1.6 How the PLL can be modulated? Explain how to set the PLL loop bandwidth.

Solution

For FM signal generation at the VCO output, the modulation signal may be directly injected to VCO tuning input. The fast varying signal than PLL loop bandwidth can modulate VCO successfully, however the slow varying one will be compensated by the PLL and does not present the modulated output.
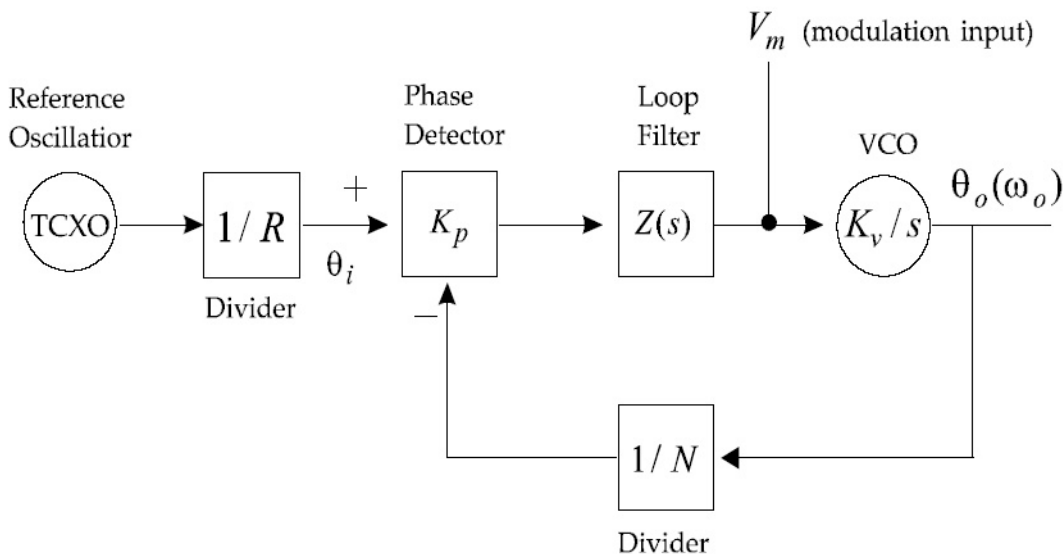

Figure 1.4 FM modulation using PLL

CHAPTER 2 PROBLEMS

2.1 A company A fabricates a thin film resistor whose sheet resistivity is 50 ohm/square and in the case of a company B, an identical thin film resistor has a sheet resistivity of 100 ohm/square. What is the difference between the processes of the two companies? Furthermore, given that the material's volume resistivity is ρ and its thickness is t, find its sheet resistivity.

Solution

The thickness of the resistor material of the company A is two times thicker than that of the company B.

The resistance R with a volume resistivity of ρ and a thickness of t is

$$R = \rho \frac{L}{tW} = R_S \frac{L}{W}$$

Thus

$$R_S = \frac{\rho}{t}$$

2.2 Given that the sheet resistivity is 50 ohm/(square) and we want to design a 100 ohm resistor. If the current flowing in this resistor is 2 mA, find its minimum width. Its rated current per width is 0.5 mA/μm.

Solution
The minimum width W_{min} theta can sustain 2mA is

$$W_{min} = \frac{2(\text{mA})}{0.5(\text{mA/μm})} = 4(\text{μm})$$

Taking W_{min} into consideration, the width is determined as 10 μm. Thus the length should be 20 μm to yield 100 ohm resistor.

2.3 The dielectric material of a MIM capacitor is Silicon Nitride and its dielectric constant is 7.2. If the area is 50 μm^2 find the thickness of a 0.53 pF capacitor. In addition, find the capacitance per unit area in (F/ μm^2).

