AN2399

MEMS Oscillators Offer Immunity to EMI

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ABSTRACT

Electromagnetic interference (EMI) has always been a big challenge for system designers in the semiconductor industry. This challenge is even bigger in today's system designs where the electronic components are tightly packed and the processor speed and data rates are higher than ever. The system clock is a major contributor to EMI generation.

MEMS oscillators have become very popular and have been steadily replacing crystal oscillators in applications that require clock generation. MEMS oscillators offer significant advantages over crystals, one of which is the flexibility in the way they can be programmed and configured.

This application note focuses on how the programmability of MEMS oscillators helps reduce EMI.

INTRODUCTION

The clock generator is a major contributor of EMI in a system. The square-wave clock signal's spectrum has a fundamental frequency, as well as a high number of odd harmonics, with lots of energy. The sharper the clock, the more energetic the harmonics; and that generates higher EMI.

Traditional methods to mitigate EMI consist of a careful layout, filtering, and shielding. All of these increase cost and board space.

When generating a clock, MEMS oscillators have become very popular and have been steadily replacing crystal oscillators in many applications in consumer, industrial, automotive, and partially in networking and telecom. MEMS oscillators offer significant advantages over crystals.

One of these advantages is that MEMS oscillators are flexible and programmable in many parameters. One of these parameters is the output driving strength, which is related to the rise and fall time of the clock signal. Slower rise and fall times reduce the clock's harmonic energy and, therefore, mitigate EMI because the energy radiated is related to the harmonics' energy content. Another programmable feature is the spread spectrum; the clock frequency is modulated over time and the peak spectral energy of the fundamental frequency and its harmonics are reduced.

The following sections focus more in details about how the MEMS oscillators' programmability of rise and fall time, as well as the spread spectrum capability, are used to reduce and mitigate EMI.

Refer to AN2340, "Immunity of MEMS Oscillators to Mechanical Stresses," for other important advantages of MEMS oscillators versus traditional crystals.

PROGRAMMABLE RISE/FALL TIME

Some Microchip MEMS oscillator families, such as the DSC11xx and DSC2010, offer the possibility of programming the CMOS output buffer's drive strength, which affects the rise and fall time of the output signal. The DSC2010 offers three inputs (OS0, OS1, OS2) that enable one of eight possible drive strengths. The DSC1101 is factory-programmed to use the highest drive strength, while the DSC1105 is programmed to use the lowest.

High drive strength is beneficial when either the application requires fast rise/fall times or when the device needs to drive a significant capacitive load. It also helps reduce the effect of power supply noise on the clock jitter.

The lowest drive strength corresponds to the slowest rise/fall time In Table 1. In this condition, the clock signal has the smoothest edges, the lowest harmonics energy content, and therefore provides the highest EMI reduction.

Figure 1 shows how the harmonics are attenuated when the output buffer's drive strength decreases.

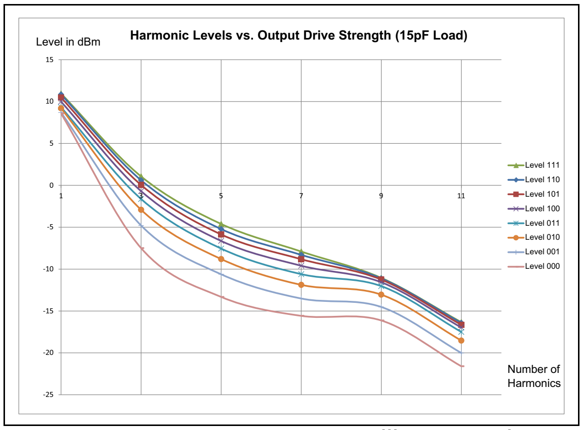

FIGURE 1: MEMS Oscillator Fundamental and Harmonics Levels for Eight Drive Strengths.

