SiTime™

SiTime Turbo Webinars

15 min

SiTime University Turbo Seminar Series

Silicon Oscillator Frequency Characteristics and Measurements

February 25, 2013

The Smart Timing Choice™

Agenda

- Oscillator frequency stability: MEMS vs. Quartz
- Common questions on frequency stability specs
- How to make accurate frequency measurement for oscillators

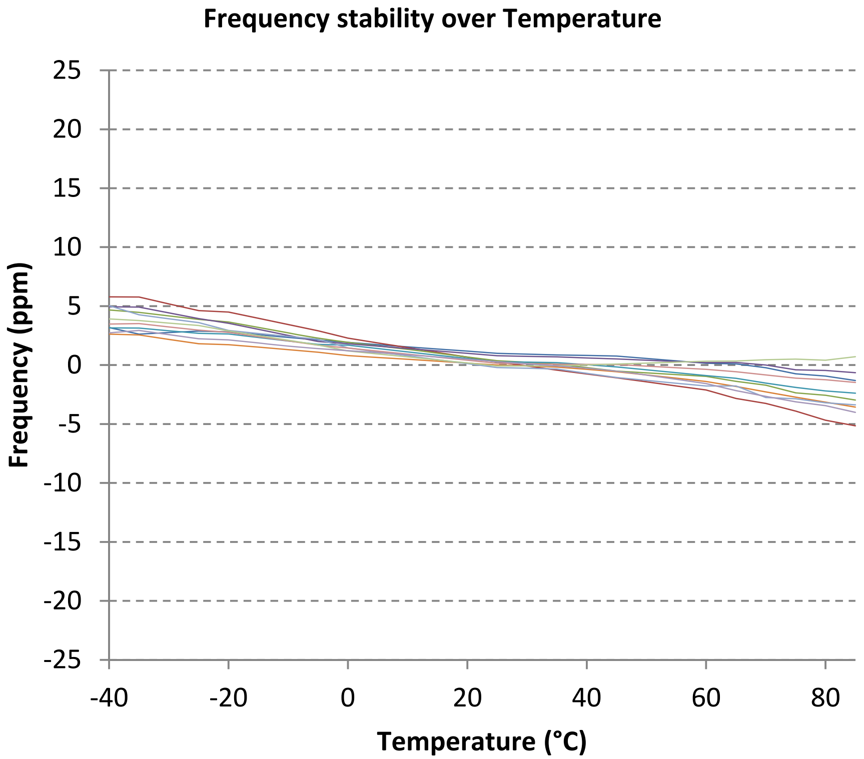
Frequency Stability

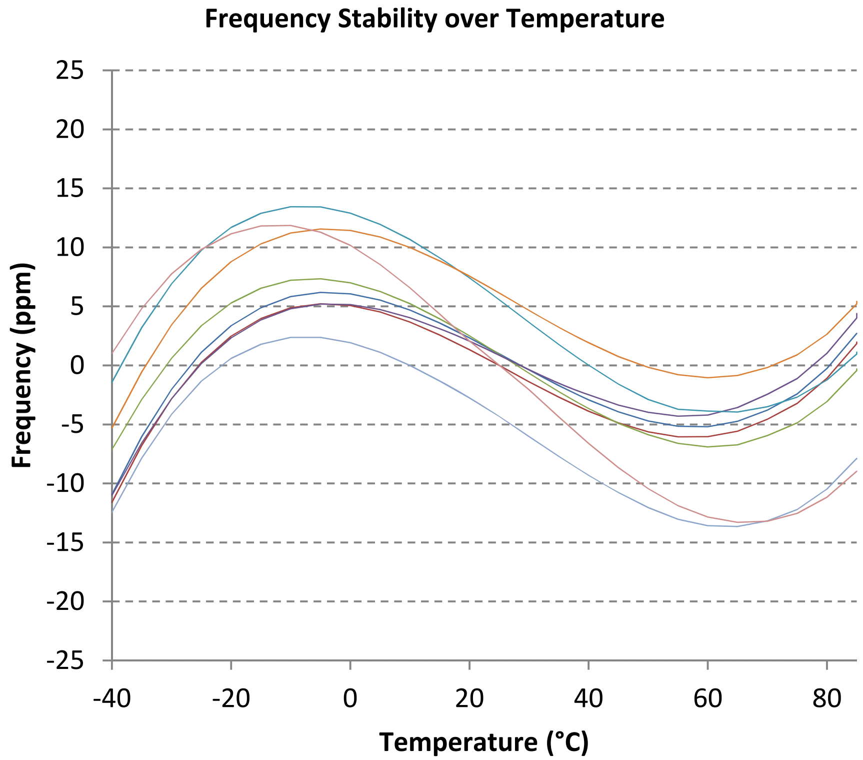
- Frequency Stability
  - Defined as relative variation of frequency from nominal
  - Expressed in part per millions (PPM)
  - Example: ±100 PPM of 100 MHz clock means frequency of clock can be
    - Lower frequency: 100 MHz – 100 PPM = 99.99 MHz
    - Upper frequency: 100 MHz + 100 PPM = 100.01 MHz

