KNOWLEDGE BASE KB-003

How to Specify Circulators and Isolators

GENERAL

This WEBSITE lists the specification of RFCI's isolator and circulator product line. Standard 3-Port and 4 Port with connectors, miniature drop-ins, and surface mount device (SMD), covering the range of 50MHz to 20GHz are described. All models have been optimized to meet the following parameters for most popular applications: bandwidth, VSWR, isolation, insertion loss, temperature and size. These and other parameters can be selectively optimized for your specific application. The following is a brief description of the various parameters and options available.

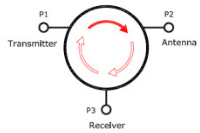

FIGURE 1
3 PORT CIRCULATOR

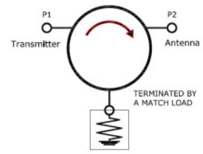

FIGURE 2
2 PORT ISOLATOR

VSWR

The reflective property of each port of an isolator or circulator is usually specified in terms of VSWR. For critical applications a Smith Chart, with an impedance plot recorded at a specified reference plane, can be provided. A typical specification for VSWR is 1.22:1; however a value of 1.10:1 can be provided for narrow-band applications.

ISOLATION

This parameter is used to specify the revers loss characteristics of an isolator. All isolators described in this catalog consist of a circulator with an internal termination. The parameters isolation, VSWR, and insertion loss are required to specify an isolator whereas a circulator is completely defined by only the VSWR and insertion loss. Although a circulator can be made into an isolator by terminating one port, it does not have an intrinsic isolation value. The isolation measured would be dependent on the VSWR of both the termination and the circulator port.

Example: A circulator has a measured VSWR of 1.22:1 for all the three ports. If a perfect test termination with a VSWR equal to 1.00 were available to place on Port 3, the resulting isolation from Port 2 to Port 1would vary between the two VSWR's. The resulting isolation value is a function of the VSWR of the test termination and how it may phase with the VSWR of the circulator port.

Most isolators are specified at 20dB but values of 26 to 30 dB can be obtained for narrow band applications.

INSERTION LOSS

This parameter is used to specify the forward loss characteristics of an isolator or circulator. Most Catalog models have an insertion loss specification of 0.25 dB to 0.4 dB Many low noise systems require an isolator with as low an insertion loss can be minimized by using special ferrite and dielectric materials. Losses as low as 0.10 dB have been provided in large production quantities.

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TEMPERATURE RANGE

The operating temperature range of an isolator or circulator is limited by the ferrite materials available. In general the lower the operating frequency, the greater the temperature sensitivity an isolator will have. Temperature compensation can be used at some operating frequencies Catalog units make use of temperatures from -40 ºC to + 85 ºC are common although some models are limited to 0 ºC to 50 ºC.

Storage temperatures are generally the military range of -54 ºC to +95 ºC, although temperature of -60 ºC to +125 ºC can also be provided.

MAGNETIC SHIELDING

Catalog units all have sufficient magnetic shielding for general handling and mounting. These units can usually be mounted to within 1/2 inch (12.7mm) of one another or from other magnetic materials without degrading electrical performance. For more stringent applications (mounting in direct contact with a magnetic plate) additional shielding may be required and necessitate a larger package size.

RFI SHIELDING

Standard coaxial units have an RFI leakage measured at close proximity of 30 to 40 dBc. Special packaging and sealing methods can improve the RFI shielding. Leakage values in excess of 60 dBc can be provided but require additional shielding to be incorporated during the initial design. Drop-in and SMD models are designed to operate in an open substrate environment. RFI leakage is usually not specified for these components.

TERMINATION RATING

The termination rating must be sufficient to safely dissipate the reverse power that is expected to occur under normal or anticipated fault conditions. The reverse power will be determined by the power applied to the input port of the isolator and the mismatch on the output port. The reverse power will be dissipated by the internal termination.

