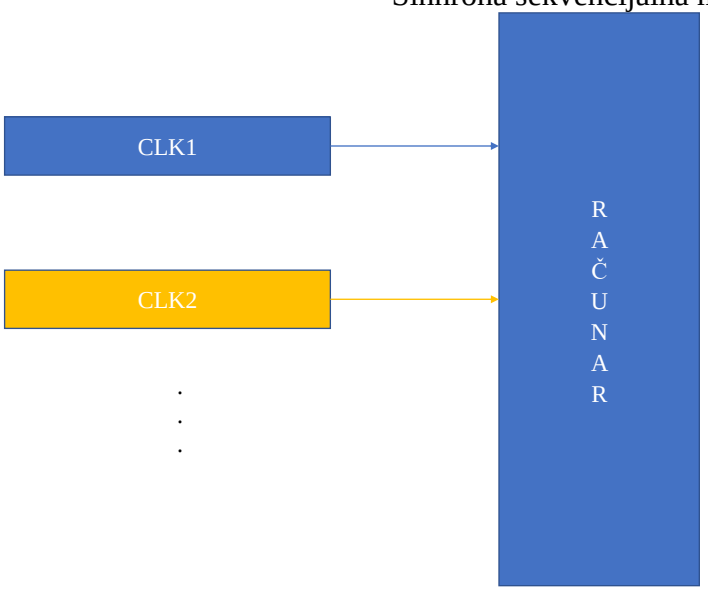
Izvori takta

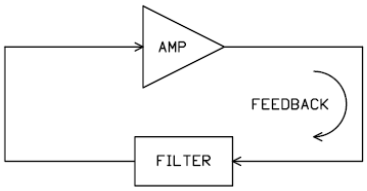
1

Sinhrona sekvencijalna mašina!



2

Po pravilu izvor taktnog signala su oscilatori

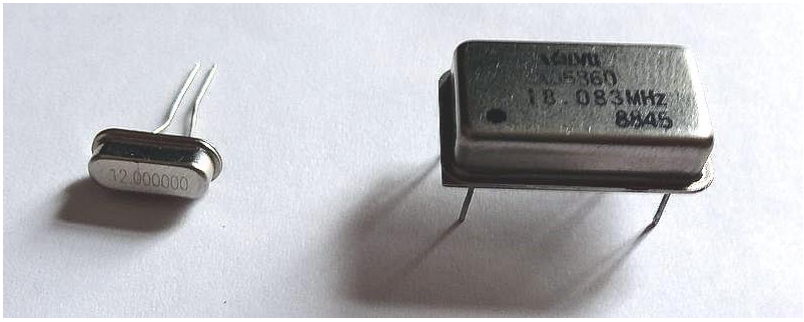


Harmonijski oscilatori
Relaksacioni oscilatori

Oscilatori sa kristalom kvarca
RC ili RL ili LC oscilatori
MEMS oscilatori
Ring oscilatori
Silicon oscilatori
…

3

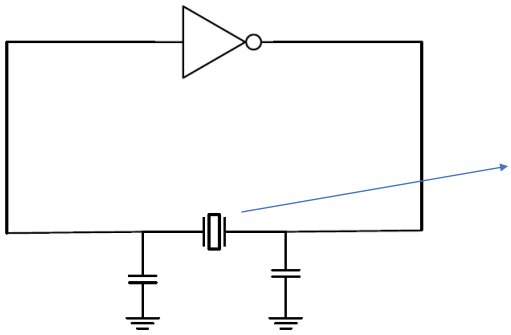
Oscilatori sa kristalom kvarca

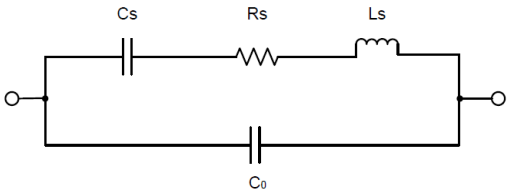


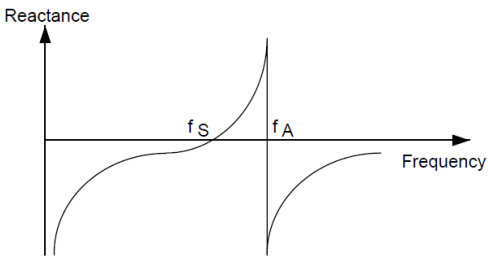
Kvarc – piezoelektrični material
Pod dejstvom električnog polja menjaju se fizičke karakteristike

