

APPLICATION NOTE  
ANV002

# ISOLATOR



[www.valvo.com](http://www.valvo.com)

Bötelkamp 31, D-22529 Hamburg, GERMANY || Phone: +49 - 40 547 544 60 Fax: +49 - 40 547 544 666 || Email: [info@valvo.com](mailto:info@valvo.com)

An Isolator is defined as non-reciprocal, passive two ports, ferromagnetic device in which power is transmitted in one direction and absorbed in the other direction.

Isolators are non-reciprocal devices, meaning their behavior in one direction is very different from that in the other direction.

### Working Principle:

An Isolator utilizes a transversely magnetized ferrite junction to direct incoming microwave energy. When a signal enters the device, it travels in the direction of the flowing magnetic field. In this way the signal is directed to the desired port on the device. An RF signal experiences a low loss in the direction of arrow and high loss in reverse direction while propagating through the Isolator (see Figure 1).

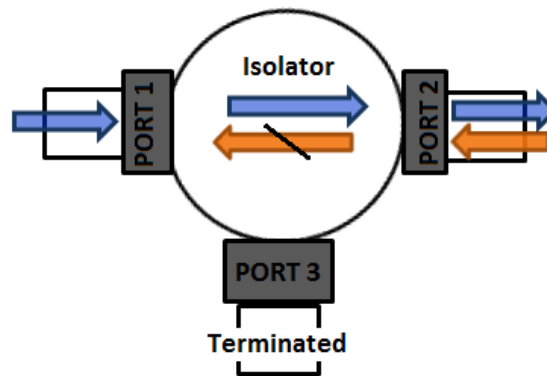


Figure 1: Isolator Working Principle

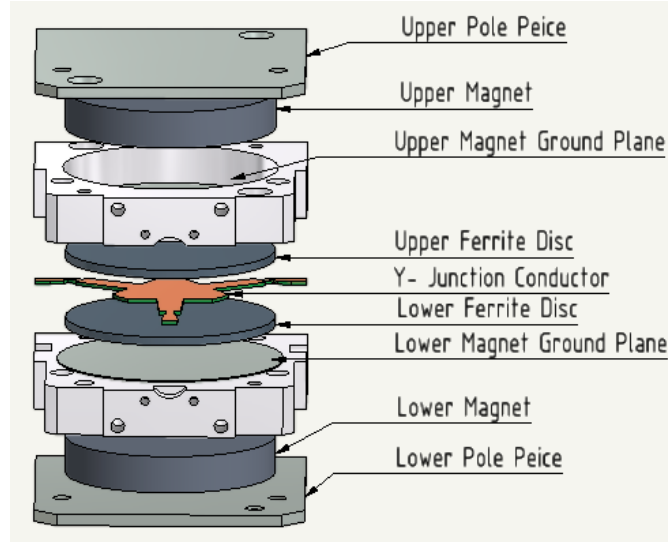
Due to only two ports, an Isolator has only one path for RF energy to flow where the power is transmitted in one direction and absorbed in the other direction. That means RF energy can only enter port 1 and travel to port 2. Any RF signal that enters from port 2 will be directed to the matched termination on port 3 and will be dissipated as heat. This mechanism heavily attenuates an RF signal entering port 2 before it reaches port 1.

To have a better idea how the applied magnetic field controls the RF signal flow in an Isolator, consider a glass filled with water. Now, stir water in a clockwise direction using a spoon. If we put small thermacol balls in water and continue to stir, it is observed that thermacol balls easily follow the circular motion of the water. Also it would be impossible for the thermacol balls to move in a counterclockwise (opposite) direction because the water motion is too strong.

The ferrite discs and permanent magnets inside the Isolator create very strong rotary magnetic fields similar to the water motion in the glass. This leads to follow the magnetic flow by any RF/microwave signals in the desired frequency band from one port towards the next adjacent port and not in the opposite direction.

