Applications Using Buried Resistor Technology

IBM Beaverton
Clint Beliveau
Advisory Engineer
clintb@us.ibm.com
503-578-4171

A Brief History……

- **IBM Beaverton / Sequent Computer Systems, Inc.**
  - Used Buried Resistor Technology since May 1995
  - Designed into 3 generations of NUMA-Q servers.
    - Sting I (Intel Pentium® Processor)
    - Scorpion (Intel Pentium-II® Processor)
    - Centurion (Intel Itanium® Processor)
  - Originally used to solve board real estate problem
- **Benefits**
  - Improved analog signal quality (lower inductance)[1]
    - 0.9 nH for 1206 SMT Resistor
    - <0.4 nH for Ohmega-ply® Resistor
  - Eliminates discrete resistors from assembly
  - Lower opportunity for assembly defects
  - Improved board reliability
  - Reduces board size

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Component Size Comparison

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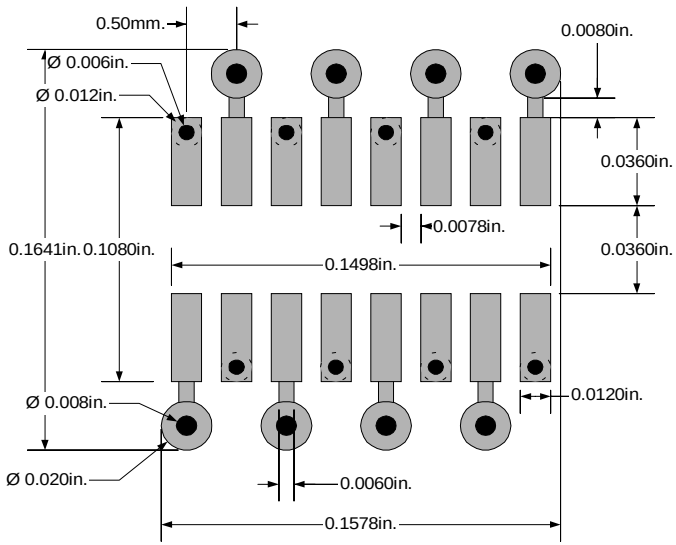
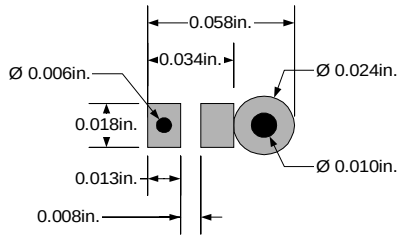
- Discrete Resistor options vs. Buried Resistor

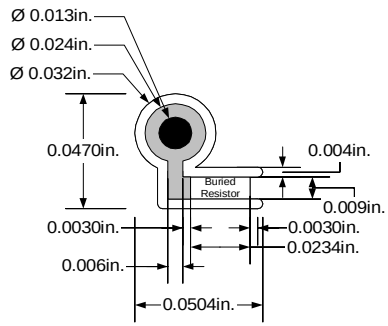
Resistor Network



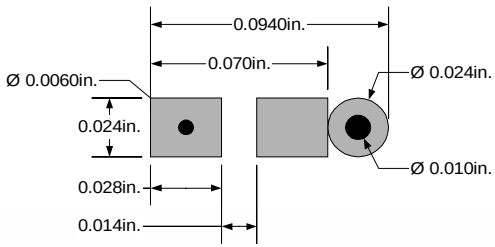
0201 Discrete Resistor



65 Ohm Buried Resistor



0402 Discrete Resistor



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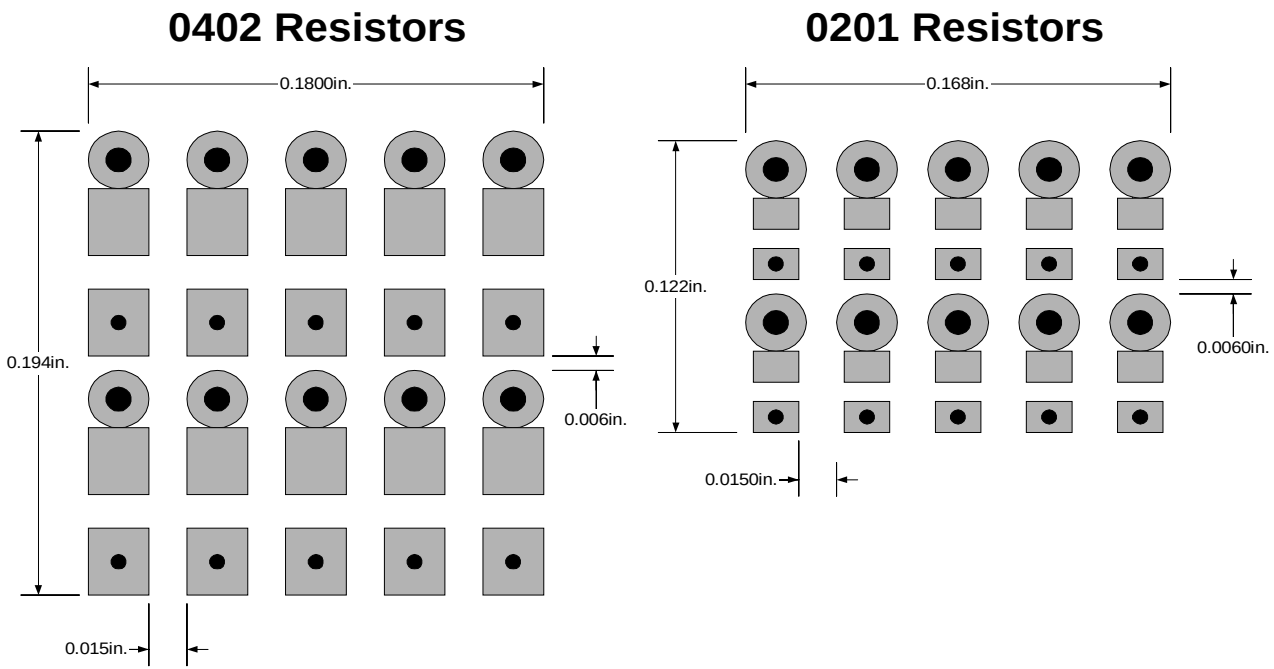
Maximized Resistor Placement

- 372 Resistors (186 per side)
  - 0402 w/blind VIAs would take ~1.3 in²
  - 0201 w/blind VIAs would take ~0.76 in²



Scorpion LYNX2 PCB

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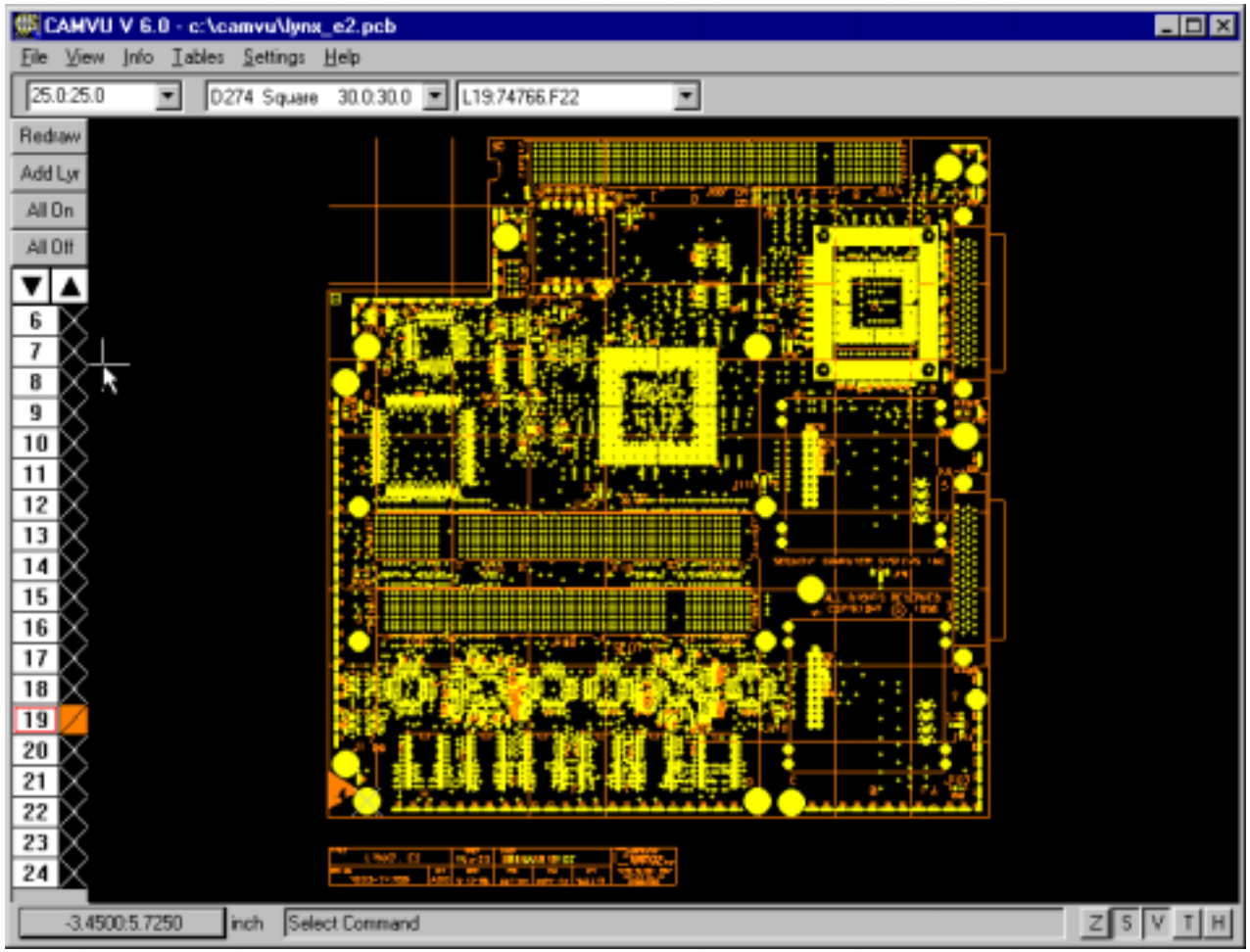
- Primary Side