$$F_{sta} = \frac{\Delta f}{f} = \frac{f - f_{nom}}{f_{nom}}$$

- Components of Frequency Stability
  - **Initial tolerance**: Stability only at room temperature, nominal VDD & load
  - **Temperature**: Frequency variation over operating temperature
  - **Voltage:** Frequency variation over power supply voltage variations
  - **Aging**: Frequency variation over long time – expressed in PPM / year

Frequency Stability vs. Temperature:
SiTime MEMS vs. Quartz Oscillators





MEMS XO

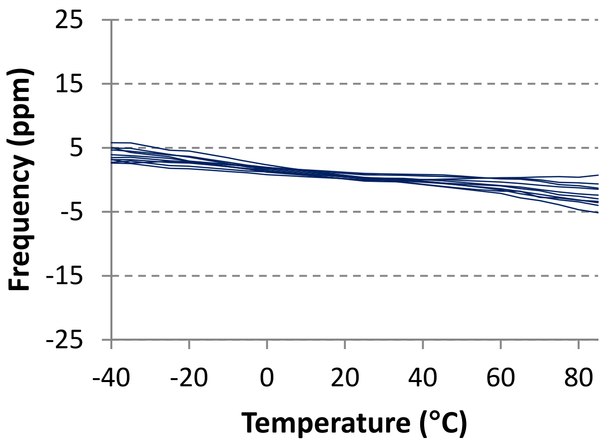
- Nearly linear across temperature
- Can achieve tighter tolerance over wider temp range

Quartz XO

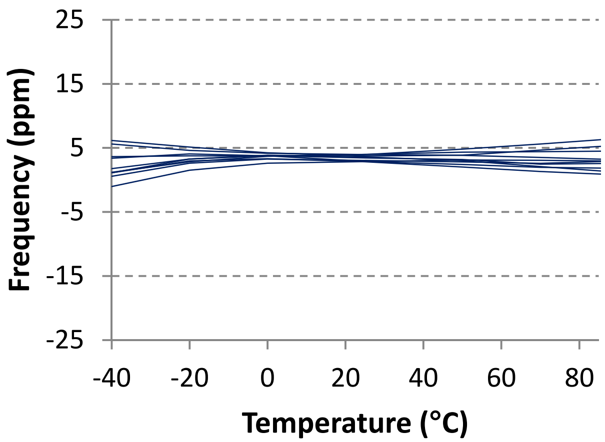
- 3rd order curve characteristics
- Steep change outsides operating range.
- Depending on orientation of the crystal cut
- Hard to achieve wider temp range.

