

Phase Modulated Waveforms

Creating PM Waveforms For PLL Loop Bandwidth Tests

Measuring the bandwidth of any kind of circuit requires signals that are spectrally flat over a range of frequencies exceeding the bandwidth of the device being tested. This type of testing is usually done with one of three types of waveforms: swept or stepped frequency sine waves, step or impulse functions, and white noise. In the case of testing a phase locked loop (PLL) a carrier must be phase modulated with these signals. The creation of a broadband signal as a phase modulated component is easily accomplished in the LeCroy LW420 series arbitrary waveform generator. We will look at two easily implemented examples of broadband signals for frequency response testing of PLL's.

The first example is the creation of a sinusoidal carrier modulated by another sine wave with a stepped frequency. The LW420 equations for each of the modulation frequency steps is:

$$X1 = \Phi_D * \text{SIN}(2 * \text{PI} * f_M * T)$$

$$X2 = V_C * \text{SIN}(2 * \text{PI} * f_C * T + X1)$$

Where:

Φ_D - Peak phase deviation

f_M - Modulation frequency

V_C - Carrier peak amplitude

f_C - Carrier frequency

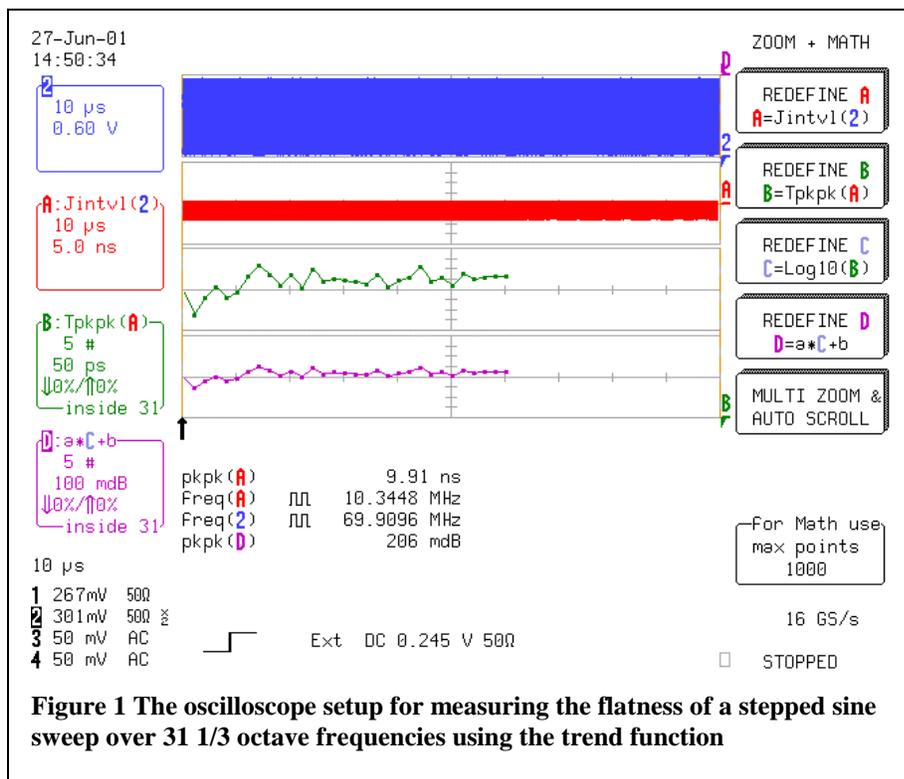


Figure 1 The oscilloscope setup for measuring the flatness of a stepped sine sweep over 31 1/3 octave frequencies using the trend function

The peak phase deviation, carrier amplitude and frequency remain fixed during the test. Only the modulation frequency is changed. If a Log-Log plot of the frequency response is desired it is advisable to step the modulation frequency in fractional octave steps. In this way, data displayed on the linearly incremented trend functions in the oscilloscope, will have logarithmic spacing.

Figure 1 shows a test of the flatness of a stepped frequency sweep on a 66.67 MHz carrier. 31 Third octave frequency steps

(the frequency ratio between steps is $2^{1/3}$) have been acquired using the trend of the peak to peak value (trace B) of the time interval error (TIE) function (trace A). The TIE function is used to demodulate the phase modulation of the carrier. The trend function was converted to dB by taking the Log_{10} of the function (trace C) and using rescale to multiply by 20 (trace D). Trace D shows the magnitude of each frequency step in dB. Observe that the peak to peak range of trace D is 0.206 dB over three decades from 10 kHz to 10 MHz.

The second example of a broadband waveform for transfer function measurement is the use of a step function to phase modulate a carrier. The equation for this function is:

$$X1 = \text{STEP}(T - T_{\text{STEP}})$$

$$X2 = V_C * \text{SIN}(2 * \text{PI} * f_C * T + X1)$$

Where:

T_{STEP} - Time at which step function occurs

V_C - Carrier peak amplitude

f_C - Carrier frequency

A flatness test for the step modulation function is shown in figure 2. As in the previous example, the TIE function (trace A) is used to demodulate the carrier. The demodulated step function is differentiated (trace B) resulting in an impulse function. The Fast Fourier Transform (FFT) of the impulse function (trace C, not shown) is used to convert the impulse into the frequency response function. FFT averaging (trace D) averages multiple sweeps and shows the average frequency response function. Note that the peak to peak variation in flatness over the 5 MHz bandwidth being measured is 1.6 dB.

