Resonators,
Filters,
and Custom Ceramic Components

Disruptive Technologies for Spectrum Management

Dielectric Laboratories Inc.
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Cazenovia, New York, USA
13035-9433
Company Overview
Dielectric Laboratories Inc. (DLI) is your global partner for application specific microwave and millimeter-wave components serving customers in military, fiber optic, wireless, medical, transportation, semiconductor and avionics markets. With more than 30 years of experience, you can turn to DLI with confidence for your high frequency Single-Layer Capacitors, Multi-Layer Capacitors, Thin Film components, heat sinks, and custom microwave solutions.

DLI continues to introduce exciting new innovations in custom ceramic resonator and filter technologies. These new patent-protected products leverage decades of ceramic and thin film experience, creative and clever design expertise, and advanced prototyping and testing capabilities.

DLI is committed to serving you and thanks you for your business!

Quality and Environmental Policy
DLI's reputation for quality and environmental responsibility is based on a commitment to not only meet customer's requirements, but to exceed expectations. The entire organization, beginning with top management, strives to achieve excellence in designing, manufacturing and delivering capacitors and integrated thin film products for high frequency applications, while maintaining safe and healthy working conditions. Furthermore, DLI commits to achieve these goals in an environmentally responsible manner through our commitment to comply with environmental regulations and implement pollution prevention initiatives. DLI strives to continually improve the effectiveness of our Quality and Environmental Management Systems through the establishment and monitoring of objectives and targets.

DLI's quality system is certified to the ISO 9001:2000 international standards and its environmental system is certified to the ISO 14001:2000 international standards.

RoHS Compliance Statement
DLI is fully committed to offering products supporting Restriction of Hazardous Substances (RoHS) directive 2002/95/EC. All DLI dielectric formulations are RoHS compliant and the company offers a comprehensive range of ceramic components free of lead. DLI complies with the requirements of the individual customer and will maintain product offerings that meet the demand of our industry.

Premier Edition June 2005
Introduction
DLI has built its global reputation as a manufacturer of high frequency, high Q capacitors. In recent years, DLI has emerged as a comprehensive manufacturer of specialty ceramic components for high frequency applications. With over three decades of material science formulation and development, more than one hundred proprietary and/or patented ceramic formulations, and multiple recent patent filings, DLI is the pre-eminent ceramic component manufacturer in the industry. The marriage of ceramic expertise, manufacturing know-how, product quality, customer service, product customization, and clever microwave and RF design engineering sets us apart from all others in the industry. This product brochure will introduce you to the unique disruptive technologies that have become part of the new DLI.

What Makes DLI Unique?
DLI has leveraged its materials, processes and engineering capabilities to produce unique products to complement the imagination of the electronic and scientific communities. DLI has more than 100 proprietary ceramic formulations offering K values from as low as 4 to more than 40,000. DLI’s ceramic formulations can be used to custom match the Thermal Coefficient of Expansion (TCE) to the customer’s implementation.

To highlight how our engineers can design terrific new products for our customers, please consider just one of many core proprietary materials. Our ‘CF’ material has these features:

- Temperature stability of ±15 ppm/°C vs. typical Alumina which has a temperature stability of +120 ±30 ppm/°C; an 8x improvement.
- Miniaturization capabilities over typical Alumina or Printed Circuit board materials. Our CF offers a size reduction of 15x compared to PWB materials and more than 2x compared to Alumina.
- ‘CF’ does not exhibit signs of aging, having been used in our SLC and MLC Product Lines for decades.
- This material does not out-gas in a space environment because of the dense nature of the fired ceramic.

DLI gives its talented design engineers a broad set of proven materials on which to implement their revolutionary design ideas. **DLI redefines the envelope!**

DLI reserves the right to make changes in product designs and/or pricing. Sales are subject to DLI’s conditions of sale. DLI has no control over conditions of use; no warranty is made or implied as to suitability for customer’s intended use. DLI shall in no event be responsible for incidental or consequential damages including, without limitation, personal injury or property damage. Please refer to our website, www.dilabs.com, for the latest revision of this catalog.
DLI has introduced a family of patent pending high-Q temperature stable cavity resonators. They provide an ideal solution for high performance, low-cost microwave or millimeter-wave oscillators and filters. This component has integral shielding, controlled coupling and tight frequency tolerances. Devices are available in both surface mount technology (SMT) and wire-bond forms, enabling automated assembly. The unique features of this patent pending device reduce circuit size and weight and eliminate the expense of fully shielded housings, manual assembly and manual frequency tuning.

- Fully shielded
- Surface mountable or wire-bondable
- Q's up to 2000+
- Frequency ranges from 1 to > 67 GHz
- Excellent frequency stability vs. temperature
- High reliability thin film gold metallization
- Frequency tolerances as low as 0.1%

DLI's Cavity Resonators set a new standard for high Q resonator performance across a broad spectrum of frequencies. High Q resonators play a critical role in system noise performance, and employing this advantage is dramatically easier and less expensive than ever before. These products include extremely stable Single Frequency Cavity Resonators (SFCR), Wide-Band Tunable Ceramic Resonators, and Two-Port Resonators described in more detail on the following pages.

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Q Comparison of Various Resonator Technologies

![Q Comparison Graph](image-url)
### A Sample of Applications:

<table>
<thead>
<tr>
<th>Systems</th>
<th>Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>Microwave &amp; Millimeter-Wave Oscillators</td>
</tr>
<tr>
<td>RADAR</td>
<td>Fundamental Fixed Frequency Oscillators - Ultra-low Phase Noise</td>
</tr>
<tr>
<td>Ground-based</td>
<td><em>(former solution: expensive DRO’s and multiplied-up crystal or SAW based device with decreased performance)</em></td>
</tr>
<tr>
<td>Avionics/Missile</td>
<td></td>
</tr>
<tr>
<td>Shipboard</td>
<td></td>
</tr>
<tr>
<td>Communications</td>
<td>Narrow-Band Tunable VCO or Phase Locked Oscillators</td>
</tr>
<tr>
<td>Base Stations</td>
<td><em>(typically ± 0.3% tuning)</em></td>
</tr>
<tr>
<td>WLAN, WLL</td>
<td><em>(former solution: varactor tuned expensive DRO)</em></td>
</tr>
<tr>
<td>SONET/SDH</td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>Integration of high performance Oscillators directly</td>
</tr>
<tr>
<td>RFID</td>
<td>without the expense and complexity of subassemblies, housing and labor intensive operations typical of former solutions.</td>
</tr>
<tr>
<td>ECM/ECCM/EW</td>
<td></td>
</tr>
<tr>
<td>Tx/Rx</td>
<td></td>
</tr>
<tr>
<td>Man Pack Radio</td>
<td></td>
</tr>
<tr>
<td>Aerospace</td>
<td>Narrow bandwidth low loss filters</td>
</tr>
<tr>
<td>Aerospace</td>
<td><em>(former solution: low loss SAW devices with frequency limitation and poor performance)</em></td>
</tr>
<tr>
<td>Intelligent Munitions</td>
<td></td>
</tr>
</tbody>
</table>

