Application Note

The LMK6B: Revolutionizing Optical Module Performance with Industry-Leading Ultra-Low Jitter BAW Oscillators

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ABSTRACT

As optical networks evolve to meet the exponential growth in data traffic, the clock references clocking these systems face increasingly stringent performance requirements. The Texas Instruments LMK6Bx represents a breakthrough in oscillator technology, delivering the industry's lowest jitter performance through a Bulk Acoustic Wave (BAW) resonator technology. The LMK6Bx's exceptional phase noise characteristics, wide frequency coverage, and compact footprint set a new standard for timing designs in optical transceiver modules, enabling superior performance in 112G, 224G, and 448G PAM-4 Ethernet and coherent optical applications.

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1 Introduction

Texas Instruments introduces the LMK6Bx BAW Oscillator, the industry's lowest jitter differential oscillator above 312.5MHz, specifically engineered to meet the stringent requirements of next-generation optical modules with 1.6T and 3.2T speeds. With breakthrough jitter performance reaching 9.3fs at 625MHz and revolutionary BAW resonator technology, the LMK6Bx sets a new standard for optical transceiver modules, switches, routers, optical equipment, high-speed Ethernet applications (112G, 224G, and 448G PAM-4), coherent optical application, NIC, and smart NIC applications.

2 LMK6Bx Oscillator for Optical Transceiver DSP Clocking

The LMK6Bx BAW oscillator is designed to serve as a reference to a optical DSP of the transceiver module. Figure 2-1 demonstrates a typical setup aiming to achieve best performance between the LMK6Bx and any optical transceiver module DSP.

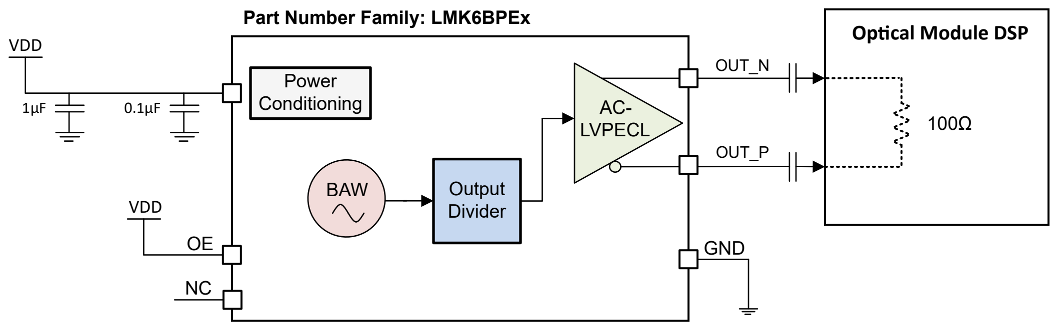

Figure 2-1. LMK6Bx Reference Clock for Optical Transceiver Module's DSP

The LMK6Bx is the industry leader in performance for frequencies above 312.5MHz. At 625MHz, the oscillator achieves a typical value of 9.3fs of RMS jitter with a 4MHz high-pass filter (HPF) and 35fs maximum (without a filter). This improved performance results in better BER for the DSP.

3 Revolutionary BAW Technology: Why BAW Technology Dominates

The resonator technology of the LMK6B BAW provides fundamental advantages over traditional quartz and MEMS oscillators.

3.1 Revolutionary Jitter Performance

The LMK6Bx uses a BAW resonator that can operate between 2.4GHz to 2.6GHz, 50 to 100 times higher than quartz or MEMS resonator frequencies, making the BAW the only resonator to operate at gigahertz frequencies. This high resonant frequency yields sharper clock edges, resulting in improved noise floor performance (above 100kHz offsets). This outperforms competitors by starting with a clean, high-frequency resonator that divides down to create sharp output edges rather than using a PLL to multiply up from lower frequencies.Table 3-1 and Figure 3-1 demonstrate the performance of the LMK6Bx operating at the core BAW frequency, achieving 17.3fs of jitter. When adding a 4MHz high-pass filter (HPF), 3.8fs RMS jitter is achieved.

