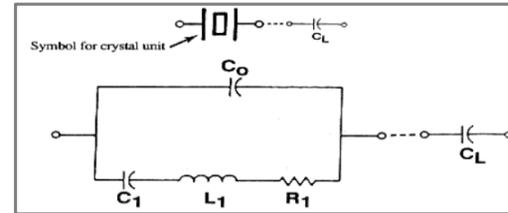
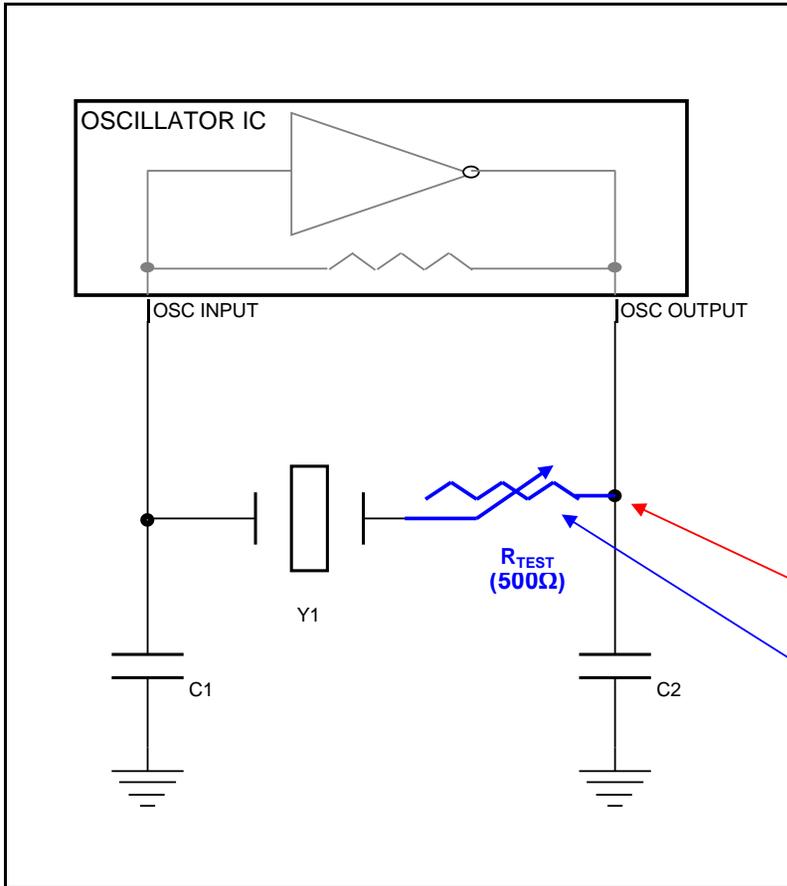


NEGATIVE RESISTANCE and OSCILLATOR CIRCUIT MARGIN

CIRCUIT MODIFICATION FOR DETERMINATION OF NEGATIVE RESISTANCE -r

- (1) You will need a known good crystal; if the ESR of the crystal is not known, the values for C0 and C1 of the crystal unit must be known in order to determine ESR
- (2) In order to determine negative resistance a variable resistor is added in series to the crystal unit; a 500Ω resistor is a good value to start with.
- (3) Increase the resistance of the variable resistor until oscillation stops, slowly turn it back until the oscillation just starts up again. Stop at this point.
- (4) Take the variable resistor 'R_{TEST}' out, and measure the adjusted resistance using a resistance meter.
- (5) Add the value of 'R_{TEST}' into the equation to determine Negative Resistance of the circuit. **Calculate the Circuit Margin, CM.**

A typical schematics of a crystal oscillator circuit is shown below.



Equivalent crystal circuit

CL = load capacitance of oscillator circuit.

- (A) Determine ESR of crystal unit:

$$ESR = R_1 \left(1 + \frac{C_0}{C_L} \right)^2$$

R₁ = RR = Rs of crystal unit.
C₀ = shunt capacitance of crystal unit.

- (B) Calculate Negative Resistance

$$-r = R_{TEST} + ESR$$

R_{TEST} = measured value of variable resistor.

- (C) Determine Circuit Margin

$$CM = \frac{|-r|}{ESR_{AVG}}$$

ESR_{AVG} = Average ESR of typical crystal lot.

- (D) RESULT:

For an optimally designed circuit the 'Negative Resistance' would be better than -100 ohms; while the Circuit Margin would be greater than 10. A Circuit Margin between 5 to 10 would be acceptable. A Circuit Margin below 5 will have 'start-up' problems and failures in manufacturing and in the field will occur.

TOUCH HERE WITH PROBE ONLY FOR WAVE SHAPE

ADD A VARIABLE RESISTOR IN SERIES TO CRYSTAL

NOTE: The oscillator schematic shown here is simplified for the purpose of determining negative resistance. Feedback resistor and phase shift resistor may be integrated or can be added externally. Both are considered to have been defined properly.