TABLE 1: RISE/FALL TIMES FOR EIGHT DRIVE STRENGTHS (15PF LOAD)

Drive Strength	Rise Time	Fall Time
Code 111 (strongest)	1.46 ns	1.95 ns
Code 110	1.48 ns	1.97 ns
Code 101	1.58 ns	2.10 ns
Code 100	1.89 ns	2.35 ns
Code 011	2.04 ns	3.45 ns
Code 010	2.33 ns	3.58 ns
Code 001	2.68 ns	4.38 ns
Code 000 (weakest)	4.53 ns	5.30 ns

SPREAD SPECTRUM

Spread spectrum is a slow modulation over time of the clock frequency. The PLL inside the MEMS oscillator is modulated with a triangular wave at 33 kHz. With such a slow modulation, the peak spectral energy of both the fundamental frequency and all the harmonics is spread over a wider frequency range. As such, energy is significantly reduced, thus providing an EMI reduction. The triangular wave is chosen because of its flat spectral density

The Microchip MEMS oscillator family DSC63xx offers several modulation options. The spreading is either center or down with respect to the clock frequency. Center spreading ranges from ±0.25% to ±2.5%, while down spreading ranges from –0.25% to –3%.

If the clock frequency is 100 MHz and central spreading with ±1% is chosen, the output clock will range from 99 MHz to 101 MHz. If down spreading with –2% is chosen, the output clock will range from 98 MHz to 100 MHz.

Figure 2 and Figure 3 show a spectrum example of the DSC6331 with a 33.333 MHz clock, modulated with a central spread of ±1%.

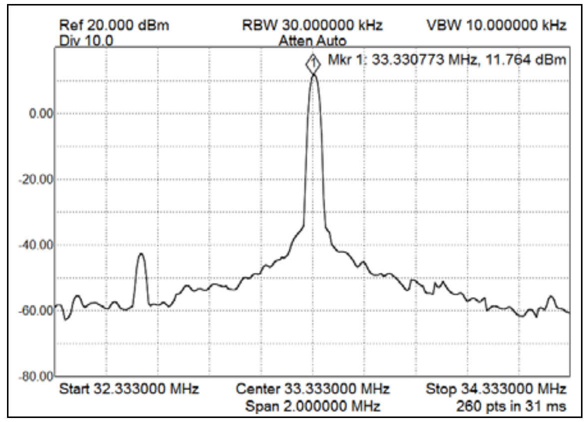

FIGURE 2: DSC6331's Spectrum at 33.333 MHz with Modulation Turned Off.

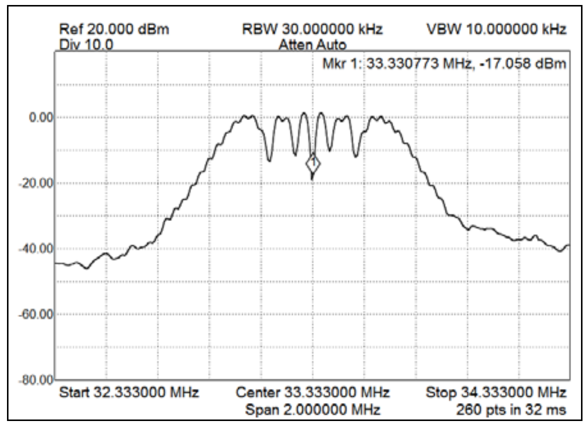

FIGURE 3: DSC6331's Spectrum at 33.333 MHz with Modulation Turned On.

It is noticeable that the spread spectrum provides a reduction of about 10 dB from the peak power. Such a reduction may also be estimated by the following equation:

EQUATION 1:

$$EMIReduction = 10 \times Log10(|S| \times fc / RBW)$$

Where:

S	Peak-to-peak spread percentage (1% in this example).
fc	Carrier frequency (33.333 MHz in this example).
RBW	Resolution bandwidth of the spectrum analyzer (30 kHz in this example).

The theoretical calculation for this example equates to 10.45 dB, which is consistent with the measurement.

Similarly to the fundamental frequency, all the harmonics are spread and attenuated in a similar fashion.

