

# Mini-Circuits® Directional Couplers

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The directional couplers offered by Mini-Circuits are designed for both commercial and military applications. All models are available in plug-in, flat-pack, surface mount, and connectorized SMA, BNC, Type N, TNC (option) packages. All units are designed and built to meet the environmental requirements of MIL-C-15370 and are manufactured to ensure statistical control of important parameters such as insertion loss and input/output return loss. Especially designed for high power applications, the H series of directional couplers can operate with up to 25 watts of RF input.

Mini-Circuits directional couplers are reactive devices featuring very low insertion loss. Most models have 3 ports, and are manufactured with an internal 50-ohm termination. In these cases, power coupled from any power incident to the output port (the reflected power) is absorbed and not available to the user. However, all 4-port (bi-directional) models have both the incident and reflected coupled power available. Examples are the ZFDC-20-1H and the BD-suffix models.

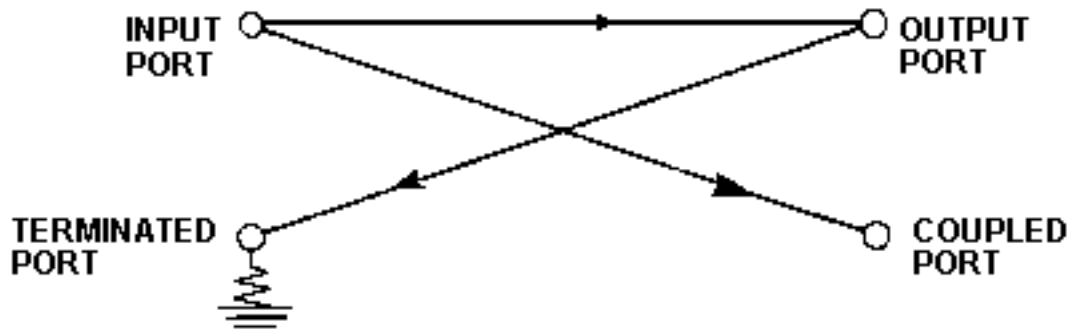
The basic function of a directional coupler is to operate on an input so that two output signals are available. However, when the input is applied to the opposite port of an internally terminated coupler, only one output signal is produced.

## **directional coupler characteristics.**

1. The output signals are unequal in amplitude. The larger signal is at the main-line output port. The smaller signal is at the coupled port.
2. The main-line insertion loss depends upon the signal level at the coupled port, as determined by design. The relationship is as follows:

<b>Coupling, dB</b>	<b>Theoretical Minimum Main Line Insertion Loss, dB</b>
6	1.2
10	.46
15	.14
20	.04
30	.004

3. There is high isolation between the coupled port and the output of the main-line.  
 A schematic representation of the coupler is as follows; the arrows show signal flow:



Key characteristics of a directional coupler include coupling coefficient, coupling flatness, main-line loss and directivity, defined on the next page. Mini-Circuits' full line of directional couplers, spanning 5 kHz to 2 GHz, provide excellent performance. They feature

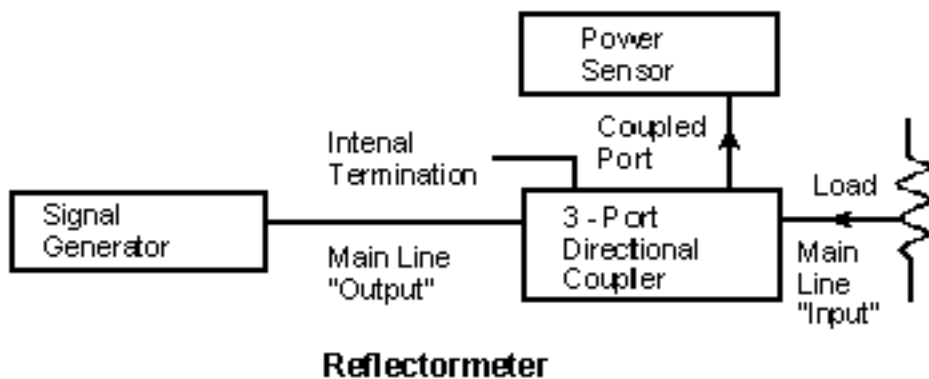
1. flat coupling over a broad bandwidth
2. low main-line loss, as low as 0.1 dB
3. directivity as high as 55 dB and
4. a wide range of coupling values, from 6 dB to 30 dB.

