LeCroy Application Brief **No. LAB 750A**

PLL Loop Bandwidth

Measuring Jitter Transfer Function In Phase Locked Loops

The propagation of jitter in phase locked loop based timing systems can be determined by measuring the jitter transfer function of the system components. This test characterizes the jitter transfer function of the device under test as a function of jitter frequency. Figure 1 shows the result of a typical jitter transfer function test made using a LeCroy LW420 arbitrary waveform generator and a LeCroy WavePro 960 digital oscilloscope with the jitter and timing (JTA) measurement option.

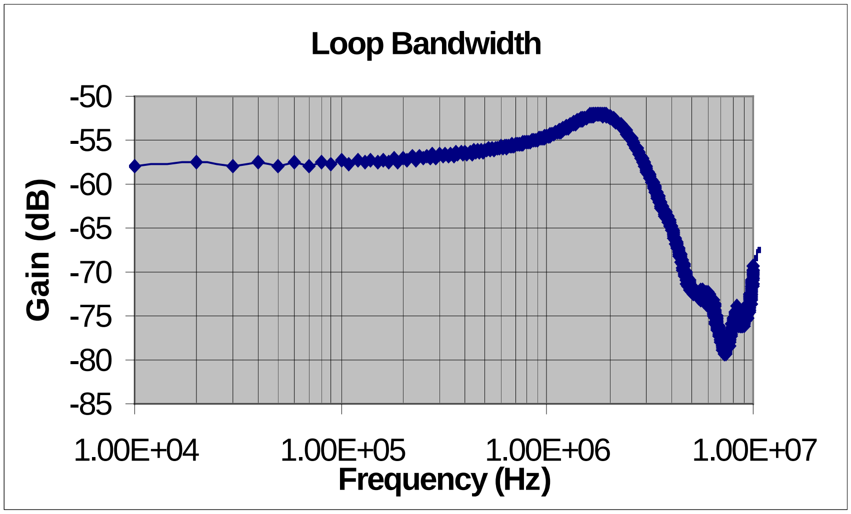


Figure 1 Loop bandwidth measurement for a PLL based zero delay clock buffer

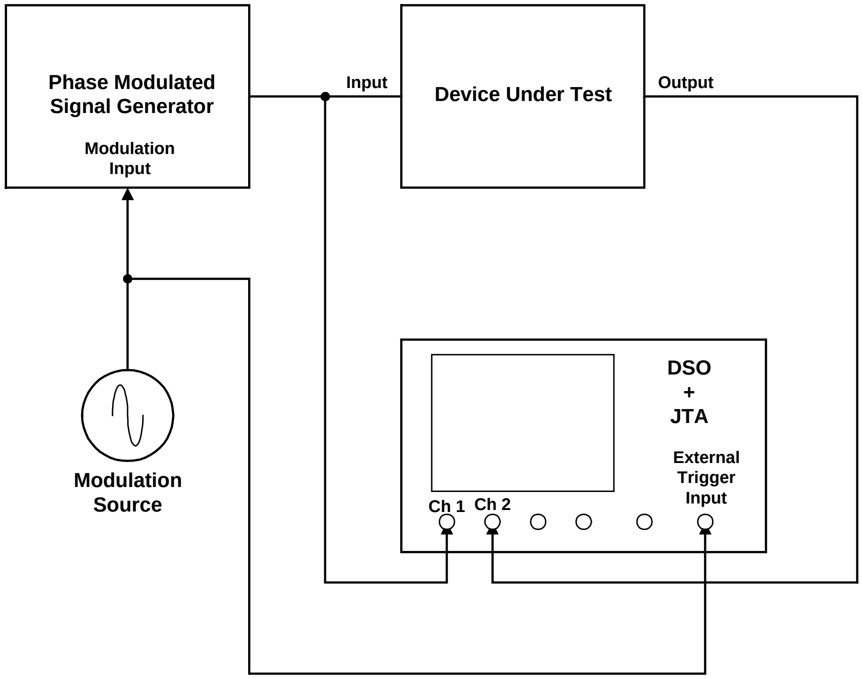


Figure 2 The test setup for measuring jitter transfer function

The test can be performed using a signal source capable of generating a phase modulated signal with controlled phase deviation and sufficient modulation bandwidth to cover the desired range of frequencies. The LeCroy LW420 allows the generation of phase modulated signals with modulation bandwidths sufficient for testing out to 10's of MHz. Tests were performed using stepped frequency sine modulation and also with a broadband step modulation function. In both cases the modulation bandwidth was flat out to greater than 10 MHz.

