Application Note

BAW Oscillator Clocking TI Processors

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ABSTRACT

Processors are an essential part of any system. In many cases, the processors fan out clock outputs to peripheral components such as Ethernet PHY, USB connectors, and so on. The performance of the processor clock outputs is dependent on external reference clock that is fed into the processor. This application note showcases the advantages of TI oscillators over quartz oscillators.

Table of Contents

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1 Introduction

TI Bulk Acoustic Wave (BAW) oscillator portfolio has device families targeted for high-performance (LMK6x) as well as low power applications (CDC6C), see *CDC6Cx Low Power LVCMOS Output BAW Oscillator*, data sheet. Both BAW oscillator families support any frequency up to 200MHz in single ended variants. This document showcases BAW oscillator advantages over Quartz oscillators, performance advantages of clocking TI processors such as the AM64x using BAW oscillators, as well as BAW oscillator clock recommendation for various TI processors.

2 BAW Overview

BAW Resonator Technology (BAW) is a micro-resonator technology that enables the integration of high-precision and ultra-low jitter clocks directly into packages that contain other circuits. In the BAW oscillator, the BAW is integrated with a collocated precision temperature sensor, an ultra-low jitter, low power integer output divider (IOD), a single-ended LVCMOS output driver, and a small power-reset-clock management system consisting of several low noise LDOs.

Figure 2-1 shows the structure of the BAW Resonator Technology. The structure includes a thin layer of piezoelectric film sandwiched between metal films and other layers that confine the mechanical energy. The BAW utilizes this piezoelectric transduction to generate a vibration.

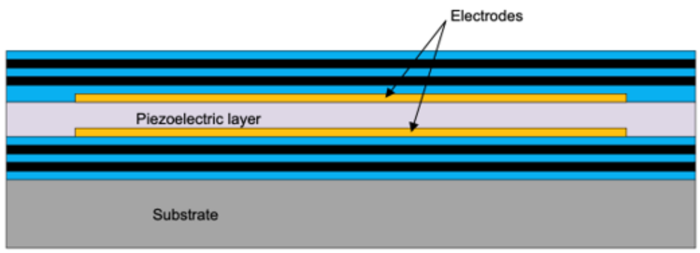

Figure 2-1. Bulk Acoustic Wave (BAW) Resonator Structure

2.1 BAW Oscillator Advantages

The LMK6x and the CDC6C have a number of advantages including frequency flexibility, temperature stability, power supply noise immunity and many others. Table 2-1 and Table 2-2 summarize these advantages and showcases how BAW oscillators have solved design limitations found while using quartz oscillators. Additional information can be found in the following application notes:

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

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 +10 ppb/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 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. Quartz Limitation 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 resonant crystal	Support any frequency from 1MHz 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

2.2 BAW Oscillator Overview

The CDC6C and the LMK6C incorporate the BAW as the resonator source. These devices are factory programmed and capable of producing large range of frequencies up to 200MHz. Figure 2-2 illustrates the simplified structure of the BAW oscillators. As each of these BAW oscillators have different use cases Table 2-3 illustrates the differences.