#### directional coupler applications

The high performance characteristics of these units enable the following signal processing functions to be accomplished:

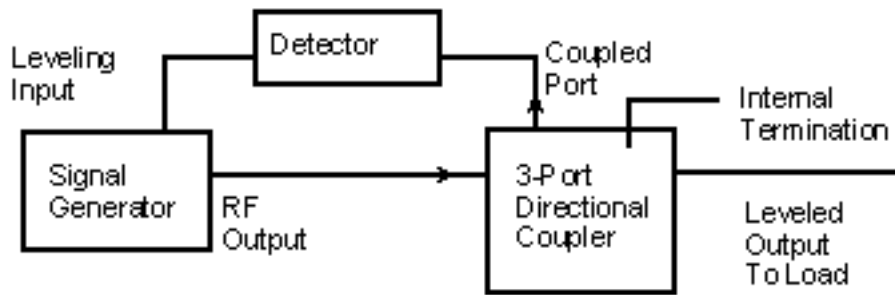
- measure incident and reflected power to determine VSWR,
- signal sampling,
- signal injection,
- signal generator/oscillator leveling,
- and power flow monitoring.

The following diagram shows how a high-directivity coupler is connected to sample reflected power from a load, which is connected to the setup after a fully-reflecting termination has been used to obtain a 0 dB return-loss reference.



The coupler is connected so that its coupled port samples power reflected from the load. It can thus be used to monitor fault conditions causing high VSWR, or to align the load device for low

VSWR. A coupler used in this manner is called a reflectometer. A leveling application is illustrated below.



**Leveled Generator**

The coupler is connected between a signal generator and a load, such that the coupled port samples power coming from the generator. It can thus monitor generator output independent of load conditions. The coupled-port signal can be used to level the generator output. Since generator output-power variation caused by load mismatch is suppressed by this feedback technique, the generator-coupler combination will have a source VSWR which is much better than that of the generator if it were not leveled.

## Modern Definition of Terms

### coupling coefficient

The ratio in dB of the incident power fed into the main port to the coupled port power when all ports are terminated by reflection less terminations.

### coupling tolerance

The allowable unit-to-unit variation in nominal coupling.

### coupling flatness

The maximum peak-to-peak variation in coupling coefficient that may be expected over a specified frequency range.

### coupling Loss

The reduction in power available to the main-line output due solely to power transferred to the coupled line. It is equal to the theoretical minimum main-line insertion loss.

## **main-line loss**

The change in load power, due to the insertion of the coupler in a transmission system, with reflectionless terminations connected to the ports of the coupler. The main-line loss includes the effect of power transferred to the coupled line.

## **directivity**

The difference in dB of the power output at a coupled port, when power is transmitted in the desired direction, to the power output at the same coupled port when the same amount of power is transmitted in the opposite direction. In the case of a bi-directional coupler, an alternative definition is the difference in dB of the power output of the two coupled ports, when power is transmitted in a constant direction on the main-line. Reflectionless terminations are assumed to be connected to all ports.

## **average power**

The CW average power handling capability with one-way transmission through the main line of the coupler under matched load conditions.

## **VSWR**

The standing-wave ratio at any port of a coupler is specified for the case of reflectionless terminations at all other ports. As with any device, VSWR is a measure of the quality of match relative to a given characteristic impedance.

## **bandwidth**

The range of frequencies over which performance falls within specific limits.

