PARALLEL RESONANT CIRCUITS

PARALLEL RESONANT CIRCUIT ANALYSIS

PROBLEMS-SOLUTIONS

BANDPASS FILTERS

QUALITY

PARALLEL RESONANT CIRCUIT OPERATION

MEASURING RESONANCE

FINDING HALF-POWER POINTS

FINDING BANDWIDTH-QUALITY (Q)

FIGURE 1 (SLIDE EP30AL-S01)

OBJECTIVE PAGE

OBJECTIVES

Given parallel resonant circuit problems, determine circuit characteristics, definition, or type Seventy percent or more must be answered correctly

Given a parallel resonant circuit, function generator, and TS-352 multimeter, measure and/or determine resonant frequency, lower bandpass frequency, upper bandpass frequency, band width, and quality All work must be with a 70% or greater accuracy

FIGURE 2 (SLIDE EP30AL-S02)

The objectives for this lesson are shown in FIGURE 2 (SLIDE EP30AL-S02)

In your last lesson you studied series resonant circuits. You were taught about their characteristics at resonance, above resonance and below resonance. Also you were taught how to measure resonant frequency. In this lesson you will be studying parallel resonant circuits and you will see that there are many similarities between series and parallel resonant circuits.

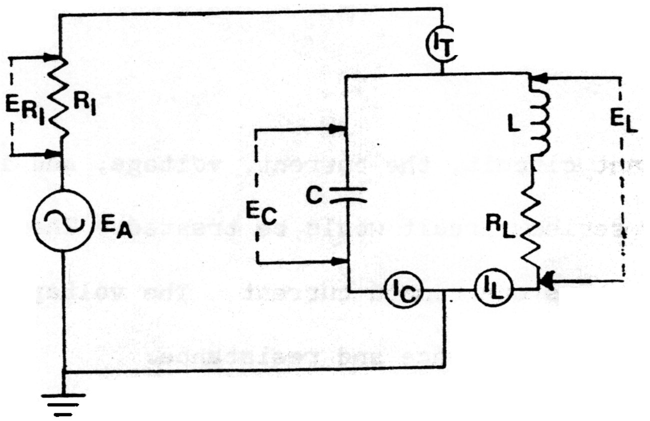


FIGURE 3

The following discussion of parallel resonance is based on the parallel resonant circuit shown in FIGURE 3.

In the circuit in FIGURE 3, the following notations will be used:

E_A = generator voltage

R_1 = generator resistance in ohms.

I_T = total current flow in amperes.

I_c = current through capacitor in amperes

I_L = current through inductor in amperes

R_L = internal resistance of inductor in ohms

L = inductance of inductor in henrys.

C = capacitance of capacitor in farads.

An important consideration in the study of parallel resonance is the circuit condition which produces resonance.

In the series resonant circuit, the current, voltage, and impedance are treated as any series circuit would be treated. There will be one path for current, thus one common current. The voltage will be dependent of the value of reactance and resistance

The parallel resonant circuit must be treated exactly as any other parallel circuit. It must be realized that the voltage is the same for each branch of the parallel circuit. The current will be the variable. Some conclusions can be drawn:

<u>First</u>, in a series circuit, <u>current is fixed,</u> but <u>voltage is variable</u>.

Second, in a parallel circuit, voltage is fixed, but current is variable.

Third, the series resonant circuit has a very low impedance at resonance

Fourth, the parallel resonant circuit has a very high impedance at resonance.

Fifth, the circuit will be analyzed on the basis of the variable:

Series resonance - voltage,

Parallel resonance - current.

The parallel resonant circuit is referred to as a "TANK" circuit. This is due to the storage and release of energy by the capacitor and inductor.

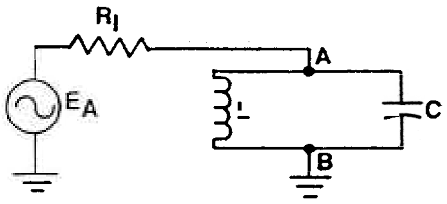


FIGURE 4

The construction of the parallel resonant (tank) circuit is shown in FIGURE 4. The inductor (coil) is connected in parallel with the capacitor. This means that whatever voltage appears across the coil will be the same across the capacitor and are both equal to the voltage AB, across the tank circuit.