Table 3-1. 2.5GHz LMK6Bx Phase Noise Values: BAW Frequency

Frequency Offset	Phase Noise (dBc/Hz) - No HPF	Phase Noise (dBc/Hz) - 4MHz HPF
1kHz	-88.1	-160.1
10kHz	-112.5	-164.4
100kHz	-135.3	-167.2
1MHz	-153.4	-165.6
10MHz	-160.1	-160.7
100MHz	-160.4	-160.4
1000MHz	-160.4	-160.4
RMS Jitter (1)	**17.3fs**	**3.8fs**

(1) Calculated with a bandwidth from 12kHz to 20MHz

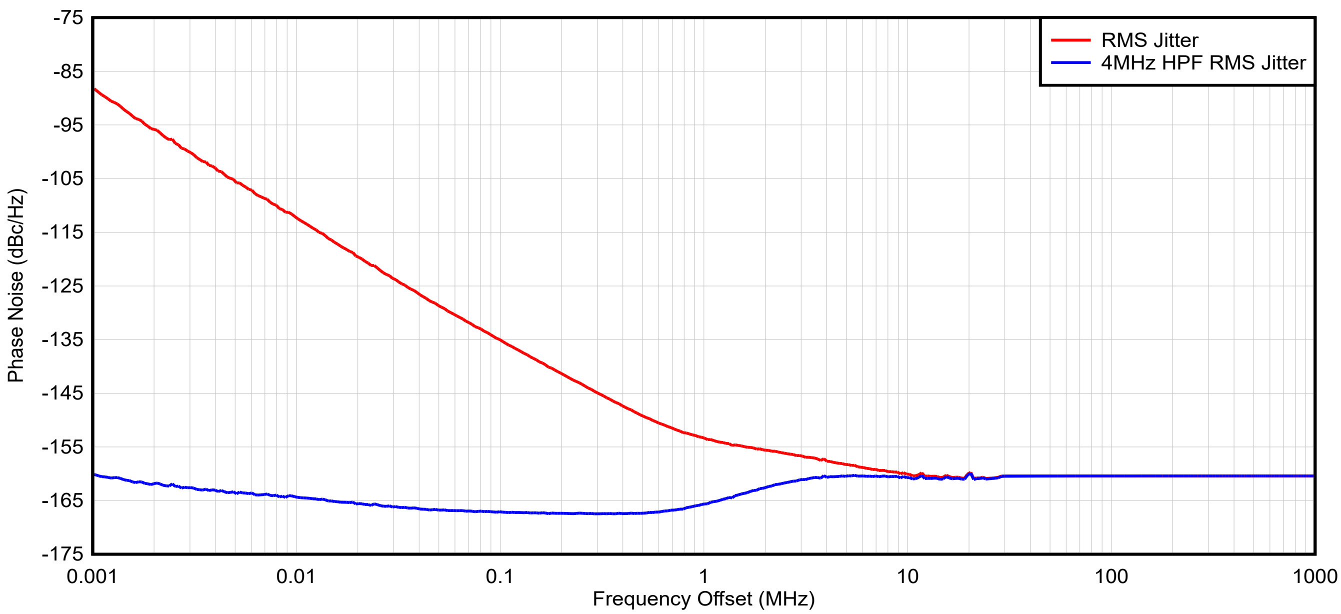

Figure 3-1. 2.5GHz LMK6Bx Phase Noise Curves: BAW Frequency

3.2 Outstanding Reliability

The LMK6Bx provides 100 times better Mean Time Between Failures (MTBF) compared to quartz-based oscillators. The BAW resonator structure contributes to this improved reliability through solid-state construction. High Reliable BAW Oscillator MTBF and FIT Rate Calculations application note covers more detail about the robustness of the BAW.

Vibration performance achieved is 1ppb/g typical from 50Hz to 2kHz while quartz oscillators typically show a few ppb/g to tens of ppb/g vibration performance. The BAW resonator's mechanical structure provides inherent vibration resistance and passes MIL-STD-F Method 2007 and MIL-STD-F Method 2002 standards as further shown in Standalone BAW Oscillators Advantages Over Quartz Oscillators. These test methods verify performance under mechanical stress and environmental conditions.

The reliability advantages stem from the semiconductor manufacturing process of the BAW resonator, which eliminates the wire bonds and mechanical mounting structures found in quartz crystals. This construction reduces failure modes associated with mechanical stress and thermal cycling.

