Filter Facts and Types

TELEDYNE MICROWAVE SOLUTIONS
Everywhereyoulook™

Filter Facts

A passive filter consists of inductors and capacitors arranged in a particular configuration (layout or topology) so that a specified band of frequencies are allowed to pass with little attenuation while undesired frequencies are rejected. There are four common types of filters using a variety of electrical functions or topologies. The four typical types of filters are band-pass, lowpass, highpass and band-stop filters.

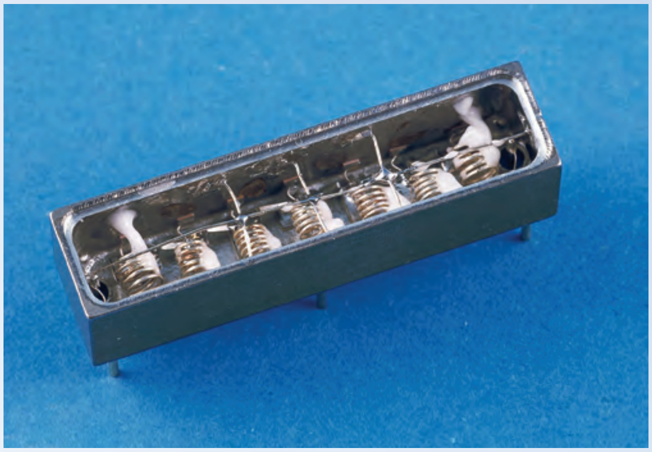
Bandpass Filters

A bandpass filter provides a good signal transmission within its passband and rejects lower and higher frequencies. The rejection does not occur as an abrupt or immediate change but in a sloping of the side skirts. The side skirts also are called the guardband or slope of rejection.

The bandpass filter is the most common filter application. Bandwidths can range from 1% to 200% of the center frequency, depending on the application.

Lowpass Filters

A lowpass filter provides good signal transmission at frequencies below the cutoff frequency. A steep rejection or abrupt change from the pass-band condition is not achievable. Similar to the bandpass filter, a slope or rejection skirt is required between the passband frequency and the desired rejection frequency.



LC Filter

Typically, lowpass filters are used to suppress 2nd and 3rd order harmonics or to reject spurious outputs from nearby transmitters.

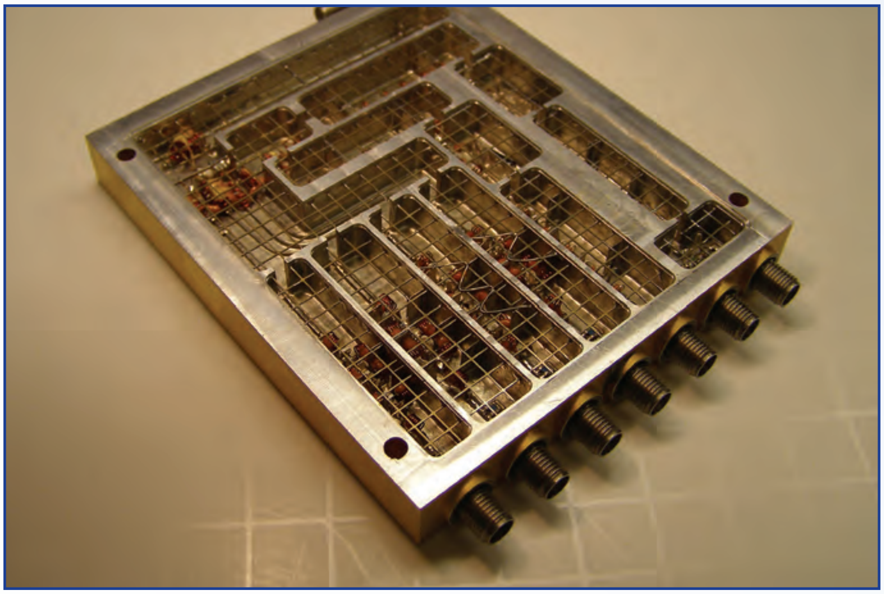
Highpass Filter

Highpass filters operate as a reverse of the lowpass filter. They are used to reject or attenuate frequencies below the frequency band. Similar to the lowpass filter, they are typically used to suppress the signal of nearby transmitters.

Bandstop Filters

Bandstop filters are also known as Notch Filters or Band Reject Filters. Bandstop filters are used when rejection or suppression is needed in the passband while allowing the signals on either side of the "notch" to pass.

Typical applications are for receivers located near a transmitter capable of sending a signal within the receivers operating range.



Lumped Element Filter

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Filter Facts

Topologies

Teledyne Microwave Solutions (TMS) technical engineering staff uses computer aided design programs to determine appropriate electrical function to meet customers' specifications. These include:

- Bessel
- Butterworth
- Chebyshev
- Elliptic
- Gaussian

Lumped Element

The elements in the filter are lumped (i.e. concentrated over a small area). The inductors are coils of wire wound around cylindrical formers, and the capacitors are parallel plate chips or similar portions of substrate material.

Combline

Combline filters, also called Cavity Filters, replace the inductors in a lumped element filter with distributed inductors or lengths of transmission line leaving the capacitors lumped, although distributed capacitance is sometimes used. Filter bandwidths can range from less than 1% to 50%.

Advantages:

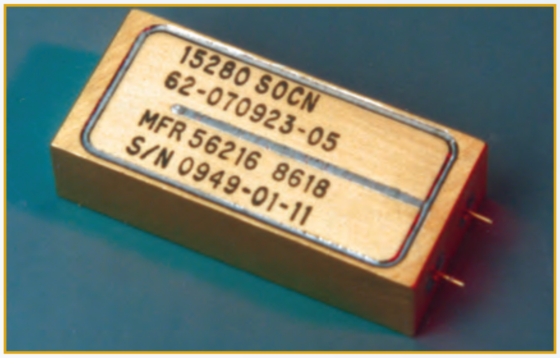
- High Q factors can be obtained (3500)
- Small size can be traded off with Q
- Bandwidths from 1% to 66% can be obtained
- Designs cover 30 MHz to 18 GHz
- Handles high power

Interdigital

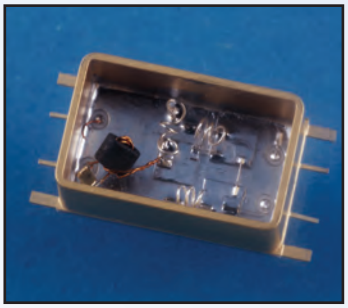
Interdigital filters are entirely distributed networks consisting of an array of short circuit quarter wavelength lines. Filter bandwidths from 1% to 80% are achievable. These are in applications where flat group delay is required.

Advantages:

- High Q factors can be obtained (5500)
- Small size can be traded off with Q
- Bandwidths from 5% to 100% can be obtained
- Designs cover 500 MHz to 12 GHz



Teledyne Microwave Solutions' technical engineering staff uses computer aided design programs to determine appropriate electrical function to meet customers' specifications.



