Circle 522

Crystal Filter for Pure Signals

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Applications such as distortion and communications measurements require distortionless sine waves as input test signals. Distortion 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, causing false readings since they can't be calibrated out.

Near-distortionless sources are available, but they're expensive, hard to use, and overkill for simple applications. The crystal filter described utilizes any inexpensive sine-wave generator to supply the test signal and filters the distortion out of the test signals prior to the measurement.

This crystal filter is simple to design and reduces 2nd harmonic distortion by 70 dB *(see the figure)*. Configured as shown in the schematic with the HFA1112 buffer, it can drive back-terminated 50-Ω loads while reducing distortion 63 dB. Furthermore, driving the crystal filter with a square-wave test signal only increases the 2nd-harmonic content by a fraction of a decibel.

The crystal is surrounded by a π network, which preserves the crystal's Q, and makes it less susceptible to loading. The crystal must be parallel-resonant to function properly 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:

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

for $V_T = 3.3$ V, and $P_{MAX} = 5$ mW.

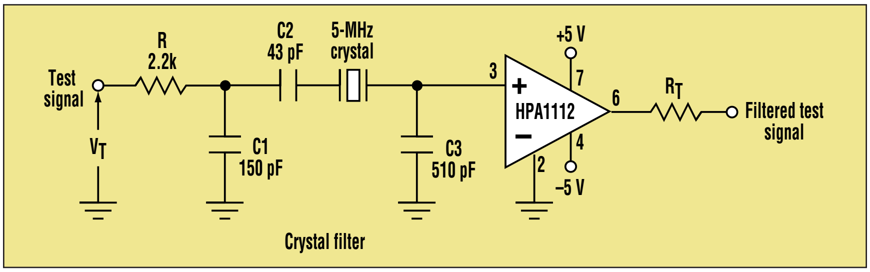
R and C1 form a low-pass filter that kills the high-frequency response and filters out noise. The –3-dB point for R1C1 should be set at the one tenth the crystal frequency or 5 MHz/10 = 500 kHz. C1 is calculated from equation 2:

$$C_1 = \frac{1}{2\pi fR} = 144\ pF \approx 150\ pF \qquad (2)$$

Load-capacitance changes tend to pull the crystal, and C3 should be large so changes are a small percentage of C3. C3 is usually selected as approximately 3 times C1. Let C3 = 510 pF. The series combination of C1, C2, and C3 should equal $C_L = 32$ pF specified by the crystal vendor.

$$\frac{1}{C2} = \frac{1}{C_L} - \frac{1}{C1} - \frac{1}{C3} \qquad (3)$$

Solving for C2 returns C2 = 44.2 pF, so 43 pF was selected. With the component values shown in the schematic, the –6-dB bandwidth is 144 Hz, equating to a crystal with a Q in excess of 45,000. The crystal filter must be constructed using a ground plane and other similar high-frequency techniques. Reducing the value of C2 by 10 pF, and adding a 20-pF variable capacitor in parallel, yields a 0.1% adjustment of the filter's center frequency, allowing compensation for manufacturing tolerances.



Using an inexpensive sine-wave generator to supply the test signal, this crystal filter filters the distortion from the signal prior to measurement. Second-harmonic distortion is reduced by 70 dB.