The oscilloscope was setup to measure the phase deviation at the output of the device under test utilizing the JitterTrack™ time interval error (TIE) function. The TIE shows the instantaneous phase change of the modulated signal. Figure 3 shows a typical test using the stepped frequency sine source. The upper trace is the output from the PLL. Trace A is the TIE function and shows the waveform of the modulating signal, in this case a sine wave. The lower trace is the trend of the peak to peak amplitude of the TIE waveform. This is the phase deviation of the PLL output signal. The trend function records the peak to peak phase deviation at each of the 30 modulation frequencies. The modulation frequencies are selected to be third (1/3) octave steps covering the range from 10 kHz to 10 MHz. When displayed on the uniform horizontal intervals of the trend function they represent logarithmic frequency steps. The vertical data is also logarithmically scaled and displayed in dB in the bottom trace (Trace D). The stepped frequency method has the advantage of using narrow band signals resulting in good dynamic range. The disadvantage is that it requires multiple acquisitions.

Another approach to perform the same measurement is to use a step waveform to modulate the input signal. In figure 4 the step response is detected (trace A), differentiated to obtain the impulse response(trace B), and Fourier transformed to convert it into the frequency response of the PLL (trace D). This technique has an advantage in that it only takes a single acquisition. However, the display is only available in a Log-Lin format. To convert to the usual Log-Log format the data has to be exported in ASCII spreadsheet format and imported to Excel. This is how figure 1 was generated.

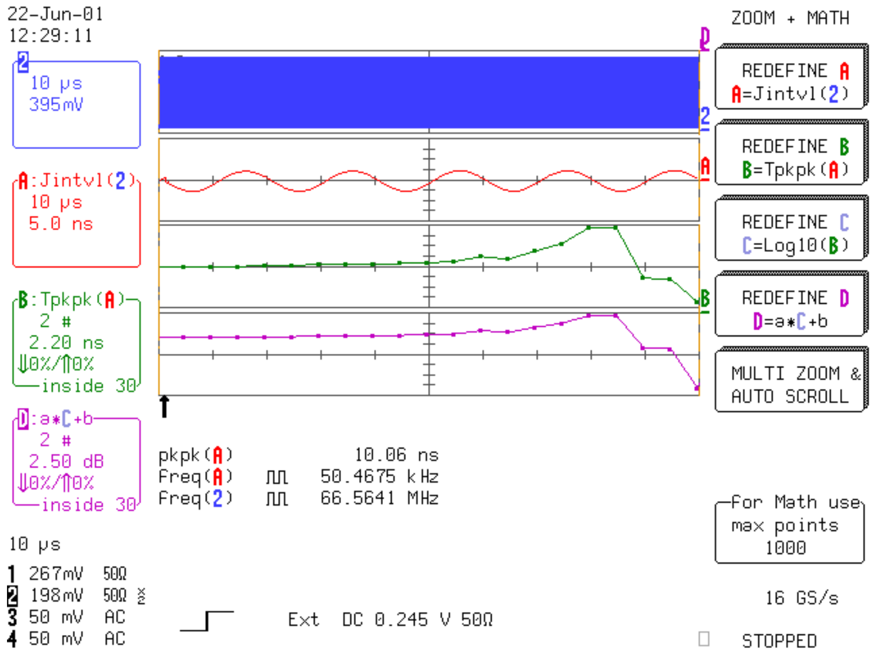


Figure 3 Measurement of PLL loop bandwidth using a stepped frequency sine source to phase modulate a 66MHz clock