### Comparison of a DLI 10 GHz Single Frequency Cavity Resonator (SFCR) With Competing Technologies

<table>
<thead>
<tr>
<th></th>
<th>DLI SFCR</th>
<th>DRO “Pack”</th>
<th>Ceramic</th>
<th>L-C</th>
<th>SAW</th>
<th>BAW</th>
<th>Microstrip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range (GHz)</td>
<td>1 – 67+</td>
<td>1 ~ 40</td>
<td>0.5 ~ 5</td>
<td>~0.3</td>
<td>0.1 ~ 3</td>
<td>1 ~ 10</td>
<td>0.5 ~ 100</td>
</tr>
<tr>
<td>Self Shielding</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>SMT Capable</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Difficult</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chip &amp; Wire Compatible</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Difficult</td>
<td>Contamination Sensitive</td>
<td>Contamination Sensitive</td>
<td>Yes</td>
</tr>
<tr>
<td>Q @ 2 GHz</td>
<td>→ 1500</td>
<td>→ 15000</td>
<td>~ 500</td>
<td>50–150</td>
<td>5~10000</td>
<td>1000–2000</td>
<td>100–200</td>
</tr>
</tbody>
</table>

**All data below is for a 10 GHz resonator**

<table>
<thead>
<tr>
<th></th>
<th>DLI SFCR</th>
<th>DRO “Pack”</th>
<th>Ceramic</th>
<th>L-C</th>
<th>SAW</th>
<th>BAW</th>
<th>Microstrip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>→ 2000</td>
<td>→ 10000</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>500 ~ 1000</td>
<td>100 ~ 300</td>
</tr>
<tr>
<td>X Size (inches)</td>
<td>0.17</td>
<td>1 (housing)</td>
<td>N/A</td>
<td>0.15</td>
<td>N/A</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Y</td>
<td>0.2</td>
<td>1 (housing)</td>
<td>N/A</td>
<td>0.15</td>
<td>N/A</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Z</td>
<td>0.06</td>
<td>0.5 (housing)</td>
<td>N/A</td>
<td>0.1</td>
<td>N/A</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Volume (in³)</td>
<td>2x10⁻³</td>
<td>0.5</td>
<td>N/A</td>
<td>~2x10⁻³</td>
<td>N/A</td>
<td>N/A</td>
<td>~2x10⁻³</td>
</tr>
</tbody>
</table>
The equivalent circuit of the Single Frequency Cavity Resonator (SFCR) near its lowest resonant frequency is shown at left. The lowest resonant mode is typically employed in oscillator and filter designs. The element values are shown for a 9.95 GHz SFCR. The resonant frequency is set by the parallel combination of \( C_p \) and \( L_p \), and the finite unloaded \( Q \) by \( R \). The series capacitance \( C_s \) connects the resonator \( L-C \) to the input pad, thus setting the coupling between the external circuit and the frequency controlling \( L-C \) resonator. The capacitance \( C_{sh} \) is a stray capacitance between the input pad and ground. All of these network elements have excellent repeatability providing tight control over resonant frequency, coupling and input impedance. The structure also provides an integrated DC blocking function, thus eliminating a tolerance sensitive element from the bill of materials. For wide bandwidth circuit modeling, S-Parameters are recommended. S-Parameters are available for downloading from our website (www.dilabs.com). The resonators are readily customized for frequency, coupling, \( Q \), tunability and assembly requirements. For additional information on custom solutions see pages 14-16.

The Graph below depicts typical Single Frequency Cavity Resonator frequency stability versus temperature for DLI standard dielectric materials.
The table above summarizes the characteristics of selected standard resonators, and below some selected simulations to illustrate the primary resonator design variables. The primary variables are frequency of resonance, cavity material dielectric constant, and length and width dimensions. The interaction of these variables is illustrated in the resonator size charts on the page 8. The loaded Q of the resonators is effected by the coupling coefficient (denoted in the tables in terms of return loss) and by material choice (dielectric constant), and by material thickness. Generally, resonators made from thick, low dielectric constant materials are capable of the highest loaded Q’s. For reference, when a resonator has a coupling coefficient of 1.0 it will exhibit an excellent return loss at the resonance frequency and the unloaded Q of the resonator will be 2 times the loaded Q value. The desired level of resonator coupling varies with individual circuit requirements such as varactor frequency trimming, or transistor negative resistance value. Resonator input impedance versus frequency and coupling level are illustrated in the Smith Chart on page 16. The unloaded Q’s of the cases shown range up to nearly 2000, clearly a new performance standard for a component compatible with automated assembly. In contrast to other “high Q” microwave resonators, DLI’s cavity resonator is completely self contained, that is its loaded Q and resonant frequency can be directly measured using RF coplanar probe technology. Thus, ambiguities of special test fixtures and components which are not appropriate to the product realization are eliminated from part evaluation.

### Measured Data from Selected Standard Resonators

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* Typical (ppm/°C)</th>
<th>Return Loss @ Resonance Typical (dB)</th>
<th>Loaded Q Typical (50 Ohms)</th>
<th>Dimensions L x W x T</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.20</td>
<td>CF Material: -2.3</td>
<td>-25</td>
<td>250</td>
<td>5.3 x 5.3 x 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.21 x 0.21 x 0.03</td>
</tr>
<tr>
<td>9.95</td>
<td>CF Material: -2.3</td>
<td>-11</td>
<td>300</td>
<td>5.6 x 4.3 x 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.22 x 0.17 x 0.03</td>
</tr>
<tr>
<td>12.80</td>
<td>CF Material: -2.3</td>
<td>-7</td>
<td>350</td>
<td>3.8 x 3.6 x 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15 x 0.14 x 0.03</td>
</tr>
<tr>
<td>18.65</td>
<td>FS Material: -7.3</td>
<td>-25</td>
<td>400</td>
<td>6.1 x 5.6 x 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.24 x 0.22 x 0.04</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C

