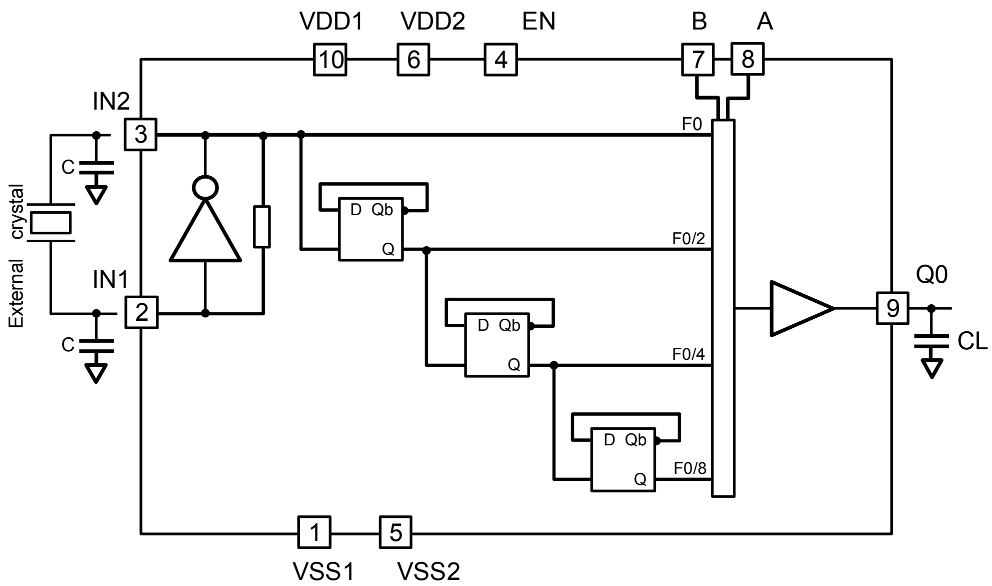
Rad-hard, crystal oscillator driver and divider

Introduction

This application note presents the computing method of the external overtone crystal oscillator parameters used in a typical application of the RHFOSC04.

Figure 1. **RHFOSC04 schematic**



1 Third overtone crystal oscillator

1.1 Presentation

The RHFOSC04 crystal oscillator is a third overtone type. The design is a "Pierce" structure, with additional inductor on the output side, for correct startup at 60 MHz.

In order to complete the start-up condition, feedback components must provide a -180° phase shift to the RHFOSC04 inverter action:

- 1st RC cell: output R of inverter / total output capacitance
- 2nd RC cell: serial R of crystal / total input capacitance

When the oscillator is running, current is exchanged between the crystal and its load capacitors, with always inverted phase voltages across them.

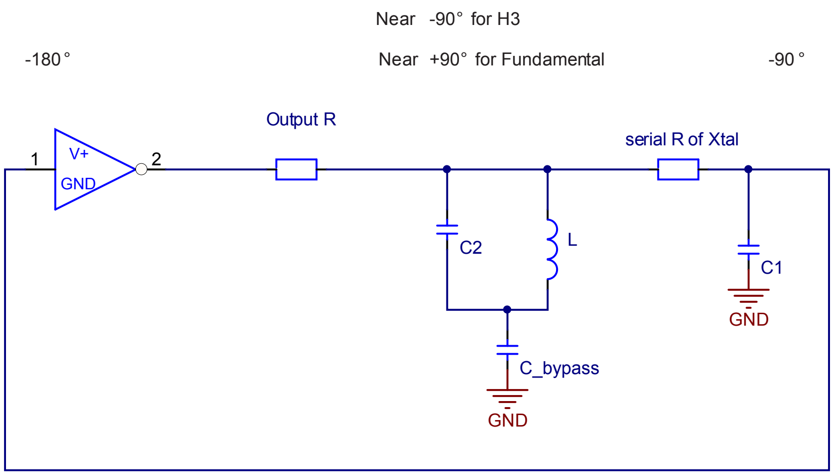
When a serial resonant crystal is used in this oscillator, the resulting frequency is always greater than target frequency, and a too high capacitor value should be necessary to converge.

For this range of frequencies (50 to 90 MHz), a third overtone crystal specified with a parallel 10 pF load is suggested. Then, the basis capacitor values of the "Pierce" design are 20 pF each; if crystal is specified with a higher CL, resulting capacitors can become too high for the oscillator to start up.

