

Capability Study of Oscillators Using GaPO₄ and Langasite Resonators

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Content

- 🚿 Scope
- \otimes GaPO₄ and Langasite (LGS) Resonators
- **✗** VCXO Applications
- **✗** OCXO Applications ■
- X Summary & Conclusions ■

Scope

- Sigma GaPO₄ and LGS are rather thoroughly characterized piezoelectric crystal materials
- ✗ Both materials are now commercially available №
- ✗ Applications in VCXO and OCXO are studied and compared to quartz crystal oscillators
- X Advantages and limitations for Frequency Control Applications are shown
- ✗ Not covered: Filter and Sensor Applications ▮

Gallium Phosphate GaPO₄



Courtesy PIEZOCRYST Graz / Austria





Langasite (LGS) La₃Ga₅SiO₁₄



Courtesy FOMOS Moscow / Russia



\times Why use these materials ?

Higher coupling factor k than quartz

	k _{max}
Quartz	7 %
Langasite	15.8 %
GaPO ₄	19 %



allows wider frequency pulling for VCXO

allows sufficient pulling for higher overtones (OCXO)

Lower frequency constant $N = f \cdot t$ than quartz

allows smaller resonators at lower frequency

Other advantages ?

🚿 Resonator data



Туре	Parameter	Value	Туре	Parameter	Value	
GaPO ₄	Frequency	10 MHz	LGS	Frequency	10.63 MHz	
Fundamental	R ₁	2.5 Ω	Fundamental $Y^{+1.5^\circ}$ - cut	R ₁	3.3 Ω	9.4 Ω
Y ^{-16°} - cut	C_1	/8 fF 4 15 nF		C_1	136 fF 8 07 pF	162 fF 9 66 pF
HC-52/U	Q	84 000	HC-52/U	Q	33 200	9800 9800
	r	53		r	59	60
GaPO ₄	Frequency	9.85 MHz	Quartz	Frequency	12 MHz 10.4 Ω 11.5 fF	
3rd overtone	R ₁	62 Ω	Fundamental AT – cut	R ₁		
	C ₁	1.06 fF		C ₁		
Y-16° - cut	C ₀	1.83 pF		C ₀	2.54 pF	
HC-52/U	Q	244 000	HC-52/U	Q	111 000	
	r	1719		r	220	

✗ Frequency vs. temperature response



✗ Frequency vs. temperature response



X Anisochronism at high drive level



3rd overtone GaPO₄ crystals show much weaker nonlinearity at higher drive level than AT 3rd, very close to SC 3rd.

This allows to drive GaPO₄ crystals harder to achieve low phase noise.

GaPO₄ and LGS VCXO



D1 = hyperabrupt varactor

VCXO schematic



VCXO Pulling characteristics

\times VCXO with GaPO₄ & with Langasite



Pulling range limited by interference with spurious resonances

A TAL Advanced Xtal Products

VCXO Pulling characteristics

≫ PR Limitation by spurious resonances



VCXO Phase Noise



Green: LGS Blue: GaPO₄ #: Quartz

GaPO₄ VCXO has better phase noise than quartz:

- similar Q, but

- higher drive level

LGS >20 dB worse:

- low resonator Q

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GaPO₄ and Quartz OCXO

🚿 OCXO in 4 pin DIL14 package 📗



requires a HC-52/U size resonator or smaller

- ➤ 10 MHz / 3rd overtone not realizable in HC-52/U with Quartz AT and SC
- ✗ GaPO₄ allows 10 MHz / 3rd due to lower frequency constant
- X LGS would also allow 10 MHz / 3rd, but resonator Q is lower

GaPO₄ and Quartz OCXO

& GaPO₄ vs. Quartz AT & SC

Туре	Parameter	Value	Туре	Parameter	Value
$GaPO_4$ 3^{rd} overtone $Y^{-16^{\circ}} \cdot cut$ $HC-52/U$	Frequency R_1 C_1 C_0 Q r	9.85 MHz 62 Ω 1.06 fF 1.83 pF 244 000 1719	Quartz 3 rd overtone SC - cut HC-43/U	Frequency R_1 C_1 C_0 Q r	10 MHz 100 Ω 0.145 fF 2.17 pF 1 120 000 15 000
Quartz Fundamental AT – cut HC-52/U	Frequency R_1 C_1 C_0 Q r	12 MHz 10.4 Ω 11.5 fF 2.54 pF 111 000 220	Quartz 3 rd overtone AT - cut HC-43/U	Frequency R_1 C_1 C_0 Q r	10 MHz 140 Ω 0.30 fF 4.15 pF 390 000 14 000

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used

OCXO Studies

✗ Measurement of Short-Term Stability

Only one GaPO₄ 9.85 MHz / 3rd was available, therefore Phase Noise test was replaced by Allan Variance measurement

✗ Measurement of warm-up characteristics

DIP OCXO Allan Variance



Short-term stability is superior for GaPO₄ OCXO

DIP OCXO Warm-up



OCXO with $GaPO_4$ resonator shows no overshoot, and is faster on frequency (after 60 sec)

Summary & Conclusions

- ✗ GaPO₄ and LGS show interesting capabilities for VCXO and OCXO applications
- ✗ VCXO in 9x14 mm size with high pulling range and low phase noise
- ✗ OCXO in DIP14 size using 3rd overtone resonators

Summary & Conclusions

≫ VCXO in 9x14 mm size

- Pulling range limited by spurious responses
 - Trade-off C_1 vs. Spurs
 - Energy trapping must be considered
- $GaPO_4$ offers better f(T) stability than LGS
- GaPO₄ shows higher Q value than LGS, close to Q-factors of quartz AT cuts
- Phase noise of GaPO₄ comparable and superior to quartz AT cut
- Low anisochronism allows higher drive level for lower phase noise

Summary & Conclusions

≫ OCXO 10 MHz in DIP14 size

- GaPO₄ Y^{-16°} cut is a good candidate for miniature OCXO with overtone resonators
- short-term stability is superior to quartz (AT fund) resonator of same size
- Warm-up time of GaPO₄ based OCXO is shorter and shows no overshoot as a quartz AT-cut
- OCXO performance of LGS not studied yet