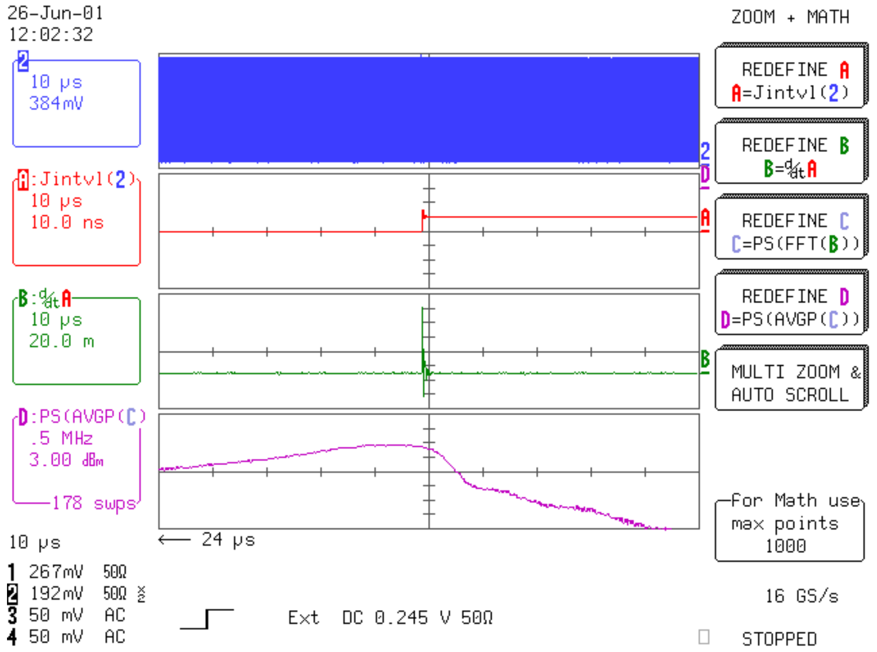


Figure 4 Measuring PLL loop bandwidth using a step waveform to modulate the clock.

If the Phase Locked Loop bandwidth is determined by using the transient phase step excitation technique outlined earlier you will obtain a frequency response function with an amplitude scale reading relative gain. If all you want is the loop bandwidth this can be determined from this display. If knowledge of the absolute gain is required then a few simple steps are required to normalize the frequency response to the input magnitude spectrum to obtain a reading of absolute gain.

The first step is to measure and record the spectrum of the phase variation of the input signal. The input signal is a 66.7 MHz sine wave with a 2 radian phase step in the center of the acquisition. This signal was created and output from a LeCroy LW420 arbitrary function generator. This acquisition should be under the same setup conditions being used for the frequency response measurement. Figure 5 shows a typical measurement of the input spectrum.

As expected the spectrum of this signal is very flat. This waveform should be stored into one of the processing memories (M1-M4).

The next step is to acquire the spectrum of the PLL output signal in response to this input signal. This is the same technique used previously and is shown in figure 6. Note that for each acquisition it is advisable to use the find function to maximize the signals dynamic range. This waveform should be stored to a different processing memory.

Once both the input and output spectral responses have been stored we can take the ratio. Since both these waveforms are logarithmically scaled the ratio is computed by taking the difference of the two spectra.

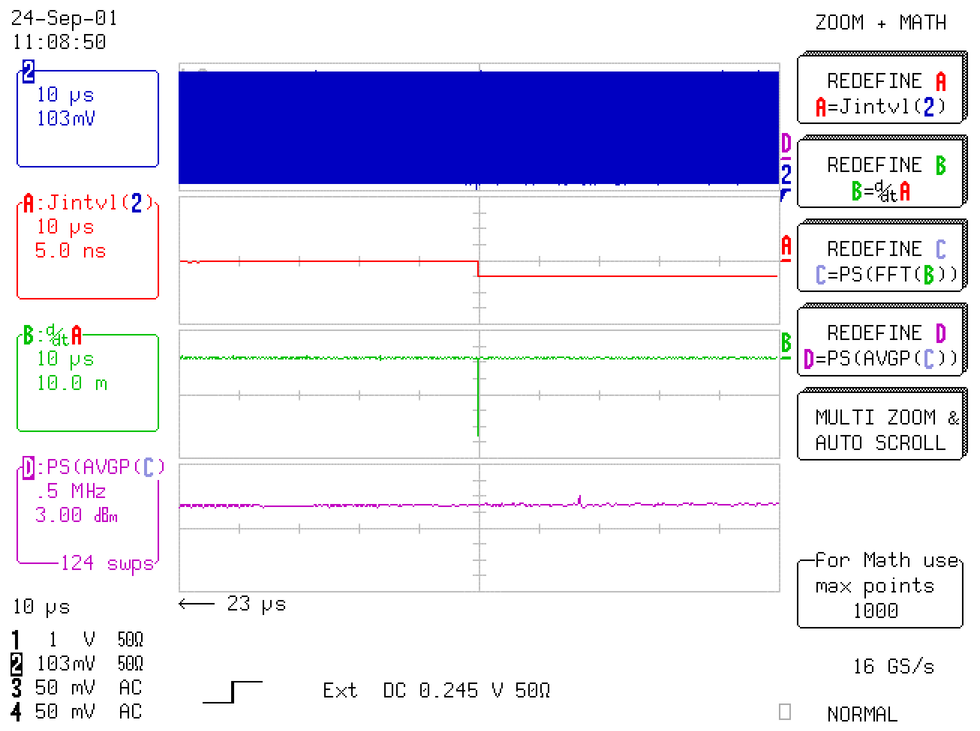


Figure 5 Measuring the spectrum of the input signal phase variation .