Reviewing the definition of a coil - it opposes a change in current and stores energy in the magnetic field.

Reviewing the definition of a capacitor - it opposes a change in voltage and stores energy in its electrostatic field

The analysis of a tank circuit in this lesson will be done on the basis that the circuit components are pure L and C, except where resistance is introduced for a load simulating the circuit that would be connected to the tank.

At resonance, as in the series resonant circuit, the inductive reactance (X_L) and capacitive reactance (X_C) are equal. From this fact we can solve for frequency, that is,

$$X_L = X_C$$

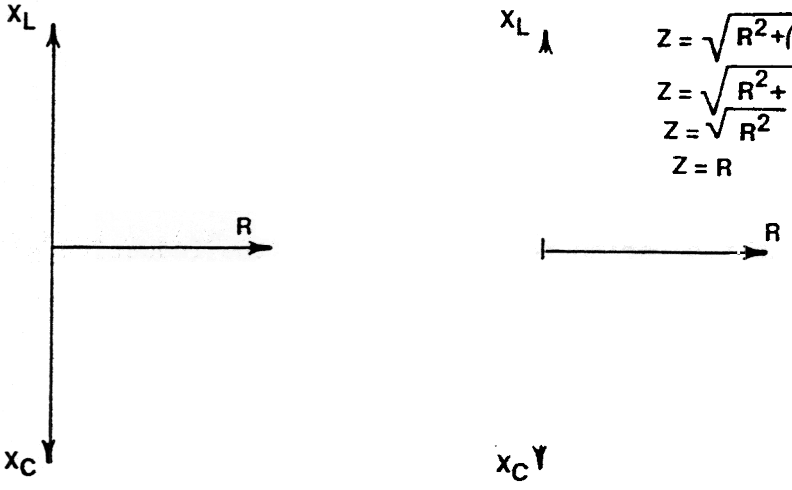
$$2 \pi FL = \frac{1}{2 \pi FC}$$

From this solving for f,

$$f = \frac{1}{2 \pi \sqrt{LC}}$$

Since this particular frequency, resonance, occurs at only one frequency this condition is defined as resonance.

In this state, at resonance, the circuit will act resistively because $X_L = X_C$ and they are 180 degrees out of phase as shown vectorally in FIGURE 5.

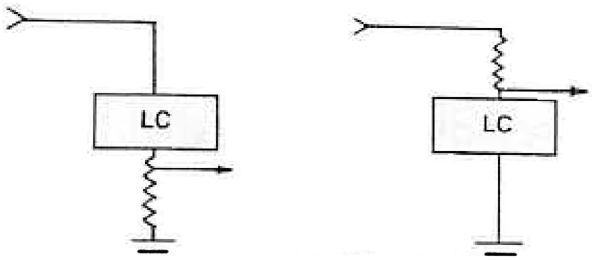


$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$Z = \sqrt{R^2 + (0)^2}$$
$$Z = \sqrt{R^2}$$
$$Z = R$$

A resonant LC circuit can be connected as one side of an AC voltage divider to pass or reject a band of frequencies.

This band of frequencies can be measured in terms of its bandwidth, and "Q", or "Quality", as will be shown further in the lesson.

The resonant frequency can be calculated from the size of the coil and the capacitor used. Either of the two formulas in FIGURE 6, can be used for this calculation.



$$F_R = \frac{1}{2\pi\sqrt{LC}} \quad \text{OR} \quad F_R = \frac{.159}{\sqrt{LC}}$$

FIGURE 6

FIGURE 7, shows one way of connecting a parallel circuit between the source of a signal and the output to the next circuit. Note that it is connected like one of the series resonant filters you have studied before

The vector diagram in FIGURE 7 shows the relationship between the reactances, the resistance and the total impedance of the circuit How do you know that the diagram represents a circuit tuned to resonance?