### Simulated Data for Selected Resonators

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* Typical (ppm/°C)</th>
<th>Return Loss @ Resonance Modeled (dB)</th>
<th>Loaded Q Modeled (50 Ohms)</th>
<th>Dimensions L x W x T</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>CG Material: 8.8</td>
<td>-22</td>
<td>290</td>
<td>8.1 x 8.1 x 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.32 x 0.32 x 0.12</td>
</tr>
<tr>
<td>5.0</td>
<td>CF Material: -2.3</td>
<td>-12</td>
<td>550</td>
<td>8.1 x 8.1 x 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.36 x 0.36 x 0.12</td>
</tr>
<tr>
<td></td>
<td>CG Material: 8.8</td>
<td>-12</td>
<td>360</td>
<td>5.1 x 5.1 x 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.20 x 0.20 x 0.12</td>
</tr>
<tr>
<td></td>
<td>FS Material: -7.3</td>
<td>-12</td>
<td>1000</td>
<td>21.8 x 21.8 x 3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.86 x 0.86 x 0.15</td>
</tr>
<tr>
<td>24.0</td>
<td>CF Material: -2.3</td>
<td>-12</td>
<td>480</td>
<td>2.0 x 2.0 x 1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.08 x 0.08 x 0.05</td>
</tr>
<tr>
<td></td>
<td>FS Material: -7.3</td>
<td>-12</td>
<td>1000</td>
<td>4.6 x 4.6 x 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.18 x 0.18 x 0.12</td>
</tr>
<tr>
<td>26.5</td>
<td>FS Material: -7.3</td>
<td>-20</td>
<td>325</td>
<td>4.2 x 4.2 x 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.16 x 0.16 x 0.02</td>
</tr>
<tr>
<td>40.0</td>
<td>FS Material: -7.3</td>
<td>-18</td>
<td>445</td>
<td>2.7 x 2.7 x 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10 x 0.10 x 0.02</td>
</tr>
<tr>
<td>50.0</td>
<td>FS Material: -7.3</td>
<td>-17</td>
<td>400</td>
<td>2.2 x 2.2 x 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.08 x 0.08 x 0.02</td>
</tr>
<tr>
<td>67.0</td>
<td>FS Material: -7.3</td>
<td>-12</td>
<td>600</td>
<td>1.6 x 1.6 x 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.06 x 0.06 x 0.04</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C
**Estimating Resonator Size**

The size of the Cavity Resonator is determined by the desired resonant frequency and the ceramic material selected. Generally, for a given frequency resonator, selecting material types which result in larger part size also result in higher Q resonators. Increased resonator height also enhances Q. For additional information consult the factory.

The charts on this page should be used as a guide for selecting the ceramic materials to be used and to closely estimate the resonator length dimension for a square device. Typical designs are nominally rectangular, with length to width aspect ratios of less than 1.2:1.

In Oscillators, the most important factor effecting phase noise performance is high resonator loaded Q. High Q is evidenced in the following graph by rapid phase slope (versus frequency) and in the narrow bandwidth of the input reflection coefficient data on pages 10-13.
Mounting Alternatives

The metallized Cavity Resonator offers unique miniaturization opportunities. Shown is an implementation where the active device and power supply bypass capacitors are assembled onto the resonator. The wirebond signal leads are kept short.

### Resonator Mounting, Interconnection and Metallization Schemes

<table>
<thead>
<tr>
<th>Mounting Code</th>
<th>Component to Circuit Interface</th>
<th>Backside Metallization</th>
<th>Topside Metallization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Mount</td>
<td>S</td>
<td>Solder - Sn/Pb or Sn [Lead free] Or Conductive Epoxy</td>
<td>Nickel/Gold</td>
</tr>
<tr>
<td>Microstrip Mount</td>
<td>W</td>
<td>Conductive Epoxy</td>
<td>Gold</td>
</tr>
<tr>
<td>Input/Output Interconnect</td>
<td>Thermocompression Wirebond</td>
<td>-</td>
<td>Gold</td>
</tr>
</tbody>
</table>

For more information on metallization codes, see page 19.

This illustration demonstrates a surface mounting technique. The first resonator is positioned with the I/O pad in view to demonstrate the alignment with the printed wire board geometry. The second illustration shows the resonator mounted in position. The third illustration shows the printed wire board geometry. A solder mask is used to control the flow of solder during assembly and insulate the input-line from shorting to the resonator ground metallization.
8.2 GHz Cavity Resonator

**Specifications**

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* Typical (ppm/°C)</th>
<th>Return Loss @ Resonance Typical (dB)</th>
<th>Loaded Q Typical (50 Ohms)</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.20</td>
<td>CF Material: - 2.3</td>
<td>-25</td>
<td>250</td>
<td>5.3 x 5.3 x 0.8</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C
9.95 GHz Cavity Resonator

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* (ppm/°C)</th>
<th>Return Loss @ Resonance Typical (dB)</th>
<th>Loaded Q Typical (50 Ohms)</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.95</td>
<td>CF Material: - 2.3</td>
<td>-11</td>
<td>300</td>
<td>5.6 x 4.3 x 0.8</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C
**Single Frequency Cavity Resonator**

**12.8 GHz, Cavity Resonator**

![Graph](image)

**Table**

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* Typical (ppm/°C)</th>
<th>Return Loss @ Resonance Typical (dB)</th>
<th>Loaded Q Typical (50 Ohms)</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.80</td>
<td>CF Material: - 2.3</td>
<td>-7</td>
<td>350</td>
<td>3.8 x 3.6 x 0.8</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C
18.65 GHz Cavity Resonator

<table>
<thead>
<tr>
<th>Resonant Frequency (GHz)</th>
<th>Temperature Coefficient of Frequency* Typical (ppm/°C)</th>
<th>Return Loss @ Resonance Typical (dB)</th>
<th>Loaded Q Typical (50 Ohms)</th>
<th>Dimensions mm</th>
<th>inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.65</td>
<td>FS Material: -7.3</td>
<td>&lt; -25</td>
<td>400</td>
<td>6.1 x 5.6 x 1</td>
<td>0.24 x 0.22 x 0.04</td>
</tr>
</tbody>
</table>

* over the range -20°C to +120°C
**Narrow-Band Varactor Tuning of Cavity Resonators**

Consider a ceramic cavity resonator for your next oscillator design. The inherent stability of ceramic offers excellent long term aging performance and temperature stability. High loaded Q’s promise excellent phase noise performance.

The use of a 2-port resonator for voltage controlled oscillator applications is represented by the loop model of the oscillator above. Frequency adjustment or modulation is easily accomplished by the introduction of the voltage variable phase shifter. Typical broadband resonator performance and the amplitude (solid) and phase (dotted) variation of the 2-port resonator over the 3 dB bandwidth are illustrated to the left.

The inherently shielded nature of the ceramic resonator, its small size, and ease of mounting present many interesting miniaturization possibilities.
A wideband VCO at microwave frequencies can be challenging to design for good phase noise. The relatively poor varactor Q degrades the loaded Q of the resonant circuit, an effect which increases with tuning range, thus degrading phase noise. To achieve the best phase noise from the oscillator, the resonator and coupling capacitors must be high Q, temperature stable and have tight tolerance. This minimizes excess tuning range and maximizes loaded Q.

DLI's Wide-Band Tunable Resonator, illustrated in the see-through 3-D graphic below, is a precision surface mounted thin film microstrip resonator with integrated coupling capacitors. DLI's proprietary ultra-stable, Hi-Q, Hi-K ceramics are employed to provide optimum performance in a miniature size. A simplified oscillator circuit incorporating the Wide-Band Tunable Resonator with integrated coupling capacitors Cs1 and Cs2 is shown above.

