

Obtain S-Parameter Data from the Probe Window

This document explains Measuring S parameters in PSpice using Probe measurements. It explains obtaining S parameter for a passive circuit (a band pass filter) and an active circuit (transistor circuit).

Introduction

This document explains Measuring S parameters in PSpice using Probe measurements. It explains obtaining S parameter for a passive circuit (a band pass filter) and an active circuit (transistor circuit).

S parameter Theory

S-parameters measure the ratio of the incident and reflected signal. The incident signals are defined as a1 and a2. The reflected signals are defined as b1 and b2. The incident and reflected signals are related to voltages and currents at ports 1 and 2 by

$$a1 = \frac{V1 + Z0I1}{2\sqrt{Z}} \quad (1)$$

$$a2 = \frac{V2 + Z0I2}{2\sqrt{Z}} \quad (2)$$

$$b1 = \frac{V1 - Z0I1}{2\sqrt{Z}} \quad (3)$$

$$b2 = \frac{V2 - Z0I2}{2\sqrt{Z}} \quad (4)$$

The scattered waves are related to the incident waves by the following set of linear equations:

$$b1 = S_{11}a1 + S_{12}a2 \quad (5)$$

$$b2 = S_{21}a1 + S_{22}a2 \quad (6)$$

Or, in matrix form as;

$$\begin{bmatrix} b1 \\ b2 \end{bmatrix} = \begin{bmatrix} S11 & S12 \\ S21 & S22 \end{bmatrix} \begin{bmatrix} a1 \\ a2 \end{bmatrix}$$

The Sij coefficients are dimensionless ratios; for most applications, the characteristic impedance of the system, Z0, is 50 ohms. S11 is the input reflection ratio and is defined as the ratio of the input port reflected wave to the input incident wave. If the incident wave at the output, a2, is set to zero, then the equations reduce to b1 = S11a1 and b2 = S21a1. Using the defining equations, this reduces to

$$S_{11} = \frac{b_1}{a_1} = \frac{V_1 - Z_0 I_1}{V_1 + Z_0 I_1} = \frac{V_1 - Z_0 I_1}{V_1 + Z_0 I_1} = 2 \left(\frac{Z}{Z + Z_0} \right) - 1 \quad (8)$$

Measuring S-Parameter Data from the PSpice Probe

Where

V_1/I_1 is the input impedance Z .

S_{21} is the forward transmission ratio and is defined as the ratio b_2/a_1 .

If the input and output load impedances of the circuit are the same, then S_{21} is the voltage measured at the output multiplied by 2. If the incident wave at the input is set to zero, then the equations reduce to

$$b_1 = S_{12}a_2$$

$$b_2 = S_{22}a_2$$

Measuring S-Parameter Data from the PSpice Probe

To make all of the necessary measurements, two sub schematics are required. These sub schematics, made in Allegro Design Entry CIS (Capture CIS), are shown in Figure.1 and Figure. 2.