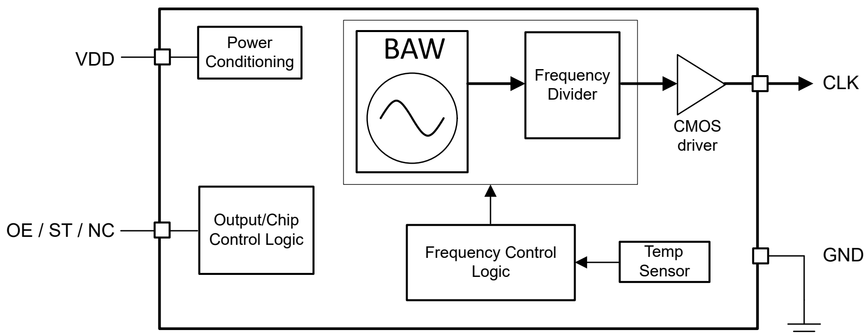

Figure 2-2. Simplified Block Diagram

Table 2-3. LMK6C and CDC6C Comparison Overview

Parameter	LMK6C	CDC6C
Output frequency range	Any frequency between 1MHz and 200MHz	Select frequencies between 250kHz and 200MHz
RMS jitter maximum[1]	0.5ps	1ps
Start up time maximum	5ms	3ms
Operating temperature range	-40 C to 105 C	-40 C to 105C
Current consumption maximum at 100MHz and 1.8V	59mA	7.2mA
Device supply voltage options	1.8V 2.5V to 3.3V	1.8V - 3.3V
Package size options	3.2mm x 2.5mm 2.5mm x 2.0mm	3.2mm x 2.5mm 2.5mm x 2.0mm 2.0mm x 1.6mm 1.6mm x 1.2mm

(1) Fout ≥ 25MHz; Integration BW: 12kHz - 20MHz

3 LMK6C Clocking Sitara AM64 Jitter Test

3.1 Jitter Test Set Up

On the TMDS64EVM a 25MHz LVCMOS oscillator is used as an input to a CDCLVC1310 clock buffer, which is then fed into EXT_REFCLK 1 of the AM64x device. This external refclk is the frequency reference for the internal PLL and clock distribution path. The AM64x device is then configured to route the internal system clock through the output of a GPO pin. The output clock phase noise performance is measured on a phase noise analyzer, and the time-domain jitter characteristics are measured using a DPOJET tool on an oscilloscope.

Jitter performance was measured using both a quartz oscillator to generate the 25MHz refclk as well as the LMK6C BAW oscillator. With LMK6C, the output clock had a 10 to 15dB noise reduction in the frequency band of approximately 100Hz to 500kHz. Spurious tones in the range of 10kHz to 100kHz are mostly likely the result of frequency mixing with other high-frequency noise sources, such as switching voltage regulators. Spurious tones had the same power with both reference frequency sources. Time-domain jitter also showed improvements with LMK6C, especially in terms of cycle-cycle jitter.