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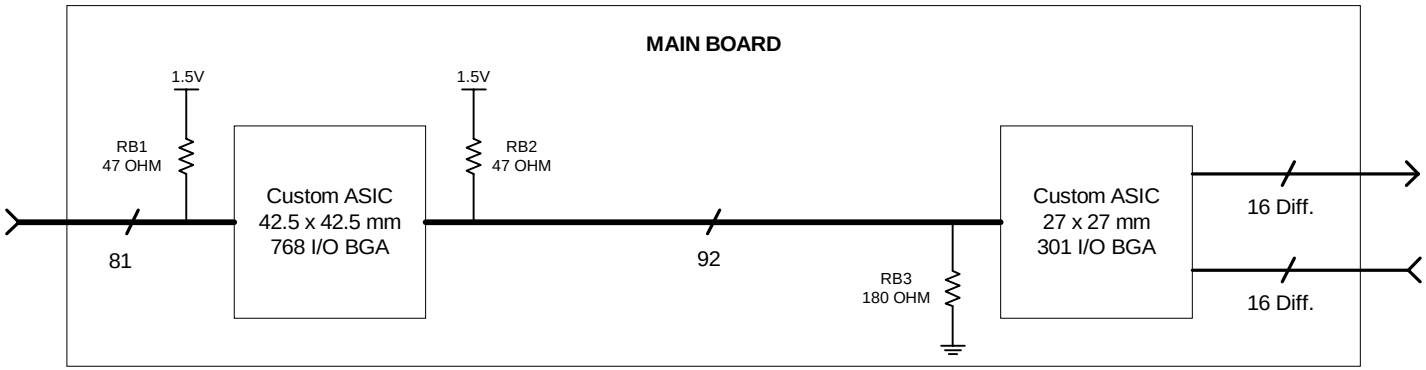
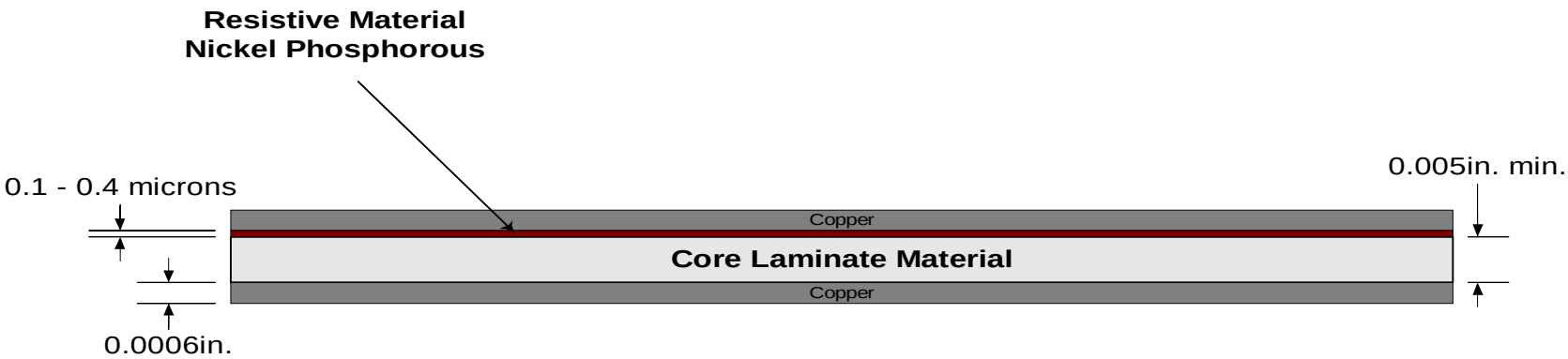
Scorpion Bus Topology



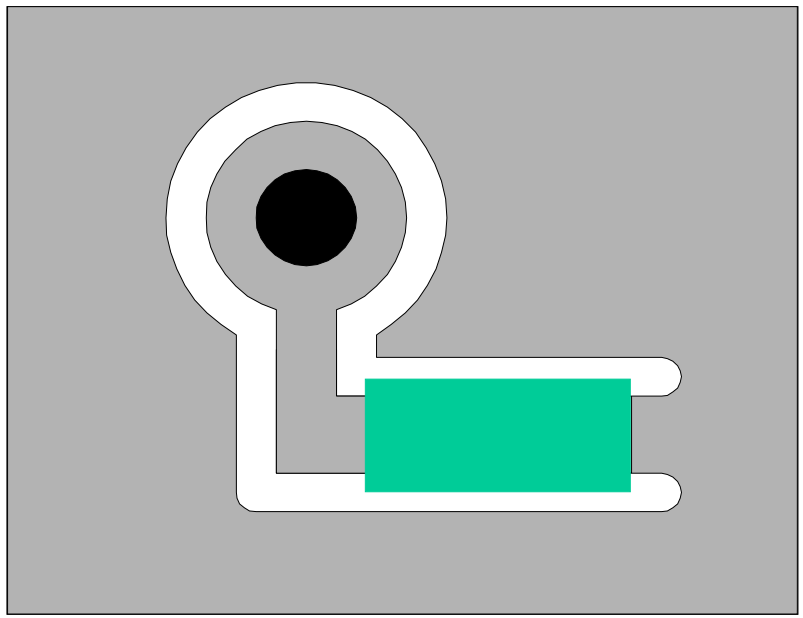
- Bus topology for Scorpion Design

Omega-Ply® Material



Buried Resistor Processing

- Formation of Buried Resistor on plane layer.
  - 1st Image, 1st & 2nd Etch Clearance (define resistor width)
  - 2nd Image & Etch Resistor Element (define resistor length)



Scorpion LYNX2 PCB

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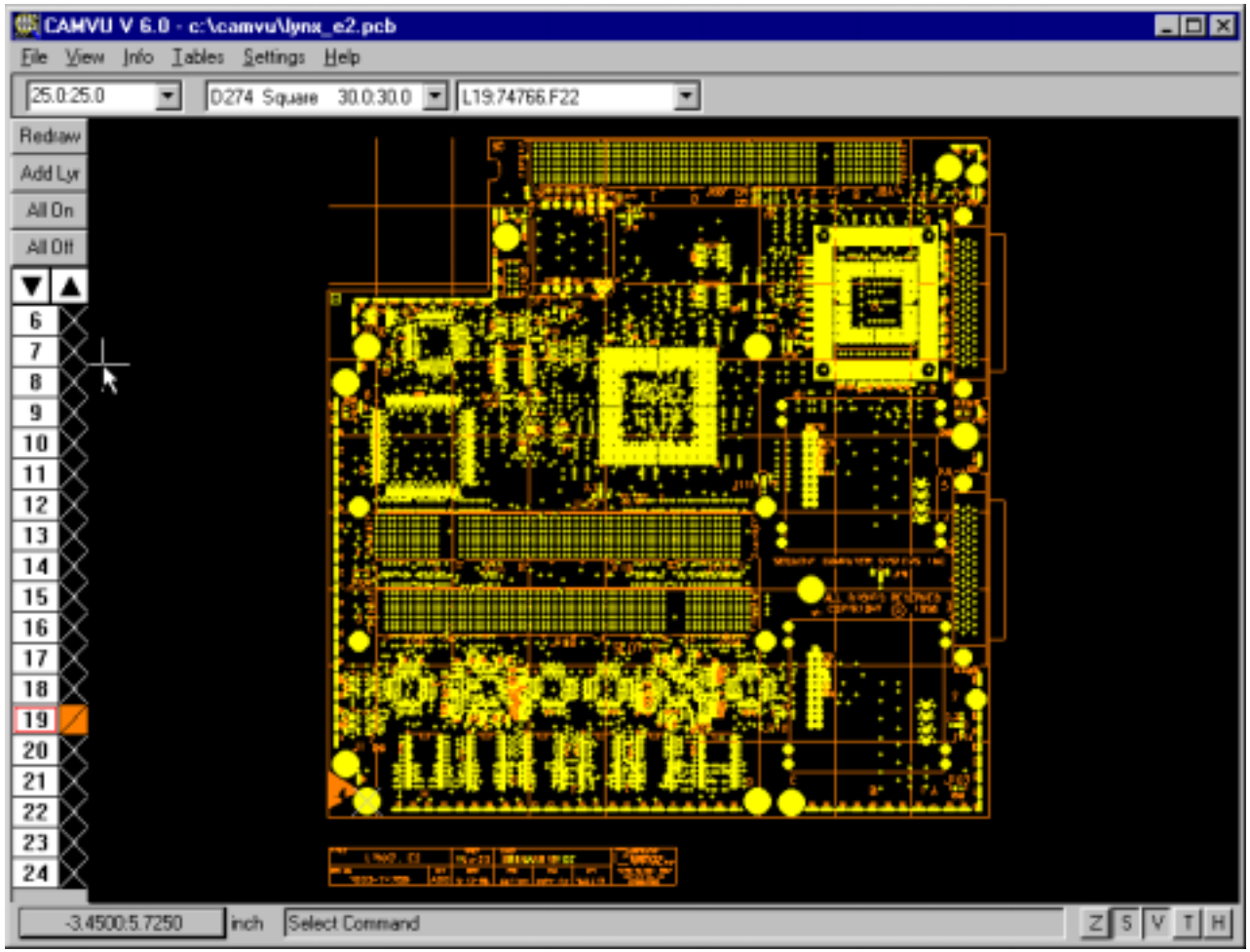
- Primary Side



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Scorpion LYNX2 PCB

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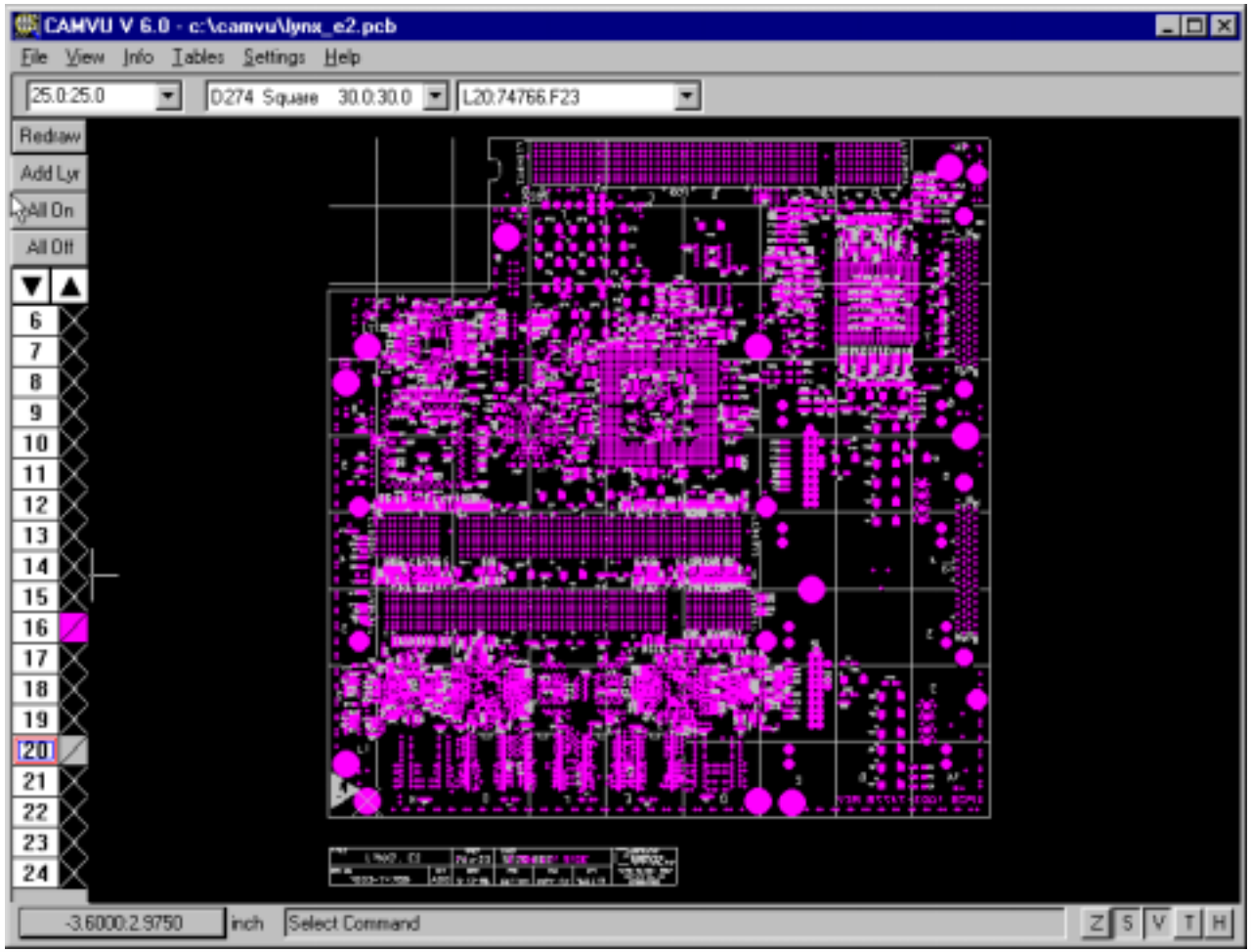
- Secondary Side



