Spread Spectrum Clock Generation Technology

Benefits of Lexmark Modulation Waveform

The advantages of Lexmark's modulation waveform for EMI attenuation derive from its unique, patented shape, one embodiment of which is shown in Figure 1. In addition to the shape shown in Figure 1, other waveforms are covered by Lexmark patents (such as the triangular, or linear, waveform). A less efficient 'sharkfin', or exponential, waveform as seen in Figure 2 is sometimes used.

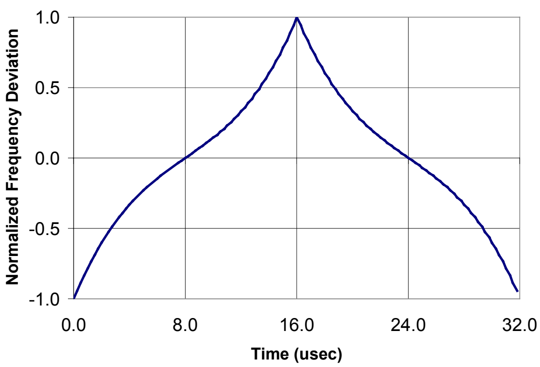

Figure 1. Patented Lexmark Modulation Waveform

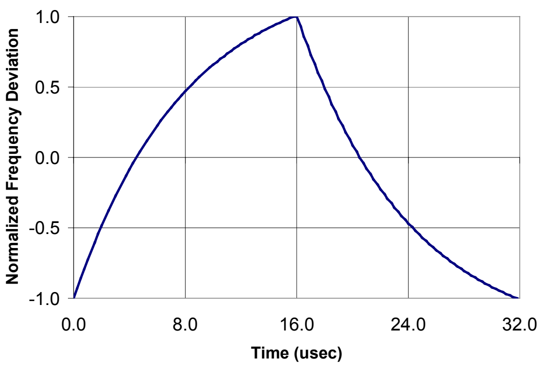

Figure 2. Typical Sharkfin Modulation Waveform

One of the benefits of the Lexmark waveform is that energy is spread out as equally as possible over the frequencies of interest. Alternative waveforms similarly spread out energy, but not as efficiently as the Lexmark waveform. Alternative techniques such as the sharkfin waveform place too much energy in narrow frequency bands at either end of the spectral profile, reducing the achievable attenuation.

In order to investigate the attenuation effects due solely to the modulation waveform, the equipment setup shown in Figure 3 can be used. This setup simulates a perfectly periodic waveform similar to that created by Lexmark's patented SSCG PLL architecture.

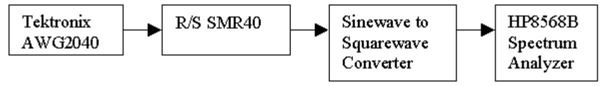

Figure 3. Experimental Test Setup

This setup simulates a 100 MHz 0.5% down-spread system clock. In this setup, the arbitrary waveform generator (AWG2040) provides the modulation waveform to the signal generator's (SMR40) FM input. The signal generator is set to 99.75 MHz with a ± 250 kHz modulation deviation. Since the output of the signal generator is a sine wave, a sine wave-to-square wave converter is used to simulate a trapezoidal clock signal. This ensures that, like real-world clock signals, higher clock harmonics are present. Next, the output of the converter attaches to a spectrum analyzer widely utilized in the industry. In order to most closely match the measurement bandwidth required for FCC and CISPR radiated emissions measurements the following settings are used. Resolution Bandwidth is set to 100 kHz and the Video Bandwidth is set to 300 kHz. These settings are extremely important and have a large impact on the effective attenuation achieved. Some SSCG vendors state EMI attenuation based on the incorrect measurement bandwidths. This can lead to a situation where the stated EMI attenuation will not be achieved in a final product.

Figures 4 and 5 show the resulting frequency spectra for a pure clock signal, the Lexmark waveform, and a typical sharkfin waveform for different clock harmonic frequencies. The base clock frequency is 100 MHz, with significant frequency content every 100 MHz. As frequency increases attenuation increases, since the energy is spread out over a percentage of the clock frequency.

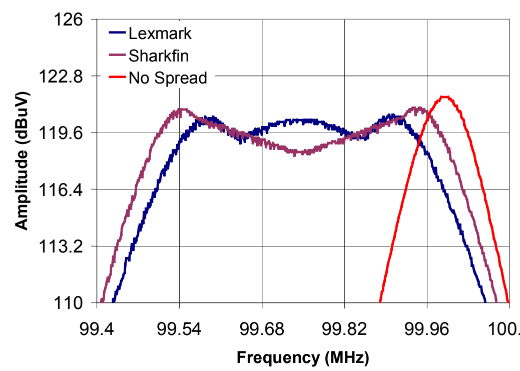

Figure 4. Clock Spectra Resulting from a Non-Modulated Clock, Sharkfin Modulated Clock, and Lexmark Modulated Clock (-0.5% Deviation, Base Clock Frequency)