4

Pirsov oscilator

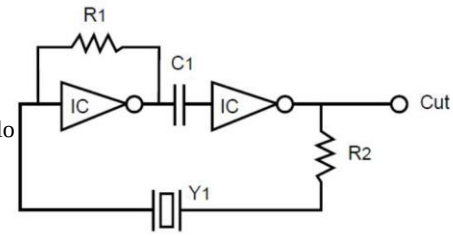


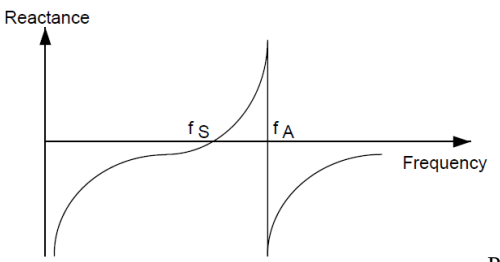




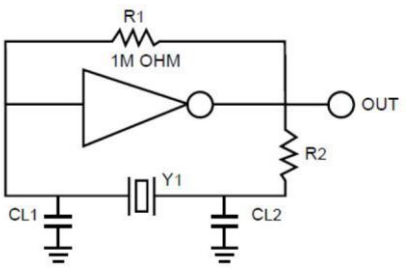
5

Serijsko rezonantno kolo



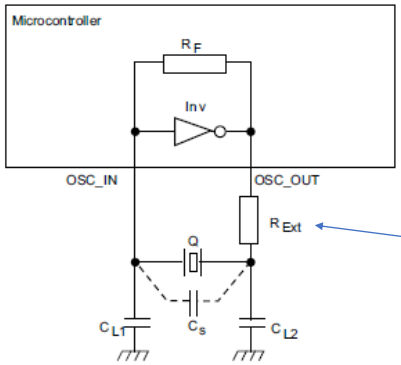


Paralelno rezonantno kolo



6

Često u praksi

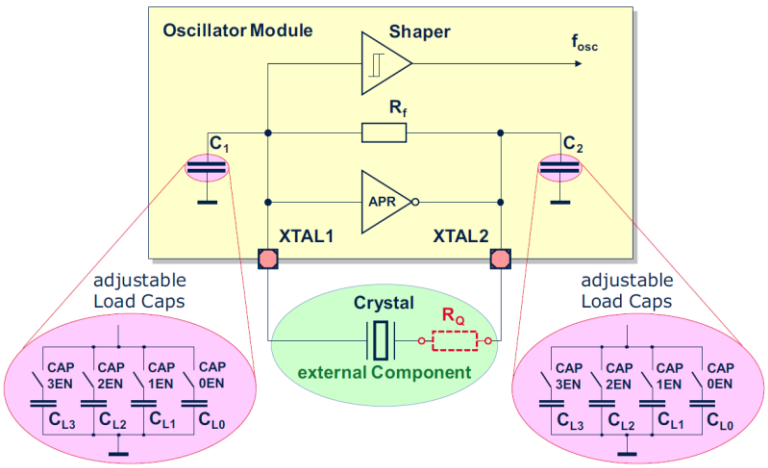


Može, ne mora, mora u zavisnosti od kristala i primene

Cs – parazitne kapacitivnosti – pinova, ulaza, pcb-a, …

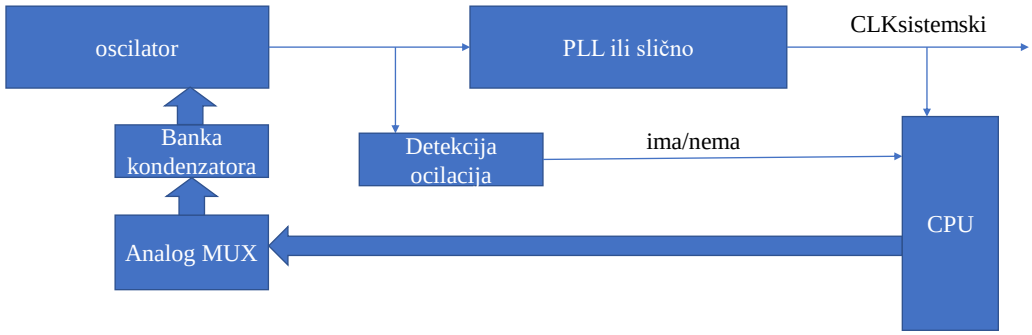
C_L – kapacitivnosti koje se dodaju da bi kolo radilo - mora

7



Oscilator radi samo ako su dobri C_L
Šta je po resetu? Koja vrednost? Kako se menja?