LC Filter / Power Divider

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Filter Facts

Suspended Substrate Stripline

These filters are also entirely distributed consisting of both series and shunt transmission line sections. These filters consist of a printed circuit board which is suspended between two parallel ground planes, providing a reasonably high Q, as most of the electric field is in the air. The wide range of achievable impedance values make suspended substrate suitable for broadband applications. Typically units exhibit less than 1 dB of loss in the passband and 60 dB of rejection within 15% of the 1 dB point. The suspended substrate filter is able to pass severe vibration requirements and extreme operating temperature of -54 to +125 degrees C with amazingly low frequency drift.

Advantages:

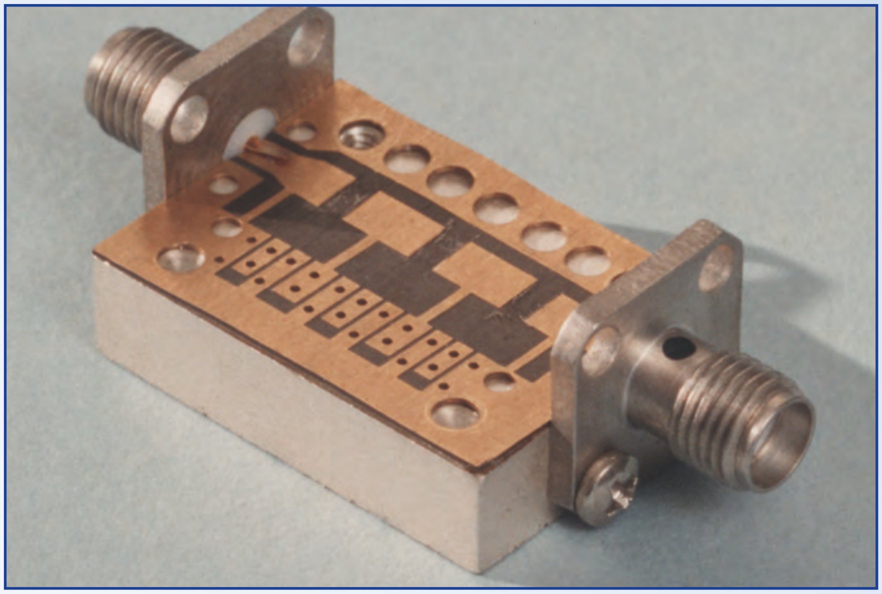
- Very selective devices are standard
- Designs cover 100 MHz to 40 GHz

Waveguide

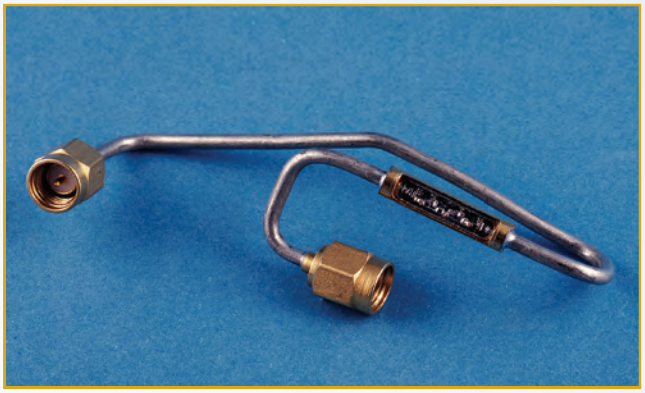
Waveguide filters consist of half wavelength cavities separated by inductive irises. These are made by placing posts through the guide and soldering them to the waveguide at both top and bottom.

Advantages:

- High power handling with low insertion loss
- Extremely high Q factor can be realized (25,000)
- Very selective devices can be made
- Designs cover 2 GHz to 40 GHz



The suspended substrate filter is able to pass severe vibration requirements and extreme operating temperature of -54 to +125 degrees C with amazingly low frequency drift.



Innovation is second nature to Teledyne KW Microwave

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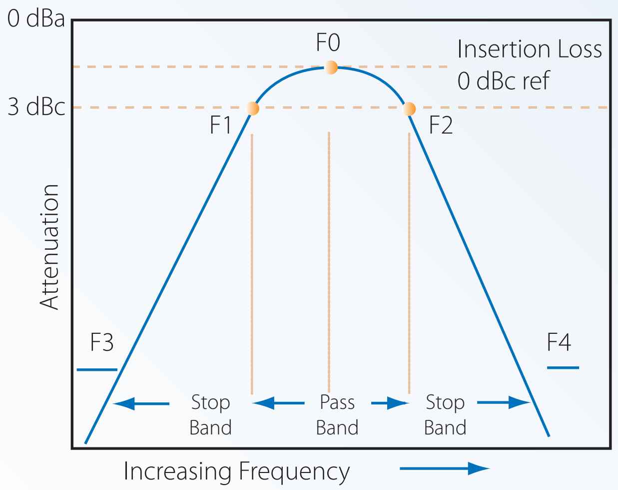
Filter Facts

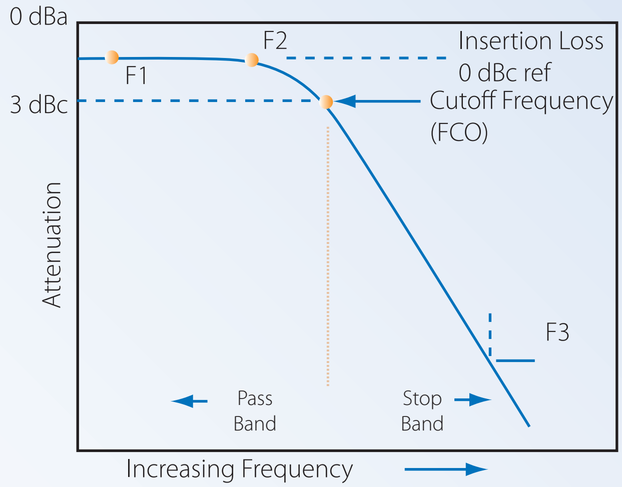
A passive filter is a device consisting of inductors and capacitors arranged in a particular configuration (topology) so that a group of specified frequencies is allowed to pass with little attenuation while undesired frequencies are attenuated.

