

Clock Oscillator Basics

Precision Time Measurements Of Crystal Oscillators

At the core of almost all modern digital systems is a high accuracy timebase based on a crystal oscillator. Crystal oscillators use the property of piezoelectricity to create waveforms with excellent frequency accuracy based on the mechanical vibration of a precision machined crystal.

Certain crystals, most notably quartz, exhibit the property of piezoelectricity. If force is applied to the faces of a piece of crystal it causes a voltage to be generated from the crystal. Conversely, if an electrical voltage is applied to a crystal it causes the crystal to deform mechanically. This process is illustrated in figure 1. If a crystal is placed into the feedback path of an amplifier

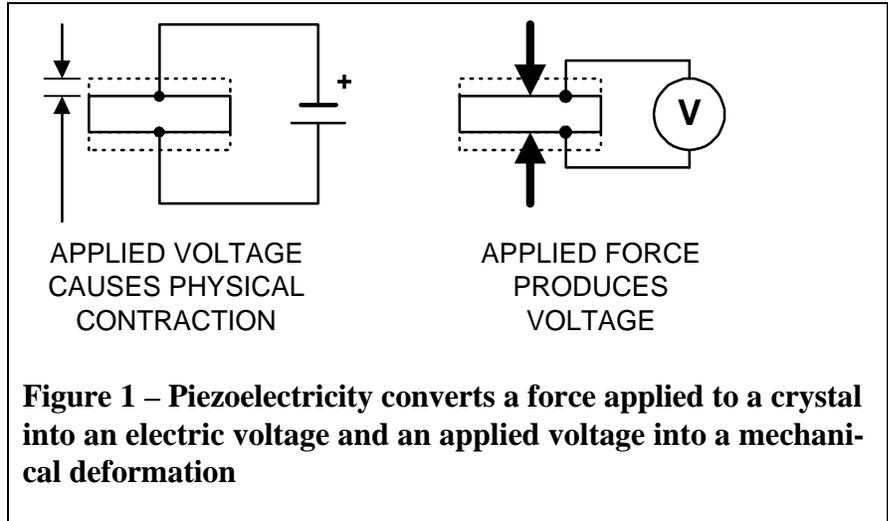


Figure 1 – Piezoelectricity converts a force applied to a crystal into an electric voltage and an applied voltage into a mechanical deformation

In the series resonant circuit the crystal is placed in a series path around the amplifier. The frequency of oscillation can be altered slightly by changing the capacitive loading on the crystal element. In this circuit the ca-

factors. First, the “cut” or orientation of the crystal blank relative to the major axes of the entire crystal. Other factors include temperature, power supply quality, mechanical vibration, gravity, aging, and loading. Designers must be able to measure and characterize these effects.

Figure 3 shows the results of a test evaluating the effect of power supply ripple on the output of an oscillator. The upper trace (Ch 2) represents 1000 cycles of a 10 MHz oscillator output signal. A 428 mV peak-peak ripple has been injected into the DC power input of the oscillator as shown in the bottom trace (CH 3). The phase variation of the oscillator relative to an ideal 10 MHz signal is measured using the JitterTrack –Interval function shown in Trace B. Trace C is the average of the interval jitter over

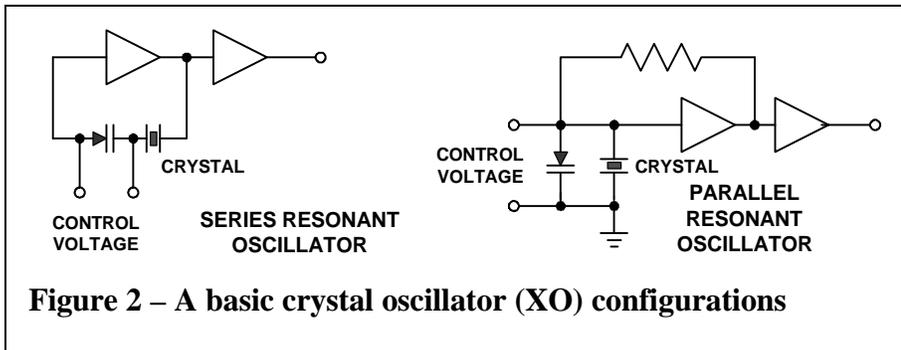


Figure 2 – A basic crystal oscillator (XO) configurations

circuit it begins to oscillate at a frequency dependent primarily on the dimensions of the crystal. Figure 2 shows the basic crystal oscillator configurations.

capacitance is varied using a varactor diode whose capacitance varies with an applied control voltage.

The frequency stability of the oscillator is a function of many

Cardinal Components Inc. Applications Brief No. A.N. 1005

100 sweeps. Averaging extracts the mean value of the interval error so that the non-correlated random jitter is removed. The parameters shown below the waveforms read the nominal frequency of the oscillator, the peak to peak variation from the ideal interval, and the rms (standard deviation) of the variation. Also shown are the mean value of the supply voltage and the peak to peak ripple. As can be seen the crystal oscillator frequency is highly dependent on the power supply ripple.

