PROBLEMS

3-1.1. Show that the maximum instantaneous energy stored in the circuit of Fig. 3-1 at resonance is $L(I_{max})^2/2$. Use this value in (3-4) to verify (3-5).

3-1.2. For the circuit shown in Fig. 3-1, prove that $V_C = QV$ at the resonance frequency.

3-1.3. In the circuit of Fig. 3-1, let $L = 100\ \mu H$, $C = 100$ pF, and $R = 5$ ohms. Find:

(a) The resonance frequency f_o.
(b) The circuit Q at resonance.
(c) The voltage V_C at resonance if $V = 10\ \mu V$.

3-1.4. For the circuit values given in Problem 3-1.3, determine the values of the complex zeros ($\gamma = \alpha \pm j\beta$) of input impedance $Z(s)$. Sketch the zero-pole diagram and show by a graphical method that the radian-frequency interval $\omega_2 - \omega_1$ between half-power points is approximately equal to 2α, and that $\beta \approx \omega_o$. The value of Q is now approximated as $Q \approx \beta/2\alpha$. Would this approximation hold if $\beta = 3\alpha$?

3-2.1.

(*a*) The circuit of Fig. 3-5 has $R_t = 2000$ ohms, $f_o = 10^7$ Hz, and bandwidth $B = 250$ kHz. Find the values of Q_t, L, and C.
(b) If the circuit is driven with $I = 2$ mA(rms), what is the magnitude of I_C?

3-3.1. A tuned transistor amplifier requires a collector load resistance $R_t = 2000$ ohms at $f = 1.6$ MHz. The output capacitance of the transistor is $C_o = 20$ pF. A load $R_L = 5$ ohms is to be transformed to R_t with the circuit shown in Fig. P3-3.1.

(a) Assume that the coil resistance r_c is negligible. Determine the values of L and C and the bandwidth B.
(b) If the inductor in the circuit is tuned with a ferrite slug, its Q_L may be as low as 50. Find the corresponding value of r_c for the inductance value used in part (a). How will this alter the value of R_t?
(c) Let $Q_L = 50$ for the coil. Solve for new values of L and C that will produce $R_t = 2000$ ohms.

3-3.2. The circuit of Fig. P3-3.2 is to be designed to transform $R_1 = 5$ ohms

Fig. P3-3.1

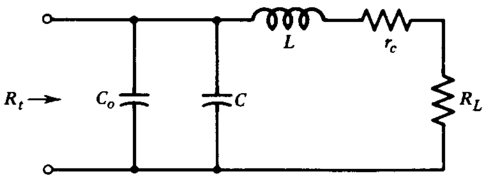
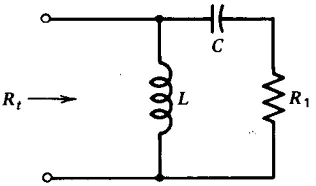


Fig. P3-3.2



to $R_t = 4\ \text{k}\Omega$ at $f_o = 20$ MHz. Assume infinite Q_L for the coil. Find the values of L, C, Q_t, and B.

3-3.3. Use the L and C values found in Problem 3-3.2, but let the coil have a value of $Q_L = 50$. Find the coil resistance r_c, and the new values of R_t, Q_t, and B.

3-3.4. If the circuit of Problem 3-3.2 is driven by a current source with internal resistance $R_s = 6\ \text{k}\Omega$, what is the bandwidth of the overall circuit?

3-3.5 Derive the *exact* expressions for ω_o and R_t found in Table 3-3.2.

3-6.1. An interstage matching network is required to transform a load resistance $R_2 = 400$ ohms into $R_1 = 1\ \text{k}\Omega$ at $f_o = 5$ MHz with bandwidth $B =$ 50 kHz. Inductance coils with $L \approx 2\ \mu\text{H}$ are desired if feasible. Neglect the coil resistance. Try the circuit of Fig. P3-6.1. Find the values of L, C_1, and C_2.

3-6.2. The values found in Problem 3-6.1 may be unsuitable. Hence a double-tapped circuit as shown in Fig. P3-6.2 is indicated. The value of R_2 is transformed up to an R_t sufficiently large to provide a reasonable value of L,

Fig. P.3-6.1

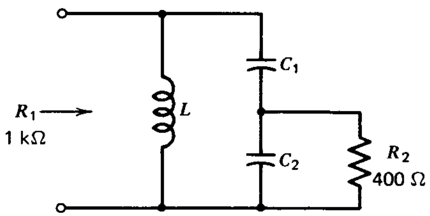
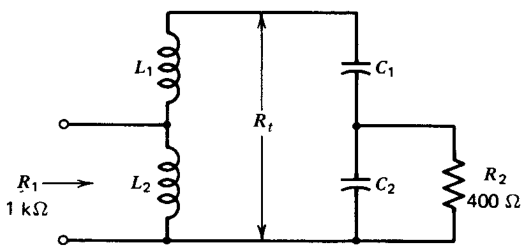


Fig. P3-6.2



and then transformed down to the desired $R_1 = 1\ \text{k}\Omega$. Assume no mutual coupling between L_1 and L_2. Find L_1, L_2, C_1, and C_2.

3.7.1. Measured inductance values for the tapped coil shown in Fig. P3-7.1 are $L_{12} = 4\ \mu\text{H}$, $L_{23} = 2\ \mu\text{H}$, and $L_{13} = 9\ \mu\text{H}$.

(a) Find the values of the mutual inductance M and the coefficient of coupling k between the two parts of the coil.