In contrast, current designs frequently employ discrete resonators and surface mount capacitor chips (MLC) to provide the coupling capacitances. The tolerances of these discrete parts cause significant variations in VCO unit to unit performance. The MLCs have lower Q's and larger, undesirable parasitic inductance than DLI's integrated thin film coupling capacitors. The lower parasitic effects of the DLI thin film integrated design reduce spurious oscillations, improve tuning characteristics and can enable higher frequency operation.
Designing a Custom Resonator

Custom Resonator Design
Design inputs:
1. Resonant Frequency, Fr
2. One port Resonator:
   Desired Return Loss (dB) at the resonant frequency (see Smith chart below)
3. Loaded Q objective
4. Case size restrictions
5. Mounting:
   A. SMT
   B. Epoxy & Wirebond
6. Two port Resonator: Maximum insertion loss at resonance

One Port Resonator:
- Return Loss (dB) at resonant frequency
- 50 ohm system
- Desired Loaded Q

Two Port Resonator:
- Maximum Insertion Loss at resonance
- QL
- Two Port QL = BW3dB/Fr

Frequency Response
(Return Loss versus Frequency)

With the impedance locus circle greater than 0.5, the return loss at resonance is reduced and greater tuning of resonant frequency with external elements is possible.

With the impedance locus circle equal to 0.5, the resonator will exhibit excellent return loss at resonance.

With the impedance locus circle less than 0.5, the return loss at resonance is reduced and the effect of external circuitry on resonant frequency is reduced.

<table>
<thead>
<tr>
<th>Case Size (inches)</th>
<th>Preferred (X.Y.Z):</th>
<th>Maximum Length:</th>
<th>Maximum Width:</th>
<th>Maximum Thickness:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fr Resonance Frequency (GHz)</td>
<td>Fr=</td>
<td>Tolerance _____%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Port Resonator:</td>
<td>Return Loss (dB)</td>
<td>RL= Nominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ resonant frequency, 50 ohm system</td>
<td>$\Gamma c &lt; 0.5$</td>
<td>$\Gamma c = 0.5$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desired Loaded Q</td>
<td>QL= Two Port QL = BW3dB/Fr=</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Port Resonator:</td>
<td>Maximum Insertion Loss at resonance</td>
<td>Loss, maximum=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency stability Operating Temperature range (°C)</td>
<td>$\Delta Fr/\Delta T= $ ppm/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Temperature:</td>
<td>Maximum Temperature:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly (SMT or Epoxy)</td>
<td>Conductive Epoxy attach</td>
<td>Solder attach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wire/ribbon bond</td>
<td>Solder type</td>
<td>Max. Process Temp. °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board Material</td>
<td>Material</td>
<td>Dielectric constant</td>
<td>Thickness</td>
<td></td>
</tr>
</tbody>
</table>
**Self Bias Network**

For self biased MIC GaAs Fet amplifiers, this device integrates source decoupling and user selectable bias resistance

### Functional Applications
- Wireless communication modules
- MIC broadband high gain RF/Microwave modules
- Bias line voltage divider and integrated decoupling capacitor

### Benefits
- Improves gain flatness and stability in GaAs FET amplifiers
- Simplifies assembly with one component
- Miniature size:.020” x .034” (.5mm x .86mm)

### Physical Characteristics

![Physical Characteristics Diagram]

### Equivalent Schematic Representation

![Equivalent Schematic Diagram]

### Resistor Values:
- R1 - 200Ω
- R2 - 100Ω
- R3 - 50Ω
- R4 - 20Ω

### Nominal Capacitance:
- 50pF

Typical application requires 2 networks

**Recommended Mounting:** The Self Bias Network should be mounted with fully metalized side down directly on the RF ground plane for best performance

### Product Number Identification

<table>
<thead>
<tr>
<th>B</th>
<th>20</th>
<th>BH</th>
<th>SBN01</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
<td><strong>Width</strong></td>
<td><strong>Material</strong></td>
<td><strong>Network Type</strong></td>
</tr>
<tr>
<td>B = Bias Network</td>
<td>28</td>
<td>BH ± 15% TC</td>
<td>B = Bias Network</td>
</tr>
<tr>
<td><strong>Frequency Range:</strong></td>
<td>1.0 to 20 GHz</td>
<td><strong>BT +22, -56% TC</strong></td>
<td><strong>SBN01</strong></td>
</tr>
</tbody>
</table>

**Physical Characteristics**

![Physical Characteristics Diagram]

**Typical Application**

![Typical Application Diagram]

Custom Networks can be designed per customer specification. Please consult Factory for additional information or special requirements.
**High Performance Filters from DLI**

**Typical Specifications**
- Frequencies from 1 to > 67 GHz
- Insertion Loss ~ 2dB
- Return Loss 15 dB typical
- Rejection 45 dB typical
- Pass band Width <15%

**Demonstrated capability of high frequency filter designs**
- Lowpass, Highpass; and Bandpass
- Designs include:
  - Tchebyshev
  - Bessel cross-coupled responses in various topologies
  - Resonators (e.g. Ring and Dual mode)
  - Edge Coupled
  - End Coupled
  - Hair-Pin
  - Interdigitated
  - Custom Variants

**Advantages of DLI Hi K materials for Microstrip Filters**
- Temperature Stability: 8 fold improvement with CF material
- Filter size reduction: 1/15th the area of PWB materials
- High repeatability
- Reduced size & cost systems