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47 Ohm Buried Resistor

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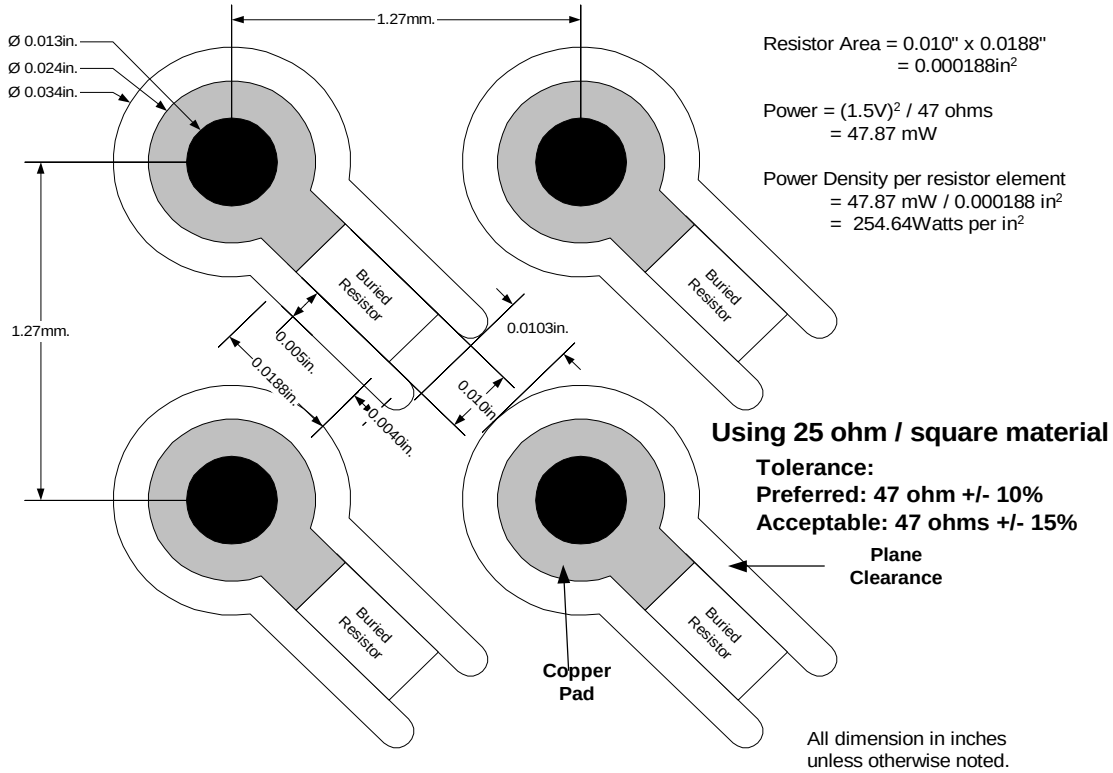

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100/100 Ohm Buried Resistor

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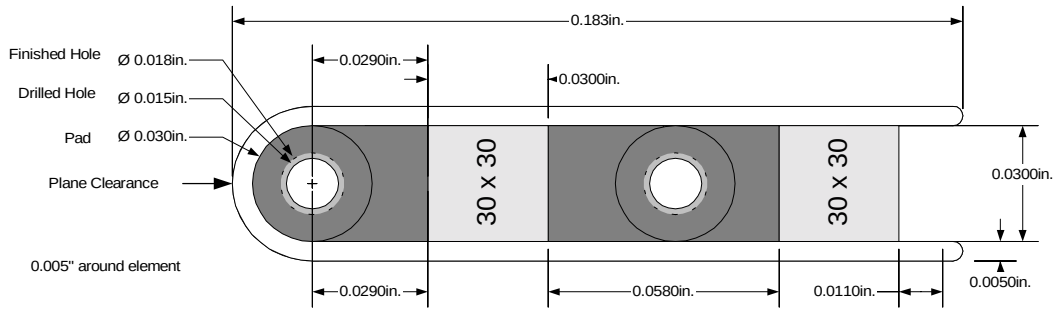
Tolerance:
Preferred: 100 ohm +/- 10%
Acceptable: 100 ohms +/- 15%

Using 100 ohm / square material



Resistor Area = 0.030" x 0.030"
= 0.0009 in^2

Power = $(1.8V)^2$ / 100 ohms
= 32.40 mW

Power Density per resistor element
= 32.40 mW / 0.0009 in^2
= 36 Watts per in^2

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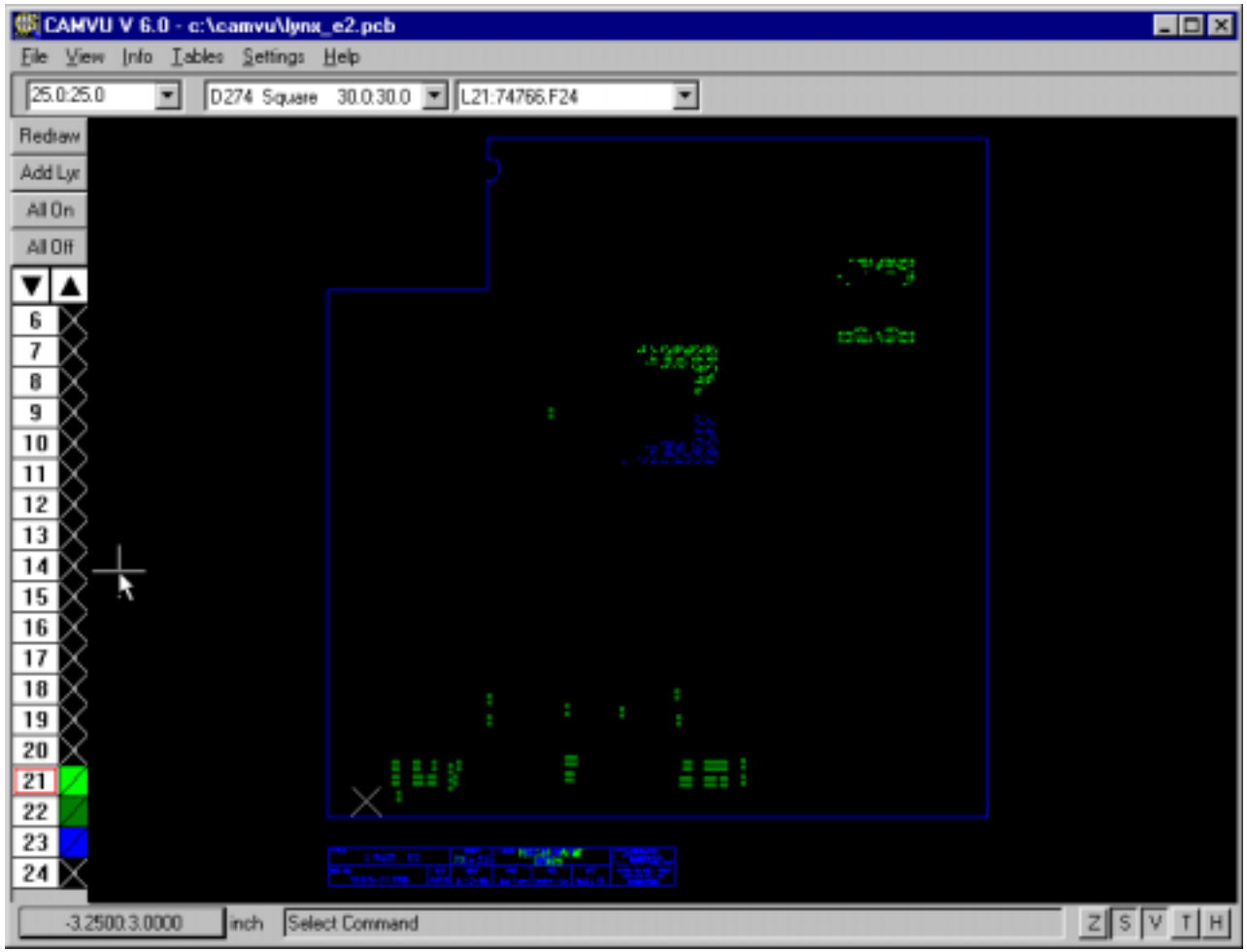
Scorpion LYNX2 PCB

- Buried Resistor Locations



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LYNX2 Cost Analysis

- **Assumptions**
  - **$200 per layer of Buried Resistor (BR)**
    - **Cost includes the following**
      - **Material**
      - **Processing**
      - **Test**
- **2 Layers of BR material @ $200 per layer**
  - 3 LYNX2 images per 18” x 24” panel
  - $400 ÷ 3 = $133.33 per PCB for BR Technology
  - 372 Buried Resistors per image
    - A total of 1116 Buried Resistors per panel
    - $400 ÷ 1116 = $0.3584 per Buried Resistor
- **Discrete resistor cost**
  - Part cost + Placement cost + Test & Repair cost
    - $0.01 + $0.10 + $0.01 = $0.12

Cost Reduction

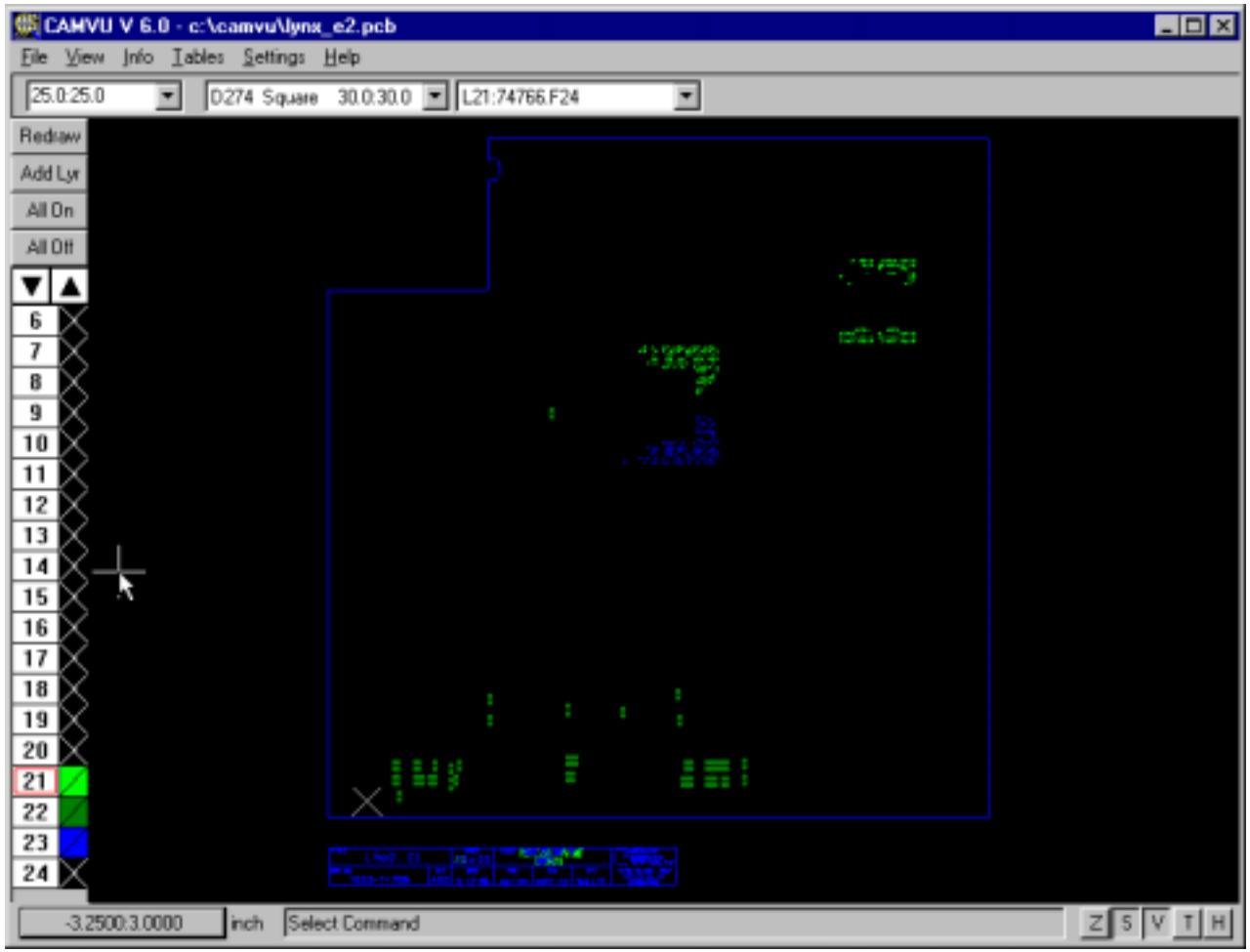
- **HOW TO……..**
  - **Take advantage of the benefits of BR Technology,**

