Microchip Low Phase Noise Crystal Oscillators

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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Date: June 28, 2022

Microchip in 5G

5G Infrastructure

Radio & Small Cell

Precision Oscillators
Network Synchronization
RF Diodes, LNAs, PAs
SAW Filters
Power over Ethernet
Ethernet Switch/PHY
FPGA
Security
AC-DC, DC-DC

Baseband

Precision Oscillators
Network Synchronization
FPGA
Security
AC-DC, DC-DC

X-Haul

Ethernet PHYs w/ Security & Timing
OTN / Ethernet Fronthaul Processors
Precision Oscillators
Network Synchronization
FPGA
Security
AC-DC, DC-DC

Edge Compute

FPGA / MPU / MCU
Flash/Storage Controllers
PCIe Switch
Network Synchronization
FPGA
Security
AC-DC, DC-DC

5G Enabled Markets

Automotive

Ethernet, PCIe®
FPGA / MPU / MCU
SAW Filters
Timing
Security
AC-DC, DC-DC

Industry 4.0

Ethernet,
FPGA
MPU / MCU
SAW Filters
Timing
Security
AC-DC, DC-DC

Medical Devices

FPGAs
MPU / MCU
SAW Filters
Security
AC-DC, DC-DC

Smart Home

MPU / MCU
SAW Filters
Security
AC-DC, DC-DC

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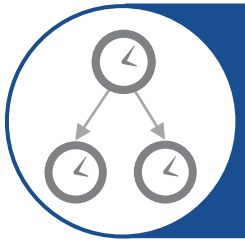
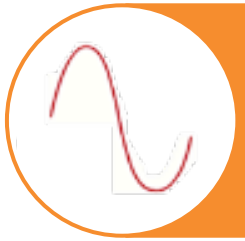
Industry's Broadest Clock and Timing Portfolio



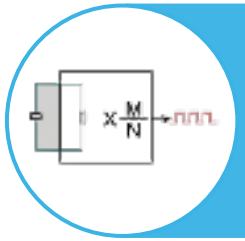
Network Synchronization

- IEEE-1588 & Synchronous Ethernet Compliant Solutions
- PTP and Servo Algorithm Software
- Sub 100fs Jitter
- Multi-channel PLLs with Up to 20 Outputs



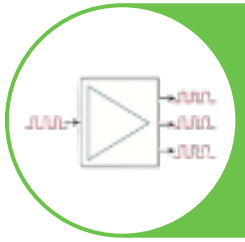
Oscillators

- **Precision OCXO/TCXO/VCSO/VCXO**
- **Low-Cost Crystals and MEMS**
- **Low Noise**
- **Low-Power OCXO & TCXO**



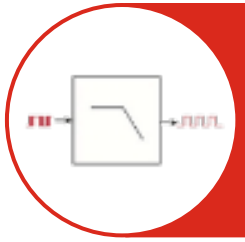
Clock Generation

- As Low as 78 fs Phase Noise
- Preconfigurable with up to 20 Outputs
- Crystal-less™ PCIe® Clock Generators



Fan Out Buffers

- Low-Additive Jitter
- Any Format In/Any Format Out
- Gen 1-5 Compliant PCIe HCSL & LPHCSL Buffers
- Up to 22 Outputs



Jitter Attenuators

- Single and Multi-channel solutions
- Any Format In/Any Format Out
- Sub 100fs Jitter Performance

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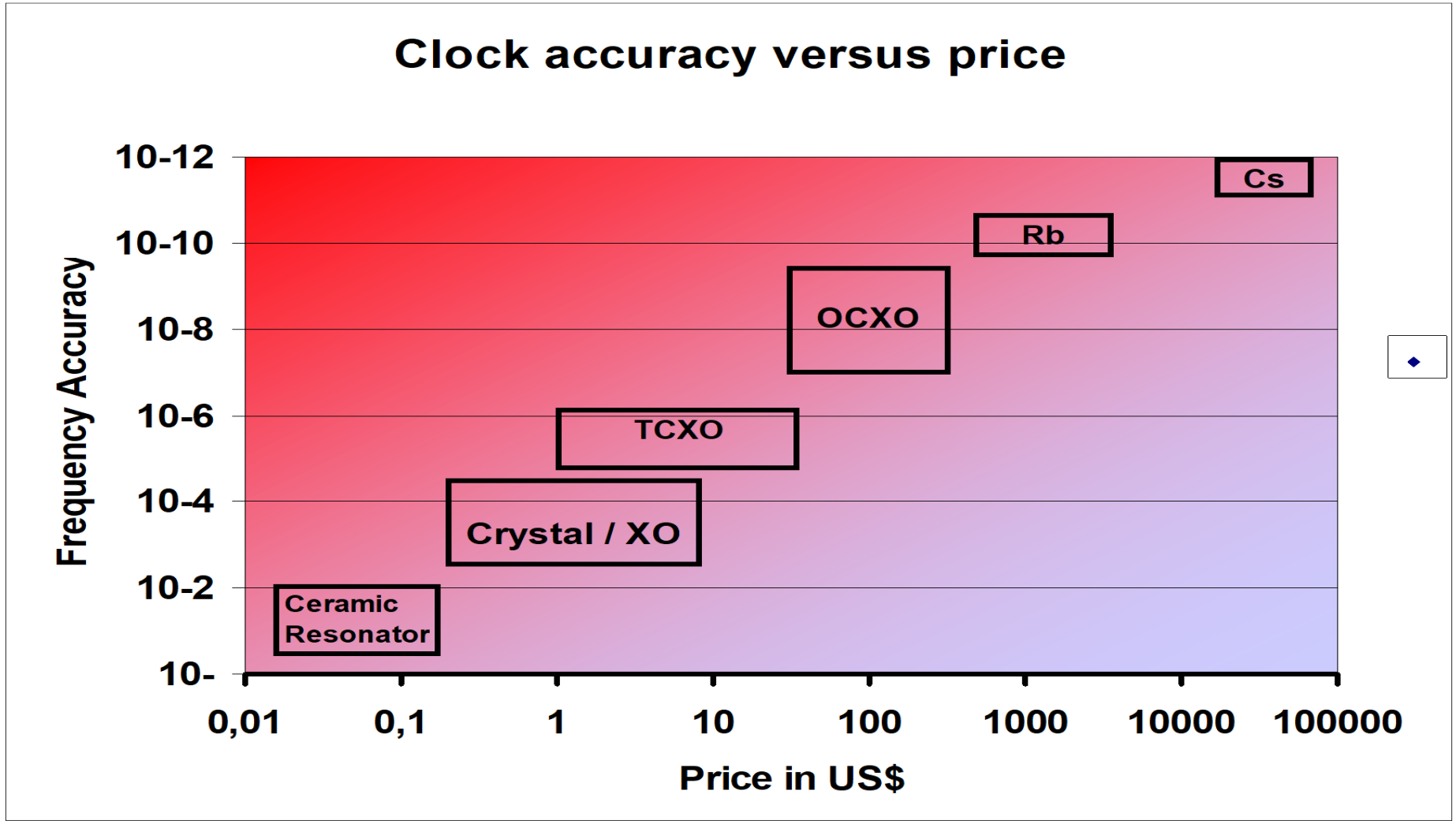
Product Training

