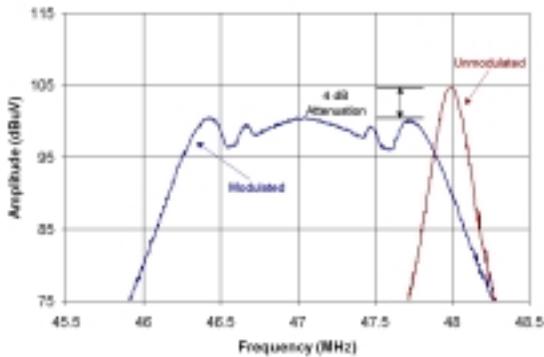




# Spread Spectrum Clock Generation Technology

The primary source of radiated emissions (which exceed regulatory limits) from digital circuits is often the system clock and all synchronous signals derived from it. The traditional method for reducing the radiated emissions is to filter all of these 'hot' signals. While effective, this can cost money and board space. A more efficient method to reduce these emissions is Spread Spectrum Clock Generation (SSCG).

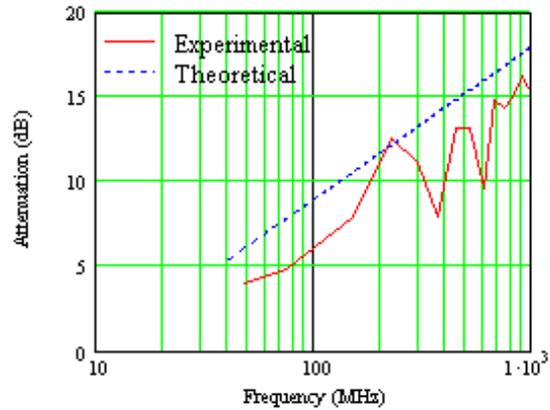
SSCG is a technique that has been utilized in PC's and peripherals for several years with great success. A spread spectrum clock is frequency modulated such that the energy is spread out over a wider bandwidth, reducing the peak radiated emissions (Figure 1). The attenuation achieved by SSCG is directly proportional to the 'flatness' of the energy spectrum: the more evenly energy is spread over a bandwidth, the more attenuation is possible.



**Figure 1. Measured Frequency Spectrum of a 48 MHz Clock Harmonic With and Without SSCG**

In addition to the reduction of radiated emissions at the fundamental clock frequency, the attenuation of SSCG increases with each successive clock harmonic. Figure 2 shows the attenuation provided by SSCG at each harmonic of a spread spectrum clock with  $-3.75\%$  deviation. This attenuation can be seen on not only the clock, but also on all signals derived from the clock. In a business where another 2dB reduction in emissions is weighed against adding \$2.00 of filtering to a product, SSCG can be essential to success.

Several phase-locked loop (PLL) architectures enable the creation of spread spectrum clocks, but Lexmark was the first to patent the third-order PLL design for use as a spread spectrum clock generator. The Lexmark SSCG design uses a standard third-order PLL with an additional programmable feedback divider to produce the Lexmark modulation waveform. This results in an optimally flat clock spectrum for better attenuation than any other spread spectrum clock generator.



**Figure 2. Measured and Theoretical Attenuation of a  $-3.75\%$  Deviation SSCG Clock**

In addition to the basic PLL architecture, several improvements are included in the patent portfolio provided with a licensing agreement. One improvement can be used to monitor the total gain of the PLL in order to select from several feedback divider tables to maximize performance for the given operating conditions. Another improvement is the synchronization function. This function resets the PLL modulation table to a predetermined starting point, providing the ability for two separate clock generators to sync together. This is an important feature for video applications. Another benefit of the Lexmark architecture is that any output frequency or modulation waveform is achievable, limited only by the bandwidth and gain of the PLL and the memory depth in the feedback divider. This lends itself to designing a single PLL block for use in several current and future products.

A sample licensing agreement is available upon request. The royalty section of the agreement includes a small one-time technology transfer fee. For low-price IC's such as 8-pin clock generators the royalty payment is a percentage of the part price. For more expensive parts such as ASICs and embedded processors, a set royalty is paid per device.

