Application Report
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Understanding TRF370x Quadrature Modulator Gain Parameters

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ABSTRACT

Because of the complex nature of the quadrature modulator, understanding the gain measurement can be confusing. This application report gives a detailed explanation on how the gain is measured and specified for the TRF370x quadrature modulator family.

Introduction

Measuring the gain of a simple RF amplifier is straightforward. For a typical RF amplifier the input and output impedances are both 50 ohms. Hence, the power gain of the amplifier is measured by:

Gain [dB] = Pout [dBm] – Pin[dBm]

This type of measurement is easy to measure with standard RF test equipment, such as a power meter and spectrum analyzer. The quadrature modulator, exemplified by the TRF370x family of devices, converts quadrature baseband signals to RF signals. This device differs from a typical RF amplifier in three ways. One, the input signals consist of two paths: I (in-phase) and Q (quadrature phase). Two, the input signals are at different frequencies compared to the output signal. Three, the input impedance at the baseband input signals is not the same as the output impedance at the RF port. This last fact dictates that measuring a power gain on the device is impractical. Instead, a voltage gain is measured and specified in the documentation.

Measuring Modulator Voltage Gain

The functional block diagram of the TRF370x modulator is shown in Figure 1. The input I/Q signals are differential. The convention used in the data sheets of TRF370x devices is to measure the input voltage as single-ended. This choice facilitates easier measuring with standard oscilloscope probes. The differential voltage is simply calculated by:

$$Vin_{differential} = 2 \times Vin_{single\text{-}ended}$$

When measuring the voltage gain of the device, the input signals and the output signals must be expressed in the same units. The input signals are measured using an oscilloscope and are measured in volts rms. This value is converted to dBV by the standard equation:

$$Vin\ [dBV] = 20 \times \log(Vin\ [Vrms])$$

The output signal is at RF frequencies and is measured with the spectrum analyzer in power units expressed as dBm. To calculate the voltage gain, the output power must be converted first to units of volts. The conversion factor for converting the units of dBm to dBV is (see Appendix A for conversion derivation):

Vout [dBV] = Pout [dBm] – 13

Once the input signal and output signal are expressed in the same units, dBV, the voltage gain can be calculated as follows:

Voltage Gain [dB] = Vout [dBV] – Vin [dBV]

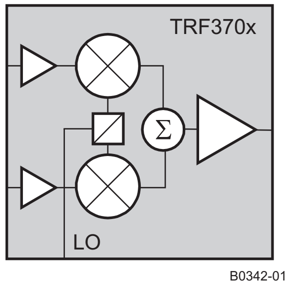

Figure 1. TRF370x Functional Block Diagram

Understanding TRF370x Data-Sheet Plots Related to Gain

Figure 1 in the data sheets of the TRF370x products shows the output power versus the input baseband single-ended voltage at one specific frequency. This figure for the TRF370317 is reproduced in Figure 2.

With a single-ended input voltage of 0.1 Vrms, the output power is approximately –3.4 dBm. The calculation for gain is as follows.

$$\text{Vin [dBV]} = 20 \times \log(2 \times 0.1\ \text{Vrms}) = -14\ \text{dBV} \quad (1)$$

$$\text{Vout [dBV]} = -3.4\ \text{dBm} - 13 = -16.4\ \text{dBV} \quad (2)$$

$$\text{Gain [dB]} = 16.4\ \text{dBV} - (-14\ \text{dBV}) = -2.4\ \text{dB} \quad (3)$$

The gain of the TRF370x devices is not plotted versus frequency. Instead, output power is plotted versus frequency. For the TRF370317, the output power is measured across frequency with a constant input signal of 98 mVrms. Using Equation 1 through Equation 3, the gain can be calculated from those plots at any desired frequency.

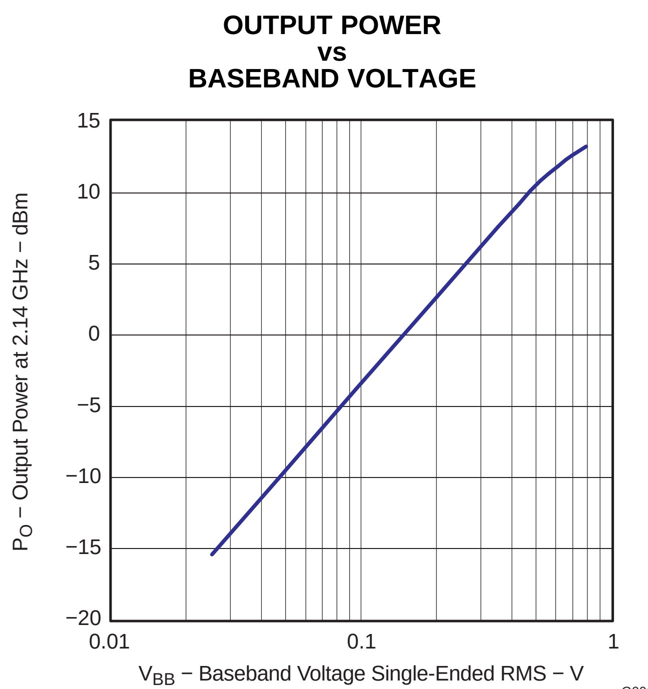

Figure 2.

Appendix A Derivation of the dBm to dBV Conversion Factor

For a given power out (Pout) expressed in dBm, convert to the units of watts:

$$\text{Pout [W]} = \frac{10^{(\text{Pout [dBm]}/10)}}{1000} \tag{A-1}$$

Given a 50-Ω system, convert the watts to volts:

$$\text{Vout [V]} = \sqrt{\text{Pout [W]} \times 50} = \sqrt{\frac{10^{(\text{Pout [dBm]}/10)} \times 50}{1000}} \tag{A-2}$$

Next, convert volts to dBV by:

$$\text{Vout [dBV]} = 20\log(\text{Vout [V]}) \tag{A-3}$$

Substitute and simplify the equation to yield the conversion factor:

$$\text{Vout [dBV]} = 20\log\sqrt{\frac{10^{(\text{Pout [dBm]}/10)} \times 50}{1000}} = 10\log\left[10\left(\frac{\text{Pout [dBm]}}{10}\right)\right] + 10\log\left(\frac{50}{1000}\right)$$

$$\text{Vout [dBV]} = \text{Pout [dBm]} - 13 \tag{A-4}$$

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