Oscillators Basic

Crystal Basics: Hierarchy of Frequency Control Devices



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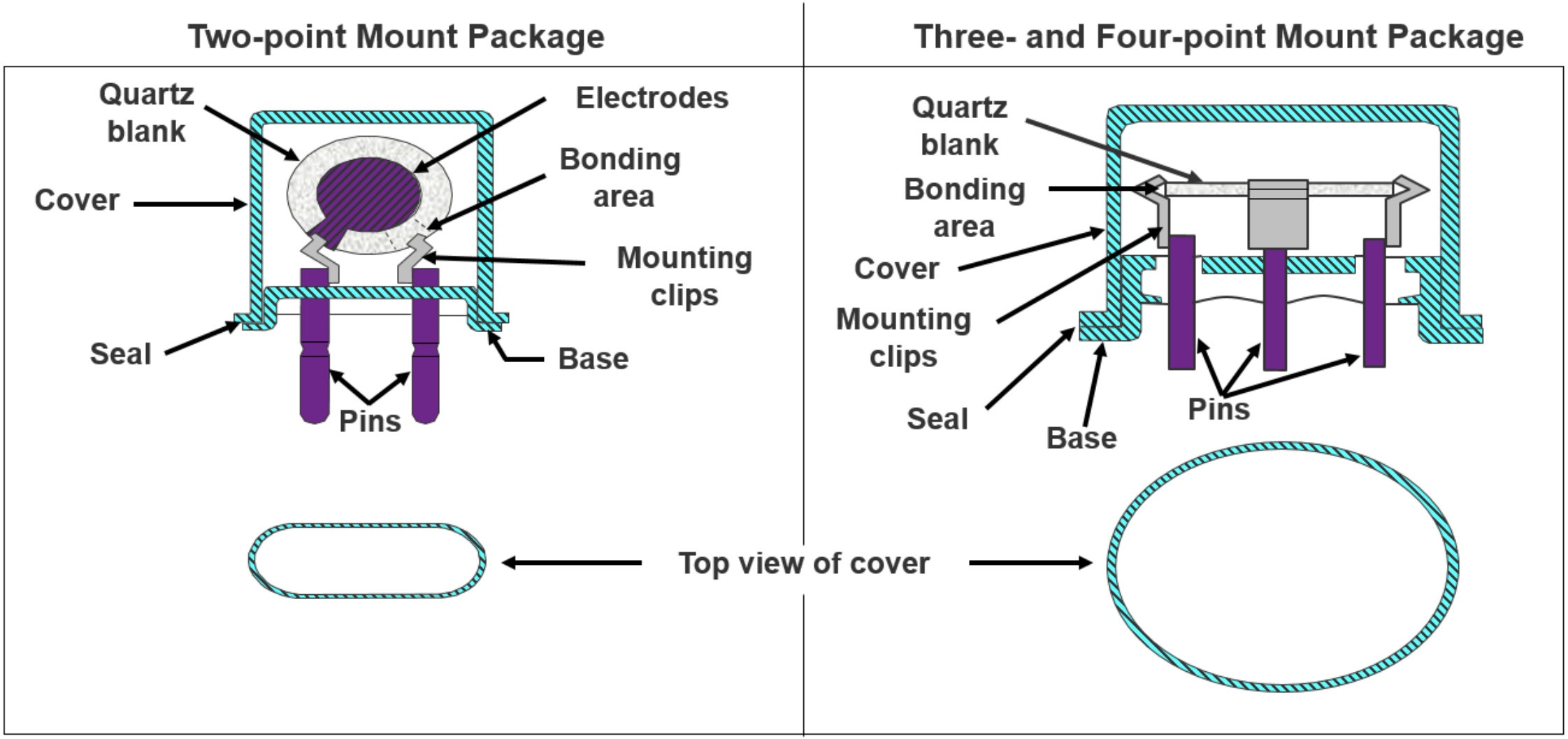
Crystal Basics: Resonator Packaging



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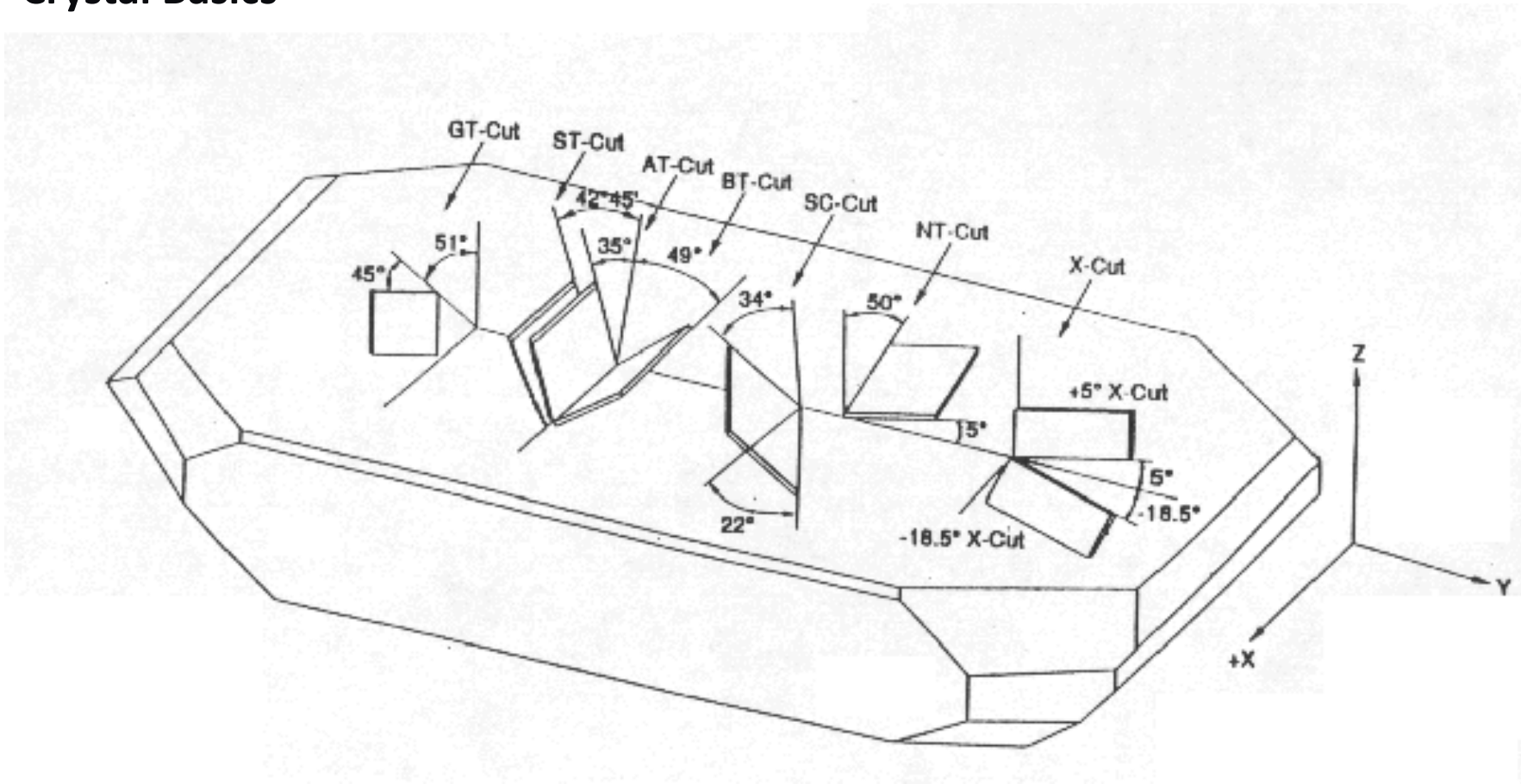
Types of Quartz Crystal Cuts