### Construction:

Typical junction Isolator consists of a Y-junction stripline circuit sandwiched between two ferrite discs, an upper and lower magnetically biased permanent magnets and ground planes. The ferrite materials, magnets are selected according to the frequency of operation, input power ratings and intended application. In an Isolator, the magnetic field is applied through the vertical axis of this assembly, results into a circulation of the RF energy from one port to the other, depending upon from which port energy is coming from.



*Figure 2: Isolator Construction Elements*

As shown in the *Figure 2*, two relatively large planes of ferrite material are arranged either in thin triangular, circular or hexagonal shapes. A Y-shaped conductor called as 'inner conductor' having three arms is interposed between these ferrite plates. This conductor junction connects to port connectors of port 1 and port 2 while third arm is connected to the termination. Outside the ferrite discs flat permanent magnets are arranged with mild steel ground planes and pole pieces. This arrangement allows concentrating magnetic flux through the assembly, magnetically biasing the garnet material. This whole arrangement is then enclosed in plated steel casing which provides a high immunity to outside magnetic influences and protection from any mechanical damages.

### Performance Parameters:

An important consideration when selecting an Isolator is to ensure the device has adequate performance specifications for the given application. Insertion loss, VSWR and Isolation are the basic and most important performance parameters for Isolators. These parameters have a direct trade off with bandwidth, with increase in the operating bandwidth there is degradation in their values.

#### Isolation:

A measure of the separation of signal levels on adjacent ports of an Isolator is called as Isolation. It is measured in *dB*. The greater the isolation value, the lesser will be the interference from a signal on one port relative to an adjacent port.

This isolation is due to a termination attached to port 3 of the Isolator. This termination inside Isolator shell is also known as the load element. When load element is perfectly matched, the RF signal is dissipated as a heat, avoiding its reflection. Isolation is mainly dependent on following two parameters:

- Termination match level
- VSWR of port 3

In case of the poor match on port 3, expected isolation is below *10 dB*. When port 3 match is improved to VSWR of *1.10:1* by using a good termination device in the circuit, then the isolation would improve to over *20 dB*. For the same quality of termination and VSWR values (*1.05:1* or better) comparatively better isolation (around *25 dB*) can be achieved for narrowband units than that for broadband units (around *15-20 dB*).

In some applications greater isolation is required (30 to 40 dB). In such situations a dual junction Isolator is used, by the combination two Isolators (see Figure 5).

The VSWR value on port 3 represents the absolute maximum amount of energy that will reflect off from port 3 when a  $50\Omega$  load is connected on it. In order to dissipate this reflected energy safely, Isolator isolation value must be equal to or higher than VSWR value for a given bandwidth.

### Insertion Loss (I.L.):

Transmission path insertion loss is another important parameter when selecting an Isolator. The total amount of energy lost while transmitting the RF signal from one port to another port of an Isolator is called as Insertion Loss.

As stated above, Isolator is a passive RF component, so a signal traveling through it will undergo some attenuation. Insertion loss is the ratio of the output signal to the input signal and is measured in decibels (dB).

$$I.L. = 10 \log_{10} \left[ \frac{P_{out}}{P_{in}} \right] \text{ [dB]}$$

The insertion loss is frequency dependent, it increases with operating frequency. Hence, insertion loss of an Isolator becomes more significant at higher frequencies due to more power being dissipated as a heat. Typical values of Isolator insertion loss are of the order 0.2 to 0.4 dB.

For the same quality of load termination and VSWR values narrowband Isolators comparatively have less insertion loss (around 0.35 dB) than that for broadband units (up to 1.5 dB).

### VSWR:

VSWR stands for voltage standing wave ratio. The ratio of the reflected power to the incident power of standing waves created due to impedance match imperfections between RF source and load.

These standing waves are unwanted as the transmitted energy gets reflected and travels back to the source. It may damage the RF signal source.