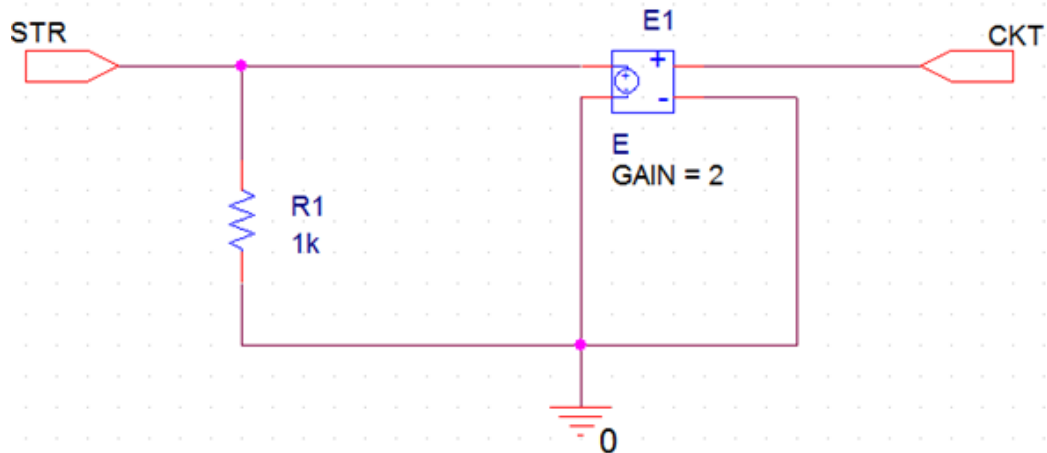


Figure 1: XMITS circuit

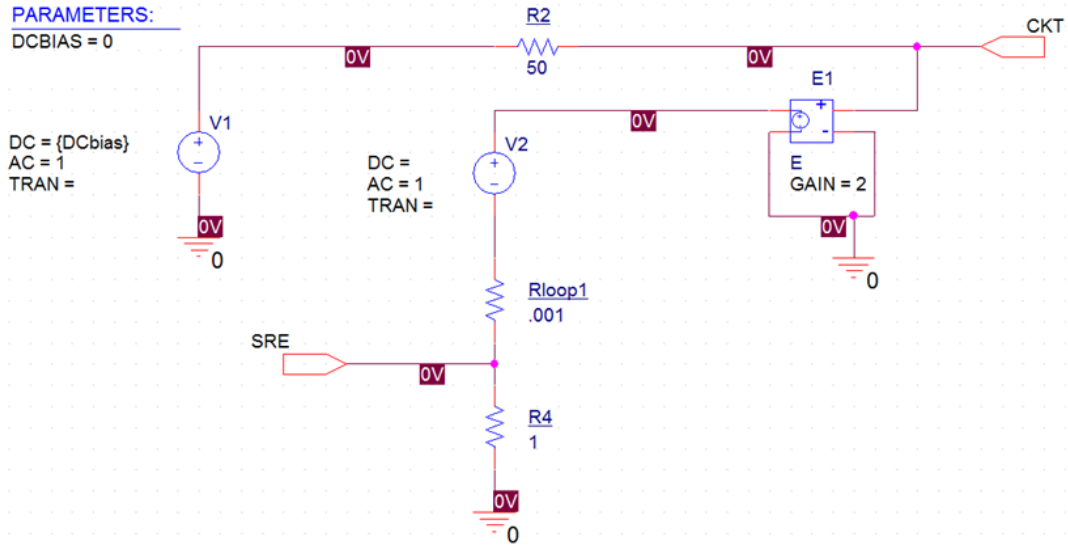


Figure 2: REFLECTS circuit

Sub Schematics

Create above circuits in Capture and create a hierarchical part for each. For the purpose of this article, these custom parts are named XMITS (Figure. 3) and REFLECTS (Figure. 4), respectively.

Sub Schematic for Transmission coefficients measurement, XMITS

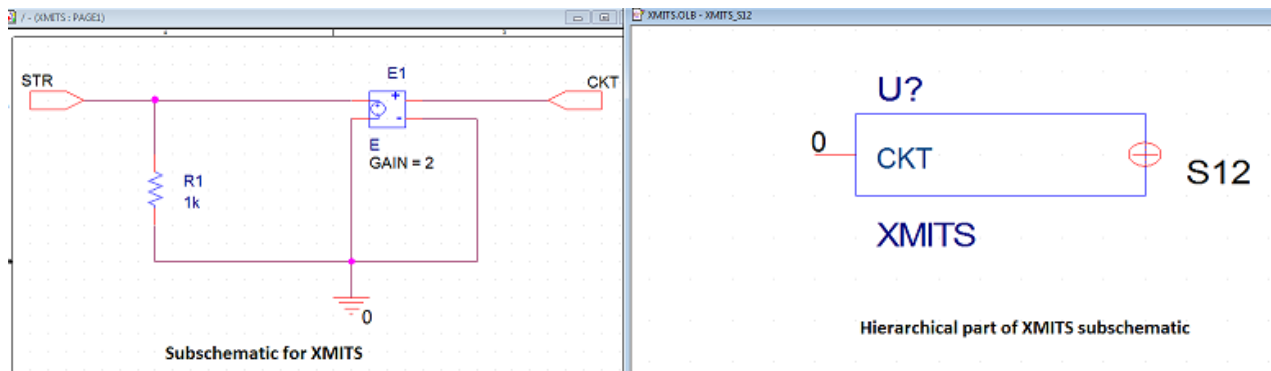


Figure 3: XMITS circuit and its hierarchical part

The XMITS circuit shown in Figure 3 is used to measure the

- >Forward transmission coefficient, S21
- >Reverse transmission coefficients, S12