3.3 Manufacturing Excellence

The LMK6Bx is manufactured entirely in TI fabrication facilities using standard plastic packaging and high-volume semiconductor wafer processes. This integrated manufacturing approach enables fast lead times and consistent supply compared to oscillators that rely on external crystal suppliers, ASIC suppliers, manufacturing, or specialized packaging processes.

The BAW resonator integrates with other semiconductor components and supports co-packaging with additional ICs. The standard semiconductor manufacturing eliminates the assembly complexity associated with discrete crystal mounting, reducing manufacturing variability and enabling higher production volumes.

4 Industry's Best Jitter Performance at Frequencies Above 312.5MHz: Setting New Standards

4.1 Unprecedented Low Jitter Specifications

The LMK6Bx delivers industry-leading jitter performance that outperforms competition. At higher frequencies, the LMK6B achieves 35fs max RMS jitter at 625MHz AC-LVPECL, which is the absolute lowest in the industry, and 28fs typ RMS jitter at 312.5MHz AC-LVPECL, also showcasing exceptional typical performance.

With this exceptional noise floor, single digit jitter values are achieved when applying the SerDes clock-data recovery (CDR) 4MHz high-pass filter (HPF) as shown on Figure 4-1 and Figure 4-2. 9.6fs typical RMS jitter at 625MHz and 19.7fs typical RMS jitter at 312.5MHz. These remarkable performance provides unprecedented timing margin for PAM-4, Ethernet clocking applications, and coherent optical applications, directly translating to improved system performance and reduced bit error rates (BER).