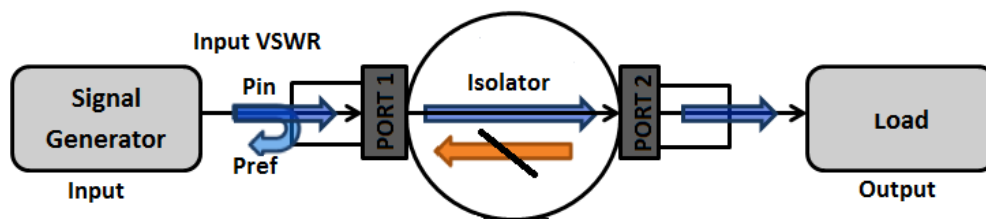


Figure 3: Isolator VSWR

The reflective property of each Isolator port is characterized by the reflection coefficient magnitude  $|\Gamma|$ .

$$|\Gamma| = \sqrt{P_{ref} / P_{in}} = V^- / V^+$$

Where

$P_{ref}$  : reflected power [W]

$P_{in}$  : incident power [W]

$V^-$  : reflected wave [V]

$V^+$  : incident wave. [V]

The resulting VSWR is given by:

$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

The effective input VSWR of an Isolator will vary as a function of the load VSWR. If the output load mismatch is increased, more energy is reflected towards the termination port. After attenuated by the isolation it is then reflected back to the input. Due to which there is increase in total VSWR observed at the input. Therefore, a low VSWR specification is always desirable.

VSWR is expressed in ratio form relative to 1 (example 1.25:1). Following are two special cases of VSWR:

- VSWR of  $\infty:1$  is obtained when the load is an open circuit
- VSWR of 1:1 is obtained when the load is perfectly matched to source impedance.

### Power Ratings:

Power ratings are a measure of maximum RF signal power handling capacity of an Isolator, without degradation in performance, signal distortion and /or attenuation. Exceeding these absolute ratings can cause malfunctioning of the Isolator. Depending on the nature of applied RF signal, an Isolator can have following different power ratings:

**Average Power Ratings:** The Average power represents the maximum power that the Isolator can handle when power is applied continuously. This can be the average power of a continuous wave (CW) signal, or the temporal average of the power of a pulsed signal. In the case of a CW signal, the average power rating of the Isolator must be greater than the average power of the applied RF signal. Whereas for pulse signal, the Isolator average power rating must be greater than the product of temporal peak and duty cycle of the applied RF signal.

**Peak Power Ratings:** The capability of the Isolator to handle applied pulsed RF signal with certain peak level. The temporal peak level of applied RF signal must not exceed the peak power rating of the Isolator.

**Reflective Power Ratings:** The capability of the Isolator terminated port (e.g. port 3) to handle and dissipate the reflected RF signal from output port (e.g. port 2) is known as reflective power ratings. This power rating depends on the quality of termination which can be customized during manufacturing process. In order to dissipate this reflected energy safely, matched termination power ratings must be equal to or higher than the reflected power ratings.

In case when the termination receives too much power for long period, it will be damaged. If the termination is damaged due to excessive power levels, the reflected signals will be directed back to the RF signal source because of the circular signal flow. The power ratings of the Isolator are determined by the following primary factors:

- **Voltage levels:** Voltage levels are ultimately determined by the incident and reflected signal levels and the effective VSWR of the Isolator.
- **Heat dissipation:** Heat is generated in the Isolator because of insertion losses and reflections. This heat is nothing but unwanted form of power. Hence, it should be dissipated otherwise it can cause following adverse effects on the Isolator operation:
  - Degaussing of the permanent magnets that bias the ferrites.
  - Once the magnets are completely degaussed, the dielectric will melt which eventually destroys the Isolator.
  - Thermal expansion of the internal circuit to distort geometric parameters and thereby degrading quoted specifications.

Heat dissipation is mainly determined by the impedance match quality and power ratings of an Isolator termination. Hence, sometimes it is beneficial to operate the Isolator with heat sink, to handle power levels which are closer to the maximum power levels of the Isolator.

### Group Delay:

The time taken by the applied RF signal to travel from input port towards the output port of the Isolator is called as Group delay. It is typically expressed in picoseconds or nanoseconds; it indicates the phase linearity of the Isolator.

Isolator group delay measurement is done using frequency domain method. This involves considering the vector S-parameter data over desired frequency range for the Isolator. From this S-parameter data set group delay is evaluated as a function of frequency.