Since the output load matches the input load, the transmission coefficients are the output voltage multiplied by 2. The E device, E1, has a gain of 2. The port labeled CKT is used to connect to the external circuit. The port, STR,

is a hidden pin as shown in Figure. 3. If it is left unconnected in a schematic, OrCAD Capture will generate a unique net. Alternatively, a specific net can be named for the connection by editing the PSpiceDefaultNet attribute value (see Figure. 4) for the XMITS part instance; this way, the STR pin will have a known label (S21 in this case) when analyzing simulation results within the Probe window.

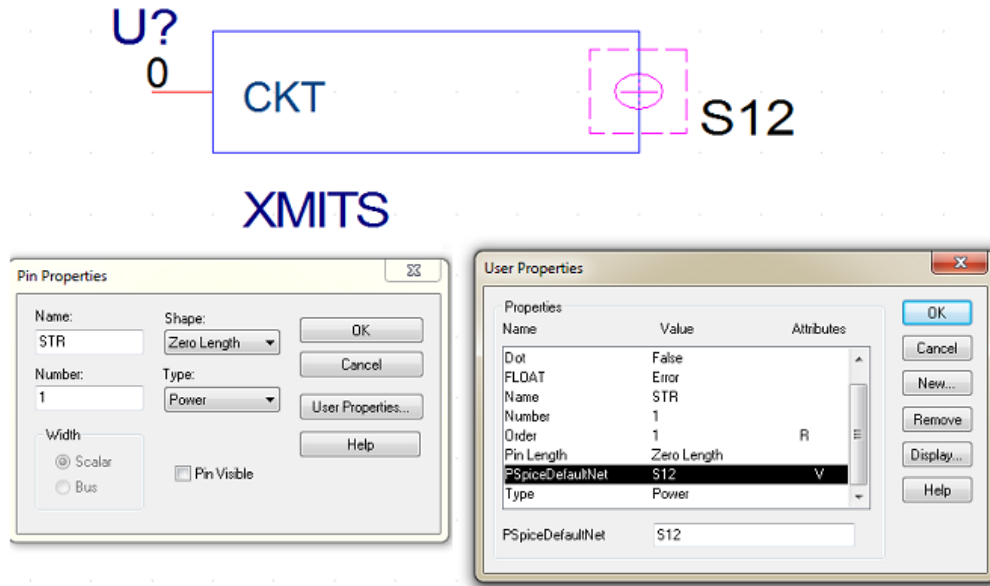


Figure 4: Pin Properties for the XMITS part showing hidden STR pin

Sub schematic for Transmission coefficients measurement, REFLECTS

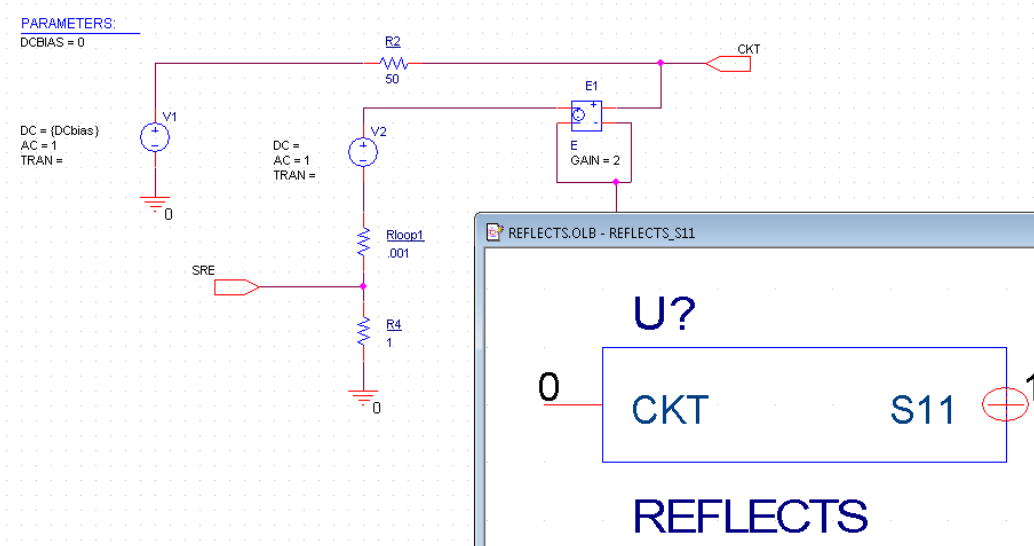


Figure 5: REFLECTS circuit and its hierarchical part

The REFLECTS circuit shown in Figure 2 is used to measure the
 ->Input reflection coefficient, S11
 ->Output reflection coefficient, S22

