Application Note for Frequency Control Products on (IoT) MCU

The market of the Internet of Things (IoT) today has triggered a sharp rise in the demand for 16 & 32-bit MCUs, and the specification requirements for MCU System Clock are also getting higher and higher. Due to simple I/O interface requirements, early 8-bit MCUs only need one set of high-frequency (MHz) Quartz Crystal to provide the System Clock required by the MCU. However, today's 16 & 32-bit MCU IoT applications, Due to the need to provide more I/O, external transmission interfaces, timing and other multi-functional requirements, two sets of high and low frequency Quartz Crystal (MHz & KHz) are used to meet the clock requirements.

1. Circuit diagram and capacitance matching when designing high-frequency (MHz) quartz crystal resonator (crystal oscillator):

EX.: For RF 2.4G application, The crystal used to use frequency at 16MHz, 12pF, Tolerance: ±10ppm

According to the design formula: 12pF=((CL1*CL2)/(CL1+CL2))+Cs+Ci

(Cs = stray capacitance of PCBA , Ci =junction capacitance of MCU)

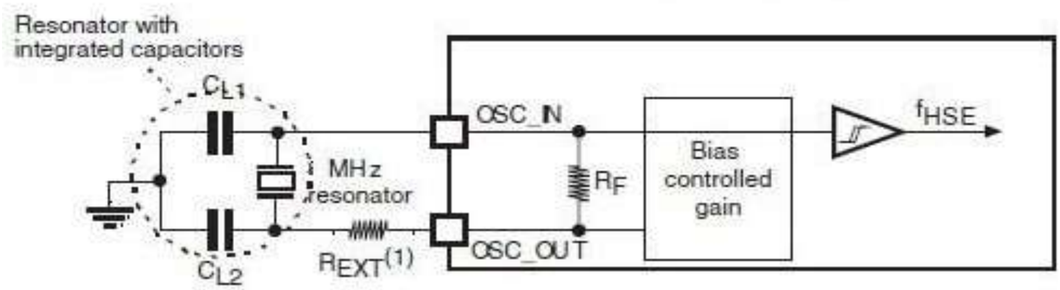
In general, Cs+Ci≒3pF, so 12-3=9pF, according to the formula: CL1=CL2=18pF

∴((18*18)/(18+18))+3pF=12pF, RF is a feedback resistor of build in device(MCU).

For high-frequency crystal oscillation circuit, it is at 1MΩ. If the device does not built-in, it can be added externally. It is usually to built-in device.

REXT is a current-limiting resistor. Generally, it can be ignored, or adding a resistor below 1kΩ to avoid excessive positive feedback to damage the crystal.

Typical application with an MHz crystal



2. **Circuit diagram and capacitance matching when designing low-frequency (KHz) quartz crystal resonator (crystal oscillator):**

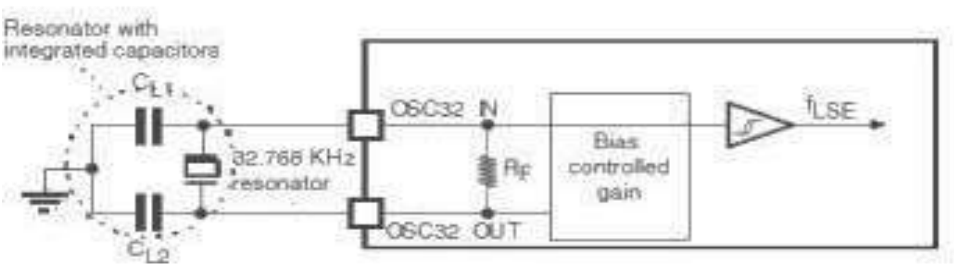
EX.: For RTC & Base band application ，Quartz Crystal used to use 32.768KHz,
CL= 12.5pF, stability: ±20ppm

According to the formula, 12.5pF=((CL1*CL2)/(CL1+CL2))+Cs+Ci

(Cs is stray capacitance of PCBA , Ci is junction capacitance of MCU)

