Application Note Crystal for Blue Tooth Audio IC

AN-PSE-18GQ-0127 **Ver. 1.0**

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Crystal for Blue Tooth Audio IC

1. Crystal frequency and frequency tuning

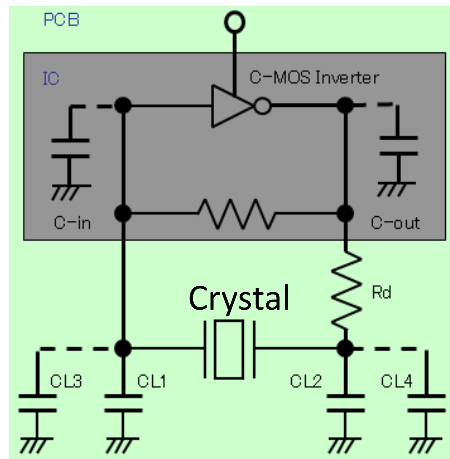
1.1. Crystal Load capacitance (Cs) and frequency

Crystal's oscillation frequency on PCB is mainly determined by crystal unit with IC oscillator, and it is influenced by external load capacitance and PCB stray capacitance. Oscillation frequency (Fosc) is given by below formula.

$$Fosc = Fr\sqrt{1 + \frac{C1}{Co + CL}}$$

Fr: Resonant Frequency of Crystal
C1: Series Capacitance of Crystal
Co: Parallel Capacitance of Crystal

$$C_L = \frac{(C_{L1} + C_{L3} + Cin)\cdot(C_{L2} + C_{L4} + Cout)}{(C_{L1} + C_{L3} + Cin) + (C_{L2} + C_{L4} + Cout)}$$



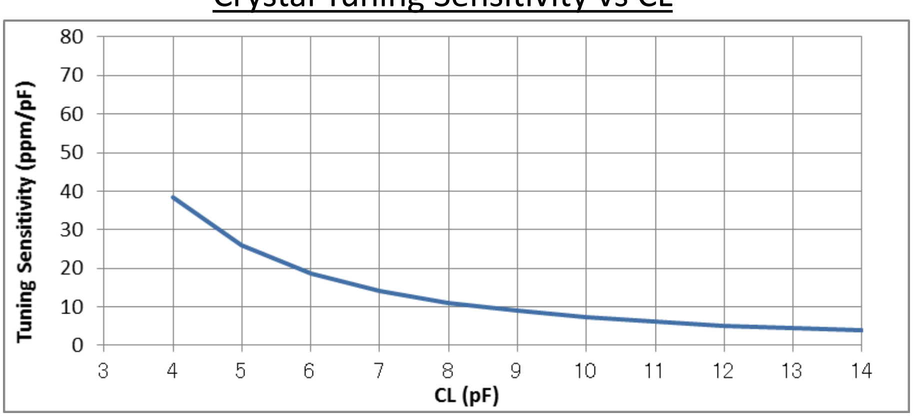
Crystal unit load frequency (FL) is specified as below formula.

$$FL = Fr\sqrt{1 + \frac{C1}{Co + Cs}}$$

When Cs and CL value is same, Crystal load frequency (FL) equals to oscillation frequency (Fosc) on PCB.

Another note is that CL value influence to Crystal's tuning sensitivity.

Crystal Tuning Sensitivity vs CL



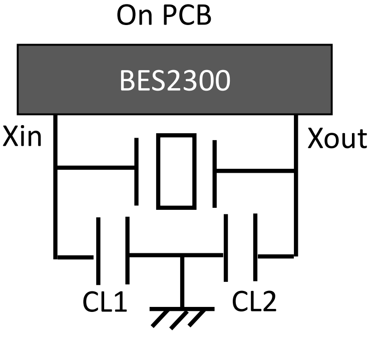
1. Crystal frequency and frequency tuning

1.2. IC Register vs Crystal frequency

BES 2000 and 2300 series integrate crystal frequency tuning circuit. Crystal frequency changes as IC internal capacitance changes. Internal capacitance are defined by 0 to 255 registers. It is recommended to confirm that crystal's initial frequency tolerance and temp shift are surely tuned by cap register range, to meet your final required tolerance.

Here is example of measurement results for BES2300 and Murata 26MHz crystal's oscillation frequency change (ppm) vs cap register.