The reflection coefficients are the input voltage multiplied by 2 minus AC unity. The E device, E1, has a gain of 2. As in the transmission coefficients measurement circuit, the interface pin labeled CKT is used to connect to the external circuit. The pin, SRE, is a hidden pin like STR described above, (see Figure. 6). The REFLECTS symbol also has a DCbias property. On active circuits, the DC level can be set on voltage source, V1, by changing the DCbias property for the REFLECTS part instance in OrCAD Capture. By default, this property is set to zero.

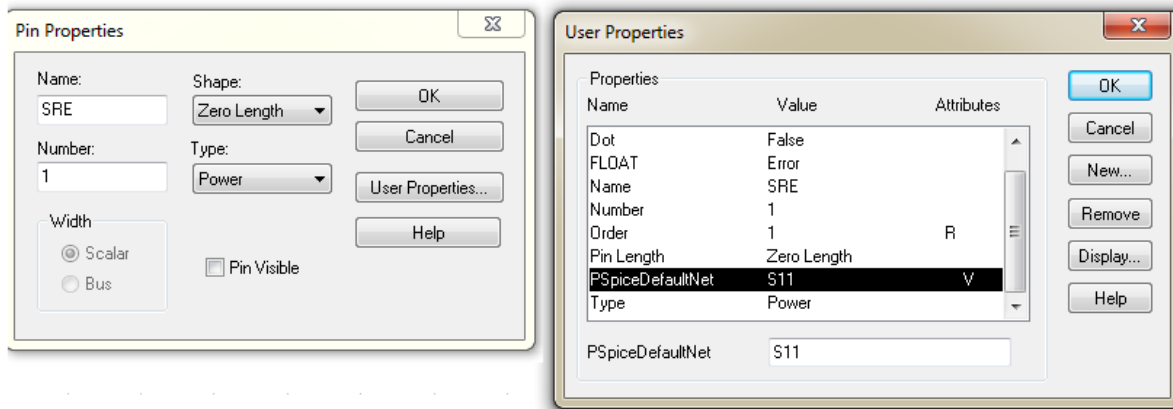
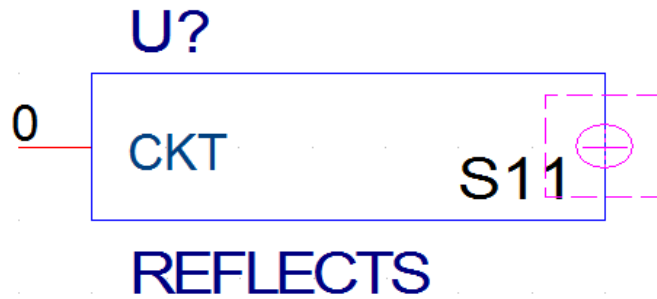


Figure 6: Pin Properties for the Reflects symbol showing hidden S_RE pin

Using the sub schematics

The sub schematics can be used for both passive and active circuits. One can also create and use symbols from these sub schematic in design. Design example referred in this application note uses XMITS and REFLECTS symbols created from these sub schematics. See Creating and Editing Parts in the OrCAD Capture User's Guide for reference to creating hierarchical parts.

