VALON TECHNOLOGY

4002 Phase Detector - Typical Applications

The Valon 4002 Phase Detector is a unique, but very useful instrument for the Lab RF toolbox. The 4002 is compact and economical and can be installed in the user's equipment to provide system monitoring.

Reflectometer

The RF power reflectometer is the most basic application of the **4002 Phase-Gain Detector**. Together with a dual-direction coupler it provides the basic sampling and detection necessary to monitor reflection coefficient or VSWR from a non-ideal load such as an antenna.

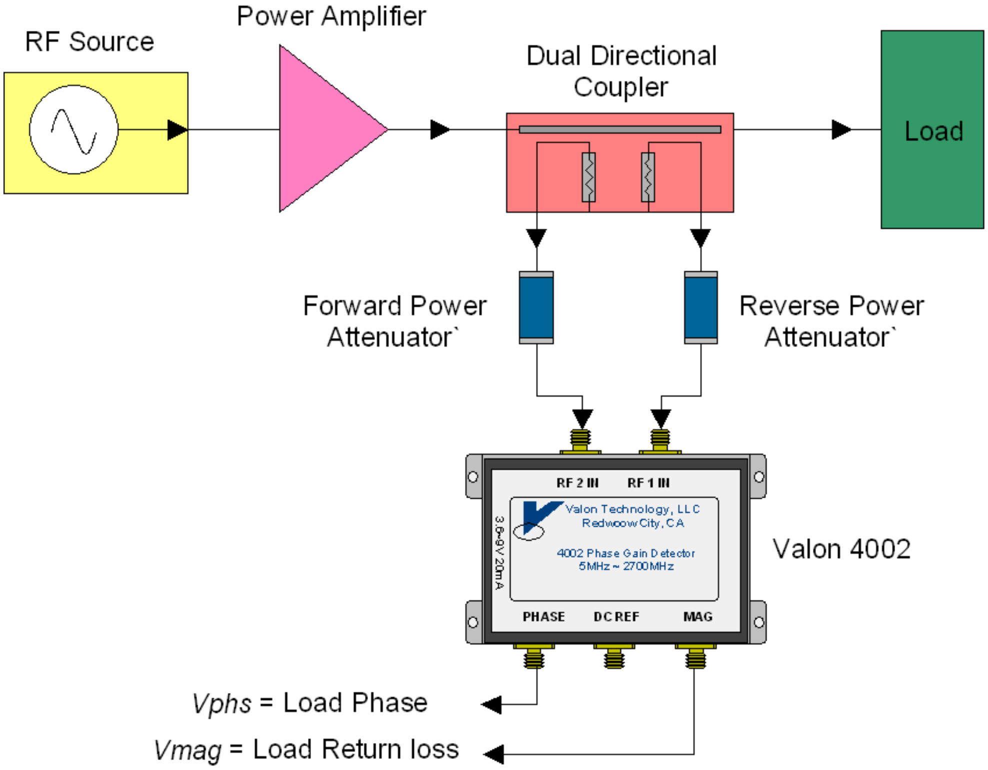

Figure 1 The Valon 4002 used as a VSWR detector

The example in **Figure 1** above shows how to connect the 4002 to a dual-directional coupler in order to measure return loss and phase of an RF Load. The coupler and attenuators need to be selected in order to accommodate the maximum forward power anticipated. For example if the power amplifier output power, PAout, is 100W or +53dBm, and the coupler coupling factor CPdB is 30dB then attenuators, AttdB should be selected in order to provide less than the maximum input power for the 4002 = 0dBm (1mW).

(1)
$$\begin{aligned}&0dBm \le PAout - CPdB - ATTdB\\&0dBm \le +53dBm - 30dB - ATTdB\\&ATTdB \ge 23dB\end{aligned}$$

For this example, the attenuators need to be greater than 23dB. A good solution would be use a pair of 30dB attenuators which would put forward detector power into the RF2in port of the 4002 at -7dBm. If the load had a VSWR of 1.2:1 the return loss would be 21dB and the reflected power into RF1in would be 21dB less than the forward power or -28dBm, still well within the range of the 4002.