Cap Register		Crystal Cs=6pF (CL1=CL2=5.6pF)	Crystal Cs=5pF (CL1=CL2=4.7pF)
		ppm	ppm
0	0000	42.55	33.69
20	0014	35.73	25.79
65	0041	25.68	14.87
128	0080	**13.58**	**1.72**
192	00C0	3.58	-8.93
235	00EB	-2.38	-15.27
256	00FF	-5.10	-18.17

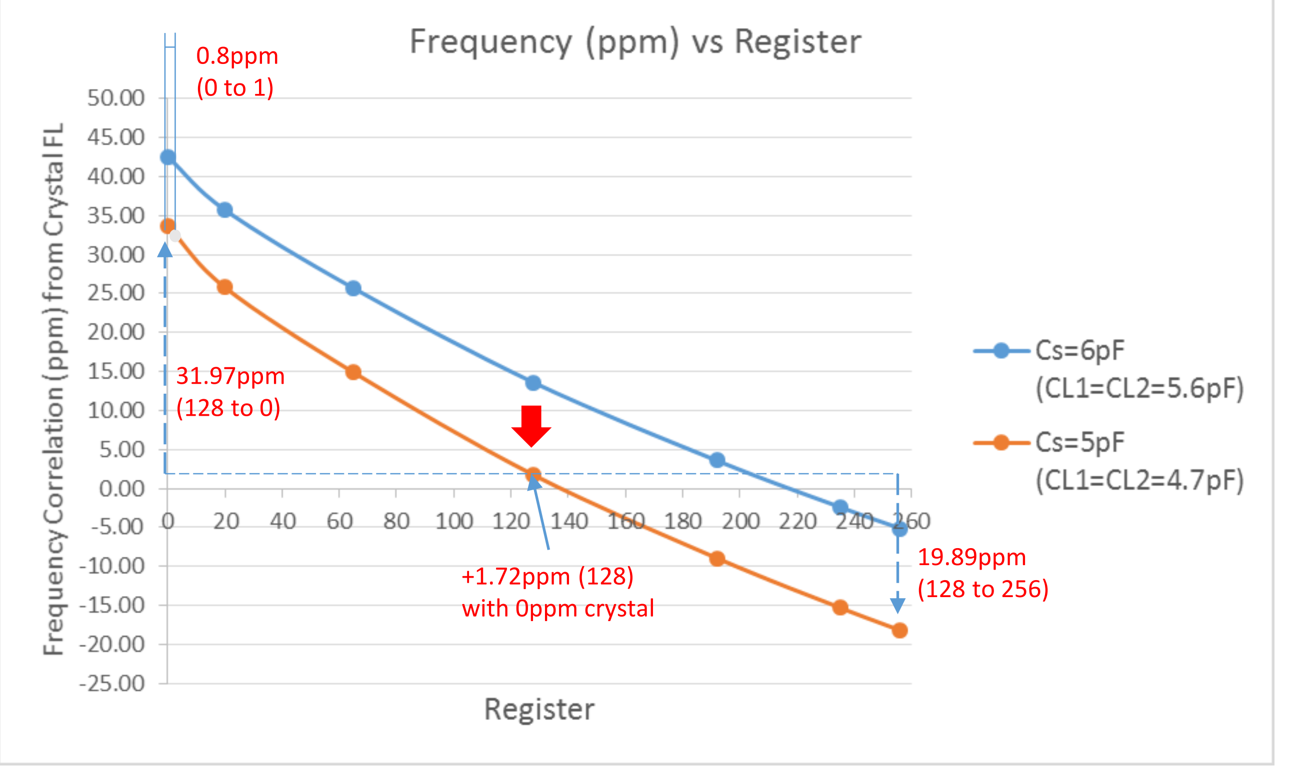


In this example, total circuit CL value of PCB with #128 register was calculated as CL=5.1pF when CL1=CL2=5.6pF. If Cs=6pF Crystal is used, frequency correlation between Fosc and FL(26MHz) is +13.58ppm at #128 cap register. It is necessary to increase CL1 and CL2 value (=increase CL to 6pF) to reduce crystal frequency. However, larger CL makes crystal tuning sensitivity lower. Wide enough frequency tuning range may not be obtained when cap register change.