Frequency Stability vs. Temperature: SiT8208/9, SiT9120/1/2, SiT1602 Series

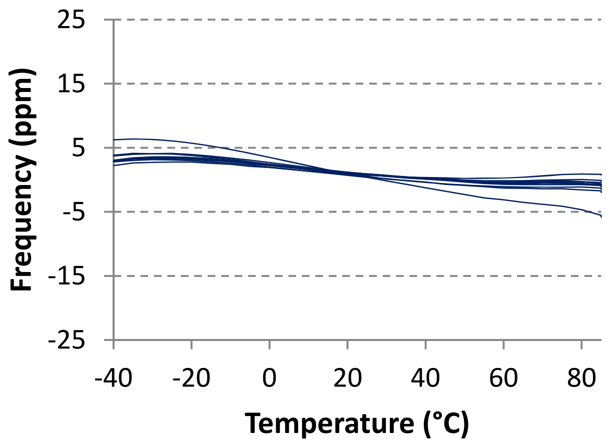
SiT8208



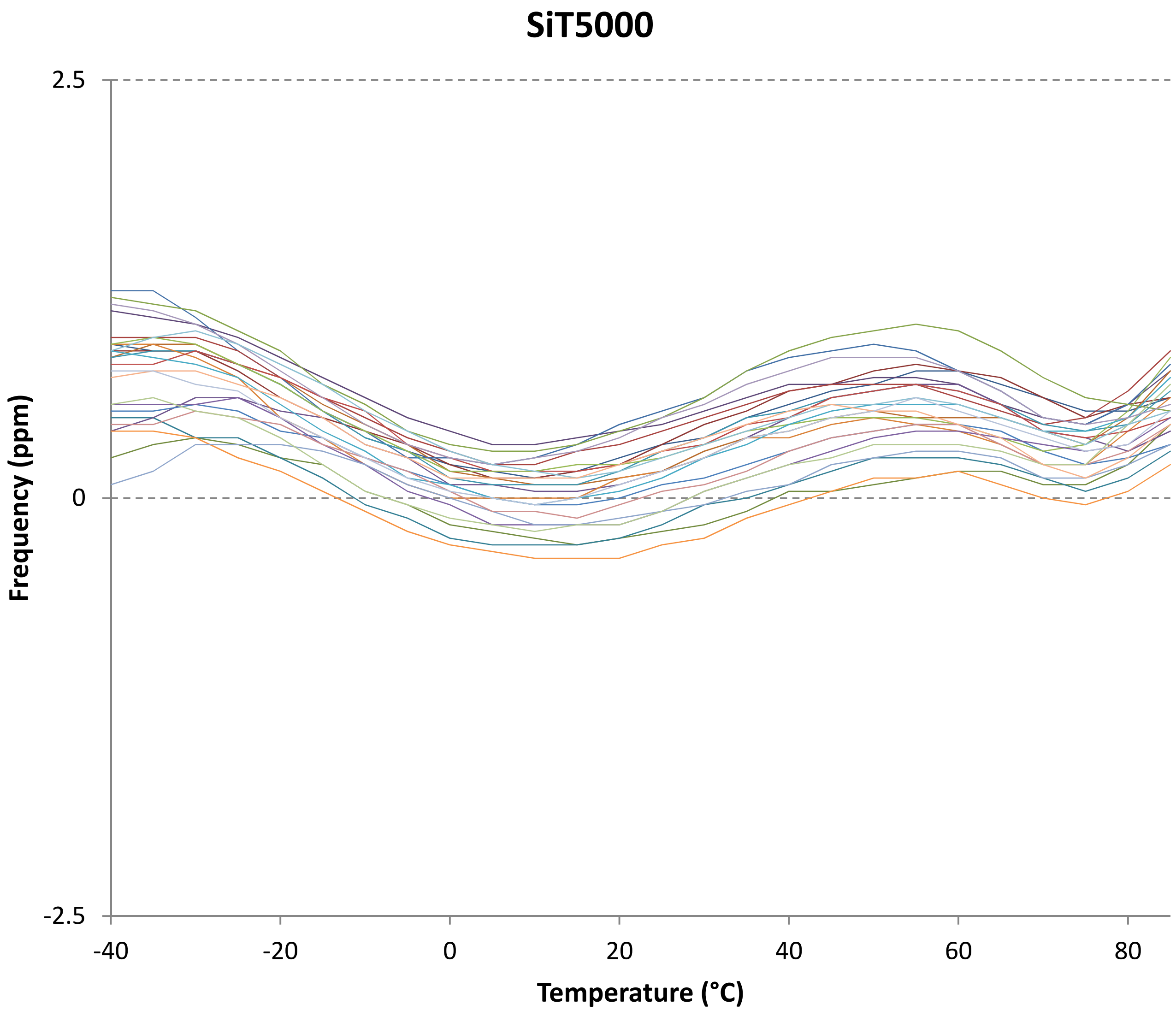
SiT9121



SiT1602

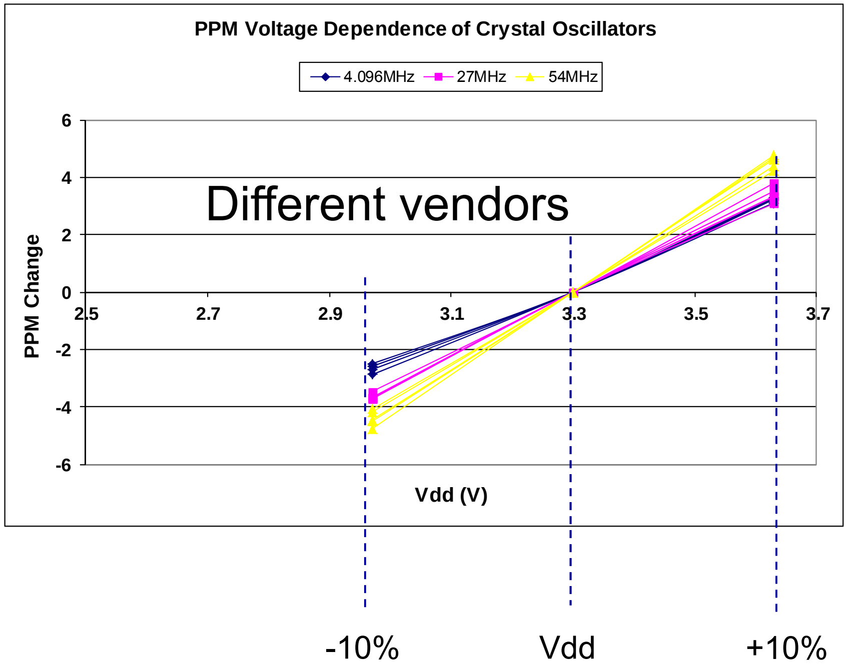


