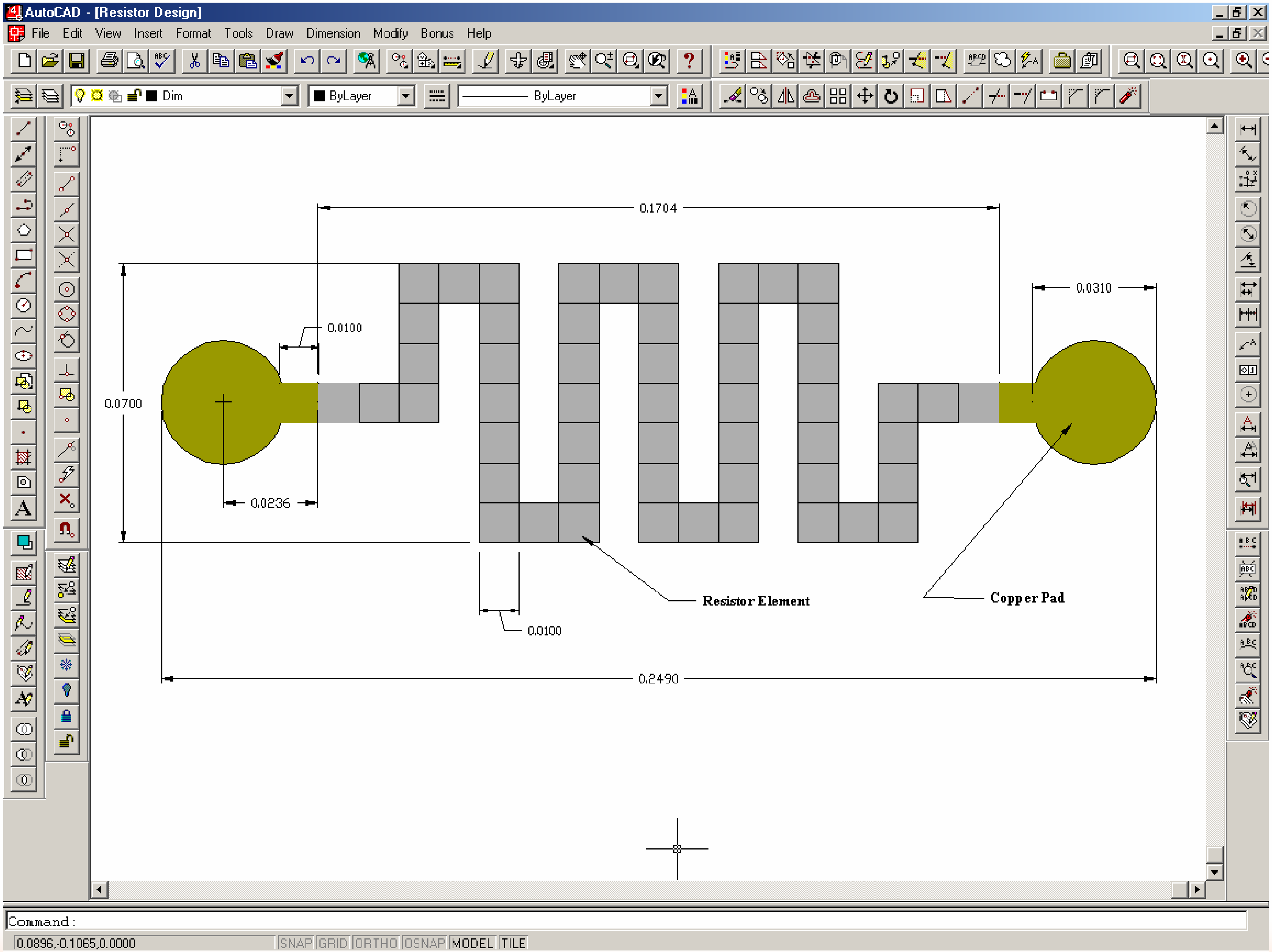
Draw No.	Resistance Value (Ohm)	RCM Used (Ohm/Sq)	Resistor Pattern	Applications
1	62	25	Bar	ECL Parallel
2	4700	100	Meander/Serpentine	Pull up/down
3	305	25	Meander	ECL Parallel
4	44	25	Bar	ECL Parallel
5	1500	100	Meander/Serpentine	Pull up/down
6	50	50	Bar	ECL Series
7	1000	250	Circular	Heating
8	200	100	Bar	Potentiometer