Mathematically, it is the negative of the rate of change of phase with angular frequency.

$$\tau_g = - (\partial\phi / \partial\omega)$$

Where,

$\phi$ : total phase shift	[Radians]
$\omega$ : angular frequency	[Radians/Seconds]
$f$ : frequency	[Hertz].

It is desirable to have a group delay value that is constant relative to all frequencies in the band of interest. A constant group delay represents a linear phase over the desired frequency band. On the other hand large fluctuations in group delay represent phase nonlinearities caused by the Isolator. These nonlinearities in a transmission path of RF signal are undesirable, as they indicate the signal degradation by the Isolator.

### Spin Waves:

Spin waves are associated with Isolator ferrite discs and their measurement is important to determine the power handling of ferrites. Power handling capability of Isolator in turn depends on the power threshold of ferrites. Above the threshold power level, there is an abrupt rise in the peak power. At certain critical RF power level, spin waves excitation starts.

Spin wave instability disrupts the RF signal driven uniform mode. The excited spin waves are out of the phase with uniform mode and have same or harmonics frequencies of the uniform mode. These form a wave pattern causing the saturation of the main resonance line width. As saturation level begins to increase absorption within the ferrite increases nonlinearly.

These spin waves eventually increase heat and Isolator insertion loss than the specified values.

### Applications:

#### Signal Source Protection:

An Isolator is used to isolate microwave components from each other when working into an open or short circuit. It isolates the unwanted reflected signals which may cause damage to the RF transmitter and other units. As shown in the Fig. Isolator is placed in the measurement path of a RF test bench between a signal source and the device under test (DUT).

By doing so we ensure that signal reflections caused by any mismatches will dissipate at the termination of the isolator and not travel back into the signal source. Isolators are used for decoupling of RF signal source and load stages thereby reducing load return loss, VSWR and intermodulation distortions.

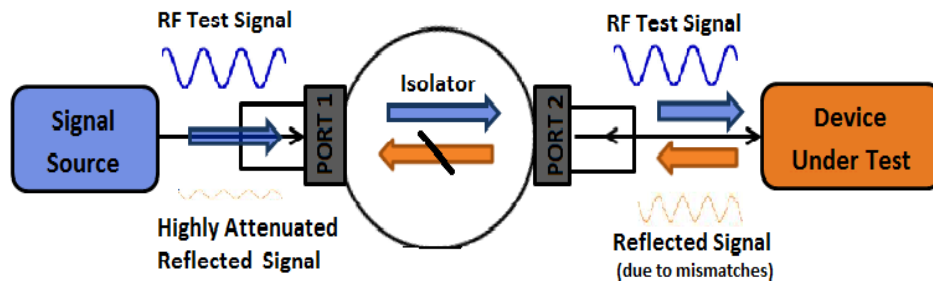


Figure 4: Signal Source Protection

### High Isolation:

For applications where higher isolation and much better directivity are needed, a dual junction Isolator is used. A dual junction Isolator is series combination two Isolators integrated in a single package.

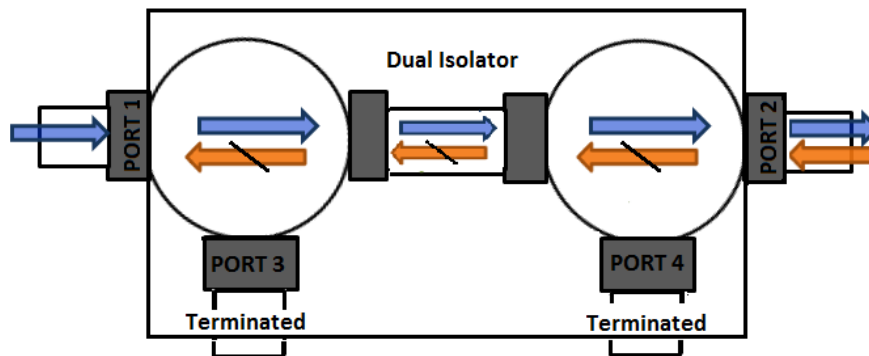


Figure 5: Dual Isolator

As shown in *Figure 5* a constructed dual Isolator has four ports with following status:

- Port 1: Input
- Port 2: Output
- Port 3: Terminated
- Port 4: Terminated

Applied RF signal is forced to flow from port 1 to port 2; while ports 3 and 4 are internally terminated with matched loads. When travelling from port 1 to port 2 transmitted signal cross two ferrite junctions. In this way very high isolation is achieved between the input and output. Typical isolation obtained with a dual Isolator is in the range of 40 to 50 dB.