Frequency Stability vs. Temperature: SiT5000 ±2.5ppm TCXO

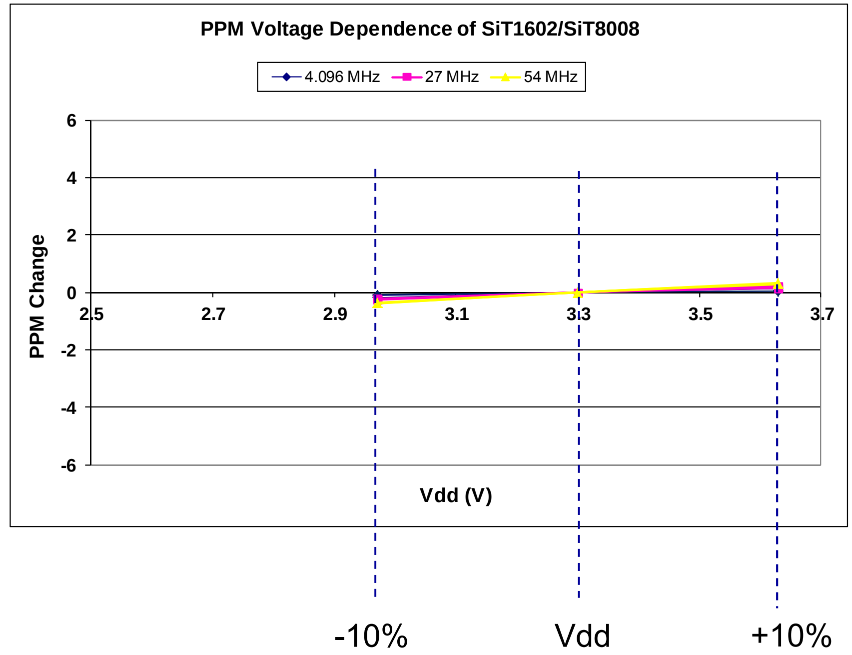


Frequency Stability vs. Supply Voltage:
SiTime MEMS vs. Quartz Oscillators

Quartz Oscillators from 3 vendors



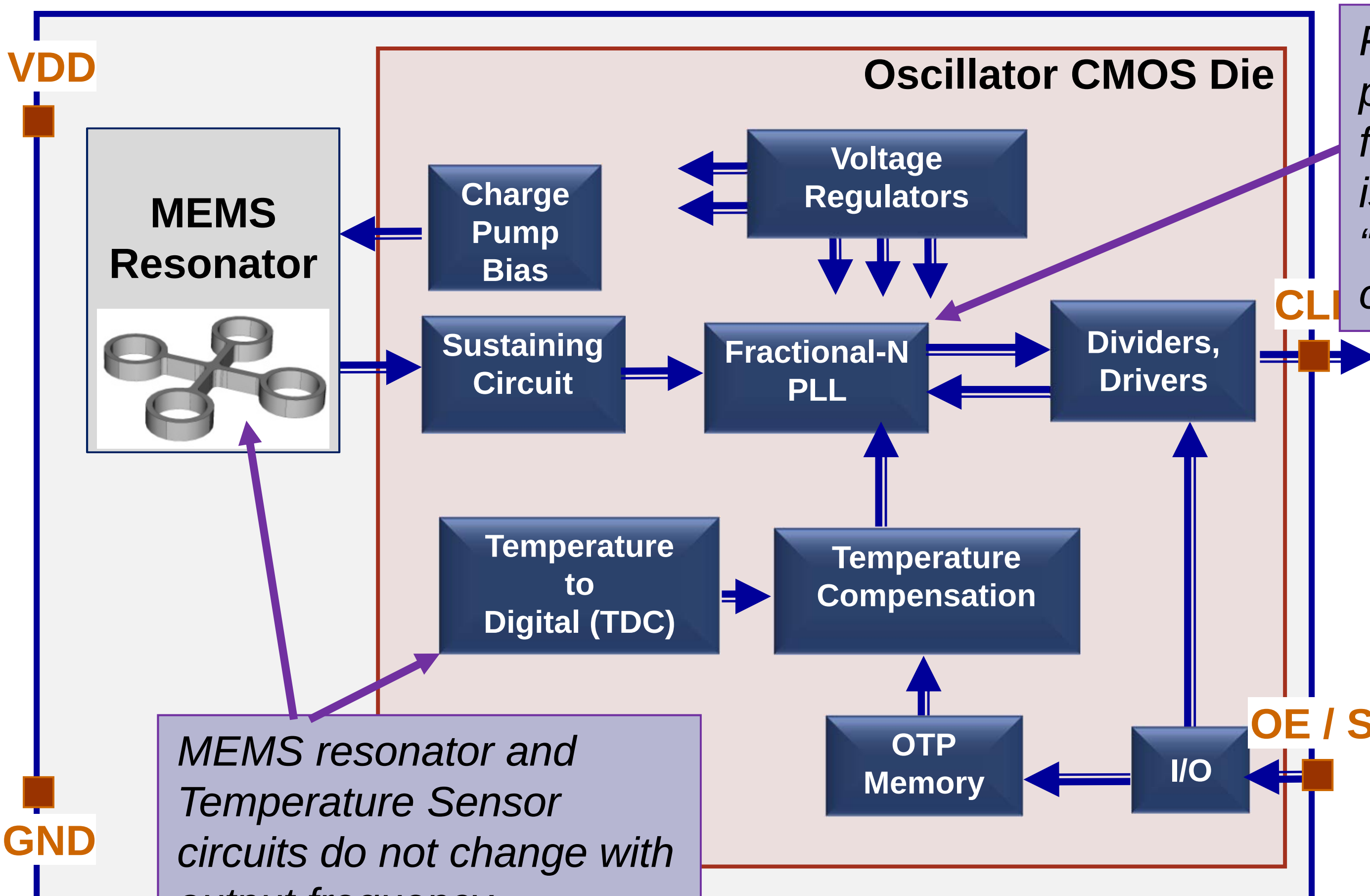
SiT1602 / SiT8008



SiTime MEMS XO has on-chip voltage regulator to achieve better performance

Common Questions on Frequency Stability

- Do SiTime MEMS oscillators frequency vs. temperature characteristics depend on output frequency? ***No***