Application Library



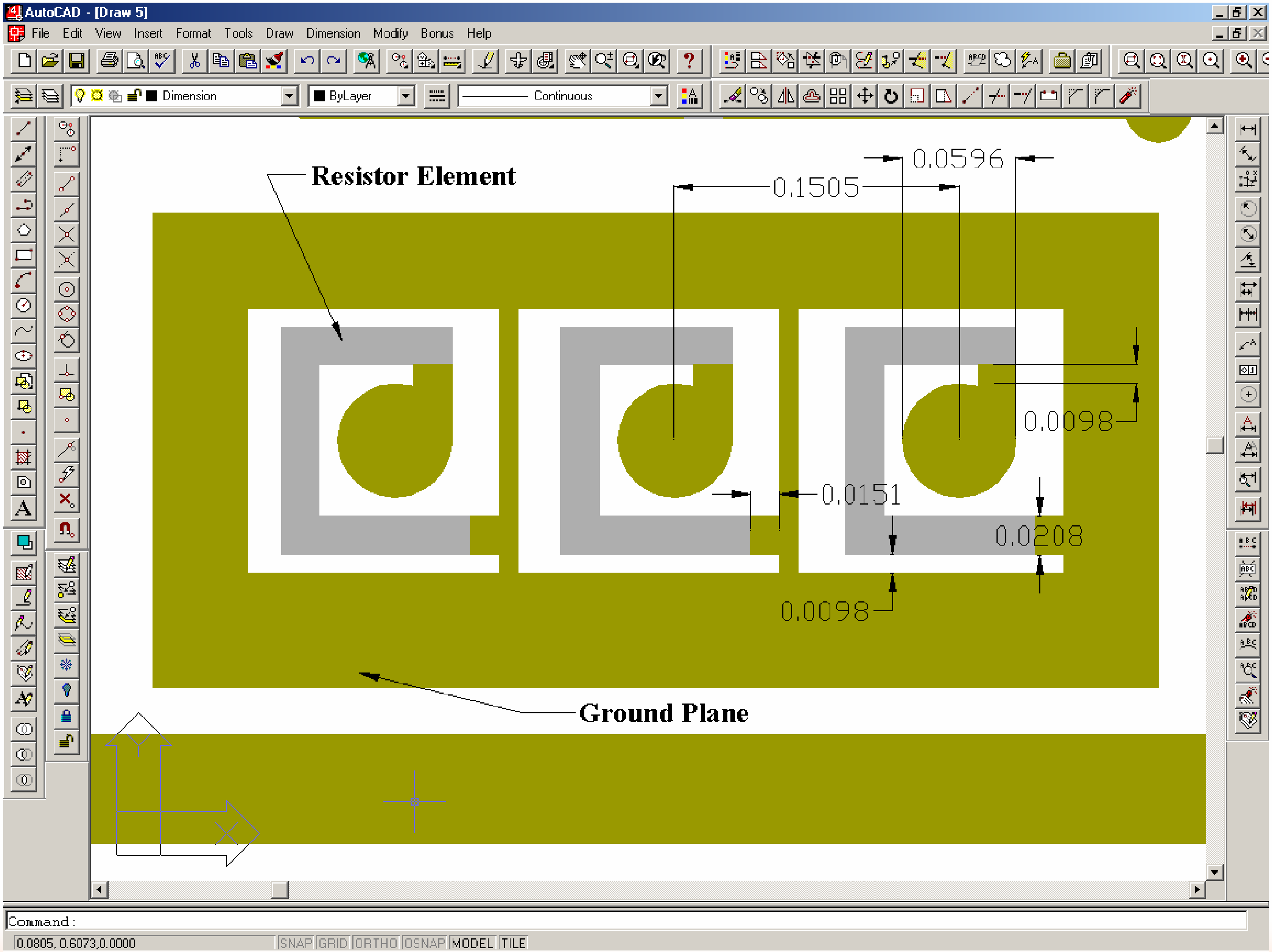
- *Draw 1 – 62 ohm resistor design under BGA.*

