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A Solution for Peak EMI Reduction with Spread Spectrum Clock Generators

Prepared by: Apps Team, BIDC
ON Semiconductor

APPLICATION NOTE

Introduction

This application note will outline Spread Spectrum Clock Generators as a method to solve peak Electromagnetic Interference (EMI) issue, parameters of the spread spectrum clock, types of spread, and depict the effect of various amounts of frequency deviation on the signal with Modulation Domain Analyzer (MDA) and Spectrum Analyzer plots.

What is the problem?

Electromagnetic Interference is the Electromagnetic emission from a device or a system that interferes with the normal operation of another device or a system (external source). It is also referred to as Radio Frequency Interference (RFI). EMI is caused by electromagnetic induction or electromagnetic radiation emitted from an external source.

Conducted EMI and Radiated EMI are the two types of electromagnetic interference. Conducted EMI is caused by the physical contact of the conductors where as radiated EMI is caused by induction (without physical contact of the conductors).

EMI is an unwanted RF energy that interferes with other systems' normal operation. It is the excess radiated energy from the interfering device or the system, beyond the limits of electromagnetic compliance.

Disturbances experienced in local receiving equipments such as television, radio, and cell phones are examples of interference due to unwanted RF energy which is EMI.

With TV reception as an example, the poor picture quality seen could be due to EMI. Interference may prevent reception altogether, may cause only a temporary loss of a signal, or may affect the quality of the sound or picture produced by the interfered equipment.

Radio frequency interference can occur due to the harmonic frequencies of the interfering device or equipment even if the interfering device itself is not operating at the interfered frequency.

This interference is unwanted by the user as this would affect the normal operation of the device or system.

Why it is to be contained?

Legal limits have been imposed on electromagnetic emissions from all digital equipments and apparatus intended for general population, by monitoring bodies like the Federal Communication Commission (FCC) in the USA, the International Special Committee for Radio Interference (CISPR) in Europe, VCCI in Japan etc. Many countries now have similar requirements for products to meet some level of Electromagnetic compatibility (EMC) regulation. CISPR sets standards for radiated and conducted electromagnetic interference.

The FCC has two classes of radiation levels, stated as Class A and Class B. Class A devices are digital devices intended for use in commercial, industrial or businesses and not intended for use by the general public or in the home. Class B digital devices are intended to be used in the home but could also be used elsewhere.

The regulations and regulators are in place to ensure that the emissions from devices / systems released to market do not interfere with the normal functioning of other devices / systems already in the market.

Non-compliant products are at risk of being recalled which can negatively impact brand image. Thus ensuring EM compliance for products becomes critical for company's success.

With faster clock speeds, lower voltage/power requirements due to the recent advances in the semiconductor and computing technology coupled with the explosion of the wireless technologies, Electromagnetic compatibility (EMC) is becoming one of the most important standard requirements in the new technology world.

How it can be contained?

Reducing the interference levels from the EMI source is among the many approaches to Electromagnetic Compatibility. This can be achieved by reducing the signal level of the source or by frequency modulation at the source. Other means are careful system design, to modify the signal routing, adding local filtering, reducing the number of interconnections, increase the separation of the coupling

path, use of passives like the EMI/RFI filters, conductive coating, shielding, and operating frequency selection.

Use of bypass or decoupling capacitors on each active device (connected across the power supply, as close to the device as possible), and rise time control of high speed signals using Series damping resistors are some of the other methods used to control EMI. Shielding is usually a last resort after other techniques have failed, because of the added expense of shielding components such as conductive gaskets.

Spread Spectrum Clock Generation (SSCG) – a Definition

Spread Spectrum Clock Generation is a method by which the energy contained in the narrow band of a clock source is spread over a wider band in a controlled manner thus reducing the peak spectral amplitude of the fundamental and the harmonics to lower the radiated emission from the clock source. This is achieved by frequency modulating the clock with a unique waveform. Linear and Hershey Kiss profiles are commonly used to achieve the peak EMI reduction.