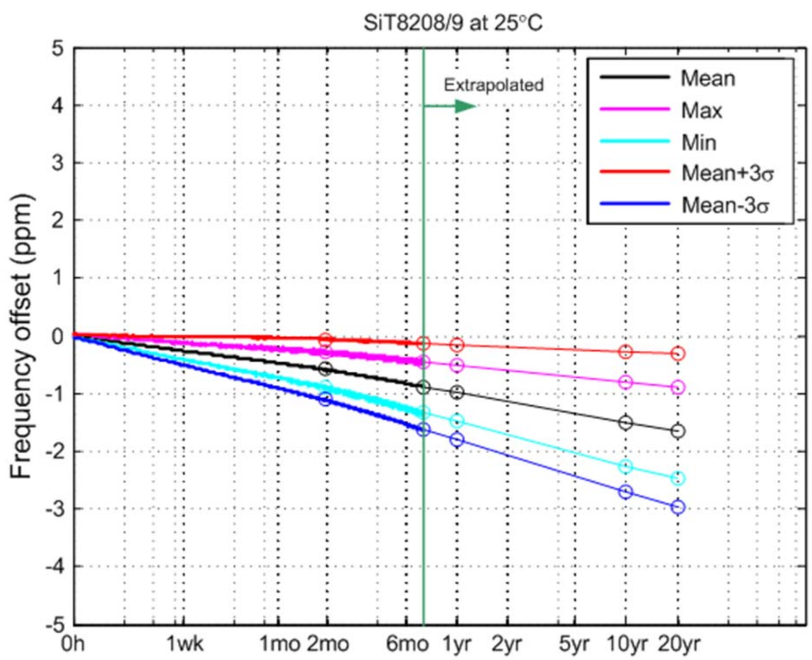


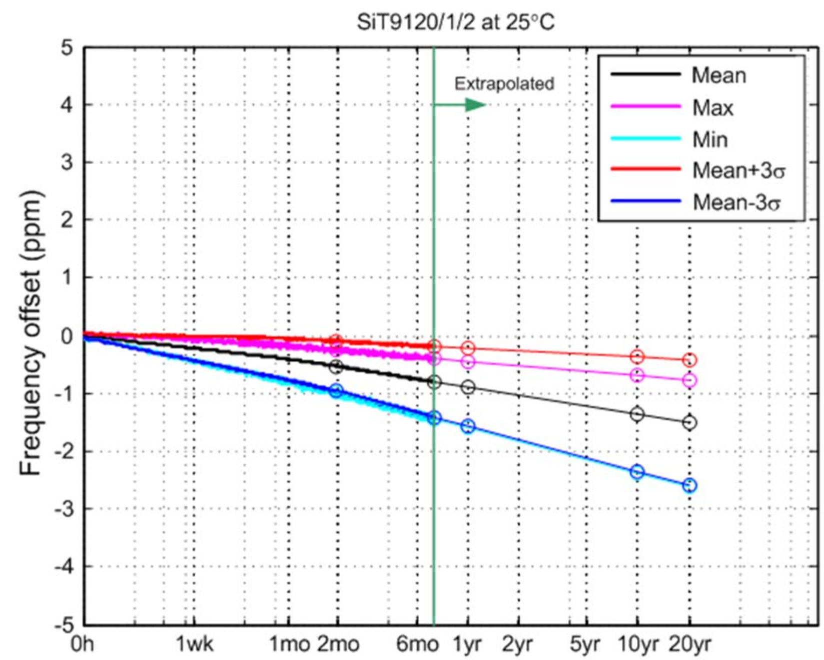
Frequency programmed by fraction-N PLL. PLL is locked to "Sustaining Circuit" output and TDC.

MEMS resonator and Temperature Sensor circuits do not change with output frequency.

Common Questions on Frequency Stability

- Can SiTime MEMS oscillators achieve aging specs better than Quartz? ***YES***

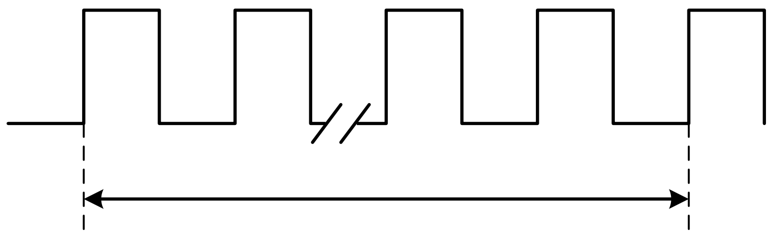




Frequency Measurement

Frequency Counter Principle

Average frequency measurement



$$f = \frac{N}{T_{Gate}}$$

- Modern frequency counter use time interval measurement over a number of clock cycles to measure frequency
  - Time internal measurement as accurate as 20ps pk-pk
  - Resolution independent of clock frequency