And

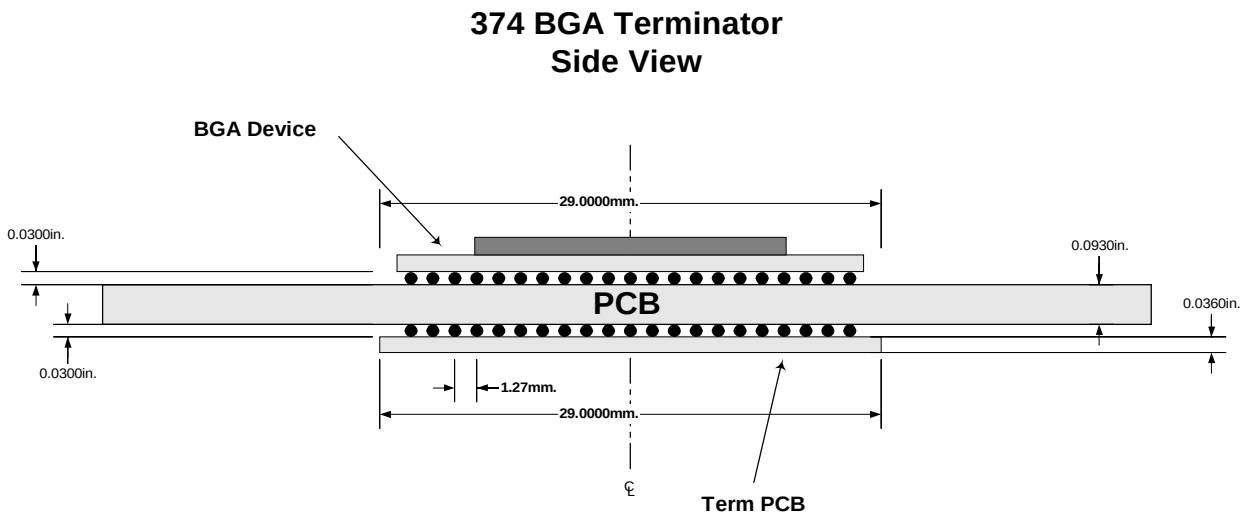
  - **Reduce cost.**

Scorpion LYNX2 PCB

- Buried Resistor Locations



"TERM" Board Concept



“TERM” Board Top View

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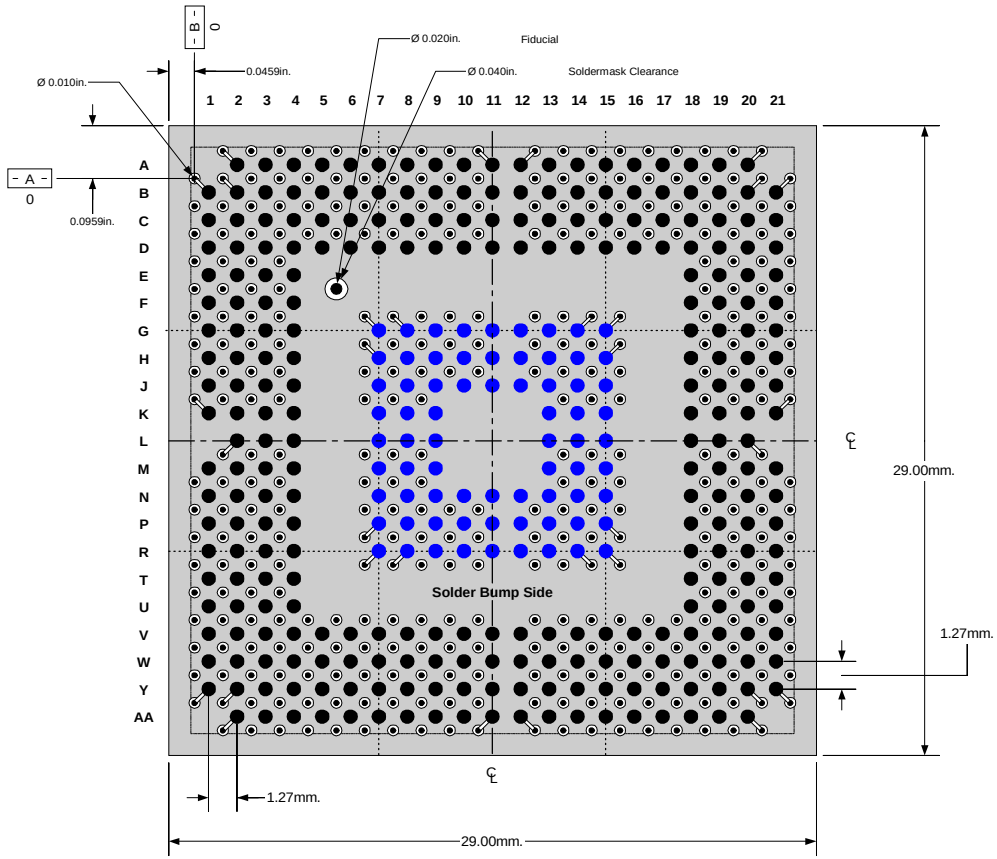

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“TERM” Board Stack-up

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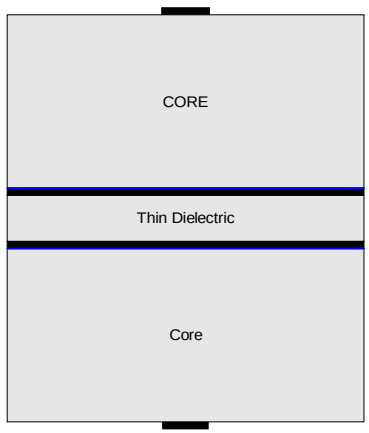
Layer		CU (mil)	Dielectric (mil)	TYPE	TRACE (mil)	Buried Resistor
1		0.6 > 1.7		SIG #1	8.0	
	CORE		15.0			330 OHM 100 OHM/SQ.
2		0.6		GROUND		
	Thin Dielectric		4.0			
3		0.6		VTERM		
	Core		15.0			65 & 75 OHM 25 OHM/SQ.
4		0.6 > 1.7		SIG #2	8.0	



BOARD THICKNESS = 0.0366 +/- 0.007 in. metal to metal

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Centurion Bus Topology

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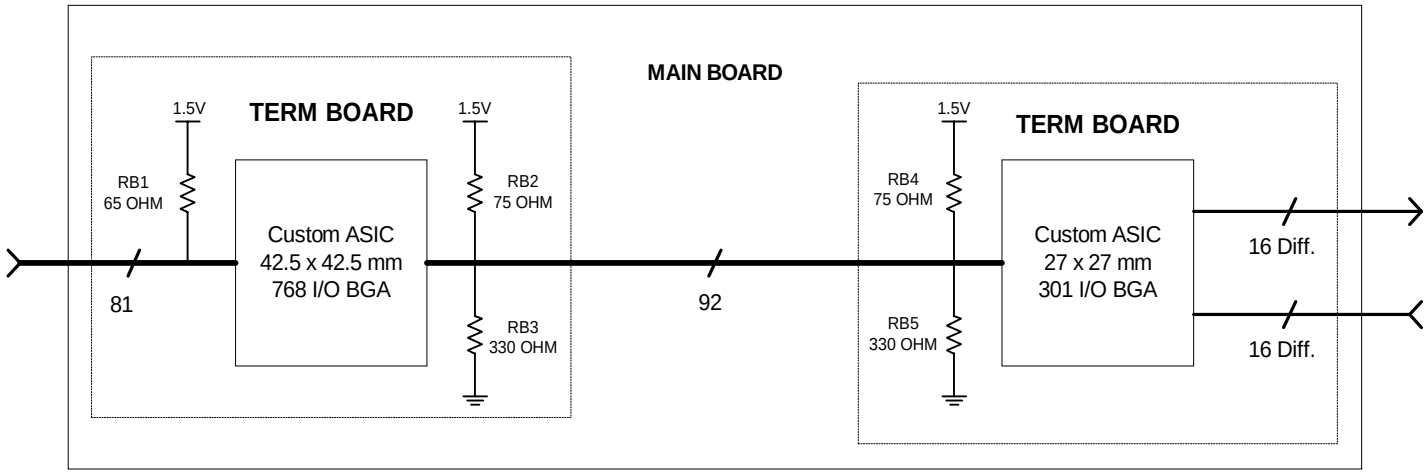
- Bus topology for Centurion Design



- Each CSCLIC TERM board contains 272 Buried Resistors
- Each DP TERM board contains 184 Buried Resistors