By varying the clock frequency over a band in a controlled manner, the time spent by the signal at a given frequency is reduced thereby the energy concentration at any frequency is reduced. Thus energy is spread over the band of frequencies reducing the peak amplitude.

Using Spread Spectrum Clock Generators – Advantages

Spread Spectrum Clock Generation provides a way to achieve EMC.

It is an active solution, preserves the integrity of the clock signal, can cover a wide frequency range to provide compliance, and is cost effective.

As compared to the traditional methods of using passive components like ferrite beads, RF chokes to suppress EMI, SSCG uses an integrated circuit of active devices to reduce the peak EMI using frequency modulation.

SSCG reduces peak EMI at the clock source, allowing system wide reduction of EMI of downstream clock and data

dependent signals. It allows for significant system cost savings by reducing the number of circuit board layers, ferrite beads, shielding and other passive components that are traditionally required to pass EMI regulations.

SSCG can be designed to be user programmable for ‘spread’ or can be custom made for the requirement.

Passive solutions predominantly use filters, and in some cases integrate ESD protection on each line for reducing EMI and consume no power. SSCG uses frequency modulation to spread the energy over a controlled band of frequencies to reduce peak EMI at source and of downstream clock and data signals. Being an active solution SSCG needs power for operation.

Definition of Modulation Parameters

Three parameters primarily control the Spread Spectrum on a clock source.

Modulation Rate (MR) is the rate at which the energy of the clock source is distributed over the band of frequencies around the output clock frequency. Modulation Rate will be much lower than the source clock frequency, and will be chosen to be above the audio frequency range.

Modulation Depth is the frequency range over which the clock will make the frequency excursion at the rate of MR. It is denoted by the percentage (%) spread which is the ratio of the band of frequency excursion (ΔF) to the output clock frequency. This would determine the amount of peak EMI reduction achievable. Generally, higher the Modulation Depth, greater is the EMI reduction. However the system constraints on the frequency variation need to be evaluated while selecting the modulation depth for a system.

Modulation profile will determine the effectiveness of the peak EMI reduction. Linear, and Hershey Kiss profiles are commonly used to implement the manner in which the frequency of the clock source is varied during spread spectrum clock generation.

Figures 1 through Figure 4 depict examples of the linear and Hershey Kiss profiles on MDA and Spectrum analyzer

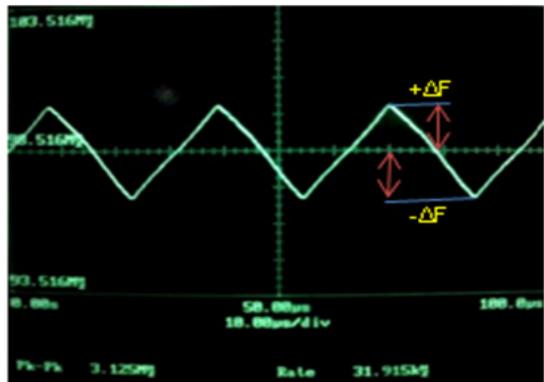


Figure 1. Linear Profile (MDA plot)

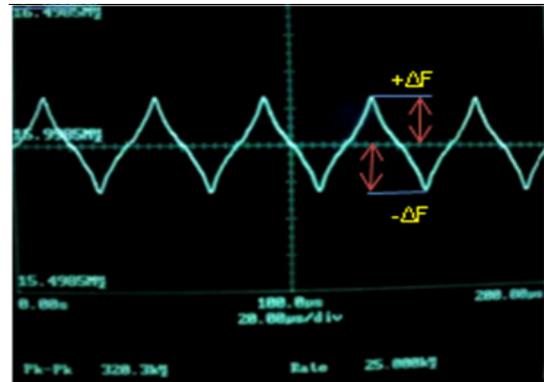


Figure 2. Hershey Kiss Profile (MDA Plot)