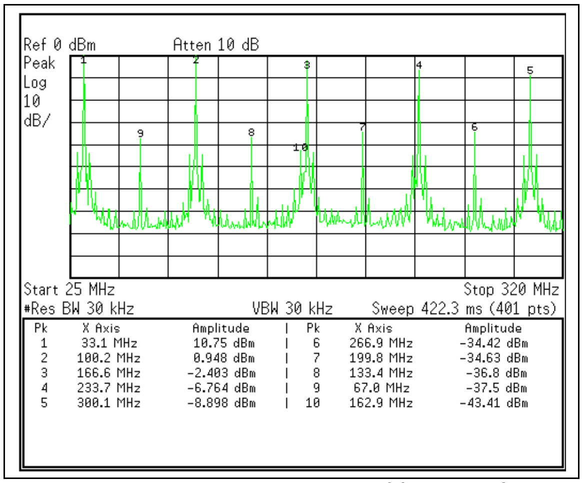

FIGURE 4: *DSC6331 with Spread Spectrum Disabled.*

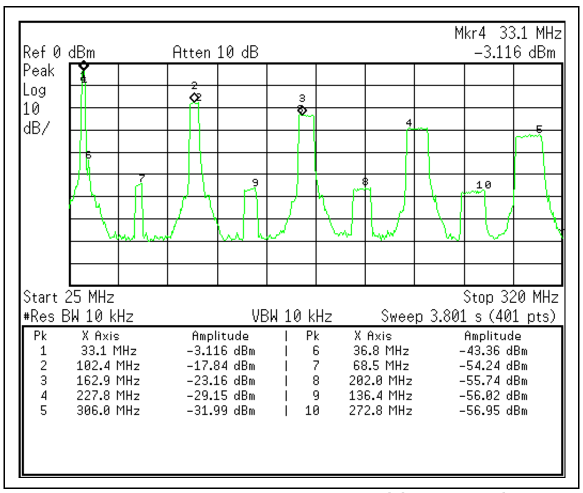

FIGURE 5: *DSC6331 with Spread Spectrum Enabled, Center Spread ±2.5%.*

Figure 6 shows how the DSC6331's fundamental frequency at 33.333 MHz and its odd harmonics are attenuated when various types of modulations are selected. For clarity, only the central spread options are shown in Figure 6. However, down spread with a corresponding percentage provides the same level of harmonic attenuation (e.g., central spread of ±1% provides the same harmonics attenuation of down spread with –2%).

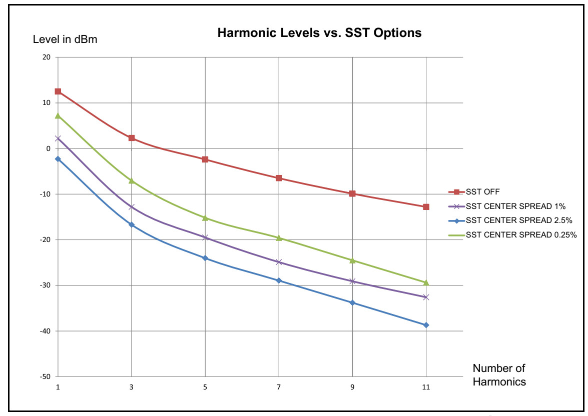

FIGURE 6: *DSC6331's Harmonic Levels with Various Spread Spectrum Options.*

CONCLUSION

EMI is a serious challenge in modern electronic designs and the clock generator is one of the main contributors to EMI. MEMS oscillators are flexible and programmable. They offer two important programmable features that help reduce and mitigate the EMI generated by the clock. The first feature is the programmable rise/fall time. Slower rise/fall times reduce the energy associated with each clock signal's harmonic, which is an indication of the energy radiated (EMI). The second feature is a slow modulation of the clock frequency called spread spectrum. This feature also produces a significant reduction in the energy associated with the clock harmonics.

These MEMS oscillators' two programmable features reduce EMI and reduce board cost and space by easing the EMI filtering and shielding design.

NOTES:

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