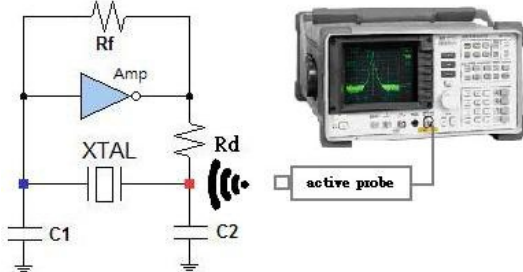


## Appendix

### A. Testing Methods of Oscillation Circuit

#### 1. Measurement of oscillation frequency



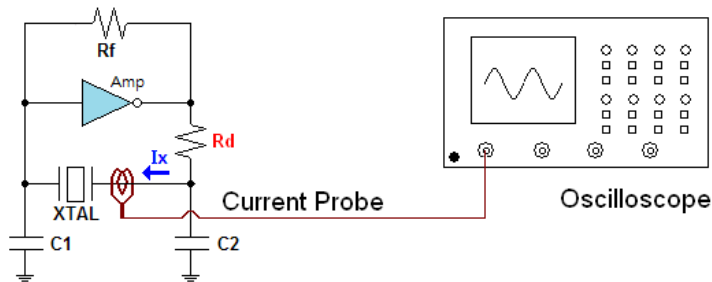
#### 2. Measurement of drive level

Drive level is equal to the power consumed by the operating crystal. As shown in figure below, measure the current ( $I_x$ ) that flows into the crystal with a current probe.

Calculation formula of Power (Drive Level) :

$DL \text{ (power)} = (I_x)^2 \times R_e$  ; where  $I_x$  : Effective current value (rms),

$R_e$  : Effective resistance,  $R_e = R_1 \times (1 + C_0/C_L)^2$  ,  $R_1$  : Series resistance



#### 3. Measurement of negative resistance

The negative resistance is used to determine the oscillation margin of oscillation circuit and predict the stability of oscillation. As shown in figure below, connect a variable resistor (VR) in series to the crystal, and then increase the resistance gradually. The crystal will stop oscillating at a certain value.

Calculation formula of Negative Resistance (-R) :

$|-R| = VR + R_e$ ,  $R_e = R_1 \times (1 + C_0/C_L)^2$  ,  $R_1$  : Series resistance