Frequency Measurement Accuracy

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$$\frac{\Delta f}{f} = \frac{\Delta f_{TB}}{f_{TB}} + \frac{\Delta TI}{T_{Gate}}$$

Time base stability

- OCXO: 0.1ppm to 1ppm
- High-end OCXO: 0.01 to 0.1 ppm
- Rubidium: 1 part-per-billion (ppb)
- GPS-disciplined: 0.01 ppb

- Require calibration if not GPS-disciplined

SiTime Uses GPS-disciplined TB:

Accurate and
Consistent across test / manufacturing sites

Time interval error

- 20 ps to a few ns (pk-to-pk)
  - < 200 ps for modern counters
- Resolution independent of input clock frequency
- Resolution improves as gate time increases
- Example: T_{Gate} = 100 ms, ΔTI = 100 ps

$$Resolution = \frac{100 \times 10^{-12}}{100 \times 10^{-3}} = 1\ ppb$$

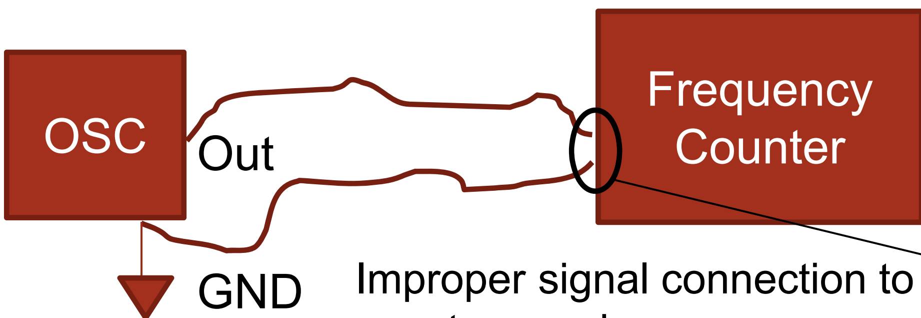
SiTime Recommendation:

Use 100 ms gate time by default

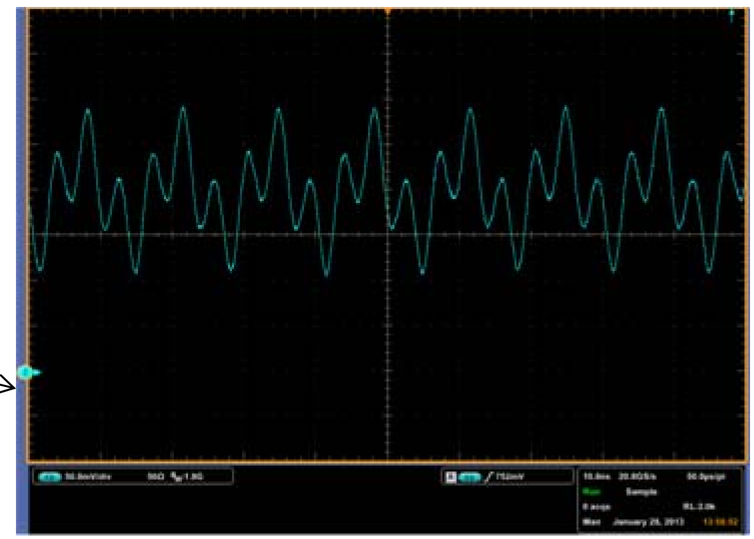
Sources of Measurement Error
Poor Connection to Frequency Counter

Trigger Error

- Noise or waveform distortion on input clock signal causing frequency measurement error
- Affected by probe setup and/or impedance mismatch



Improper signal connection to counter causing erroneous triggering and wrong frequency measurement.

