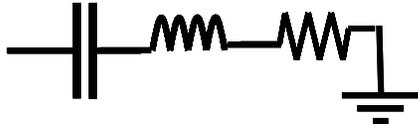


Due Friday, 1/19 at 5 pm. Homework box on 3<sup>rd</sup> floor of HFH

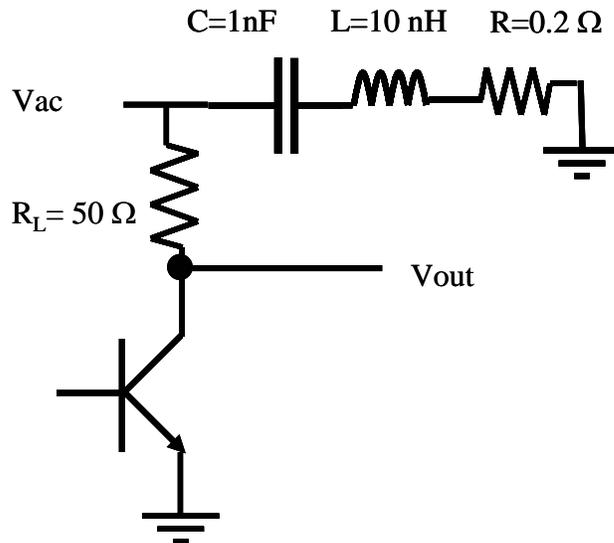
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1. A leaded 1 nF capacitor was found to have the equivalent circuit as shown.

$$C=1\text{nF} \quad L=10\text{ nH} \quad R=0.2\ \Omega$$



- Determine the unloaded  $Q$  at 10 MHz and the self resonant frequency.
- Calculate and sketch the magnitude of the impedance of the capacitor vs frequency.
- The capacitor is used as a bypass cap in the amplifier circuit below. Plot  $|V_{ac}/V_{out}|$  vs frequency. If  $V_{out} = 1\text{ V ac}$ , find the minimum and maximum values of  $V_{ac}$ .



- How would you modify the circuit so that the maximum  $V_{ac}$  at 10 MHz is less than 1 mV?  
1 mV at 100 KHz?

**Bypass capacitors.** You have seen how wires act as inductors. About 16 nH per inch is typical. Connections to a power supply through wires of any significant length produce a high impedance at radio frequencies. Thus, any illusion that VCC or VDD is at AC ground on the circuit should be rejected. Even with short leads, a typical power supply does not present low output impedance at radio frequencies. Therefore, a local AC ground with low impedance is needed right at the circuit itself to keep the AC signal out of the power supply (VCC or VDD) connection on the circuit board or module or IC chip. This is the function that the bypass capacitor performs.

In order for the capacitor to be effective in attenuating AC signals on the DC voltage line, it must present low impedance at any frequency where the circuit under design exhibits gain. This is to avoid oscillation problems due to an unintended positive feedback loop through the power or ground connection. Thus, the capacitor must be selected so that both real and imaginary parts are small. The series resistance and series inductance are the main factors limiting the effectiveness. Choosing chip capacitors over leaded capacitors helps reduce inductance significantly. Low series resistance (ESR) is also important. Often, identical capacitors are connected in parallel to reduce both L and R while also increasing C.

Using a larger single capacitor is often less effective than using several smaller ones in parallel. This is especially true of electrolytic or tantalum capacitors which have large series inductances. These are fine for low frequency bypassing (below 100 KHz) but worse than useless at radio frequencies. If the bypass impedance must extend to such low frequencies, then a multi-stage bypass is needed that includes both ceramic (low inductance) and electrolytic/tantalum capacitors.

2. It is very convenient when analyzing circuits with nonideal components to transform between a series and parallel equivalent representation. There is a simple transformation for this that is accurate at a single frequency. In many cases, this is sufficient.

Show that

$$R_P = R_S (Q^2 + 1)$$

$$X_P = X_S \left( \frac{Q^2 + 1}{Q^2} \right)$$

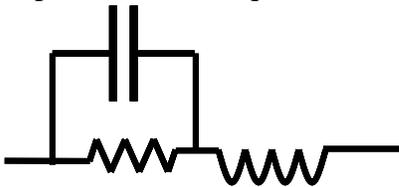
where  $X_P$  and  $X_S$  are the reactances of the parallel and series circuits respectively.

Note: This transformation will prove to be useful for simplifying hand analysis.

3. A series RL network consists of a 10 nH inductor and a 2 ohm resistor. Use the above transformation to find an equivalent parallel network with the same impedance at 1 GHz.

4. Calculate the impedance and reflection coefficient associated with the network in problem 3.

5. The impedance of a resistor was measured over frequency as shown below. Using the equivalent circuit model for the resistor, derive component values that make the impedance of the equivalent circuit match the data.



freq	Zin1
10.00 MHz	20.000 + j0.478
110.0 MHz	19.996 + j5.253
210.0 MHz	19.986 + j10.028
310.0 MHz	19.970 + j14.804
410.0 MHz	19.947 + j19.581
510.0 MHz	19.918 + j24.359
610.0 MHz	19.883 + j29.138
710.0 MHz	19.842 + j33.918
810.0 MHz	19.795 + j38.700
910.0 MHz	19.742 + j43.484

6. Plot the source voltage V1 and load voltage VL as a function of time for the network below.