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CSCLIC Term Panelization

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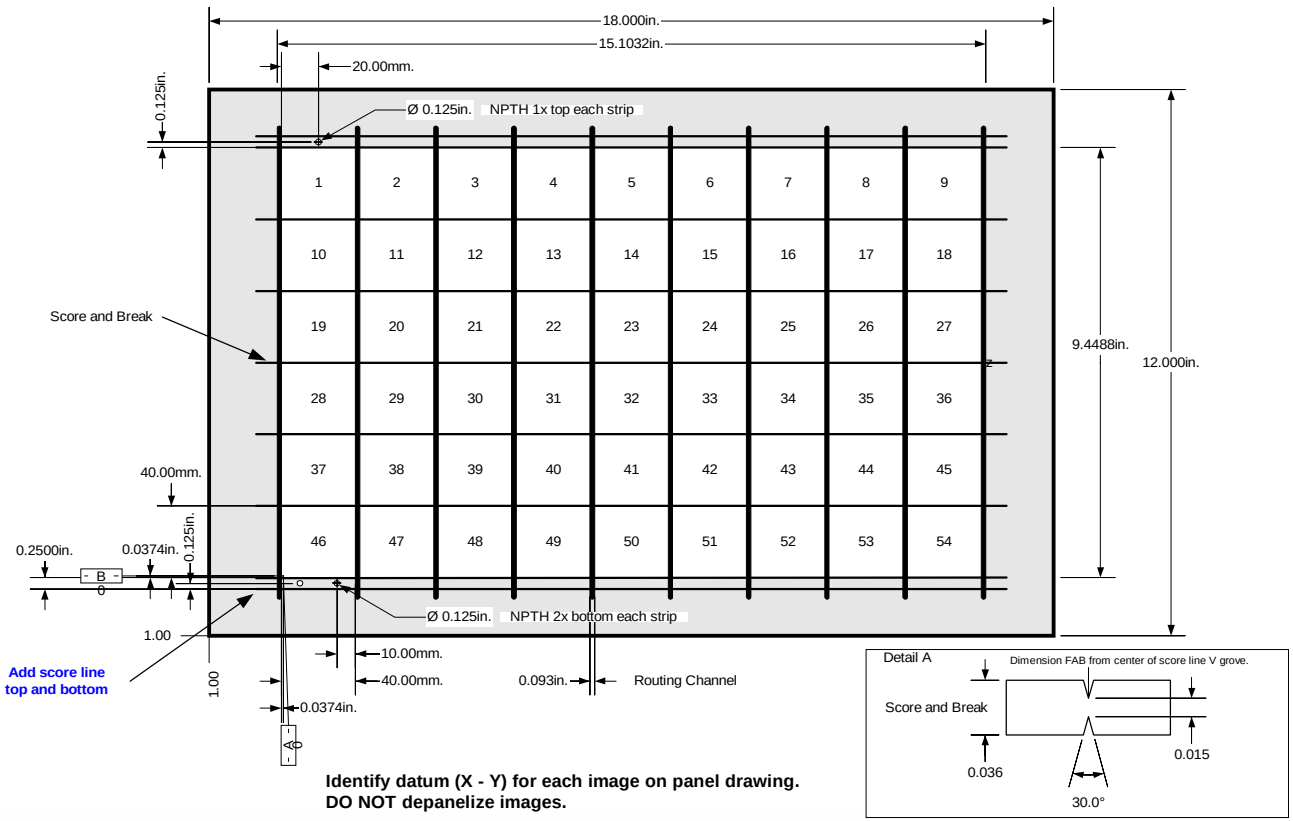
Centurion Term-CSCLIC Panelization



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DP Term Panelization

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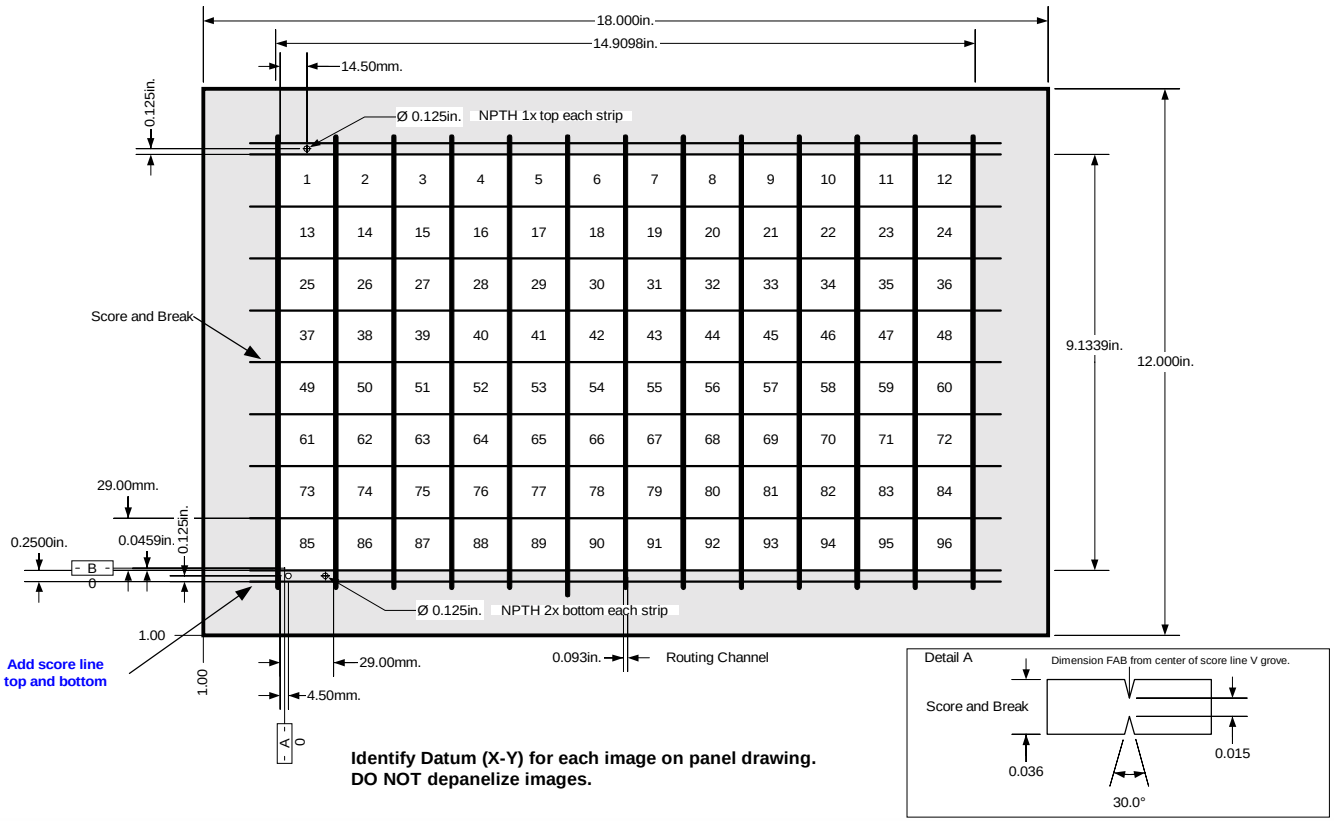
Centurion Term-DP Panelization



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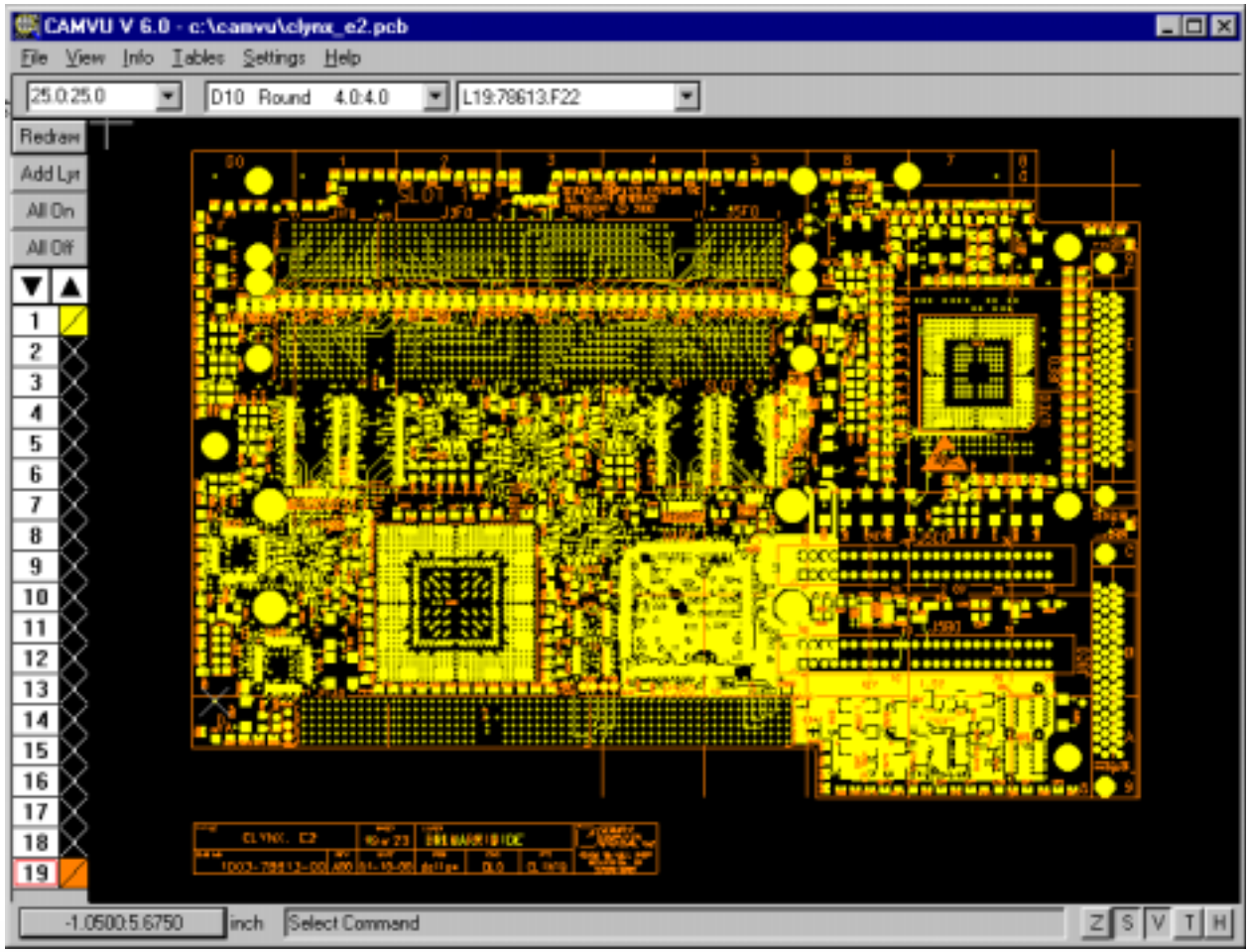
Centurion CLYNX PCB

