Disruptive Component Technologies
for RF & Microwave Systems

Miniature Microwave Thin Film Filters & Components

- Custom Designs/ Hi-K Ceramics
- 300MHz ~50GHz
- SMT
- Chip & Wire

Thin Film Build to Print Fabrication

- Wide range of standard & DLI proprietary Ceramics
  4<K<40,000
- Metallization: TiW, Pt, Ni, Cu, Au,
- TaN resistors
- Features to 0.5 mils
- Laser Vias / Filled Vias
- Polyimide Multi-layer, in R&D
- RF testing service/ Screening option

Single Layer Ceramic Capacitors

- Widest selection of SLC’s
  4<K40,000
- Temperature stable / Hi-Q matching
- Decoupling/ DC blocking
- Metallization, many options
- Microwave Modeling CAPCAD™
- Custom Solutions

Hi-Q MLC’s

- 0402 ~3838 case sizes
- RF Power
- Broadband DC Blocks
Performance Advantages of DLI Thin Film Devices

- **Strengths**
  - Temp Stability
  - Repeatability
  - Reduced Size
- **Wider Band**
- **Steeper Skirts**
- **Higher Frequency Advances**
- **Multi-Device Packaging**
DLI Filters, 5G Advantages

- **Small size (footprint & height)**
  - High dielectric constant, Hi-Q materials offer reduced size versus on PCB
  - Use K= 13, 23, 67 to shrink size (PCB typically 2-4); 3-10x reduction is size

- **Temperature stable RF to (~3ppm/°C)**
  - Smaller modules and higher power amplifiers (GaN) mean denser, higher temperature variation in packages. DLI filters are inherently temperature stable over wide temp range; -55 to 125°C

- **Excellent RF repeatability**
  - Using thin film manufacturing, we can guarantee repeatability on large batches of filters to offer more repeatable performance and lower cost of next level assembly – No Tuning!

- **Repeatable SMT performance to 20GHz +**
  - DLI has been building surface mount filter devices for >10 yrs and is excelling at higher frequency filtering for mounting in low cost printed wire board technology

- **Wider band performance, steeper skirts**
  - DLI Hi-Q, Hi-K, temp stable technology offers the ability for higher selectivity, wider bandwidth and lower loss filters than many competing tech for lower cost

- **Higher Power**
  - Using DLI, we can build components that withstand higher power than traditional chip technology. Devices can be designed to handle over 20 Watts of power.
Filter Temperature Stability
18 GHz Band-pass Filters (-55 to +125 °C)

“CF”

99.6% Alumina

140MHz Shift
300 MHz Shift

Most Systems Specify -40 to +85°C
# Materials for Temperature Stability

<table>
<thead>
<tr>
<th>Substrate Material</th>
<th>Dielectric Constant (Tolerance)</th>
<th>Typical Loss Tangent</th>
<th>Coefficient of Thermal Expansion (ppm/°K)</th>
<th>Temperature Coefficient of Capacitance (ppm/°C)</th>
<th>Surface Finish (m-inch)</th>
<th>Temp Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.6% Alumina (Al2O3) PI</td>
<td>9.9 (± 0.15) @1MHz</td>
<td>0.0001</td>
<td>6.5-7.5</td>
<td>P120 ± 30</td>
<td>&lt;5</td>
<td>Poor</td>
</tr>
<tr>
<td>PG</td>
<td>13 (± 0.5)</td>
<td>0.0002</td>
<td>7.6</td>
<td>P22 ± 30</td>
<td>&lt;5</td>
<td>Good</td>
</tr>
<tr>
<td>CF</td>
<td>25 (± 1)</td>
<td>0.0003</td>
<td>9.0</td>
<td>0 ± 15</td>
<td>&lt;5</td>
<td>Excellent</td>
</tr>
<tr>
<td>CD</td>
<td>38 (± 1)</td>
<td>0.0004</td>
<td>5.8</td>
<td>N20 ± 15</td>
<td>&lt;5</td>
<td>Good</td>
</tr>
<tr>
<td>CG</td>
<td>67 (± 3)</td>
<td>0.0008</td>
<td>9.0</td>
<td>0 ± 30</td>
<td>&lt;5</td>
<td>Very Good</td>
</tr>
</tbody>
</table>
Repeatable Performance from DC to 50GHz

