Application Note

Comparing BAW vs. Quartz Oscillator Radiated Emissions

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ABSTRACT

Modern day electronics in automotive and industrial applications face the difficult task of passing strict CISPR-32 radiated emission standards due to a variety of factors. Higher density power supplies, faster high-speed digital circuits, smaller form-factor PCB layouts, and a desire to reduce cost through less shielding all contribute to increasing levels of electromagnetic interference. Clocking and Timing products are important contributors to system-level emissions performance, minimizing radiated emissions in particular is crucial for proper system design. This application note introduces the Texas Instruments (TI) *CDC6C* Bulk Acoustic Wave (BAW) oscillator family, explains the technical value proposition, and benchmarks the radiated emissions performance against three traditional crystal clock quartz oscillators.

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Trademarks

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1 Introduction

Achieving CISPR-32 radiated emissions limits for many industrial customers is important for releasing new products, particularly in applications such as HVAC and Motor Drive. Clock and timing products play a critical role in passing stringent Class B limits. Selecting oscillator components with lower radiated emission levels can provide additional design margin, reducing the peak amplitude of spurs at various points across the frequency spectrum.

This application note discusses the TI CDC6C oscillator incorporating BAW resonator technology, and explains feature differences across device variants. The radiated emissions performance for CDC6C is then analyzed and benchmarked relative to crystal clock quartz oscillators available today. Using a CISPR-32 pre-compliant test setup, three frequencies are tested with both BAW and quartz oscillators, examining the peak spur values across the frequency spectrum 30MHz to 1GHz. This methodology can be applied to other CISPR standards as well.

2 CDC6C BAW Oscillator Family

Bulk Acoustic Wave is a micro-resonator technology that enables the integration of high-precision and ultra-low jitter clocks directly into packages that contain other circuits. BAW consists of a piezoelectric material sandwiched between two electrodes, converting electrical energy to mechanical-acoustical energy, producing reliable oscillations that result in a high-frequency, stable clock output. Read more in the *Top 5 Things to Know About TI BAW Resonator Technology*, technical article.

CDC6C integrates BAW resonator technology with a low-jitter, low-power integer output divider (IOD) along with an LVCMOS output driver. This allows flexibility in frequency output within the range of 250kHz to 200MHz. Figure 2-1 details the CDC6C internal block diagram. This has several integrated low-noise, low dropout (LDO) regulators that reduce power supply noise, providing a clean clock output. An internal precision temperature sensor feeds the frequency control logic block to reduce oscillation frequency variation. These frequency corrections enable CDC6C to maintain output frequency within ±50ppm accounting for all internal error sources and 10 years of aging.

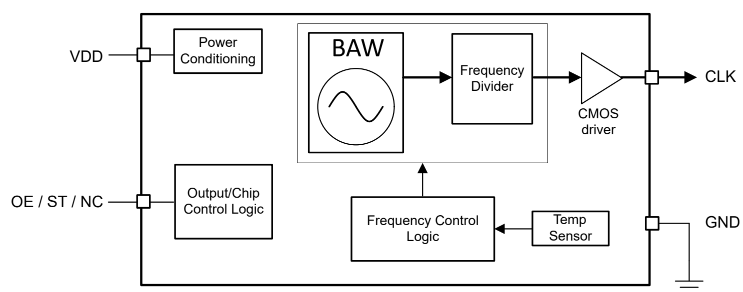

Figure 2-1. CDC6C Internal Block Diagram

CDC6C BAW oscillators are available in industry-standard small packages (3.2mm × 2.5mm, 2.5mm × 2.0mm, 2.0mm x 1.6mm, and 1.6mm x 1.2mm). Unlike passive crystal resonators, CDC6C oscillators do not require external tuning capacitors, which allows for both PCB size and BOM cost reductions as shown in Figure 2-2.