Passive circuit implementation

The circuit shown in Figure. 7 is a fourth-order Butterworth bandpass filter with a center frequency of 250 MHz. The first circuit measures S11 and S21. The second circuit measures S12 and S22. For simulation, the AC analysis settings are 500 linear points from 200 MHz to 350 MHz. The results of the analysis are shown in Figure 8. Extract the attached Test_Case.zip to find the passive folder with this example.

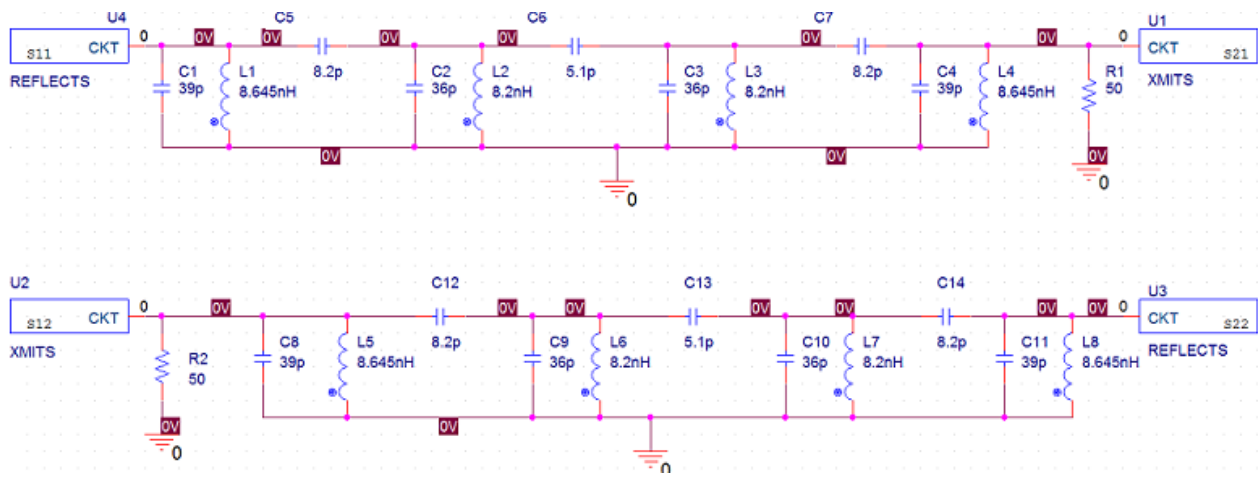


Figure 7: Bandpass filter example

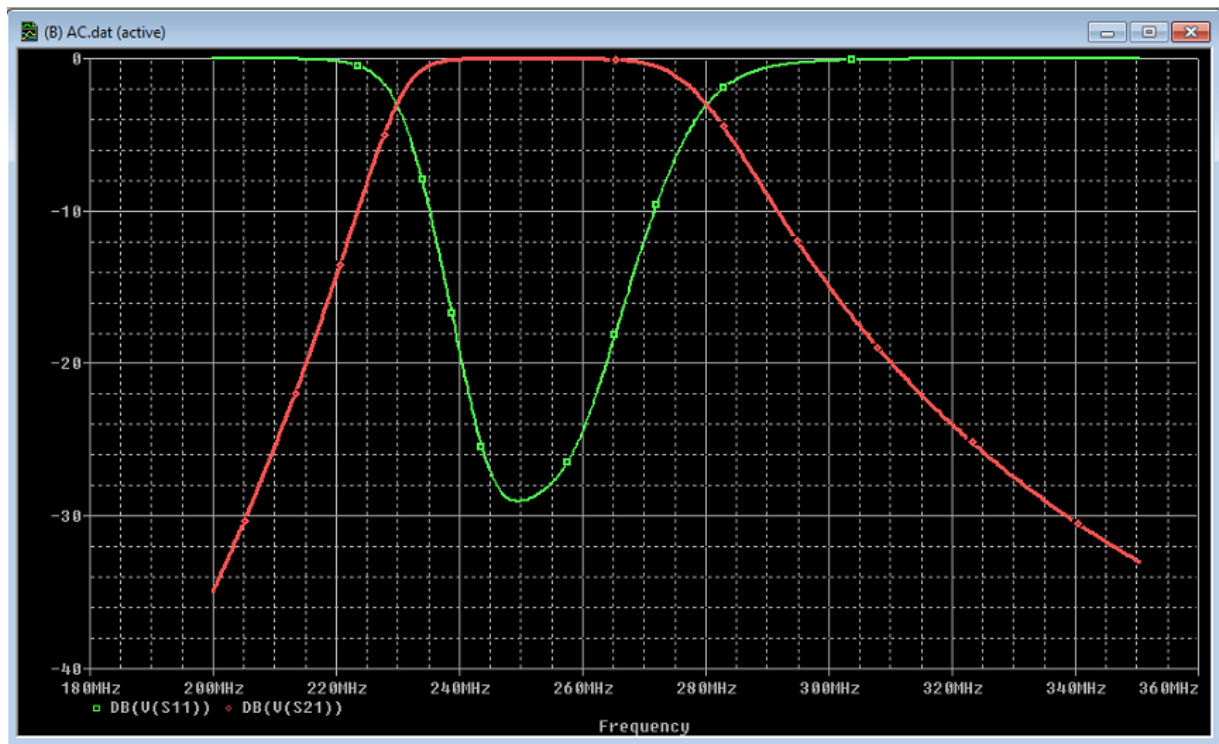


Figure 8: S11 and S21 for Filter Example

Active Circuit implementation

It is also possible to measure the s-parameters of an active circuit. To illustrate this, we have chosen to measure the s-parameters of the RF transistor, MRF5711/MC. Figure 9 shows the circuits for this example.