Crystal Basics



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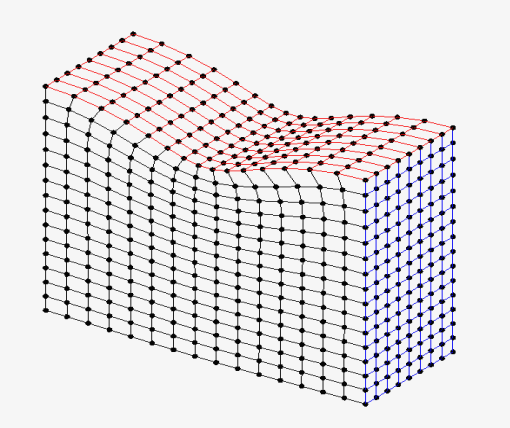
How Do SAW/BAW Devices Work?

Piezo-Electric Effect: electrical energy ⇔ mechanical (acoustic) energy

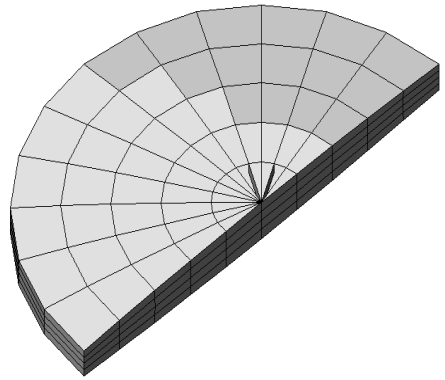
Surface Acoustic Waves:

- Filters
- Resonators



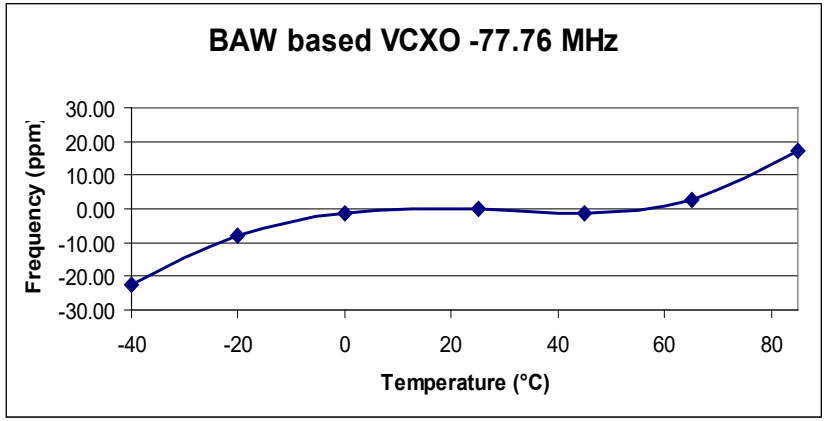
Bulk Acoustic Waves:

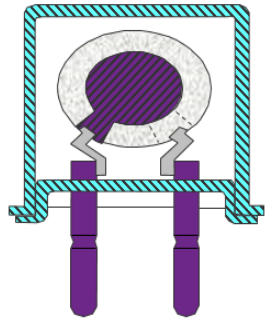
- Crystals
- Monolithic Crystal Filters



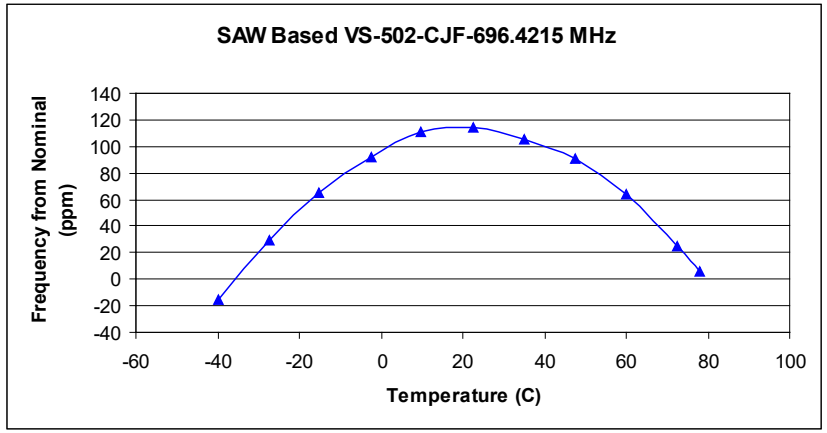
Performance Difference from VCSO and VCXO

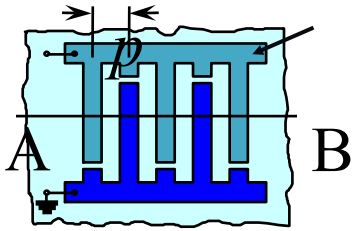
- **BAW (VCXO)** temperature coefficient is cubic and will move ~ ± 20 ppm over industrial temperature range





- **SAW (VCSO)** temperature coefficient is parabolic in nature and will move ~± 150 ppm over industrial temperature range





- To compensate for these differences, VCSOs have a deviation sensitivity (Kvco) in ppm/V which is ~ 5 times higher than a comparable VCXOs

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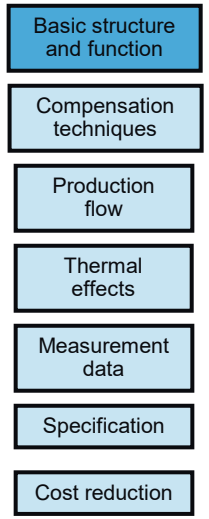
Product Training-II