Excellent Repeatability
250 Samples, 3 Lots

70 Samples from Multiple Substrates
- 10 mil CF (K23) material

35 GHz Filter
70 Samples
AFL3431B (2 lots & 3 diff plates)
S-Band SMT Filters
Repeatability 100 samples

S11 Repeatability 20 Samples
Miniature SMT 5 GHz BPF

Size 0.4x0.18 inches [10.2x4.6mm], shield cover
3.7 GHz SMT Filter synthesizer LO chain

Exceptional stop-band Performance,

Frequency (GHz)

Magnitude (dB)
Integrated High Pass & Low Pass Filters

5~18 GHz pass band ~140% Bandwidth
2.2 GHz High Power Filter
50 Watt CW

Protection from RF Breakdown, Condensation & altitude
Outstanding Rejection Possible
Shielded sample w/connectors
Advanced Passband Flatness Techniques

8 Pole Filter with 0.25dB p-p Flatness
(Thin Film Resistor networks incorporated)
28 GHz Bandpass Filter

Surface Mount Device for 5G applications

BPF, 26.65-29.5GHz, V2.6, Typical Performance

\[ S_{21}, \text{Typical} \]

\[ S_{11}, \text{Typical} \]
SMT 40~43 GHz Filter

Demonstrated Excellent Performance in Surface Mount Form

4 Pole Filter
Size: 0.275 x 0.080 in
7.0 x 2.0 mm
What’s New

• Catalog Products
  • Bandpass Filters
  • Lowpass Filters
  • Highpass Filters
  • Power Dividers
  • Couplers, 10 & 20dB BIT
  • Gain Equalizers
## DLI SMT Filter Technology Made Easier

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Center Frequency</th>
<th>Passband</th>
<th>Insertion Loss (@Fc)</th>
<th>Length (Inches)</th>
<th>Width (Inches)</th>
<th>Height (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>@ 25°C</td>
<td>-40°C to +85°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B012MD5S</td>
<td>1.227 GHz</td>
<td>1.22 to 1.23 GHz</td>
<td>3.5 dB</td>
<td>0.670 (17.02)</td>
<td>0.600 (15.24)</td>
<td>0.100 (2.54)</td>
</tr>
<tr>
<td>B016MD5S</td>
<td>1.575 GHz</td>
<td>1.57 to 1.58 GHz</td>
<td>3.5 dB</td>
<td>0.670 (17.02)</td>
<td>0.600 (15.24)</td>
<td>0.100 (2.54)</td>
</tr>
<tr>
<td>B028RF2S</td>
<td>3 GHz</td>
<td>2 to 4 GHz</td>
<td>2.5 dB</td>
<td>0.450 (11.43)</td>
<td>0.400 (10.16)</td>
<td>0.113 (2.87)</td>
</tr>
<tr>
<td>B033ND5S</td>
<td>3.3 GHz</td>
<td>3.1 to 3.5 GHz</td>
<td>2.0 dB</td>
<td>0.393 (9.98)</td>
<td>0.353 (8.97)</td>
<td>0.128 (3.25)</td>
</tr>
<tr>
<td>B057MD7S</td>
<td>5.7 GHz</td>
<td>5.5 to 6.1 GHz</td>
<td>2.3 dB</td>
<td>0.475 (12.1)</td>
<td>0.275 (7.00)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>B056RC4S</td>
<td>6 GHz</td>
<td>4 to 8 GHz</td>
<td>3.0 dB</td>
<td>0.450 (11.43)</td>
<td>0.230 (5.84)</td>
<td>0.100 (2.54)</td>
</tr>
<tr>
<td>B060NC5S</td>
<td>6 GHz</td>
<td>5.5 to 6.5 GHz</td>
<td>2.0 dB</td>
<td>0.500 (12.7)</td>
<td>0.200 (5.08)</td>
<td>0.088 (2.24)</td>
</tr>
<tr>
<td>B080MB5S</td>
<td>8 GHz</td>
<td>7.5 to 8.5 GHz</td>
<td>2.0 dB</td>
<td>0.500 (12.7)</td>
<td>0.180 (4.57)</td>
<td>0.100 (2.54)</td>
</tr>
<tr>
<td>B096QC2S</td>
<td>10 GHz</td>
<td>8 to 12 GHz</td>
<td>2.5 dB</td>
<td>0.400 (10.66)</td>
<td>0.180 (4.57)</td>
<td>0.100 (2.54)</td>
</tr>
<tr>
<td>B120MB1S</td>
<td>12 GHz</td>
<td>11.5 to 12.5 GHz</td>
<td>2.0 dB</td>
<td>0.525 (13.34)</td>
<td>0.225 (5.72)</td>
<td>0.090 (2.27)</td>
</tr>
<tr>
<td>B148QF0S</td>
<td>15 GHz</td>
<td>12 to 18 GHz</td>
<td>3.6 dB</td>
<td>0.550 (13.97)</td>
<td>0.150 (3.81)</td>
<td>0.098 (2.49)</td>
</tr>
<tr>
<td>B161L0S</td>
<td>16 GHz</td>
<td>15.5 to 20 GHz</td>
<td>4.0 dB</td>
<td>0.695</td>
<td>0.250</td>
<td>0.093</td>
</tr>
</tbody>
</table>
Catalog Filter  P/N: B056RC4S