(b) If $V_{13} = 10$ volts is applied across the coil, what are the values of V_{12} and V_{23}?

3-7.2. Design a tapped-coil circuit like that of Fig. 3-16 to transform $R_2 = 10$ ohms to $R_t = 250$ ohms at $f_o = 4$ MHz. Use a coil with $L = 2\ \mu\text{H}$ and coupling coefficient $k = 0.25$. Find the tap location and necessary tuning capacitance with the help of the curves in Section 3-7.

3-7.3. Repeat Problem 3-7.2 with $R_2 = 50$ ohms, $R_t = 200$ ohms, $f_o = 30$ MHz, $L = 2\ \mu\text{H}$, and $k = 0.1$.

3-8.1. A single-tuned transformer (Fig. 3-26) is to be designed to transform $R_2 = 1\ \text{k}\Omega$ to $R_t = 10\ \text{k}\Omega$ at $f_o = 16$ MHz with bandwidth $B = 160$ kHz.

(a) Determine the values for L_1, L_2, M, k, and C for $Q_p = 1$.

(b) Repeat for $Q_p = 10$.

3-8.2. Solve Problem 3-6.1 by the use of a single-tuned transformer to see whether it offers any advantage.

3-8.3. Figure P3-8.3*a* shows two transistors coupled by an interstage matching network that is to be designed to provide a voltage gain, $|A_v| = |V_2/V_1| = 50$, from the base to the collector of $Q1$ at center frequency $f_o = 5$ MHz, with bandwidth $B = 50$ kHz. The collector load impedance for $Q2$ will be assumed identical with that for $Q1$ so that both stages have the same input impedance. Base-biasing resistors (not shown) are assumed to be so large that their effect can be ignored. For the desired operating point, $V_{CE} = 10$ V and $I_C = 1$ mA, the data sheet for the transistors gives $h_{ie} = 2500$ ohms and $h_{fe} = 100$, measured at $f = 1$ kHz. Also, for $V_{CE} = 20$ V, $I_C = 10$ mA, and $f = 100$ MHz the data sheet gives $|h_{fe}| = 3$. At $V_{CB} = 5$ V the value of $C_{obo} = 4$ pF, which represents a high-side estimate of C_μ for use in the simplified hybrid-pi equivalent circuit of Fig. 3-8.3*b*. (See Fig. 4-3 for more information on the hybrid-pi circuit.)

Fig. P3-7.1

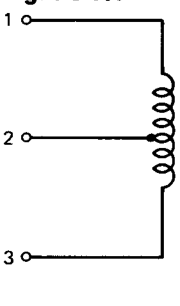
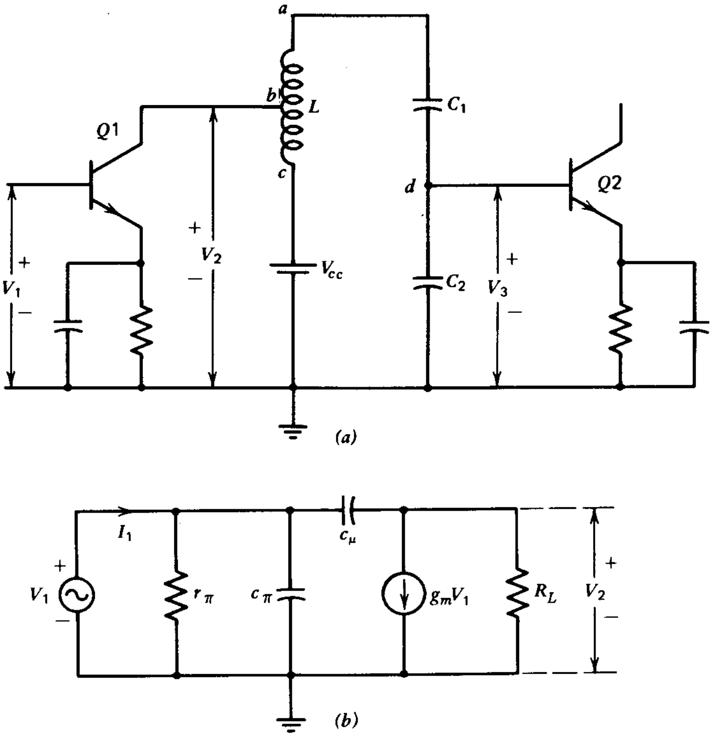


Fig P3-8.3



(a) In the hybrid-pi circuit, let $r_\pi = h_{ie} = 2500$ ohms and $C_\mu = 4$ pF. From the above data, compute the values of f_T and C_π at $I_C = 10$ mA. Then estimate the value of C_π and g_m at $I_C = 1$ mA.

(b) From the hybrid-pi model, derive expressions for the voltage gain, $A_v = V_2/V_1$, and input admittance, $Y_i = G_i + jB_i = I_1/V_1$. Use the values from part (a) to determine the load resistance R_L needed for $A_v = 50$ and the complex value of Y_i that results when this load is used.

(c) Find the equivalent parallel resistance R_p and capacitance C_p represented by Y_i. ($Y_i = 1/R_p + j\omega C_p$.) These values represent the load that the matching network sees between point d and ground in Fig. P3-8.3a. Similarly, R_L is the load presented to the collector of $Q1$ at point b.

(d) Choose a value for the inductance L. Assume that it has a value of $Q_L = 200$. Find the values of C_1 and C_2 to obtain the specified bandwidth. Take the coil losses into account but ignore the effect of the output impedance of $Q1$.

(e) Find the position of the tap (point b) on the inductor to provide the proper load for the transistor.