Rather than increasing CL (external CL1 and CL2), changing Crystal Cs value is more safe method. Using Cs=5pF crystal, frequency difference of Fosc and FL is minimized because of CL and Cs is almost same.

As for CL1 and CL2 selection, CL1=CL2=4.7pF with PCB equals to CL=4.9pF and can be a slightly wider tuning range, comparing to CL=5.1pF. Frequency correlation at #128 is also minimized.

Crystal oscillation frequency change (ppm) vs IC internal cap register
BES2300 with 26MHz crystal



When the register changes from #128 to #0 and from #127 to #255, it is achievable to increase frequency by 31.97ppm and to decrease frequency by 19.89ppm. Although Crystal's initial FL tolerance worst case are 26MHz +/-10ppm, tuning range is wide enough to tune the oscillation frequencies on PCB. Also, there are wide margin to tune crystal's temperature shift, which is +/-10ppm specification as well.

Example of requirements;
Initial RF tolerance = within 2.441GHz +/-5kHz (=+/-2ppm)
RF tolerance including temp = within 2.441GHz +/-10KHz (=+/-4ppm)

Note) Please ask Murata for detail check on your PCB characterization.

2. Crystal oscillation characteristics

2.1. Summary – Oscillation Margin, Drive Level

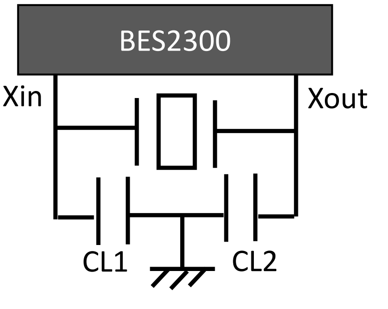
As different CL1=CL2 (CL) value make different circuit conditions, crystal characteristics also change, in such as oscillation margin, drive level and so on. It is necessary to check these characteristics, even at the worst case by register change.

Measured oscillation characteristics

Parameter	Measured results
Oscillation margin	12.1 [times]
Drive level	21 [uW]
Actual load capacitance	4.9 [pF]
Nominal frequency shift (from 26MHz)	2 [ppm]
Start up time of crystal	0.35 [ms]

Oscillation characteristics by each Register

Register	Oscillation Margin (times)	Drive Level (uW)
00(00)	-	-
128(80)	12.1	21.0
256(ff)	9.3	23.0



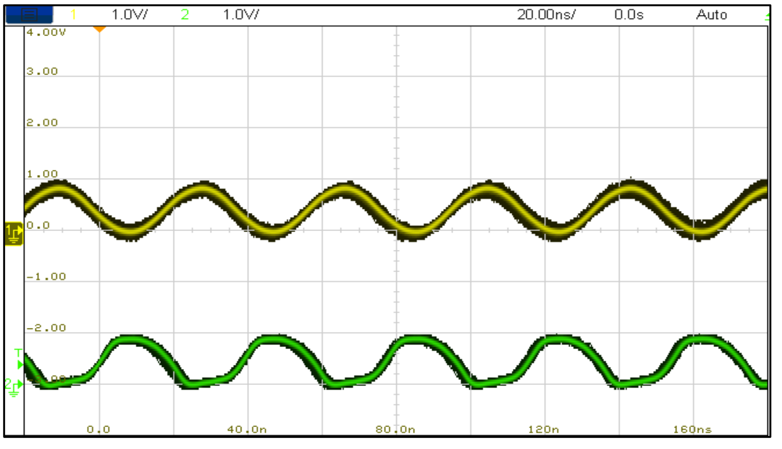
CL1=CL2=4.7pF
Crystal Cs=5pF

・Oscillation margin was high enough even at 256 register.
・Drive Level was low enough even at 256 register.
⇒ Crystal stably oscillates with all register range.

All of above results have been measured on evaluation board of BES2300 from BESTECHNIC, with optimized circuit conditions for XRCGB26M000F1H89R0. Refer DFR-18-1353, issued by Murata, for more detail.

