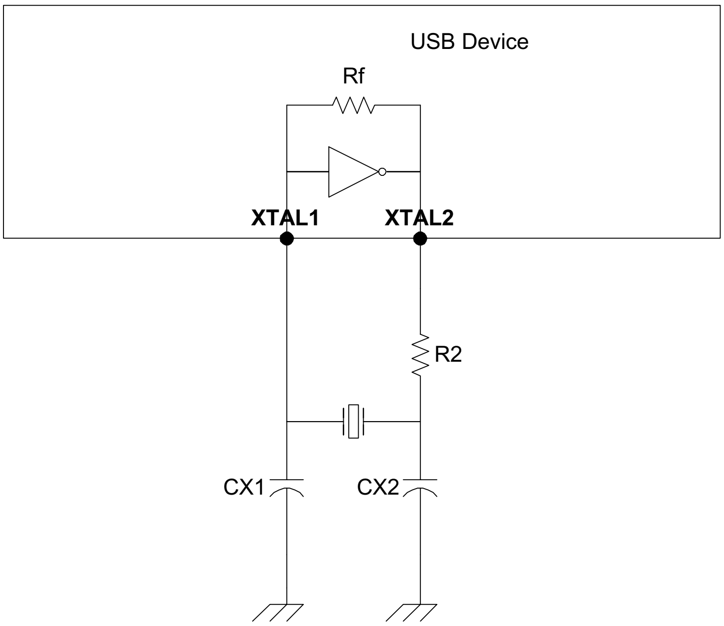
August 10, 2000

Crystal Oscillator Selection for USB Device

Crystal Oscillator Selection for USB Device

CRYSTAL SELECTION

In any crystal-based oscillator circuit, the oscillator frequency is based almost entirely on the characteristics of the crystal that is used. Therefore, it is important to select a crystal that meets the design requirements.
We at Philips Semiconductors—APIC have explicitly specified only the parameters of ESR and shunt capacitance for a common crystal to match our oscillator CMOS design.
The choice of crystal load capacitance can be selected through the standard crystal formulae, which will be mentioned in the following page.



This circuit diagram shows an implementation of Pierce Oscillator on our USB device. The feedback resistor R1 has been integrated into our USB device. This resistor is used to provide DC bias to a CMOS inverter for inversion amplifier operation. Too large an R sets the circuit unstable while too small a resistor makes the amplifier gain small. We have chosen 100 kΩ for its optimal bias.

The resistor R2 is used to reduce the power dissipation of the crystal oscillation circuit. Omitting this component will result in crystal driven at a higher voltage level, which will result in higher power dissipation. If R2 is 1 Ω, the power dissipation will be less 1μW, which is still within the specification of the crystal, as stated in the next table.

Crystal Oscillator Selection for USB Device

Crystal Specification

Parameter	Symbol	Typical value	Typical value	Notes
Nominal Frequency	F_O	6.00 MHz	12.00 MHz	
Frequency Tolerance		± 50 ppm	± 50 ppm	
Load Capacitance	C_L	16 pF	16 pF	
Shunt Capacitance	C_s	3 pF	3 pF	
Equivalent series resistance	R1	80 Ω	80 Ω	
Drive Level	D_L	100 µW	100 µW	
Drift Stability in operating Temperature		± 50 ppm	± 50 ppm	
Aging per year		± 3 ppm	± 3 ppm	

This table shows the typical crystal specification used in a USB semiconductor application. The USB specification states that a USB Hub application requires at least 500 ppm of oscillation frequency. As most of the common crystals nowadays have an accuracy of 50 ppm or better, we suggest you use a typical crystal with these parameters.

We require an equivalent series resistor of less than 100 Ω and shunt capacitance to be not more than 7 pF to achieve reliable oscillation startup.

Load capacitance (C_L) is a critical crystal parameter which specifies the capacitive load that must be placed across the crystal pins for the crystal to oscillate at its specified frequency. It influences the actual oscillation frequency, as the crystal manufacturer actually 'trims' the crystal to oscillate at its nominal frequency for the given specified load capacitance. Note that the C_L is the capacitance that the crystal needs to 'see' from the oscillator circuit; it is not the capacitance of the crystal itself.

From the crystal parameters, use the following formula to get into the required capacitance load for the crystal to oscillate on the right frequency.

$$C_L = \frac{C_{X1} \cdot C_{X2}}{(C_{X1} + C_{X2})} + C_S$$

Based on the load capacitance formulae, the following table has been tabulated as a selection guide for both 6 MHz and 12 MHz crystal.

Crystal Oscillator Selection for USB Device

SYMBOL	PARAMETER	VALUE	EXTERNAL COMPO-NENT
R1	Series resistance	< 100 Ω	
C_s	Shunt capacitance	< 7 pF	
C_L	load capacitance (C_p is not included)	8 pF	Cx1 = 15 pF, Cx2 = 15 pF
		12 pF	Cx1 = 22 pF, Cx2 = 22 pF
		18 pF	Cx1 = 33 pF, Cx2 = 33 pF

We suggest that you use a crystal with Parameter of C_L = 8 to 18 pF. And C_s (Shunt capacitance) =< 7 pF , with typical value of 3 pF. The ESR of crystal must be 100 Ω or less. The external capacitors used would be 18 pF to 22 pF excluding the consideration of onboard parasitic capacitance.

Note:
For most applications, although the exact frequency is not very important, e.g., 10,000,000 Hz or 10,000,050 Hz; .a deviation in C_L of a few pF will result in only a slight change of frequency. For a typical crystal, this would be in the range of 10 ppm/pF. So if C_L is 18 pF instead of 20 pF the frequency will be 10,000,200 Hz instead of 10,000,000 Hz.