4~8 GHz Band Pass
Size: 0.45 x 0.23 inch [12.1 x 7.0 mm]
## Lowpass Filters

SMD, Typically >35dB Rejection

<table>
<thead>
<tr>
<th>Part Number</th>
<th>3 dB Cutoff</th>
<th>Passband</th>
<th>Max Insertion Loss in Passband</th>
<th>Min VSWR in Passband</th>
<th>Length Inches (mm)</th>
<th>Width Inches (mm)</th>
<th>Height Inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L050XF9S</td>
<td>5 GHz</td>
<td>DC - 4 GHz</td>
<td>1 dB</td>
<td>1.288:1</td>
<td>0.220 (5.58)</td>
<td>0.180 (4.57)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L065XG9S</td>
<td>6.5 GHz</td>
<td>DC - 6 GHz</td>
<td>1.3 dB</td>
<td>1.22:1</td>
<td>0.220 (5.58)</td>
<td>0.180 (4.57)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L095XG9S</td>
<td>9.5 GHz</td>
<td>DC - 9 GHz</td>
<td>1.3 dB</td>
<td>1.12:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L117XH4S</td>
<td>11.7 GHz</td>
<td>DC - 11 GHz</td>
<td>1 dB</td>
<td>1.43:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L128XH4S</td>
<td>12.8 GHz</td>
<td>DC - 12 GHz</td>
<td>1.2 dB</td>
<td>1.38:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L157XG3S</td>
<td>15.7 GHz</td>
<td>DC - 15 GHz</td>
<td>2.2 dB</td>
<td>1.3:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.103 (2.62)</td>
</tr>
<tr>
<td>L185XF4S</td>
<td>18.5 GHz</td>
<td>DC - 18 GHz</td>
<td>2.2 dB</td>
<td>1.4:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.098 (2.49)</td>
</tr>
<tr>
<td>L204XF4S</td>
<td>20.4 GHz</td>
<td>DC - 20 GHz</td>
<td>1.8 dB</td>
<td>1.43:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.098 (2.49)</td>
</tr>
<tr>
<td>L254XF3S</td>
<td>25.4 GHz</td>
<td>DC - 25 GHz</td>
<td>1.4 dB</td>
<td>1.3:1</td>
<td>0.220 (5.58)</td>
<td>0.140 (3.56)</td>
<td>0.098 (2.49)</td>
</tr>
</tbody>
</table>
Lowpass Filters
Rejection 3 Harmonics

Catalog Low Pass Filters

Magnitude (dB)

Frequency (GHz)
New Catalog Highpass Filters

Chip & Wire Hybrid versions available also!

