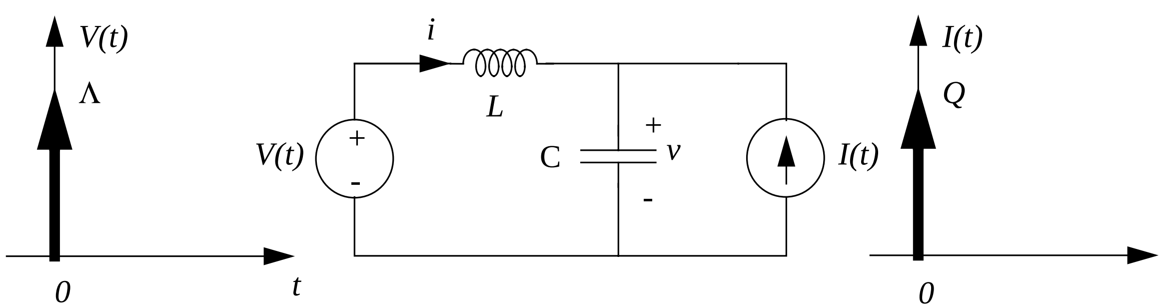
Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits

Homework #9
Handout F98-046

Issued 11/4/98 – Due 11/11/98

Exercise 9-1: The network shown below begins operation at rest at $t = 0^-$. At $t = 0$, both sources apply an impulse to the network. The voltage source impulse has area Λ, and the current source impulse has area Q. Determine $v(t)$ and $i(t)$ for $t \geq 0^+$.

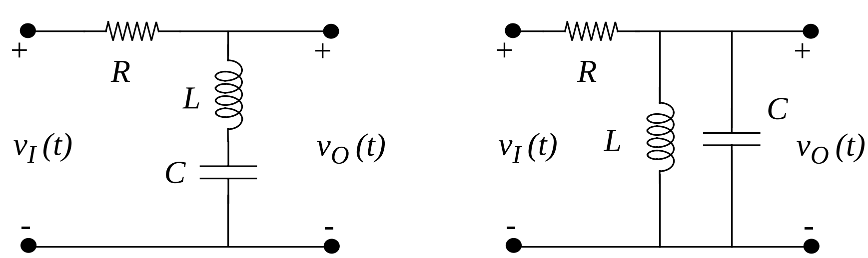


Problem 9-1: The two networks shown below are driven in sinusoidal steady state by the voltage $v_I(t) = V_I \cos(\omega t)$. Their outputs take the form $v_O(t) = V_O \cos(\omega t + \phi)$.

(A) For both networks, find V_O and ϕ as functions of V_I and ω using impedance methods.

(B) For both networks, let $R = 1000\ \Omega$, $L = 47$ mH and $C = 4.7$ nF. Plot and clearly label V_O/V_I for $2\pi \times 10^3$ rad/s $\leq \omega \leq 2\pi \times 10^5$ rad/s; use a linear axis for V_O/V_I, and a logarithmic axis for ω. You need only plot enough points to outline the dependence of V_O/V_I on ω.

(C) Describe the filtering function of each network, and how each network acts to perform its function.



Problem 9-2: This problem examines the very simple tuner for an AM radio shown below. Here, the tuner is the parallel inductor and capacitor. The injection of radio signals into the tuner by the antenna is modeled by a current source, while the Norton resistance of the antenna in parallel with the remainder of the radio is modeled by a resistor. (You will learn about antenna modeling in 6.014.) The AM radio band extends from 540 kHz through 1600 kHz. The information transmitted by each radio station is constrained to be within ± 5 kHz of its center frequency. (You will learn about AM radio transmission in 6.003.) To prevent frequency overlap of neighboring stations, the center frequency of each station is constrained to be a multiple of 10 kHz. Therefore, the purpose of the tuner is to pass all frequencies within 5 kHz of the center frequency of the selected station, while attenuating all other frequencies.

