

## ULTRA LOW NOISE SPREAD-SPECTRUM CRYSTAL OSCILLATORS

### EMI Protection and Spread-Spectrum Technology:

The FCC and the European Community (under CE Mark EMC Directive) require electronic devices to comply with appropriate radiation emission standards. Other international communities such as Asia and Australia are also following the same rules. Practically every electric device and equipment generate unintended electromagnetic radiation, which will get worse as technology advances, especially with even faster electrical signals required in PC, digital devices and equipment.

With the recent advance in semiconductor and computing technology, (faster clock speeds, lower voltage/power, etc.), coupled with the explosion of the wireless technologies, it is easy to understand why EMC is becoming one of the most important standard requirements in the new-technology world.

In the past, shielding and filtering were the most prevalent method used to control EMI. This method of shielding and filtering can get very expensive. As frequency increases, the effects of transmission line and ground impedance will amplify the radiation, and at the same time wavelength decreases, making shielding and filtering less effective.

The present trend is to control EMI at the source, the single clock oscillator using spread-spectrum technology.

### THEORY:

Spread-spectrum is, more or less, frequency modulating the clock signal with a unique waveform. In the frequency domain, this is equivalent to reducing the peak by distributing the energy of each fundamental and harmonic over a wide range. The spread-spectrum method must be controlled and slow compared to the clock rate to guarantee that the change in the clock rate is transparent to the system. Essentially, spread-spectrum is a modulation method where the modulation is measured as a percentage.

For example, a 0.5 percent modulation means that a 100MHz clock is modulated between 99.5MHz and 100.5MHz. This is called a center 0.5 percent modulation, since the 100MHz fundamental frequency remains the center frequency. The designer must keep in mind that both cycle-to-cycle and pea-to-peak jitter must remain within the system's specifications.

Another important factor is the modulation frequency, which is usually in the kilohertz range. This is basically a measure of the rate at which the frequency is swept between 99.5 and 100.5. The linear sweep is predictable and most prevalent.

Overall, the spread spectrum method has allowed system performance to increase without compromising EMI. Using Abracon spread-spectrum clock oscillators will not only reduce packaging, shielding, and design-cycle costs, but also expedite time-to-market of products which otherwise may fail regulatory EMI limits and standards. Abracon ultra low noise series oscillators provide an economical solution to expensive EMI problems.

## LOW EMI CRYSTAL CLOCK OSCILLATORS

Spread Spectrum Technology used to reduce EMI has been integrated into industry standard 8 and 14 pin DIP packages and surface mount versions as small as 5 X 7 mm. These products are perfect drop-in replacement clock oscillators where EMI reduction of up to 20 dB is needed.

Typical system designs start out with some fundamental clock source, such as a crystal, ceramic or can oscillator, at some frequency, lets say 48 MHz, which drives a processor, memory, serial/USB interfaces and some front panel controls. The 48 MHz clock is changed into other timing components such as clock multipliers found in PLL based processors, memory controllers, and interface controllers. The original 48 MHz clock quickly becomes 96 MHz or 24 MHz to drive a serial interface. These fundamental and harmonic frequencies can make it very difficult for compliance engineers to achieve certification.

During the design phase, if the proper package and frequency is chosen for the clock source, the flexibility in future modifications is increased. Even after the design phase is done, there will always be hot spots that will require some form of filtering or shielding. If all that is needed is to slow down the rise time of one or two specific nets, but this is not usually the case. If, however, the EMC engineer sees that the agency limits have been exceeded by 10 dB in several higher frequency harmonics, production must wait until compliance is achieved. When this happens, there are 3 possible ways to solve the problem, re-design in an attempt reduce EMI, filter and shield every net that is offending compliance or change the bill of material to call out a Low EMI Clock Oscillator.

SSC takes advantage of the fact that a frequency-modulated carrier will have lower peak energy than a non-modulated carrier. By frequency modulating the carrier, the energy is spread out over a wider range of frequencies, thereby reducing the peak energy contained in any one frequency. Comparing a modulated clock to a non-modulated clock on a spectrum analyzer, it can be seen that the peaks of the modulated clock and harmonic frequencies are lower in relative strength. The difference in relative strength of the energy of the clock is measured in dB. Sweeping the frequency of the fundamental clock back and forth at some rate will cause a reduction in peak energy. The wider the spread the greater the peak energy reduction. To determine how much spread you need for a given application use the simple formula below to calculate the necessary dB reduction. This formula assumes an ideal clock with a 50% duty cycle and only predicts the EMI reduction of odd harmonics.