## **bi-directional coupler**

Another name for a 4-port coupler; that is, a single coupler having no internal termination. It is intended to allow forward and reflected signals to be sampled simultaneously.

## **dual directional coupler**

The combination of two 3-port couplers having their main lines cascaded, and their internally terminated ports facing each other at the interface between the couplers. This provides bi-directional coupler action, but with independent use of the coupled ports: A mismatched load applied to either of them will not affect the other.

# Most Often Asked Questions About Directional Couplers

*Q. What is the difference between a 3-port and a 4-port coupler?*

**A.** A directional coupler is basically a 4-port network. The main-line and auxiliary line each have 2 ports: A 3-port coupler has one end of this auxiliary line, the "isolated port," internally terminated. When all 4 ports are made available to the user, the device is called a "bi-directional coupler."

*Q. What advantage does a 3-port coupler have over a 4-port?*

**A.** Directivity of a coupler is strongly affected by the impedance match provided by the termination at the isolated port. Furnishing that termination internally ensures high performance.

*Q. Can a 4-port coupler be used to sample forward and reflected power simultaneously, by placing measuring instruments at both ports of the coupled line?*

**A.** Yes, but with care to provide good impedance match at all 4 ports of such a "bi-directional coupler." A coupler's directivity can be no better than the return loss of the terminations at the far-end main-line and coupled line ports; poor directivity causes inaccurate power monitoring by leaking forward and reflected signals into one another's paths. An alternative approach which overcomes this limitation is to use two 3-port couplers back-to-back; this combination is called a "dual directional coupler."

*Q. Is a coupled port an input or an output?*

**A.** It can be used as either. The coupling factor determines the attenuation between main-line and coupled line signals in both cases.

*Q. How is directivity measured when the 4th port is internally terminated?*

**A.** Measure the loss from the main-line input to the coupled port with the main-line output terminated. Then reverse the main-line connections. The difference in dB readings is the directivity.

*Q. How good does the directivity of a coupler have to be, as a reflectometer, to measure the return loss of an unknown impedance?*

**A.** A mathematical determination requires knowledge of phase relationships in a given case, but as a guide, less than 1dB error will result when the directivity is 20dB greater than the unknown's return loss.

*Q. How is power rating determined for pulsed-RF operation?*

**A.** The first limitation to peak pulse power which a coupler can handle is determined by

dividing the average power rating by the duty factor of the pulse train. This applies when the duration of each pulse is much shorter than the thermal time constant of the internal terminating resistor. If the pulse duration is greater than about a millisecond, the peak-power should be reduced.

A further limitation may be necessary to avoid saturation of the transformer core used in the coupler to avoid compression and distortion of the signal. For specific applications, consult the factory.

***Q. What performance degradation occurs if a 50-ohm directional coupler is used in a 75ohm system?***

**A.** The most pronounced effect is a reduction in directivity because the internal 50-ohm termination would give a VSWR of 1.5:1. The directivity would be limited to the corresponding return loss, 14 dB.

***Q. What effect does DC current through the main-line have upon performance?***

**A.** Most Mini-Circuits' couplers have their ports at DC ground. Therefore DC current would not pass through from in to out. However, for those models designed to pass DC current, when the current is large relative to RF current, signal compression and distortion due to core saturation may occur.

***Q. Does the input power rating apply equally to the main-line and coupled port?***

**A.** Not for a 3-port coupler. The coupled port rating is less, because power applied to the coupled port is almost entirely dissipated in the internal termination.

***Q. If the external load on the output port is mismatched, where does the reflected power go?***

**A.** Most goes back to the input port. A portion of it, corresponding to the coupling factor, is dissipated in the internal termination.

***Q. How do similar coupler designs in different case styles or with different connectors compare in performance?***

**A.** Performance is similar, except at high frequencies, where the rule generally is "the smaller, the better."

***Q. How important is grounding of pins?***

**A.** All ground pins should be connected to ground with short path length to obtain full directivity and VSWR performance.