**Typical Filter Specifications**

<table>
<thead>
<tr>
<th>Center Freq (GHz)</th>
<th>Material Code</th>
<th>3dB Bandwidth (MHz)</th>
<th>Filter Type</th>
<th># of Poles</th>
<th>Passband Insertion Loss (dB)</th>
<th>Low Side -40 dB Point (GHz) (1)</th>
<th>High Side -40 dB Point (GHz) (1)</th>
<th>Mounting Code (2)</th>
<th>Length inches (mm)</th>
<th>Width inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.14</td>
<td>CF</td>
<td>350 (16%)</td>
<td>Interdig</td>
<td>7</td>
<td>1.8</td>
<td>1.80 (3)</td>
<td>2.36 (3)</td>
<td>S</td>
<td>0.740 (18.8)</td>
<td>0.400 (10.2)</td>
</tr>
<tr>
<td>3.5</td>
<td>CF</td>
<td>165 (5%)</td>
<td>SDMRF</td>
<td>12</td>
<td>2.5</td>
<td>3.08</td>
<td>3.9</td>
<td>M</td>
<td>0.900 (22.9)</td>
<td>0.330 (8.4)</td>
</tr>
<tr>
<td>4.2</td>
<td>CF</td>
<td>250 (6%)</td>
<td>SDMRF</td>
<td>12</td>
<td>2.4</td>
<td>3.63</td>
<td>4.72</td>
<td>M</td>
<td>0.900 (22.9)</td>
<td>0.330 (8.4)</td>
</tr>
<tr>
<td>5.6</td>
<td>CF</td>
<td>410 (7%)</td>
<td>Edge Cpl</td>
<td>5</td>
<td>2.2</td>
<td>5.21</td>
<td>6.13</td>
<td>M</td>
<td>0.925 (23.5)</td>
<td>0.260 (6.6)</td>
</tr>
<tr>
<td>6</td>
<td>CF</td>
<td>590 (10%)</td>
<td>SDMRF</td>
<td>16</td>
<td>3.7</td>
<td>5.62</td>
<td>6.53</td>
<td>M</td>
<td>0.700 (17.8)</td>
<td>0.330 (8.4)</td>
</tr>
<tr>
<td>6.5</td>
<td>CF</td>
<td>390 (6%)</td>
<td>SDMRF</td>
<td>16</td>
<td>2.7</td>
<td>5.96</td>
<td>7.24</td>
<td>M</td>
<td>0.700 (17.8)</td>
<td>0.330 (8.4)</td>
</tr>
<tr>
<td>9.7</td>
<td>CF</td>
<td>420 (4%)</td>
<td>End Cpl</td>
<td>7</td>
<td>2.9</td>
<td>9.36</td>
<td>10.04</td>
<td>M</td>
<td>1.500 (38.1)</td>
<td>0.100 (2.5)</td>
</tr>
<tr>
<td>37</td>
<td>FS</td>
<td>760 (2%)</td>
<td>End Cpl</td>
<td>3</td>
<td>2.2</td>
<td>34.83</td>
<td>39.67</td>
<td>M</td>
<td>0.325 (8.3)</td>
<td>0.100 (2.5)</td>
</tr>
</tbody>
</table>

Note 1: higher rejection can be achieved with a cover.
Note 2: see definition of mounting codes on adjacent page.
Note 3: data shown for this filter is for -30 dB point.
## Miniature Ceramic Filters

### Part Number Identification

<table>
<thead>
<tr>
<th>AFL</th>
<th>06000</th>
<th>B300</th>
<th>S</th>
<th>P</th>
<th>-xxxx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>Center</td>
<td>Frequency</td>
<td>Bandwith</td>
<td>Mounting</td>
<td>Code</td>
</tr>
<tr>
<td>Family</td>
<td>Family</td>
<td>Family</td>
<td>Family</td>
<td>Family</td>
<td>Family</td>
</tr>
<tr>
<td>GGmmm</td>
<td>mm</td>
<td>S,W,M</td>
<td>T= Tape/Reel</td>
<td>P=Tray</td>
<td></td>
</tr>
<tr>
<td>Example:</td>
<td>B300=300MHz</td>
<td>(see below)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06000=6.00GHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Filter Mounting, Interconnection and Metallization Schemes

<table>
<thead>
<tr>
<th>Mounting Code</th>
<th>Component to Substrate Interface and Input/Output Interconnect</th>
<th>Solder Metallization</th>
<th>Backside Metallization</th>
<th>Topside Metallization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Mount</td>
<td>S</td>
<td>Nickel/Gold</td>
<td>Sn/Pb or Sn [Lead free]</td>
<td>Nickel/Gold</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Or</td>
<td>Conductive Epoxy</td>
<td></td>
</tr>
<tr>
<td>Microstrip Mount</td>
<td>M</td>
<td>Component to Substrate Interface</td>
<td>Solder - Sn/Pb or Sn [Lead free]</td>
<td>Nickel/Gold</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Or</td>
<td>Conductive Epoxy</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Input/Output Interconnect</td>
<td>Thermocompression - Wirebond</td>
<td>Gold</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Or</td>
<td>Ribbon Lead</td>
<td></td>
</tr>
</tbody>
</table>

### Mounting Codes and Metallization

**S** Surface Mount - Conductive epoxy or solder mount.
- Nickel/Gold on the top and bottom surfaces of the device.
- Nickel Metallization: 20 micro-inches typical.
- Gold Metallization: 5 to 20 micro-inches typical.
- For solder applications gold is held to a minimum to prevent embrittlement in the solder system.

**W** Microstrip Mount - Wirebond Interconnection - Conductive epoxy mount.
- Gold on the mounting surface and Gold on the top surface.
- Gold Metallization: 50 micro-inches minimum, 100 micro-inches typical.

**M** Microstrip Mount - Wirebond Interconnection - Conductive epoxy or solder mount.
- Nickel/Gold on the mounting surface and Gold on the top surface.
- Nickel Metallization: 20 micro-inches typical.
- Gold Metallization Bottom Surface: 5 to 20 micro-inches typical.
- For solder applications gold is held to a minimum to prevent embrittlement in the solder system.
- Gold Metallization Top Surface: 50 micro-inches minimum, 100 micro-inches typical.

For customized metallization systems - consult factory.
Ceramic Microstrip Filters

2.14 GHz Bandpass Filter

Unique Features

- 7-Pole Tchebyshev on K=23 ceramic
- Low loss: 1.8dB typical
- Temperature stable +/− 15ppm/°C
- Surface mountable
- Small size: 0.4 x 0.75 x 0.035 inches
- No tuning
- Good cost/size/performance tradeoff

The plot below illustrates filter performance repeatability in a surface mount configuration. Multiple devices fabricated on a single substrate, stringent material controls and precise processing enable excellent part repeatability at the lowest cost possible.
DLI's engineers select from numerous filter topologies to solve your frequency management problem. Size, cost, and performance tradeoffs are considered. Whether you have a new requirement or are trying to architect a topology to fit an existing slot, consider a ceramic solution.

Classical filter topologies can yield excellent performance in a small footprint when fabricated on ceramic substrate materials. Miniaturization reaches new levels by employing DLI high-k ceramic formulations. Different techniques of placing the resonant structures are observed in the accompanying photographs. Lower frequency implementations rely on folded resonators whereas high frequency designs generally use end coupled designs. Coupling is managed to yield the desired pass band/reject band performance. The correct placement of the input/output structures manage the impedance of the structure.

Performance requirements are easily converted to an implementation with the aid of classical modeling tools. The final physical implementation is verified using electromagnetic simulators and DLI proprietary software. Design and prototype time is minimized.