All units and drop-in models have terminations rated at 1K watt peak and 200 watts average power. If frequency, bandwidth, and size permit, higher peak and average power values can be specified. Average power rating of less than 50 watts for the higher frequency Standard Models usually do not require cooling other than mounting to heat sink. Higher power levels may require the termination be mounted directly to a heat sink or use other forms of cooling. Allowance must be made for some degradation in isolation performance for the higher power rated terminations.

POWER RATING

The input power to an isolator or circulator can be supplied from a CW or a pulsed sourced. In the case of a pulsed source both the peak and average power components of the pulse train should be specified in order to determine an adequate safety margin for a particular model.
The peak power can be at high enough level to cause breakdown or arcing. This generally results in permanent degradation of performance. A proper connection selection and an optimized internal geometry are required to maximize the peak power capability of a particular model.

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Contingent on the peak power level and other parameters, units can be provided that will operate to altitudes in excess of 100,000 feet without breakdown.

The peak power level can also cause an increase in the insertion loss in a below resonance type design, due to non-linearity effects of the ferrite material. This increase can occur at peak power levels considerably lower than that required for breakdown or arcing. The increased insertion loss will cause more power to be dissipated in the ferrite region of the device, which will result in overheating. Higher peak power levels can be obtained by using special doping of ferrite materials.

Non-linearity effects insertion loss do not occur in the above resonance models. Most drop-in models below 3 GHz center frequency are also above resonance designs.

The average power rating of an isolator or circulator is determined by the insertion loss, internal geometry of ferrite region, and type of cooling available. The insertion loss of an isolator or circulator will cause some of the average power to be absorbed and dissipated in the ferrite region as heat. Adequate cooling is necessary to insure the ferrite material does not reach an excessive temperature. Mounting to a heat sink for cooling is sufficient in many cases if the average power is moderate.

In high power applications, a component with a high VSWR connected to the output port of an isolator will reflect a substantial amount of power. The temperature of the ferrite region as well as the internal voltage will increase causing the performance to deteriorate or arcing to occur before full rated input power can be realized.

Isolators and circulators that must meet stringent peak and average power levels require design considerations of many electrical parameters. The normal and worst case load VSWR conditions and available cooling must be specified when ordering high models.

CONNECTORS

Connectors used on the Standard Coaxial Models are SMA and N type female. Other connector types can be provided based on operating frequency and package size, however certain types may cause electrical degradation. Most versions of SMA and Type N connectors can be supplied for special applications. Removable versions of SMA male and female connectors can also be provided.

INSERTION PHASE

Many applications require isolators and circulators to be supplied as phase matches sets. Although the catalog models are not phase matched, this feature can be provided on a specified basis. The tolerance in phase matching will depend on the particular model and size of the lot to be matched. Phase matched pairs can usually be provided within 5 degrees.

Linearity of the insertion phase can also be specified, it is usually defined as a deviation from a best fit straight line of insertion phase versus frequency.

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Load Improvement Factor Using an Isolator

$$VSWR_{max} = VSWR_{iso} \times \frac{1+A}{1-A}$$

where

$$A = ANTILOG_{10} \frac{ISOLATION + 20 \times LOG_{10} \frac{B-1}{B+1}}{20}$$

and

$$B = VSWR_{iso} \times VSWR_{load}$$

e.g. ISOLATION	=	-20dB
ISOLATION VSWR	=	1.25
LOAD VSWR	=	2.00

$$B = 1.25 \times 2.00 = 2.50$$

$$A = ANTILOG_{10} \frac{-20 + 20 \times LOG_{10} \frac{2.5-1}{2.5+1}}{20} = ANTILOG_{10} \frac{-20 + 20 \times LOG_{10}\ 4286}{20}$$

$$= ANTILOG_{10} \frac{-20 + 20 \times (-.3680)}{20} = ANTILOG_{10} \frac{-27.26}{20}$$

$$= ANTILOG_{10} -1.368 = .04285$$

$$VSWR_{max} = 1.25 \times \frac{1+.04285}{1-.04285} = 1.36$$

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