Application Library



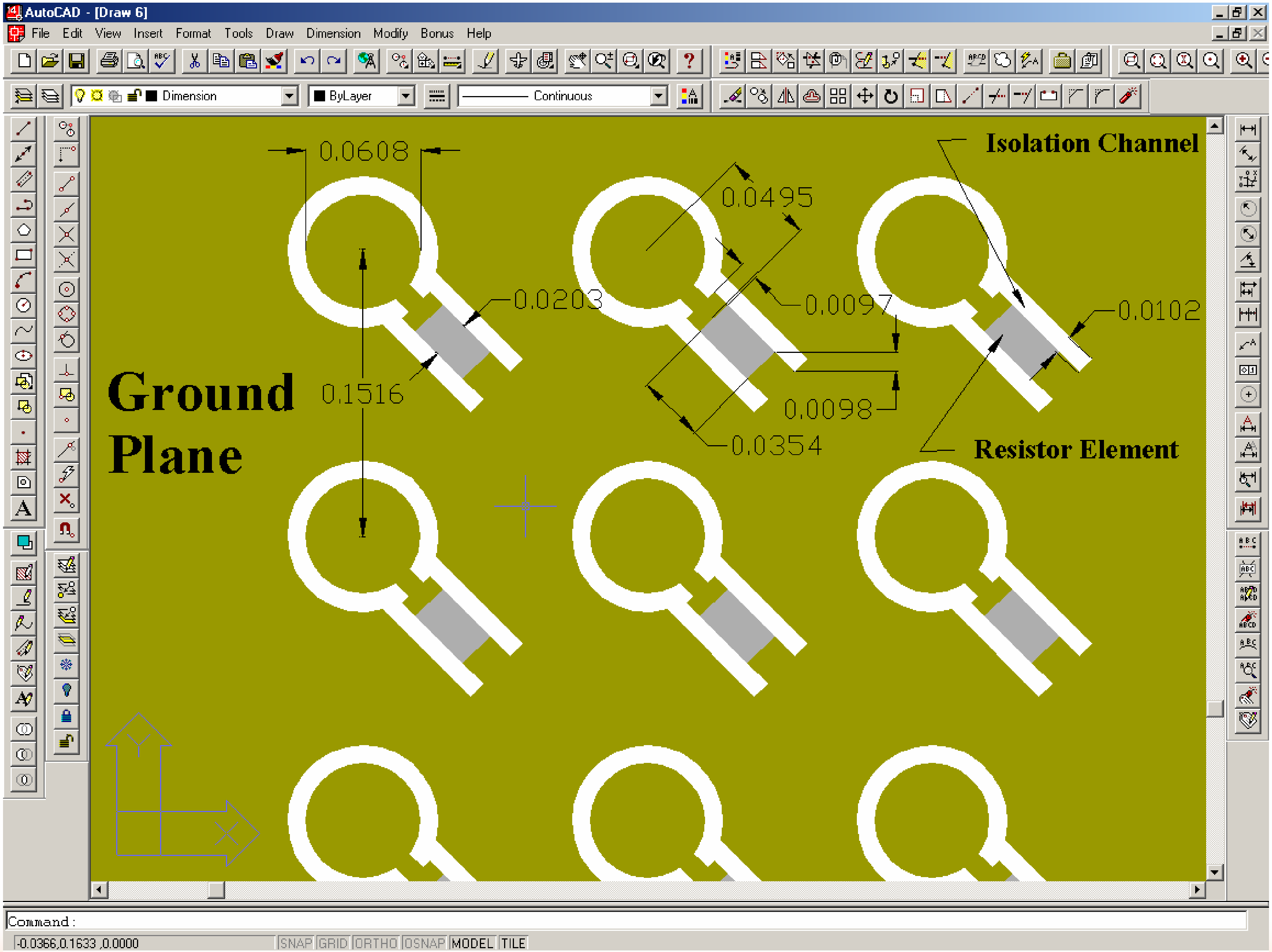
- *Draw 2 – 4.7K ohm resistor design.*

Application Library



