

Frequency Multiplication Methods Compared

1 Two older methods of multiplication are compared to a new analog method of multiplication developed for high frequency oscillators.

1.1 Fourier (Figure 1)

This is the easiest analog mode of multiplication and it uses a Fourier-series. Each periodic signal can be defined as a sum of a fundamental frequency and a proportion of it's harmonics. If you convert the sine wave output of an oscillator into a square wave, then you can use the following relation :

$$x(t) = \sin(\omega t) + \frac{1}{3} * \sin(3 * \omega t) + \frac{1}{5} * \sin(5 * \omega t) + \dots$$

Next you have to choose the right sub-harmonic. You select it with a band-pass filter to reject the others. There is a disadvantage, however, you can use only odd factors of multiplication.

Note: Works well only for low frequencies.

1.2 PLL (Figure 2)

This is the easiest way to multiply frequency. In this method the output frequency is not a direct multiplication of the reference frequency but comes out of a voltage controlled independent oscillator that is synchronised to the reference frequency by a phase comparator . The frequency to be compared is divided by the **multiplying factor n**. Because of the frequency division, the VCO must produce the **multiplied by n** frequency after division into the feed-back loop to have the same frequency at the comparator inputs.

Note: Easy implementation for a large range of frequencies. **Poor jitter** because of the delay introduced by the feed-back loop and comparator.

1.3 Parametric (Figure 3)

Fordahl has developed a new analog method of multiplication using a hardware implementation of a multiplying function based on transfer of parameters between semi-conductors that give, at the output, a selectable coefficient of multiplication with a rejection of sub-harmonics. An output bandpass filter is added to improve the rejection of these sub-harmonics

Because of the analog type of multiplication **the spectral purity of the frequency $n * F_{ref}$ is improved and the phase-noise and jitter reduced**

Note: Works well for low and high frequencies

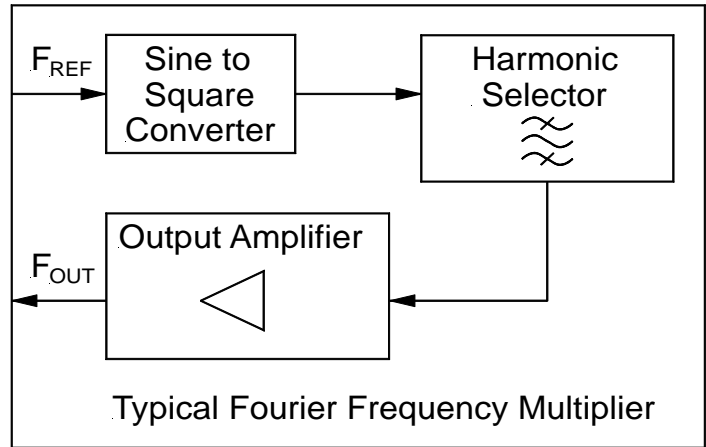


Figure 1 Fourier Multiplication

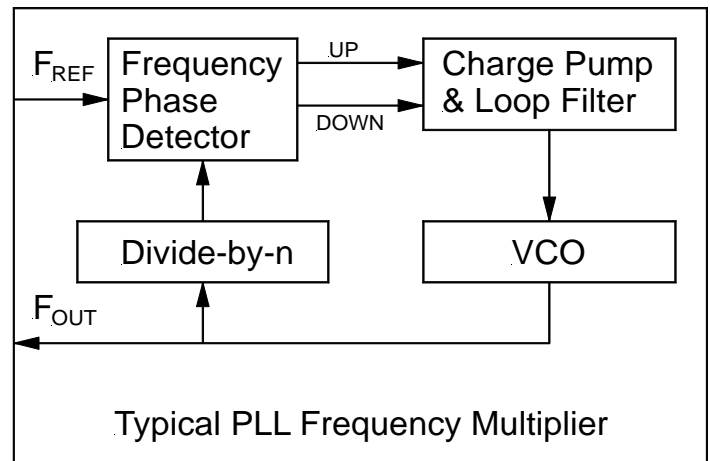


Figure 2 PLL Multiplication

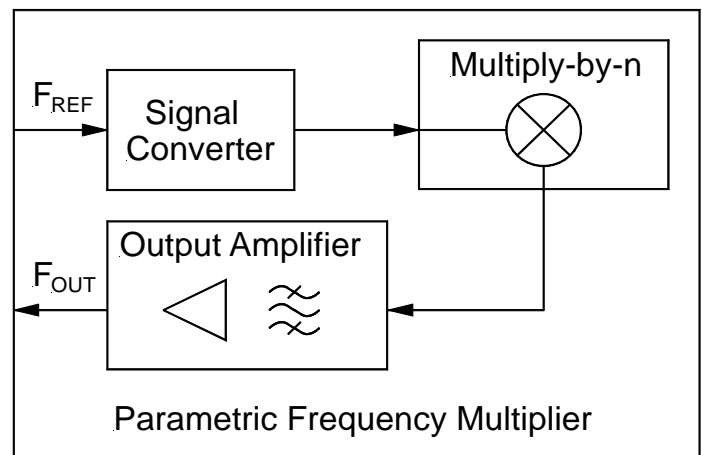


Figure 3 Parametric Multiplication

2 Spectrum for high frequency oscillators : 622.08MHz (for example)

2.1 Fourier

With this method of multiplication it is possible to reach theoretically more or less the same result as with the parametric multiplication. In practice this is very difficult because the inductors and capacitors to be used for high frequencies are too small and and too hard to adjust .