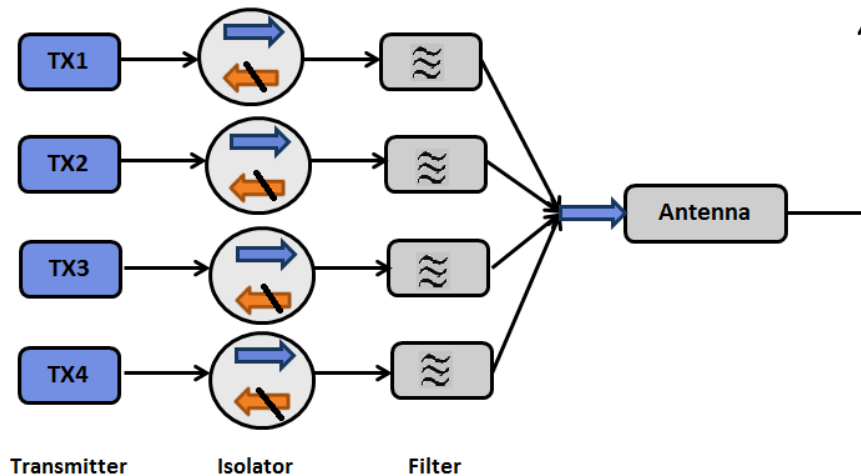
### RF Link Combiner:

Apart from its typical applications an Isolator can be used as a RF signal combiner for multiple transmitters in the VHF/UHF bands.

As shown in the *Figure 6*, the transmitter is connected to a cavity, which is tuned to its signal, via an Isolator. Depending on coupling of the cavity cable lengths of  $\lambda/4$  or odd multiples of it or  $\lambda/2$  or multiples of it, connect the different cavities with a star point, which leads to the antenna.

The transmitter signal travels to the star point through the Isolator 1 and the cavity 1. The other transmitters have different operating frequencies, therefore the cavities are tuned to different frequencies too, and the

cables transform their impedances to high impedance at the star point. This allows the signal of the transmitter TX1 travel to the antenna, attenuated about  $1.5\text{ dB}$  by cavity 1 and losses in the cables and the other cavities. The losses in the other cavities depend upon the frequency spacing, the coupling and the Q-factors of the cavities. The major advantage of this configuration is that, the total loss of the signal in the combining network does not increase significantly with increase in the number of transmitters. For the 4 transmitters the combining loss is typically  $2\text{ dB}$  which is much less than the combining loss of  $7\text{ dB}$  using the conventional  $3\text{ dB}$  Hybrids. In this manner the combining network of up to 18 transmitters can be formed in the UHF-band.



*Figure 6: Radio Link Combiner*

Using the above principle RF amplifier stage combiner and radio link combiner networks can be designed using Isolators.

### RF Decoupling:

When transmitter / receiver is directly connected to an antenna it may be influenced by antenna impedance changes. These impedance variations are caused due to snow or near-by obstacles, can introduce the intermodulation products. This can be avoided by an Isolator connected between antenna transmitter/receiver.

The same principle can be used to achieve fine tuning, reduce coupling and avoid overloading between two or more amplifier stages.

### Application Areas:

Isolators are an important device for any industry that utilizes radio frequency or microwave signals for communication. Following are some industrial fields served by Isolators:

- Television & Radio broadcasting
- Radio links & telecommunication networks
- Aviation & navigation industries
- Military equipment & Radar systems
- Laboratory measurement systems
- Industrial microwave heating



### Operating Precautions:

Like other high frequency components Isolators have some kind of operating safety and handling precautions. In this section the Isolator protection measures have been considered.