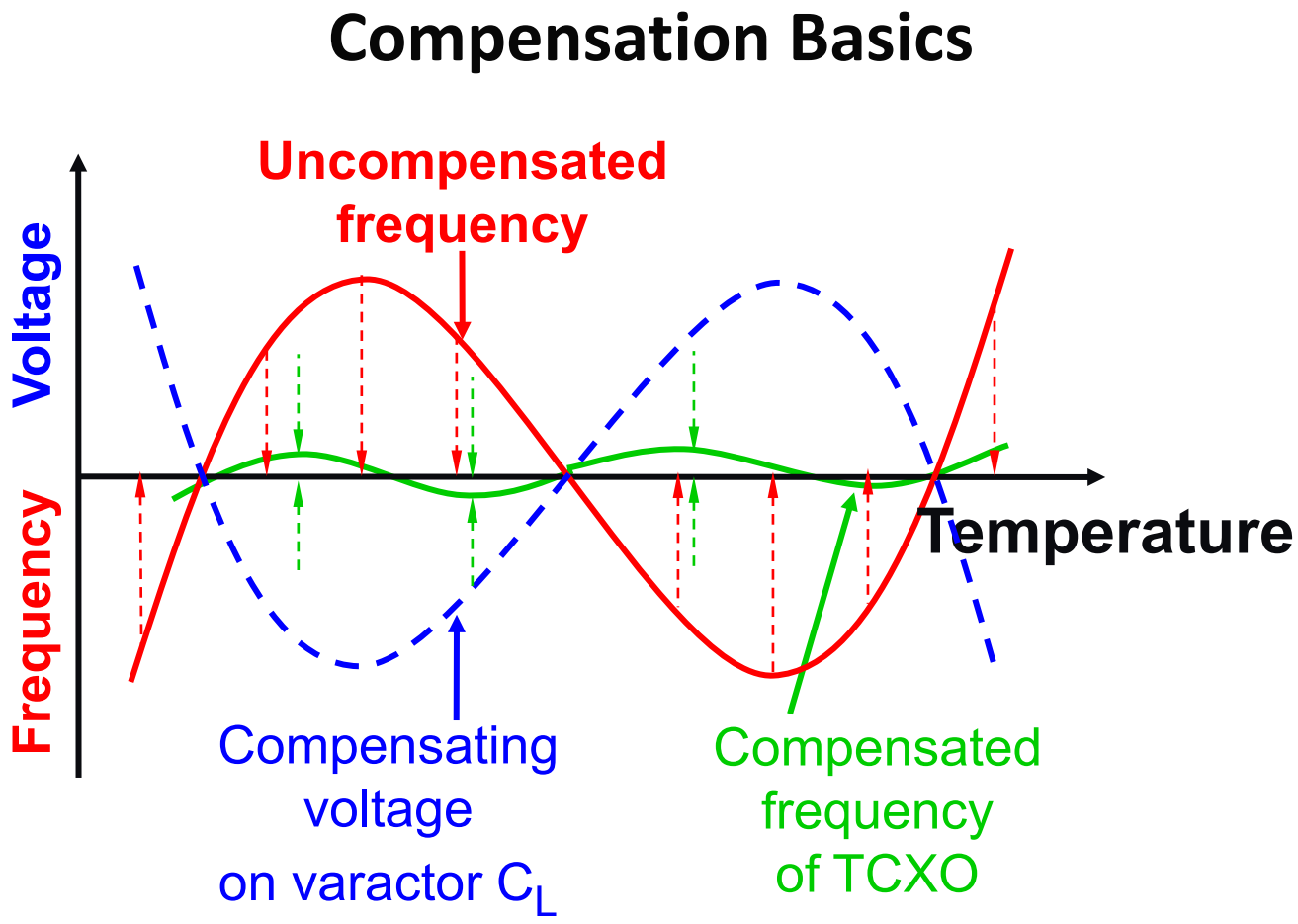
TCXO Basic

Basic Structure and Function

- TCXO = Temperature Compensated Xtal Oscillator
- To get a 15 to 75 times better frequency stability than a VCXO or a PXO while the power consumption remains the same.
  Up to 300 times total for DDC-TCXOs: MCXOs
- To close the gap between a high end PXO/VCXO and a medium end OCXO.
  To replace low end OCXOs
- A temperature compensation network is used to:
  - sense the ambient temperature
  - pull the crystal frequency to its nominal value
- Oscillator- and output- buffer-stage are identical to a VCXO.



Compensation Techniques



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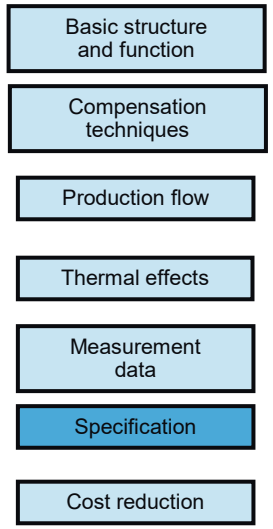
Specification

- **Main selection criteria**
  - **Frequency stability vs. temperature:**
    0 to 50°C → ±0.02ppm …. ±4ppm
    -20 to 70°C → ±0.02ppm …. ±6ppm
    -40 to 85°C → ±0.03ppm …. ±12ppm
  - **Aging:**
    ± 0.5ppm/year ….. ± 1ppm/year
    ± 2ppm/10years ….. ± 5ppm/10years
  - **Power consumption:**
    1mA to 5mA → clipped sinewave output; < 30MHz
    15mA max → HCMOS output; < 30MHz; Cload = 15pF
  - **Package:**
    SMT - 3.2 x 5mm²; 5 x 7mm²; 9 x 14mm²; 22 x 25mm²;
  - **Pulling range (if needed):**
    > ±5ppm …. < ±30ppm (depends on package)



