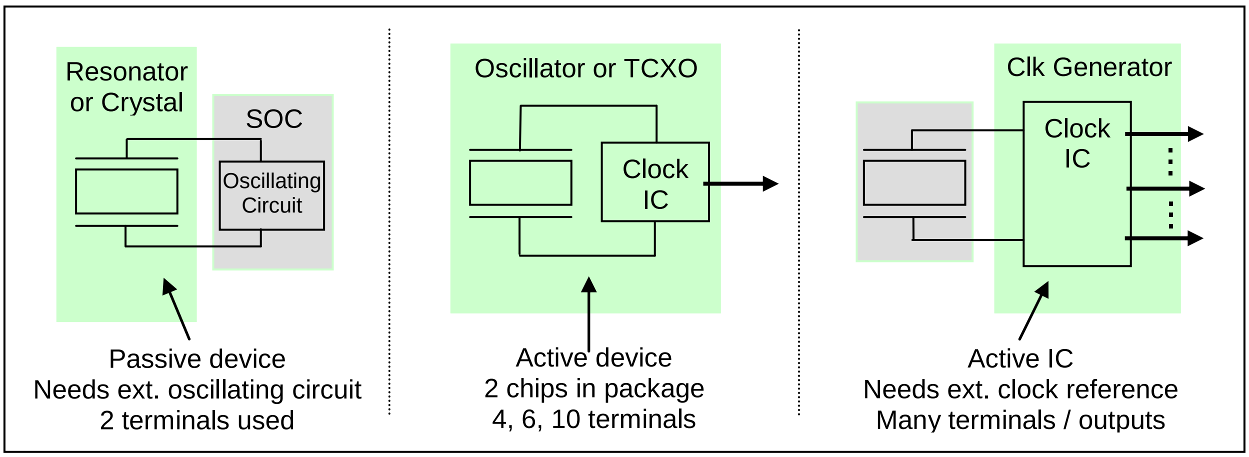
SiTime SiT156x and SiT157x Super-TCXOs
Frequently Asked Questions

1. What is a TCXO?
A TCXO is a temperature-compensated oscillator. As compared to a resonator/crystal (X, XTAL) or a clock generator, an oscillator (XO, TCXO, VCXO, etc.) comprises both the resonator and oscillator circuitry within one device.



2. What are SiT156x and SiT157x Super-TCXOs?
The SiT156x family consists of 32 kHz Super-TCXOs, while the SiT157x family of Super-TCXOs offers frequencies from 1 Hz to 1 MHz. Both families feature ±5 ppm all-inclusive stability (initial offset and over -40 to +85°C), and have a total footprint of 1.2mm^2. In addition, these devices offer extremely stable dynamic stability in the presence of fast temperature ramps, a feature that is unique to these Super-TCXOs. Because these Super-TCXOs are the industry's smallest, most accurate, low-power, low-frequency timing solutions, they are ideal for wearables, IoT, mobile, wireless modules and other battery-operated space-sensitive products.

3. How does SiTime achieve such accuracy, small size, and low power?
SiTime's TempFlat MEMS™ technology enables extremely small silicon MEMS resonators, which are 0.4 mm x 0.4 mm in size. These resonators are mated with sophisticated, low-power, mixed-signal PLL technology, with an accurate temperature sensor and compensation circuitry. The complete system of MEMS and programmable analog forms the Super-TCXO that is finely tuned to provide the best accuracy, smallest size, and lowest power.

4. How is on-chip temperature compensation used?
Super-TCXOs are calibrated (trimmed) over multiple temperature points to guarantee extremely tight stability (± 5 ppm) over -40 to +85°C. The temperature coefficient of Super-TCXOs is calibrated and corrected over temperature with an active temperature correction circuit.