### Operating Temperature:

The material properties of ferrites and magnets used in Isolators are temperature dependent. This can cause unstable performance characteristics over operating range. This mainly depends on the magnetic field, applied to saturate the ferrite material. Following techniques can extend the Isolator temperature performance range by a significant amount.

- Temperature compensated magnets and ferrites materials need to be used where wide temperature ranges are required.
- For proper thermal behavior Isolator is installed such that ambient temperature air must be allowed to circulate freely.
- External heat sinks and forced air cooling systems must be used under high heat dissipations and high ambient temperatures.

### External Magnetic Fields:

Isolators have permanently biased magnets that produce strong fields to control RF signal flow. When an Isolator is placed in close proximity to another magnet/magnetic fields the two magnetic fields interact with each other.

Isolators are normally semi-shielded for operation in close proximity of large ferrous objects or external magnetic fields to minimize magnetic interference.

Even if the Isolator is magnetically shielded, strong AC field can affect its characteristics and even demagnetize the internal magnets, causing complete de-tuning. This mechanism is known as degaussing. At this stage the Isolator magnets are unable to control the RF signal flow. Hence, during storage it is recommended that Isolators should be separated by at least *3 inches* from other magnetic devices.

### On Site Mounting:

To ensure the satisfactory performance and avoid any mechanical damage to the Isolator following measures should be taken into account:

- With a proper assembly mount an Isolator in its specified operating conditions only
- Do not put too much stress on Isolator connectors
- If possible avoid mounting an Isolator near strong AC fields, magnetic fields and high power sources

### Packaging Types:

Depending on the application environment requirements various connector types can be supplied on Isolators such as:

- Drop-In Isolators
- N-Type Isolators
- SMA Coaxial Isolators
- Surface Mount Isolators

Some connectors however, cause limitations in the electrical performance of the high frequency and broad bandwidth Isolators. The package size may have to be increased to accommodate certain connector types. In general SMA male or female connectors are the most popular and easiest to install. Many times N-Type and right angle connectors of various types are used. Some connectors, however, cause limitations in the electrical performance of the high frequency and broad bandwidth Isolators.

Another connector configuration can be obtained by mounting the Isolator on a waveguide adapter. These devices are known as Isoadaptors. In such devices the large waveguide section provides a rigid base for the usually smaller coaxial circulator. These units are particularly useful when both waveguide and coaxial connectors are required. For example, the waveguide port can accept a signal directly from a waveguide antenna, while the output from a SMA connector port can be fed directly to solid-state amplifier.

Isolators can also be supplied with removable connectors. The connector shell can be removed to allow the center conductor to be directly soldered to a circuit board. Normally a high temperature solder is used for the internal solder joint so the pin will not move while being soldered to the board. This type of component is known as drop in Isolator.

# ABOUT VALVO

Valvo Bauelemente GmbH is a Germany based company specializing in design and developments of standard as well as special RF and microwave ferrite components. Valvo Bauelemente GmbH has more than 30 years of experience in providing well-rounded expertise solutions, technologies and design techniques.

The core of the company is a highly experienced team of respected technologists with developments of performance specific, high reliability complex products. The company has delivered excellent performance in several International R&D projects.

All products are controlled to the highest standards for guaranteed delivery and customer satisfaction.

## PRODUCTS

Valvo Bauelemente GmbH is focused on 50 MHz to 18 GHz Circulators, Isolators, Waveguides, and microwave ferrite devices. We offer narrow and broad band devices in coaxial, waveguide, drop-in constructions which are ideally suited for integration into compact systems.

Our highly skilled staff has a strong working knowledge and experience on a variety of ferrite devices with over 2,000 existing designs. This makes us possible to offer custom product solutions in addition to wide range standard product solutions.

For more information regarding products, technical data please visit [www.valvo.com](http://www.valvo.com) or please contact our sales department on [info@valvo.com](mailto:info@valvo.com) for any specific requirements.



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