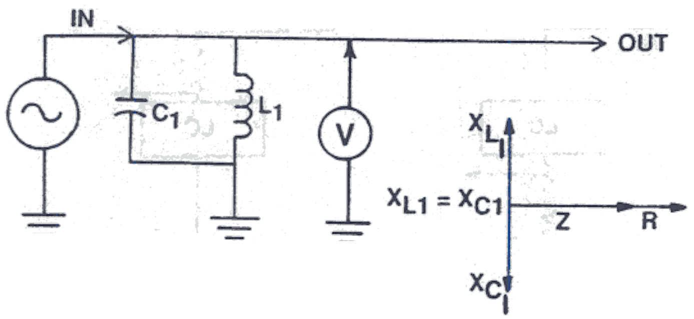


FIGURE 7

The inductive and capacitive reactance are equal to each other and the impedance is the resistance. Therefore, the circuit is at resonance.

The student is familiar with vector diagrams showing a shift in phase between the voltages in a series circuit, with current being the same. This shift in phase is true because current in a series circuit is the same throughout the circuit

In a parallel circuit is it the current or the voltage which is the same for the components which are in parallel with each other?

As shown by the voltmeter symbol in FIGURE 7, the same voltage is felt across C_1 and L_1 at the same time, because they are both connected to the same point.

SOMETHING has to shift in a reactive circuit, because the voltage leads the current by 90 degrees in a coil, and the voltage lags the current by 90 degrees in a capacitor. So, if you can't write voltage to replace the reactances in the vector diagram, <u>what CAN you write</u>? What does shift, in and out of phase, in parallel reactors?

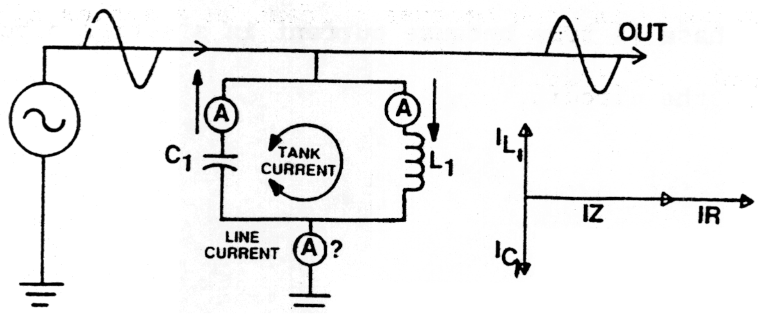


FIGURE 8

<u>It is the current</u> which shifts. At resonance, the currents in the capacitor and inductor are 180 degrees out of phase with each other, as shown by the arrows beside their ammeters.

At resonance, the current flows back and forth in a circle within the tuned circuit, rather than through it, as shown by the double-headed arrow inside the tuned circuit.

The parallel tuned circuit is called a "Tank" circuit, because energy is stored within it, in the form of an oscillating current like water is stored in a water tank.

If all of the energy of the AC sine wave is used up in maintaining the oscillating current within the tank, how much AC current does it cause to flow in the line, as shown by the meter at the bottom of the tank?

At resonance, there would be NO AC line current flowing. The opposing currents in the tank, which would be 180 degrees out of phase with each other, would cancel each other so far as line current is concerned.

If then, there is no current flowing through the tank into the line at resonance, is the tank circuit impedance high or low at resonance? Refer to Ohm's Law to help figure out the answer.

