Load Capacitance Measurement

One of the most commonly used crystal oscillation circuit nowadays is Pierce-gate as shown in figure 1. It comprises a simple inverter gate, a feedback resistor Rf, two external load capacitors Ca and Cb, and a crystal X1.

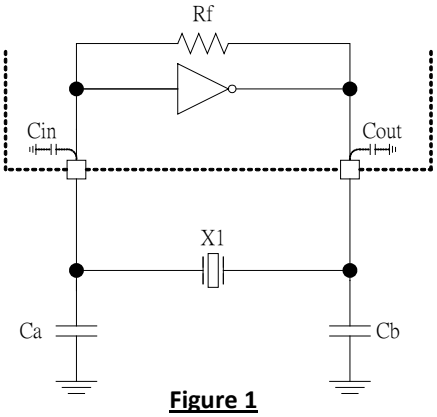

Figure 1

The equivalent circuit is shown in figure 2. At resonance, the crystal becomes a resistance RL in series with an inductance LL. The gate amplifier and its associated components form a negative resistance –R in series with a load capacitance CL. According to Barkhausen criteria for oscillation, the reactance of LL would be exactly equal but opposite in sign to that of CL, and therefore the closed loop reactance becomes zero. In addition, the absolute magnitude of –R (|–R|) must be greater than or equal to RL in order to have loop gain greater than or equal to unity. The ratio |–R|/RL is called *oscillation allowance*. Higher oscillation allowance provides better safety margin when environment condition changed, such as temperature and humidity.

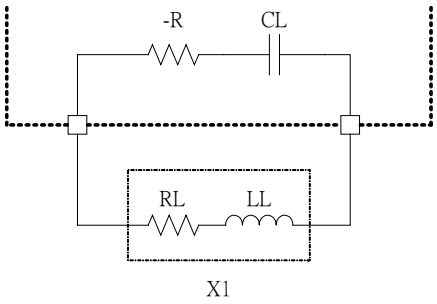

Figure 2

The equivalent circuit CL can be estimated by a simplified equation:

$$CL = \frac{(Ca+Cin)(Cb+Cout)}{Ca+Cin+Cb+Cout} + Cstray \qquad (1)$$

where

Cin = internal pin capacitance of the gate input
Cout = internal pin capacitance of the gate output
Cstray = overall stray capacitance of the PCB

The above equation has been simplified with some assumption made, and should be used for rough estimation only. A more precise model would include the transconductance (gm) of the gate inverter, and also the C0 of the crystal.

Another practical way to find CL is by using a crystal network analyzer and a spectrum analyzer. The circuit oscillating frequency *fosc* would be picked up by non-contact hi-impedance probe (or antenna), and measured by a high precision spectrum analyzer with frequency accuracy at least 0.1ppm or better. Then the sample crystal would be removed from the PCB and measured with a precise crystal network analyzer. Measure the CL at which FL equals *fosc*. If an automatic crystal network analyzer is used (e.g. KOLINKER KH1800), the CL, C0, Rs and other crystal parameters could be measured automatically with compliance to IEC60444-11 international standard.

If an automatic crystal network analyzer is unavailable, the crystal parameters could also be measured with a general network analyzer. Please refer to the IEC60444 standard, or search "Direct Impedance Method" from the internet for details.

HONG KONG AUTOMOTIVE X'TALS LIMITED
Unit M, 24/F, Shield Industrial Centre, 84-92 Chai Wan Kok Street, Tsuen Wan, New Territories, Hong Kong
Phone: (852) 35112388 Fax: (852) 35112420 Email: hkxtals@HongKongCrystal.com