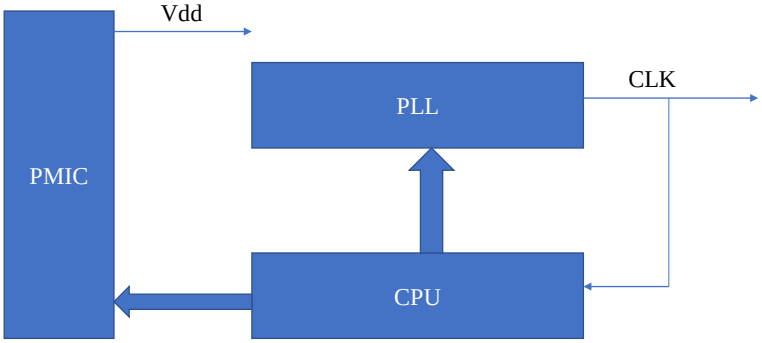
8



Nema ulaznog takta - PLL osciluje na sopstvenoj učestanosti

9

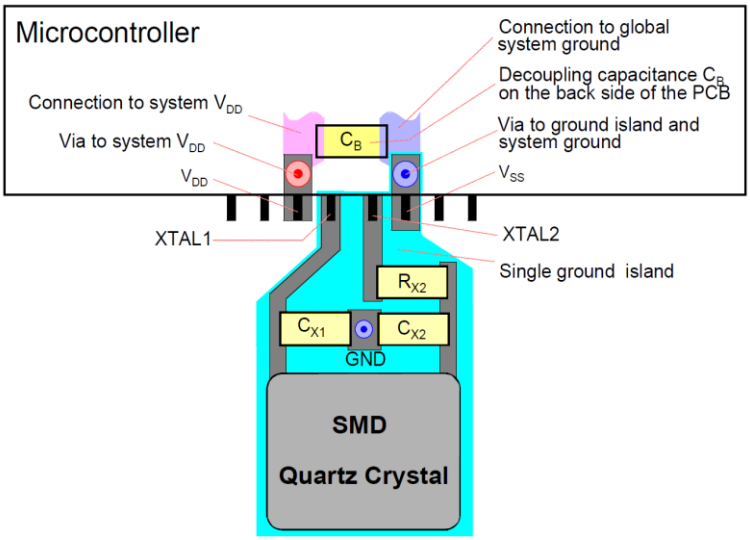
Otkud PLL?



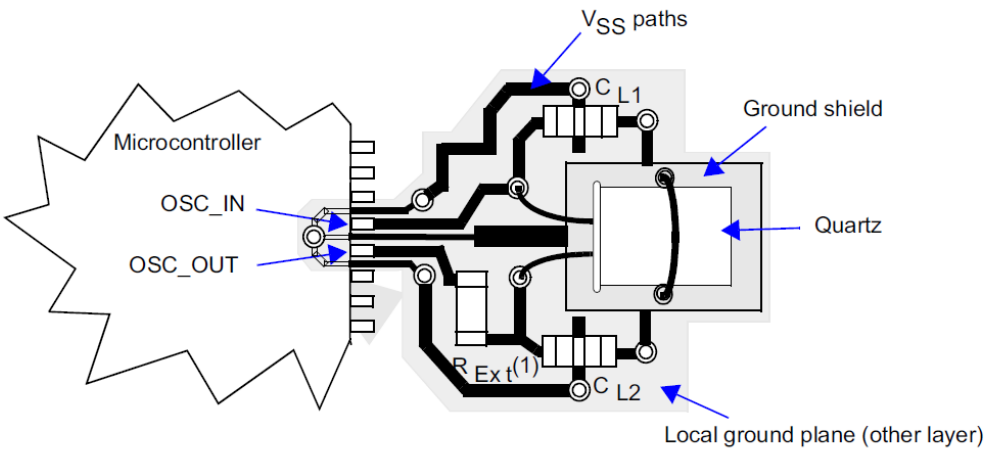
Smanji potrošnju – nema posla – smanji učestanost – smanji napon