The return loss, RTNLdB, of the load is now available at the MAG output connector. Vmag follows this expression:

(2) $$VMAGmV = MCP - [(RF2INdBm - RF1INdBm) * \frac{30mV}{dB}]$$

Where MCP is the one half the reference output = 900mV. An example for an ideal case where the dual directional coupler has no insertion loss, infinite directivity, and the coupling factor is 30dB and the attenuators values are 30dB exactly:

Let the Load have a return loss of 6dB or a VSWR or 3:1. In this example the power at RFIN2 is:

(3) $$\begin{gathered} RF2INdBm = PAout - CPdB - ATTdB \\ RF2INdBm = +53dBm\ - 30dB\ - 30dB\ \ = \ -7dBm \end{gathered}$$

The power at RF1IN is then:

(4) $$\begin{gathered} RF1INdBm = PAout - RTNLdB - CPdB - ATTdB \\ RF1INdBm = +53dBm\ - 6dB\ - 30dB - 30dB = -13dBm \end{gathered}$$

The VMAG voltage output from the 4002 then is:

(5) $$VMAGmV = MCP - [(RF2INBm\ - RF1INdBm) * \frac{30mV}{dB}]$$

$$VMAGmV = 900mV - [(-7dBm - -13dBm) * \frac{30mV}{dB}] = \ 720mV$$

The load return loss is then simply;

(6) $$RTMLdB = \left[(MCP\ - VMAGmV) * \frac{dB}{30mV}\right] = [(\ 900mV - 720mV) * \frac{dB}{30mV}] = \ 6dB$$

In the real world, where the coupler and attenuators are not perfect then a more accurate method is to first calibrate the reflectometer system by substituting an RF short for the Load. The return loss of the RF short is 0dB. Note, you should only use this method for RF sources that can tolerate 100% reflected power. Most low power sources, under a few watts can, some high power sources can momentarily, best to consult the source or power amplifier's manufacturer's data sheet.

With the short applied, measure and record Vmag_short_mV. Then apply the unknown load and record Vmag_load_mV. The load return loss is found by this expression:

(7) $$RTNLdB = \left[\left(Vmag_{short_{mV}} - Vmag_{load_{mV}}\right) * \frac{1}{30mV}\right] dB$$

Delay Line Frequency Discriminator (DLD)

The delay line frequency discriminator, or simply DLD, is a unique device for analyzing frequency changes vs. time events. Unlike a spectrum analyzer that measures RF amplitude vs. frequency, or an oscilloscope that can measure RF voltage vs. time, the DLD measures RF frequency vs. time. Typically, frequencies vs. time measurements, when required, are made with commercially available instruments such as modulation domain analyzers (MDA). This is a very expensive and uncommon instrument and not normally found in many laboratories. An inexpensive and simple alternative to the MDA is a DLD that you can assembly from some simple components.

Only three circuit elements are required to assembly as very useful DLD, a suitable delay line, a power splitter, and some form of phase detector. The 4002 Phase Gain Detector provides an excellent linear phase detector which is ideal for this application.

A simple implementation of a DLD used to characterize the frequency step response of an RF source (DUT) is shown in Figure 2 below. A controller is used to set the frequency of the DUT as well as provide a trigger signal to the oscilloscope. Other signal points of interest such as the VCO tuning voltage could be applied to an available channel of the oscilloscope for analysis to control commands and observed simultaneously with the DLD output.