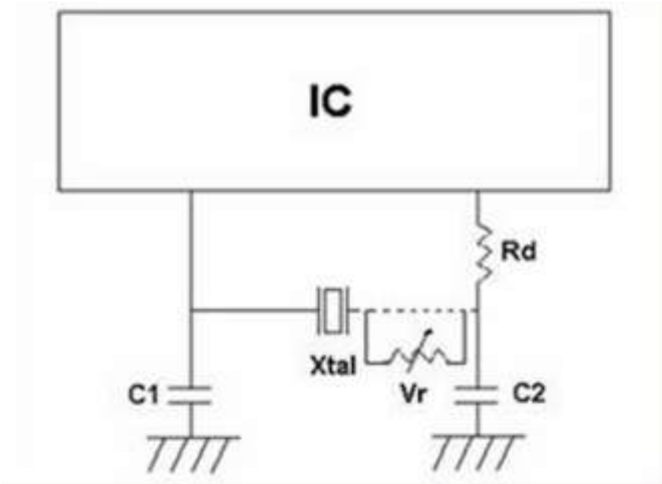
Normally Cs+Ci ≒ 3pF , so 13-3=10pF , CL1=CL2=20pF ∴((20*20)/(20+20))+3pF=13pF
RF is an internal feedback resistor of device，normally is 10MΩ in oscillator circuit . It can be added if it does not built-in device (MCU), but it is usually built-in already.。

Typical application with a 32.768 kHz crystal



3. Negative resistance│-R│ & Oscillation Allowance :

The negative impedance is another important parameter when designing an oscillator circuit

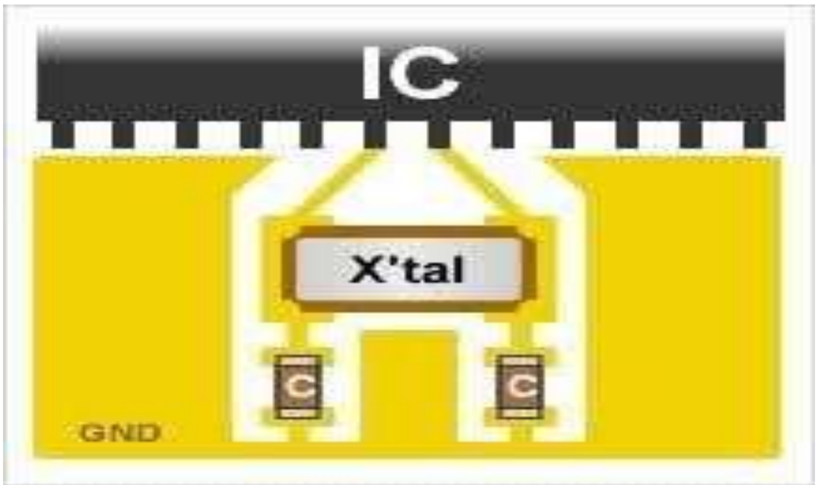


-R : The test method is as shown in the figure above:
To connect a VR in series to the crystal, adjust the VR until the crystal has no output frequency. Remove the VR and measure the resistance of VR. The measured value is the -R value on the oscillation circuit.

-R value is better ≧ (5~10) x ESR , (ESR : Equivalent Series Resistance of the quartz crystal)
When –R < 3 , due to insufficient oscillation allowance of the quartz crystal, it may cause no oscillation or unstable oscillation and start-up time delay etc.,..

4. PCB Layout design guide – KHz Quartz Crystals:

4-1. The recommendation layout schematic is listing for YIC 3215E series (3.2*1.5mm , 2 pads, 32.768KHz SMD crystal)



4-2. General consideration for PCB layout & quartz crystal ：

a. PCB wiring should be as short as possible, the distance should be < 10~15mm between IC and Crystal.

b. It is better to layout PCB ground layer under crystal as possible. 。

c. There are no sensitive signal lines through except oscillator circuit running under Crystal body.

d. The placement of crystal should avoid put on the edge of the PCB in order to avoid the possibility of damage on quartz chip when the PCB is dropped down . It also helpful for designer to make a better ground layer layout.

e. Crystal **is a heat-sensitive component**, it is different from R/L/C , **do not place it close to the heat source of the PCB or the entire machine.**

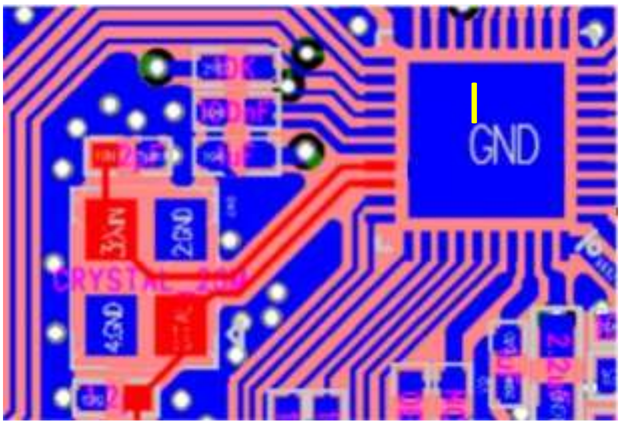
f. Metal Can Crystal (Such as 49 and cylindrical DT-26, DT-38 series), It is prohibited to hand-solder the body of crystal directly, This would cause internal crystal oscillator damaged and desoldering by overheating