Ima posla – povećaj napon – povećaj učestanost – povećana i potrošnja

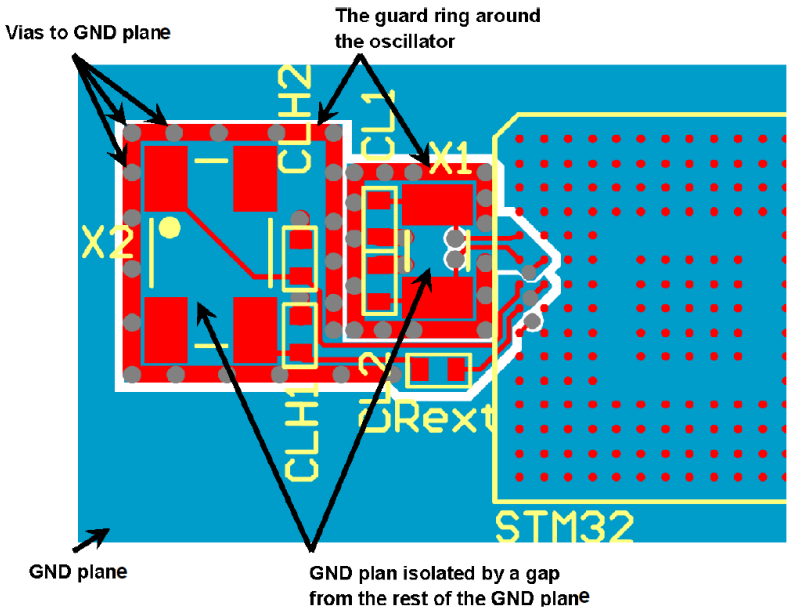
10


Microcontroller
Connection to global system ground
Decoupling capacitance C_B on the back side of the PCB
Via to ground island and system ground
Connection to system V_{DD}
Via to system V_{DD}
V_{DD}
V_{SS}
C_B
XTAL1
XTAL2
Single ground island
R_{X2}
C_{X1}
C_{X2}
GND
SMD
Quartz Crystal

11


V_{SS} paths
Microcontroller
OSC_IN
OSC_OUT
C_{L1}
Ground shield
Quartz
R_{Ext}(1)
C_{L2}
Local ground plane (other layer)

12



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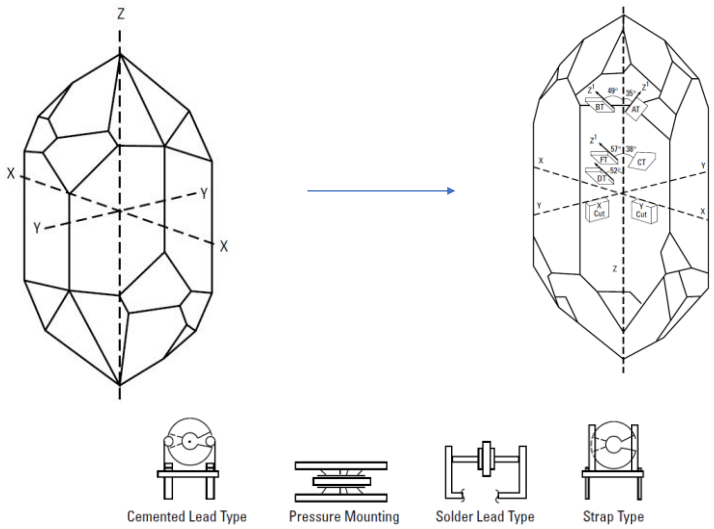
Različiti načini „sečenja“ – različite fizičke i električne karakteristiku



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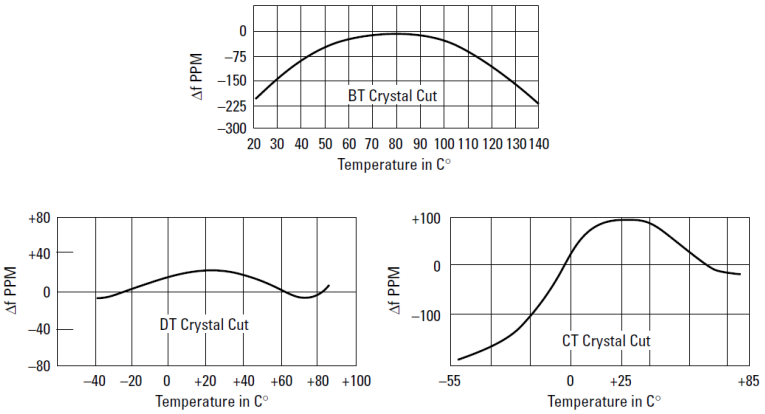
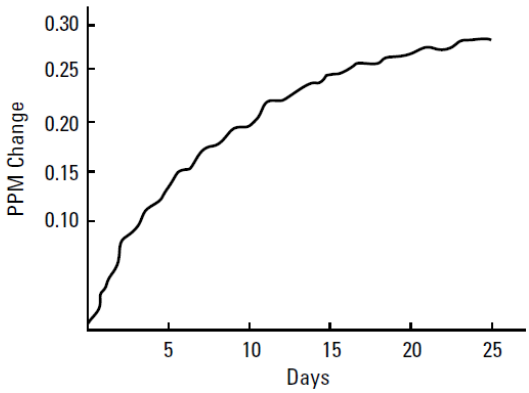
Zavisnost učestanosti od temperature