Four common types of filters

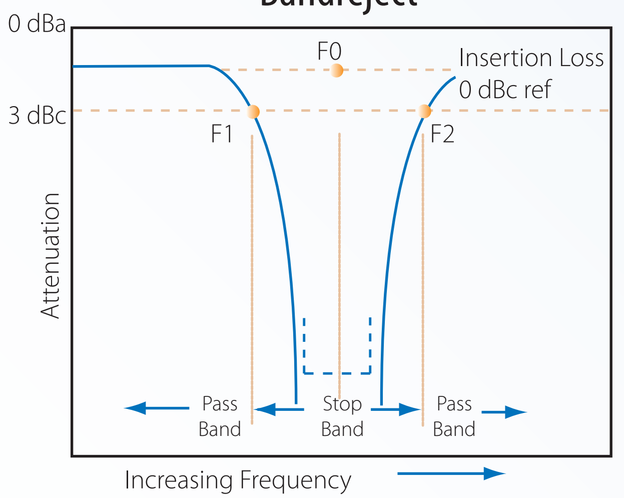
Bandpass



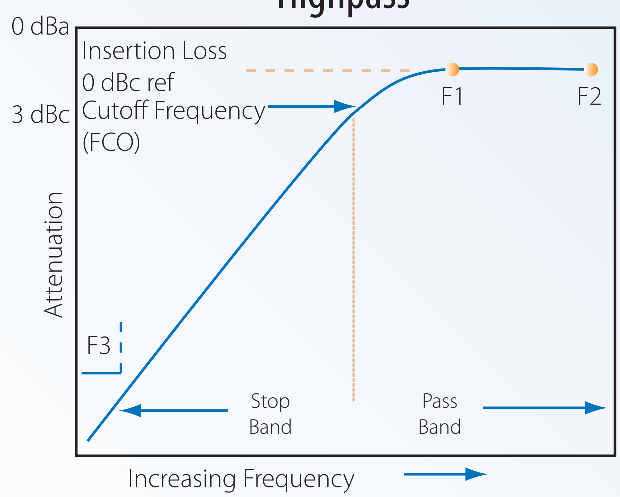
Lowpass



Bandreject



Highpass



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FILTER TYPES

Lumped Element

Frequency Range: 10 MHz To 25 GHz

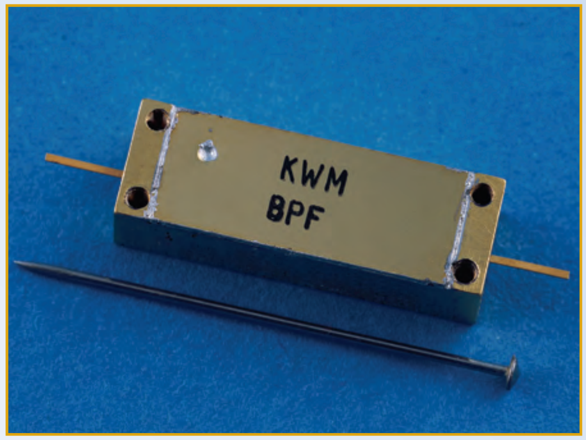
High Selectivity

Group Delay Equalized

Small Size

Can Be Used On A Variety Of Applications

Available In The Following Configurations: Bandpass, Lowpass, Highpass And Notched



Teledyne KW Microwave offers ultra-miniature discrete filters in a wide range of frequencies and design approaches. In-house research and development efforts, coupled with proprietary computer software, helps maintain Teledyne at the leading edge of technology.

Filters with excellent thermal characteristics are achievable through the use of high Q, thermally stable dielectric materials and special constructions techniques.

High mechanical integrity is achieved with lightweight aluminum housings when used in conjunction with our in-house laser welder.

Teledyne KW Microwave fabricates its filters using resonators with discrete capacitors and inductors, i.e. in a lumped form. High-Q porcelain chip capacitors and air-spaced inductive coils are soldered to an RF quality substrate.

Teledyne employs unique proprietary techniques to compensate for changes in filter performance over temperature. Stability of <5 ppm/^{O}C are readily achieve over the temperature range of -55 to +125 ^{O}C.

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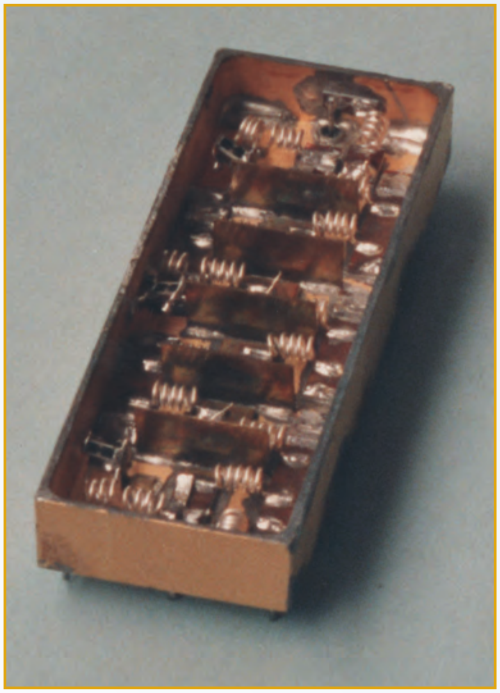
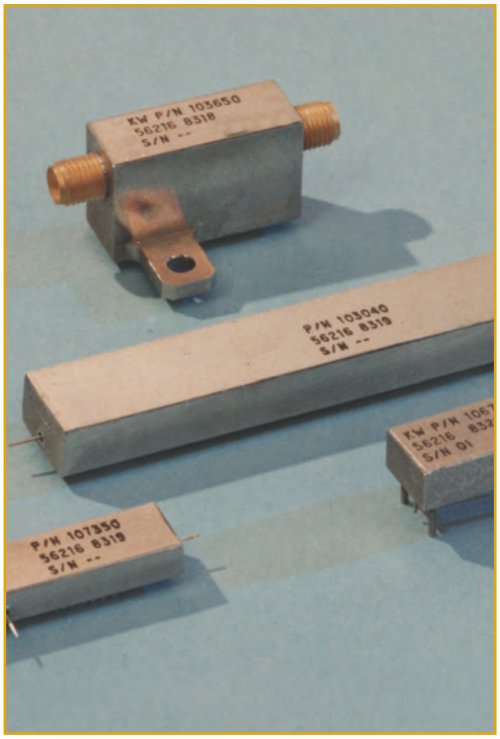
Lumped Element

Typical Performance





Bandpass Filters

Passband (Ripple)	VSWR	Insertion Loss @ Fo	60dB Rejection From Fo		Dimensions
MHz		dB (max)	dBc	MHz	Inches
.450 - 30 (.75 dBc)	1.5:1	1.5	-30 -30	.225 60	2.5 x 2.0 x .8
29.85 - 30.15 (2 dBc)	2.0:1	8.0	-50 -50	28.3 31.7	1.5 x .75 x .27
159.5-1605 (3 dBc)	1.5:1	5.0	-35	+/-5	2.6 x 1.2 x 1.0
307-323 (1 dBc)	1.5:1	3.0	-20 -20	290 340	.57 x .4 x .24
700 - 1600 (2 dBc)	2.0:1	2.0	-58 -60	650 1800-3500 18500	2.7 x .5 x .3
1226 +/- 10 1575 +/- 10 (3 dBc)	1.5:1 1.5:1	1.0 1.0	-60 -50	800 2000	1.5 x 1.0 x .5
1900 - 5900 (1 dBc)	1.5:1	1.0	-70 -55	900 7900-20000	1.5 x .3 x .25
15.2-25 (1 dBc)	1.5 1	3	-75	18.0	.750 x .3 x .3

Lowpass Filters

Cut Off Freq.	VSWR	Stopband	Insertion Loss (max)	Dimensions
MHz		MHz dBc	dB	Inches
95	1.5:1	-90 @ 123	2.5	1.4 x .4 x .4
620	1.5:1	-90 @ 806	2.5	1.9 x .4 x .4
1900	1.5:1	-90 @ 2470 - 4950	2.5	1.4 x .4 x .4
5700	1.5:1	-90 @ 7400 - 15000	2.5	1.15 x .4 x .4
11500	1.5:1	7400 - 15000 -30 @ 13000	1.5	1.25 x .4 x .4