Calculation for dB reduction:

$$\text{dB} = 6.5 + 9(\text{Log}_{10}(\text{F})) + 9(\text{Log}_{10}(\text{BW}))$$

Where; **F** = Frequency in MHz and **BW** = total % spread (2.5% = .025)

Using a 96 and 480 MHz clock with a 2.5% spread, the theoretical dB reduction would be;

$$\text{dB @ 96 MHz (Fund)} = 6.5 + 17.84 - 14.4 = 9.92$$

$$\text{dB @ 480 MHz (5th)} = 6.5 + 24.13 - 14.4 = 16.21$$

Regulatory agencies control the maximum amount of radiated RF energy. Unwanted RF energy is considered EMI, which causes interference in local receiving equipment such as television, radio, cell phones and pagers.

Agencies, such as the Federal Communications Commission, regulate the amount of radiated energy in terms of voltage, distance and frequency. 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. In general, Class B levels are more difficult to meet than Class A.

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The following chart lists the voltage levels allowed under FCC Rules and Regulations, Part 15, for both Class A at 10 meters and Class B at 3 meters.

Frequency (MHz)	Class "A" (10 meters)		Class "B" ( 3 meters)	
	uV/m	dB(uV/m)	uV/m	dB(uV/m)
30 - 88	90	39	100	40
88 - 216	150	43.5	150	43.5
216 - 960	210	46.5	200	46
>960	300	49.5	500	54

### FCC Class A and B Limits

If the equipment under test exceeds these limits, the excess energy must be reduced to within agency limits. Reducing the excess amount of EMI to just under the agency limits is dangerous because there is no guarantee that the differences in manufacturing and environmental changes might cause the energy to increase slightly. Most companies require a safety margin to ensure that the device always complies with agency limits even when manufacturing processes or environmental conditions change. Reducing a particular offending frequency that is 10 dB, for example, over the limit at the 5th harmonic can be very difficult. The problem is further complicated by a company imposed 4-dB safety margin.

Replacing the original clock source with a Low EMI Clock Oscillator is the most efficient way to systemically reduce EMI by a large amount. Referring to figure 1, the 5th harmonic of a 96 MHz clock has been reduced by greater than 15.5 dB just by replacing the original clock oscillator with a Low EMI Clock Oscillator.

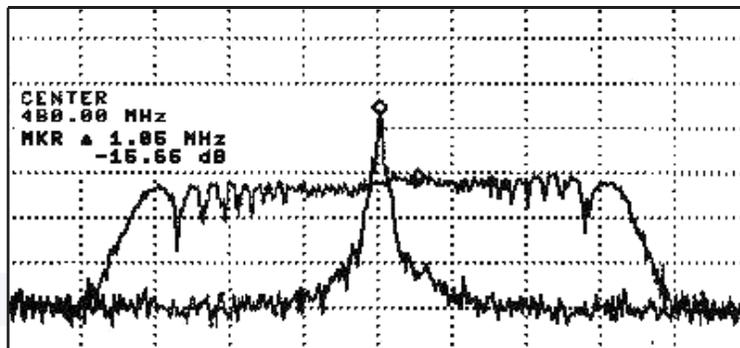


Figure 1.

Low EMI Clock Oscillators ASSM, ACSH, ACSO and ASSL series operate over a frequency range from 4 to 128 MHz at 3.3 and 5.0 volts in commercial and industrial temperature ranges. Products cover a wide range of applications, including automotive, medical, industrial control and computer peripherals such as printer, scanner, copiers and any other digital systems requiring EMI clocking solutions.