For this reason we use this method only for low frequencies.

2.2 PLL (Figure 4)

This plot shows the spectral purity of the output frequency of a 622.08 MHz PECL oscillator that was designed using a PLL.

Note: With some new types of digital PLL's, it is possible to reach better spectral purity, jitter and phase noise. The results are better than with a standard PLL, **but they don't reach the level of Fordahl's new method of multiplication.**

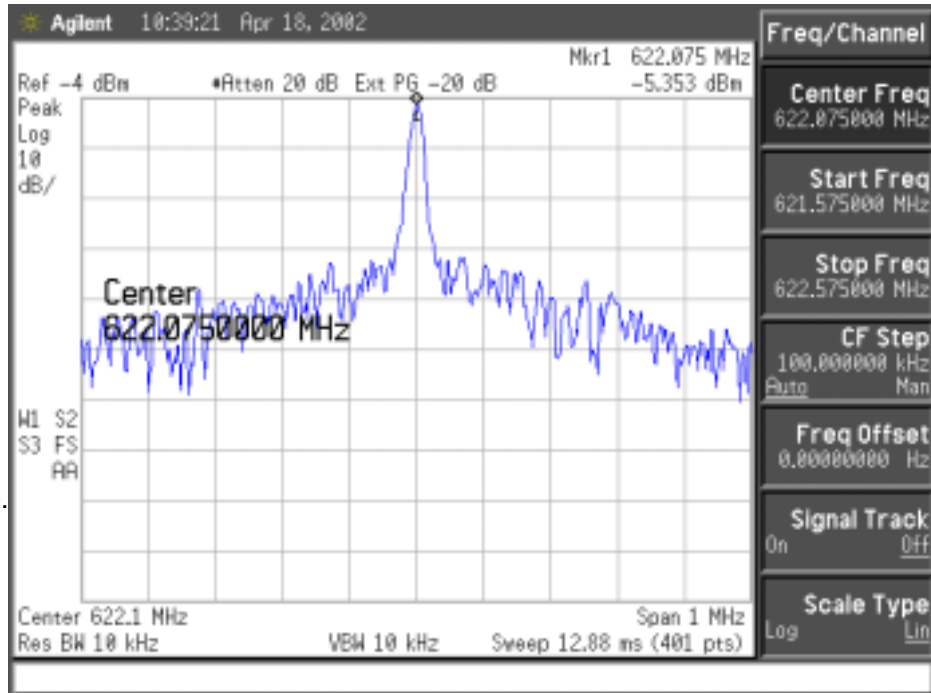


Figure 4 Output Spectrum of a Competitor's Oscillator Using a PLL

2.3 Parametric (Figure 5)

Again, this plot shows the spectral purity of the output frequency on a 622.08 MHz PECL oscillator. However, this plot was taken of a Fordahl oscillator using this new method of multiplication. It is important to note the substantial performance improvement in the spectrum.

Note : The shape of the output spectrum is about the same as with the Fourier method for the lower frequencies.