Highpass Filters

Cut Off Frequency	VSWR	Passband	Stopband	Insertion Loss (max)	Dimensions
GHz		GHz	GHz (dBc)	dB	Inches
.420	1.5:1	.420 - 1.0	-42 @ .350	1.5	1.4 x .4 x .4
1.0	1.5:1	1.0 - 4.0	-75 @ .50	1.0	1.0 x .4 x .39
1.75	1.5:1	1.75-10.0	-55 @ .50	1.0	1.0 x .5 x .4
6.0	2.0:1	6.0-18.0	-65 @ 4.0	1.0	.875 x .4 x .35
10.5	1.8:1	10.5 - 18.0	-40 @ 9.1	1.5	.875 x .3 x .3

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Combline and Interdigital Filters

30 MHz - 18 GHz

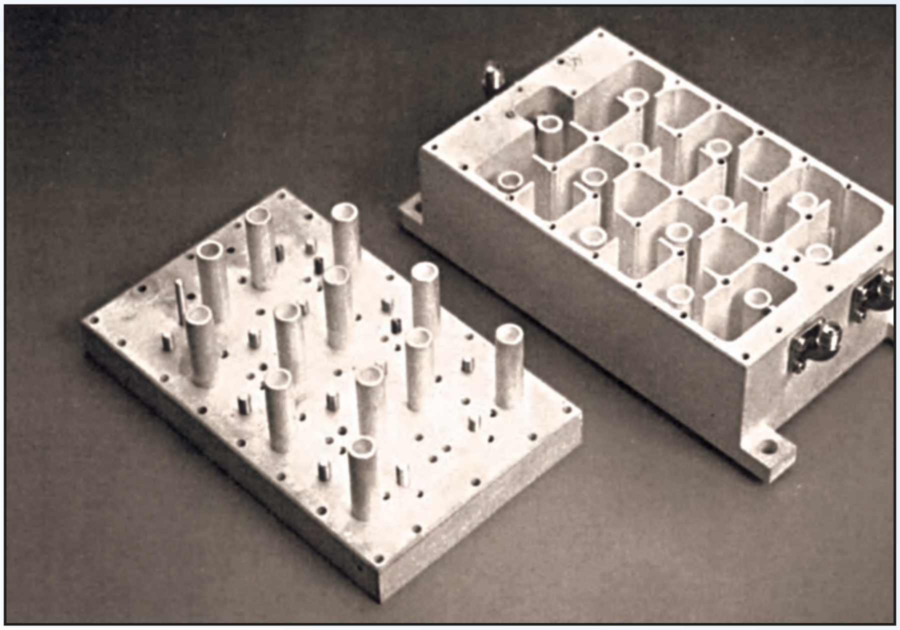
Bandwidth Of 1% To 66%

Low Loss

Combline filters are bandpass filters used in the frequency range of 30 MHz to 18 GHz. The structure consists of a series of TEM resonators of circular or rectangular cross-section resonated by a capacitor at the open circuit end. The bandwidth and response of the filter is governed by the coupling of each resonator to its immediate neighbor. This is also a function of the resonator size, resonator spacing and ground plane separation. Typical construction is silver plated aluminum. This achieves the lowest passband loss while maintaining a light weight. Computer design programs result in close correlation between theoretical and actual performance.

In applications where flat group delay narrowband filters are required, linear phase responses of typically 1 - 5% variations over 70% of the filter bandwidth can be achieved.

As the frequency of operation is reduced, the reactance components increase in physical size. But, for a given Q, the size of an air-spaced inductor increases as the frequency decreases.



Typical Combline Filter

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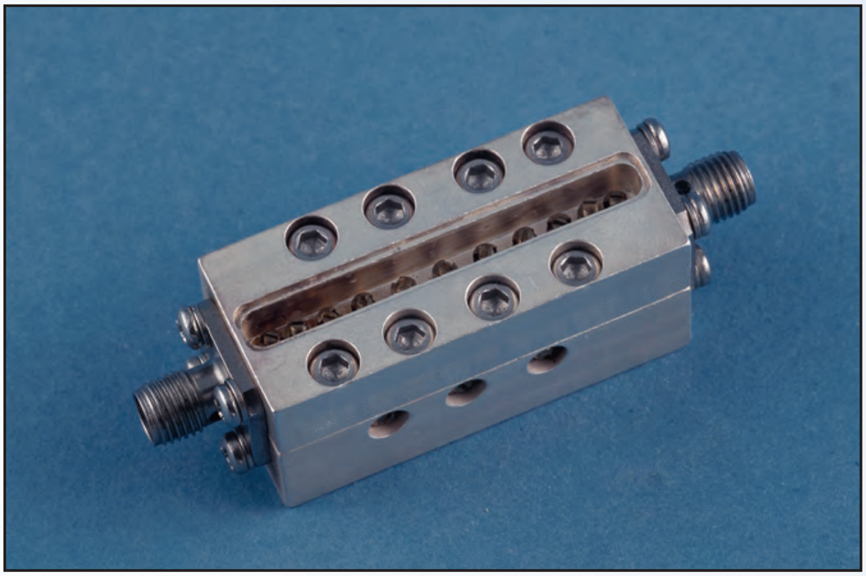
Combline and Interdigital Filters

Specification	Model K2C	Model K3C	Model K6C	Model K7C
Fo: (standard)	30 - 450 MHz	400 - 3000 MHz	2000 - 6000 MHz	6000 - 12400 MHz
(special)	20 - 600 MHz	250 - 4000 MHz	1500 - 14000 MHz	500 - 18000 MHz
# of Sections	3 to 6	2 to 7	2 to 7	2 to 4
Maximum VSWR	1.5:1	1.2:1	1.2:1	1.5:1
Temperature Range	-54° to + 100° C	-54° to + 100° C	-54° to + 100° C	-54° to + 100° C



Small Combine Filter

Interdigital Filters

Teledyne's interdigital filters fill the need for moderate and wide bandwidth filters in the 1.0 to 12 GHz. frequency range. Our standard unit is available with up to 17 sections, while custom designs can have 20 sections. Teledyne KW Microwave's interdigital filters offer low loss, high "Q" performance in package styles suitable for many applications, including space.

Specification	Standard	Special
Frequency Range	1000 - 10000 MHz	500 - 12000 MHz
# of Sections	3 to 10	3 to 20
Maximum VSWR	1.5:1	1.3:1
Temperature Range	-54° to +100° C	-54° to 125 °C