<table>
<thead>
<tr>
<th>Part Number</th>
<th>3dB cutoff</th>
<th>Passband</th>
<th>Typical Insertion Loss in Passband</th>
<th>Minimum VSWR in Passband</th>
<th>Length inches (mm)</th>
<th>Width inches (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H060XHXS</td>
<td>6 GHz</td>
<td>6.5 - 20 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.200 (5.08)</td>
</tr>
<tr>
<td>H080XHXS</td>
<td>8 GHz</td>
<td>8.5 - 22 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.200 (5.08)</td>
</tr>
<tr>
<td>H100XHXS</td>
<td>10 GHz</td>
<td>10.5 - 23 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.175 (4.445)</td>
</tr>
<tr>
<td>H120XHXS</td>
<td>12 GHz</td>
<td>12.5 - 30 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.175 (4.445)</td>
</tr>
<tr>
<td>H140XHXS</td>
<td>14 GHz</td>
<td>14.5 - 28 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.175 (4.445)</td>
</tr>
<tr>
<td>H160XHXS</td>
<td>16 GHz</td>
<td>16.5 - 32.5 GHz</td>
<td>1dB</td>
<td>1.43 : 1</td>
<td>0.450 (11.43)</td>
<td>0.175 (4.445)</td>
</tr>
<tr>
<td>H182XHXS</td>
<td>18.2 GHz</td>
<td>18.75 - 28 GHz</td>
<td>1dB</td>
<td>1.7 : 1</td>
<td>0.450 (11.43)</td>
<td>0.175 (4.445)</td>
</tr>
</tbody>
</table>
Highpass Filters GHz

Corner frequencies: 6, 8, 10, 12, 14, 16, and 18
Thin Film in Phase Power Dividers

- SMT & Wire-bond versions
- Frequency Range: DC to 50 GHz
- Resistive Dividers
- Multi-section Wilkinson Dividers
- Thin Film Benefits:
  - Excellent amplitude & phase characteristics
  - Excellent unit to unit repeatability
  - Integrated Thin Film Isolation resistors
  - Superior power handling
  - Superior isolation
6-18 GHz Wilkinson Power Divider

Features:
- Broadband performance
- Compact SMT Package utilizing DLI Hi-K materials
- 0.185 x 0.180 x 0.020 inches
- 4.70 x 4.57 x 0.51 mm
- Excellent Phase and Amplitude Balance

**Electrical**
- Frequency Range (GHz): 6 to 18
- Nominal Power Splitting (dB): 3.0 (typical)
- Nominal Phase Shift (degrees): 0.0 (typical)
- Amplitude Balance (dB): ±0.025 max.
- Phase Balance (degrees): ±3.0 (max.)
- Excess Insertion Loss (dB): 0.7 (typical)
- Return Loss (dB): 20 (typical)
- Isolation (dB): 20 (typical)
6-18 GHz 4-Way Wilkinson Power Divider: PDW06089

Compact SMT Package utilizing DLI Hi-K materials

Footprint: 0.25 x 0.30 in [6.35 x 7.62 mm]

Low Loss Broadband performance   Excess loss: 0.7dB Typ.
2-18 GHz 2:1 SMT Power Divider

- 8 section Wilkinson (In-Phase)
- Blue curve is Isolation, S23
- Excellent RF Repeatability

Excellent RF Repeatability (5 parts graphed)
"5G" 28 GHz 4-Way Power Divider

Footprint: 0.220 x 0.130 in (5.5 x 3.25mm)
Ideal for Patch Antenna Arrays
## Resistive Power Dividers Selection Chart

<table>
<thead>
<tr>
<th>Description</th>
<th>Packaging</th>
<th>Frequency Range</th>
<th>Package Size (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Way (1 sec)</td>
<td>PDR06380</td>
<td></td>
<td>75 Triangular</td>
</tr>
<tr>
<td>2-Way (1 sec)</td>
<td>PDR06390</td>
<td></td>
<td>75 x 70</td>
</tr>
</tbody>
</table>
2 Way Resistive Power Divider