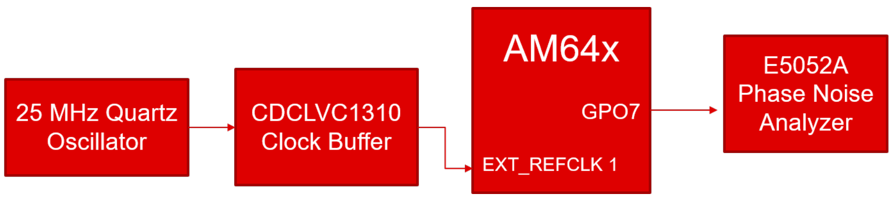

Figure 3-1. Quartz Test Block Diagram

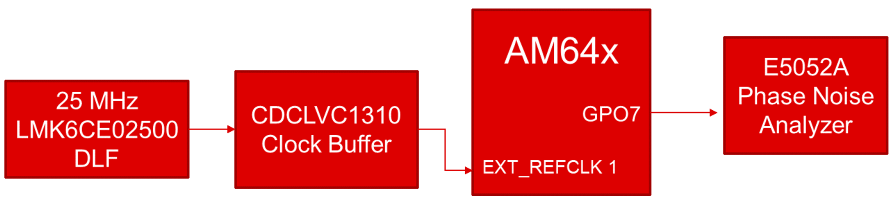

Figure 3-2. LMk6C Test Block Diagram

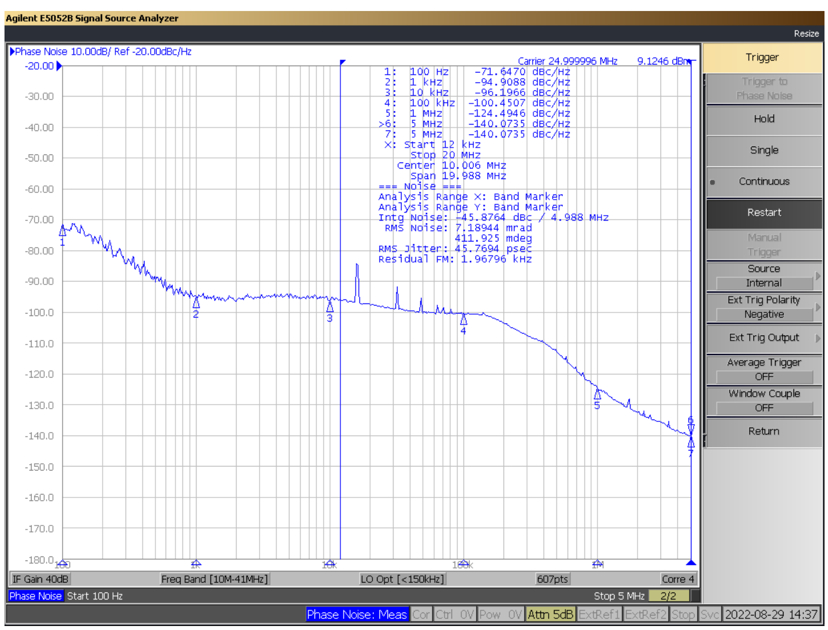

Figure 3-3. Quartz Oscillator GPO7 Phase Noise Plot

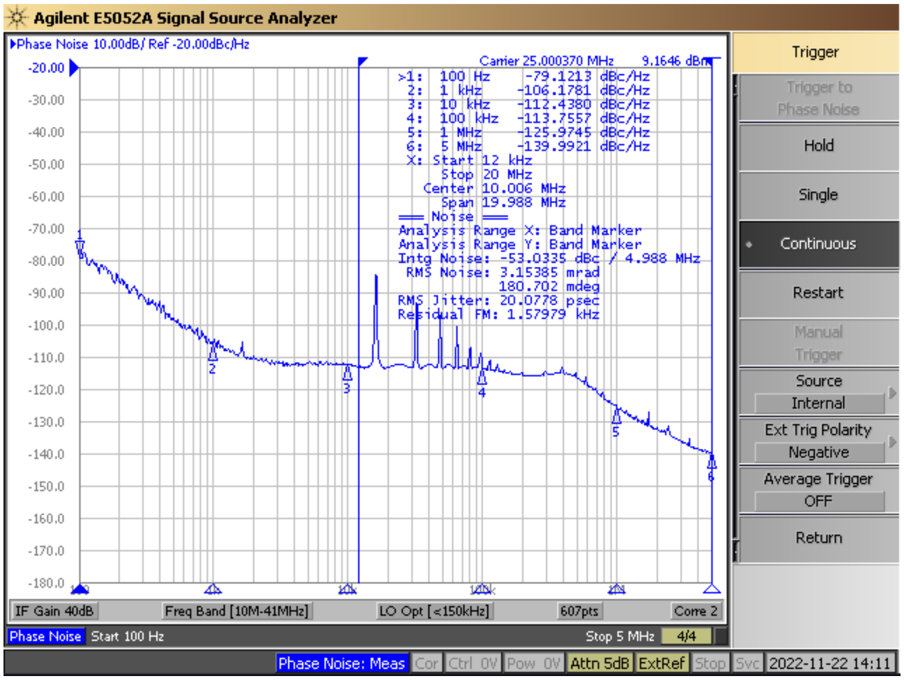

Figure 3-4. LMK6C Oscillator GPO7 Phase Noise Plot

Table 3-1. Jitter Performance Comparison

	Quartz (ps)	LMK6C (ps)	Quartz and LMK6C Delta (ps)
RMS Jitter	45.7694	20.0778	25.6916
Period Jitter (pk – pk)	59.265	59.126	0.139
Period Jitter (std. dev)	6.7860	6.4285	0.3575
N-cycle Jitter (pk-pk)	170.49	151.05	19.44
N-cycle Jitter (std. dev)	18.695	16.896	1.799

4 Generic Guide for Clocking AM6x and TDA4x Families

This section highlights different TI processor families and the respective clocking requirements. All of the processors listed in Table 4-1 have the same VIL, VIH and frequency stability requirement from the clock reference input with majority difference being the frequency and start up time required. Table 4-2 lists BAW oscillator clock recommendation as well as the oscillator's corresponding performance specification.