- Primary Side



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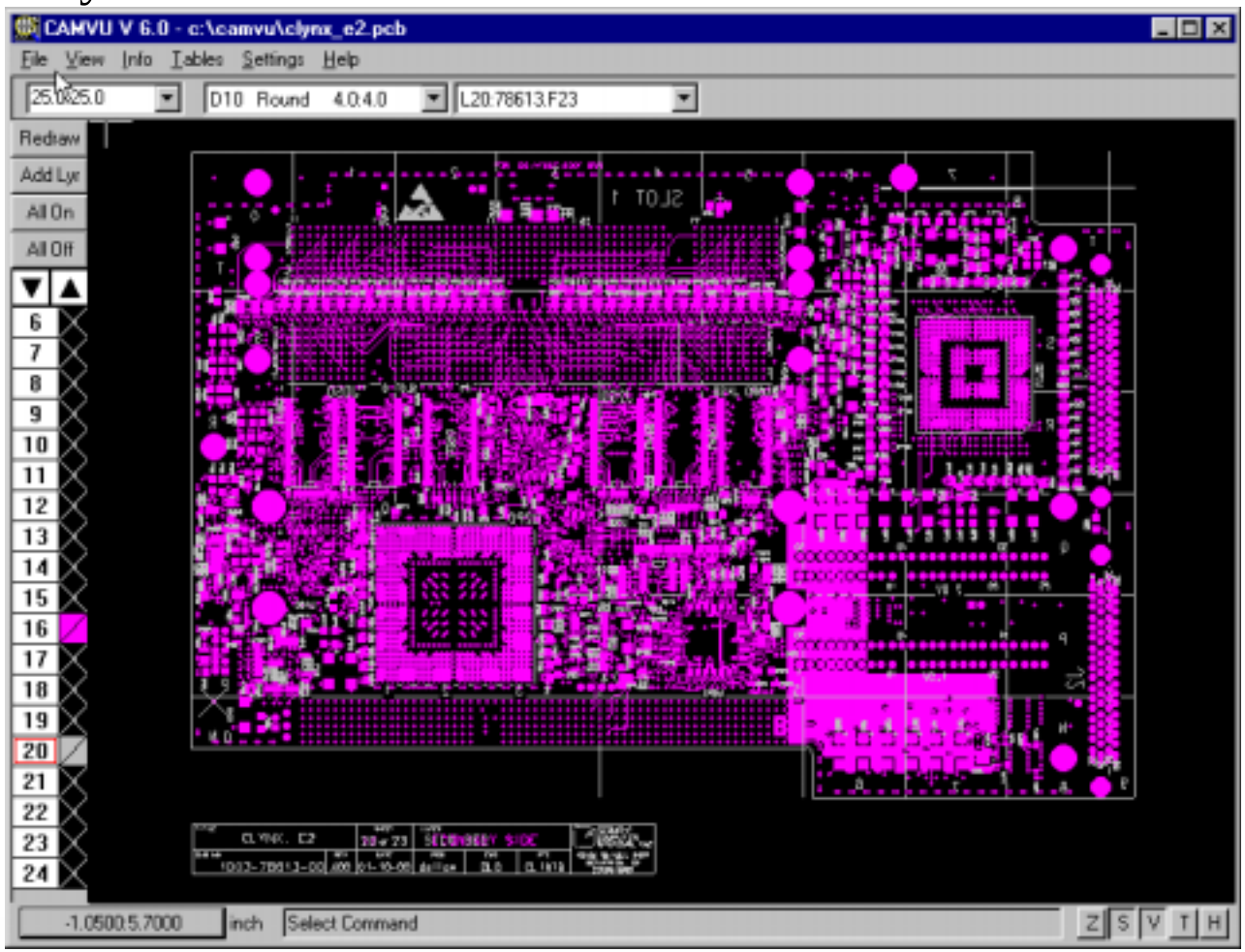
Centurion CLYNX PCB

- Secondary Side



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65 Ohm Buried Resistor

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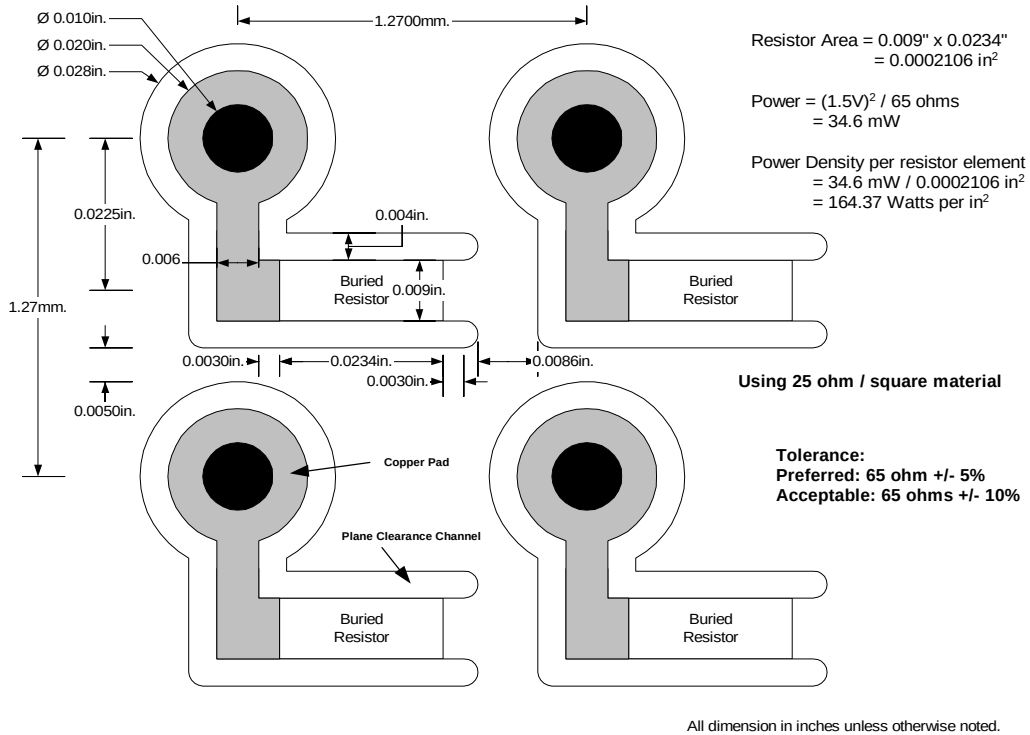

Resistor Area = 0.009" x 0.0234"
= 0.0002106 in^2

Power = $(1.5V)^2$ / 65 ohms
= 34.6 mW

Power Density per resistor element
= 34.6 mW / 0.0002106 in^2
= 164.37 Watts per in^2

Using 25 ohm / square material

Tolerance:
Preferred: 65 ohm +/- 5%
Acceptable: 65 ohms +/- 10%

All dimension in inches unless otherwise noted.

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75 Ohm Buried Resistor

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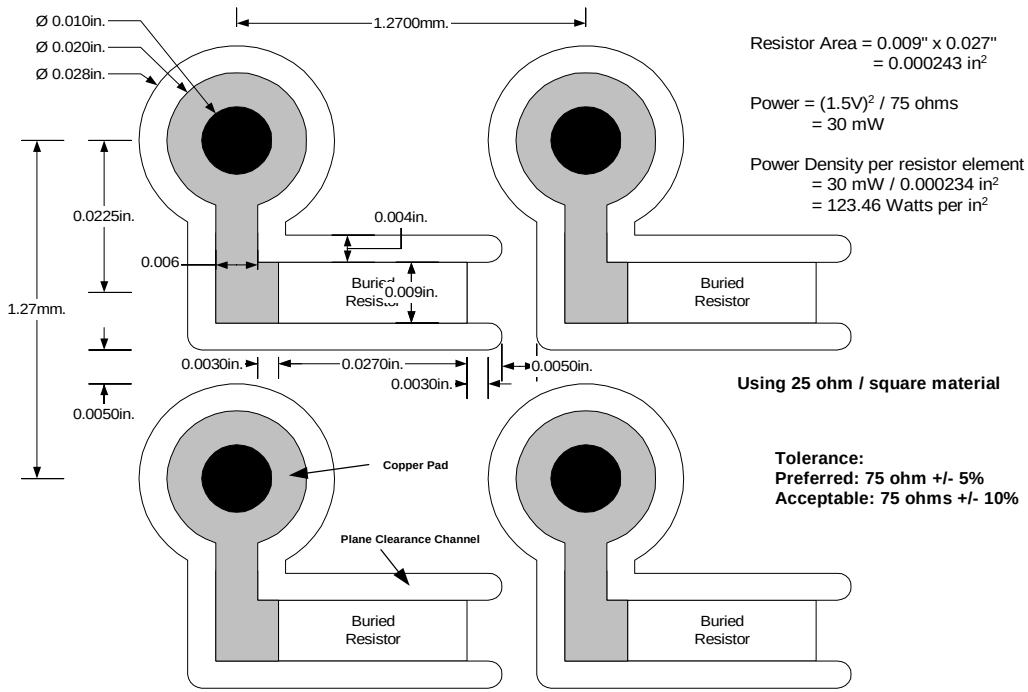

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330 Ohm Buried Resistor

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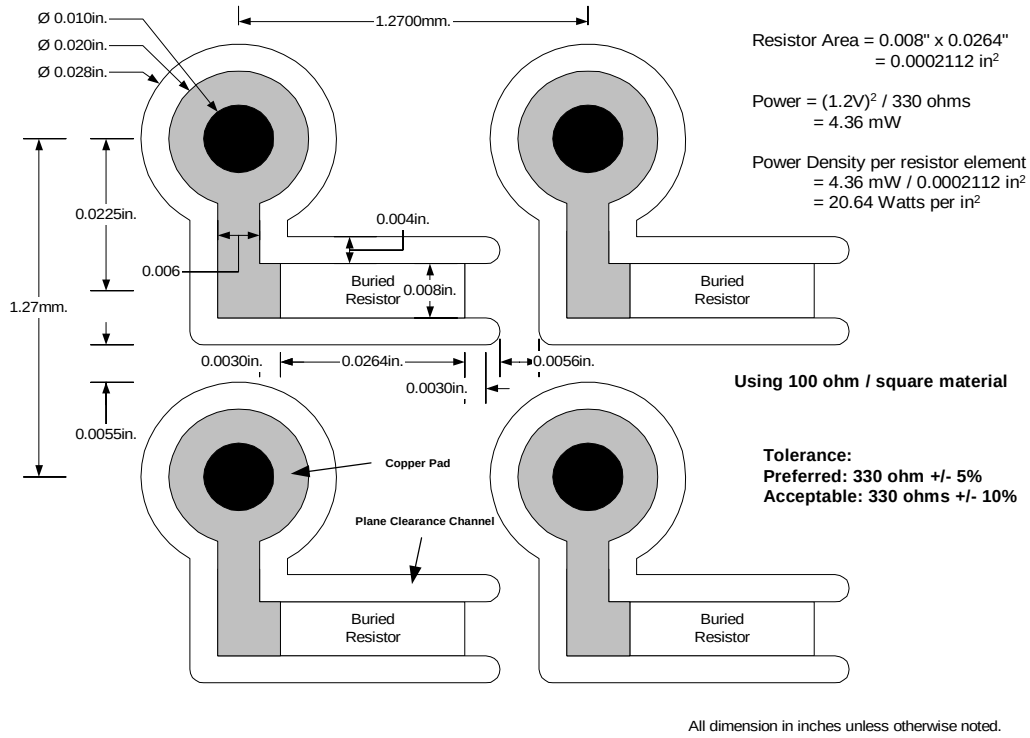

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Tolerance Chart

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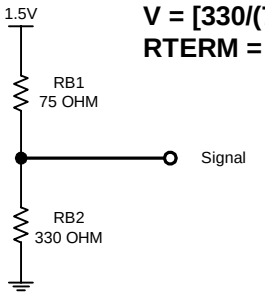
Resistor Ratio