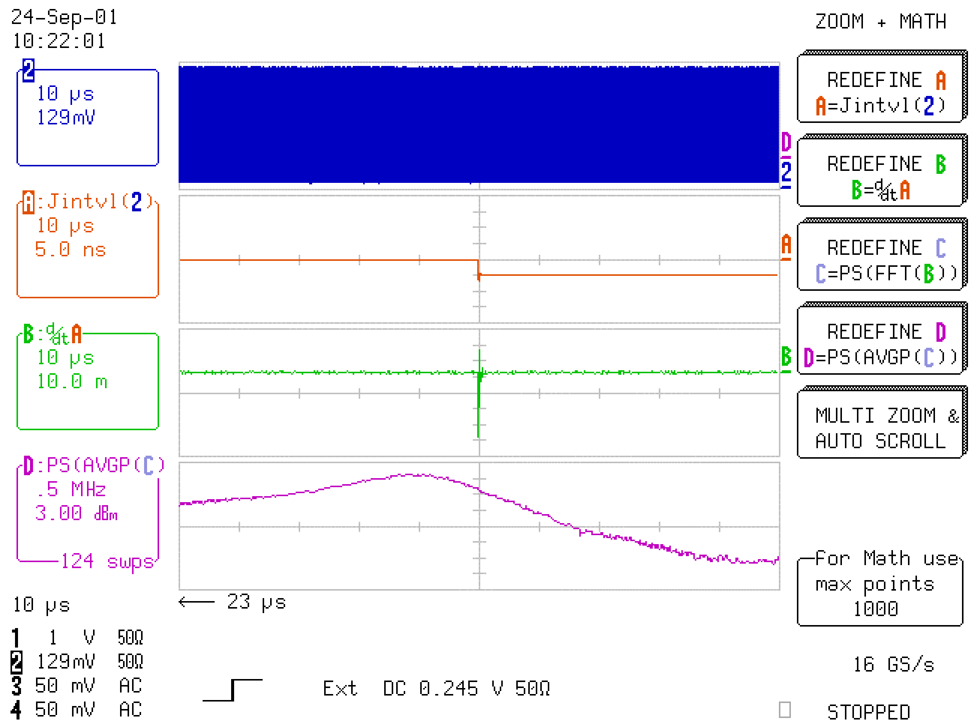


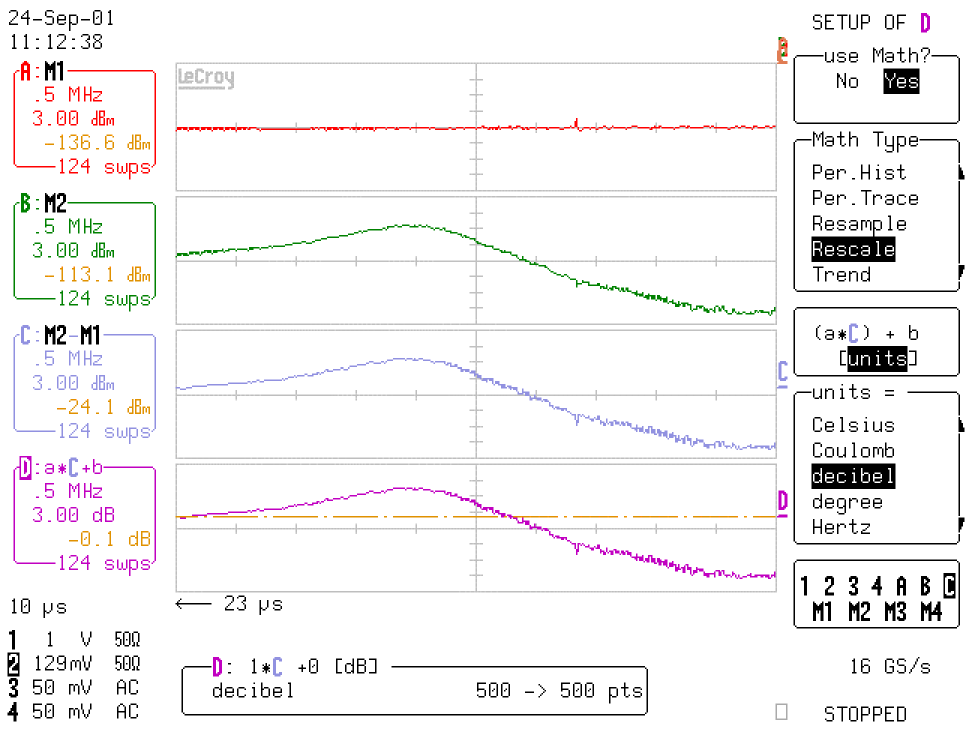
Figure 6 The measurement of the PLL output response to an input step function in phase at the carrier frequency of 66.7 MHz.