5. PCB Layout design guide –MHz Quartz Crystals:

5-1. The recommendation layout schematic is listing for YIC XT324 series (3.2*2.5mm , 4 pads, SMD crystal)

5-2. General consideration for PCB layout & quartz crystal :

a. PCB wiring should be as short as possible, the distance should be < 10~15mm between IC and Crystal.



b. It is better to layout PCB ground layer under crystal as possible

c. There are no sensitive signal lines through except oscillator circuit running under Crystal body.

d. The placement of crystal should avoid put on the edge of the PCB in order to avoid the possibility of damage on quartz chip when the PCB is dropped down . It also helpful for designer to make a better ground layer layout.

e. Crystal is a heat-sensitive component. it is different from R/L/C , do not place it close to the heat source of the PCB or the entire machine.

f. In order to reduce the echo reflection of waveform on the output line, the impedance of the output lines must be as consistent as possible.
In order to achieve impedance consistent on output lines, the output trace design is also one of the important keys.
As shown in the figure below, it can be converted 45° angle from a right angle, or a rounded curve design can be used to improve the consistency of output impedance.
In addition, a perforated designs or T-branch designs should be avoided. 。

Output line pattern curve examples

g. The placement of crystal is not next to a switching power supply or AC power to prevent any power influence on crystal from PCB power or AC power , it is also helpful to designer for better ground layer design at the same time. 。

h. To increase more ground layers in multi- layer PCB. it is also helpful for stabilizing the temperature rise of crystals

i. In order to prevent capacitive coupling , crystal should be placed far away from high-frequency components and traces.

j. Crystal should be isolated with other devices as possible.

6. YIC recommends frequency control products for IoT MCU

6-1. MHz Quartz Crystals

Frequency (MHz)	Tolerance (ppm)	Load (CL pF)	Working Temperature (℃)	Dimension (YIC series) (mm)
40	10	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
32	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
27.12	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
27	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
26	10,20,30	6,8,9,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
25	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
24.576	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
24	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	1.6x1.2 (XT114) 2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)

22.1184	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
20	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
18.432	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
16	10,20,30	6,8,9,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
14.31818	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
13.56	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
12	10,20,30	6,8,10,12,18,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
8	10,20,30	10,12,18,20	-20~+70 -40~+85	3.2x2.5 (XT324) 5.0x3.2 (XT532,XT534)

※Optional for YIC 49US、49SMT 49SLMT series

6-2. MHz Crystal Oscillators (SPXO)

Frequency (MHz)	Stability (ppm)	Voltage (V)	Working Temperature (℃)	Dimension (YIC serise) (mm)
1, 6, 8, 11.0592, 12, 18.432, 20, 24, 25, 26, 27, 32, 33.333, 40, 48, 54,66.667, 100,125, 150	25,50	1.8, 2.5, 3.0, 3.3, 5	-20~+70 -40~+85	SMD 2.0x1.6 (OSC-S21) 2.5x2.0 (OSC-S22) 3.2x2.5 (OSC-S3) 5.0x3.2 (OSC-S5) 7.0x5.0 (OSC-S7) Through-Hole Full Size (OSC-F) Half Size (OSC-H)

6-3. KHz Quartz Crystals

Frequency (KHz)	Tolerance (ppm)	Load (CL pF)	Working Temperature (℃)	Dimension (YIC series) (mm)
32.768	10,20	7,9,12.5	-20~+70 -40~+85	SMD 1.6x1.0 (1610E) 2.0x1.2 (2012E) 3.2x1.5 (3215E) 6.9x1.4 (6914E) 8.0x3.8 (MC306) Through-Hole 2x6 (DT-26) 3x8 (DT-38)

6-4. KHz Crystal Oscillators

Frequency (KHz)	Stability (ppm)	Stab ility (V)	Working Temperature (℃)	Dimension (YIC series) (mm)
32.768	10,20,25,50	1.8, 2.5, 3.0, 3.3	-20~+70 -40~+85	2.0x1.6 (OSC-S21RTC) 2.5x2.0 (OSC-S22RTC) 3.2x2.5 (OSC-S3 RTC) 5.0x3.2 (OSC-S5 RTC) 7.0x5.0 (OSC-S7 RTC)

6-5. KHz RTC (DTCXO)

Frequency (KHz)	Stability (ppm)	Voltage (V)	Working Temperature (℃)	Dimension (YIC series) (mm)
32.768	±5	2.2 ~ 5.5	-40~+85	SMD 10.3x5.0x3.4 (RC8025T)

※The above table is the commonly used specifications,

Other unlisted specifications include wide temperature -40~+125℃.

For more detail, welcome to contact with YIC window

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