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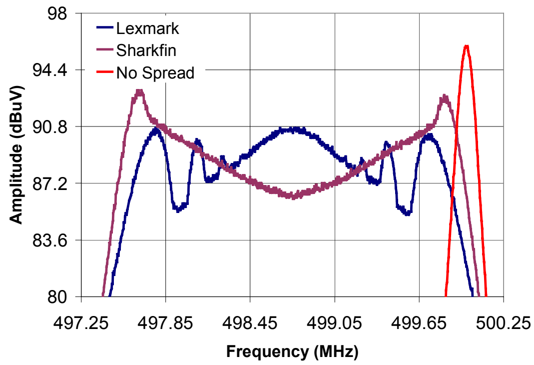

Figure 5. Clock Spectra Resulting from a Non-Modulated Clock, Sharkfin Modulated Clock, and Lexmark Modulated Clock (-0.5% Deviation, 500 MHz Harmonic)

As shown, at all harmonics noted in Figure 6, the Lexmark modulation waveform performs better than the sharkfin waveform. The maximum attenuation for a given waveform was determined by measuring the maximum amplitude of the non-spread clock spectrum and subtracting the maximum amplitude of the spread clock spectrum. Figure 6 shows attenuation versus frequency for a 100 MHz, 0.5% down-spread clock signal. At 100 MHz, neither profile attenuates much due to the narrow deviation percentage. However, the Lexmark waveform attenuates 1.8 times better (in terms of dB) than the sharkfin (0.86 dB vs. 0.48 dB). This trend continues for every harmonic shown, with the Lexmark waveform providing 7.58 dB attenuation at 800 MHz compared to only 4.36 dB for the sharkfin waveform. If more attenuation is needed, a wider deviation percentage should be considered.

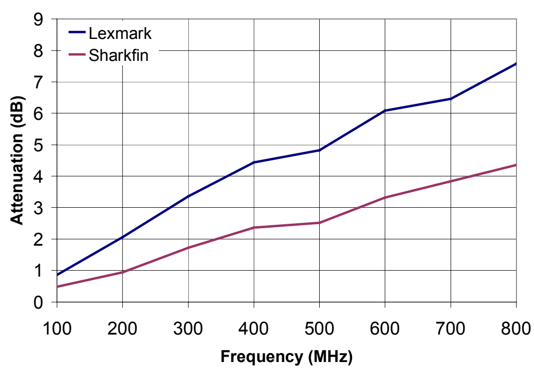

Figure 6. Comparison of Lexmark Modulation Waveform and Sharkfin Modulation Waveform Attenuation

The roughly 3 dB difference in attenuation between the Lexmark waveform and the sharkfin waveform at higher frequencies can be significant. During final product radiated emissions certification, the extra 3 dB may be all that stands between passing as-is, versus adding, for example, fifty cents worth of ferrite filters to pass. This can be a significant impact to the profit margin of a high-volume product.

Additional Benefits of Lexmark Technology

Another benefit of Lexmark technology, aside from the optimized modulation profile, is the flexibility of Lexmark's patented SSCG PLL architecture (Figure 7). Since the modulation waveform is generated by a RAM table instead of being hard-wired, it can be changed to compensate for silicon process changes. This gives the ability to preserve attenuation performance without another silicon spin to adjust PLL parameters. This also allows product designers to increase deviation percentage at the last minute to achieve that extra attenuation that might be necessary to pass radiated emissions certification and avoiding adding cost to the product. Typical PLL architectures that implement the sharkfin modulation waveform do not have this ability, and are very susceptible to process changes.

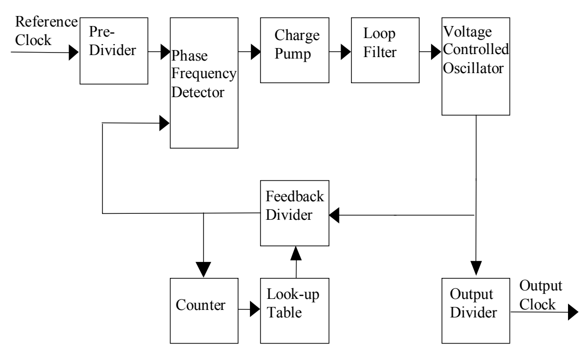

Figure 7. Typical Simplified Lexmark SSCG PLL Architecture

The architecture shown in Figure 7 also creates a highly repetitive, smooth modulation waveform and has the ability to control the most important aspects of the modulation waveform. If a PLL tracks the SSCG PLL, a smooth waveform is extremely important to maintain lock and minimize clock skew. Sudden changes in frequency cause the largest amount of clock skew. Lexmark's architecture allows the designer to optimize the modulation waveform to minimize its effects on tracking skew. Architectures that produce less predictable modulation profiles may cause unforeseen skew problems with down-stream PLL's.

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