5. **What applications need a highly-accurate, ultra-small, low-power, low-frequency TCXO?**
The rapidly emerging IoT and wearable segments are the perfect applications for a precision 32 kHz reference clock. For example, the typical wearable application has a very small battery (typically < 300 mAHr) and is extremely space limited. A Super-TCXO, with its ±5 ppm stable clock, can more precisely turn the wireless interfaces on and off than a quartz device, which minimizes the ON time of the wireless interface, and extends battery life. Other applications for a low-frequency Super-TCXO include industrial IoT (smart utility meters, E-meters, lighting, security), consumer electronics (health and wellness monitors, home automation, portable audio) and mobile devices (tablets, e-readers, and phones).

6. **What functions do Super-TCXOs provide in these applications?**
These TCXOs provide various timekeeping functions such as:
   - Reference for real time clock (RTC)
   - Reference for audio subsystem
   - Sleep clock for connectivity interface (Bluetooth, Bluetooth Low Energy - BLE, WiFi)

7. **Where is a 32 kHz Super-TCXO reference clock used in an IoT or wearable application?**
Wearables, for example, typically need two 32 kHz reference clocks; one for the BT/BLE chip's sleep clock and one for the MCU/SOC's RTC. Since SiT156x/7x TCXOs are active components, they can easily drive two loads – something a resonator cannot do. One SiT156x/7x can replace multiple quartz XOs or XTALs, reducing BOM, saving space and cost. The active TCXO also provides flexibility of placement on a space-constrained board.

8. **What is a sleep clock?**
A sleep clock is the reference clock that runs while the rest of the system is idle, hibernating, or turned completely off. 32 kHz is the ideal sleep clock frequency because it consumes the least amount of power and easily divides down to 1-second (for timekeeping). Most systems require a reference clock that is always running to drive the system RTC so it can keep track of time. In systems that include wireless connectivity, the 32 kHz sleep clock is used as the low-power reference clock when the wireless subsystem (e.g., Bluetooth, BLE, WiFi) is not operating.

9. **How does accuracy (stability) affect the sleep clock and system power?**
During a connected state, wireless subsystems operate in a cyclic sleep scenario to save power, periodically waking to receive pings from the central or master system. To wake up at the precise time, the peripheral wireless device relies on the accuracy of the 32 kHz sleep clock. Due to inherent inaccuracies of the master and slave sleep clocks, the peripheral device must wake up earlier, to avoid missing the ping from the master. During this early ON time, power is consumed, causing a power penalty. Using a highly accurate ±5 ppm Super-TCXO, compared to traditional quartz crystals with 180 to 200 ppm, can enable longer sleep time and save significant system power.

10. **What products are in the SiT156x and SiT157x families?**
The SiT1566, SiT1568 and SiT1576 are the first devices in the Super-TCXO family. All three devices come in a 1.5 x 0.8 x 0.6 (H) mm chip-scale package and are extremely accurate. Timekeeping accuracy is achieved with all-inclusive ±5 ppm stability (even in the presence of temperature ramp) and low-noise performance with ultra-low 2.5 ns maximum integrated phase jitter (IPJ_{RMS}) and 35 ns maximum peak-to-peak period jitter. For additional board-level stability, the SiT1568 has an auto-calibration feature to ensure ±5 ppm stability after accounting for errors introduced by assembly-

related stressors. The SiT1566 and SiT1568 have 32.768 kHz output frequency; the SiT1576 offers factory programmable frequency from 1 Hz to 1 MHz.

Wearable & IoT Requirements	SiT1566 32 kHz	SiT1568 32 kHz	SiT1576 1 Hz – 1 MHz
Best Frequency Accuracy Best Timekeeping, Longest Battery Life **All-inclusive ±5 PPM Stability**	√	√	√
Auto-Calibration after Overmolding **±5 PPM Stability after Assembly Stress**	-	√	-
Programmable Frequency **1 Hz to 1 MHz**	-	-	√

11. Can SiT156x and SiT157x Super-TCXOs be integrated into a SIP module?
Yes, because SiT156x and SiT157x TCXOs are composed of two all-silicon die in a chip scale package, they can be overmolded and integrated into a SIP/module. Furthermore, the unique, in-system auto-calibration feature of the SiT1576 compensates for board-level stress-induced frequency errors and improves accuracy after assembly, reflow, underfill and/or overmolding.