Table 4-1. Processor Clock Requirements

<table>
<tr><th>Processor Device</th><th># of External High-frequency oscillators</th><th>Frequency (MHz)</th><th>VDD (V)</th><th>Start up time (ms)</th><th>VIL (V) (max)</th><th>VIH (V) (min)</th><th>Stability (ppm)</th></tr>
<tr><td>AM62x</td><td>1</td><td>25</td><td>1.8</td><td>4</td><td rowspan="11">0.35x VDD</td><td rowspan="11">0.65xVDD</td><td rowspan="11">±50[1], ±100[2]</td></tr>
<tr><td>AM64</td><td>1</td><td>25</td><td>1.8</td><td>4</td></tr>
<tr><td>AM67</td><td>1</td><td>25</td><td>1.8</td><td>4</td></tr>
<tr><td>TDA4VEN
TDA4AEN</td><td>1</td><td>25</td><td>1.8</td><td>4</td></tr>
<tr><td>AM68</td><td>1</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8</td><td>9.8</td></tr>
<tr><td>AM69</td><td>1</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8, 3.3</td><td>9.8</td></tr>
<tr><td>TDA4VM (Q1)
DRA829</td><td>2</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8</td><td>9.5</td></tr>
<tr><td>DRA821</td><td>1</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8</td><td>9.5</td></tr>
<tr><td>TDA4VH-Q1
TDA4AH-Q1
TDA4VP-Q1
TDA4AP-Q1</td><td>1</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8</td><td>9.5</td></tr>
<tr><td>TDA4VE-Q1
TDA4AL-Q1
TDA4VL-Q1</td><td>1</td><td>19.2, 20, 24, 25, 26, 27</td><td>1.8</td><td>9.5</td></tr>
</table>

(1) Ethernet RGMII and RMII using derived clock
(2) Ethernet RGMII and RMII not used

Table 4-2. Clock Recommendation for Processors

<table>
<tr><th>Processor Device</th><th>Clock Part Number</th><th>Frequency Support Range (MHz)</th><th>VDD (V)</th><th>VIL (V) (max)</th><th>VIH(V) (min)</th><th>Stability (ppm)</th><th>Startup time max (ms)</th></tr>
<tr><td rowspan="2">AM62x
AM64
AM67
TDA4VEN
TDA4AEN
AM68
AM69
TDA4VM (Q1)
DRA829
DRA821
TDA4VH-Q1
TDA4AH-Q1
TDA4VP-Q1
TDA4AP-Q1
TDA4VE-Q1
TDA4AL-Q1
TDA4VL-Q1</td><td>CDC6C</td><td>250kHz to 200MHz</td><td>1.8V to 3.3V</td><td>0.6V</td><td>1.3V</td><td>±25</td><td>3ms</td></tr>
<tr><td>LMK6C</td><td>1MHz to 200MHz</td><td>1.8V
2.5V to 3.3V</td><td>0.6V</td><td>1.3V</td><td>±25</td><td>5ms</td></tr>
</table>

5 Summary

Based on tests performed on AM64x processor and BAW oscillator advantages over quartz the following are key observations.

- Vibration and mechanical shock have minimal impact on BAW oscillator performance.
- BAW oscillators can support wide range of frequencies from a single IC alleviating supply constraints
- LMK6C oscillator significantly improved output jitter of the AM64x processor which allows for higher performance clock outputs
- BAW oscillator can meet different TI processor requirements described in the respective data sheets as shown in Table 4-2.

6 References

- Texas Instruments, *CDC6Cx Low Power LVCMOS Output BAW Oscillator*, data sheet.
- Texas Instruments, *LMK6x Low Jitter, High-Performance BAW Oscillator*, data sheet.
- Texas Instruments, *High Reliable BAW Oscillator MTBF and FIT Rate Calculations,* application note.
- Texas Instruments, *Standalone BAW Oscillators Advantages Over Quartz Oscillators,* application note.
- Texas Instruments, *Vibration and Mechanical Shock Performance of TI's BAW Oscillators,* application note.