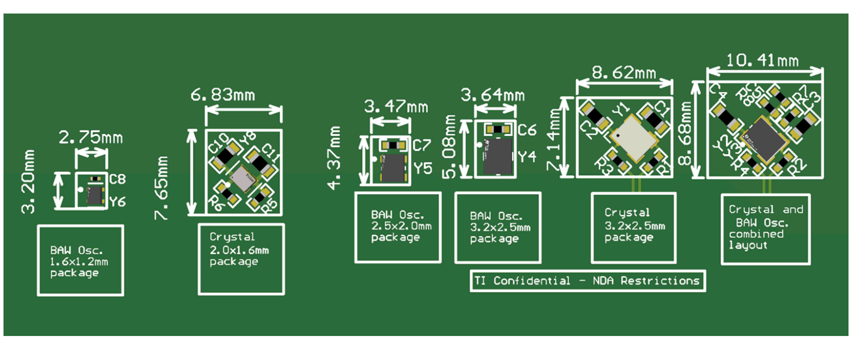

Figure 2-2. CDC6C Oscillator Available Packages and Layout Example

CDC6C is pin and package compatible with many single-ended 4-pin quartz oscillator land patterns on the market, and often is a drop-in replacement without any surrounding component changes. Read more here: *Universal Land Patterns for BAW Oscillators*

CDC6C has a number of advantages including frequency flexibility, temperature stability, power supply noise immunity among others. Tables below summarize these advantages and showcase how BAW oscillators have solved design limitations found in some quartz oscillators. Additional information in the following application notes:

- *Standalone BAW Oscillators Advantages Over Quartz Oscillators*, application note
- *Vibration and Mechanical Shock Performance of TI's BAW Oscillators*, application note
- *High Reliable BAW Oscillator MTBF and FIT Rate Calculations*, application note.

Table 2-1 outlines the BAW advantages over traditional quartz oscillators in the areas of frequency flexibility, temperature stability, and reduced sensitivity to vibration and mechanical shock.

Table 2-1. BAW Resonator versus Quartz Resonator

Parameter	Quartz	BAW	Advantage
Frequency Flexibility	Output frequency is controlled through mechanical parameters that cannot be modified once cut.	Alleviates supply constraints, single IC supports large range of frequencies through one time programming (OTP).	BAW oscillator
Temperature Stability	Uncompensated quartz oscillator frequency vs temperature response resembles a parabolic curve with larger ppm variation.	±10ppm (Maintains temperature stability irrelevant of temperature range.)	BAW oscillator
Vibration	Can be as high as +10ppb/g. Typically does not pass MIL-STD.	Typical is 1 ppb/g. Passes MIL_STD_883F Method 2002 Condition A	BAW oscillator
Mechanical Shock	Typically does not pass MIL-STD. Can fail at 2,000g.	Less than 0.5ppm variation up to 1500 g. Passes MIL_STD_883F Method 2007 Condition B	BAW oscillator

Table 2-2 outlines BAW advantages in reduced power supply noise, lower failure rate, frequency flexibility, reliable supply chain, and common landing pattern.

Table 2-2. Quartz Limitations Solved by BAW Oscillator

Parameter	Quartz limitation	BAW Oscillator Design
Power supply noise	Typically has no integrated LDO	Integrated LDO for improved power supply noise rejection (-72dBc PSRR at 500kHz, 50mV ripple)
Mean time between failure	33 million hours of operation	3.3 billion hours of operation
Frequency flexibility	Limited by resonator crystal ; different frequencies require different resonator crystal	Support any frequency from 250kHz to 200MHz in LVCMOS variant
Supply chain	Multiple third party manufacturing to support build of different components (resonator, ASIC, Package)	Fabricated, assembled, and packaged in house by TI
Land pattern	Land pattern can depend on supplier	Universal - industry standard footprint

3 Radiated Emissions Test Results

For each oscillator device under test, an input voltage of 3.3V was applied from a low-noise power board. Figure 3-1 shows the test setup and associated connections for the power supply and CDC6C EVM oscillator board.