Solution

$$C = 0.53(\text{pF}) = \frac{\varepsilon_o \varepsilon_r A}{t} = \frac{8.854(\text{pF/m}) \times 7.2 \times 50(\text{μm}^2)}{t(\text{μm})}$$

$$t = \frac{8.854 \times 10^{-6} \times 7.2 \times 50}{0.53} = 6.0 \times 10^{-3}(\text{μm}) = 6.0(\text{nm})$$

The sheet capacitance C_S is

$$C_S = \frac{0.53(\text{pF})}{50(\text{μm}^2)} = 10.6 \ (\text{fF} / \text{μm}^2)$$

2.4 In the equivalent circuit of an inductor such as that in **Fig**. 2.10, show that the approximate magnitude of the impedance at resonance is

$$|Z_{max}| = \frac{(\omega_o L)^2}{R}$$

$$\omega_o = 1 / \sqrt{LC}$$

Solution
The impedance of $Z(\omega)$ of the inductor equivalent circuit

$$Z(\omega) = \frac{(R + j\omega L)\dfrac{1}{j\omega C}}{R + j\left(\omega L - \dfrac{1}{\omega C}\right)}$$

Near the resonance $Z(\omega)$ can be approximated as

$$Z(\omega) = \frac{(R + j\omega L)\dfrac{1}{j\omega C}}{R + j\left(\omega L - \dfrac{1}{\omega C}\right)} \cong \frac{(R + j\omega_o L)\dfrac{1}{j\omega_o C}}{R} \cong \frac{(j\omega_o L)\dfrac{1}{j\omega_o C}}{R} = \frac{(\omega_o L)^2}{R}$$

2.5 In this text, we have covered the method of extracting the equivalent circuit of a capacitor from $|Z(\omega)|$ characteristics obtained from impedance analyzer such as that shown in **Fig**. 2.8. The impedance of the equivalent circuit of a capacitor is

$$Z(\omega) = R + jX = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Using this, the real and imaginary parts for frequency can be obtained by graphical representation. Then show that the approximate impedance near the resonant frequency ω_o is

$$Z(\omega) \cong R + j2L(\omega - \omega_o)$$

Solution

$$Z(\omega) = R + jX = R + j\left(\omega L - \frac{1}{\omega C}\right) = R + j\omega L\left(1 - \frac{1}{\omega^2 LC}\right) = R + j\omega L\left(1 - \frac{\omega_o^2}{\omega^2}\right)$$

$$= R + j\omega L\left(\frac{\omega^2 - \omega_o^2}{\omega^2}\right) = R + jL\frac{(\omega - \omega_o)(\omega + \omega_o)}{\omega}$$

$$= R + jL\frac{(\omega - \omega_o)(\omega + \omega_o)}{\omega} \cong R + j2L(\omega - \omega_o)$$

2.6 Similar to Problem 2.5 above, for a parallel resonant circuit, show that the admittance near the resonant frequency, $Y(\omega)$ is given by

$$Y(\omega) \cong G + j2C(\omega - \omega_o)$$

Solution
The admittance of a parallel resonant circuit can be expressed as

$$Y(\omega) = G + jB = R + j\left(\omega C - \frac{1}{\omega L}\right)$$

This is similar to $Z(\omega)$ in problem 2.5. Thus,
$$Y(\omega) \cong G + j2C(\omega - \omega_o)$$

2.7 (ADS Problem) In Example 2.2, the equivalent circuit of the 10 pF capacitor from Murata are obtained using the slope of the reactance versus frequency and resonance frequency such as

$$\left.\frac{\partial X}{\partial f}\right|_{f_o} = 4\pi L \text{ and } \omega_o = 1/\sqrt{LC}.$$

In another way, the equivalent circuit can be obtained using the impedance plot in log-log scale. Compute the equivalent circuit values using ADS.