If your company is interested in discussing a licensing agreement, please contact:

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<http://www.lexmark.com/sscg>



# Spread Spectrum Clock Generation Technology

## Additional Information

Lexmark's modulation waveform provides the best attenuation because of its unique, patented shape shown in Figure 4. Some spread spectrum clock generators use a 'sharkfin' modulation waveform, which performs almost as well as a triangular waveform (Lexmark patents also cover the triangular waveform). Figure 5 shows the attenuation performance of the Lexmark modulation versus a symmetric triangular modulation profile. The unique Lexmark modulation waveform provides between 2 and 5 dB better attenuation than the nearest competing method.

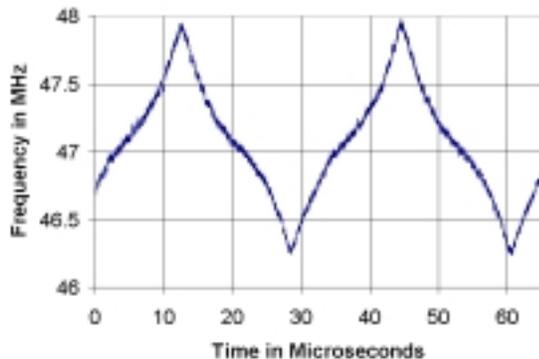


Figure 4. Patented Lexmark Modulation Waveform

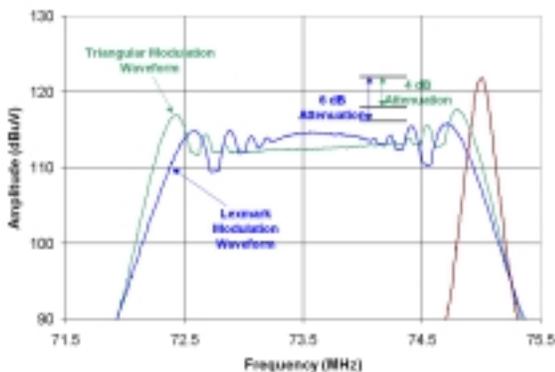


Figure 5. Clock Spectra Resulting from a Non-Modulated Clock, Triangular Modulated Clock, and Lexmark Modulated Clock (-3.75% Deviation)

There are a few functional issues that accompany the use of any spread spectrum clock. One such issue is the use of downstream PLL's that must track the spread spectrum clock. The frequency deviation on spread clocks can be such that a downstream PLL will either lose lock, or filter out the modulation, thereby negating its benefits. In order to prevent this, the bandwidth of the

downstream PLL must be large enough that it can track a modulated clock. Some implementations of SSCG do not change frequency as smoothly as the Lexmark method and may exacerbate this problem. Part of the software package included in the licensing agreement simulates the output clock of a tracking PLL given a specific clock input.

One of the most important functional issues with SSCG involves serial communications. For many applications such as USB, ethernet, or UART communications, a stable clock is necessary. In these cases the clock tolerance is too tight to permit any useful clock modulation. Typically, Lexmark will use a separate PLL or oscillator for these applications. The separate oscillator or PLL will then usually run the SSCG PLL.

## References

### Papers

The following papers are available upon request, or on our website at:

<http://www.lexmark.com/sscg>

- [1] K. B. Hardin, J. T. Fessler, D. R. Bush, "Spread Spectrum Clock Generation for the Reduction of Radiated Emissions," Proceedings of the 1994 IEEE International Symposium on Electromagnetic Compatibility, Chicago, IL., August 22 - 26, 1994, pp.227 - 231.
- [2] K. B. Hardin, J. T. Fessler, D. R. Bush, "A Study of the Interference Potential of Spread Spectrum Clock Generation Techniques," Proceedings of the 1995 IEEE International Symposium on Electromagnetic Compatibility, Atlanta GA., August 14 - 18, 1995, pp.624 - 629.
- [3] K. B. Hardin, et. al., "Design Considerations of Phase-Locked Loop Systems for Spread Spectrum Clock Generation Compatibility," Proceedings of the 1997 IEEE International Symposium on Electromagnetic Compatibility, Austin TX., August 18-22, 1997.
- [4] H. G. Skinner, K. P. Slattery, "Why Spread Spectrum Clocking of Computing Device is Not Cheating", Proceedings of the 2001 IEEE International Symposium on Electromagnetic Compatibility, Montreal, Canada, August 13 - 17, 2001.

### Patents

The following patents are included in the licensing agreement.

- [5] U.S. Patents 5,488,627; 5,631,920; 5,867,524, 5,872,807; 6,167,103; 6,292,507.