PPM – part per milion - 10^{-6}

15

Zavisnost od starenja



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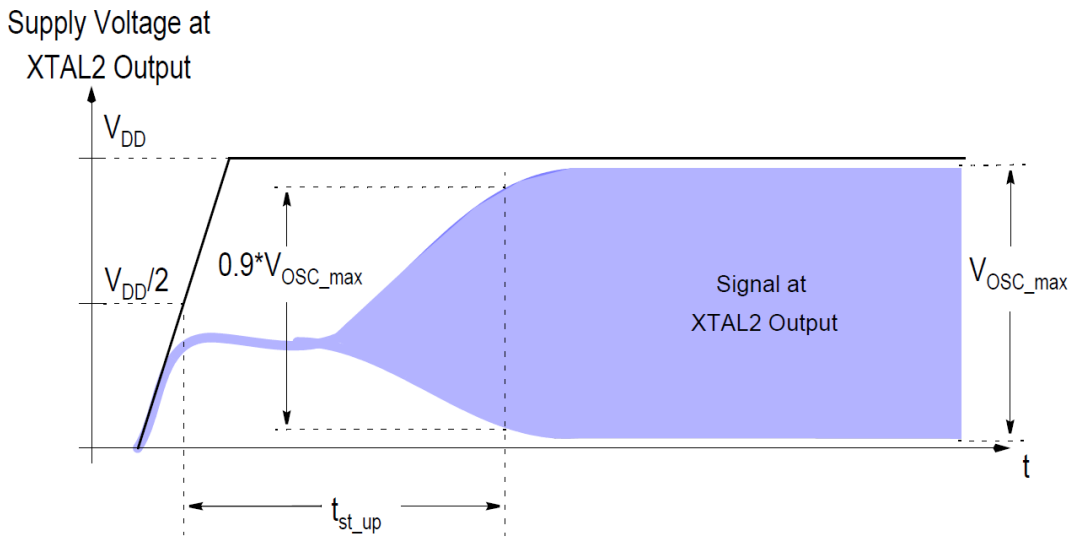
Vreme uspostavljanja oscilacija



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Dobra vremenska referenca – ali ne apsolutno tačna
Nisu baš pouzdani sa stanovišta da sigurno prorade i rade

Preporuke od strane proizvođača mikrokontrolera

Table 9. NDK compatible crystals (not exhaustive list)

Part number	Frequency	ESR max	C_L	Drive level (DL)
NX8045GE STD-CJL-6	4 MHz	150 Ω	8 pF	500 µW max
	8 MHz			
NX5032GA STD-CSU-1	8 MHz	300 Ω		500 µW max
NX8045GB STD-CSJ-1	8 MHz	220 Ω		
	16 MHz	150 Ω		
NX3225GA STD-CRA-1 NX3225GB STD-CRA-2	16 MHz	120 Ω		200 µW max
NX3225SC STD-CRS-1 NX3225SA STD-CRS-2				
NX5032GA STD-CSU-2				
NX5032SD STD-CSY-1	16 MHz	100 Ω	12 pF	100 µW max

ESR – equivalent series resistance

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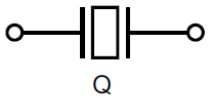
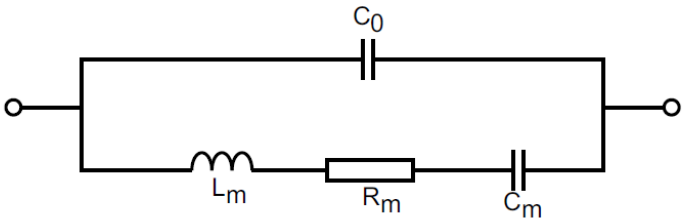


≡



$$F_s = \frac{1}{2\pi\sqrt{L_m C_m}}$$

$$F_a = F_s\sqrt{1+\frac{C_m}{C_0}}$$

$$F_p = F_s\left(1+\frac{C_m}{2(C_0+C_L)}\right)$$

PRIMER

Equivalent component	Value
R_m	8 Ω
L_m	14.7 mH
C_m	0.027 pF
C_0	5.57 pF

- F_s = 7988768 Hz
- F_a = 8008102 Hz

If the load capacitance C_L is equal to 10 pF the crystal oscillates at F_p = 7995695 Hz.

To have an oscillation frequency of exactly 8 MHz, C_L must be 4.02 pF.

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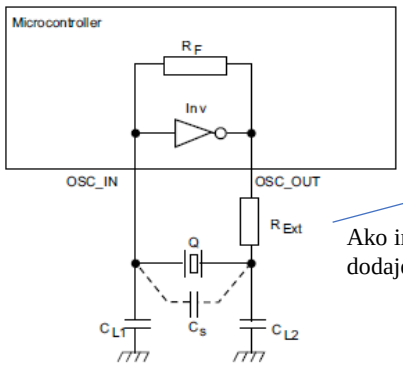

Ako ima dodaje se

$$DL = \frac{ESR \times (\pi \times F \times C_{tot})^2 \times (V_{pp})^2}{2}.$$

$$ESR = R_m \times \left(1+\frac{C_0}{C_L}\right)^2$$

$C_{tot} = C_{L1} + (C_s / 2) + C_{probe}$ where:

- C_{L1} is the external load capacitance at the amplifier input
- C_s is the stray capacitance
- C_{probe} is the probe capacitance