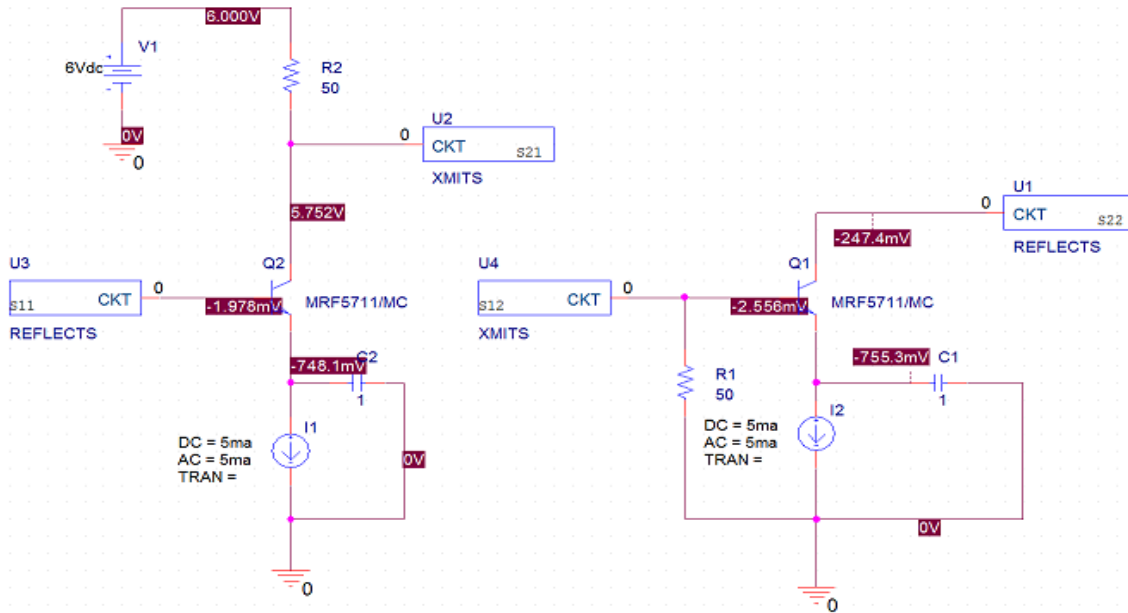


Figure 9: Transistor example

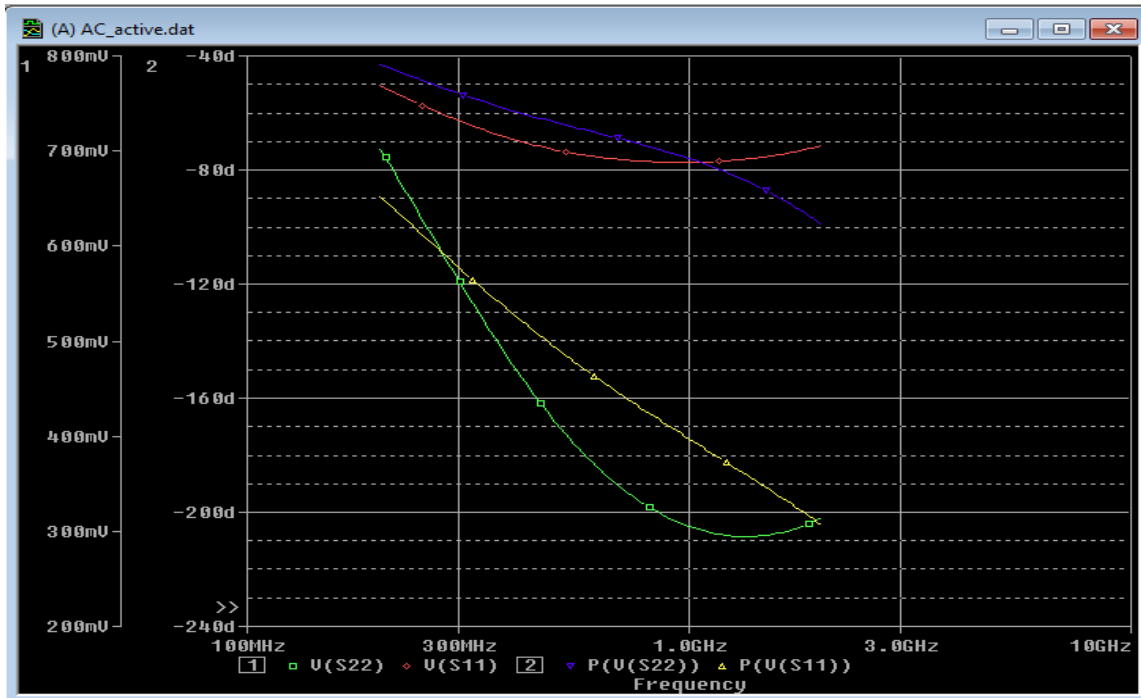