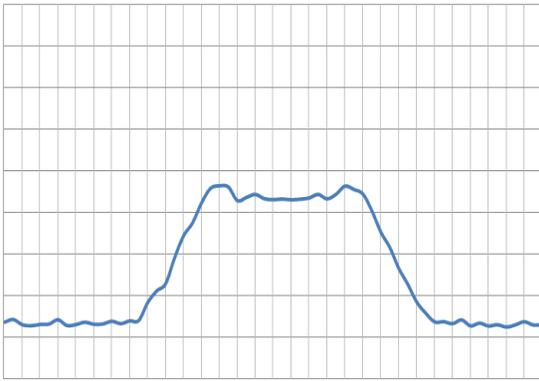


Figure 3. Linear Profile (Spectrum Plot)

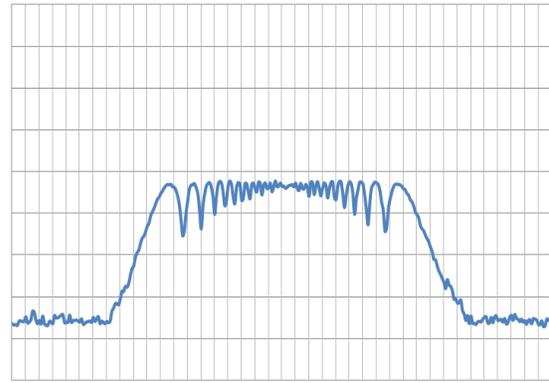


Figure 4. Hershey Kiss Profile (Spectrum Plot)

Types of Spread

There are three types of spread modes based on the relationship of the frequency excursion of the modulated clock to the non-modulated clock.

Centre spread is where the average frequency of the spread spectrum clock will be the same as that of the non-modulated output clock. In a system where the non-modulated output clock is of the same frequency as the input frequency, the output clock will vary from $(f_c - \Delta f)$ to $(f_c + \Delta f)$ at MR as per the modulation profile. It can be represented as

$$f_o = f_c \pm \Delta f$$

where f_o = modulated output clock frequency

f_c = input clock frequency

Δf = frequency excursion band

For example, a 100 MHz clock with a $\pm 1\%$ modulation depth indicates that the modulated clock is varying over a band of 99 MHz to 101 MHz.

MDA plot in Figure 5 and Spectrum Analyzer plot in Figure 6 depict the same.

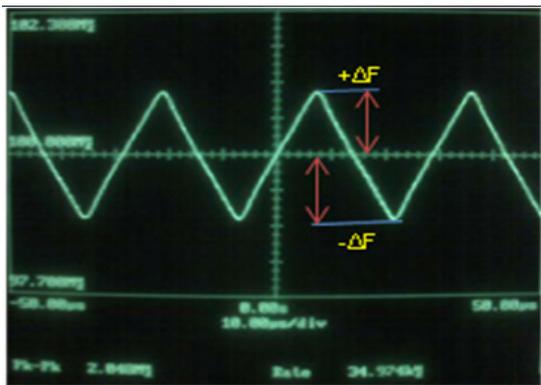


Figure 5. Centre Spread (MDA Plot)

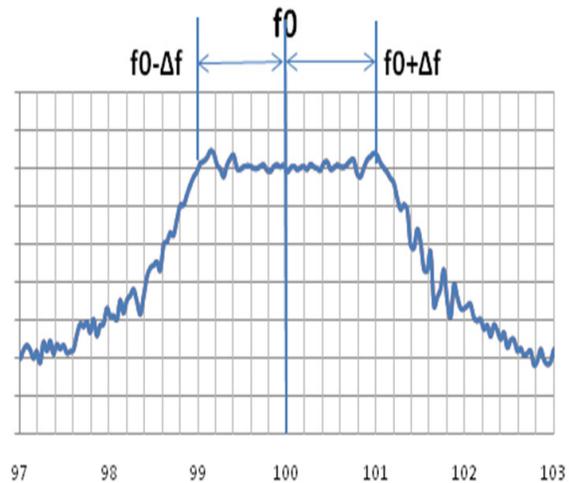


Figure 6. Centre Spread (Spectrum Analyzer Plot)