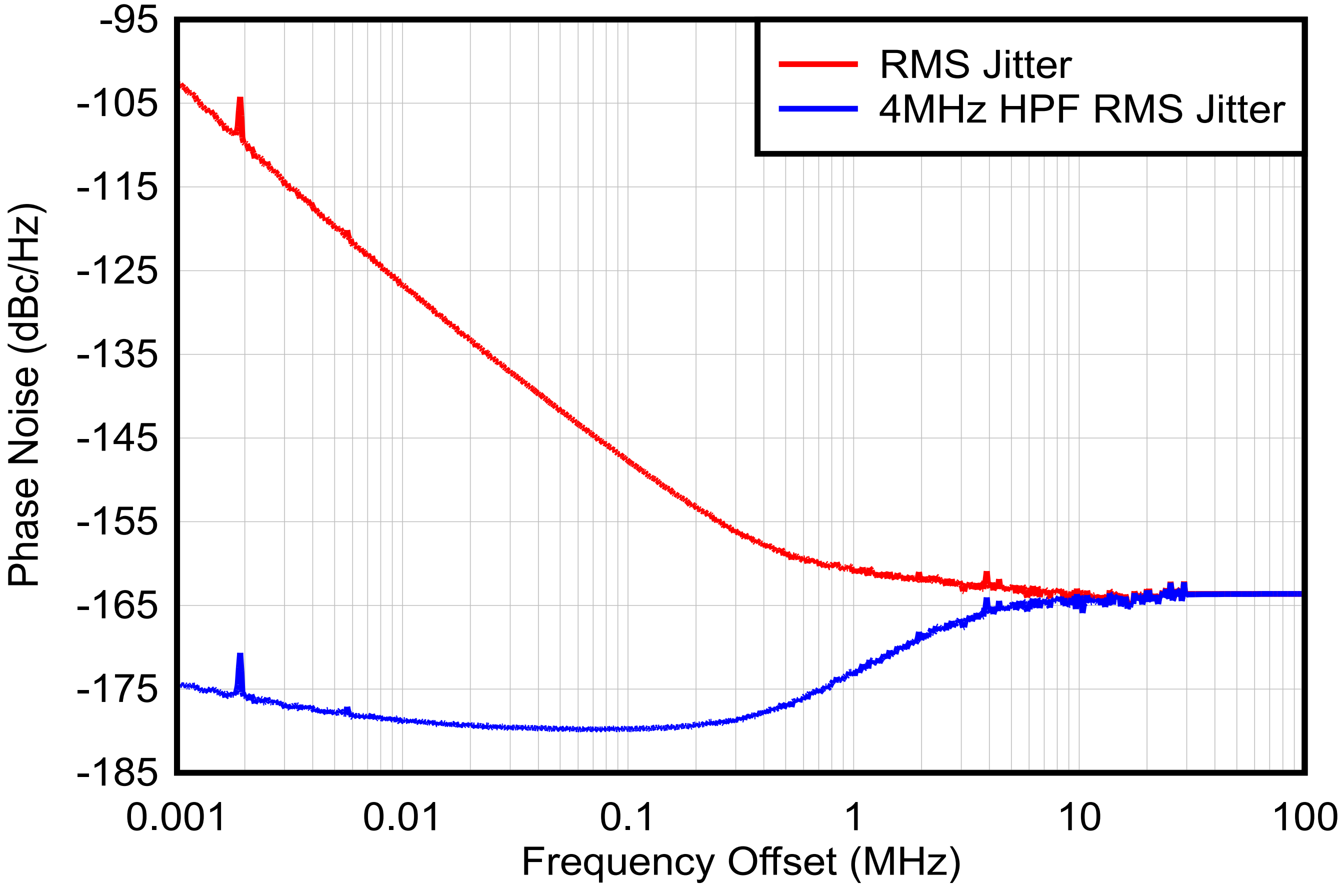

Figure 4-1. LMK6Bx AC-LVPECL 625MHz Typical Phase Noise Plot - 4MHz HPF RMS Jitter 9.6fs and RMS Jitter 18.1fs (12kHz to 20MHz)

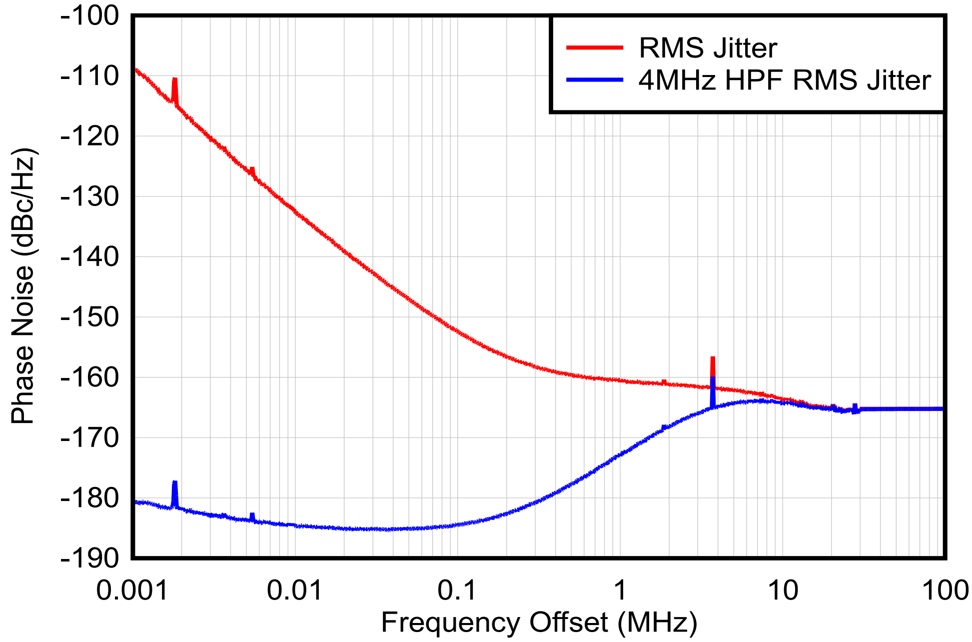

Figure 4-2. LMK6Bx AC-LVPECL 312.5MHz Typical Phase Noise Plot - 4MHz HPF RMS Jitter 19.7fs and RMS Jitter 28.2fs (12kHz to 20MHz)

4.2 Exceptional PSRR Performance

The LMK6Bx has exceptional PSRR performance across output frequencies and output types. At 156.25MHz with 50mVpp supply ripple across ripple frequencies above 10kHz, the LMK6Bx LVDS maintains a PSRR below -78dBc without requiring a decoupling capacitor. At 312.5MHz, the PSRR stays below -74dBc without a decoupling capacitor. With a decoupling capactior, the LMK6Bx LP-HCSL PSRR is below -83dBc at 156.25MHz and below -79dBc at 312.5MHz. Table 4-1 through Table 4-4 expands on LMK6B's exceptional performance across ripple frequencies above 10kHz, output types, with and without a decoupling capacitor, and output frequencies while inducing a 50mVpp supply ripple.