2. Crystal oscillation characteristics

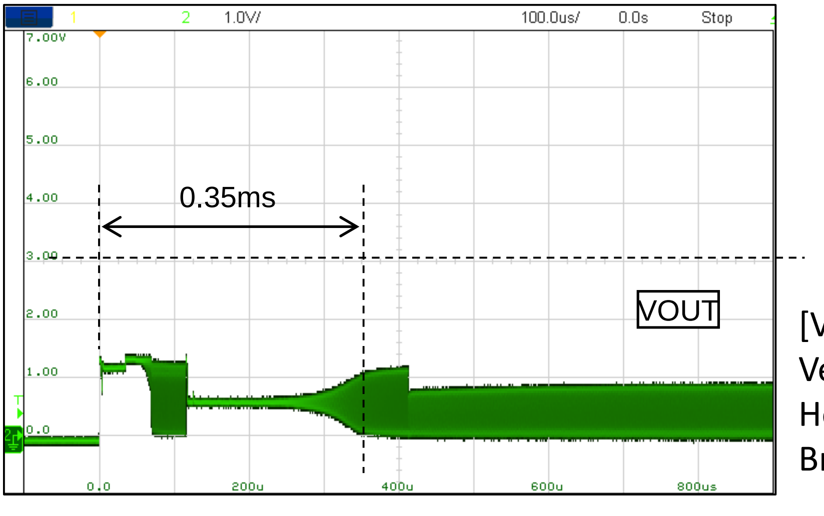
2.2. Oscillation Amplitude



[VIN/VOUT]
Vertical: 1V/div.,
Horizontal: 20ns/div.
Broken line: GND

VIN [V]			VOUT [V]		
High	Low	p-p	High	Low	p-p
0.9	-0.1	0.9	0.9	-0.1	1.0

2.3. Oscillation Start up time



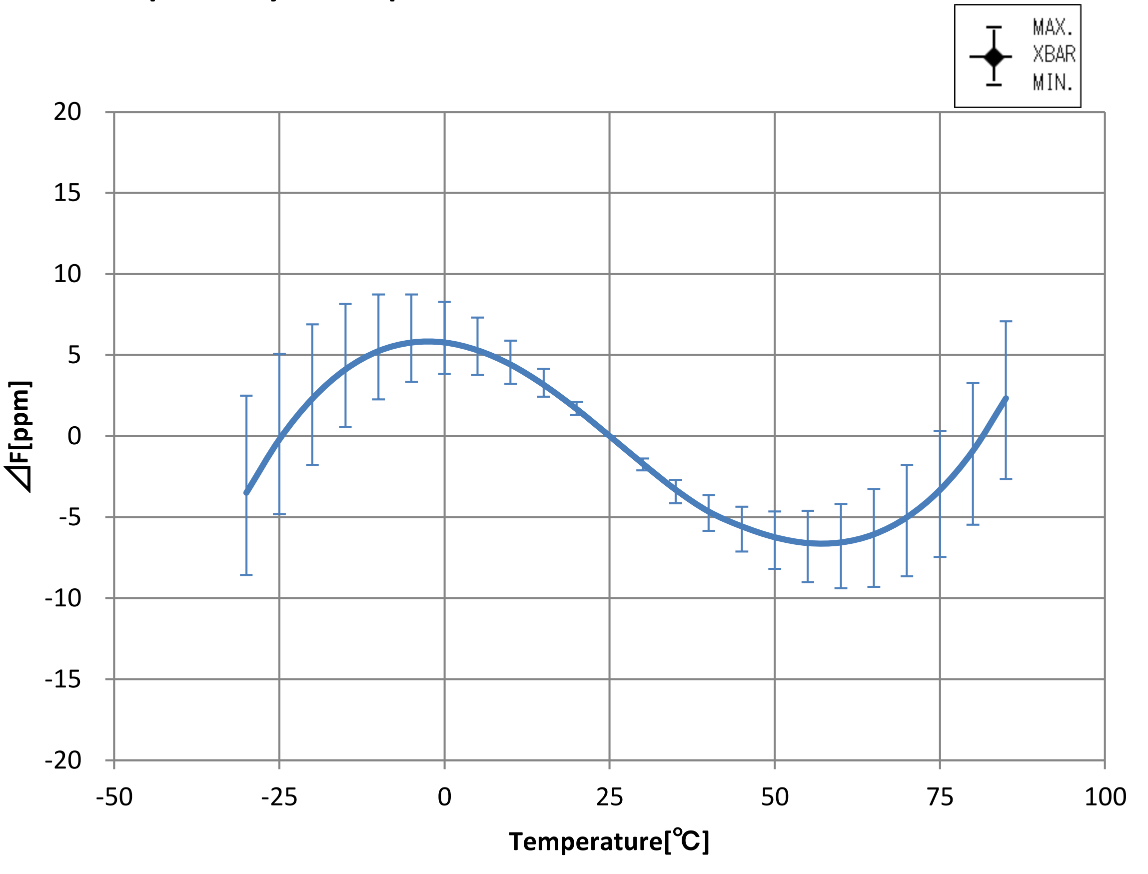
[VIN/VOUT]
Vertical: 1V/div.,
Horizontal: 100ns/div.
Broken line: GND