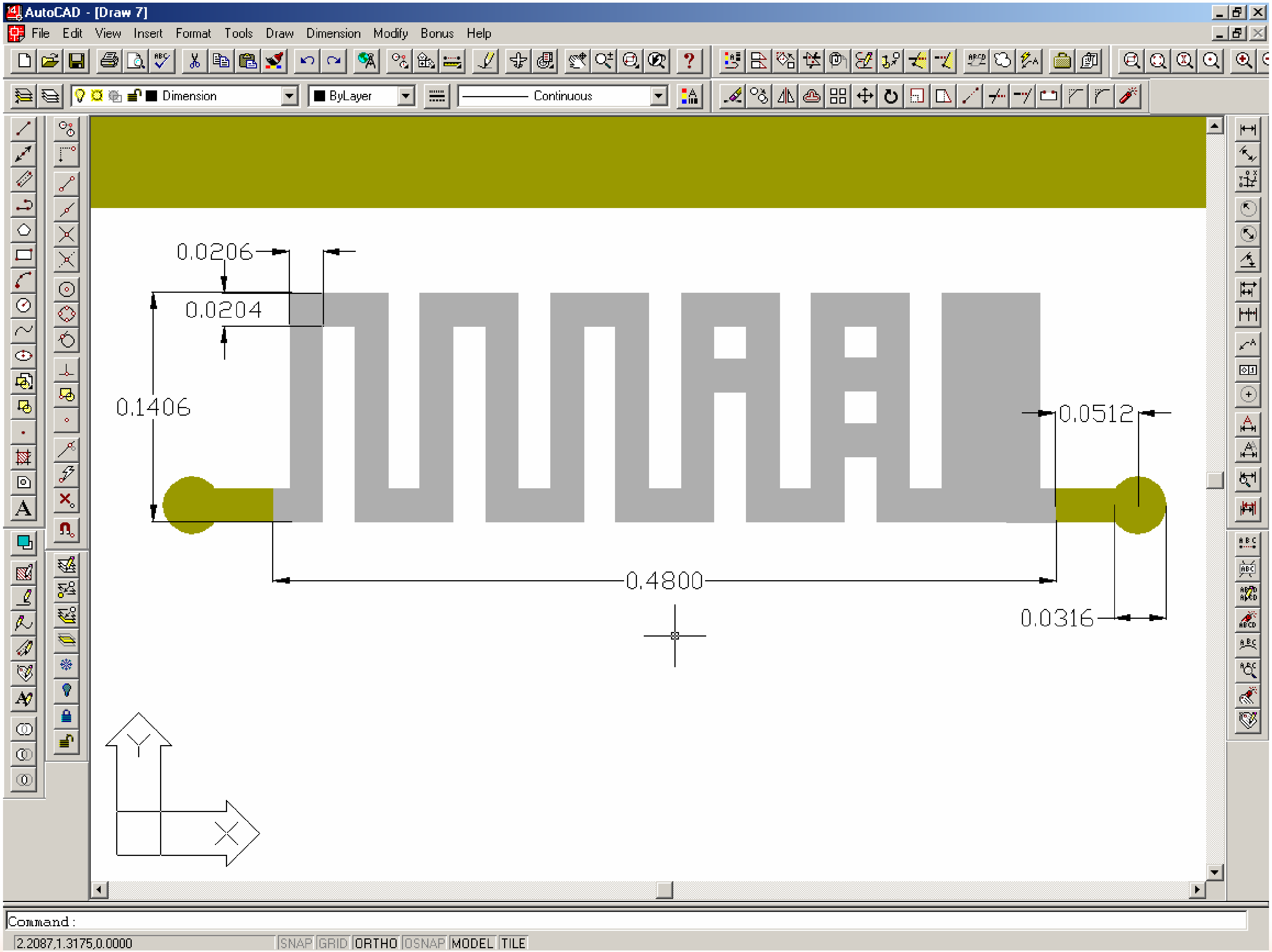
▲ *Draw 3 – 305 ohm resistor design.*

Application Library



- *Draw 4 – 44 ohm resistor design.*