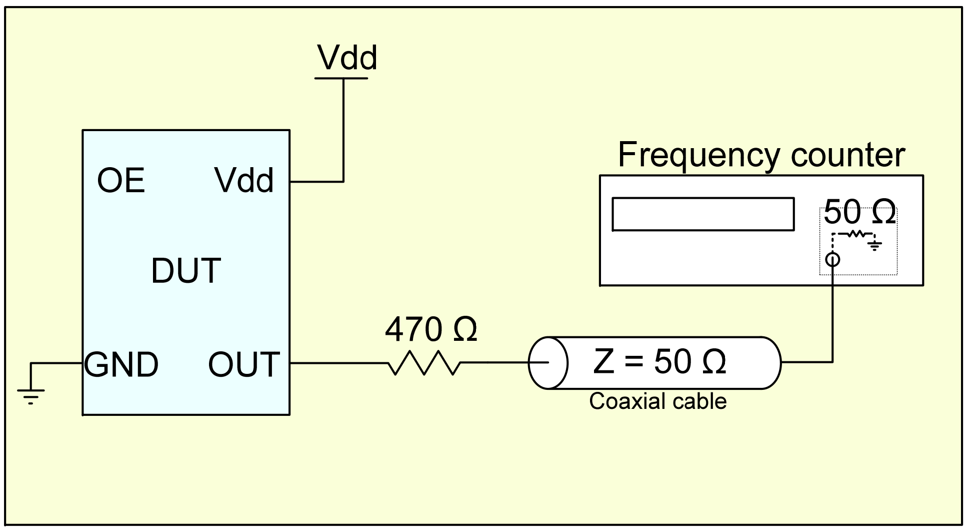


Proper Connection to Frequency Counter

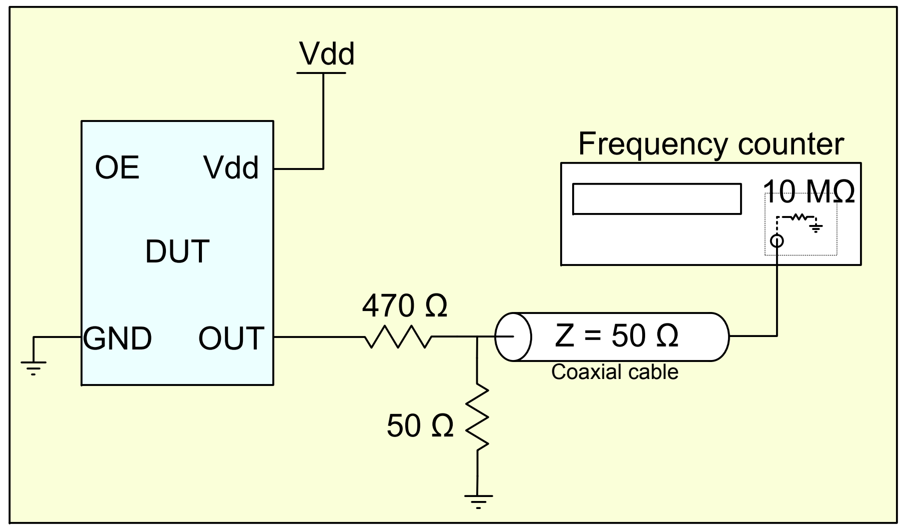
Loading Effect on Oscillator

- Counters have 50 ohm or Hi-Z inputs
- Driving 50 ohms load can increase oscillator IDD significantly
  - Increased IDD means more power dissipation and higher die temperature
- Driving high-impedance counter inputs can cause significant reflections → possible frequency measurement error

Connecting oscillator output to 50ohm input;
Coaxial cable terminated at the counter



Connecting oscillator output to Hi-Z input;
Coaxial cable terminated at the source



How to Make Accurate Frequency Counter Measurement?

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- Choose proper Gate Time (>100 ms)
- Use good internal time-base option (<0.1ppm OCXO), or
  - Use external frequency reference for accurate and repeatable measurements across instruments (GPS-disciplined sources)
- Use probe setup that minimizes loading to oscillator and provides good signal integrity

Contact Information

- **For Questions, contact SiTime Technical Support**
  Technicalsupport@sitime.com

- ***Turbo Webinar* pdf downloads on SiTime's web site**

- **Webinar recordings are posted on SiTime's web site**

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  - All new webinars are posted within 24 hours