Typical sample at Set=3.3V, +25deg C

All of above results have been measured on evaluation board of BES2300 from BESTECHNIC, with optimized circuit conditions for XRCGB26M000F1H89R0. Refer DFR-18-1353, issued by Murata, for more detail.

2. Crystal oscillation characteristics

2.4. Frequency temperature characteristics



Measured by Murata standard test fixture

3. Reference Circuit

3.1. BES2300 with XRCGB26M000F1H89R0

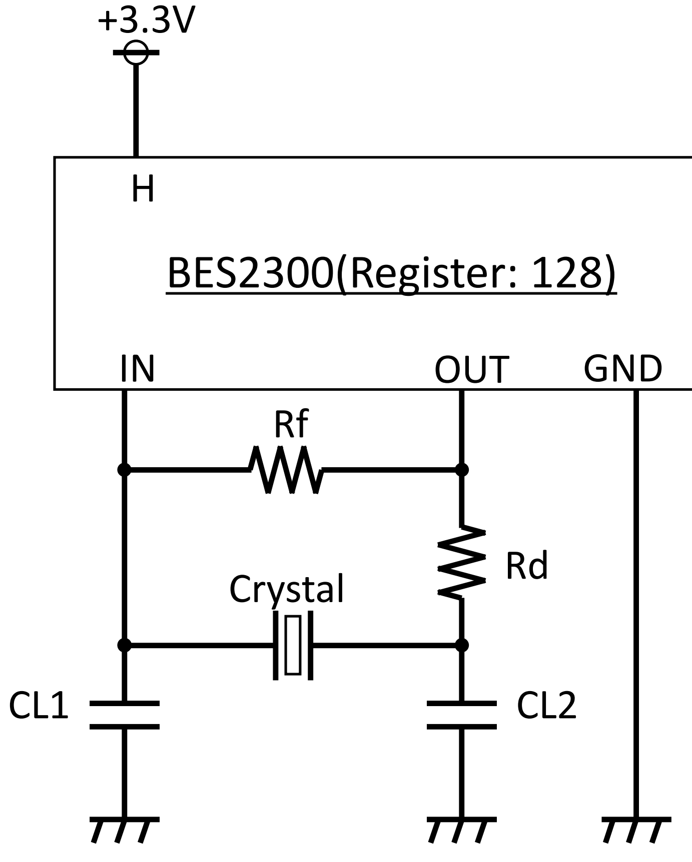


Figure of oscillation circuit

Symbol	Parameter	Optimized value
Rf	Feedback resistor [ohm]	No mount
Rd	Damping resistor [ohm]	0
CL1	External capacitance [pF]	4.7
CL2	External capacitance [pF]	4.7

3. Reference Circuit

3.2. Specification of XRCGB26M000F1H89R0

Parameter	Spec. of Murata's crystal
Murata Part Number	**XRCGB26M000F1H89R0**
Size [mm] (L x W x H)	2.0 x 1.6 x 0.7
Frequency tolerance [ppm]	+/-10
Frequency drift over temp. [ppm] (-30 to 85deg.C)	+/-10
ESR [ohm] (*1)	60 max.
Load cap CL [pF] (*2)	5.0
Drive level [uW] (*3)	300 max.

(*1): Equivalent Series Resistance. Resistance of the crystal.
(*2): Specified capacitance for frequency sorting on crystal.
(*3): Withstand-ability for how high power the crystal can use by.
Refer oscillation characteristics data for actual power consumption on crystal.

Revision Record

Version	Revised	Murata		Bestechnic	
		Author	Date	Author	Date
1.0	Issued	Tetsuro Kurihara	Dec. 3 2018	Kevin Luo	Dec..18 2018