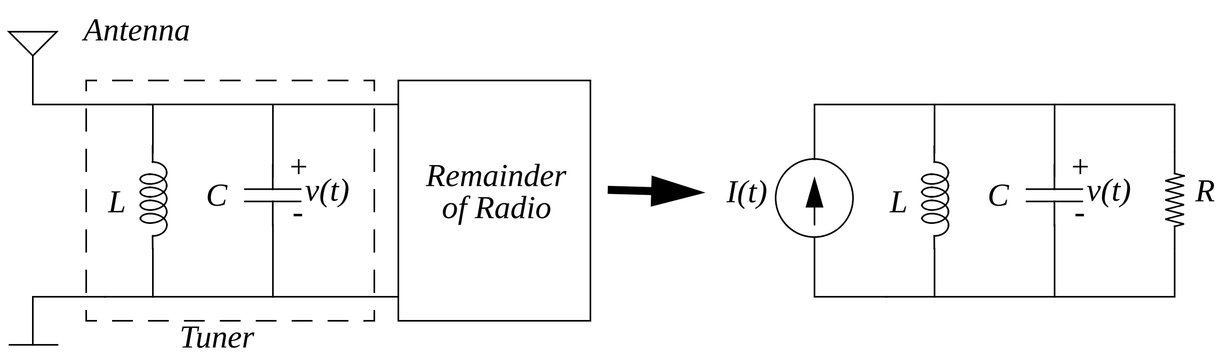
(A) Assume that $I(t) = I\cos(\omega t)$. Find $v(t)$ where $v(t) = V\cos(\omega t + \phi)$, and both V and ϕ are functions of ω. Note that $v(t)$ is the output of the tuner, namely the signal that is passed on to the remainder of the radio.

(B) For a given combination of I, C, L and R, at what frequency is V maximized?

(C) Assume that $L = 365\ \mu$H. Over what range of capacitance must C vary so that the frequency of maximum V/I may be tuned over the entire AM band. Not that tuning the frequency of maximum V/I to the center frequency of a particular station tunes in that station.

(D) As a compromise between passing all frequencies within 5 kHz of a center frequency and rejecting all frequencies outside that band, let the design of R be such that $V(1\text{ MHz} \pm 5\text{ kHz})/V(1\text{ MHz}) \approx 0.25$ when the tuner is tuned to 1 MHz. Given this design criterion, determine R.

(E) Given your design for R, determine $V(1\text{ MHz} \pm 10\text{kHz})/V(1\text{ MHz})$. Also, determine Q for the tuner and its load resistor when the tuner is tuned to 1 MHz.



Problem 9-3: This problem explores the Thevenin and Norton equivalence of networks operating in sinusoidal steady state. The resistors, capacitors and inductors in these networks are all linear, and the voltage and current sources in these networks all operate at the same frequency.

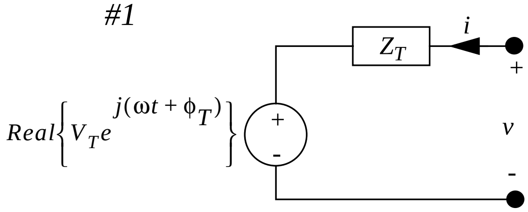
(A) Determine the relations between V_T, Z_T, ϕ_T, I_N, Z_N and ϕ_N which must exist so that the v-i relations for Networks #1 and #2 are identical at their terminals under sinusoidal steady state operation. In doing so, treat V_T, ϕ_T, I_N and ϕ_N as real constants. Note that it is also assumed that the terminal variables v and i operate in sinusoidal steady state at the frequency ω.

(B) Review the corresponding arguments for networks involving only resistors and sources, and then briefly explain why Networks #1 and #2 may serve as the Thevenin and Norton equivalents, respectively, of an arbitrary network operating in sinusoidal steady state at the frequency ω.

(C) Determine V_T, ϕ_T and Z_T in the Thevenin equivalent of Network #3.

(D) Suppose Z_T in Part C is to be implemented with either Network #4 or #5. Determine R_T and C_T in Network #4, and R_T and L_T in Network #5, in terms of R, L, C and ω. Hint: consider matching Z_T^{-1} rather than matching Z_T. Under what circumstances is Network #4 preferred over Network #5, and vice versa?

#1



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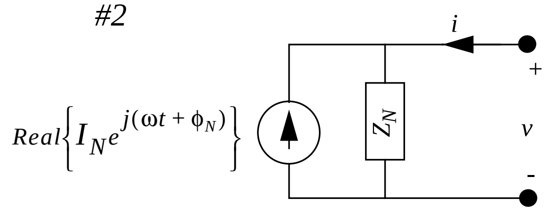

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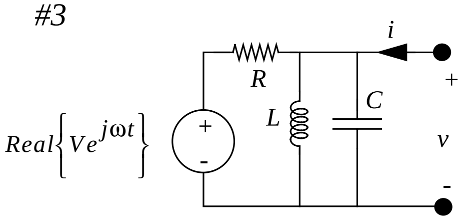

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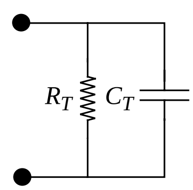

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