Application Note of Crystals/Oscillators for IoT MCUs

The trend of the Internet of Things (IoT) has led to a rise in the demand for 16 & 32 bit MCUs, and increased the requirements for the MCU's System Clock.

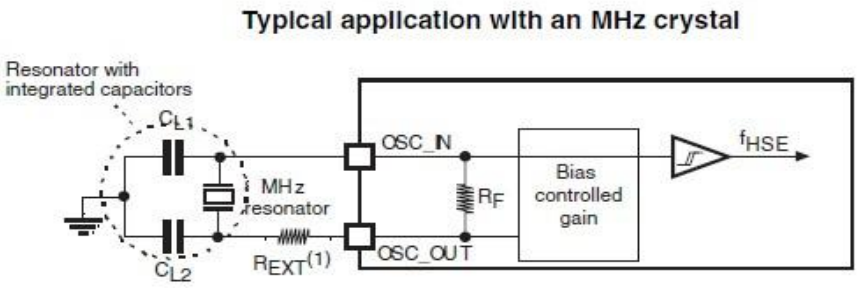
Early 8-bit MCUs require a simple I/O interface, so only one set of high-frequency (MHz) Quartz Crystals can provide the system clock required by the MCU, but today's 16 & 32-bit MCU IoT applications, due to the need for more I/O and transmission interface and timing requirements, the high and low frequency Quartz Crystal (MHz & KHz) is used to meet the requirements of the system clock.

A. Circuit diagram design and capacitor matching for MHz quartz crystal:

EX.: In RF 2.4G applications, Crystal's common frequency is 16MHz, 12pF, 10ppm.
According to the design formula: 12pF=((CL1*CL2)/(CL1+CL2))+Cs+Ci (Cs is the stray capacitance of PCBA, Ci is the junction capacitance of MCU)

In general, Cs+Ci=about 3pF, so 12-3=9pF, import formula: CL1=CL2=18pF ∴
((18*18)/(18+18))+3pF=12pF

RF is a built-in feedback resistor, which is 1MΩ in the MHz Crystal circuit. If the MCU is not built-in, it can be added. REXT is a current limiting resistor, generally not added.



B. Circuit diagram design and capacitance matching for KHz quartz crystal:

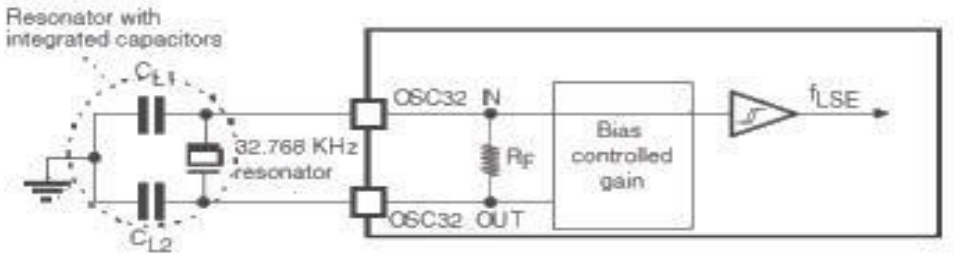
EX.: When applied in RTC & Base band, Quartz Crystal commonly used frequency is 32.768KHz, CL= 12.5pF, Stability= 20ppm

According to the design formula: 12.5pF=((CL1*CL2)/(CL1+CL2))+Cs+Ci (Cs is the stray capacitance of PCBA, Ci is the junction capacitance of MCU)

In general, Cs+Ci=about 3pF, so 13-3=10pF, import formula: CL1=CL2=20pF ∴ ((20*20)/(20+20))+3pF=13pF

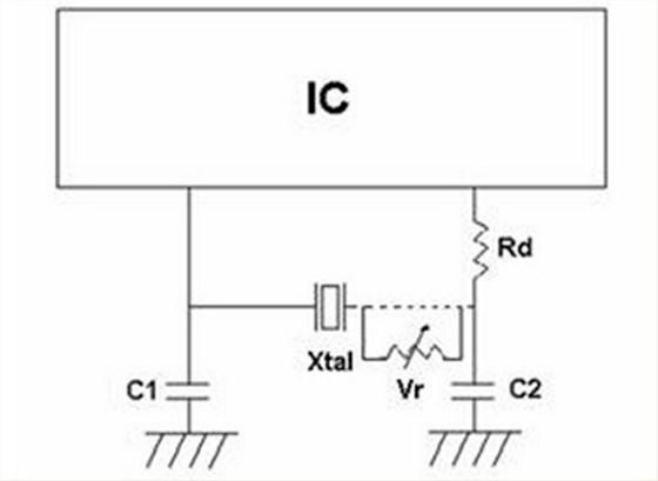
RF is a built-in feedback resistor, which is 10MΩ in the KHz Crystal circuit. If the MCU is not built-in, it can be added. It is usually built-in.