$V_{RMS} = \frac{V_{pp}}{2\sqrt{2}}$, where V_{pp} is the peak-to-peak voltage measured at C_{L1} level

F = crystal frequency

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Tip	Stabilnost	Aplikacije
XO — Oscillator	20 - 100 ppm	•Those requiring a general-purpose clock, such as consumer electronics and computing:microprocessors •digital state machines •video and audio clocking •low-bandwidth data communications, e.g., USB and Ethernet
VCXO — Voltage Controlled Oscillator	< 50 ppm	•Clock synchronization in:telecom •broadband •video •instrumentation
TCXO – Temperature Compensated Oscillator and VC-TCXO — Voltage Controlled TCXO	0.5 - 5 ppm	•High-performance equipment that requires very stable frequencies:networking •base stations •femtocells •smart meters •GPS systems •mobile systems
SSXO – Spread Spectrum Oscillator	20 - 100 ppm	•Microprocessor-based clocking:desktop PCs •laptops •storage systems •USB
FSXO – Frequency Select Oscillator	20 - 100 ppm	Those requiring frequency agility and multi-protocol serial interfaces.
DCXO – Digitally Controlled Oscillator	0.5 - 100 ppm	•Clock synchronization intelecom •broadband •video •instrumentation

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Watch kristal

f = 32768 Hz

$32768=2^{15}$

$32768:2^{15}=1s$

OPERATING CONDITIONS / ELECTRICAL CHARACTERISTICS

PARAMETERS	CONDITIONS	ECS-.327-CDX-2217			UNITS
		MIN	TYP	MAX	
Frequency			32.768		KHz
Frequency Tolerance	@ +25°C			± 20	ppm
Load Capacitance			12.5		pF
Drive Level	DL		0.1	0.5	µW
Equivalent Series Resistance	R1			80K	Ω
Turnover Temperature		+20	+25	+30	°C
Temperature Coefficient		-0.028	-0.034	-0.040	ppm/°C²
Shunt Capacitance	Co		1.3		pF
Aging (First Year)	@ +25°C ±3°C			±3	ppm
Operating Temperature	Topr	-40		+85	°C
Storage Temperature	Tstg	-55		+125	°C
Insulation Resistance	@ 100V DC	500M			Ω

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Tačno vreme - časovnici

20ppm od godinu dana
$20 \times 10^{-6} \times 365 \times 24 \times 60 \times 60 = 630.72$s približno 10 minuta ili minut po mesecu

1. Kupiti kvalitetne kristale

2. Kupiti „lošije“ kristale
   očekivati da oscilator radi na istoj temperaturi
   u projektu podesiti komponente tako da na toj temperaturi bude „tačan“ – 36.5 stepeni

3. Raditi proces kalibracije, baždaranje
   za svaki primerak
   za uzorak

Šta je najbolje?

Kalibracija košta - oprema + rad

Komponente iz iste serije (ista proizvodna traka, smena, radnik, …) imaju približno iste karakteristike

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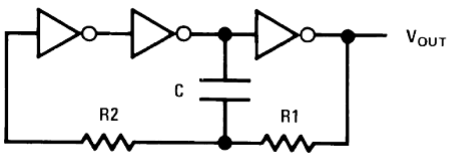
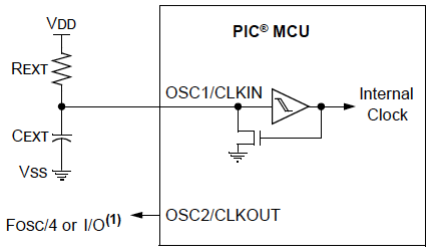
RC oscilatori





ΔRC u %
% = 10^{-2} = ppm x 10^4

For REXT values below 2.2 kΩ, oscillator operation may become unstable, or stop completely. For very high REXT values (e.g. 1 MΩ), the oscillator becomes sensitive to noise, humidity and leakage. Thus, it's recommended to keep REXT between 3 kΩ and 100 kΩ.

Pouzdano startuju!
I brzo!
Vremenska referenca – „katastrofa“

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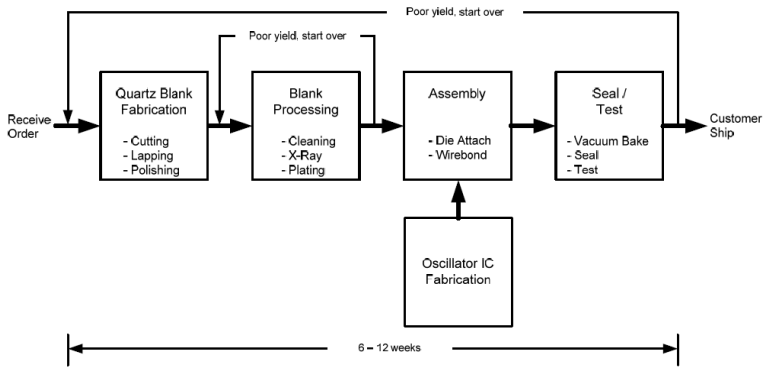
MEMS – micro-electromechanical systems