5.6 GHz Edge Coupled Bandpass Filter
**Ceramic Microstrip Filters**

**9.7 GHz Bandpass Filter**

- 7-Pole End Coupled Filter
- 4% Bandwidth (400 MHz)
- Insertion Loss < 2.7dB
- Manufactured on CF Material, K=23
- Small size (1.1”x0.1”x0.03”)

**Measured Response of Filter in Fixture**

The End Coupled resonator topology employed here is well suited for low percentage bandwidths (typically in the 2~5% range) and high out of band rejection. The 9.7 GHz filter is pictured both individually and attached to a carrier, which enables screw assembly and form /fit /function substitution for a larger more costly alternative. DLI’s high K material is utilized here for size and weight reduction. In a typical application conductive epoxy attachment to the floor of a channeled shield housing would be employed. With proper shielding, very high levels of rejection are possible. Approximately 70 dBC was achieved in this design. If designed for printed circuit materials the performance and repeatability would be inferior, and the filter length would be over 3 inches.
Ceramic Microstrip Filters

37 GHz Bandpass Filter

- Thin Film Gold on Fused Silica
- 3-Pole End-Coupled Tchebyshev
- 600 MHz Band-width (1.6% BW)
- <2.2 dB Insertion loss
- Size: 0.32 x 0.10 x 0.01 inches

The End Coupled resonator topology is applied to this 2% bandwidth filter. The narrow width (0.100 inches) of this filter design facilitates high isolation by enabling a below waveguide cut-off shielded housing. In a typical application conductive epoxy attachment to the floor of a channeled shield housing would be employed. Precision photolithography enables excellent unit to unit repeatability at low cost. DLI has precision measurement capability up to 67 GHz with the Vector Network Analyzer shown below. Both fixture and RF coplanar probe testing are employed, depending on the application.
Symmetrical Dual Mode Resonators
- High selectivity
- Low Insertion Loss
- Compact size

High K ceramic
- Miniaturization
- Temperature stable
- Hi-Q (low loss)

Applications for Dual Mode Resonator Bandpass Filters
The small size, low insertion loss and the sharp cutoff of the dual mode bandpass filters make them ideal for:
- Communications Receivers RF and IF Applications
- Frequency Synthesizer and Oscillator Applications
- Instrumentation
- RADAR Applications
Symmetrical Dual Mode Resonator Filters

4.2 GHz Dual Mode Bandpass Filter

6 GHz Dual Mode Bandpass Filter

6.5 GHz Dual Mode Bandpass Filter
Ceramic Cavity Filters

- Utilizes single pole ceramic cavity resonator design
- Small Size - 0.17 X 0.2 X 0.03 inches for a 10.5 GHz filter
- LO/Multiplier chains/RF pre-select/image filtering
- Patent Pending

10.5 GHz Ceramic Cavity Filter

Ceramic cavity resonator technology can be employed in conjunction with DLI's stable, high Q ceramics to create precise, small, low loss bandpass filters. Using a two port implementation, a very small robust filter can be created. Wide reject band performance without spurious modes is possible. The small, shielded nature of the ceramic cavity filter implementation makes it an ideal choice for integration in low noise receiver front ends with the antenna and pre-amplifier.
Ceramic Cavity Filters

Cascading of Filters

The filtering characteristics of a series-cascading ceramic cavity resonator is demonstrated below. The single ceramic cavity resonator which contains one resonator and generates one transmission zero is introduced as the most basic building block for modular design of Bandpass filters. Higher-order Bandpass filters are designed by cascading single cavity resonators to generate the required transmission zeros. A simple example model filter is designed to validate the model and the design approach. The performance of the cavity resonator filter, especially the bandwidth ratio, is improved significantly in comparison with that of the single cavity resonator filter. The synthesis and design of these filters are based on models which cascade the designed cavity resonator at the vicinity of center bandwidth frequency. In early designs, up to 3% relative bandwidths have been achieved.

Two Single-Cavity Filters Cascaded at 10.4 GHz

Cascaded Cavity Filter Performance
**Mounting**

Two mounting techniques in common usage are designed to optimize performance of filters at microwave frequencies. Reliable connectivity is assured by selecting the correct metallization for the signal traces and mounting surfaces for the desired mounting and interconnecting technique. The metallization schemes offered support these mounting techniques. Customized metallization systems are available upon request.

The above illustration demonstrates a microstrip mounting technique. The circuit is relieved to accommodate the filter. The bottom surface of the filter is attached directly to the system ground plane using conductive epoxy. A minimum of 50 micro-inches and typically 100 micro-inches of gold are provided on the top surface to facilitate reliable wirebonding. [Cleaning of the surfaces using UV ozone etch or ultra-sonic techniques is always recommended to insure the highest quality of bonds.] Metallization codes W or M are suitable for this assembly method. If metallization code M is selected, solder attach of the part is enabled if thermal coefficients of expansion are compatible.

Surface mounting techniques typically rely on solder bond between the bottom conductor of the component and the ground conductor of the circuit. Note the use of multiple ground vias between the component and the system ground plane to insure optimal performance. The input/output signal connection can be realized using castellations and solder reflow. Nickel metallization is provided for solder attachment. A thin outer layer of gold is provided to prevent oxidation of the nickel. The gold is minimized to eliminate embrittlement in the solder joint. This metallization code is S.
### Defining a Custom Filter

#### Type
- Bandpass (BP), Lowpass (LP), Highpass (HP)

#### Center Frequency, \( F_c \) (GHz)
\[ F_c = \quad \text{GHz} \]

#### 3 dB Bandwidth (MHz)
\[ \text{BW}_3\text{dB} = \quad \text{MHz} \]

#### Insertion Loss (IL) @ \( F_c \) (dB)
\[ \text{IL} = \quad \text{dB} \]

#### Return Loss (RL) @ \( F_c \): dB Reference - 50 Ohms
\[ \text{RL} = \quad \text{dB} \]

#### Upper Frequency Rejection:
- \( \quad \text{dB} \) @ \( \quad \text{MHz} \)

#### Lower Frequency Rejection:
- \( \quad \text{dB} \) @ \( \quad \text{MHz} \)

#### Power Handling (Watts)
- Power (average) = \( \quad \text{Watts} \)
- Power (peak) = \( \quad \text{Watts} \)

#### Operating Temperature Range:
\[ T_{\text{min}} = \quad ^\circ\text{C}, \quad T_{\text{max}} = \quad ^\circ\text{C} \]

#### Mounting Technique:
- Surface Mount (S) or Microstrip (M)

#### Size (limits):
- Length\( \quad \text{inches or mm} \)
- Width\( \quad \text{inches or mm} \)
- Thickness\( \quad \text{inches or mm} \)

#### Figure:
- IL = \( \quad \text{dB} \)
- Ripple\( \quad \text{dB} \)
- Bandwidth\( \quad \text{MHz} = \quad \% \)
- \( F_{\text{center}} = \quad \text{MHz} \)
Ceramic Duplexers and Diplexers

DLI utilizes the unique advantages offered by its proprietary ceramic formulations as the differentiator from typical RF and Microwave manufacturers. DLI will design both Duplexers and Diplexers to customer specifications. The distinction between the two is subtle, but the understanding is essential to proper design. Duplexers are three port devices used to separate and combine frequencies, having two filters with a common driving point covering two frequency bands. Diplexers are three port devices used to separate and combine frequencies, having one filter covering all frequency bands.