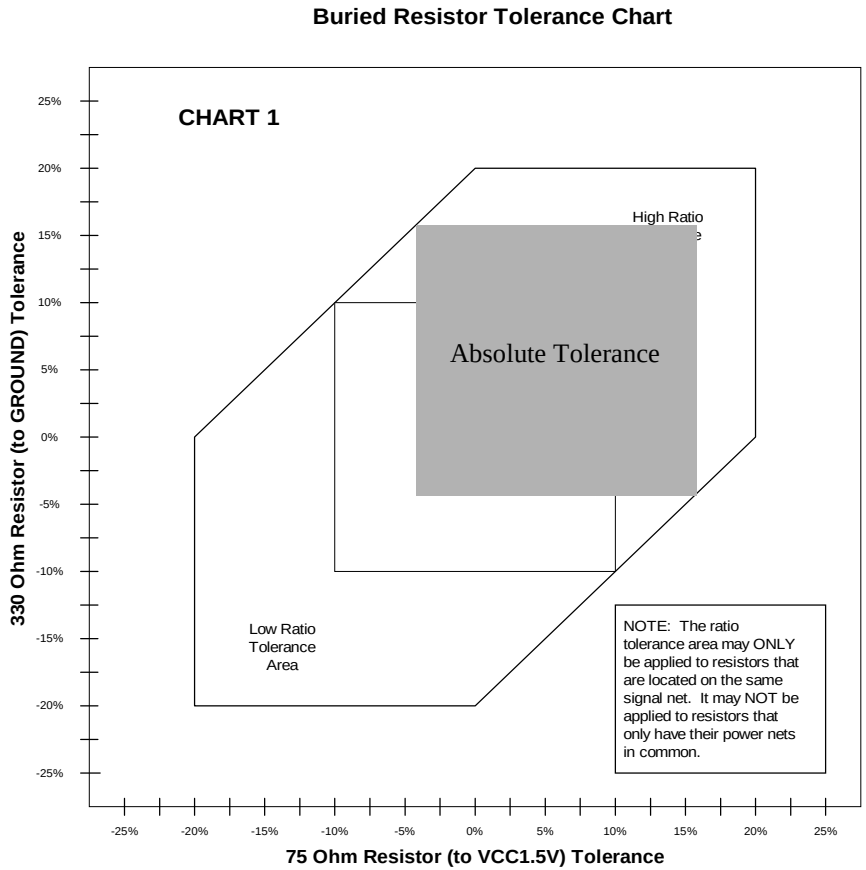


Nominal Termination Voltage and Zo
V = [330/(75 + 330)] * 1.5 = 1.22V
RTERM = (330 * 75)/(330 + 75) = 61.11 ohms

If RB1 = 86.25 ohms (+15%)
Then RB2 must be between 379.5 and 313.5 ohms (+15% and -5%)

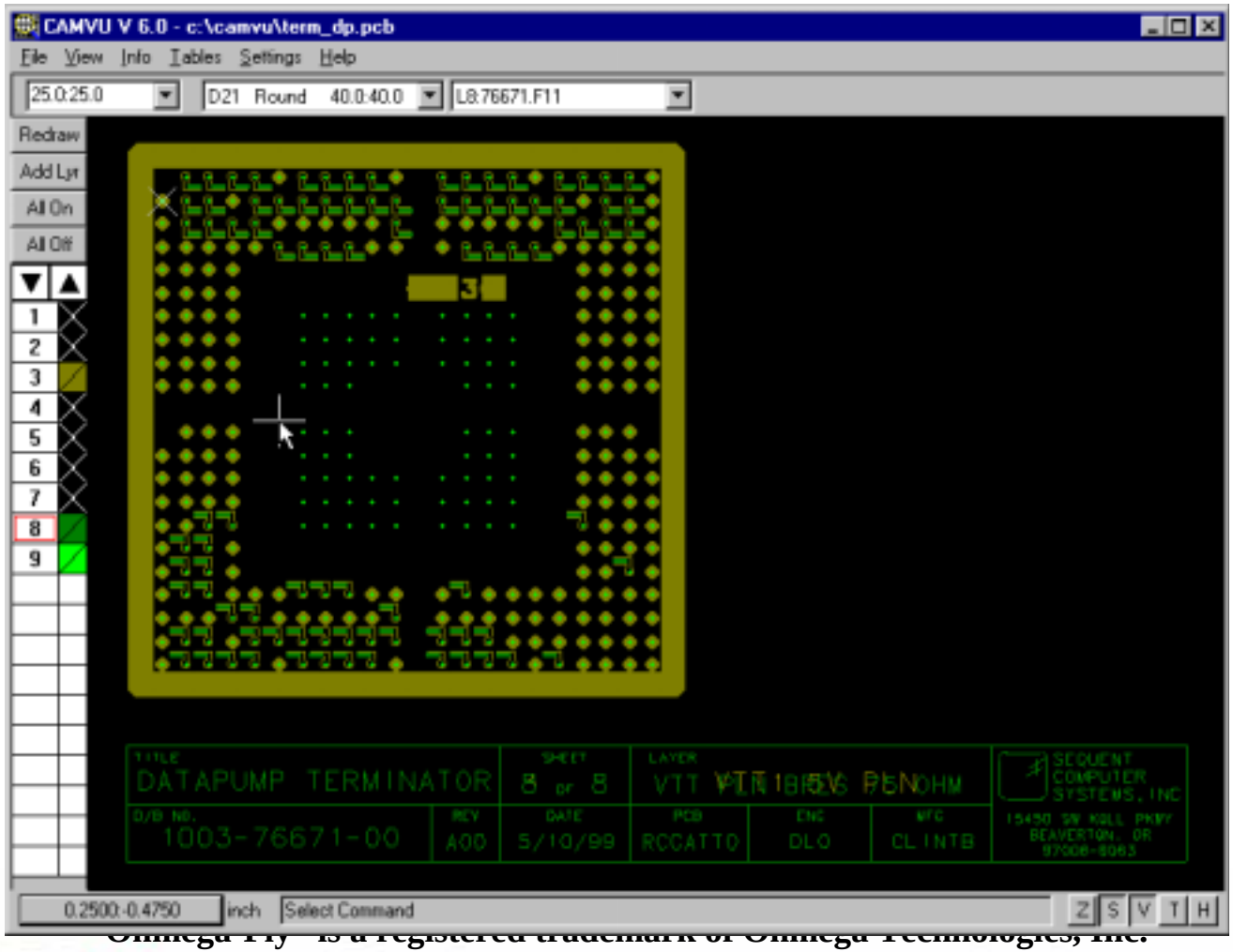
V = [379.5/(86.25 + 379.5)] * 1.5 = 1.22V (+15%)
RTERM = (379.5 * 86.25)/(379.5 + 86.25) = 70.28 ohms

V = [313.5/(86.25 + 313.5)] * 1.5 = 1.18V (-5%)
RTERM = (313.5 * 86.25)/(313.5 + 86.25) = 67.64 ohms



DP Term Gerber's

- 75 Ohm Buried Resistors (VTT)



DP Term Gerber's

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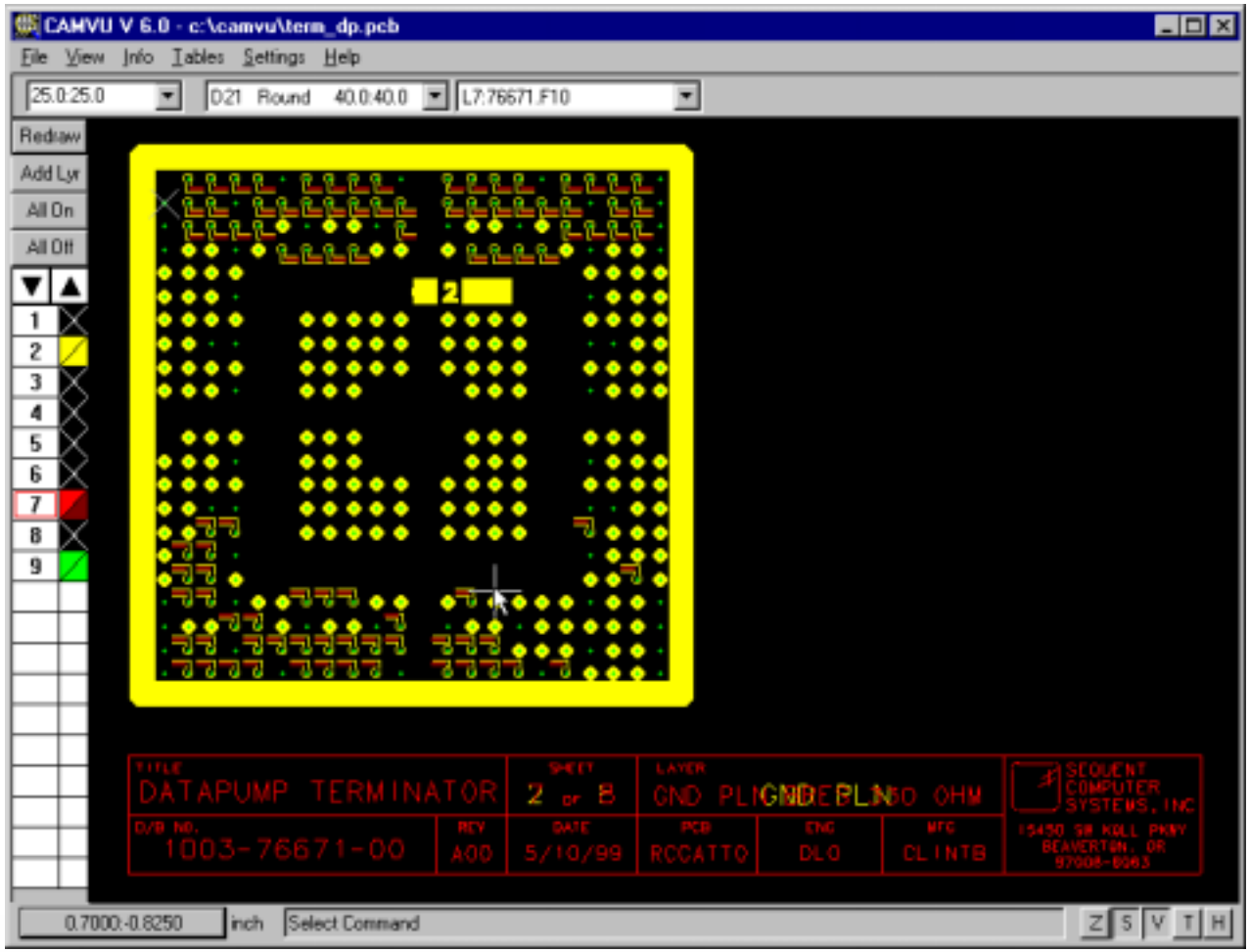
- 330 Ohm Buried Resistors