If an overtone crystal is used in a classic "Pierce" structure without any inductor, resulting frequency is the fundamental. If an inductive reactance is forced lower than the capacitance one for the fundamental (Fig.2), it cancels the start-up condition of the oscillator (+90° instead of -90° into a feedback cell).

Regarding the third harmonic frequency of the crystal, using properties of the LC cell, inductor impedance is lower than capacitance one. Then, resulting reactance is forced by the capacitance, and the goal is reached. See figure below.

Figure 2. Crystal equivalent schematic



1.2 Computing the application schematic values

The crystal is supposed to be specified as 60 MHz, third overtone, CL = 10 pF. Input capacitance of the oscillator is 20 pF, composed of:

- parasitic value Cp from the chip and from the board layout, supposed to be around 10 pF
- capacitor C1 (10 pF)

On the output side, it is necessary to take care of the inductor to compute the value of C2 (balanced currents are expected). LC cell is supposed to have a resonant frequency near 2/3 of H3 (target frequency), we consider H2 (H2=H3*2/3).

If we assume that the current is normalized to 1 for this H2 frequency, we have:

At H_2: $I_{C2,H2}$ = 1; $I_{L,H2}$= -1 (I_L is negative because in opposite phase to I_{C2})

At H_3: $I_{C2,H3}$ = 1.5; $I_{L,H3}$= -1 /1.5

At H3: $I_{C1,H3}$ = $I_{C2,H3}$+ $I_{L,H3}$= 1.5-1/1.5

Using relationship at H2, we obtain:

$$I_{C1,H2} = \frac{I_{C1,H3}}{1.5} = \frac{1.5 - 1/1.5}{1.5} \approx 0.555 \tag{1}$$

The relationship between C2 and C1 is:

$$C_2 + C_p = \left(C_1 + C_p\right)/0.55 \tag{2}$$

The voltages on C1 and C2 terminals have the same amplitude (C_b negligible.) and are in opposite phase:

$$\begin{cases} I_{C1,H2} \approx 0.555 \\ I_{C2,H2} = 1 \end{cases} \Rightarrow \frac{C_1}{0.555} \approx C_2 \tag{3}$$

Using the same parasitic capacitor C_p at each end, the relation becomes as follows:

$$\frac{C_1 + C_P}{0.555} = C_2 + C_P \tag{4}$$

$$C_2 = \frac{C_1 + C_P}{0.555} - C_P = 26pF \tag{5}$$

the closest standard value is: C_2 = 27 pF

At H_2:

$$Z(C_2) = Z(L) \ \Rightarrow \ \frac{1}{2\pi f\left(C_2 + C_P\right)} = 2\pi f L \tag{6}$$

$$L = \frac{1}{4\pi^2 f^2\left(C_2 + C_P\right)} \approx 0.43\mu H \tag{7}$$

The closest standard value is 0.47 µH.

The table below summarizes component values:

Table 1. Typical values (inputs)

Inputs		
_Fh3	60 MHz	H3 = F quartz
_Fh2	40 MHz	H2 = (2/3) *H3
_Fh1	20 MHz	H1= (1/3)*H3
_Cl	10 pF	C load
_Cp	10 pF	C parasite

Table 2. Typical values (results)

Results	
_C1	10 pF
_C2	27 pF
_L	0.47 uH

Table 3. Impedance

	@H1	@H2	@H3
Z(C2+Cp)	215 Ω	108 Ω	72 Ω
Z(L)	59 Ω	118 Ω	177 Ω

The tables above give component values for an oscillator using a third overtone crystal, specified with a capacitance load of 10 pF; bypass capacitor value is not critical (10 nF to 100 nF).

The final frequency depends on the evaluation of parasitic capacitors. An accuracy of +/-10 ppm is possible.

H2 frequency is chosen in order to simplify computing. Resonant frequency is not critical.