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Waveguide Filters

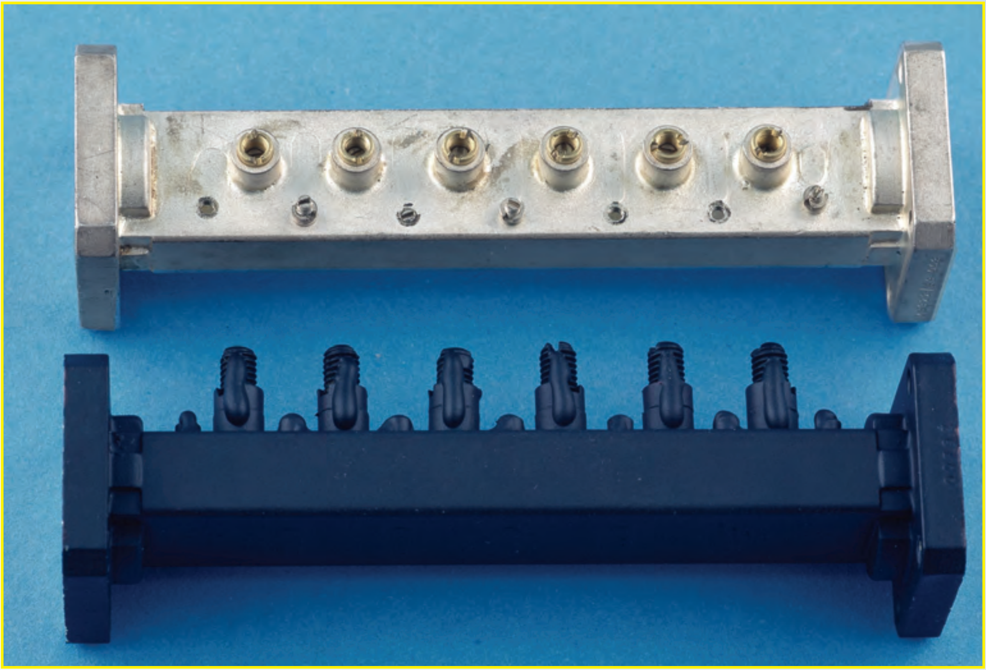
2 GHz To 40 GHz

Bandpass, Lowpass Or Notch Configurations

Provides For Lower Insertion Loss

Good For High Power Requirements

Waveguide Or Coaxial Interface



The major advantages of waveguide filters are high power handling and low loss performance.

Waveguide filters can be used in the frequency range of 2 GHz to in excess of 40 GHz. Waveguide can support an infinite number of field patterns (modes), each with a different guide wavelength. The normal mode used is the dominant TE in rectangular waveguide, although other configurations are used for special applications.

Rectangular Waveguide Filters

These can have lowpass, bandpass or bandstop characteristics. Lowpass filters are formed by means of a corrugated waveguide structure with adjacent high and low impedance sections.

The normal construction for bandpass filters is to place inductive obstacles, typically an array of posts, along a waveguide at spacings close to a half wavelength apart. The size, number and transverse spacings for the posts are the parameters that vary the filter bandwidth while the longitudinal spacing determines the center frequency of the filter.

Bandstop filters can be made by placing short circuited cavities approximately a quarter wavelength apart along the filter body.

The major advantages of waveguide filters are high power handling and low loss performance. Waveguide filters are fabricated in aluminum, brass, copper or Invar. Materials are selected to ensure that the lowest possible passband insertion losses are achieved. The advantage of Invar construction is its low thermal expansion which provides optimum temperature stability. Aluminium construction is best suited were weight is of major importance. All filters have tuning screws which are locked and sealed with epoxy.

"Waveguide filters are fabricated in aluminum, brass, copper or Invar."

The interface is normally in the appropriate waveguide size. However, for most types, integral coaxial transitions on one or both ports are available as options.

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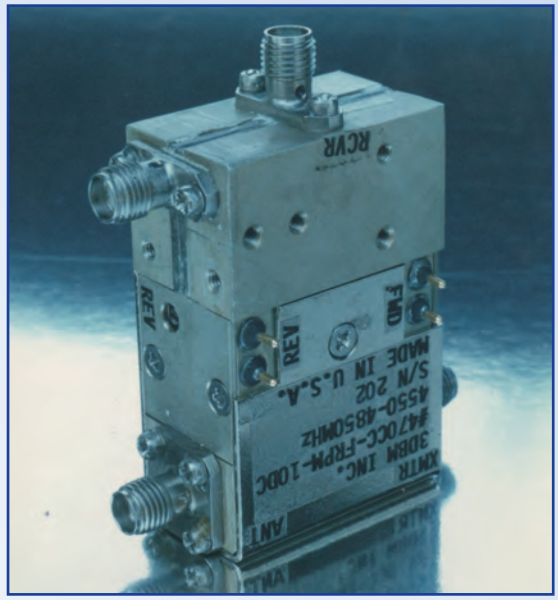
Iso Filters

Can Apply To Any Catalog Standard Filter

Good Out Of Passband VSWR

Low - Loss Impact



One solution to limit reflected power is to use an Iso-Filter

Teledyne KW Microwave have a number of integrated solutions available to improve out of band performance.

As implied, an Iso-Filter is the combination of an isolator and a filter. The main advantage of the Iso-Filter is in how the filter itself works. When a signal hits the input port of a filter one of two things can happen to the energy; it can pass through (transmission) or it can be reflected (return loss or VSWR). Although the overall performance of a filter can be set by the number of sections and the Q or size of each of the sections almost all of its selectivity is due to reflectivity of the device outside of its passband.

What this means is the return loss or VSWR is very bad outside of the passband. Therefore any signals in these frequency ranges will be reflected back to the generating source. In most cases, this is not a problem; but, if it is, there are a limited number of solutions. They are listed below:

1. The most simple and cost effective solution is the use of an attenuator pad. The worse case return loss will be twice the loss value of the attenuator pad. For example a 3 dB pad will have a minimum of 6 dB return loss. Unfortunately not all applications can afford the extra insertion loss.

2. The next simplest solution is an Iso-Filter. The isolator will typically be less than 1 dB of loss with a rejection of better than 20 dB. These typically cost more than the attenuator pads.

3. The third alternative is a terminated complimentary multiplexer scheme. These have the least amount of effect on the insertion loss, however they are very costly custom items. This usually relates to long lead times.

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Diplexers and Multiplexers

10 MHz To 26 GHz

Lumped Element

Combline

Interdigital

Stripline

Waveguide Filters

Suspended Substrate

Contiguous

Non-contiguous

Teledyne KW Microwave has designed and manufactured a wide variety of multiplexers using lumped element, combline, interdigital, suspended substrate, stripline, and waveguide filters. Dimensions range from 0.3 X 0.6 X 1.0 inches for a L-band lumped element diplexer, to 2 X 3 X 8 inches for a high power coaxial diplexer in the same frequency band.

Designs are obtained using analytical techniques implemented by proprietary computer programs, and basically are guaranteed to work with little or no empirical adjustments, apart from the usual tuning arrangements.

Multiplexers provide a passive, low-loss, means of splitting or combining two or more signals of different frequencies at a common port while providing isolation between the signal ports.

In addition to the standard filter parameters, the following specs are required when defining multiplexer performance.

Crossover Insertion Loss

The absolute insertion loss at the point of equal loss between adjacent channels of a multiplexer.

Crossover Frequency (Fc)

Fc refers the frequency at the point of crossover. This parameter is important to the systems designer and provides an easily identified reference point in the measurement of multiplexer performance.

Narrowband Multiplexers.

Narrowband multiplexers (channel bandwidths less than 20%) are formed by combining bandpass filters. Contiguous and non-contiguous multiplexers are available and, depending on the characteristics required of each channel, may be fabricated using lumped element, combline, interdigital or suspended substrate designs. In each case, the overall performance is close to the performance achievable from discrete bandpass filters in the particular technology.

If appropriate, hybrid solutions can be provided.