Application Library



▲ *Draw 5 – 1.5K ohm trimmable resistor design.*

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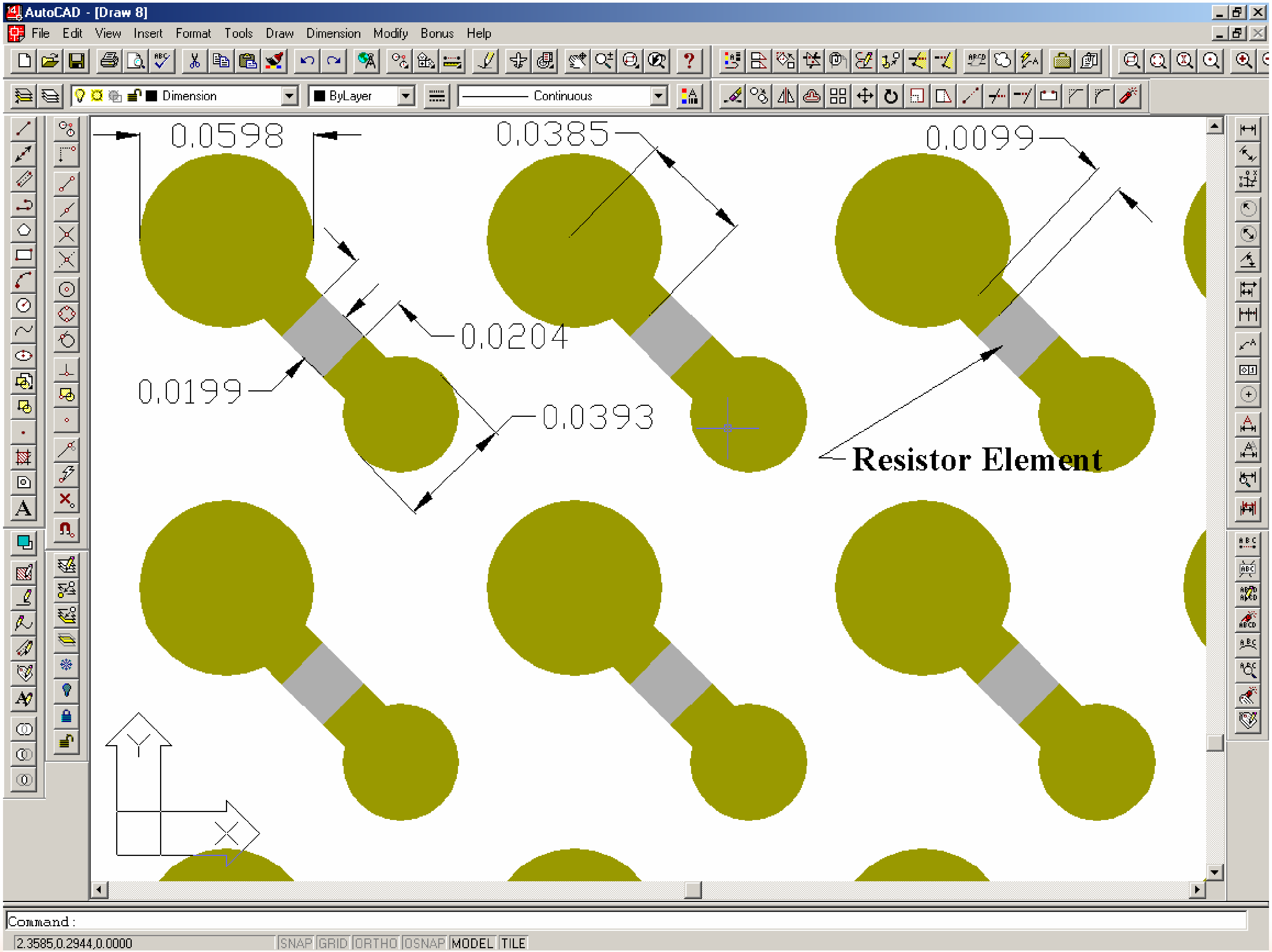
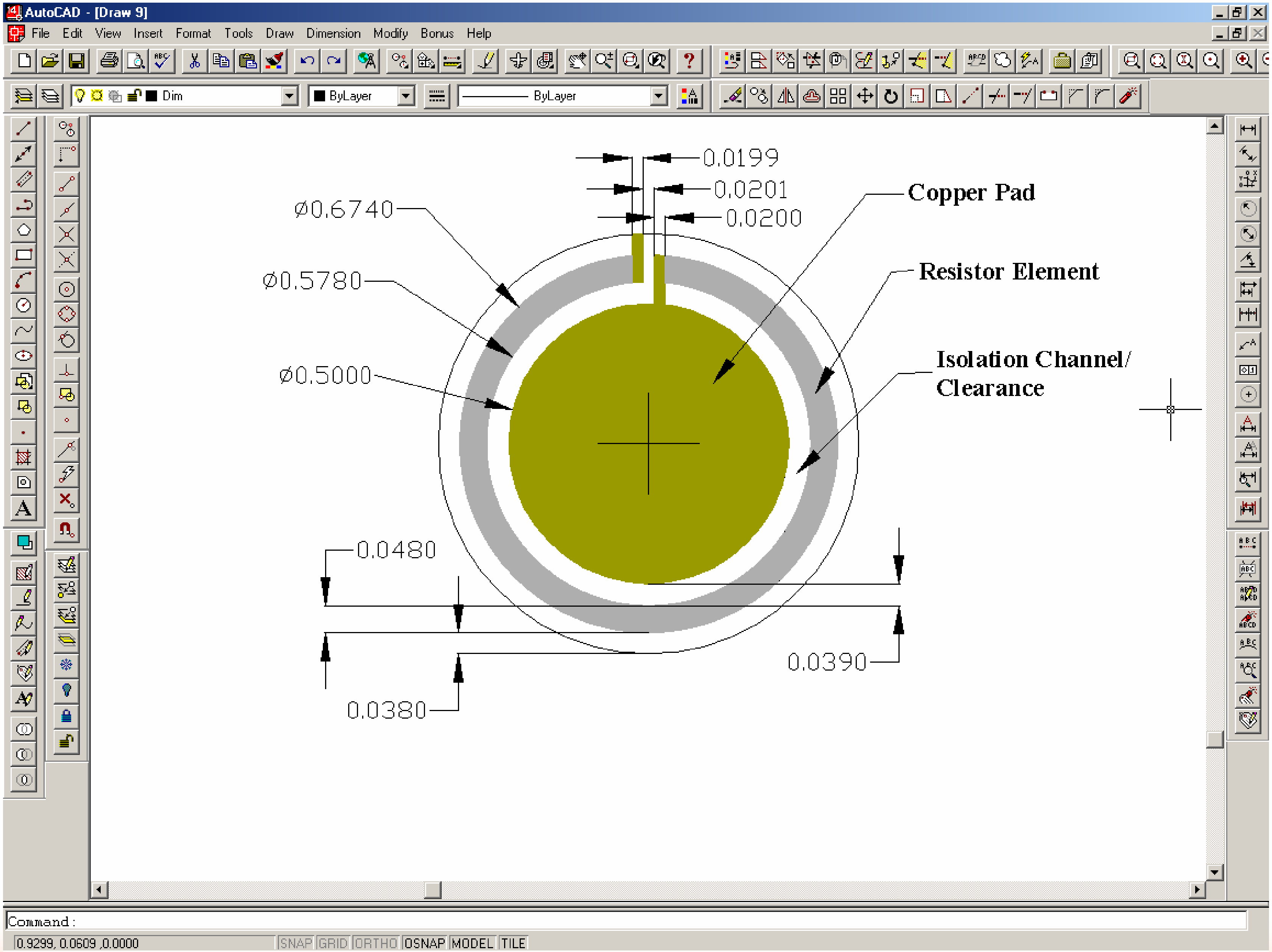
Application Library



