Frequency Response Measurements

Derive Frequency Response From Step Response

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.

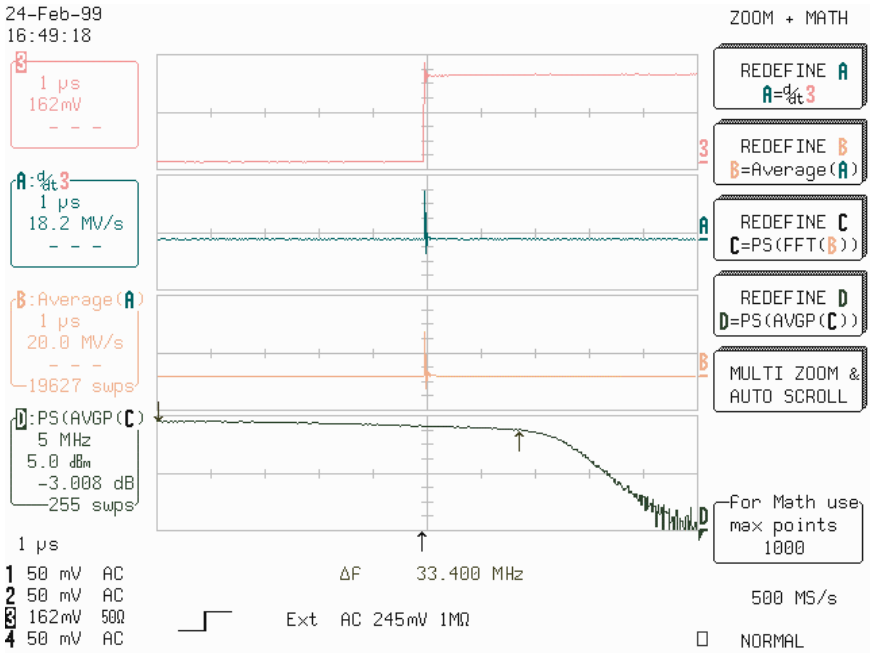

Figure 1 – Transforming the measured step response of a filter into the frequency response.

An example of this measurement and analysis is shown in figure 1. A 1 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 3). The frequency response function is the Fourier transform of the circuits impulse response. The impulse response can be derived from the measured step response by differentiating the step response. This step is performed in trace A in figure 1.

To increase the dynamic range of this measurement and improve signal/noise ratio the impulse response is averaged as shown in trace B.

The Fast Fourier Transform (FFT) is used to convert the impulse response into the frequency response function. Trace C, not shown applies the FFT to trace B. Trace D, the FFT Average function, provides averaging in the frequency domain for further improvement in dynamic range. Note that number of points used in the calculations is user selectable. In this example the transform size is set to 1000 points yielding a 500 point frequency spectrum. LeCroy oscilloscopes support FFT calculations with transform sizes of up to 4 Mpoints, dependent on the options installed.

Trace D, is the frequency response function shown as a plot of log amplitude (power spectrum) vs. linear frequency. Relative time cursors have been setup to measure the 3 dB point of the low pass filter as 33.4 MHz.

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

Figure 2 shows the data from trace D in figure 1, re-plotted Log – Log format using an Excel spreadsheet.

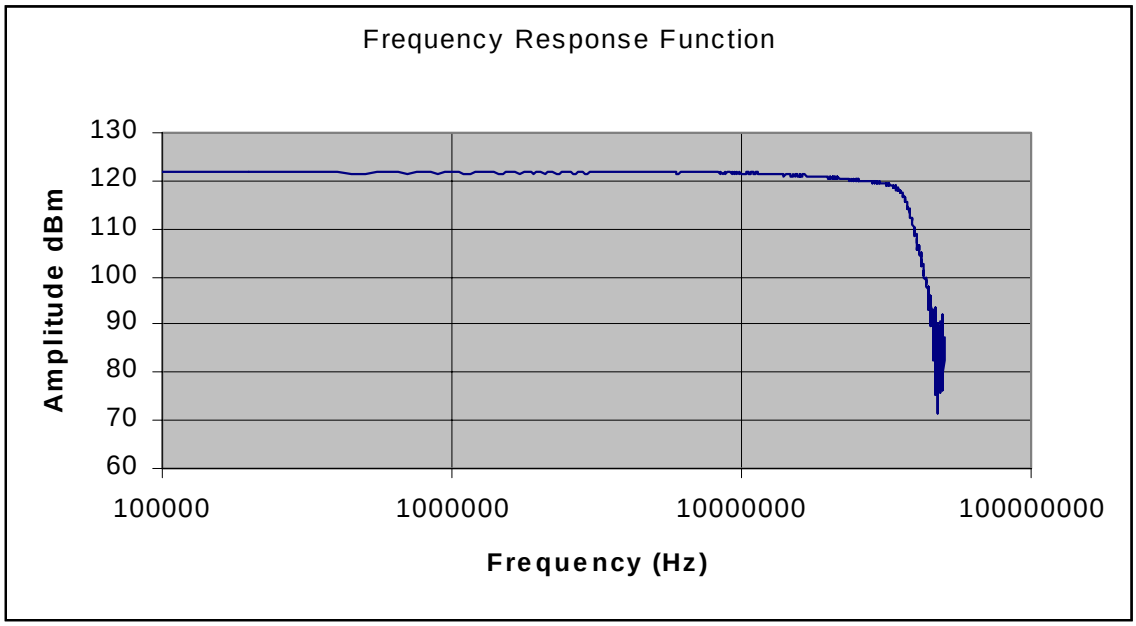

Figure 2