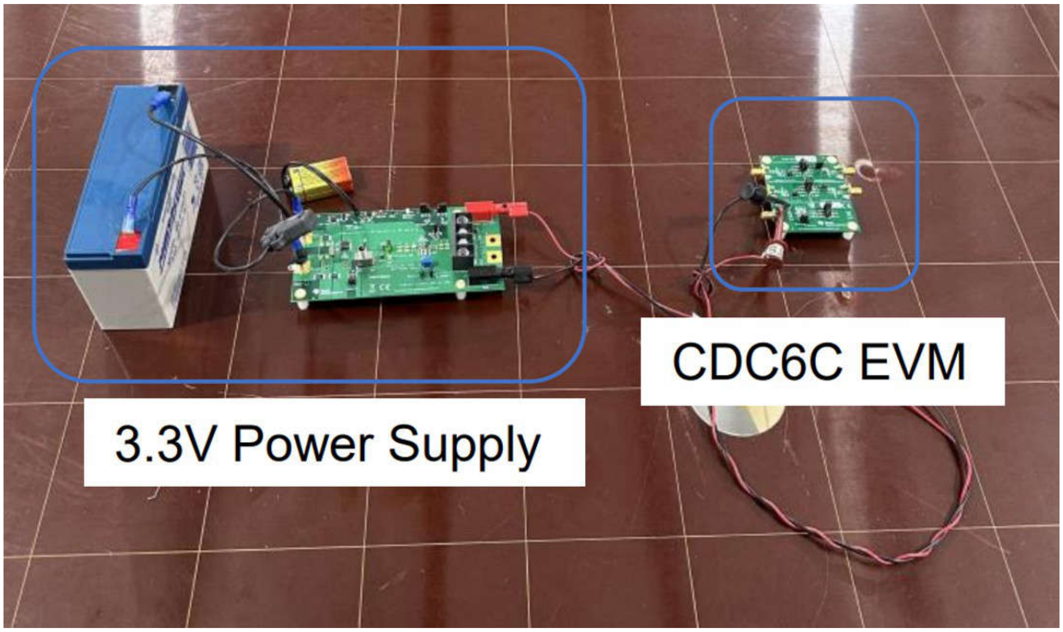

Figure 3-1. Radiated Emissions Test Setup Circuit Board Connections

Figure 3-2 shows the filtering circuitry for the 3.3V power supply. This contains a low noise LDO that provides a 3.3V source to the CDC6C EVM oscillator board which contains additional bypass capacitors for noise filtering.

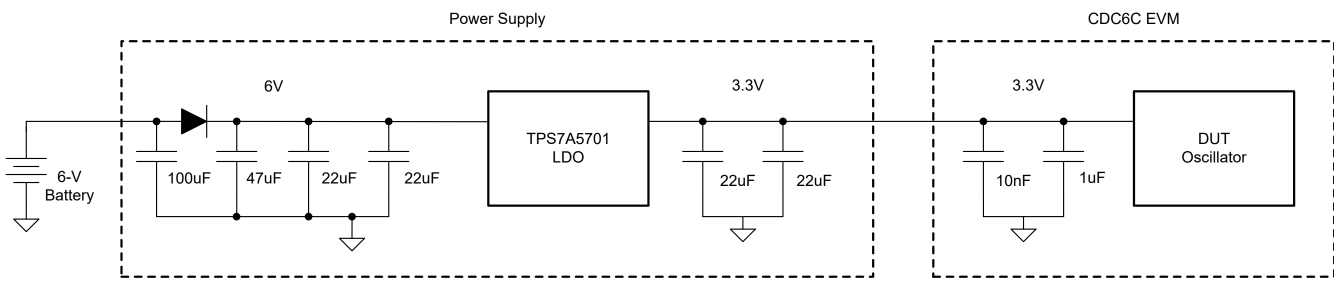

Figure 3-2. Radiated Emissions Test Setup Schematic

The CDC6C and competitor oscillators were soldered on to the CDC6C EVM and tested one at a time. Radiated emissions data was collected in a pre-compliant CISPR-32 radiated emissions setup using horizontal antenna orientation. Table 3-1 summarizes the devices tested and the associated frequency.

Table 3-1. Devices Under Test

Manufacturer	Part Number	Frequency
TI	CDC6CE025000EDLFR	25MHz
TI	CDC6CE050000EDLER	50MHz
TI	CDC6CE024000EDLER	24MHz
Competitor A	Competitor A	25MHz
Competitor B	Competitor B	50MHz
Competitor C	Competitor C	24MHz

Figure 3-3 and Figure 3-4 show emissions performance across frequency for the 25MHz devices, Competitor A quartz oscillator and CDC6CE025000EDLFR BAW oscillator respectively. Table 3-2 highlights how TI BAW oscillator can have between 1dB to 4dB emissions improvement versus the quartz oscillator tested.