Product Training-III

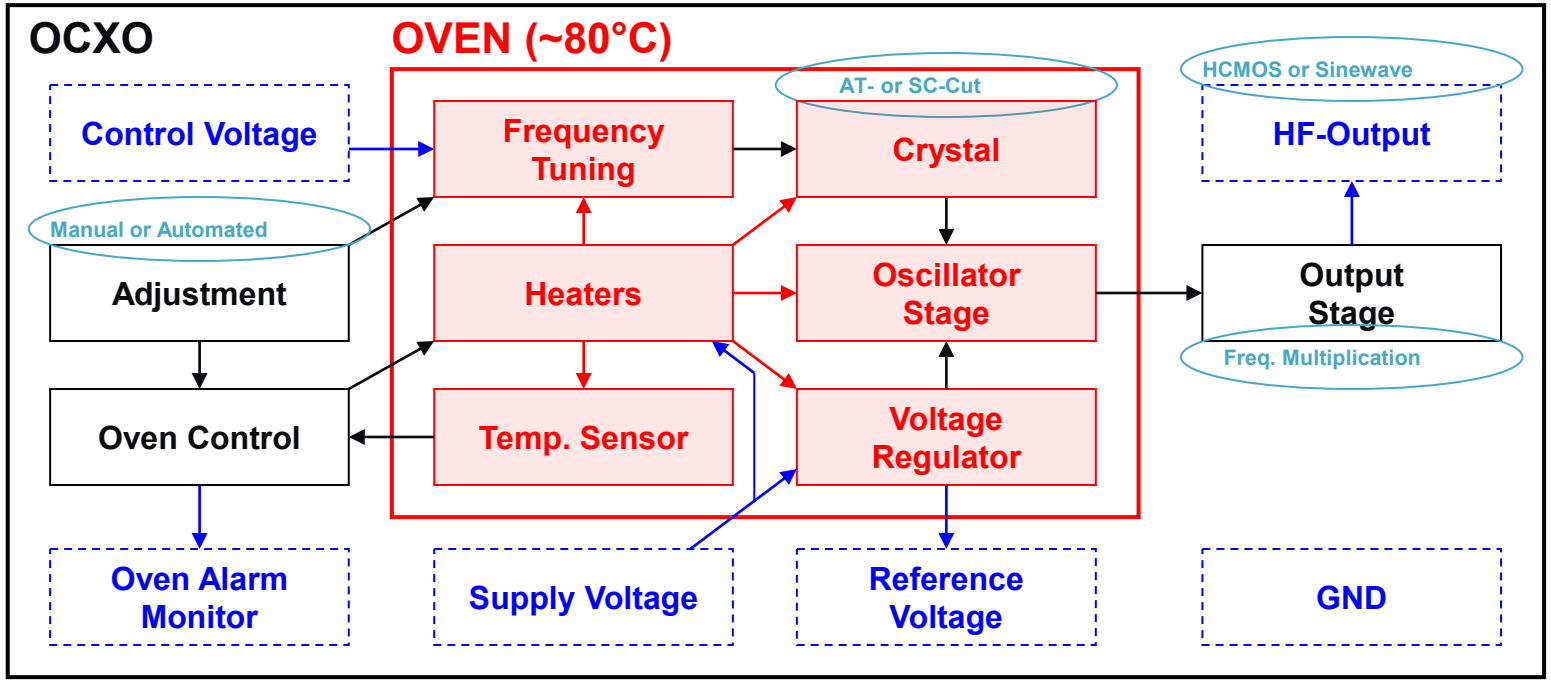
OCXO Basic

OCXO Tutorial Basic Description

OCXO = Oven Controlled Xtal (Crystal) Oscillator

-Improves frequency vs. temperature stability due to stable crystal temperature

-Most stable crystal oscillator



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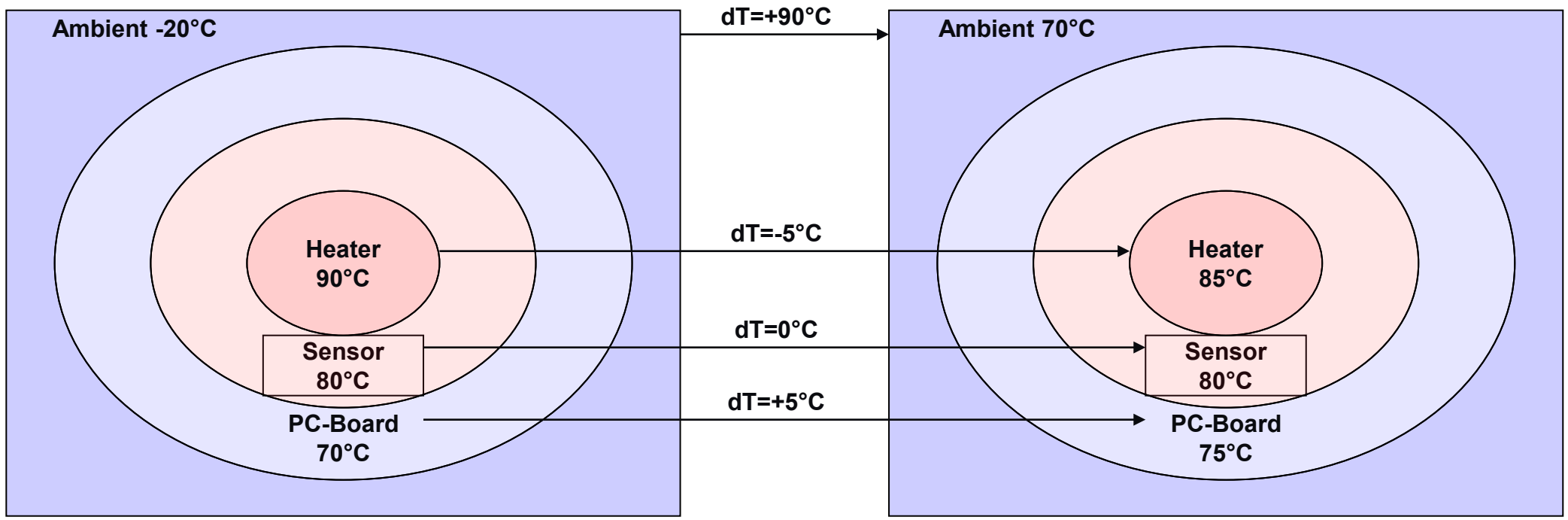
OCXO Tutorial Thermal Quality

- The thermal Q describes the ratio between a temp change of the ambient and the corresponding temperature change in the oven.
- A good temperature stability results in a high Q.
- The area near the temperature sensor has a very high Q.
- The area near the heater usually has a poor negative thermal Q.
- The area at the border of the PCB usually has a poor positive thermal Q.
- Conclusion: Avoid temperature gradients to improve thermal Q.

$$Q_{TH} = \frac{\Delta T_{Ambient}}{\Delta T_{Oven}}$$



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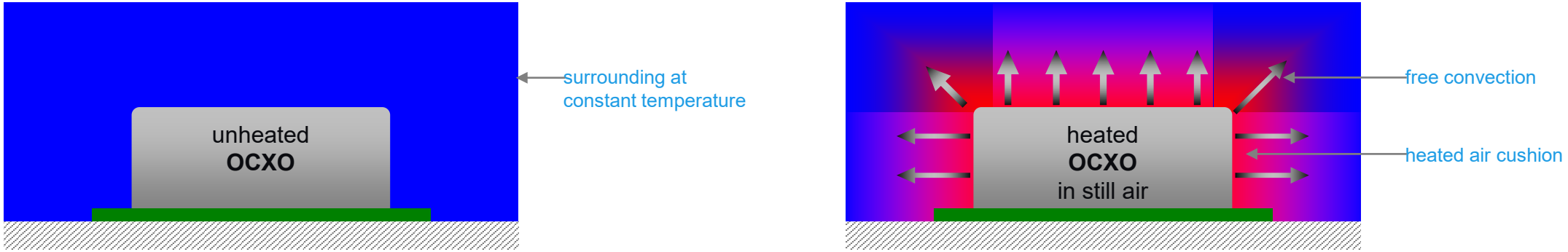
OCXO Tutorial Airflow

The impact of airflow on the surrounding of an OCXO:

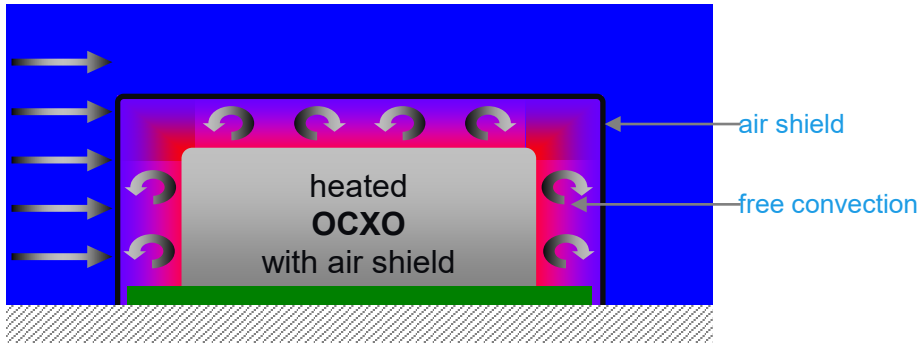


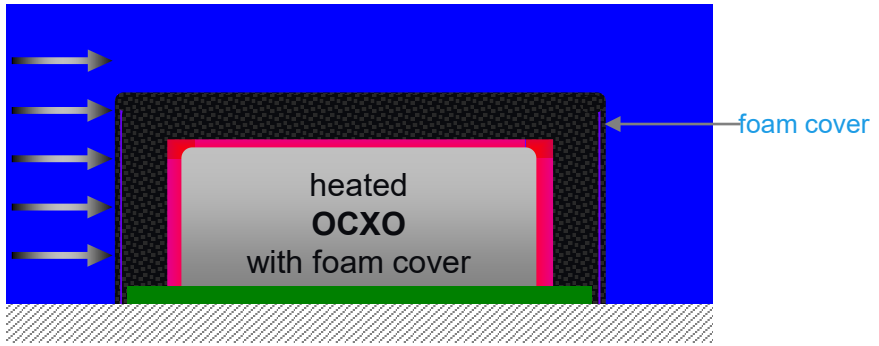
Operation in still air:

- The OCXO heats up the air around its enclosure.
- This warm air cushion acts as additional insulation towards the environment.
- Therefore the cover temperature is considerable higher than the ambient temperature.
- Heat is transferred because of free convection.
- Due to the hot surrounding the power of the OCXO is fairly low.

OCXO Tutorial Airflow -II

The impact of airflow on the surrounding of an OCXO:





Shielding the airflow:

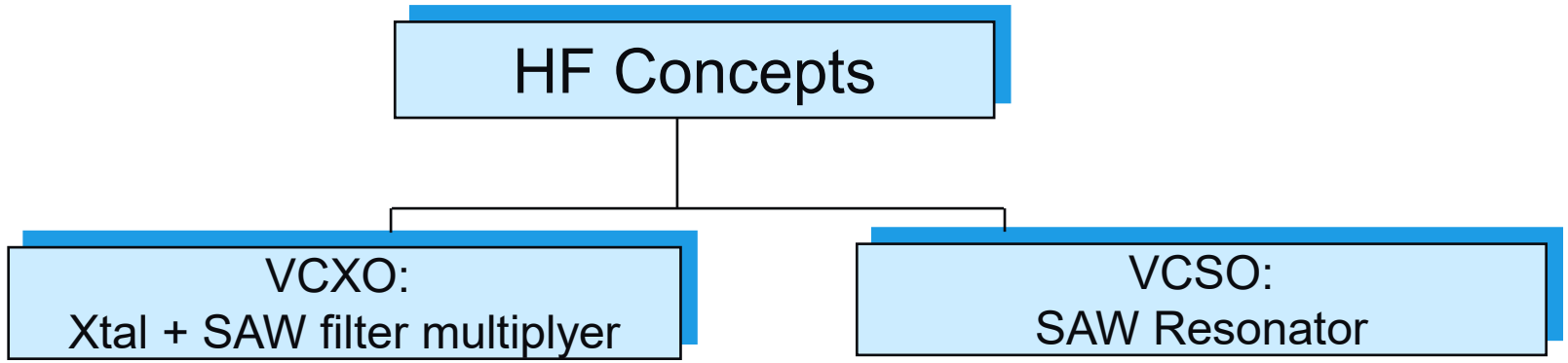
- A simple air shield (e.g. made of plastic) improves the short-term stability in turbulent environments significantly.
- Mount the shield with a gap of few millimeters to the OCXO enclosure.
- Inside the shielding the air may move slightly due to free convection.
- Use foam covers to suppress free convection.
- In general, it is preferable to have additional thermal insulation around the OCXO.

VCSO vs. VCXO

Realization of Frequencies

	f Range			*Typical concept*
VCXO	10MHz	…	50MHz	Fundamental crystal
	50MHz	…	200MHz	3rd overtone crystal
	200MHz	…	1GHz	3rd overtone crystal + SAW Filter multiplier
VCSO	400MHZ	…	1,5GHz	SAW Resonator
	1,5GHz	…	6GHz	SAW Resonator + multiplier

VCSO vs. VCXO



↑ Good temperature stability
↑ High linear pulling range
↑ Good close to carrier PN
↑ Good subharmonics suppression

↓ Higher device costs
↓ Max. output frequency ≈ 1GHz

↑ Up to 6GHz using multiplier stages
↑ Good PN & Jitter performance
↑ Single ended or balanced output
↑ High modulation BW
↑ No subharmonics up to 1,5GHz

