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# Microcontroller Clock - RC Oscillator, Crystal or Resonator?

*Crystals, ceramic resonators, RC oscillators and silicon oscillators are four types of clock source suited for use with microcontrollers. The optimum clock source type for a particular application is dependent on factors including cost, accuracy and environmental parameters. This application note discusses various factors associated with microcontroller clock selection and compares these oscillator types.*

Also see: Microcontroller Clock Support Solutions

Clock sources for microcontrollers can be grouped into two types: those based on mechanical resonant devices, such as crystals and ceramic resonators; and RC (resistor, capacitor) oscillators. Two examples of discrete oscillators are shown in Figure 1. Figure 1a shows a Pierce oscillator configuration suitable for use with crystals and ceramic resonators while Figure 1b shows a simple discrete RC oscillator.

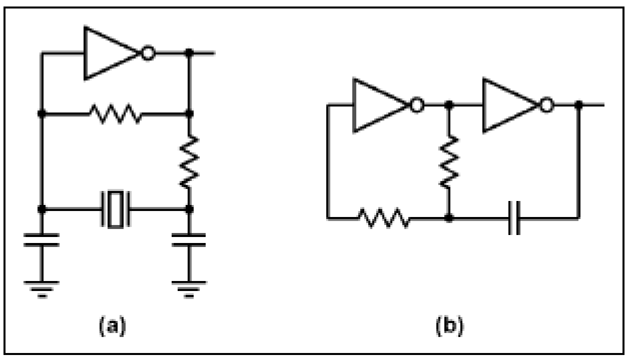


*Figure 1. Discrete oscillator circuit examples.*

Crystal and ceramic resonator-based oscillators typically provide very high initial accuracy and a moderately low temperature coefficient. RC oscillators provide fast startup and low cost but generally suffer from poor accuracy over temperature and supply voltage, with variations of 5% to 50% of nominal output frequency.

While the circuits illustrated in Figure 1 are capable of producing clean reliable clock signals, the performance of these can be heavily influenced by environmental conditions and circuit component choice. Care should be taken with the component selection and layout of all oscillator circuits. Ceramic resonators and their associated load capacitance values have to be optimized for operation with particular logic families. Crystals, with their higher Q, are not so sensitive to amplifier selection but are susceptible to frequency shifts (and even damage) when overdriven. Environmental factors that influence oscillator operation include electromagnetic interference (EMI), mechanical vibration and shock, humidity and temperature. These factors give rise to output frequency changes and increased jitter and can, in severe cases, cause the oscillator to stop functioning.

Many of the problems described above can be avoided through the use of oscillator modules. These are self-contained oscillators with a low impedance square wave output and guaranteed operation over a range of conditions. The two most common types are crystal oscillator modules and integrated RC oscillators (silicon oscillators). Crystal oscillator modules provide similar accuracy to discrete crystals. Silicon oscillators are more precise than discrete RC oscillators and many provide comparable accuracy to ceramic resonator based oscillators.

Another consideration of oscillator selection is power consumption. The power consumption of discrete oscillator circuits is primarily determined by the feedback amplifier supply current and by the in-circuit capacitance values used. The power consumption of amplifiers fabricated in CMOS is largely proportional to operating frequency and can be expressed as a power dissipation capacitance value. For example, the power dissipation capacitance value of an HC04 inverter gate is typically 90pF. For operation at 4MHz from a 5V supply this equates to a supply current of 1.8mA. Add to this a crystal loading capacitance value of 20pF and the total supply current becomes 2.2mA. Ceramic resonator circuits typically specify larger load capacitance values than crystals and draw more current accordingly. By comparison, crystal oscillator modules typically draw between 10mA and 60mA supply current. The supply current for silicon oscillators depends on type and function and can range from a few micro-amps for low (fixed) frequency devices to tens of milli-amps for programmable parts. A low power silicon oscillator, such as the MAX7375, draws less than 2mA when operating at 4MHz.

The optimum clock source for a particular application is determined by a combination of factors including accuracy, cost, power consumption and environmental requirements. The following table summarizes the common oscillator types discussed, together with their strengths and weaknesses.

**Table 1**

| Clock Source | Accuracy | Advantages | Disadvantages |
|---|---|---|---|
| Crystal | Medium to High | Low cost | Sensitive to EMI, vibration, damp<br>Drive circuit matching |
| Crystal Oscillator Module | Medium to High | Insensitive to EMI, damp.<br>No additional components or matching issues. | High cost<br>High power consumption<br>Sensitive to Vibration Large size |
| Ceramic Resonator | Medium | Lower cost | Sensitive to EMI, vibration, damp<br>Drive circuit matching |
| Silicon Oscillator | Low to Medium | Insensitive to EMI, vibration, damp Fast startup<br>Small size/no additional components or matching issues. | Temperature sensitivity generally worse than crystal and ceramic resonator types.<br>High supply current with some types. |
| RC Oscillator (discrete) | Very Low | Lowest cost | Usually sensitive to EMI, vibration, damp Poor temperature and supply voltage rejection performance.<br>Usually large size |

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