Figure 10: S11 and S22 magnitude and phase

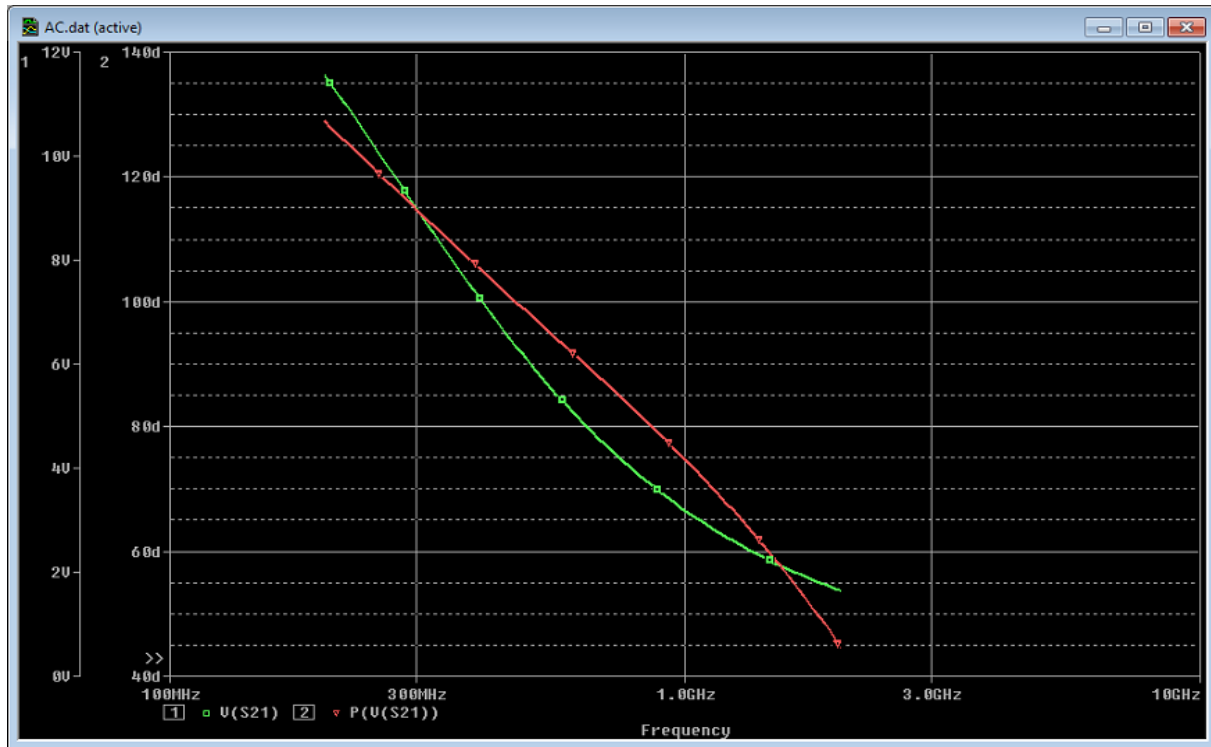