↓ Moderate subharmonics using filter
↓ Moderate pulling range linearity

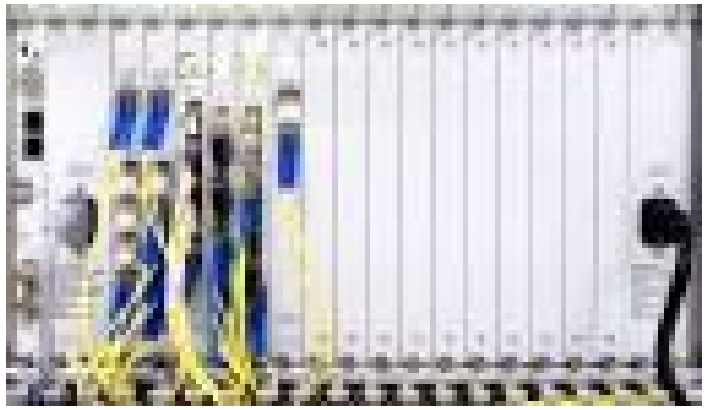
Product Training-IV

Low Phase Noise Crystal Oscillators

Markets For Low Phase Noise

Radar and EW

Test and Measurement



Optical Networks

Medical Imaging

Satcom Terminals

Data Centers

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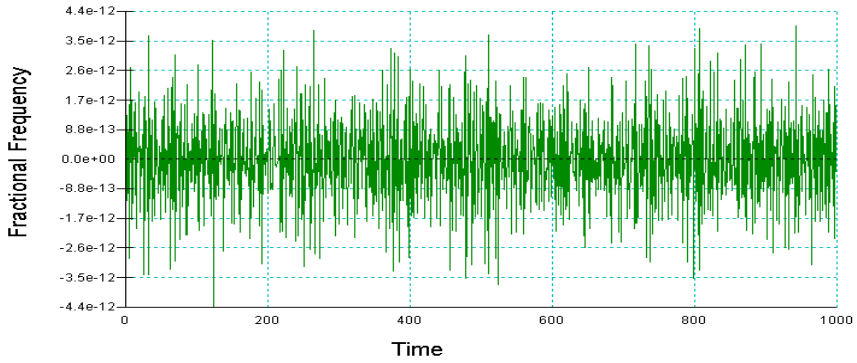
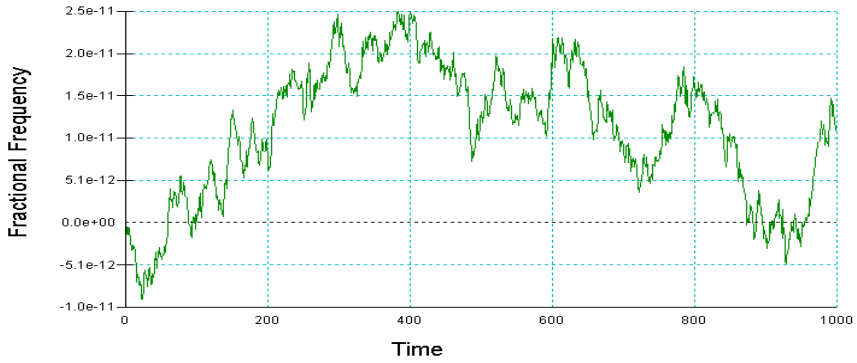
Noise

What is Noise?

- Noise is energy that may interfere with or degrade a system's effectiveness.
- The output of an ideal oscillator has a signal with a perfectly stable frequency and amplitude.
- The output of a real oscillator always deviates from the ideal as a consequence of both internal and external influences.





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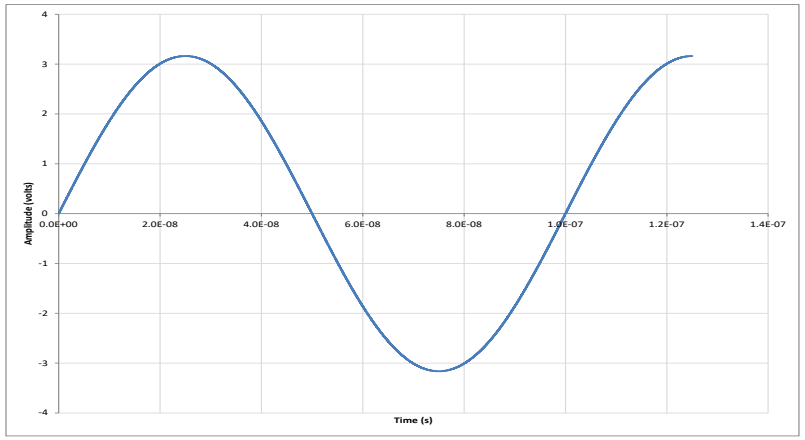
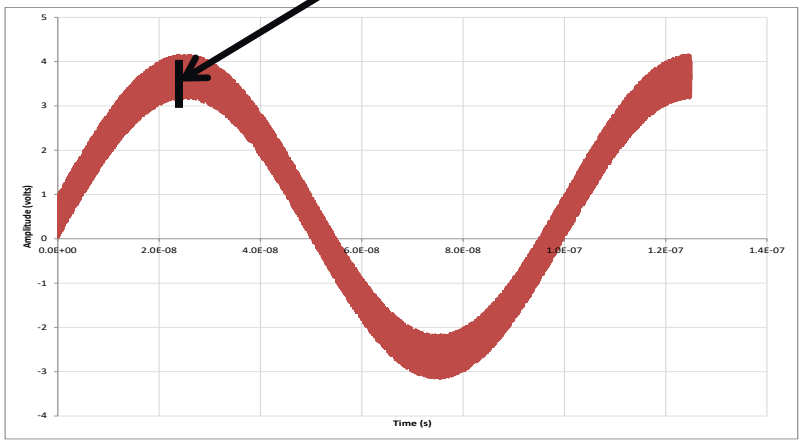
AM and PM Modulation