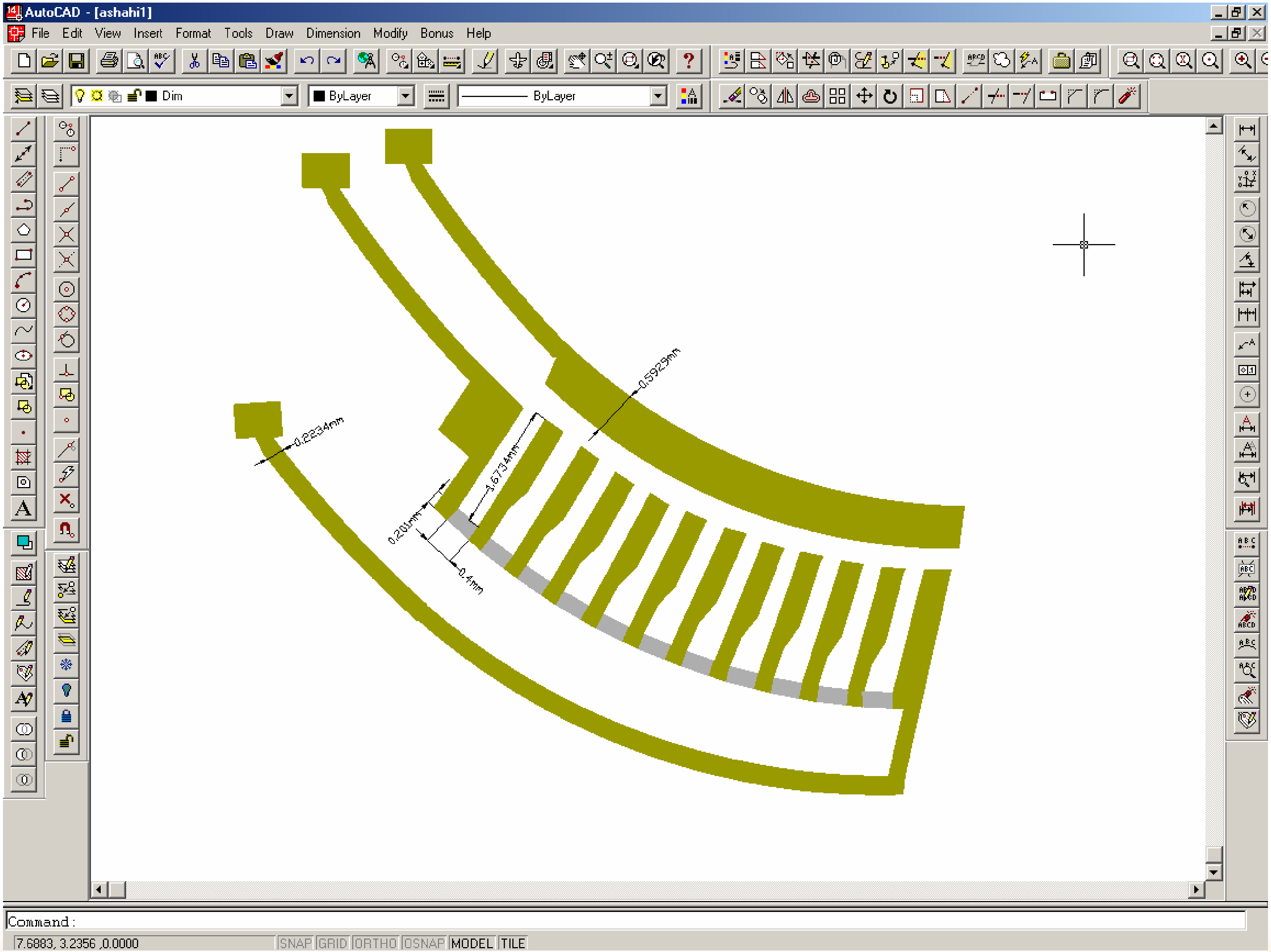
▲ *Draw 6 – 50 ohm series termination resistor design.*

Application Library



▲ *Draw 7 – 1K ohm resistor design (heater).*

Application Library



▲ *Draw 8 – Potentiometer resistor design.*

OHMEGA TECHNOLOGIES, INC.

4031 ELENDA STREET

CULVER CITY, CA 90232-3799

PHONE: (310)559-4400

FAX: (310)837-5268

WEB SITE: http://www.ohmega.com

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