Crystal Filter Yields Pure Sine Waves

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Introduction

Electronic applications such as distortion and communications measurements require pure (distortionless) sine waves as input test signals. Distortion contained in test signals causes two problems. First, the test signal distortion content must be calibrated so it can be subtracted out of the measurement. Second, processing a distorted test signal usually creates unique harmonics which cause false readings because they can't be calibrated out.

Signal sources which approach distortionless operation are available, but they are expensive, bulky, hard to use, and overkill for simple applications. The crystal filter described here utilizes any inexpensive sine wave generator to supply the test signal, and it filters the distortion out of the test signals prior to the measurement. This crystal filter is inexpensive, simple to design, and it reduces 2nd harmonic distortion by 70dB. Configured as shown in the schematic with the HFA1112 buffer, it can drive back terminated 50Ω loads while reducing distortion 63dB. Furthermore, driving the crystal filter with a square wave test signal only increases the 2nd harmonic content by a fraction of a dB.

The crystal is surrounded by a π network which preserves the crystals Q, and makes it less susceptible to loading. The crystal must be parallel resonant to function with the π circuit. The manufacturer specifies the crystal loading capacitance, C_L, and the maximum input power, P_{MAX}. The series resistor, R, limits the crystal power, and although it is an optimistic approximation, Equation 1 can be used to select R.

$$R \geq \frac{V_T^2}{P_{MAX}} = \frac{3.3^2}{5} K \approx 2.2K \qquad \text{(EQ. 1)}$$

For V_T = 3.3V and P_{MAX} = 5mW

R and C_1 form a low pass filter which kills the high frequency response and filters out noise. The -3dB point for R, C_1 should be set at one tenth the crystal frequency or 5MHz/10 = 500KHz. C_1 is calculated from Equation 2.

$$C_1 = \frac{1}{2\pi fR} = \frac{1}{2\pi(5EE5)(2.2EE3)} = 144pF \approx 150pF \qquad \text{(EQ. 2)}$$

Load capacitance changes tend to pull the crystal, and C_3 should be large so changes are a small percentage of C_3. C_3 is usually selected as approximately 3 times C_1. Let C_3 = 510pF. The series combination of C_1, C_2, and C_3 should equal C_L = 32pF specified by the crystal vendor.

$$\frac{1}{C_2} = \frac{1}{C_L} - \frac{1}{C_1} - \frac{1}{C_3} \qquad \text{(EQ. 3)}$$

C_2 calculates 44.2pF, so it was selected as 43pF. With the component values shown in the schematic, the -6dB bandwidth is 144Hz, and this equates to a crystal Q exceeding 45,000. The crystal filter must be constructed using a ground plane and other similar high frequency techniques. Reducing the value of C_2 by 10pF, and adding a 20pF variable capacitor in parallel with C_2 yields a 0.1% adjustment of the filter's center frequency. This adjustment range can compensate for normal manufacturing tolerances.

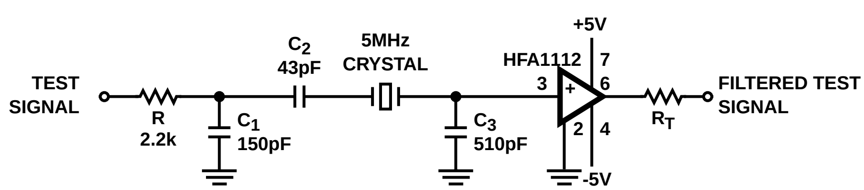

FIGURE 1. CRYSTAL FILTER

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