

Experiment 01 - RF Power detection

1 Introduction

This (and the next few) laboratory experiment explores the beginnings of microwave measurements, starting in the mid twentieth century. The purpose of using these now-obsolete methods is to teach the student the fundamentals that are otherwise invisible to the user of the modern measurement systems.

This experiment has two components. The first part consists of generating a response curve of a basic microwave measurement tool: the square-law detector. In the process of generating this curve, the student comes across a few crucial concepts. The first is that an engineer must know the exact conditions under which a measurement tool provides reliable data. As will be discussed, a square-law detector is only useful over a specific range of input power levels and a specific range of frequencies. Second, the material properties of a device often motivate why that device is used for a specific task. For example, a crystal detector rectifies a radio signal, converting it from alternating current to a pulsing direct current.

Experiment design is undoubtedly the most difficult aspect of an engineering project. However, after an engineer successfully establishes an experimental procedure, he or she often has to run this experiment under many different conditions or many different times. Often, the economy of scale in doing so makes it very worthwhile for the engineer to automate the measurement. Automation not only speeds up the measurement process, but it also can significantly decrease the likelihood of operators' error in a measurement. The second part of this lab is to use BenchVue to automate your measurements of the crystal detector in the first part.

Keysight Technologies's BenchVue software for the PC offers engineers and technicians involved in design and validation an easy and intuitive way to accelerate testing with no programming necessary. Multiple instrument measurement visibility and data capture improves the way users interact with their instruments and the entire bench. Compared to alternative software linking test and measurement instrument data to PC applications, BenchVue provides easier viewing, capturing and exporting of data and screen shots. It is compatible with many DMMs, power supplies, function generators, signal analyzers, and oscilloscopes. Refer to "BenchVue Overview" guide on the website for more details.

The background section of this lab provides you information on why crystal detectors are used and how they function. Do not be concerned with having a full understanding of this section. It is merely included to be used as a reference for when questions arise during laboratory work and to help you make conclusions when you write your report.

2 Background

Square-law detectors

All experimental measurements made in the microwave region depend upon the ability to detect the presence of RF power. By far, the bulk of these measurements are made by two common detection systems, "square-law detectors" and heterodyne systems. The latter are considered to be linear detectors since the usable output signal is proportional to the electric field, or RF voltage, applied to this detector. Our present concern is with the square-law detectors. These devices find the widest use because they are extremely simple.

The square-law devices used for the detection of low-level RF power include the crystal diodes and thermally sensitive devices such as bolometers, barretters, and thermistors. They derive their name from the fact that the output, a voltage or a current, is approximately proportional to the square of the input RF voltage or current. Thus, this output is proportional to the applied input power.

Figure 1 shows a typical response of an RF detector in which the square-law region is clearly indicated.

Although barretters and thermistors are useful in the absolute measurement of power, for most laboratory measurements it is sufficient to determine the relative power or field strength levels. These relative power measurements

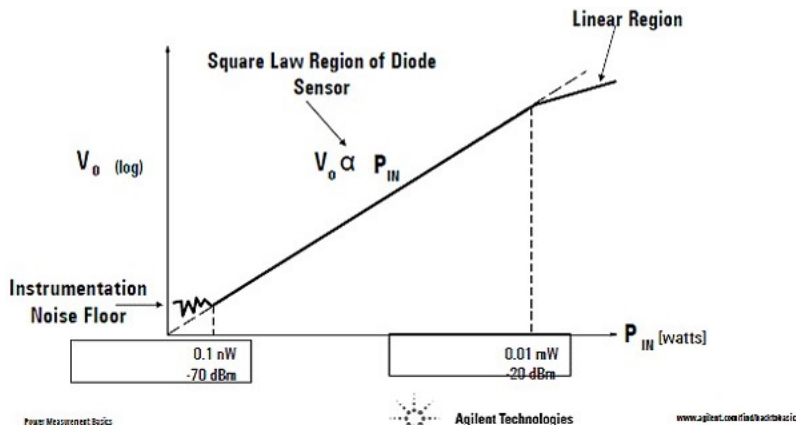


Figure 1: Typical characteristic curve of an RF detector. Image courtesy of Agilent Technologies

may be made on unmodulated signals giving a direct current or voltage from the detector. For the utmost sensitivity, the detector should be followed by some signal amplification before the output is presented on an indicator. The problems associated with stable, high gain DC amplifiers can be avoided by using an RF source that is modulated at an audio frequency. The resulting low-level detected audio signal may be easily amplified in a narrow band, high gain amplifier. As indicated in Figure 2, a crystal detector can be used to detect very small signals by the use of a low-noise amplifier following its low-pass output.