Down spread is where the maximum frequency of the spread spectrum clock will be the same as that of the non-modulated output clock. In a system where the non-modulated output clock is of the same frequency as the input frequency, the output clock will vary from $(f_c - \Delta f)$ to f_c at MR as per the modulation profile. It can be represented as:

$$f_o = f_c - \Delta f$$

where f_o = modulated output clock frequency

f_c = input clock frequency

Δf = frequency excursion band

For example, a 100 MHz clock with a -1% modulation depth indicates that the modulated clock is varying over a band of 99 MHz to 100 MHz.

MDA plot in Figure 7 and Spectrum Analyzer plot in Figure 8 depict the same.

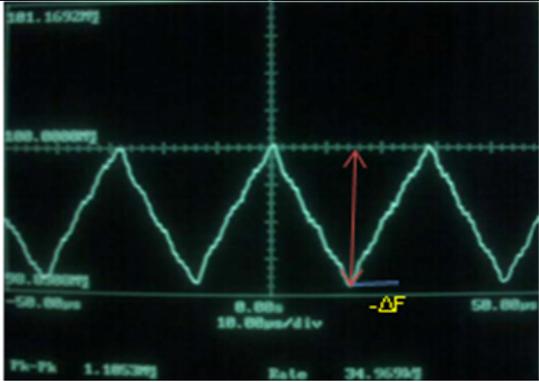


Figure 7. Down Spread (MDA Plot)

Up spread is where the minimum frequency of the spread spectrum clock will be the same as that of the non-modulated output clock. In a system where the non-modulated output clock is of the same frequency as the input frequency, the output clock will vary from f_c to $(f_c + \Delta f)$ at MR as per the modulation profile. It can be represented as

$$f_o = f_c + \Delta f$$

where f_o = modulated output clock frequency

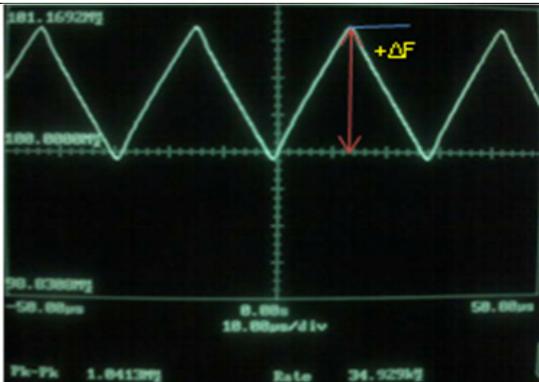


Figure 9. Up Spread (MDA Plot)

The effect of different modulation depth on the peak spectral amplitude reduction is shown in Figure 11. It is seen that with the increase in modulation depth, peak amplitude reduction increases. Peak spectral amplitude of an un-modulated clock (SSOFF) is also given for reference.

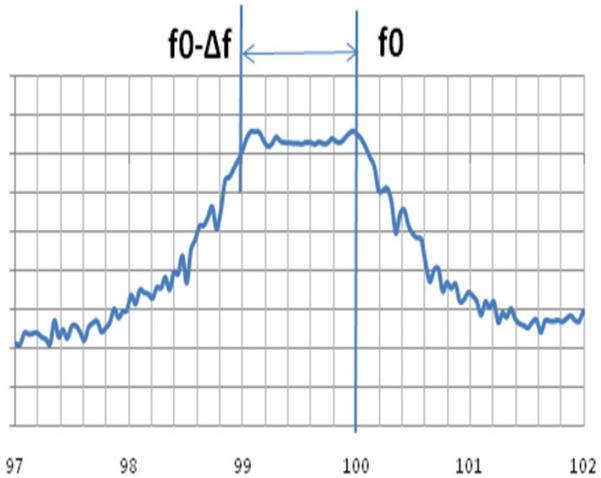


Figure 8. Down Spread (Spectrum Analyzer Plot)

f_c = input clock frequency

Δf = frequency excursion band

For example, a 100 MHz clock with a +1% modulation depth indicates that the modulated clock is varying over a band of 100 MHz to 101 MHz

MDA plot in Figure 9 and Spectrum Analyzer plot in Figure 10 depict the same.