DC to 40 GHz
Directional Couplers

- **Benefits**
  - Extremely small size
  - High Frequency, Ka Band offering
  - Surface Mount
  - Chip & Wire
  - Extreme repeatability
  - High Directivity
  - Operating Temp: -55 to 125°C
<table>
<thead>
<tr>
<th>Part Number</th>
<th>Frequency Range (GHz)</th>
<th>Mean Coupling Value (dB)</th>
<th>Passband Coupling Variation Typ. (dB)</th>
<th>Insertion Loss Typ. (dB)</th>
<th>Return Loss Typ. (dB)</th>
<th>Isolation Typ. (dB)</th>
<th>Directivity Typ. (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPC06073</td>
<td>4 to 8</td>
<td>10</td>
<td>± 1.5</td>
<td>0.3</td>
<td>20</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>FPC06076</td>
<td>4 to 8</td>
<td>20</td>
<td>± 1.5</td>
<td>0.3</td>
<td>20</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>FPC06074</td>
<td>8 to 12</td>
<td>10</td>
<td>± 1.0</td>
<td>0.3</td>
<td>14</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>FPC06077</td>
<td>8 to 12</td>
<td>25</td>
<td>± 1.0</td>
<td>0.3</td>
<td>15</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>FPC06075</td>
<td>12 to 18</td>
<td>10</td>
<td>± 0.5</td>
<td>0.3</td>
<td>15</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>FPC06078</td>
<td>12 to 18</td>
<td>20</td>
<td>± 1</td>
<td>0.3</td>
<td>15</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>FPC07181</td>
<td>20 to 40</td>
<td>20</td>
<td>± 1.5</td>
<td>0.3</td>
<td>20</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>FPC07182</td>
<td>20 to 40</td>
<td>10</td>
<td>± 1.5</td>
<td>0.3</td>
<td>20</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>FPC07183</td>
<td>24 to 33</td>
<td>3</td>
<td>± 1.0</td>
<td>0.3</td>
<td>15</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>FPC06700</td>
<td>5.9 to 6.5</td>
<td>3</td>
<td>1</td>
<td>0.5</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06701</td>
<td>10.7 to 12.75</td>
<td>3</td>
<td>1</td>
<td>0.5</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06633</td>
<td>8.5 to 11</td>
<td>3</td>
<td>1</td>
<td>0.5</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06913</td>
<td>6 to 18</td>
<td>20</td>
<td>1</td>
<td>0.3</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06719</td>
<td>6 to 18</td>
<td>10</td>
<td>1</td>
<td>0.3</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC07180</td>
<td>2 to 18</td>
<td>20</td>
<td>4.5</td>
<td>0.8</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06881</td>
<td>DC to 40</td>
<td>20</td>
<td>NA</td>
<td>0.5</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>FPC06882</td>
<td>DC to 40</td>
<td>30</td>
<td>NA</td>
<td>0.5</td>
<td>15</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>
4-8GHz 10dB Directional Coupler

FPC06073 (10dB) / FPC06076 20dB
Package size: 0.170 x 0.080 in
4.32 x 2.03 mm
4-8GHz 10dB Coupler Performance

Measured on 10mil RO4350

Graph showing frequency vs. magnitude and directivity.
12-18GHz 20dB Directional Coupler

FPC06075 (10dB) / FPC078 20dB
Package size: 0.100 x 0.080 in
2.54 x 2.03 mm
12-18GHz 20dB Coupler Performance

Measured on 10mil RO4350
Cavity Filters

- Scalable from: ~6 to 15 GHz
- Bandwidths: 1 to 5%
- Resonator Q: 600 to 1200
  - Depending on:
    - Frequency
    - Ceramic material
    - Thickness
- Excellent for:
  - Narrowband
  - low pass band insertion loss
  - Completely Shielded – good isolation

Mounting Options:
- SMT to Stripline
- SMT to Microstrip (Filter supplied on PWB interposer)
- Epoxy & Wire-Bond
4 Pole Cavity Filter
8300 MHz

Cavity High Q Enables Low Loss Narrow band Filter
Cavity Filter Advances

- ~30% better Q, ~800 @ 8GHz

- Improved Frequency precision
  - Improved material screening & models
  - Laser trim method developed ~0.1%

- Solder Surface Mountable
  - Interposer board matched to your board
4 Cavity Filters

Synthesizer Switched Filter Bank

5 Pole Cavity Filters

Frequency (GHz)

Magnitude (dB)
Gain Equalizers

- Thin Film ‘R-C’ network
- Can be very small (0302 case)
- Flattens Amplifier Gain response
  - Positive Gain Slope
- Customization:
  - Low frequency loss
  - Minimum loss frequency
- Applications:
  - 10, 20 & 40 Giga-bit SONET
  - EW & Military Radars
Gain Equalizer

Equalizer Typical Performance
Gain Equalizer EW Series

Typical Application: EW systems

DC~18GHz
1 to 3.5dB slopes, 0302 Case size
THANK YOU