$E = IZ$ $\qquad\qquad$ $Z(\infty) = \dfrac{E}{I=0}$

$\uparrow$

The Ohms Law formula which was studied first as E = IR, can be used for impedance as well. E = IZ, as shown above, is used to solve for impedance, when given voltage and current. It can be seen by the second formula that if the current drops to zero at resonance, then impedance at resonance rises to infinity

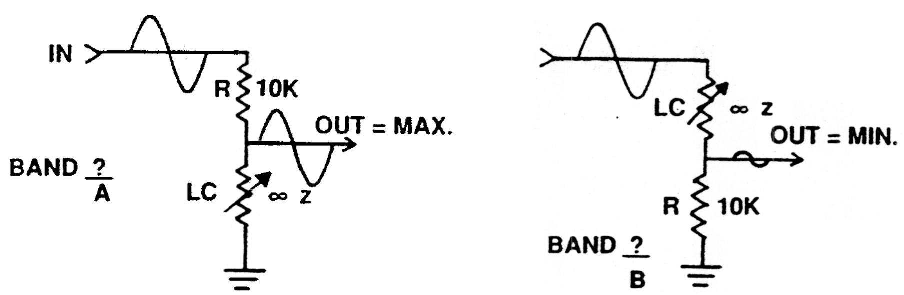


FIGURE 9

Now we are back to something you have studied before. The tuned LC circuit can be placed in series with a fixed resistor to form a voltage divider. The output would depend upon the relative opposition of the LC circuit and the resistance.

Keep in mind that a parallel tuned circuit at resonance is the opposite of a series tuned circuit. At resonance, the parallel tuned tank circuit has practically infinite impedance. Therefore, all the signal voltage will be felt across the tank. At resonance, tank will act almost like an open circuit to the signal.

With this characteristic of having almost infinite opposition at resonance in mind, compare circuits "A" and "B", in FIGURE 9, and decide which one is a bandpass circuit, and which one is a band reject circuit.

Circuit "A" is the bandpass tuned circuit because the infinite impedance being at the bottom of the voltage divider will result in a maximum signal out at resonance. Circuit "B" has the infinite impedance at resonance at the top, so, at resonance, none of the signal can get through it to the output.

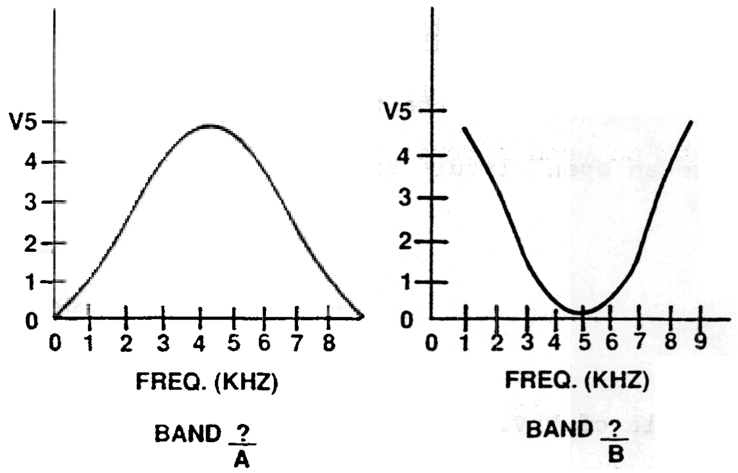


FIGURE 10

There should be no problem in the labeling of these graphs of output voltage. Which graph represents a bandpass circuit and which one represents a band reject circuit, in FIGURE 10.

Graph "A" is for a bandpass circuit. Because the tank circuit has a high impedance at resonance, the voltage across it peaks at the resonant frequency. In a bandpass circuit, the output is taken across the tank circuit.

Graph "B" is for a band reject circuit. Its output is taken across the resistance which is in series with the tank. Because the tank has high impedance at resonance, it drops all of the signal voltage, leaving no voltage to be felt across the output load resistor.

As mentioned earlier in the lesson the quality (Q) of the tank circuit will tell us several things essential to the best quality filter.