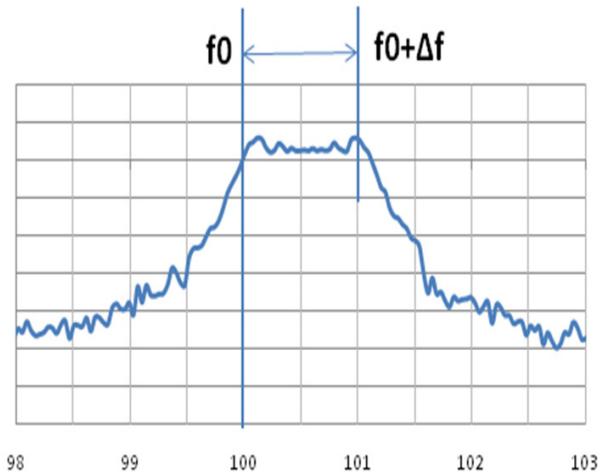


Figure 10. Up Spread (Spectrum Analyzer Plot)

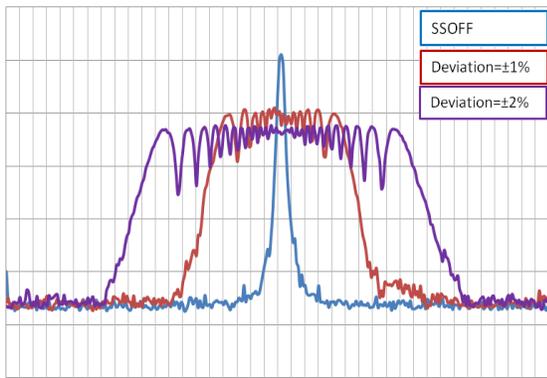


Figure 11. Effect of Variation in Modulation Depth

The peak amplitude reduction for various odd harmonics of a frequency modulated clock is shown in Figure 12. It is seen that the peak EMI reduction increases with the harmonic frequency. At the harmonic frequencies, the energy distribution is over a wider band. As such we see higher peak EMI reduction with the increased harmonic frequency. It is also seen that with increased frequency deviation, the peak EMI reduction also increases.

ON Semiconductor’s patented TIMING SAFE™ technology extends the benefits of conventional spread spectrum technology to synchronized clock and data interfaces. This allows system designers to address EMI

problems on local clocks rather than global clocks. More information on TIMING SAFE technology can be found at http://www.onsemi.com/pub_link/Collateral/AND8443-D.PDF

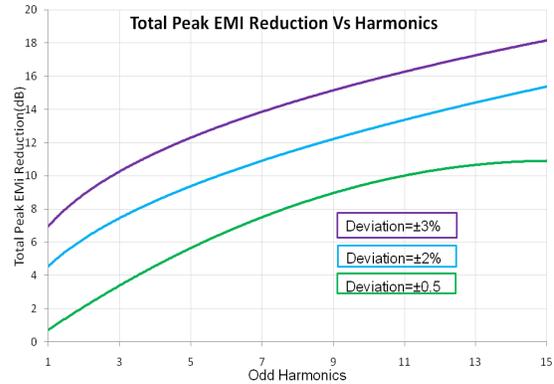


Figure 12. Peak EMI Reduction Across Harmonics

ON Semiconductor has many Spread Spectrum Clock Generators addressing the needs of various segments of the industry like computing, consumer, and industrial, to achieve EM compliance. For product details visit the website <http://www.onsemi.com>

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