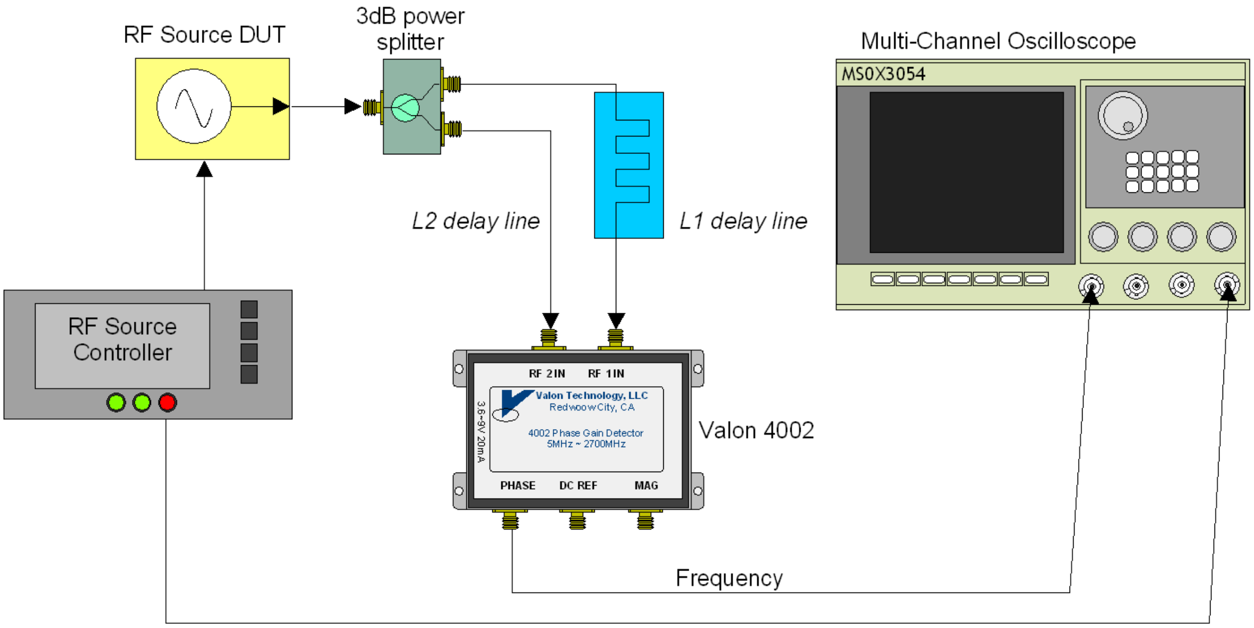

Figure 2 Delay line frequency discriminator setup used to test a signal source.

Some experimentation of the line lengths L1 and L2 is required in order to optimize the desired measurement type. The difference in line lengths of L1 and L2 is what determines the frequency scale or sensitivity. The greater the difference between lengths L1 and L2 the more sensitive the DLD will be to frequency changes.

The 4002 uses a form of exclusive OR (XOR) phase detector. The XOR phase detector has a very linear phase response with the disadvantage of having an unambiguous phase detection range is limited to pi radians or 180°. This limits the maximum frequency deviation the DLD can resolve. This limitation is not a problem but some thought in selecting the delay line length is required.

Delay Line Discriminator Example

There is a need to test a frequency synthesizer in order to evaluate the time it takes to change frequency and settle. The setup shown in Figure 2 is used and in this example the synthesizer is stepped from f_1 =1600MHz to f_2 =1700MHz is shown.

Let the two available delay line cables be L1=10cm, L2=50cm then:

(8) Phase difference at the lowest frequency: $\Delta\emptyset low = 2\pi(L2 - L1)\frac{1}{V_P}\frac{f_1}{c} = 1106\, deg$, and

(9) Phase difference at the highest frequency: $\Delta\emptyset high = 2\pi(L2 - L1)\frac{1}{V_P}\frac{f_2}{c} = 1175\, deg$.

Where $c = 2.998 * 10^{10}\frac{cm}{sec}$ and V_P is the velocity factor which in this case is 0.695 for PTFE cable.

The resulting phase difference seen by the phase detector over this range is 69deg which is less than maximum range of the phase detector.

Under software control, the synthesizer is stepped in 10MHz increments from 1600MHz to 1700MHz at 10ms per step. The controller provides a convenient trigger pulse whenever the synthesizer is at 1600MHz which is used to trigger the oscilloscope.