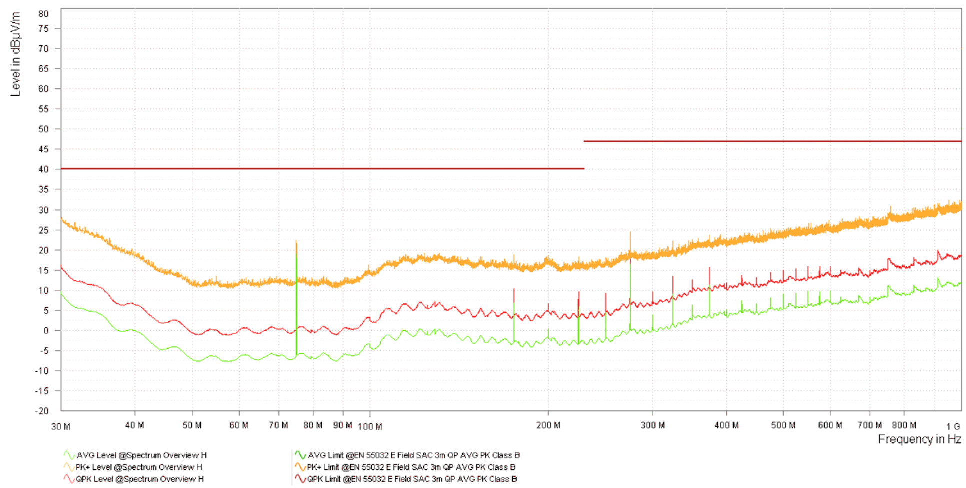

Figure 3-3. Competitor A Quartz Oscillator

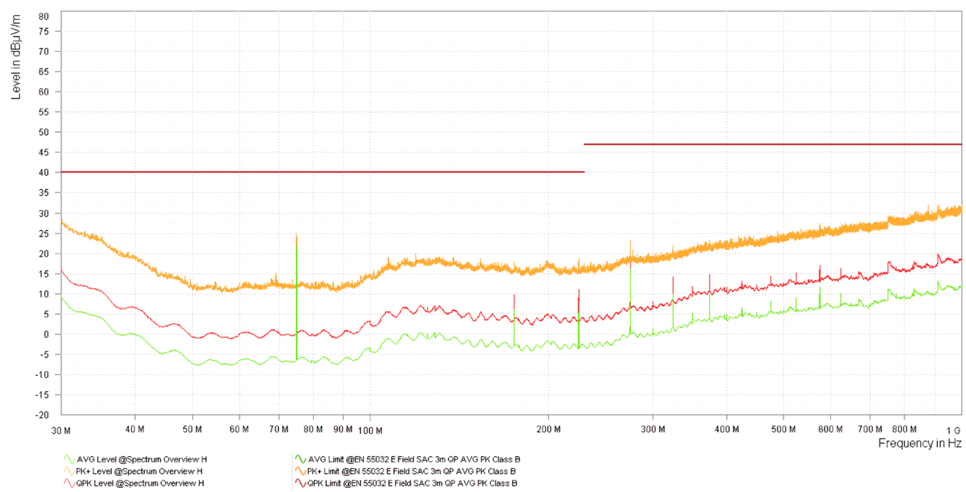

Figure 3-4. CDC6CE025000EDLFR BAW Oscillator

Table 3-2. Competitor A v. CDC6CE025000EDLFR Peak Emissions Comparison

Frequency	Competitor A	CDC6CE025000EDLFR	TI Delta
75MHz	23dB	25dB	+2dB worse
175MHz	No spur above 11dB baseline	No spur above 10dB baseline	-1dB better
225MHz	No spur above 10dB baseline	No spur above 11dB baseline	+1dB worse
250MHz	No spur above 9dB baseline	No spur above 5dB baseline	-4dB better
275MHz	25dB	24dB	-1dB better

Figure 3-5 and Figure 3-6 show emissions performance across frequency for the 50MHz devices, Competitor B quartz oscillator and CDC6CE050000EDLER BAW oscillator respectively. Table 3-3 highlights how TI BAW oscillator can have between 2dB to 6dB emissions improvement versus the quartz oscillator tested.