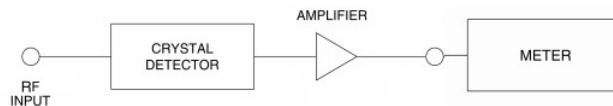


Figure 2: Simplified schematic for RF power detection

The detector must be able to follow the modulation envelope of the RF signal to obtain a usable audio output signal. An audio modulation frequency of 1,000 Hz is a good compromise frequency. It is sufficiently high that the selective circuits in the amplifier can reject ripple voltages from the power supply, and low enough to be compatible with time constants of the barretters and crystals. Thermistors, however, have a time constant of approximately 0.1 second and would require a considerably lower frequency of modulation.

The range of power levels that can be detected or accurately measured is limited at higher power levels by the deviation of the device from the square law characteristic and at the very low power levels by the noise produced by the detector itself and the following amplifying system as depicted in Figure 1.

3 Pre-lab

1. Explain how representing input power and output voltage in log scale might benefit the representation of square-law region? **Hint:** Look at Figure 1 and think of the mathematical function that relates them. Also, look at question 2 below.
2. In the scenario illustrated in Figure 2, if the gain of our detector (i.e. the gain of the amplifier before the output terminal) was made 4 times larger, how would the slope of its output (in log scale) (see Figure 1) change (if at all)?
3. What is the limit power of Keysight 8474B RF detectors ?

4 Equipment

- Agilent MXG Analog Signal Generator (N5183A).
- Keysight Digital Voltmeter (DVM) (34461A).

- Keysight 8474B Crystal Detectors.
- N-type, BNC cables.
- Software: BenchVue.

5 Procedure

In this lab, you will measure the response of RF detectors to identify some of their characteristics. Characteristics of these RF detectors are important to identify, because we will need to use them to do future measurements. Not knowing their limitations and designed operating conditions might lead to malfunctions during a measurement setup and hence incorrect collected data.

1. Arrange the lab equipment as shown in Figure 3. The crystal detector can be directly connected to the microwave source to minimize the number of cables you need and eliminating the N-type cable. Set the source frequency to 600MHz. Obtain data to plot a curve of RF power -50dBm to 15dBm in 5dBm steps. Plot the data with the RF power (in dBm) on the linear x -axis and the DC voltage (in **millivolts**) on the y -axis (logarithmic scale).

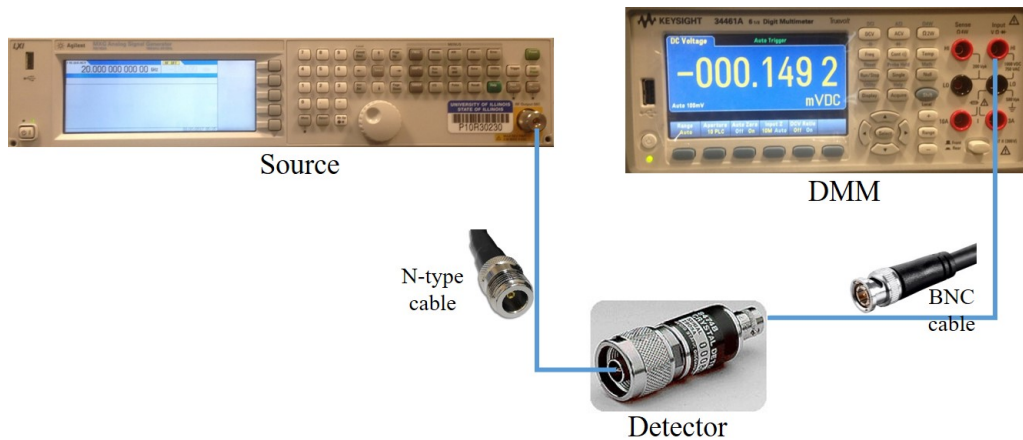


Figure 3: RF power measurement setup

2. From your curve of RF power into the detector vs. DC voltage out of the detector, determine the “square-law” range of your detector (it is recommended that you would perform a best-line-fitting on the data to show its linearity)¹. Figure 4 shows an example. What is the measured slope of the detector in the square-law region? How does the measured curve compared with what you would expect from a detector (discuss about different ranges of the input power: too low, too high, neither low nor high power regions)? How is it compared to the datasheet [1]?
3. The next part of this lab is to automate the process you just went through. Figure 5 illustrates the equipment set up. They will communicate with each other via USB connection.