Table 4-1. LMK6Bx PSRR Performance at 156.25MHz and a 50mVpp Ripple Without a Decoupling Capacitor Across Ripple Frequencies and Output Types

Ripple Frequency (kHz)	Spur (dBc)		
	LVDS	LP-HCSL	AC-LVPECL
10	-86.1	-86.8	-80.8
100	-79.4	-87.0	-76.5
300	-79.3	-87.6	-75.3
500	-79.4	-86.9	-75.4
800	-78.1	-84.8	-75.3
1000	-78.1	-83.3	-75.2
1500	-78.7	-80.0	-75.5
1800	-78.7	-78.7	-75.6
2000	-78.8	-77.8	-75.8
4000	-80.5	-80.3	-76.4
7000	-85.5	-143.1	-75.5
10000	-90.7	-148.8	-132.5

Table 4-2. LMK6Bx PSRR Performance at 312.5MHz and a 50mVpp Ripple Without a Decoupling Capacitor Across Ripple Frequencies and Output Types

Ripple Frequency (kHz)	Spur (dBc)		
	LVDS	LP-HCSL	AC-LVPECL
10	-81.0	-77.5	-69.7
100	-74.0	-87.6	-63.3
300	-74.2	-82.3	-62.5
500	-74.4	-78.2	-62.6
800	-74.2	-73.9	-62.4
1000	-74.2	-71.6	-62.4
1500	-74.4	-67.3	-62.6
1800	-74.6	-65.8	-62.7
2000	-74.7	-65.0	-62.9
4000	-75.0	-67.2	-64.8
7000	-132.2	-133.5	-124.1
10000	-133.7	-138.4	-126.2

Table 4-3. LMK6Bx PSRR Performance at 156.25MHz and a 50mVpp Ripple With a 0.1µF Decoupling Capacitor Across Ripple Frequencies and Output Types

Ripple Frequency (kHz)	Spur (dBc)		
	LVDS	LP-HCSL	AC-LVPECL
10	-84.0	-95.4	-78.9
100	-86.7	-108.0	-82.1
300	-95.6	-155.4	-91.1
500	-100.0	-158.3	-95.7

Table 4-3. LMK6Bx PSRR Performance at 156.25MHz and a 50mVpp Ripple With a 0.1µF Decoupling Capacitor Across Ripple Frequencies and Output Types (continued)

Ripple Frequency (kHz)	Spur (dBc)		
	LVDS	LP-HCSL	AC-LVPECL
800	-102.4	-158.5	-99.4
1000	-104.2	-158.1	-100.9
1300	-106.4	-159.0	-103.0
1500	-107.6	-158.7	-104.1
1800	-108.8	-158.5	-105.4
2000	-109.3	-159.8	-106.1
3000	-160.0	-160.0	-108.4
4000	-161.9	-159.3	-109.3
5000	-163.4	-161.0	-159.2

Table 4-4. LMK6Bx PSRR Performance at 312.5MHz and a 50mVpp Ripple With a 0.1µF Decoupling Capacitor Across Ripple Frequencies and Output Types

Ripple Frequency (kHz)	Spur (dBc)		
	LVDS	LP-HCSL	AC-LVPECL
10	-79.6	-76.2	-69.2
100	-82.6	-96.5	-70.6
300	-91.8	-101.2	-80.0
500	-96.3	-102.1	-84.6
800	-99.7	-102.4	-88.5
1000	-101.2	-102.9	-90.3
1300	-103.3	-104.3	-92.6
1500	-104.5	-105.2	-93.8
1800	-106.0	-105.2	-95.5
2000	-106.0	-106.2	-96.4
3000	-158.0	-157.5	-100.1
4000	-101.6	-102.9	-102.8
4900	-160.3	-158.1	-104.3

4.3 Competitive Advantages: Dominating the Market

4.3.1 LMK6B PSRR Performance Against Competition

Independent testing against leading competitors demonstrates the LMK6B's exceptional PSRR performance. Both tests we're performed with both oscillators operating at 156.25MHz, the LMK6Bx with AC-LVPECL output type and 2.5V supply and oscillator 1 with LVDS output type and 1.8V supply.

Without any decoupling capacitors, the LMK6Bx outperforms Oscillator 1 across all ripple frequencies, achieving 15dBc better PSRR above 5MHz. Figure 4-3 illustrates the setup used to test PSRR for both oscillators and Table 4-5 summarizes the data gathered between oscillators.