Typical Specifications

- Frequencies from 1 to > 67 GHz
- Insertion loss < 3 dB
- Return loss 20 dB minimum
- Isolation > 50 dB

Features and Benefits

- Highly integrated SMT or wirebond formats
- Available in gold and copper metallizations
- Photolithography defined
- Accurately reproducible

Below is one example of a UMTS Duplexer. This discrete ceramic Duplexer utilizes high performance ceramic thin film materials from DLI. Thin film technology offers these types of devices with the ability to meet conflicting and challenging demands for size reduction, low insertion loss, bandwidth, as well as ideal matching conditions. In this case the DLI designed device eliminated 2 separate filters and an isolator in one-fifteenth the size of a PWB implementation with far better temperature stability.
**Bias Filter Network**

Designed to filter RF signals from bias and control lines from 10MHz to 40GHz

**Functional Applications**
- Wireless communication modules
- Ideal varactor decoupling element
- High gain RF/Microwave modules
- Ideal GaAs FET gate biasing device
- MMIC multichip modules

**Benefits**
- Filters noise and RF from Supplies.
- Reduces RF feedback through bias supplies.
- Simplifies assembly - one component replaces many.
- Designed with large 4 mil wirebond pads for assembly ease.

---

**Physical Characteristics**

- **Total Series Resistance:** 600 nominal
- **Total Shunt Capacitance:**
  - BT material - 140pF nominal
  - BH material - 95pF nominal
- **DC Ratings:** Volts Max: 50V  I(mA) Max: 10mA

**Recommended Mounting:** The Bias filter Network should be mounted with fully metallized side down directly on RF ground plane for maximum isolation performance.

---

**Part Number Identification**

<table>
<thead>
<tr>
<th>Product</th>
<th>Width</th>
<th>Material</th>
<th>Network Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>28</td>
<td>BH</td>
<td>BFN01</td>
</tr>
</tbody>
</table>

**Product**: B = Bias Network  
**Width**: 28  
**Material**: BH ± 15% TC  
**BT +22,-56% TC**

---

**Equivalent Schematic Representation**

---

**Isolation vs Frequency**

Custom Filters can be designed per customer specification. Please consult factory for additional information or special requirements.
**Gain Equalizer**

*Used to compensate for the Gain Slope of other elements*

### Functional Applications
- Equalizer compensates for module Gain Slope
- Broadband communications, RADAR, phased arrays
- SONET modules to 40+ GHz

### Benefits
- Superior microwave performance
- Excellent repeatability
- Ease of assembly, reduced size and cost

### Typical Application

Excellent, repeatable microwave performance is achieved by application of precision thin film fabrication and DLI Hi-K Ceramic materials. DLI’s unique design solution provides near Ideal R-C frequency response, far superior to "Stacked R-C chip" Assemblies.

### Performance

![Graph showing frequency response and insertion loss](image)

### Table of Specifications

<table>
<thead>
<tr>
<th>Part #</th>
<th>Resistor (R)</th>
<th>Low Frequency Insertion Loss, 50 ohm system (dB)</th>
<th>Equivalent Capacitance (pF)</th>
<th>F&lt;br&gt;&lt;sub&gt;S&lt;/sub&gt; (GHz)</th>
<th>Mounting Attachment material: S=solder E=epoxy</th>
<th>L</th>
<th>W</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEQ 2199</td>
<td>43 Ω</td>
<td>-3.0</td>
<td>1.15</td>
<td>16</td>
<td>E</td>
<td>0.028&quot; ± 0.002&quot; (0.711 ± 0.051 mm)</td>
<td>0.016&quot; ± 0.002&quot; (0.406 ± 0.051 mm)</td>
<td>0.007&quot; ± 0.001&quot; (0.178 ± 0.025 mm)</td>
</tr>
<tr>
<td>AEQ 2050</td>
<td>30 Ω</td>
<td>-2.2</td>
<td>0.33</td>
<td>34</td>
<td>E</td>
<td>0.030&quot; ± 0.002&quot; (0.762 ± 0.051 mm)</td>
<td>0.016&quot; ± 0.002&quot; (0.406 ± 0.051 mm)</td>
<td>0.005&quot; ± 0.001&quot; (0.127 ± 0.025 mm)</td>
</tr>
<tr>
<td>AEQ 2234</td>
<td>50 Ω</td>
<td>-3.5</td>
<td>0.31</td>
<td>32</td>
<td>E</td>
<td>0.032&quot; ± 0.002&quot; (0.813 ± 0.051 mm)</td>
<td>0.018&quot; ± 0.002&quot; (0.457 ± 0.051 mm)</td>
<td>0.005&quot; ± 0.001&quot; (0.127 ± 0.025 mm)</td>
</tr>
<tr>
<td>AEQ 3042</td>
<td>9 Ω</td>
<td>-0.8</td>
<td>12.5</td>
<td>7</td>
<td>S</td>
<td>0.040 ± 0.002&quot; (1.02 ± 0.051 mm)</td>
<td>0.020 ± 0.002&quot; (0.508 ± 0.051 mm)</td>
<td>0.006 ± 0.001&quot; (0.152 ± 0.025 mm)</td>
</tr>
<tr>
<td>AEQ 3055</td>
<td>20 Ω</td>
<td>-1.6</td>
<td>9.0</td>
<td>7</td>
<td>S</td>
<td>0.040 ± 0.002&quot; (1.02 ± 0.051 mm)</td>
<td>0.020 ± 0.002&quot; (0.508 ± 0.051 mm)</td>
<td>0.006 ± 0.001&quot; (0.152 ± 0.025 mm)</td>
</tr>
</tbody>
</table>

Custom Equalizers can be designed per customer specification. Please consult Factory for additional information.
Gain Equalizer

Metallization:
Epoxy mount (type "E"): Top side: TaN resistor, TiW, 100 μ inch Au minimum.
Bottom side: TiW, 100 μ inch Au minimum.
Solder mount (type "S"): Top side: TaN resistor, finish: 20 μ inch Au maximum over 30 μ inch Ni
Bottom side finish: 20 μ inch Au maximum over 20 μ inch Ni

Die Attachment recommendations:
The gap in the microstrip line should nominally be equal to dimension "S" (see table).

Mounting attachment material:
"E" type are conductive epoxy only
"S" type can be solder or conductive epoxy

<table>
<thead>
<tr>
<th>Product</th>
<th>Minimum Loss Frequency</th>
<th>Resistance in ohms</th>
<th>Mounting Technique</th>
<th>Package</th>
<th>Drawing #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>GG in GHz</td>
<td>R50=50 ohms</td>
<td>S=solder attach</td>
<td>T=tape/reel</td>
<td>P=waffle pack</td>
</tr>
<tr>
<td>Ex: 34 is 34GHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DLI's miniature Thin Film Gain Equalizers have a microwave frequency response which is so close to ideal that it can be modeled by the simple parallel R-C circuit shown on the preceding page. This is a convenient model for Spice (time domain) simulations. Other common equalizer implementations using stacked R-C chips are not accurately modeled by this circuit. For highest accuracy frequency domain simulations, S-parameters are recommended.