Crystal oscillator stability can also be very sensitive to temperature variation. Designers have developed a number of effective techniques for maximizing the stability of oscillators. In the area of temperature stability the basic crystal oscillator (XO) can be improved by sensing the internal temperature and using a control circuit to compensate the oscillator frequency. This results in a temperature compensated crystal oscillator (TCXO). The TCXO can improve stability by a factor of 20:1 over a simpler uncompensated oscillator. Figure 4 shows a block diagram of a TCXO.

Another approach is to enclose the oscillator in a temperature controlled oven and regulate the ambient temperature. This is an oven controlled crystal oscillator (OCXO). Oven controlled oscillators can improve stability even

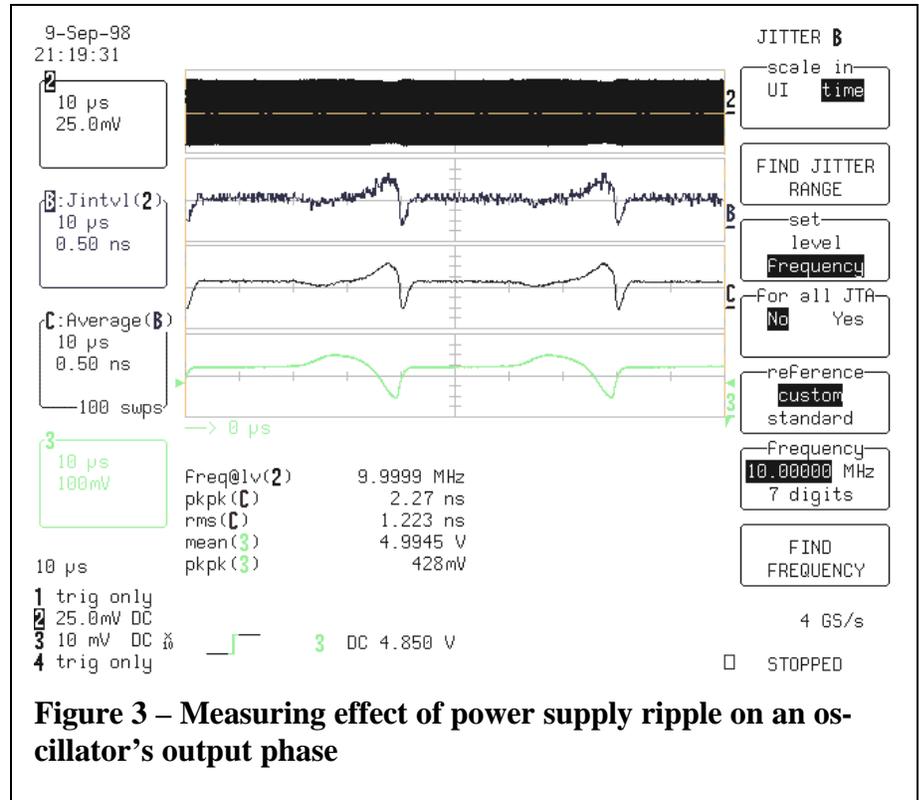


Figure 3 – Measuring effect of power supply ripple on an oscillator’s output phase

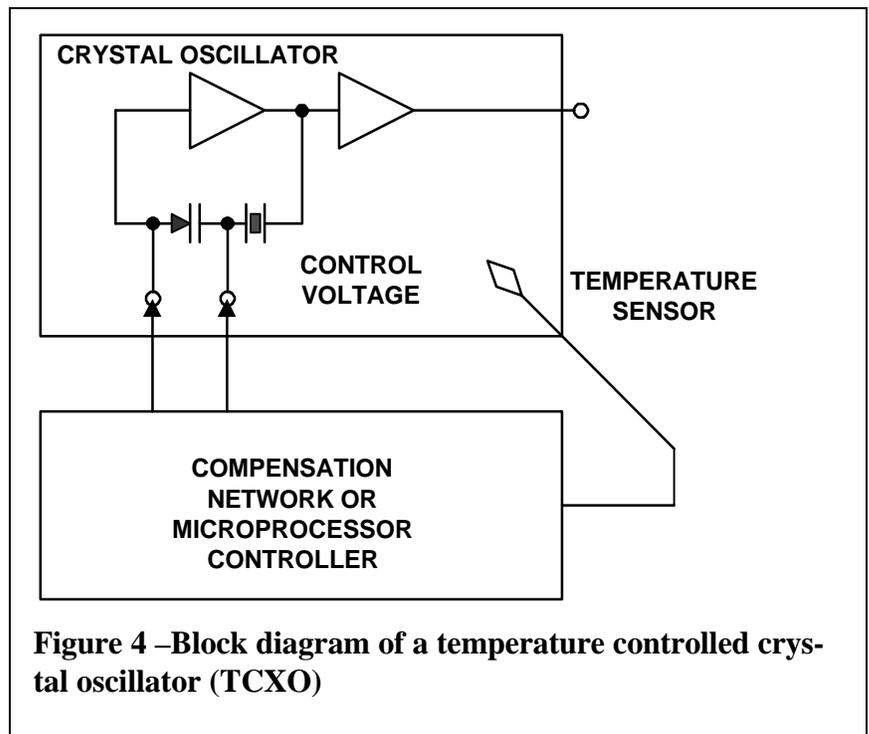


Figure 4 –Block diagram of a temperature controlled crystal oscillator (TCXO)

more compared with comparable TCXO’s.