This process is shown in figure 7, which shows the steps involved with the calculation. Trace A contains the input spectrum. Trace B is the output spectrum. These are shown for reference only as they don't have to be visible to enable the calculations.

Trace C performs the difference of the logarithmic spectra yielding the ratio of the output to input spectra. The vertical units should be in dB, not dBm. The user has to correct this by using the rescale function to change to the correct units. This is done in trace D.

The data from Trace C can be exported to Excel in spreadsheet ASCII format and plotted on a Log-Log scale as shown in figure 8.

In a similar fashion the two component spectra could have been transferred and the entire calculation completed in Excel.



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11:12:38

A: M1
.5 MHz
3.00 dBm
-136.6 dBm
124 swps

B: M2
.5 MHz
3.00 dBm
-113.1 dBm
124 swps

C: M2-M1
.5 MHz
3.00 dBm
-24.1 dBm
124 swps

D: a∗C+b
.5 MHz
3.00 dB
-0.1 dB
124 swps

10 µs ⟵ 23 µs

1 1 V 50Ω
2 129mV 50Ω
3 50 mV AC
4 50 mV AC

D: 1∗C +0 [dB]
decibel 500 -> 500 pts

16 GS/s
☐ STOPPED

SETUP OF D
use Math? No Yes
Math Type: Per.Hist, Per.Trace, Resample, Rescale, Trend
(a∗C) + b [units]
units = Celsius, Coulomb, decibel, degree, Hertz

Figure 7 The math operations used to normalize the PLL loop response to the spectrum of the input signal and correctly label the vertical scales.

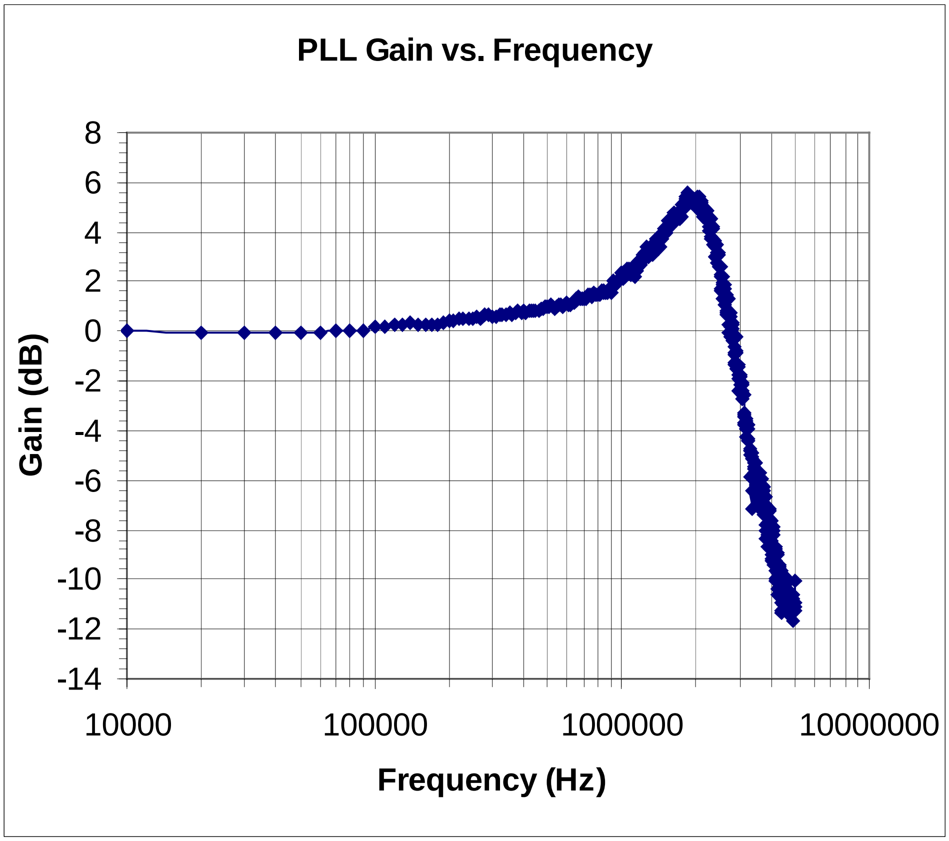

Figure 8 The Log-Log plot from Excel