Oscilatori sa kristalom kvarca



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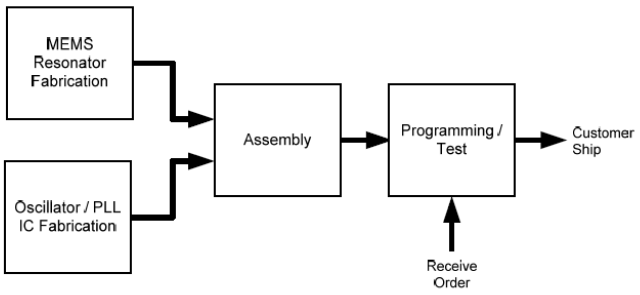
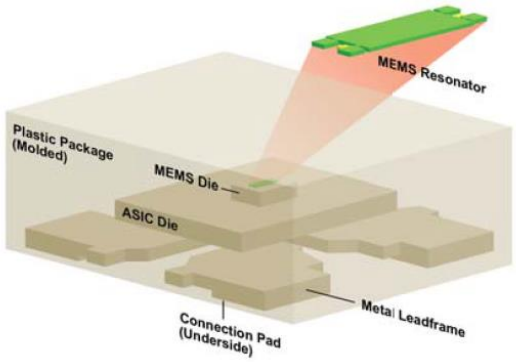
MEMS oscilatori





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	Traditional Crystal Oscillator	Microchip MEMS-Based Oscillator	Features
Frequency Stability Over Temperature	◐	●	■ MEMS offers ±10 ppm over wide temperature range ■ Microchip quartz achieves superior aging
Size	◔	●	■ MEMS offers ultra-small footprints (1.6 × 1.2 mm) ■ Leads industry trend in size reduction
Reliability	◐	●	■ MEMS wafer-stage ultra-clean hermetic seal ■ Microchip quartz separates crystal and ASIC enclosures
Jitter Close-In Phase Noise	◔	◐	■ Microchip quartz is superior with reduced close-in phase noise ■ MEMS and quartz comparable at high-frequency offsets
Features	○	●	■ Selectable frequencies from one output ■ OTP programmable at any frequency, anytime
Start-Up	◐	●	■ MEMS achieves fast start-up time (<2 ms) ■ Eliminate start-up issue of crystal-based designs
Integration	○	●	■ Multiple outputs from a single device ■ Utilizes highly integrated ASIC

● Best ○ Worst

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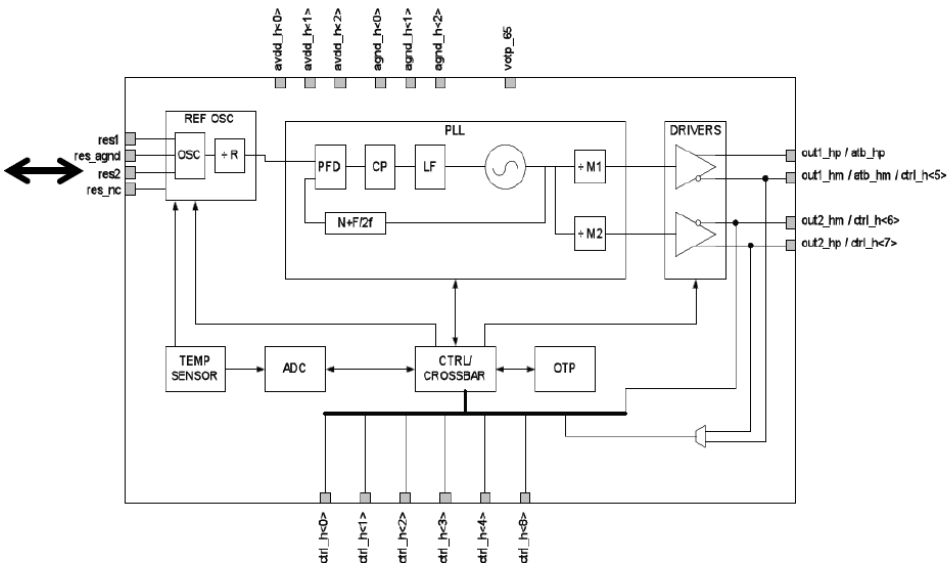