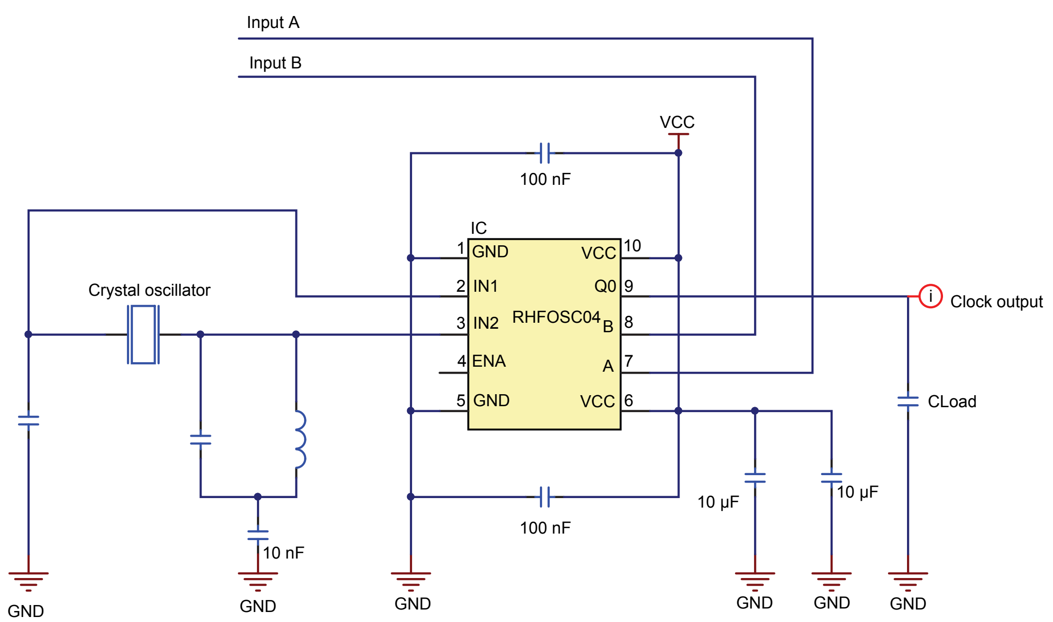
A value too close to H3 frequency is not recommended, because of the too high impedance reached, which can open the feedback network of the oscillator.

1.3 Specifications for component values of the RHFOSC04 oscillator

Crystal oscillator: H3, parallel resonant mode, with 10 pF load:

- Rs < 50 Ohms, +/-50ppm (freq. and T °)
- LC: near H2 resonant
- L, C1, C2: +/-10% tolerance
- L: DC resistance < 0.3 Ohms