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CSCLIC Term Gerber's

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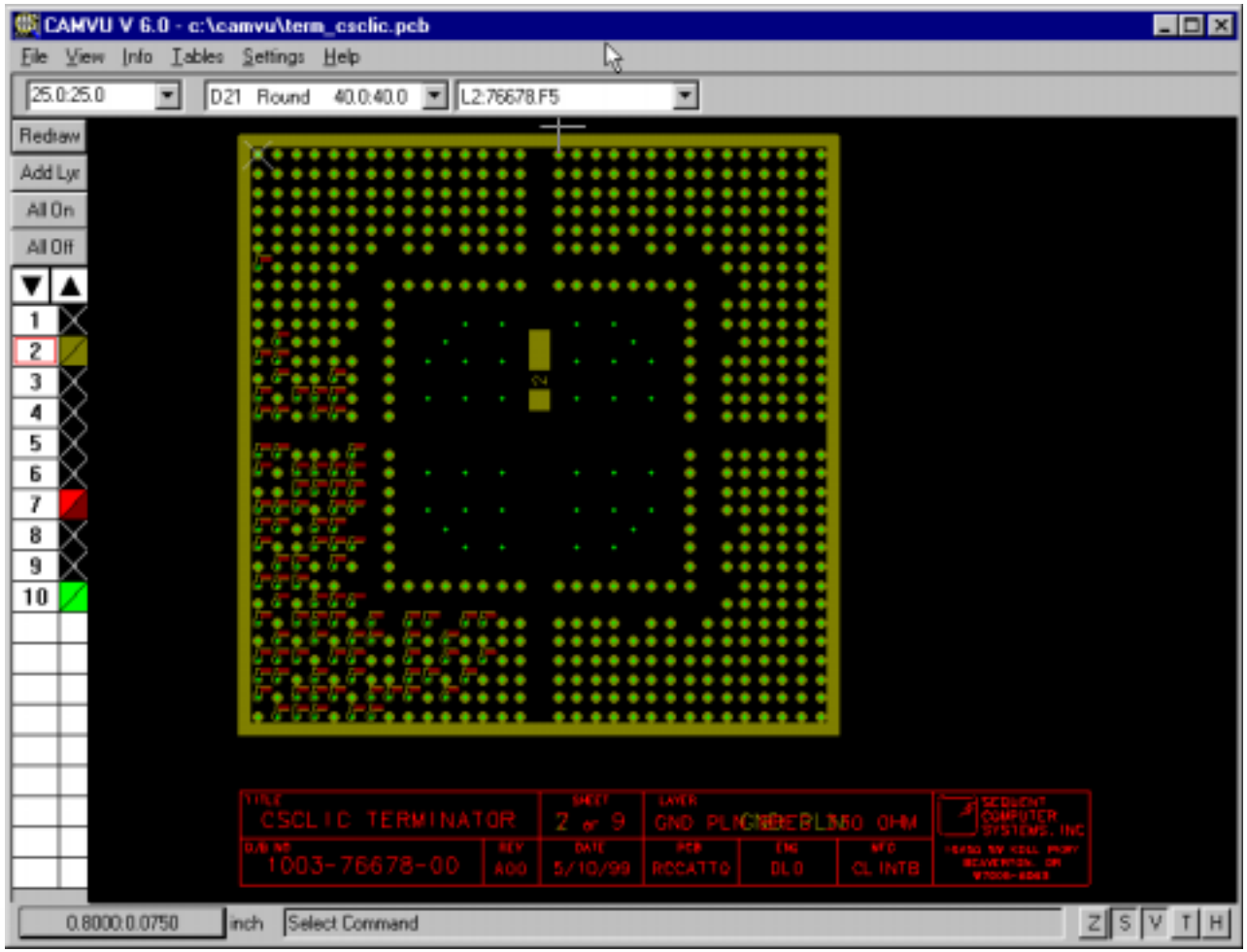
- 330 Ohm Buried Resistors



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CSCLIC Term Gerber's

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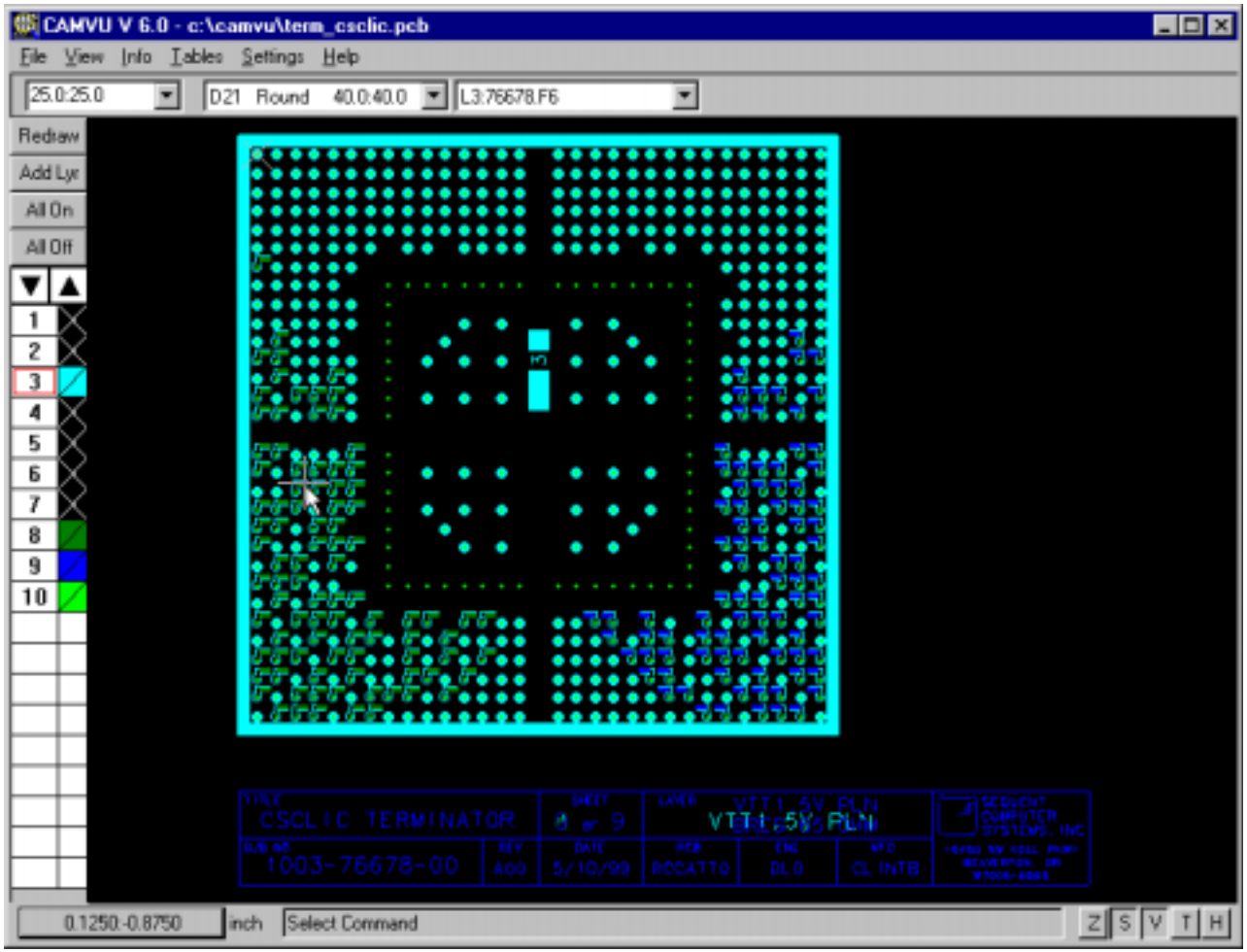
- 75 Ohm and 65 Ohm Buried Resistors



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Centurion CLYNX PCB

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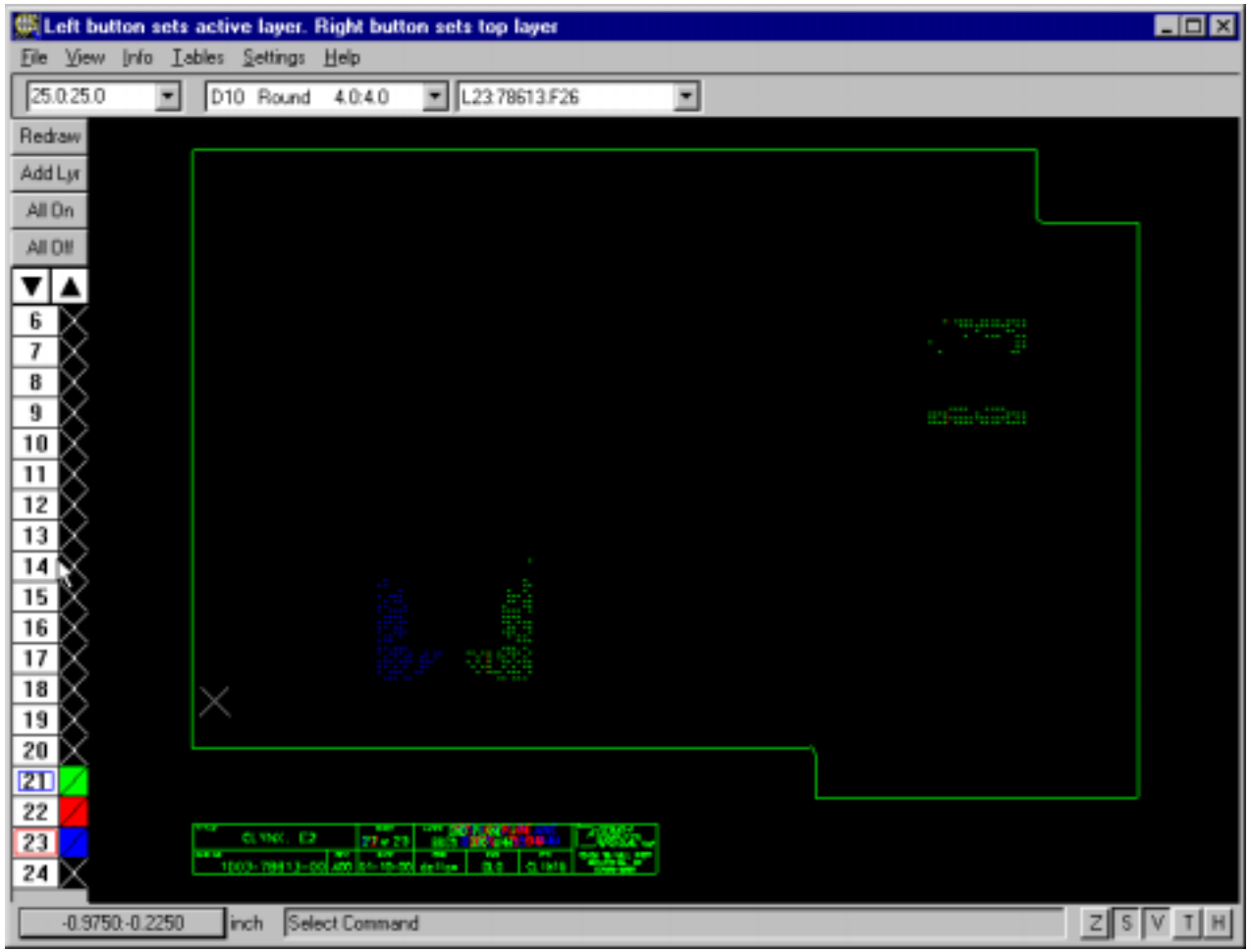
- Buried Resistor Locations



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CLYNX Cost Analysis

- **Assumptions**
  - **$200 per layer of Buried Resistor (BR)**
    - **Cost includes the following**
      - **Material**
      - **Processing**
      - **Test**
- **CSCLIC TERM Cost**
  - 108 CSCLIC TERM images per 18” x 24” panel (18 1x6 strips)
  - 272 Buried Resistors per CSCLIC TERM
    - A total of 29,376 Buried Resistors per panel
    - $400 ÷ 29,376 = $0.0136 per Buried Resistor
- **DP TERM Cost**
  - 192 DP TERM images per 18” x 24” panel (24 1x9 strips)
  - 184 Buried Resistor per DP TERM
    - A total of 35,328 Buried Resistors per panel
    - $400 ÷ 35,328 = $0.0113 per Buried Resistor

CLYNX Cost Analysis

- **Actual Costs Savings**
  - **Reduced Size of PCB**
    - **LYNX2 3 images per panel. Cost of FAB = $385.00**
    - **CLYNX 5 images per panel. Cost of FAB = $98.00**
    - **Cost Savings of $287.00**
  - **Actual Cost CSCLIC TERM**
    - Cost of FAB = $15.25
    - Cost of solder bumping process = $2.50
    - Total = $17.75
  - **Actual Cost DP TERM**
    - Cost of FAB = $10.05
    - Cost of solder bumping process = $2.50
    - Total = $12.55
- **Total Realized Cost Savings**
  - $385.00 - ($98.00 + $17.75 + $12.55) = $256.70

Acknowledgments

The author would like the thank the following individuals for their help in preparing and reviewing this presentation

Wally Doeling "W" Consulting

Bruce Mahler Ohmega Technologies, Inc.

[1]Implementation of Buried Resistor on PCB's

Wallace Doeling

"W" Consulting

1998 Automata International Technical Seminar