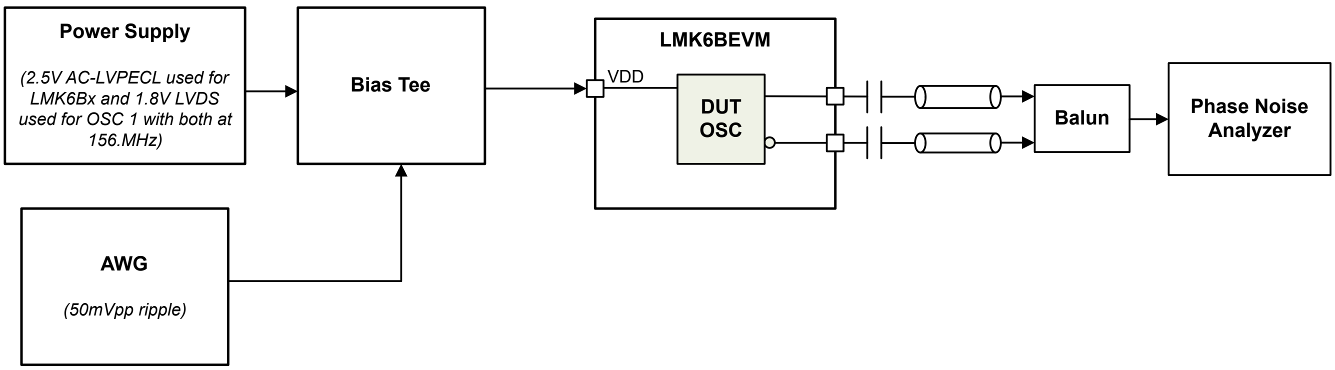

Figure 4-3. PSRR Test Setup Without Any Decoupling Capacitors

Table 4-5. PSRR Performance Comparison Between LMK6Bx and Oscillator 1 Without Any Decoupling Capacitors

Ripple Frequency	LMK6B Spur (dBc)	Oscillator 1 Spur (dBc)
50kHz	-60.41	-60.40
100kHz	-61.20	-60.01
200kHz	-62.12	-60.44
500kHz	-63	-61.8
1MHz	-61.77	-61.23
2MHz	-64.95	-59.243
5MHz	-73.85	-58.65
10MHz	-76.88	-61.49
15MHz	-79.33	-64.873
19MHz	-81.3	-67.87
20MHz	-81.11	-68.47

With a 0.1µF decoupling capacitor, the LMK6Bx achieves 3dBc to 6dBc better performance than Oscillator 1 across all ripple frequencies. The LMK6Bx performs less than -71dBc per spur for ripple frequencies above 50kHz. Figure 4-4 shows the setup used to test PSRR for both oscillators and Table 4-6 summarizes the data obtained.

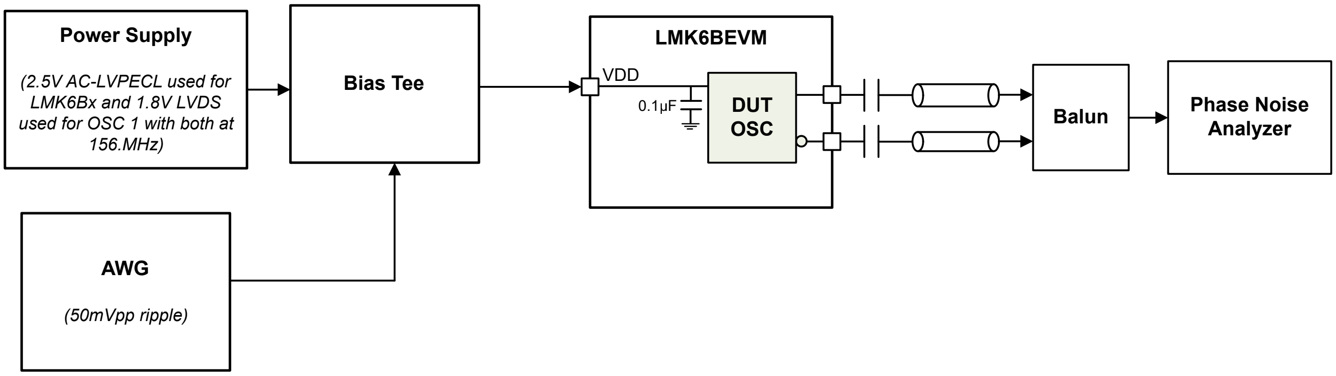

Figure 4-4. PSRR Test Setup With a 0.1µF Decoupling Capacitors

Table 4-6. PSRR Performance Comparison Between LMK6Bx and Oscillator 1 with a 0.1µF Decoupling Capacitor