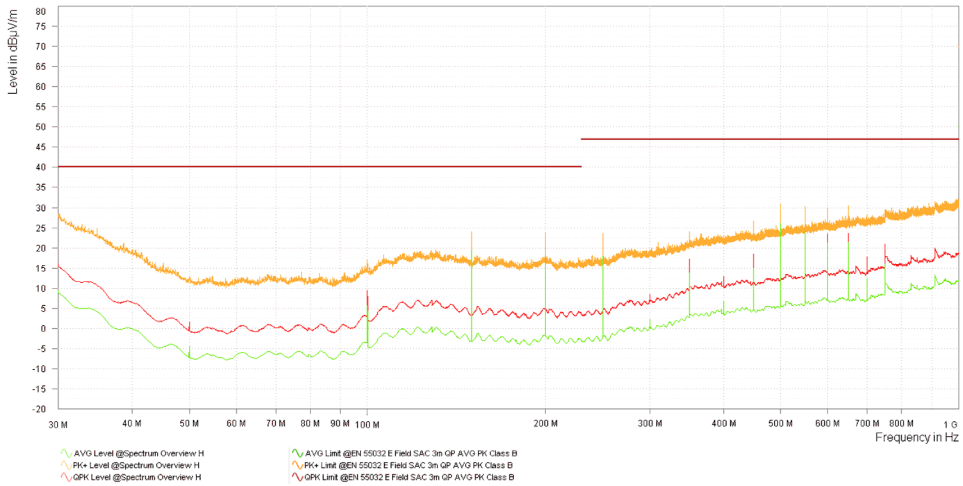

Figure 3-5. Competitor B Quartz Oscillator

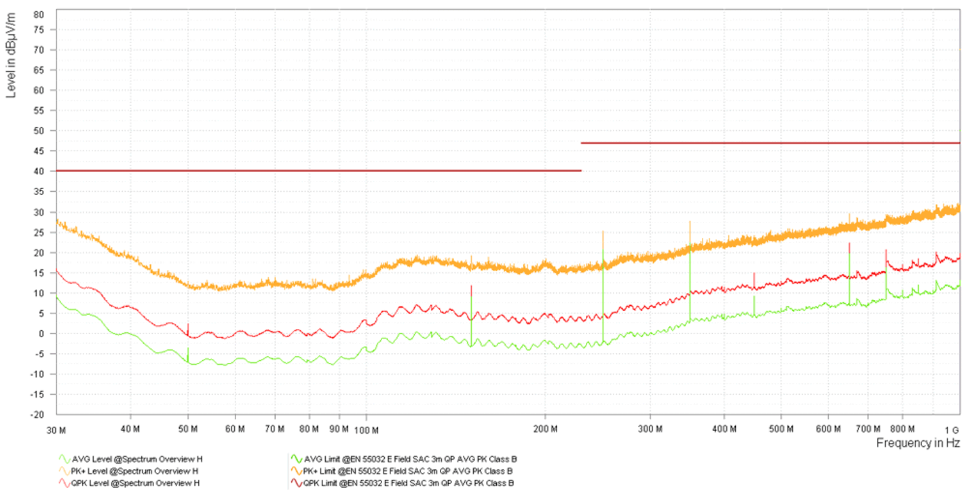

Figure 3-6. CDC6CE050000EDLER BAW Oscillator

Table 3-3. Competitor B v. CDC6CE050000EDLER Peak Emissions Comparison

Frequency	Competitor B	CDC6C050000EDLER	TI Delta
100MHz	17dB	No spur above 15dB baseline	-2dB better
150MHz	24dB	19dB	-5dB better
200MHz	24dB	No spur above 18dB baseline	-6dB better
250MHz	24dB	25dB	+1dB worse
350MHz	24dB	28dB	+4dB worse
450MHz	27dB	24dB	-3dB better
500MHz	31dB	No spur above 25dB baseline	-6dB better
550MHz	30dB	No spur above 26dB baseline	-4dB better
600MHz	30dB	No spur above 26dB baseline	-4dB better
650MHz	No spur above 30dB baseline	No spur above 30dB baseline	Similar

Figure 3-7 and Figure 3-8 show emissions performance across frequency for the 24MHz devices, Competitor C quartz oscillator and CDC6CE024000EDLER BAW oscillator respectively. Table 3-4 highlights how TI BAW oscillator can have between 3dB to 18dB emissions improvement versus the quartz oscillator tested.