Solution
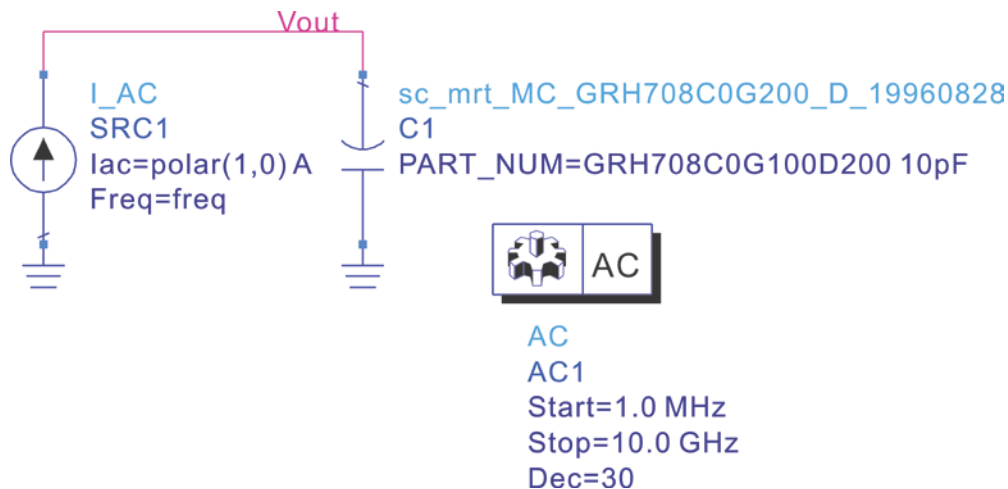Fig. 2.1 shows the simulation schematic for impedance plot.

Figure 2.1 Simulation schematic setup for impedance plot. Here log sweep is set to 30 points/decade

The simulated impedance is shown in Fig. 2.2. Using the impedance values at markers, the series equivalent circuit values can be obtained. From the minimum value, the value of R can be obtained and $R=0.363 \ \Omega$. The following equations for C and L are written in the Display window.

Eqn   C=1/(2*pi*m2*indep(m2))
Eqn   L=m3/(2*pi*indep(m3))

The computed $C = 9.9$ pF and $L=0.96$ nH. The values of R, C, and L are close to those computed in Example 2.2 but shows little differences. The error of R is mainly due to the sparse sweep points. The differences of the other values are believed to come from different approximations in the computation of element values.
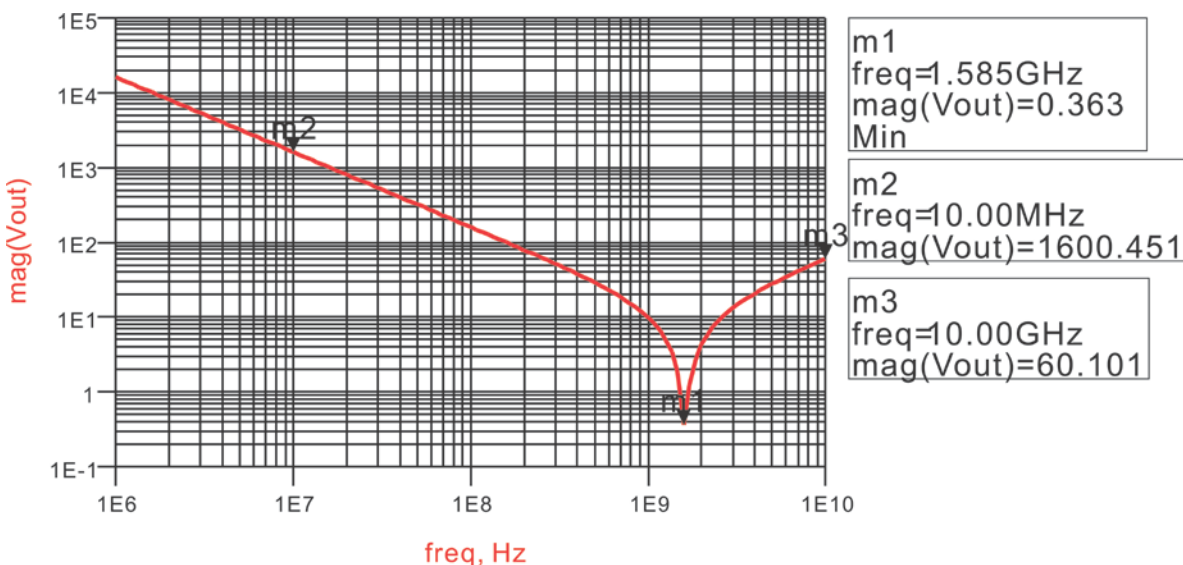

Figure 2.2 Simulated impedance for the Murata 10 pF capacitor.