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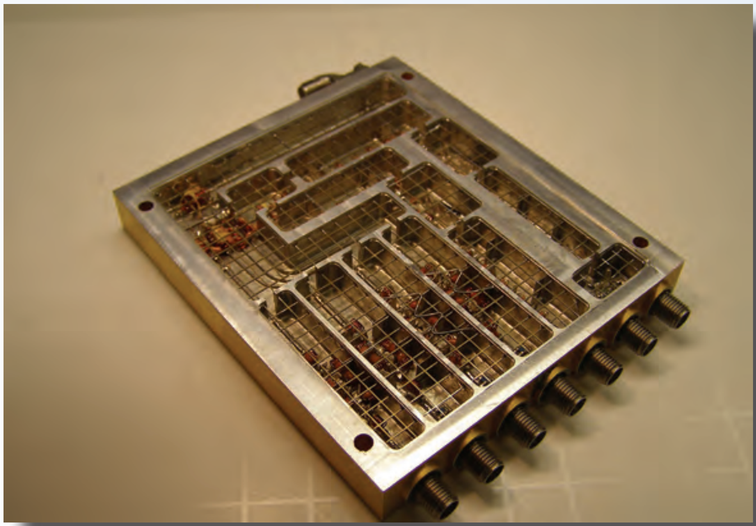
Diplexers and Multiplexers



Contiguous and non-contiguous multiplexers are available and, depending on the characteristics required of each channel, may be fabricated using lumped element, combline, interdigital or suspended substrate designs.

Broadband Multiplexers

Broadband diplexers operating from 20-2000 MHz are formed by combining a highpass filter with a lowpass filter and modifying critical element values to ensure a good input and output match and improved rejection in the stopbands. More complex multiplexers are achieved by cascading diplexers.

SPECIFYING MULTIPLEXERS

When specifying multiplexers please provide the following information:

1. Number of Channels
2. Bandwidth of Channels
3. Passband Insertion Loss
4. Stopband Frequencies
5. Stopband Rejection
6. Crossover Frequencies
7. Crossover Insertion Loss

Teledyne KW Microwave is able to offer the following special options:

AMPLITUDE MATCHING
PHASE MATCHING
GROUP DELAY MATCHING

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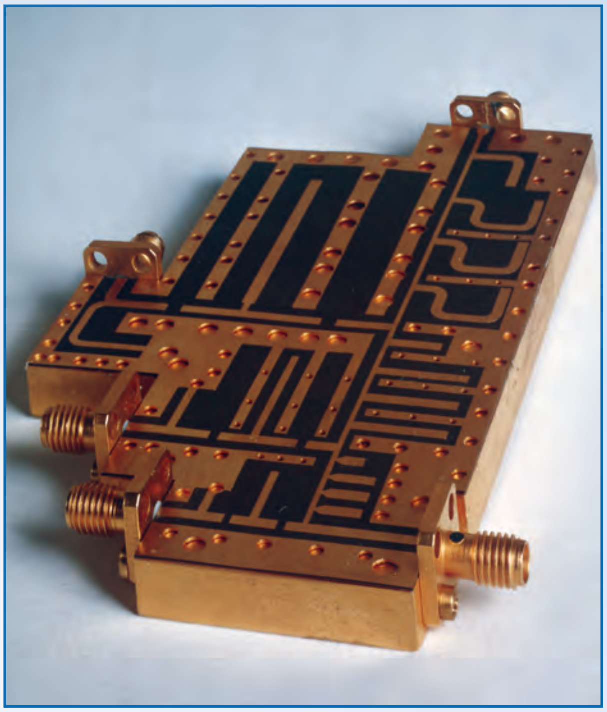
Diplexers and Multiplexers

Suspended Substrate Multiplexers

Suspended substrate readily lends itself to broadband configurations and is widely used in systems where small size, high performance and light weight are essential features.

Using this technology, broadband diplexers covering DC to 26.5 GHz are formed by combining a highpass filter with a low pass filter with modifications to critical values to ensure good input and output match and improved rejection in the stop-band. More complex multiplexers are designed by cascading diplexers. These diplexers can achieve < 5 dB crossover insertion loss, 60 dB of rejection within 10-15% of crossover, while exhibiting less than 1 dB insertion loss within the passband. The passbands are the bands outside the crossover regions, which are within +/-5% of the crossover frequencies.

Skirt characteristics can be supplied at both extreme band edges where 60 dB attenuation is achieved.



Suspended Substrate Multiplexer

Channelizers

These filter banks are often used in receivers having good resolution, high speed and high probability of intercept. Such units are fed from a common antenna with the common input multiplexed to provide a bank of channels each defined by a bandpass filter and terminated in a video detector.

Depending on the frequency and bandwidth of the receiver, and the bandwidth and selectivity of each channel, the multiplexing may be achieved in a variety of ways. Power splitting, tandem circulators, traditional loss-less multiplexers, lossy and loss-less manifold multiplexers and hybrid solutions are utilized.

The ultimate channel frequency performance is similar to that obtained from an individual bandpass filter of the same format.

Typical Performance of Suspended Substrate Multiplexer

Frequency Range:	DC - 26.5 GHz Crossover Frequency Range: 0.5 - 16 GHz
Passband Insertion Loss:	4.5 - 5.0 dB
Selectivity (typical):	>60 dB within 10 - 15% of crossover
Temperature Range:	-55 to +125 °C.

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Diplexers and Multiplexers

Typical Coaxial Diplexers (Combline and Interdigital)

Passbands/MHz	VSWR	Insertion Loss Across Passband/dB	Rejection From F_o dB / MHz		Typical Dimensions/Inches
1773-1973 1825-1845	1.25:1	1.5	70 85	32 32	7.1 x 3.2 x 1.63
2318-2354 2383-2419	1.25:1	1.5	60 60	62 62	4.90 x 3.0 x 2.065
2330-2344 2394-2408	1.25:1	1.5	60 60	30 30	7.38 x 3.8 x 1.97

Suspended Substrate Diplexers

Frequency Range/GHz	Cross-Over Frequency/GHz	Cross-Over Frequency Insertion Loss/dB	Passband Insertion Loss/dB	VSWR	Selectivity 60 dB / GHz	Dimensions/Inches
DC-4.0	2.0	4.5	1	1.6:1	DC-1.7 2.3-4.0	3.0 x 2.5 x .65
DC-8.0	4.0	4.5	1	1.6:1	DC 3.4 4.6-8.0	2.5 x 2.5 x .5
DC-10.0	6.0	4.5	1	1.6:1	DC-5.1 6.9-10.0	2.0 x 2.0 x .5
DC-12.0	8.0	4.5	1	1.7:1	DC-6.8 9.2-12.0	1.5 x 1.3 x .5
DC-15.0	10.0	4.5	1	1.8:1	DC-8.5 11.5-15.0	1.3 x 1.2 x .5
DC-18.0	12.0	4.5	1	1.8:1	DC-10.2 13.8-18.0	1.0 x 1.0 x .5
DC-20.0	14.5	4.5	1	1.8:1	DC-11.9 16.1-20.0	1.0 x .5 x .9
DC-18.0	8.0	4.8	1	1.9:1	DC-6.8 9.2-18.0	1.2 x .8 x .5