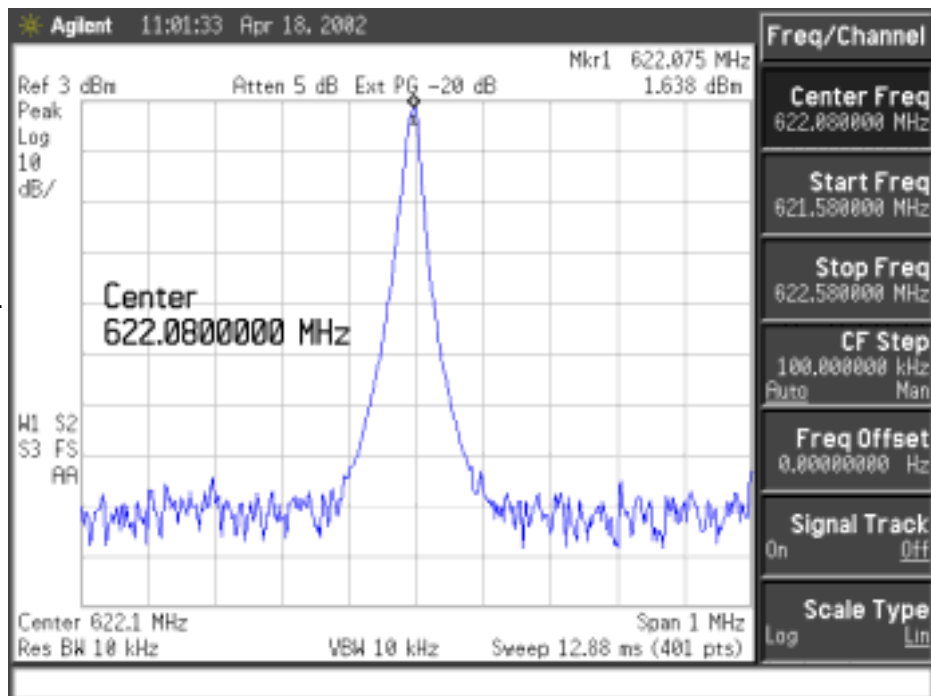


Figure 5 Output Spectrum of Fordahl's New Parametric Multiplication Oscillator

3 Phase-noise for high frequency oscillators : 622.08MHz (for example)

3.1 Fourier

We don't have phase-noise curves for this method in the range of frequencies discussed for the reasons explained on chapter 2.1.

3.2 PLL vs. Parametric Multiplication (Figure 6)

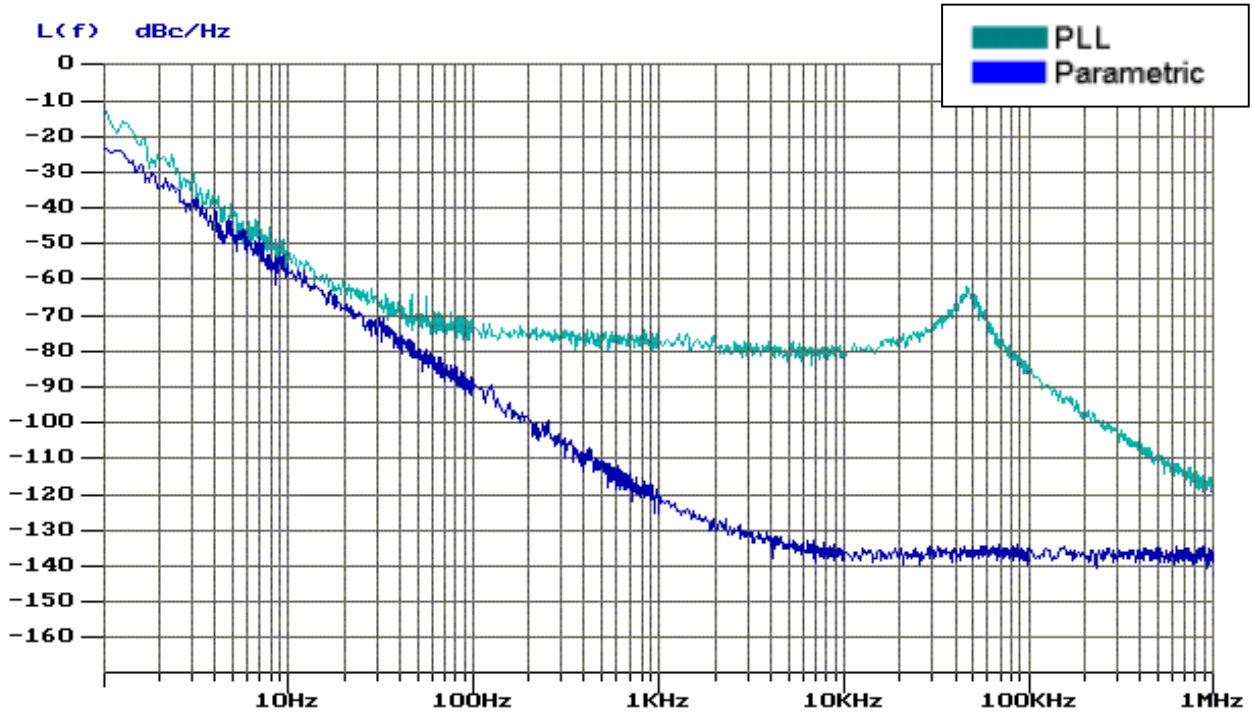


Figure 6 Phase Noise Comparison of PLL vs. Parametric Multiplication at 622.08 MHz

4 Advantages / Disadvantages of each method described (Table 1)

	Fourier	PLL	Parametric
Frequency range	Low frequencies (Limited by the too small values of the components for the high frequencies)	Low and high frequencies	Low and high frequencies
Spectral purity	Good	Poor	Good
Jitter	Good	Poor excepted for the new kinds of DPLL's where it is acceptable	Good
Phase-noise	Good	Poor excepted for the new kinds of DPLL's where it is acceptable	Good
Spurious	Good	More spurious than with other methods	Good
Supply current	Low current	High current	Low current
Supply voltage range	Higher voltage	Low voltages	Low voltages

Table 1 Comparison of Fourier, PLL, and Parametric Multiplication Methods