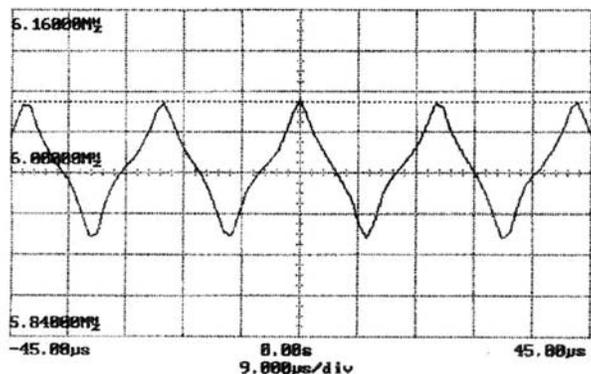
For further information on Low EMI Clock Oscillators, including pricing, availability, datasheets, application notes, and peak reduction calculator, contact Abracon Corporation at 1-949-448-7070 or online at [www.abracon.com](http://www.abracon.com).

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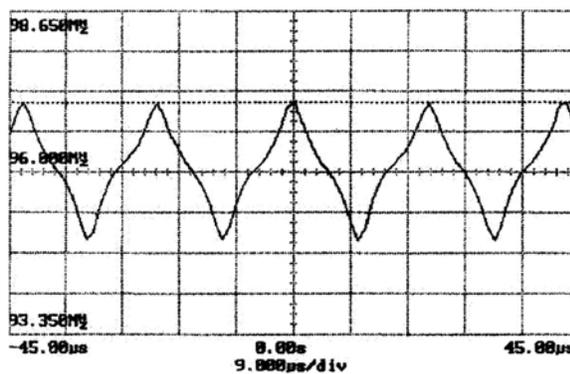
### MODULATION FREQUENCY

Modulation Frequency is the frequency or rate at which the frequency of the clock sweeps from the peak minimum frequency to the peak maximum and back to the peak minimum frequency again. This parameter frequency is stated in kHz in datasheets and is in the range of 20-150 kHz. There are several conditions that will dictate the maximum and minimum modulation frequency. The minimum modulation frequency should be greater than 20 kHz, which is the above the audio range and lower than 100 kHz. The maximum modulation frequency is determined by several factors including the loop bandwidth of downstream PLL's. The modulation rate of the ACSH and ASSML is in the range of 31.25 kHz to 62.50 kHz. The modulation rate of these devices varies with the operating frequency, but will stay in this range for an operating frequency of 4 MHz to 128 MHz.

The modulation profile of the ACSH / ASSML is pre-programmed and follows a specific pattern, which gives the highest amount of EMI reduction. The modulation profile can be seen on a Time Domain Analyzer, which displays frequency over time. The scans in figure 1, below shows a 6.00 MHz and a 96 MHz profile specific information relating to BW, Modulation Frequency and profile Envelope.



Fmin = 5.925 MHz  
Fmax = 6.088 MHz  
Modulation Frequency = 46.84 kHz  
BW% =  $((6.088 - 5.925) / 6.000) \times 100 = 2.7\%$



Fmin = 94.882 MHz  
Fmax = 97.159 MHz  
Modulation Frequency = 46.85 kHz  
BW% =  $((97.159 - 94.882) / 96.000) \times 100 = 2.37\%$

**FIGURE 1**

### BANDWIDTH

Bandwidth is the amount of modulation applied to the original clock frequency. Bandwidth is specified in terms of percentage of the clock frequency. If the frequency of a given clock is 40 MHz and the modulation applied is a total frequency swing of 1.0 MHz, the BW% would be  $1/40 = 0.025$  or 2.5%. Generally speaking, the higher the bandwidth the greater the EMI reduction. There are practical boundaries to this statement and the application of large spreads should be used cautiously. A bandwidth of a greater than 5% is extreme and should be tested fully before going to production. The bandwidth of a modulation clock can be measured on a Spectrum Analyzer and more accurately on a Time Domain Analyzer. Applying modulation to the fundamental clock frequency also applies the same amount of BW% spread to the harmonic frequency of that clock. If the fundamental clock frequency is 40.0 MHz, the 3rd harmonic would be 120 MHz and the 5th harmonic would be 200 MHz. In this example, a 2.5% spread at the fundamental frequencies also applies 2.5% spread at the 3rd and 5th harmonics as well. The effect of modulation on EMI reduction at the higher harmonics is greater than at the fundamental frequency; this is because a 2.5% spread at 40 MHz is 1.0 MHz but a 2.5% spread at 120 MHz is 3.00 MHz.