The "stacked R-C chip" implementation, illustrated in the figure below has many issues in both design and manufacturing which lead to lower performance, and higher product cost. The equivalent circuit model below more accurately predicts the frequency response of the stacked chips. At microwave frequencies, the additional parasitic circuit elements are required. The effect of ESL, the equivalent inductance of the chip capacitor is particularly important as it causes a more peaked response as seen in the figure on the next page.
Gain Equalizer

DLI's gain equalizer frequency response is compared with that of an ideal R-C, and stacked R-C chips in the figure below. The stacked R-C chip model utilizes the same Rchip and Cchip values as in the ideal R-C model. The key point is that the chip component R and C values used in a stacked chip equalizer are generally not the ideal values for specifying the DLI single chip gain equalizer. The next section discusses specifying the part by frequency response parameters, or in terms of the ideal R-C values.

Custom Equalizer Design Inputs:

- Low frequency loss or resistance value
- Fo minimum loss frequency or capacitance determined using equivalent circuit model on page 32.
- Case size restrictions - 50 ohm microstrip line width is a typical maximum case width objective

<table>
<thead>
<tr>
<th>Case Size (inches)</th>
<th>Preferred:___________ Maximum Length:________ Maximum Width:________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Loss Frequency (GHz)</td>
<td>Fo_________ GHz</td>
</tr>
<tr>
<td>Low Frequency Loss (dB), 50 ohm system</td>
<td>Design Resistance (ohms)________ Loss (dB)________</td>
</tr>
<tr>
<td>Operating Temperature Range (°C)</td>
<td>Minimum Temperature:________ Maximum Temperature:________</td>
</tr>
<tr>
<td>Power Dissipation (mw)</td>
<td>Conductive Epoxy attach________ Solder attach________</td>
</tr>
<tr>
<td>Assembly Method (SMT or Epoxy)</td>
<td>Solder type________</td>
</tr>
<tr>
<td>Board Material</td>
<td>Material________ Dielectric constant________ Thickness________</td>
</tr>
</tbody>
</table>
Global Support

DLI is committed to supporting your needs worldwide. Please contact us at:

Factory, Sales & Application Engineering

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Email: bnyulassy@dilabs.com  
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Tel: (+86) 21-6360-7308  
Fax: (+86) 21-6360-4596  
Email: chinasales@dilabs.com  
Additional sales offices in Beijing, Suzhou, Shenzhen and Wuhan

DLI also offers support through an extensive network of regional representatives and distributors. Please consult our sales offices or web site for your local representative.
Single Layer Capacitors

<table>
<thead>
<tr>
<th>Di-Cap®</th>
<th>Border Cap</th>
<th>Gap Cap</th>
<th>Bar Cap</th>
<th>Binary Cap</th>
<th>T-Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest performance SLC for RF, MW and MMW applications from 100 MHz to 100 GHz. Most cap for size 0.02 - 4300 pF</td>
<td>SLC w/1- or 2-sided recessed metallization to minimize the potential for shorting during die attach. Ideal for epoxy attach. 0.02 - 1500 pF</td>
<td>Series configured precision SLC for elimination of wire-bonds and microstrip applications. Minimum performance variation.</td>
<td>Multiple decoupling/bypass or blocking SLC configured in a single array. Ideal for decoupling MMICs.</td>
<td>Multi-value - binary tunable SLC for design tuning or MIC hybrids.</td>
<td>SLC used in series connected open circuited transmission line and is designed for repeatable resonance behavior.</td>
</tr>
</tbody>
</table>

Multi-Layer Capacitors

<table>
<thead>
<tr>
<th>C04</th>
<th>C06</th>
<th>C08</th>
<th>C11</th>
<th>C17</th>
<th>C22</th>
<th>C40</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04 x 0.02</td>
<td>0.06 x 0.03</td>
<td>0.08 x 0.05</td>
<td>0.055 x 0.055</td>
<td>0.11 x 0.11</td>
<td>0.22 x 0.25</td>
<td>0.38 x 0.38</td>
</tr>
<tr>
<td>0.1 – 10pF</td>
<td>0.1 – 47pF</td>
<td>0.1 – 100pF</td>
<td>0.1 – 100pF</td>
<td>0.1 – 1000pF</td>
<td>1 - 2700pF</td>
<td>1 - 5100pF</td>
</tr>
<tr>
<td>UL only</td>
<td>UL &amp; CF</td>
<td>UL only</td>
<td>UL, CF, AH</td>
<td>UL, CF, AH</td>
<td>CF &amp; AH</td>
<td>CF &amp; AH</td>
</tr>
<tr>
<td>100V WVDC</td>
<td>250V WVDC</td>
<td>250V WVDC</td>
<td>250V WVDC</td>
<td>1000V WVDC</td>
<td>2500V WVDC</td>
<td>7200V WVDC</td>
</tr>
</tbody>
</table>

Build-to-Print Thin Film Processing

Let DLI be your complete Thin Film Foundry. DLI has provided comprehensive build-to-print services to its customers for years. You can leverage decades of ceramic and thin film processing experience, prototyping and testing capabilities, and engineering support to meet your exacting needs.

Precision Variable Capacitors

Voltronics Corporation is one of the world’s largest and most respected precision variable capacitor manufacturers. Consistent product quality, excellent customer service and product customization flexibility set Voltronics apart from its competitors. Whether it’s a reliable high voltage or a high purity non-magnetic or a lower cost high performance application, Voltronics has the right variable capacitor for you. Voltronics has been a Dover company since 2004.

<table>
<thead>
<tr>
<th>Teflon</th>
<th>Glass &amp; Sapphire</th>
<th>Air</th>
<th>Ceramic</th>
<th>Non-caps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost, miniature 0.3 thru 12 pF Available in non-mag Surface mount</td>
<td>Sealed sapphire 0.6 thru 8 pF Available in non-mag Surface mount</td>
<td>Solder sealed 0.6 thru 14 pF Surface mount</td>
<td>Low cost 1/2-turn 1.25 thru 130 pF Surface or through-hole mount</td>
<td>Custom inductors, diodes and screws Non-magnetic only</td>
</tr>
<tr>
<td>High Voltage Up to 2KV 0.2 thru 55 pF Extended Voltage Up to 15KV 0.1 thru 85 pF Available in non-mag</td>
<td>Sealed Glass 1.0 thru 250 pF Surface mount Vertical, panel &amp; Horizontal Mount</td>
<td>Epoxy sealed 0.6 thru 14 pF Surface mount</td>
<td>Higher voltage single turn Surface or through-hole mount</td>
<td>Connectors &amp; Cable Assemblies PC Plug, Straight &amp; 90° Crimp Jack Non-magnetic only</td>
</tr>
</tbody>
</table>

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