- **Amplitude and Phase perturbations on a periodic signal:**

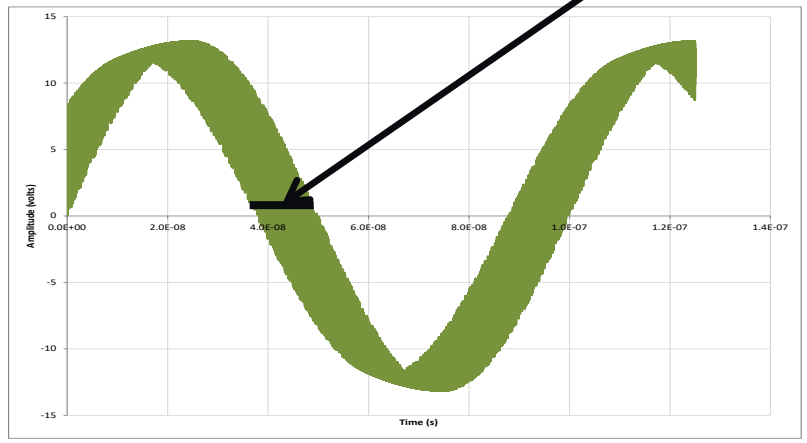
$V(t) = [V_0] \sin[2\pi f_0 t]$



$V(t) = [V_0 + \varepsilon(t)] \sin[2\pi f_0 t]$



$V(t) = [V_0] \sin[2\pi f_0 t + \phi(t)]$



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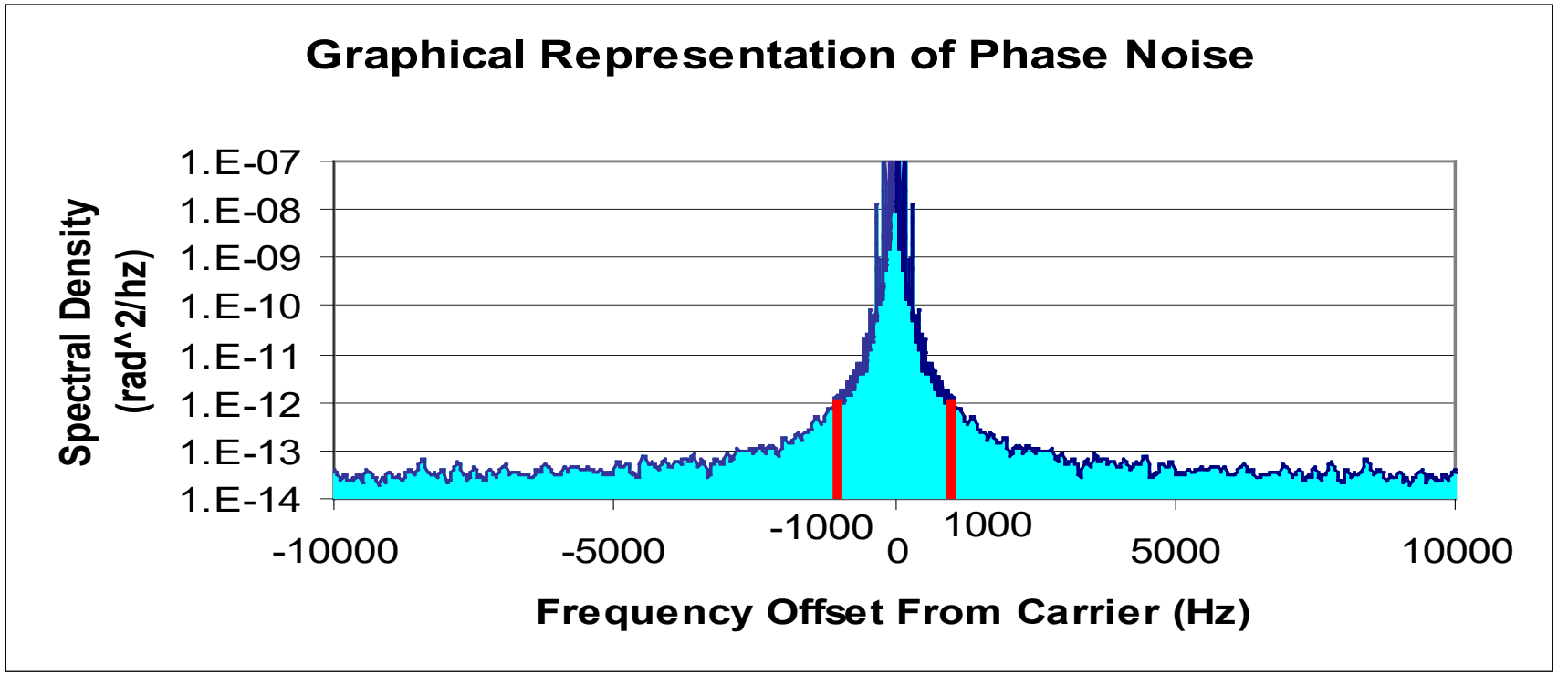
Phase Noise

- Phase noise is a comparison of the of the noise (power) with a 1Hz Bandwidth at an offset f1 away from the carrier, to the total carrier signal power.
- Ratio of red to blue area



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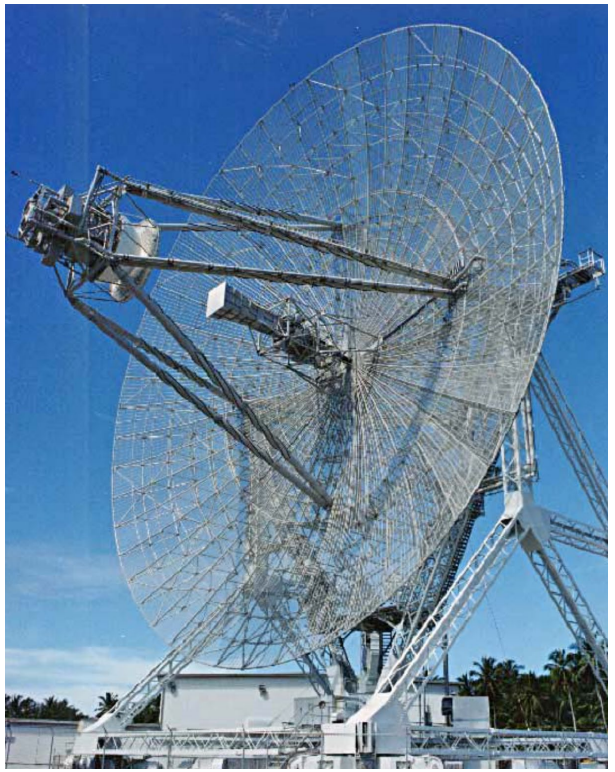
Applications

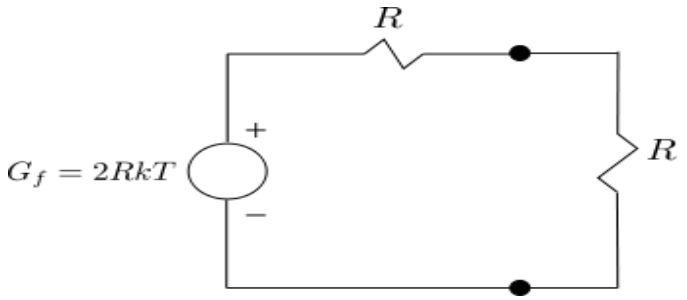
How can noise impact system performance?



- **Analog Communications:**
  - Decreases receiver sensitivity
  - PLL tracking problems
  - Decreases sensor sensitivity
- **Digital Communications:**
  - Increases bit-error rate
  - Decreases data rate
  - Excessive phase accumulation
- **Radar Systems:**
  - Increases the minimum signal level returned by target necessary for detection

Noise Sources

- **Sources of Noise**



Deterministic Sources

- Vibration
- Noisy power supply
- Line Noise
- Coupling to other frequency sources
- Bump on the table
- Nearby transmitters

Stochastic (Random)

- Thermal
- Passive devices
- Active devices
- Resonators
- Oven controllers

Product- Space Qualified

Space-Qualified oscillators

- **Microchip designs and manufactures Space VCXOs, TCXOs and OCXOs**
  - Precise time and frequency solutions for customers with the most demanding performance requirements

- **9600/9700/9800 models offer an unsurpassed combination of small size, low-power and performance, 5MHz – 125MHz**

- **9500 Series Master Oscillators provide the worlds best performance for Frequency Stability and Phase Noise, up to 100MHz**

- **Heritage Programs**
  - GPS IIF, GPS III, MUOS, SBIRS, PAN
  - COSMO IV, CLOUDSAT, Messenger, DSAC

Model 9500B – 5-600 MHz OCXO

Model 9800 – 50-200 MHz OCXO

Model 9960/9940 – 10-600 MHz TCXO/VCXO

Model 9600/9700 – 5-25 MHz OCXO

Space-CSAC

- Radiation Tolerance: 20 Krad and no SEL to 64 MeV.cm^2/mg
- Low SWaP, COTS product
- Target LEO applications

Source: NASA/JPL-Caltech

Key Specifications:

- <120 mW Power Consumption
- <17 cc in Volume
- ±5.0E-10 Tempco
- <9.0E-10 month aging rate, typical
- Operating Range: -10°C to +70°C
- 180s warm-up time
- 1PPS disciplining

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Thank You