Note: Selectivity typically with 15% of crossover frequency

Suspended Substrate Triplexers

Frequency Range/GHz	Cross-Over Frequency/GHz	Cross-Over Frequency Insertion Loss/dB	Passband Insertion Loss/dB	VSWR	Dimensions/Inches
DC-4.0	1.0, 2.0	5.0	1.0	1.8:1	7.75 x 2.6 x 0.65
DC-12.4	4.0, 8.0	4.8	1.0	1.7:1	4.0 x 2.5 x 0.5
DC-18.0	8.0, 12.0	4.8	1.0	1.8:1	2.5 x 1.5 x 0.5

Note: Selectivity typically with 15% of crossover frequency

Suspended Substrate Quadraplexers

Frequency Range/GHz	Cross-Over Frequency/GHz	Cross-Over Frequency Insertion Loss/dB	Passband Insertion Loss/dB	VSWR	Dimensions/Inches
DC-18.0	4.0, 8.0, 12.0	5.0	1.0	2:1	5.0 x 2.5 x 0.5
DC-18.0	6.0, 10.0, 12.0	5.0	1.0	2:1	4.5 x 2.25 x 0.5

Note: Selectivity typically with 15% of crossover frequency

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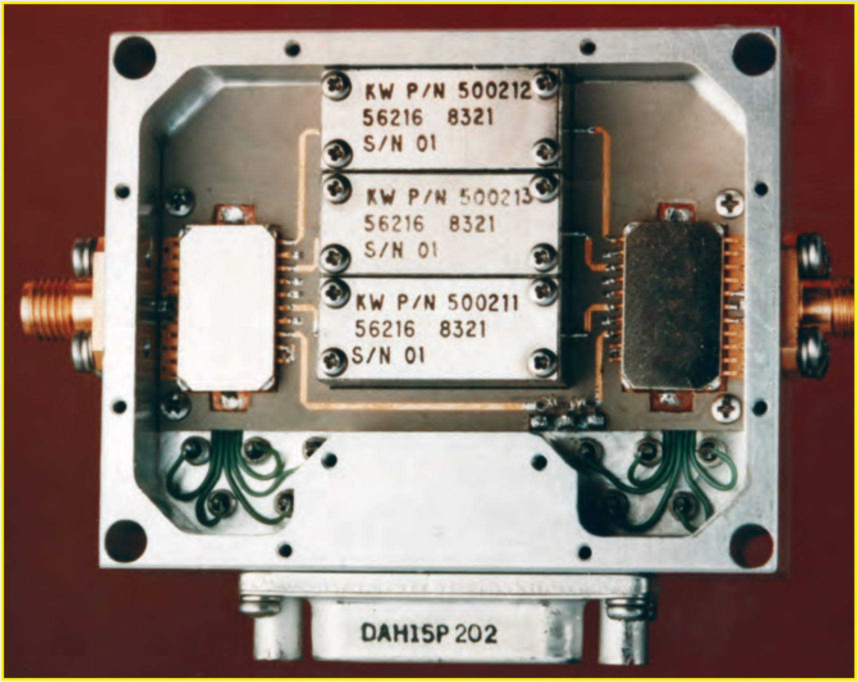
Switch Filters and PIN Diode Switches

Switch Filters

Teledyne KW Microwave can offer a variety of standard switch filters or custom designs for a customers unique application. Our current designs extend from 10 MHz to 26 GHz and have a typical switching time of 500 ns. These switch filters can be designed for pre-selection, harmonic rejection, signal leveling or multiply band frequency separation.

Teledyne KW Microwave will use a GaAs MMIC or discrete diode to control the switching technology. The switch can be integrated with suspended substrate lumped element, combline, printed microstrip filter technology. High Q lumped element filters are primarily utilized where size of the package is a major concern and the need for high output rejection is required.

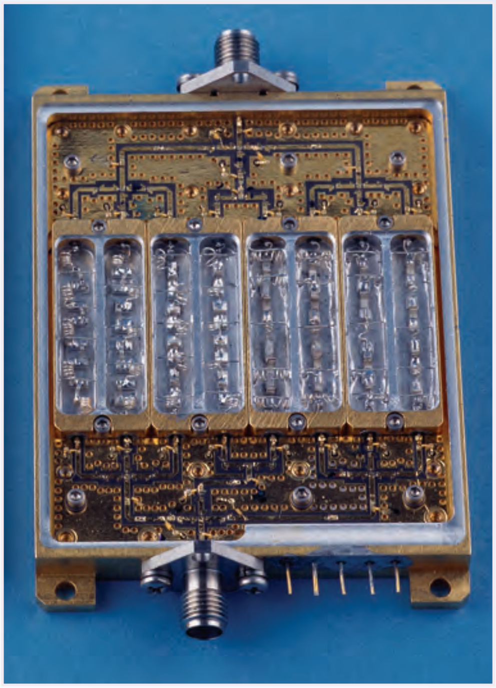


PIN Diode Controlled Switch

PIN Diode Switches

Teledyne KW Microwave offers a wide range of pin diode control products. We use GaAs Pin Diode or GaAs MMIC technology to achieve the durability, switching speed and electrical performance characteristics of our switches. Our switches have excellent insertion loss and VSWR performance over a wide operating band.

Teledyne offers our pin diode control products with standard logic controls of TTL, CMOS or ECL.



8 Channel Switch Filter

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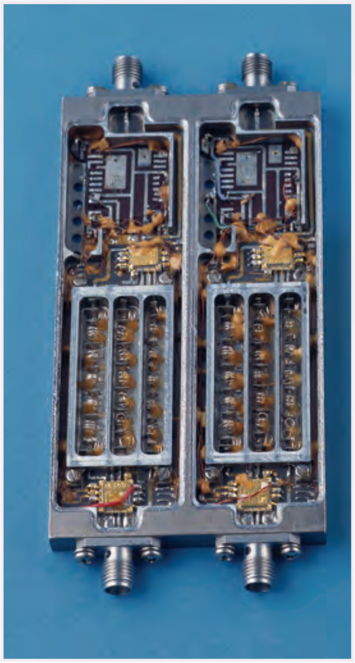
Switch Filters and PIN Diode Switches



Two 3 channel switch filters in a single package

Typical Switched Filter Requirements

1. NUMBER OF CHANNELS	n = (No. of Filters)
2. FILTER SPECIFICATIONS:	Standard Filter Spec's
3. ISOLATION:	>50 dB
4. Ultimate Rejection:	>60 dB
5. DC Power & Control:	+ 5 V @ 60 mA -15V@60mA TTL, BCD
6. RF Power:	100 mW
7. Video Leakage:	100 mV P-P
8. Switching Speed [1]:	1 μs (slow)
	200 ns (moderate)
	100 ns (fast)
9. Connectors:	SMA or PIN
10. Size:	Height .25" - 1.0" Width .5" - 3.5" Length 1.25" - 6.0"
11. Insertion Loss:	2 - 6 dB Typical
12. VSWR:	1.6:1 max.

Note: [1] Switching too fast with narrowband filters will cause ringing

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Glossary of Terms

Absolute attenuation: Attenuation measured with the zero dB, or reference point, equal to the signal level present with the filter removed from the test setup (straight-through).

Attenuation: Power loss in dB evidenced by a signal passing through a dissipative network (bandpass filter).