Figure 3. Parameters in a typical validation schematic



1.4 Start-up time

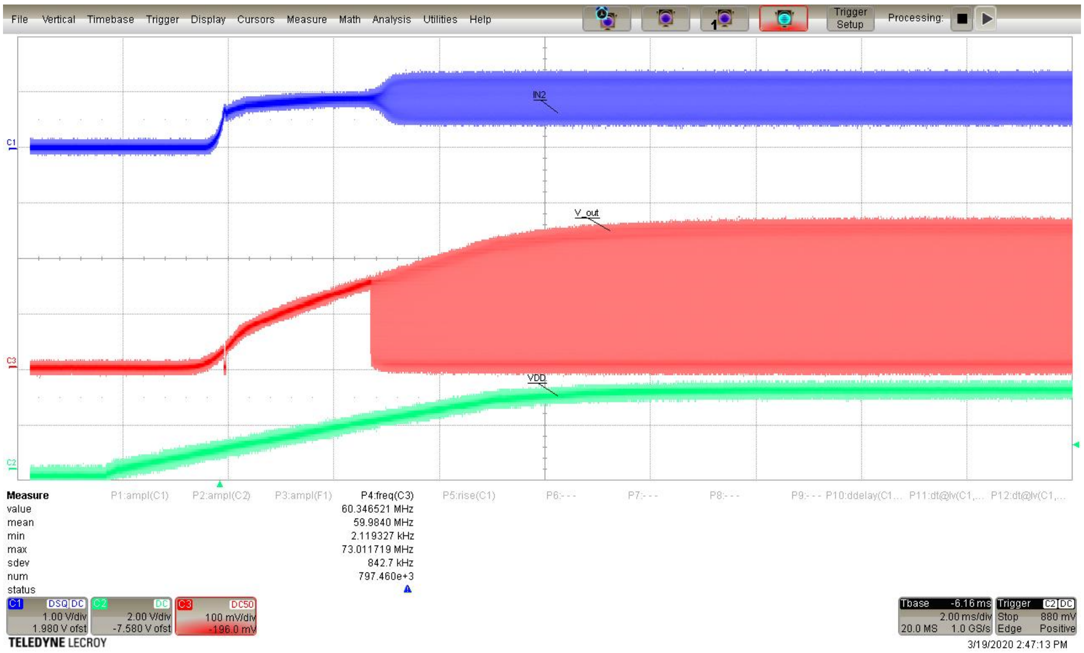


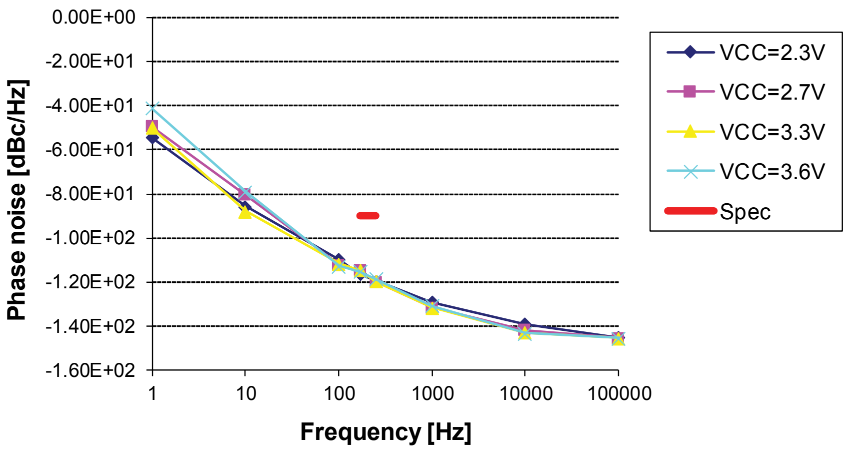
Figure 4. Start-up time

Typical value of start-up time under those conditions is about 8 ms.

1.5 Dynamic tests

1.5.1 Phase noise

Figure 5. Phase noise for 60 Mhz at different V_{CC}



1.5.2 RMS jitter

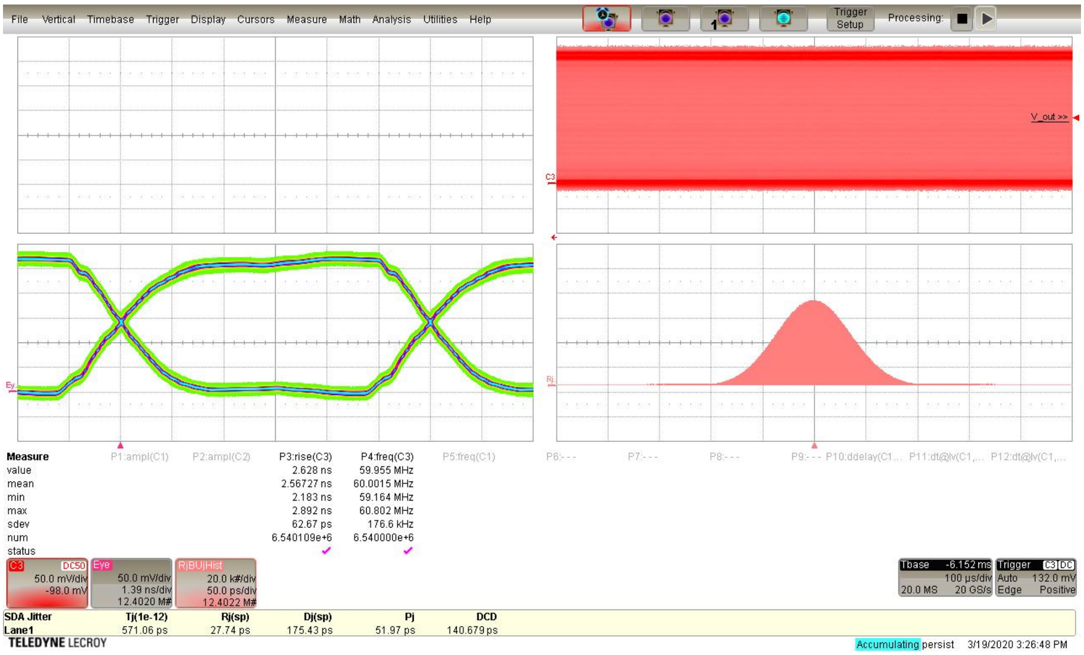
RMS jitter 1 MHz band

Table 4. RMS jitter measured for 3 samples at V_{CC} = 3.3 V

Frequency	Conditions	Part	25 °C	Units
60 MHz	VCC=3V3	P60	5.5 E-12	s
		P61	6.7 E-12	
		P62	5.2 E-12	

1.5.3 Eye diagram

Figure 6. Clock output eye diagram



Revision history

Table 5. Document revision history

Date	Version	Changes
07-May-2020	1	Initial release.
26-May-2020	2	Updated the title. Changed the root part number RH-OSC04 to RHFOSC04.

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