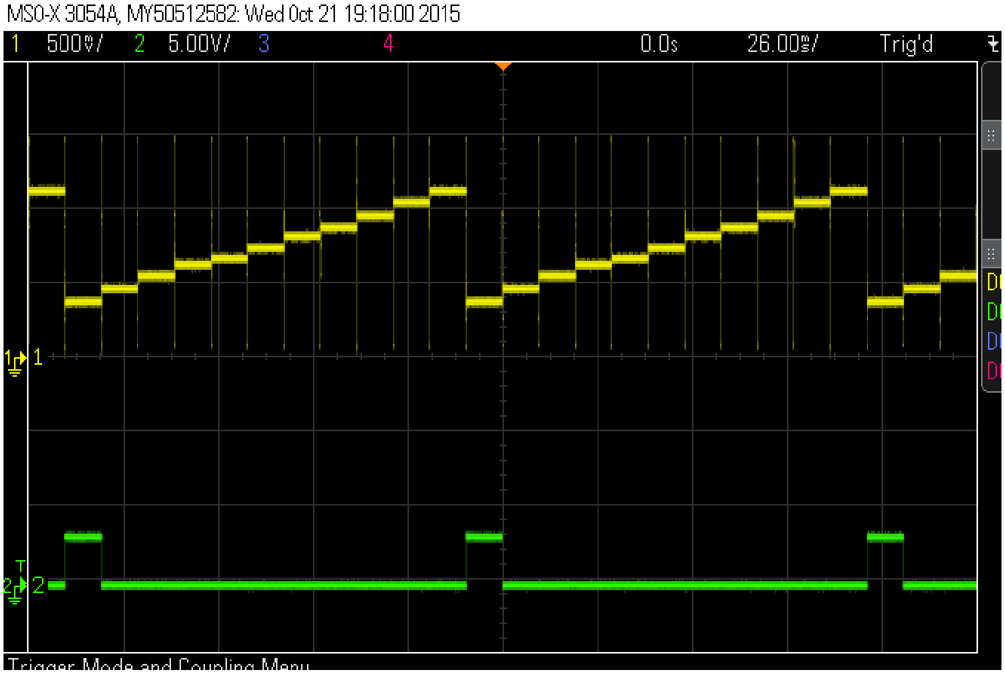

Figure 3 Signal source step frequency from 1600MHz to 1700MHz in 10MHz steps. Yellow trace phase detector output, green trace is start trigger.

Figure 4 below shows another view using all available channels of a 4-channel oscilloscope to monitor DLD output with the yellow trace, the VCO tuning voltage with the blue trace, the digital lock detector output with the pink trace, and the internal synthesizer band select logic with the green trace.

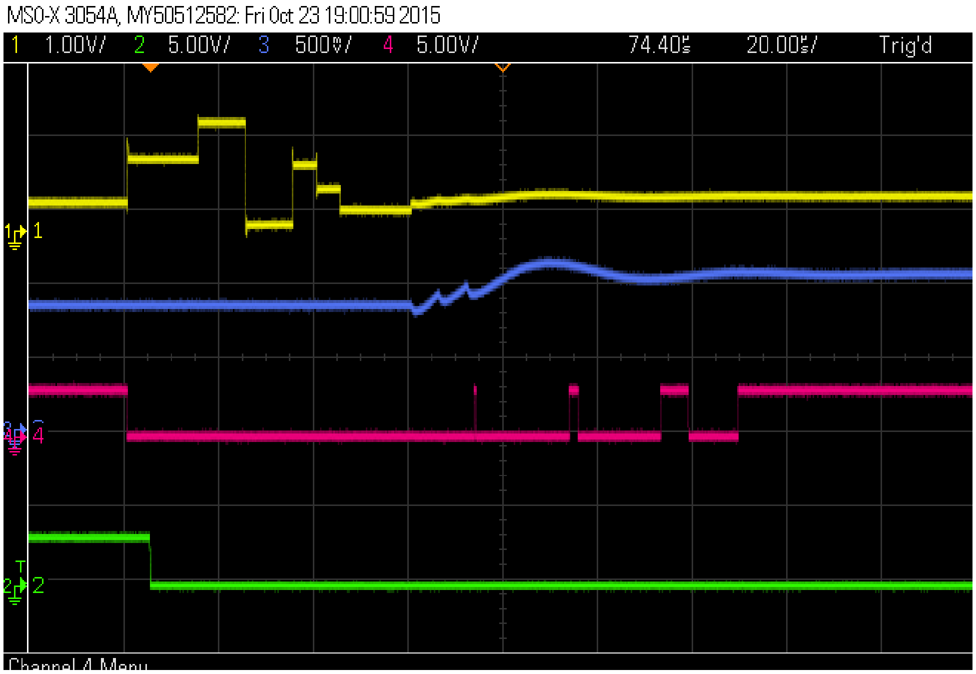

Figure 4 Yellow trace phase detector output, blue trace is VCO tuning voltage, pink trace is synthesizer internal lock-detect, green trace internal synthesizer band select.

Your questions about how to use the 4002 Phase Detector in your system are welcomed. Please contact Valon Support for more information on how you can integrate the 4002 into your system or test bench.