FILTER PIN CONNECTORS

BENEFITS

The use of a filter connector has many significant advantages over the standard connector plus the use of separate filters. These include:

a. Weight and space savings of 75% and more are typical (Table 1).

TABLE 1 TYPICAL WEIGHT/SPACE SAVINGS			
	Standard Connector With Separate Filters	Filter Connector	Savings Realized
Space (cu. in.)	10.1	2.6	78%
Weight (grams)	495	189	72%

b. Greater reliability. In the filter connector, a single termination is all that is required. The standard connector requires three wiring connections: one to the connector; and one to each end of the filter. These additional terminations, plus the U-shaped failure rate of the discrete filter add up to increased costs for inspection and increased failure rates for the discrete filters and connector combination, when compared to the filter-connector.

c. Filtering occurs at the point at which unwanted signals would otherwise enter or exit the system. As a result, maximum unit efficiency is obtained.

d. Crosstalk or terminal-to-terminal coupling is virtually eliminated in the filter circuit design.

e. The need for "dog boxes" or false panels to prevent the radiations of the wires from the connector to discrete filters from affecting equipment is eliminated. Special assembly checks to assure the low impedance grounding of the filters and this enclosure are eliminated.

f. Cost comparisons show that total systemic costs favor the filter connector when the majority of lines in higher density connectors need filtering. (For filtering just a few lines, discrete filters are less total expense).

FILTER CONTACT DESIGN

Without altering the normal function of a standard connector contact, the filter contact provides attenuation at frequencies above a prescribed point (low pass). Through the use of special ceramic and ferrite compounds, shaped, plated and located appropriately, a network approximating a Pi-section low-pass filter is achieved on any or all contacts on a standard connector. "L" and multilayer capacitive "C" filters are also in use.

In the Pi-filters, a high-permeability ferrite tube surrounds the contact forming the equivalent series inductor (through of as a one-turn toroid). The shunt capacitor members appear as a result of selective plating of a high dielectric constant ceramic tube. Both ends of this ceramic tube which concentrically envelops the ferrite are attached to the contact to form an extremely compact circuit. The plated outside diameter of the ceramic tube is the common electrode and is attached to the shell through a ground plane. In addition to this interconnection of filter to shell, the ground plans forms an "electric wall" preventing alternate paths for radiated leakage, a frequent problem in discrete filter circuits at higher frequencies.

The "L" section filters usually consist of a multilayer capacitor concentric about the central pin (or socket) contact with a ferrite next to it. The ground plane connects to the capacitor. This type of filter increases RF resistance at high frequencies and compensates for resonances that may occur in purely capacitive designs (usually above 600 MHz). Most filter connector manufacturers design for this, and hence the often-wide differences between "typical" and "guaranteed minimums." (Always check specifications and if minimum are not specified, contact the supplier for firm inputs.)

OPERATING CHARACTERISTICS

Typical manufacturer electrical and filter capacities are as follows:

AVAILABLE FILTER		LOW FREQ	MID FREQ	STD FREQ	HIGH FREQ
VOLTAGE RATING		200 V DC - 120 V AC RMS 400 Hz			
CURRENT RATING		7.5 AMP DC			
INSULATION RESISTANCE, 2 MIN. ELECTRIFICATION TIME MAX. AT 25° C AND 500 V DC		5000 MEGOHMS MINIMUM	10,000 MEGOHMS MINIMUM		
DWV, SEA LEVEL, WITH 500 MICRO-AMPS MAX. CHARGE/DISCHARGE		500 V DC (MAY BE RUN CONCURRENTLY WITH INSULATION RESISTANCE)			
CAPACITANCE AT 1 KHz, .1 V RMS PICOFARADS		75,000 150,000	6,000 12,000	2,500 5,000	500 1,000
ATTENUATION PER MIL-STD-220 AT 25°C WITH NO APPLIED VOLTAGE OR CURRENT	FREQ MHz	ATTENUATION (db)			
	.1	2-5			
	1	15 MIN	2-5		
	2	20 MIN	5 MIN	2-5	
	10	35 MIN	20 MIN	12 MIN	2-5
	100	50 MIN	55 MIN	50 MIN	30 MIN
	500 TO 10,000	50 MIN	60 MIN	60 MIN	50 MIN

Figure 1: Filter Specifications

The 3 dB point is defined as the frequency at which the pass band ends and the attenuation per octave filter-capability really begins to take effect. This is also the frequency at which the filter has reduced the power by 50%, as shown by the following:

$$dB = [10 \log (\frac{P_2}{P_1})] = 10 \log (\frac{1}{2}) = 3 \text{ dB}$$

The cut-off frequency (3 dB level) can be seen in relationship to the load and source resistances (R_L and R_S) by the following equation for a simple first order low pass shunt capacitor filter.

$$3 \text{ dB} = A = 20 \log_{10} \left| 1 + j\, \omega C \left(\frac{R_L R_S}{R_L + R_S}\right) \right|$$

where: A = attenuation at cut-off frequency

$j = 1\sqrt{-1}$

$\omega = 2\pi f$

C = filter capacitance

For systems with greater resistances (vendor data usually references a 50 ohm balanced system) significantly better filter effectiveness is seen, and the 3 dB point is found at lower frequencies.

Temperature: Most filter contacts can take 150°C or higher without damage, but the user must keep in mind the shift in capacitance just after the Currie Point is passed (typically around 130°C) and the fact that at higher temperatures you are operating at lower values of the attenuation curve.

