Frequency Response Measurements

TECHNICAL BRIEF

Derive Frequency Response from Step Response

June 13, 2013

Summary

Measuring the frequency response of a device based upon its step response.

Introduction

Filters, amplifiers, and control systems are usually characterized by their frequency response functions. These functions are usually shown in graphical form as plots of log amplitude vs. log frequency called Bode plots. Oscilloscopes are primarily time domain measuring instruments. They represent acquired waveforms as a time series, plotting signal amplitude as a function of time. Utilizing the mathematical capabilities available in modern digital oscilloscopes it is possible to derive the frequency response function of a circuit based on the measured time response to a step function.

Note that the rise time of the step must be fast enough to insure a flat input spectrum. You can use the same method without the device under test to check the flatness of the frequency response of the source and oscilloscope.

An example of this measurement and analysis is shown in Figure 1.

Figure 1: Transforming the measured step response of a filter into the frequency response

A 10 kHz square wave is applied to a low pass filter and the output of the filter is acquired and displayed in the top trace (Ch 1). The frequency response function is the Fourier transform of the circuit's impulse response. The impulse response can be derived from the measured step response by differentiating the step response. This step is performed in math trace F1 in Figure 1.

The Fast Fourier Transform (FFT) is used to convert the impulse response into the frequency response function. Trace F2 applies the FFT to trace F1. Using the dual operator capability of the math traces the FFT Average function is also computed in trace F2 and provides averaging in the frequency domain for improvement in dynamic range.

Trace F2, is the frequency response function shown as a plot of log amplitude (power spectrum) vs. linear frequency. Zoom trace, Z2, is used to expand the vertical scale of the frequency response plot to 1 dB per division. Relative time cursors have been setup to measure the 3 dB point of the low pass filter as 36 MHz.

This data can be converted into a classic Bode plot by saving the frequency spectrum in spreadsheet format and plotting it in Log-Log format using a spreadsheet, such as Microsoft Excel.

Figure 2 shows the data from trace F2 in Figure 1, re-plotted as a Bode plot in Log – Log format using an Excel spreadsheet.

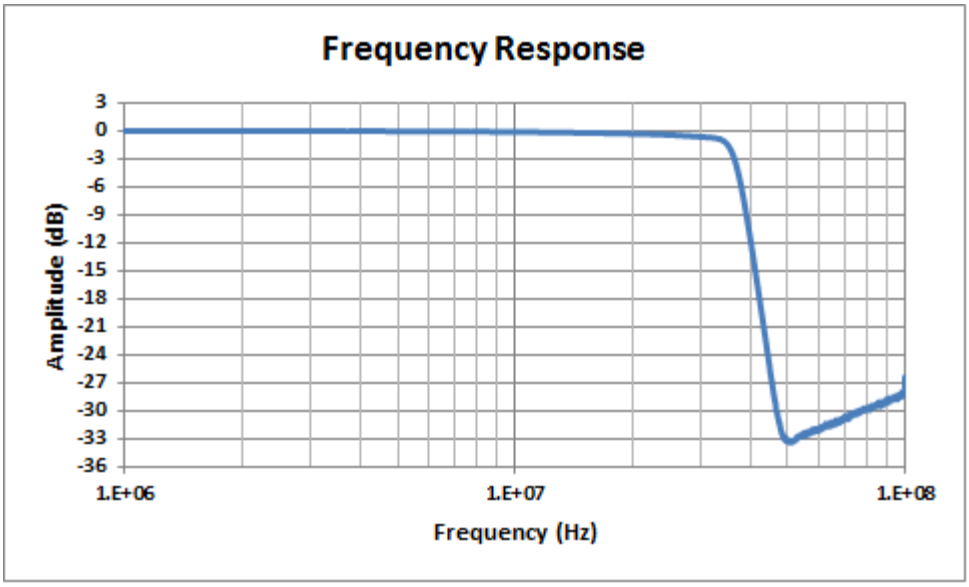

Figure 2: A bode plot based on the frequency response measured in trace F2 and saved in spreadsheet format

Measuring the frequency response based on the step response is a quick method to check on the response of a device using the oscilloscope.