The choice of which signal to employ is up to the user. The stepped frequency test provides better dynamic range and greater flatness. The step function input requires fewer measurement steps at the expense of lower dynamic range and reduced flatness.

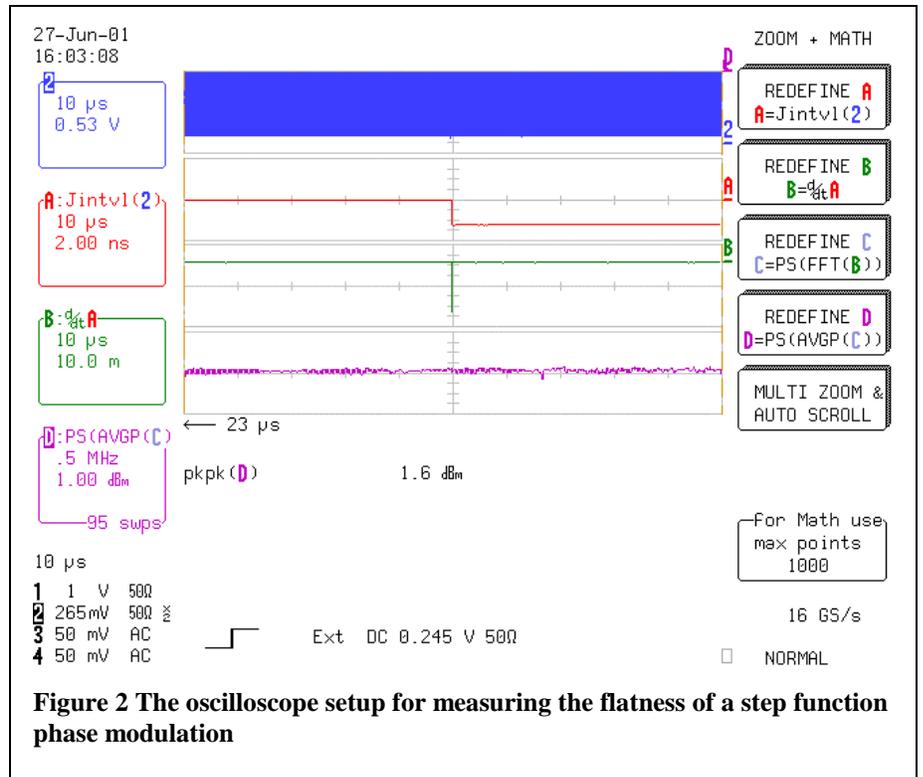


Figure 2 The oscilloscope setup for measuring the flatness of a step function phase modulation

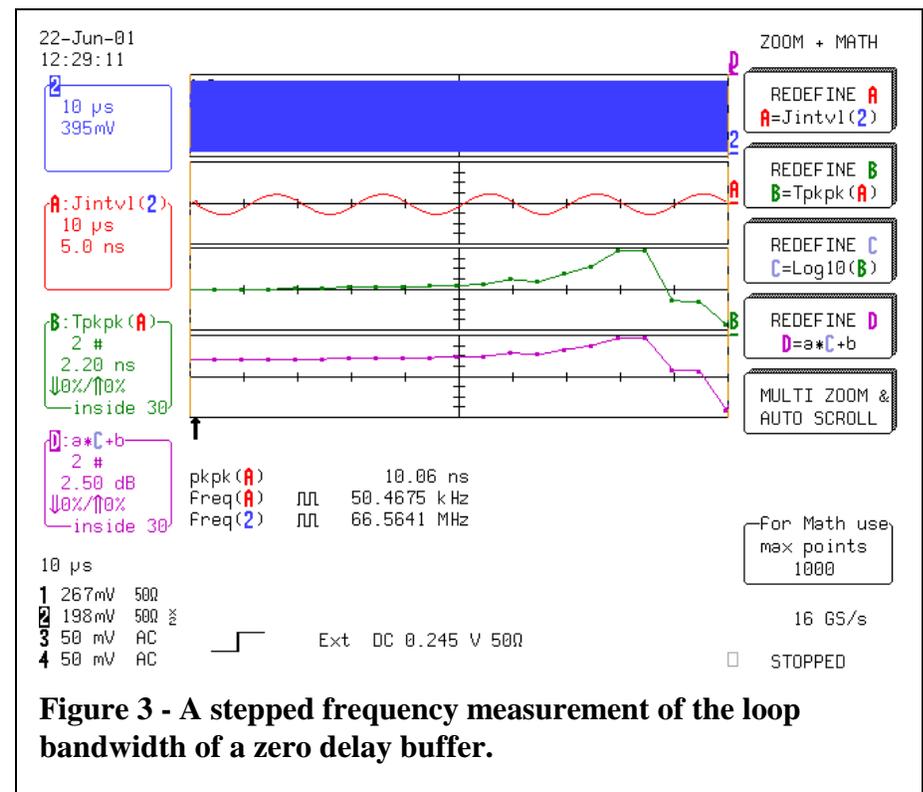


Figure 3 - A stepped frequency measurement of the loop bandwidth of a zero delay buffer.

An example of a stepped frequency test of the PLL loop bandwidth of a zero delay buffer

is shown in figure 3. The test method is described in LeCroy application brief LAB750.