Homework #5 Solution Set

(17 points - 1 per problem)

13. A certain quartz crystal has the following parameters: Ls=1.38H, Cs=.019 pF, Rs=68 W, and Cm = 4.9 pF. Calculate the following:
a) The series-resonant frequency
b) The crystal's terminal resistance at series resonance
c) The parallel-resonant frequency
d) The Q at series resonance
*e) The pole-zero spacing, in Hz***.**

a) $$f_s = \frac{1}{2p\sqrt{L_s C_s}} = \frac{1}{2p\sqrt{(1.38H)(0.019pF)}} = \underline{\underline{982.887KHz}}$$

b) Zt @ Series Resonance is approximately Rs, or <u>68 Ohms</u>.

c) $$C_t = \frac{C_s C_m}{C_s + C_m} = \frac{(.019pF)(4.9pF)}{(.019pF + 4.9pF)} = .01892661pF$$

$$f_p = \frac{1}{2p\sqrt{L_s C_t}} = \frac{1}{2p\sqrt{(1.38H)(.01892661pF)}} = \underline{\underline{984.791KHz}}$$

d) $$Q_s = \frac{X_s}{R_s} = \frac{X_L}{R_s} = \frac{2pf_s L_s}{R_s} = \frac{(2p)(982.887KHz)(1.38H)}{68\Omega} = \underline{\underline{125{,}330}}$$

e) $$Pole-Zero-Spacing = f_p - f_s = 984.791KHz - 982.887KHz = \underline{\underline{1.904KHz}}$$

*14. Repeat the calculations of problem 13 for a crystal with Ls=1.05H, Cs=.029 pF, Rs=73 W, and Cm = 5.5 pF***.**

a) $$f_s = \frac{1}{2p\sqrt{L_s C_s}} = \frac{1}{2p\sqrt{(1.05H)(0.029pF)}} = \underline{\underline{912.067KHz}}$$

b) Zt @ Series Resonance is approximately Rs, or <u>73 Ohms</u>.

c) $$C_t = \frac{C_s C_m}{C_s + C_m} = \frac{(.029pF)(5.5pF)}{(.029pF + 5.5pF)} = .02884789pF$$

$$f_p = \frac{1}{2p\sqrt{L_s C_t}} = \frac{1}{2p\sqrt{(1.05H)(.02884789pF)}} = \underline{\underline{914.468KHz}}$$

d) $$Q_s = \frac{X_s}{R_s} = \frac{X_L}{R_s} = \frac{2pf_s L_s}{R_s} = \frac{(2p)(912.067KHz)(1.05H)}{73\Omega} = \underline{\underline{82{,}428}}$$

e) $$Pole-Zero-Spacing = f_p - f_s = 914.468KHz - 912.067KHz = \underline{\underline{2.401KHz}}$$

*15. How can it be determined whether a crystal is being used in series or parallel mode in a crystal oscillator circuit***?**

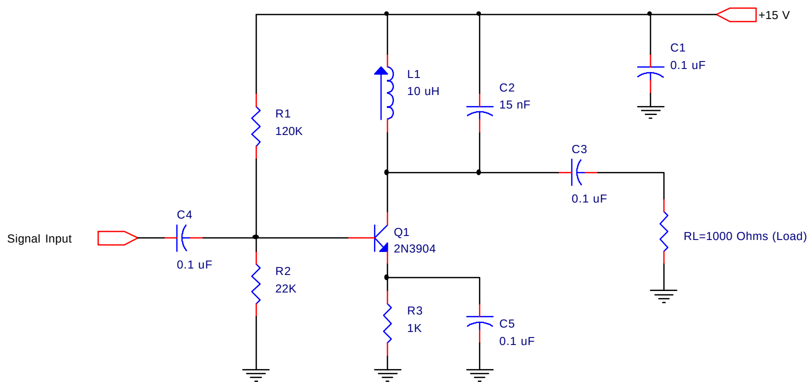
If the crystal can be replaced with a short (and the circuit continues oscillating), the circuit is operating in series mode. If the crystal is open-circuited and circuit can still

oscillate, the mode is series. [Where there is no discrete LC tank in the circuit, this rule may not apply quite so easily, as in a common-collector Colpitts crystal oscillator.]

*16. Why must component leads and wires be kept as short as possible in RF circuits***?**

Keeping leads short prevents them from being antennas, which is highly undesirable (causes unwanted coupling and feedback). Long leads also have extra stray capacitance and inductance, which degrades circuit operation.