ATTENUATION TEST METHODS

The standard method of testing is per MIL-STD-220A, "Method of Insertion-Loss Measurement." To obtain smoother test curves, some suppliers add 50 ohm resistance between the filter and the test terminals. The user can check for this by seeing if the attenuation curve crosses the zero dB line or starts at 6-8 dB. The resistor shifts the results-curve up approximately 6 dB but otherwise should not affect accuracy.

INTERNAL CONSTRUCTION

Filter contacts: The filters are attached by various means to the central metal contact around the circumference. Manufacturers are limited by the fact that these hybrid filter connectors must mate with standard, often MIL-specification mates and therefore have fixed center-to-center contact spacing. Wall thickness reaches a mechanical/physical minimum and then the filter O.D. is maximized.

Ferrite materials can be selected for their permeability and thermal stability. The ceramic capacitor material is usually varied based upon the following:

$$C = \frac{K\,(.614)\,(B)}{\log_{10}\left(\frac{O.D.}{I.D.}\right)}$$

O.D. = tube outside diameter
I.D. = tube inside diameter
B = electrode length

The above sometimes may be an over simplification since it does not include fringe capacitance.

Ground Plans: This is the area of greatest difference between suppliers and several methods have been shown to have equally good performance. Thus, performance, *not internal* design, should be specified.

The most common forms seen use one of the following:

1. Conductive epoxy or soldering the filter to a solid metal ground plate. (Connector is epoxy potted).
2. Multiple finger tines from photo-etched copper alloy material grasp the filter O.D. (contacts are rigidly held in place but may be removed for repairability).

The first technique provides rugged construction, and the epoxy must be very closely matched for thermal expansion to the metal shell.

The second method is patented by ITT Cannon Electric.

Other ground plane approaches include the use of conductive elastomer materials (usually silicone rubber). These would be good for crimp filters except for their shrinkage and setting characteristics. Resistances and, thence, conduction of the noise current will vary with thermal aging.

Termination: Termination types are typically solder pot, printed circuit pin terminals, or crimp contacts (the latter having the filter on the removable contact). Solder termination can result in a shorter connector since the contact retention areas are not required.

Crimp inserted filter contacts are still developmental as evidenced by user-reported problems, including the following: inadvertent use of damaged filters; reduced insulation resistance and attenuation due to handling of filter, dirt in grounding area; reduced attenuation due to ground plane "yields" (they must give and permit multiple insertion-extraction), lack of contact availability for field replacement, etc. They are usually rear insertion and front release in design. This is sometimes awkward due to limited behind-panel space.

APPLICATION CONSIDERATIONS

Attenuation: The user should be careful not to over-specify the level of attenuation needed. For example, shifting from a "Pi" filter of typically 8000 picofarads with a 3 dB point at 1 MH_Z, to a multilayer "C" filter of 100,000 picofarads will often double the price.

A.C. Voltages: A filter that has a 200 volt DC working voltage typically has a 125 AC rms working voltage. Thus, D.C. is not equivalent to A.C. rms. De-rating for altitude is typical of connectors. A good rule-of-thumb to follow is that the D.C. voltage value for 70,000 feet is one-third that of sea level.

Transients: Filter connectors are available to meet the DC requirements of MIL-STD-704A, but not always the AC spike levels. Thus, protection must be provided in those instances.

Repairability: Considering the cost of filter connectors, repairability is a desirable feature. This should be performed by the manufacturer who should be expected to re-issue it with a full warranty. However, under certain failure modes, repairability is not possible, whether the connector is of crimp or solder termination design.

Mounting: The filter connector and the panel must have conductive surfaces. If flange-mounted, usually the four screws will provide sufficient surface pressure and EMI gasketing is not needed. Integral filtering in cable-connecting plugs is *not* recommended due to the rugged physical abuse usually given cables and plugs. The use of grounding fingers between bayonet type connectors and plugs is required in order to duplicate the filter's wall mounted performance. Possible poor conductivity from the plug to the receptacle, and then to the panel is another problem.

Termination: For solder pots, use low powered irons (60 watts or under) at highest temperature. Performance is equivalent to non-filter type connectors as long as reasonable core is used. MIL-STD-454 is often referenced. For crimp; be sure correct special tools are provided. Check the surface conditions and cleanliness of filter O.D. before and after crimping. Use design wherein each contact has its own retention mechanism wherever possible to avoid mislocation with respect to ground plane.

PROBLEMS AND FAULT-FINDING

The most common application problems occur when: (1) the connector shell is not grounded properly; (2) the wrong filter attenuation was specified; or (3) the filter was destroyed by inadvertent dielectric (hi-pot) testing at *standard* connector levels above filter capability.

In trouble-shooting, always check the capacitance and the insulation resistance. Damaged parts so located often can be repaired at factory. If the filter has shorted to ground, then normally, it has suffered from excessive voltage and the ground plane around it may have also been damaged.

PRODUCT AVAILABILITY

Filter connectors are available from many suppliers as equivalents or mates to the following standard types:

MIL-C-26482	NAS-1599
MIL-C-83723	NASA-40M39569B

Dual sourcing can often be obtained for these other types:

ARINC 404	MIL-C-24308	MIL-C-27599
MIL-C-38999	MIL-C-83733	MIL-C-5015

Hermetic (glass-to-metal) sealed versions with leakage rates of 10^{-8} atmosphere cc/sec. are available. Several manufacturers have in-line adapters of the MIL-C-26482 variety that fit between mating connectors to provide immediate filtering without rewiring. The in-line filtered adapters are good for testing to see if a certain filter provides sufficient attenu ation but are not recommended for volume production due to expense over the filtered receptacles.

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