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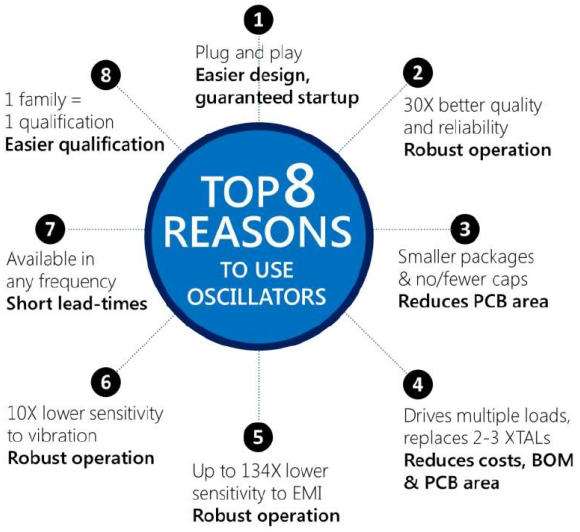

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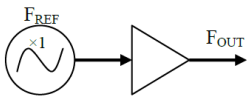
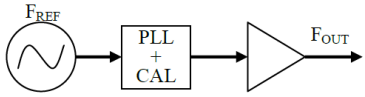
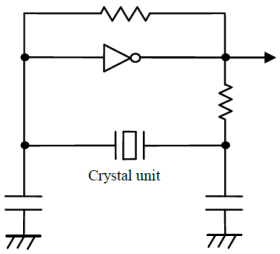
1) Crystal Oscillator(Fundamental)



2) Si-MEMS Oscillator



1) Crystal Oscillator basic structure



2) Si-MEMS Oscillator basic structure

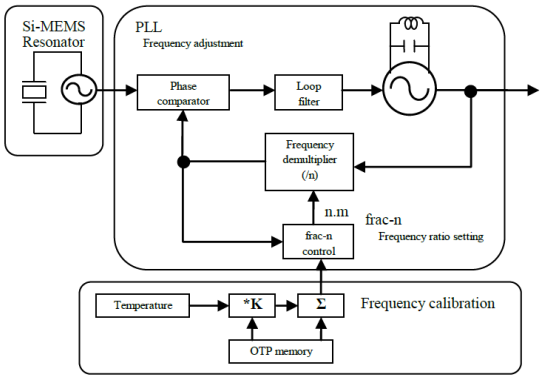


Fig.1 Oscillator basic structure

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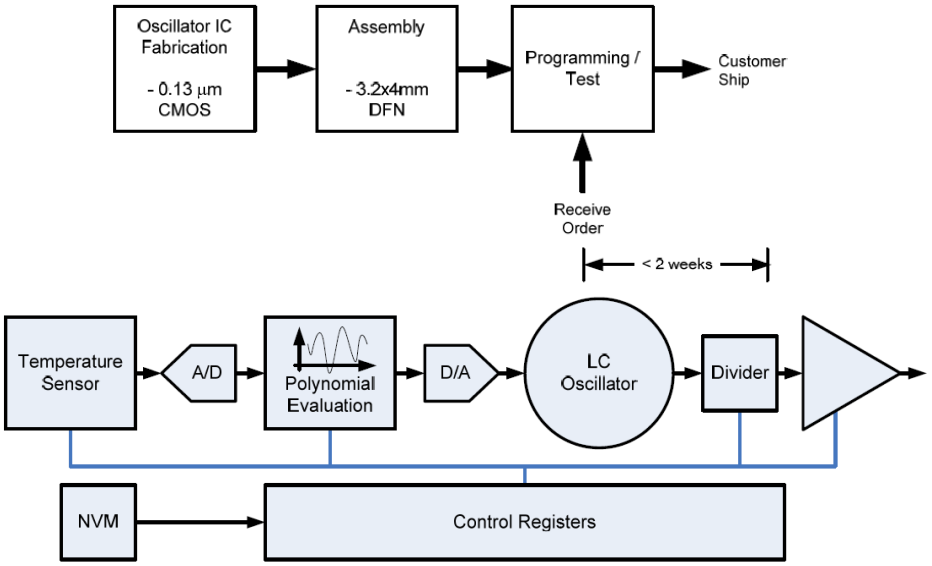
Silikon oscilatori



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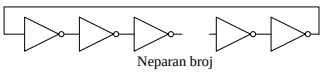
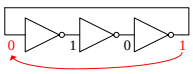
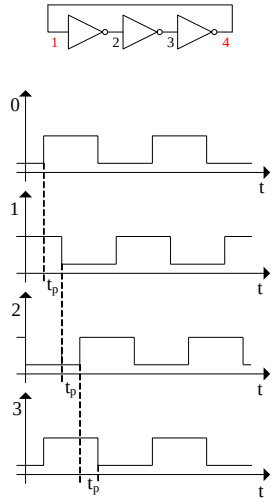
Ring oscilatori





$T=nt_p$



$T/2=3t_p$

$T=6t_p$

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Često – Više od jednog izvora takta

Po pravilu