Bandpass filter: A filter that passes one band of frequencies and rejects both higher and lower frequencies.

Bandreject filter: A filter that rejects one band of frequencies and passes both higher and lower frequencies. Commonly referred to as a notch filter.

Bandwidth: The width of the passband of a bandpass filter. Typically the frequency difference between the lower (Fl) and upper (F2) 3 dB relative attenuation points.

Bessel function: A mathematical function used to yield a maximally constant time delay in a filter, with little if any consideration for amplitude response. This function is very close to a Gaussian response.

Butterworth function: A mathematical function used to yield a maximally constant amplitude response in a filter, with little if any consideration for time delay or phase response.

Cauer function: See Elliptic function.

Center frequency (Fo): In standard bandpass filters, the center frequency is geometrically related to the 3 dB points Fl and F2.

$$Fo = \sqrt{F1xF2}$$

In linear phase (constant delay) band-pass filters the center frequency is arithmetically related to the 3 dB points Fl and F2.

$$Fo = \frac{F1 + F2}{2}$$

Crossover frequency: The frequency at which two adjacent channels (the upper frequency of the lower channel and the lower frequency of the upper channel) are of equal amplitude.

Crossover loss: The loss that occurs at the crossover frequency.

Cut-off frequency (Fco): The upper passband edge in lowpass filters, the lower passband edge in highpass filters, or the passband edge closest to the stopband.

Decibel (dB): A unit used to express the logarithm of the ratio between two amounts of power, P1 and P2. By definition:

$$dB = 10LOG_{10} \frac{P1}{P2}$$

Diplexer: A two-channel multiplexer of bandpass/bandpass design or highpass/lowpass design, with or without additional highpass and lowpass close-up filters.

Dissipation: Energy losses in a filter due to resistance.

Distortion: Generally, the modification of signals that produces undesirable end effects. These modifications can relate to phase, amplitude, and delay. The distortion of a sine wave is usually defined as the percentage of signal power remaining after the fundamental sine wave component has been removed.

Elliptic function: A mathematical function used to yield the squarest possible amplitude filter response with a given number of circuit elements. The elliptic function has a Tchebycheff response in both the passband and the stopband. The elliptic function filter has a poorer phase and transient response than any of the classical transfer functions.

Envelope delay: The propagation time delay of the envelope of an amplitude modulated signal as it passes through a filter. Sometimes called time or group delay, envelope delay is proportional to the slope of the phase shift response vs frequency curve. Envelope delay distortion occurs when the delay is not constant at all frequencies in the passband region.

Filter Q: An important parameter of bandpass and bandreject filters that affects both insertion loss and rejection.

$$\text{Loaded Q} = \frac{\text{Center Frequency (Fo)}}{\text{3 dB Bandwidth}}$$

Gaussian function: A mathematical function used to yield a filter that passes a step function with zero overshoot. Similar to a Bessel function filter.

Group or time delay: See envelope delay.

Highpass filter: A filter that passes high frequencies and rejects low frequencies.

Impedance: Usually taken as equal to L/C where L is total series inductance in Henrys and C is the total shunt capacity in farads. Characteristic impedance is measured in ohms (Ω).

Impulse: A pulse whose width is of such short duration that it may be regarded as infinitesimal - a spike.

Isolation: Typically the amount of attenuation between the switched filter's "On" channel and the "Off" channel(s).

Linear phase filter: A general term that defines a class of filters that exhibits a constant change in degrees per unit of frequency. The plot of frequency vs phase results in a straight line. This type of filter ideally provides a constant delay in its passband.

Load impedance: The impedance that normally must be connected to the out-put connections of the filter in order to meet filter specifications.

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Glossary of Terms

Lowpass filter: A filter that passes low frequencies and rejects high frequencies.

Monotonicity: Characteristic of the filter response that refers to the changes in slope of the attenuation response in the stopband (no comebacks). Properly designed lumped-element filters can exhibit monotonic responses of two to three octaves from center frequency.

Multiplexer: A frequency-selective network of filters in which one terminal of each filter is connected to a common port. Signals applied to the common port are separated according to the filter characteristics. Signals applied to the isolated ports are combined according to the filter characteristics.

Overshoot: The percentage by which an output signal exceeds it steady-state value when subjected to an input step function, pulse, impulse, or ramp.

Passband: The frequency range in which a filter is intended to pass signals.

Passband ripple: Variations in attenuation vs frequency within the passband of the filter.

Phase shift: The changing of phase of a signal as it passes through a filter. A delay in time of the signal is referred to as phase lag. In normal networks, phase lag increases with frequency, producing a positive envelope delay.

Pulse: Two step functions, one in the positive direction and one in the negative direction - separated in time by the pulse width.

Q (component): Quality factor of a capacitor or inductor equal to the ratio of its reactance to its equivalent series resistance.

Ramp: Linear increase or decrease of voltage or current during a specified time before reaching steady state.

Relative attenuation: Attenuation measure with the point of minimum attenuation taken as the reference, or zero dB. Relative attenuation equals attenuation minus insertion loss.

Response: Used to describe how a filter responds to input signals defined as the ratio of the input signal compared to the output signal (for amplitude and phase response).

Ringing: A damped oscillation in the out-put signal as a result of an input step function, pulse, impulse, or ramp.

Ripple: Refers to the wavelike variation in the amplitude response of a filter, usually measured in dB. Tchebycheff and elliptic function filters ideally have equal ripple characteristics; i.e., differences it peaks and valleys of the amplitude response in the passband are always the same. Butterworth, Gaussian, and Bessel function filters have no ripple.

Rise time: The length of time, on the initial input signal rise, it takes a step function at the output of a filter to move from 10% to 90% of its steady-state value.

Setting time: The time it takes for the output signal to settle within a specified overshoot percentage after the input has been subjected to a step response pulse, impulse, or ramp.

Shape factor: A useful way of specifying filters:

BANDPASS:

$$S = \frac{\text{ATTENUATION BANDWIDTH}}{\text{3 dB BANDWIDTH}}$$

BANDREJECT:

$$S = \frac{\text{3 dB BANDWIDTH}}{\text{ATTENUATION BANDWIDTH}}$$

LOWPASS:

$$S = \frac{\text{ATTENUATION FREQUENCY}}{\text{3 dB CUT-OFF FREQUENCY (Fco)}}$$

HIGHPASS:

$$S = \frac{\text{3 dB CUT-OFF FREQUENCY (Fco)}}{\text{ATTENUATION FREQUENCY}}$$

Step function: Sudden rise or drop in voltage or current.

Stopband/reject band: The area of frequencies where it is desirable to reject or attenuate all signals as much as possible.

Switching time: The difference in time between the input signal reaching 50% of its steady state and the output reaching 90% of its RF envelope.

Transitional filter: A filter that compromises between high-skirt selectivity and flat, passband group delay.

Tchebycheff function: A mathematical function that produces a filter response that ripples within certain bounds. This function produces a more square (greater rejection) amplitude response than the Butterworth function, but has greater phase shift and time-or group-delay variations. Tchebycheff function filters are designed to exhibit certain ripple response within the passband (.01 dB ripple, .05 dB ripple, etc).

Time or group delay: See envelope delay.

Transient response: The filter's response in time to an input signal.

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