*17. What would the operating frequency of the amplifier of figure 4-24 be if L1=100 uH and C2=470 pF***?**



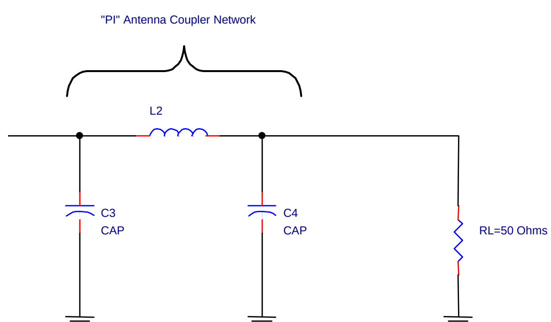
[Figure 4-24]

$$f = \frac{1}{2p\sqrt{LC}} = \frac{1}{2p\sqrt{(100mH)(470\,pF)}} = \underline{\underline{734.1KHz}}$$

*18. Why is trickle bias used in a class AB amplifier***?**

Trickle bias is used to eliminate crossover distortion, which is caused when both active devices turn off at zero crossing.

*19. Draw the schematic diagram of a PI low-pass section as used in an antenna coupler***.**



The above circuit is a single PI network. You can tell when a PI network is designed for a 1:1 impedance match; the two capacitors will be equal values in this case.

*20. What three functions are accomplished by the PI network following a class C power amplifier***?**

The three functions are (1) Impedance matching, (2) Harmonic attenuation, and (3) Reconstruction of the carrier sine wave, which is really the time-domain explanation for harmonic attenuation -- removing the harmonics leaves only the fundamental carrier sine wave.

*21. What peak-to-peak collector voltage should be present in a properly-functioning class C power amplifier***?**

The peak-to-peak collector voltage should be approximately twice *Vcc* **when the amplifier is being driven to full output.**

*22. If the modulator of figure 4-32 produces 30 Watts when dead-keyed, what audio information power is required in order to achieve 100% modulation***?**

The information power is approximately equal to the sideband power:

$$P_{audio} = P_{sidebands} = P_c(\frac{m^2}{2}) = 30W(\frac{1^2}{2}) = \underline{\underline{15Watts}}$$

23. Convert the following power levels into dBm units:
a) 1 mW ; b) 2 mW ; c) 10 mW ; d) 20 mW ; e) 200 mW ; f) 4 W ; g) 100 **W**

a) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{1mW}{1mW}\right) = \underline{\underline{0dBm}}$

b) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{2mW}{1mW}\right) = \underline{\underline{+3dBm}}$

c) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{10mW}{1mW}\right) = \underline{\underline{+10dBm}}$

d) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{20mW}{1mW}\right) = \underline{\underline{+13dBm}}$

e) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{200mW}{1mW}\right) = \underline{\underline{+23dBm}}$

f) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{4W}{1mW}\right) = \underline{\underline{+36dBm}}$

g) $dBm = 10\log\left(\frac{P}{1mW}\right) = 10\log\left(\frac{100W}{1mW}\right) = \underline{\underline{+50dBm}}$

*24. A certain stage has a power gain of 10 dB, and an input power of 23 dBm. Express the output power in dBm units***.**

The power output can be calculated by adding the dB units:

P_{out} **(dBm) =** $P_{in}(dBm) + G_{dB}$ **= 23 dBm + 10 dB = 33 dBm**

*25. What power, in Watts, corresponds to a level of 33 dBm***?**

The dBm power level can be converted back to a power level by solving equation (4-5) for power:

(4-5) $dBm = 10\log\left(\frac{P}{1mW}\right)$

$$P = 1mW \times 10^{\left(dBm/10\right)} = 1mW \times 10^{\left(33dBm/10\right)} = \underline{\underline{2W}}$$

The same result can be obtained by factoring the decibel units. 33 dBm is really 10 dB + 10 dB + 10 dB + 3 dB above 1 mW, which is 1 mW x 10 x 10 x 10 x 2, which is 2 Watts.

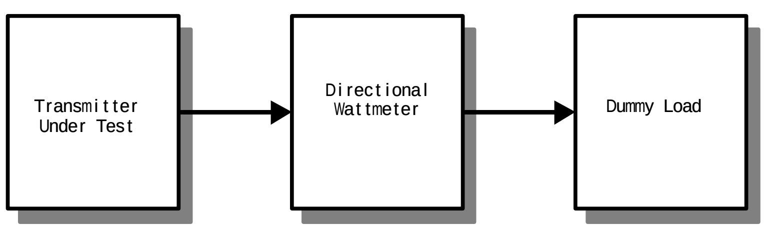
*26. What are the two hazards associated with transmitter repair work***?**

The two primary hazards are exposure to high voltages and radio frequency field exposure.

*27. What is a transceiver***?**

A transceiver is a combination of a receiver and transmitter in one package.

*28. Draw a diagram showing how a directional wattmeter can be used to measure transmitter power output***.**



[Figure 4-36]

*29. What must be connected between a transmitter and a spectrum analyzer (or frequency counter) in order to prevent equipment damage***?**

An RF Attenuator or RF Sampler must be connected between the units. Both units reduce the power level in a calibrated manner so that the spectrum analyzer does not receive more input power than it can handle (usually 1 Watt or less).