Typical application with a 32.768 kHz crystal



C. Negative impedance │-R│ & Oscillation Allowance:

Generally, another important parameter is often overlooked in designing an oscillating circuit, which is a Negative Impedance.



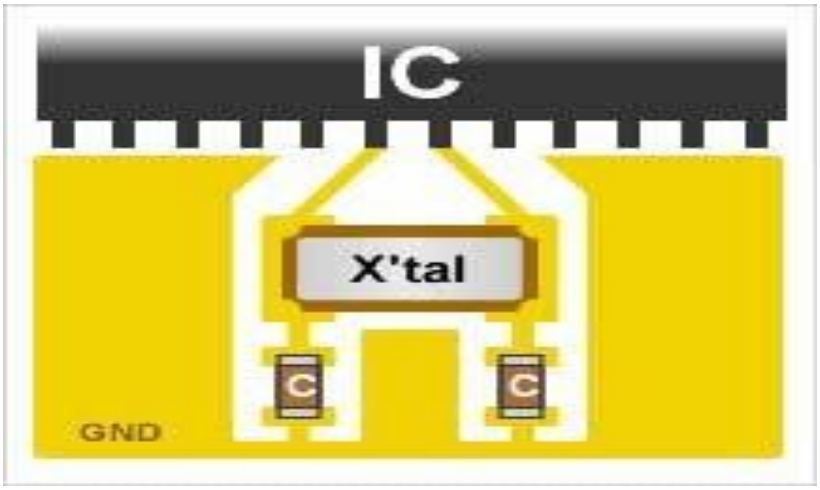
The -R test method is as shown above:

Connect one VR to the Crystal circuit, adjust the VR until the Crystal no output frequency, and take off the VR , then to measure VR resistance value. This value is the -R value in the oscillation circuit.

-R value should be ≧ (5~10) * ESR max. (where ESR is the equivalent resistance of quartz crystal). When -R is less than 3 times, it is easy to be due to the oscillation margin of quartz crystal (Oscillation Allowance) is insufficient, and there are problems such as stop oscillation or unstable oscillation, and prolonged oscillation start-up time.

D. PCB Layout design note:

D-1. The recommended layout below is for a YIC's 3215E series crystal (3.2*1.5mm, 2 pads, 32.768KHz smd crystal).



D-2. PCB layout design and general considerations for Quartz Crystal:

1. PCB layout should be as short as possible, distance between IC and Crystal should be less than 10~15mm

2. Try to lay the GND layer under the crystal.

3. Under the crystal body, do not have the sensitive signal line besides the oscillation circuit.

4. Crystal should not be placed on the edge of the PCB as much as possible to avoid damage to the quartz wafer due to PCB falling, and a good GND layer can be laid out.

5. Quartz Crystal/Oscillator is a component with heat sensitive characteristics which is not same as R/L/C, do not place it near the heat source of PCBA or device.

6. Metal Can crystal (such as 49 series and cylinder DT-26, DT-38 series) is not be allowed to directly solder the crystal body (to ground), which is very easy to cause excessive temperature and damaged by de-soldering the inside of the crystal.

E. YIC recommends Crystals/Oscillators for IoT MCUs

E-1. MHz Quartz Crystals

Frequency (MHz)	Tolerance (ppm)	Load capacitance (CL pF)	Operation Temperature (℃)	Dimension (Series) (mm)
40	10	8,9,10,12	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
32	10,20,30	8,9,10,12	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
27.12	10,20,30	8,10,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
27	10,20,30	8,9,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
26	10,20,30	8,9,10	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
24	10,20,30	8,9,10,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
20	10,20,30	9,10,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
16	10,20,30	9,10,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
12	10,20,30	8,10,12,20	-20~+70 -40~+85	2.0x1.6 (XT214) 2.5x2.0 (XT224) 3.2x2.5 (XT324)
8	20,30	18,20	-20~+70 -40~+85	5.0x3.2 (XT532,XT534)

※YIC 49US, 49SMT and 49SLMT series are also optional

E-2. MHz Crystal Oscillators (SPXO)

Frequency (MHz)	Stability (ppm)	Vcc (V)	Operation Temperature (℃)	Dimension(Series) (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)

E-3. KHz Quartz Crystals

Frequency (KHz)	Stability (ppm)	Load Capacitance (CL pF)	Operation Temperature (℃)	Dimension(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)

E-4. KHz Crystal Oscillators

Frequency (KHz)	Stability (ppm)	Vcc (V)	Operation Temperature (℃)	Dimension(Series) (mm)
32.768	10,20,25,50	1.8, 2.5, 3.0, 3.3	-20~+70 -40~+85	2.0x1.6 (OSC-S21 RTC) 2.5x2.0 (OSC-S22 RTC) 3.2x2.5 (OSC-S3 RTC) 5.0x3.2 (OSC-S5 RTC) 7.0x5.0 (OSC-S7 RTC)

E-5. KHz RTC (DTCXO)

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

※ The above table lists the common specifications only. For other unlisted specifications include wide temperature -40~+125°C, please contact YIC.