Before you dive in and create your BenchVue project, you should read this first. In general, files should not be saved on $C:\backslash$. Instead, your files should be saved on $U:\backslash$ so that they are still available to you regardless of which EWS computer you’re using and so they are not erased when the Network Admins do their periodic cleaning or upgrading.

You are now about to write a simple programm in BenchVue where the user defines the minimum power, maximum power, number of power points, and source frequency. The program will communicate with the instruments and collect the detector output voltages and convert them to the logarithmic voltage format, and display both the linear and logarithmic values on the computer screen. The program will then save the data in .csv file format. Since this format is compatible with other applications such as Keysight ADS, it’s easier for you to later imported the data to ADS.

¹Here is a quick way to do it using Excel.

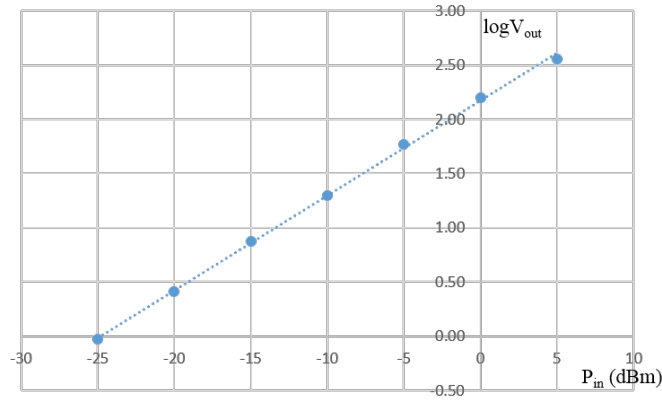


Figure 4: An example of best line-fit data to show “square-law” region

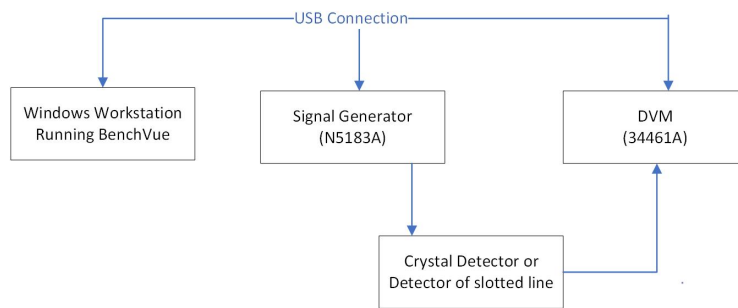


Figure 5: Block diagram of automated measurement setup

For those who are not familiar with BenchVue, there is also a step-by-step guide for creating the test sequence in the guide named “BenchVue Overview”. Remember to include a screenshot of your program for the report.

4. Have your program ready then set the source frequency and power range as same as step 1, then perform the automated measurement. Wait until the measurement is done, and take a screen shot of the data window for your report.

Notice that there are some clicking noises from the generator during the measurement. These clicking noises happen corresponding to some “bumps” in the plot. Verify that and try to explain what could cause these clicking noises.

Remember to save measurement data into a .csv file when the program pops up a window and asks you.

5. Plot data. Find the “square-law” region in your plot by placing markers on the limits of this region. Compute the slope of the response. Compare it with the result in step 1. Explain any discrepancies (if any) between them.

6 Conclusion

1. Write down the slope and the intercept to help you plot the “square-law” region of the 8474B detector, similar to Figure 4. Why is it important to determine the “square-law” region for the detector?
2. Comment on the use of BenchVue in this experiment. What would be pros and cons using BenchVue to automate your measurement?

References

- [1] Datasheet, Keysight 8474B/C/E Planar-doped Barrier Diode Detectors 0.01 to 50 GHz.