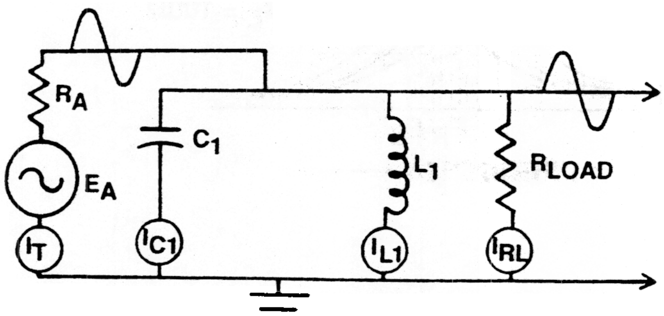


FIGURE 11

FIGURE 11, along with FIGURE 12, will show the result of going from infinite resistance to a small resistance for the load. It can be seen that Quality (Q) is a function of bandwidth (BW) and BW is dependent on the upper (F_2) and lower (F_1) bandpass frequencies

The circuit and the output of a bandpass filter is shown in FIGURES 11 and 12. It has been explained that impedance is maximum current is minimum and the output voltage is maximum at resonance.

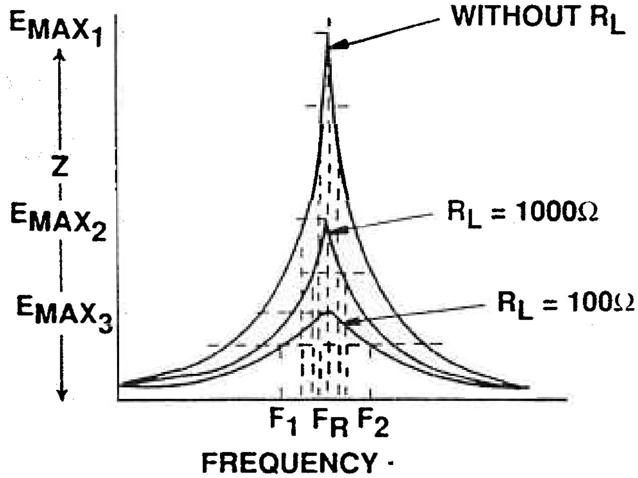


FIGURE 12

When the load R_{L_2} is changed from infinite, no load, to 1000 ohms (R_{L_2}) as shown in FIGURE 12, a third path for current flow will be established through the load, I_{RL_2}. This in turn will increase total current through R_A. The voltage drop across R_A will increase reducing the peak output shown at R_{L_2} = 1000 ohms, or E_{MAX2}.

To calculate the 1/2-power point voltage, the following formula would be used:

$$E_{1/2PW} = E_{MAX2} \times .707.$$

Thus establishing the lower (F_1) and the upper (F_2) bandpass frequencies.

The signal generator amplitude can be reduced to give an $E_{1/2PW}$, voltage to find F_1 and F_2. From series resonance, bandwidth (BW) = $F_2 - F_1$ and from this

$$Q = \frac{F_R}{BW} \text{ or } \frac{F_R}{F_2 - F_1}$$

The other method can be used effectively here to show what happens to Q as the load changes:

Without R_L

$$Q = \frac{R_L}{X_L} = \frac{\infty}{X_L} = \infty$$

With R_L = 1000 ohms

$$Q = \frac{R}{} = \frac{1000}{X_L}$$

With R_L = 100 ohms

$$Q = \frac{R}{} = \frac{100}{X_L}$$

From this we can see how the Q, goes down as the resistance goes down. The use of the word LOAD, means that a larger load requires a resistance and a higher current. No load means to have infinite resistance and minimum current.

To summarize, the construction of a Parallel Resonant (tank) cir- was shown, with the inductor (coil) connected in parallel with the capacitor

The resonant frequency was determined on the basis of $X_L = X_C$, producing

$$F = \frac{1}{2 \pi LC}$$

The location of the 1/2-power points were determined by taking 0.707 times the maximum voltage, allowing the upper and lower band-pass frequencies to be located.

The impedance was found to be maximum at resonance; sometimes referred to as anti-resonance

Having determined the bandwidth, the Q_1 of the circuit was calculated.

The loading effect on the circuit, was discussed and the Q_1 was shown to decrease as the load was increased.

d. SUMMARY:

Circuit construction.

Circuit analysis at resonance.

Circuit analysis above resonance.

Circuit analysis below resonance.

Circuit applications.

Formulas.

2. APPLICATION: (NOTE: Issue PE Worksheet to students. TIME: 50 Min

a. Directions to instructor.

(1) Supervision