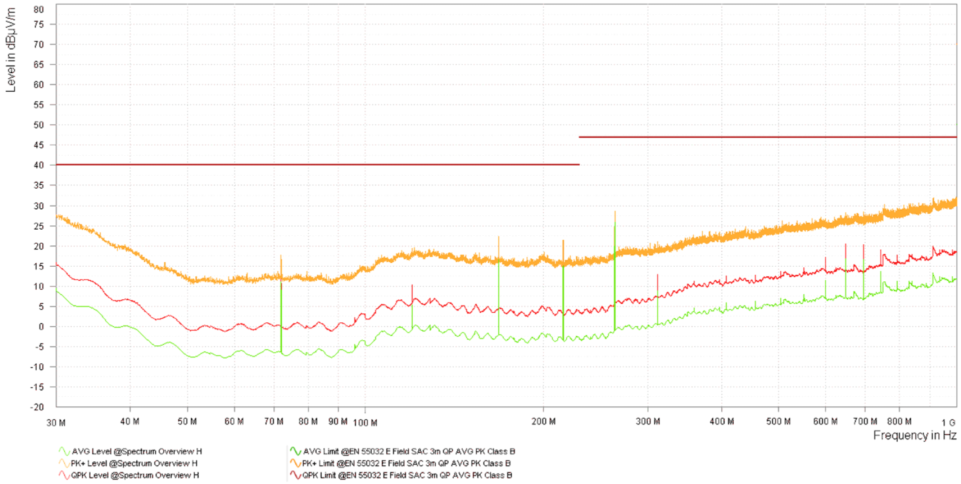

Figure 3-7. Competitor C Quartz Oscillator

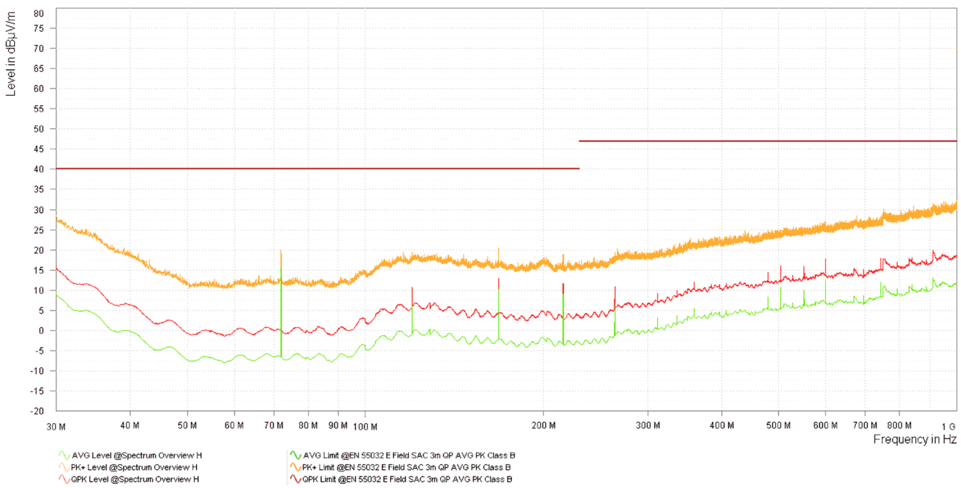

Figure 3-8. CDC6CE024000EDLER BAW Oscillator

Table 3-4. Competitor C v. CDC6CE024000EDLER Peak Emission Comparison

Frequency	Competitor C	CDC6CE024000EDLER	TI Delta
72MHz	18dB	20dB	+2dB worse
120MHz	No spur above 11dB baseline	No spur above 11dB baseline	Similar
168MHz	23dB	No spur above 20dB baseline	-3dB better
216MHz	22dB	No spur above 19dB baseline	-3dB better
264MHz	29dB	No spur above 11dB baseline	-18dB better
312MHz	No spur above 13dB baseline	No spur above 9dB baseline	-4dB better

Analyzing the results as a whole, on average TI CDC6C BAW oscillator exhibits lower radiated emission levels than the traditional crystal clock quartz oscillators tested.

4 Summary

This application note demonstrates the improved radiated emissions levels achievable with Texas Instruments CDC6C BAW oscillator family relative to some crystal clock oscillators in the market. While passing CISPR-32 Class B radiated emissions limits involves additional design considerations, CDC6C can enable improved system-level EMI performance.

5 References

- Texas Instruments, *Standalone BAW Oscillators Advantages Over Quartz Oscillators*, application note.
- Texas Instruments, *Top 5 Things to Know about TI BAW Resonator Technology*, technical article.
- Texas Instruments, *High Reliable BAW Oscillator MTBF and FIT Rate Calculations*, application note.
- Texas Instruments, *Vibration and Mechanical Shock Performance of TI's BAW Oscillators*, application note.
- Texas Instruments, *Universal Land Patterns for LMK6D, LMK6P, LMK6H BAW Oscillators*, application note.

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