Figure 11: S21 Magnitude and Phase

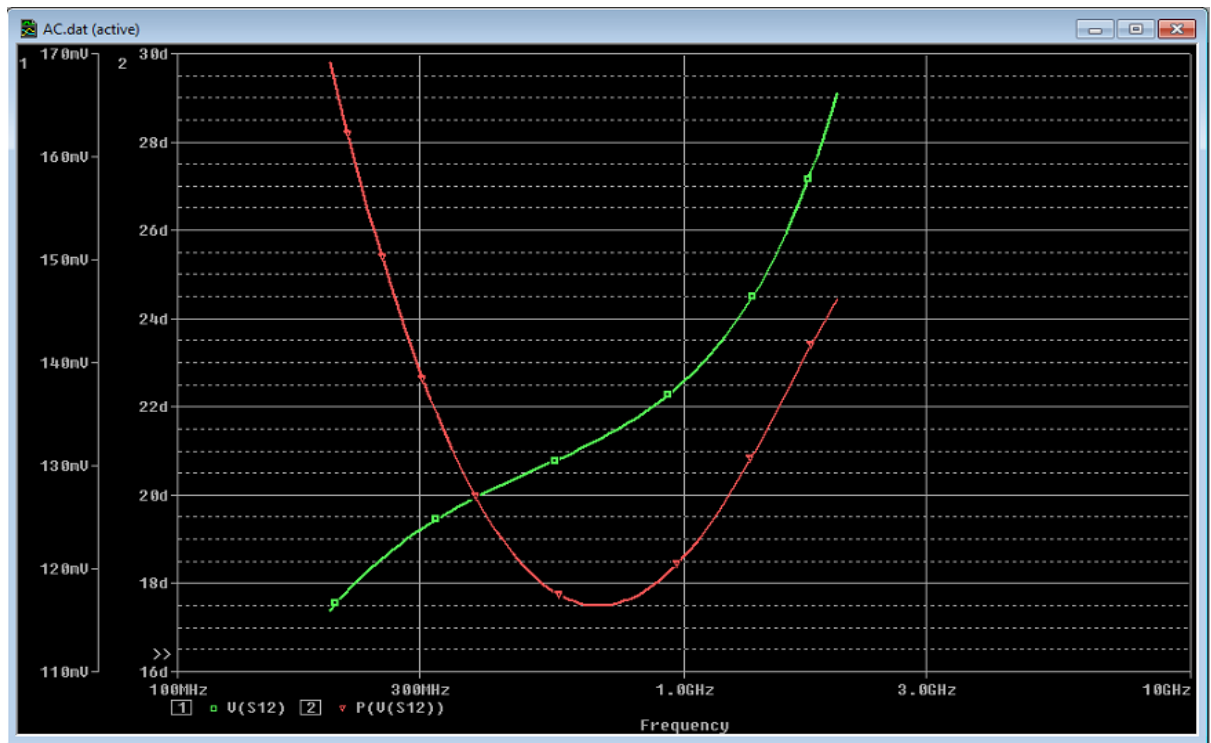


Figure 12: S12 Magnitude and Phase