Ripple Frequency	LMK6B Spur (dBc)	Oscillator 1 Spur (dBc)
50kHz	-71.21	-68.26
100kHz	-72.11	-65.59
200kHz	-75.56	-69.89
500kHz	-80.68	-75.96
1MHz	-88.36	-85
2MHz	-93.80	-90.24
5MHz	-100.25	-93.70

4.3.2 Holistic Competitor Comparison

Table 4-7 lists key parameters where the LMK6Bx surpasses or matches competition. In summary, the LMK6Bx has four times higher output frequencies than competitors, allowing better DSP PLL performance through higher input frequencies into the DSP's PLL PFD. The LMK6Bx aslo has the lowest output jitter at 625MHz in the market, enabling better BER results.

Table 4-7. Optical Module Top Players Competitor Comparison

Vendor	TI	Vendor 1		Vendor 2	
Part Number	**LMK6B**	**Oscillator 1**	**Oscillator 2**	**Oscillator 3**	**Oscillator 4**
Smallest Package	2.0mm x 1.6mm	2.0mm x 1.6mm	2.5mm x 2.0mm	2.0mm x 1.6mm	2.0mm x 1.6mm
Widest Temperature Range	-40°C to 105°C	-40°C to 105°C	-40°C to 105°C	-40°C to 105°C	-40°C to 105°C
Tightest Frequency Stability(1)	±20ppm	±20ppm	±50ppm	±20ppm	±20ppm
Aging	10-year at 85°C	10-year at 25°C	10-year at 25°C	10-year at 85°C	10-year at 85°C
Output Type Options	LVDS, HS-LVDS, AC-LVPECL, LP-HCSL, Custom Swing	LVPECL, LVDS, HS-LVDS, HCSL	LVPECL, LVDS, HS-LVDS	LVDS, LVPECL, HCSL, LP-HCSL, FlexSwing	LVDS, LVPECL, HCSL, LP-HCSL, FlexSwing
Highest Output Frequency	2500MHz	500MHz	625MHz	644.53125MHz	625MHz
RMS Jitter (12kHz to 20MHz) at 156.25MHz	AC-LVPECL: 47fs (typical)	LVPECL: 70fs (maximum)	N/A	LVPECL: 100fs (maximum)	LVPECL: 100fs (maximum)
	LVDS: 52fs (typical)	LVDS: 60fs (maximum)	N/A	LVDS: 100fs (maximum)	LVDS: 100fs (maximum)
	LP-HCSL: 44fs (typical)	HCSL: 70fs (maximum)	N/A	HCSL or LP-HCSL: 100fs (maximum)	HCSL or LP-HCSL: 100fs (maximum)
RMS Jitter (12kHz to 20MHz) at 625MHz	AC-LVPECL: 35fs (maximum)	N/A	LVPECL: 40fs (maximum)	Data not publicly available	Data not publicly available
	LVDS: 35fs (maximum)	N/A	LVDS: 40fs (maximum)	Data not publicly available	Data not publicly available
	LP-HCSL: 50fs (maximum)	N/A	HCSL: N/A	Data not publicly available	Data not publicly available

(1) Inclusive of all factors, including aging shown on the row below

5 LMK6Bx Description and Other Benefits

5.1 Comprehensive Output Options, Flexibility, and Other Key Specifications

The LMK6Bx is a fixed-frequency, factory-programmed, ultra-low jitter BAW oscillator offering unmatched versatility with multiple factory-programmed output formats: LVDS, HS-LVDS, AC-LVPECL, LP-HCSL, and Custom Swing. HS-LVDS and Custom Swing output swing can be programmed in 50mVppd steps from 350mVppd to 2Vppd for 3.3V supply and for 2.5V supply, 350mVppd to 1.5Vppd for Custom Swing and 350mVppd to 1.6Vppd for HS-LVDS. The LMK6Bx also has two function pins. Pin 1 has output enable (OE) and standby (ST) control and pin 2 offers output frequency selection (FSEL), where the frequency specified in the OPN can be divided by two or four. The LMK6Bx is the only oscillator in the market that can provide one OPN for the 3 most common frequencies used in the optical module market, providing supply and ordering simplicity. Figure 5-1 shows a block diagram of the LMK6Bx.

