Applications Using Buried Resistor Technology

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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

Ohmega-Ply® is a registered trademark of Ohmega Technologies, Inc.
Component Size Comparison

- Discrete Resistor options vs. Buried 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

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Scorpion LYNX2 PCB

- Primary Side

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Scorpion Bus Topology

- Bus topology for Scorpion Design
Omega-Ply® Material

Resistive Material
Nickel Phosphorous

0.1 - 0.4 microns

0.0006in.

Core Laminate Material

Copper

0.005in. min.
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

- Primary Side
Scorpion LYNX2 PCB

- Secondary Side

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47 Ohm Buried Resistor

Resistor Area = 0.010" x 0.0188"
= 0.000188 in²

Power = (1.5V)² / 47 ohms
= 47.87 mW

Power Density per resistor element
= 47.87 mW / 0.000188 in²
= 254.64 Watts per in²

Using 25 ohm / square material

Tolerance:
Preferred: 47 ohm +/- 10%
Acceptable: 47 ohm +/- 15%

All dimensions in inches unless otherwise noted.

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100/100 Ohm Buried Resistor

Resistor Area = 0.030" x 0.030" = 0.0009 in²

Power = (1.8V)² / 100 ohms = 32.40 mW

Power Density per resistor element = 32.40 mW / 0.0009 in² = 36 Watts per in²

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

Using 100 ohm / square material
Scorpion LYNX2 PCB

- Buried Resistor Locations
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

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“TERM” Board Concept

374 BGA Terminator
Side View

BGA Device

PCB

Term PCB
**“TERM” Board Stack-up**

<table>
<thead>
<tr>
<th>Layer</th>
<th>CU (mil)</th>
<th>Dielectric (mil)</th>
<th>TYPE</th>
<th>TRACE (mil)</th>
<th>Buried Resistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6 &gt; 1.7</td>
<td>15.0</td>
<td>SIG #1</td>
<td>8.0</td>
<td>330 OHM 100 OHM/SQ.</td>
</tr>
<tr>
<td>2</td>
<td>0.6</td>
<td>4.0</td>
<td>GROUND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.6</td>
<td>15.0</td>
<td>VTERM</td>
<td></td>
<td>65 &amp; 75 OHM 25 OHM/SQ.</td>
</tr>
<tr>
<td>4</td>
<td>0.6 &gt; 1.7</td>
<td></td>
<td>SIG #2</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

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

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Centurion Bus Topology

- Bus topology for Centurion Design

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

Ohmega-Ply® is a registered trademark of Ohmega Technologies, Inc.
Identify datum (X - Y) for each image on panel drawing. DO NOT depanelize images.
Centurion Term-DP Panelization

Identify Datum (X-Y) for each image on panel drawing. DO NOT depanelize images.

Score and Break

Detail A

Dimension FAB from center of score line V groove.

Add score line top and bottom

Routing Channel

Score and Break

Dimension FAB from center of score line Y groove.
Centurion CLYNX PCB

- Primary Side

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Centurion CLYNX PCB

- Secondary Side

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65 Ohm Buried Resistor

Resistor Area = 0.009" x 0.0234" = 0.0002106 in²
Power = \( (1.5V)^2 / 65 \text{ ohms} \)
\( = 34.6 \text{ mW} \)
Power Density per resistor element
\( = 34.6 \text{ mW} / 0.0002106 \text{ in}^2 \)
\( = 164.37 \text{ Watts per in}^2 \)

Using 25 ohm / square material

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

All dimensions in inches unless otherwise noted.
75 Ohm Buried Resistor

Resistor Area = 0.009" x 0.027" = 0.000243 in²

Power = \((1.5V)^2 / 75\) ohms
= 30 mW

Power Density per resistor element = 30 mW / 0.000234 in²
= 123.46 Watts per in²

Using 25 ohm / square material

Tolerance:
Preferred: 75 ohm +/- 5%
Acceptable: 75 ohms +/- 10%

All dimensions in inches unless otherwise noted.

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330 Ohm Buried Resistor

Resistor Area = 0.008" x 0.0264" = 0.0002112 in²

Power = (1.2V)² / 330 ohms = 4.36 mW

Power Density per resistor element = 4.36 mW / 0.0002112 in² = 20.64 Watts per in²

Using 100 ohm / square material

Tolerance:
Preferred: 330 ohm +/- 5%
Acceptable: 330 ohms +/- 10%

All dimension in inches unless otherwise noted.
Resistor Ratio

Nominal Termination Voltage and Zo

\[ V = \frac{330}{(75 + 330)} \times 1.5 = 1.22V \]

\[ \text{RTERM} = \frac{330 \times 75}{330 + 75} = 61.11 \text{ ohms} \]

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

\[ V = \frac{379.5}{(86.25 + 379.5)} \times 1.5 = 1.22V (+15\%) \]

\[ \text{RTERM} = \frac{379.5 \times 86.25}{379.5 + 86.25} = 70.28 \text{ ohms} \]

\[ V = \frac{313.5}{(86.25 + 313.5)} \times 1.5 = 1.18V (-5\%) \]

\[ \text{RTERM} = \frac{313.5 \times 86.25}{313.5 + 86.25} = 67.64 \text{ ohms} \]

NOTE: The ratio tolerance area may ONLY be applied to resistors that are located on the same signal net. It may NOT be applied to resistors that only have their power nets in common.

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DP Term Gerber's

- 75 Ohm Buried Resistors (VTT)
DP Term Gerber's

- 330 Ohm Buried Resistors
CSCLIC Term Gerber's

- 330 Ohm Buried Resistors
CSCLIC Term Gerber's

- 75 Ohm and 65 Ohm Buried Resistors

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Centurion CLYNX PCB

- Buried Resistor Locations
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

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1Implementation of Buried Resistor on PCB’s
   Wallace Doeling
   “W” Consulting
   1998 Automata International Technical Seminar