12. What applications benefit from SIP and modules?
Wearable, IoT and mobile products are examples of applications that benefit. These applications are driving miniaturization which is achieved, in large part, by modularization of subsystems. Modules in a mobile phone include power management (PMU, µDC-DC converter), RF/FEM power amplifier, storage/SSD, and connectivity (BLE, WLAN) modules; each of which can shrink in size by approximately 35 to 90% through modularization.

13. How is auto-calibration performed?
After the system is assembled and the PCB is ready for production test, the SiT1568 is auto-calibrated during final system test.

- A GPS-disciplined precision 10 MHz clock is applied to the SiT1568
- The SiT1568 32.768 kHz clock is compared to the precision 10 MHz clock
- The resulting error is removed

Please see the datasheet for more details.

14. What is the typical frequency offset of Super-TCXOs before and after auto-calibration?
After assembly: ±5 ppm
After overmolding: ±10 to ± 20 ppm
After auto-calibration: Less than ±5 ppm

15. How long does it take for the auto-calibration process during production?
Approximately 2 seconds typical, 5 seconds maximum. Keep in mind, auto-calibration is applied during the system test, thus will be scaled. The result is a 2 to 5 second range which occurs in parallel with the rest of the system test.

16. Are SiT156x and SiT157x Super-TCXOs used to replace an XTAL or XO or both?
SiT156x and SiT157x are primarily used to replace one or more quartz-based XTALs to reduce system power consumption and size. These families can also replace a low-frequency quartz oscillator for size reduction. Battery-operated products use low frequency clocks, and quartz crystals are not available in low frequencies in very small packages. Super-TCXOs enable ultra-small size at low frequencies ranging from 1 Hz to 1 MHz.

17. How did SiTime achieve such small package size?
Small size is an inherent advantage of MEMS-based oscillators. In quartz crystal technology, physics dictates that the lower the frequency, the larger the crystal resonator. MEMS resonators do not have the same constraint. The typical die size of SiTime's MEMS resonator is 0.4 x 0.4 mm and its mass is 1/3000th the mass of a typical quartz crystal resonator. Because SiTime's MEMS resonators are fully encapsulated in silicon and manufactured in CMOS fabs, they can be packaged using modern IC packaging technologies including WLCSP (wafer-level chip scale packaging). SiT156x/7x devices come in a CSP measuring 1.5 x 0.8 mm which is the industry's smallest oscillator package.

18. Who is the competition?
There is no direct competition. SiTime has the smallest, lowest power, most accurate solution. A summary of the comparison with quartz 32 kHz TCXOs is shown below.

Specification	Quartz A	Quartz B	Quartz C	SiT156x	SiTime Advantages
All-Inclusive Max Frequency Stability (ppm)	8	7.5	5	5	Up to 40% better
1st year Max Aging (ppm)	3	3	NA	1.5	2x better
Max Period Jitter (ns_{p-p})	NA	NA	NA	35	Ideal for audio applications
Package (Footprint)	3225 SMD ($8mm^2$)	3225 SMD ($8mm^2$)	2520 SMD ($5mm^2$)	1508 CSP ($1.2mm^2$)	Up to 85% smaller
Max Package Height	1 mm	1.3 mm	1.0 mm	0.6 mm	Up to 55% less height

19. Are SiT156x and SiT157x Super-TCXOs price competitive?
Yes, as with all SiTime products, pricing is very competitive. SiTime can offer excellent pricing because we manufacture our devices in silicon and use a fabless semiconductor model, benefiting from the entire semiconductor infrastructure. Reference pricing is available upon request.