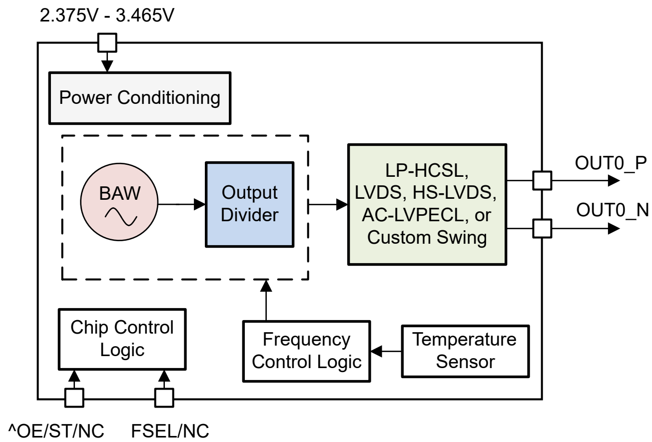

Figure 5-1. LMK6Bx Simplified Block Diagram

The oscillator can operate from 2.375V to 3.465V, has an operating temperature of -40°C to +105°C (PCB temperature), and can achieve ±25ppm (10-year aging at 25°C PCB) or ±20ppm total frequency accuracy (10-year aging at 85°C PCB). The LMK6Bx comes in a 2.0mm × 1.6mm, 2.5mm × 2.0mm, and 3.2mm × 2.5mm. For more information, refer to the LMK6Bx Data Sheet.

5.2 Streamlined In-Chip Integration and Cost Savings

The LMK6Bx not only has integrated regulators to eliminate external LDOs and ferrite beads, but also simplified output terminations that require fewer passive components. This integrated approach reduces PCB area and system cost—an excellent choice for space-constrained applications.

5.3 Implementation Guidelines to Replace Competition

The LMK6Bx can be used to replace competitor LVPECL, LVDS, HS-LVDS, LP-HCSL, and HCSL oscillators. To replace LVDS, HS-LVDS, and LP-HCSL oscillators, the LMK6Bx can be dropped in without any required changes. For LVPECL and HCSL competitor oscillators, some changes are required since the LMK6Bx requires less external component to save on area and cost. For a detailed explanation on how to replace LVPECL and HCSL oscillators with the LMK6Bx, refer to the LMK6Bx Data Sheet.

6 Summary

The LMK6B represents a paradigm shift in oscillator technology for optical modules. By combining revolutionary BAW resonator technology with industry-leading jitter performance, comprehensive output options, and integrated design features, the LMK6B delivers unmatched value for next-generation optical systems. The key differentiators of the LMK6Bx are:

- Industry's lowest jitter at high frequencies (4MHz HPF RMS jitter at 625MHz HS-LVDS is 9.3fs)
- Exceptional PSRR performance below -85dBc for HS-LVDS with spurs being 15dBc lower than some competitors
- Industry's highest frequency output of 2.5GHz output at 3.8fs HS-LVDS 4MHz HPF RMS jitter
- More system-integrated design by eliminating external LDO, ferrite beads, and termination passives decreasing area and cost
- Manufacturing and supply excellence using TI factories to achieve fast lead times

For optical module designers requiring the absolute best timing performance, lowest system cost, and fastest lead times, the LMK6Bx is the definitive answer. Contact Texas Instruments today to begin designing with the industry's most advanced oscillator technology.

7 References

1. Texas Instruments, *LMK6Bx Data Sheet*, datasheet.
2. Texas Instruments, High Reliable BAW Oscillator MTBF and FIT Rate Calculations, application note.
3. Texas Instruments, Standalone BAW Oscillators Advantages Over Quartz Oscillators, application note.

8 Revision History

Changes from Revision * (March 2026) to Revision A (May 2026) **Page**

- Corrected typo.. 9