9–8 Find the Laplace transforms of the following functions and plot their pole-zero diagrams:

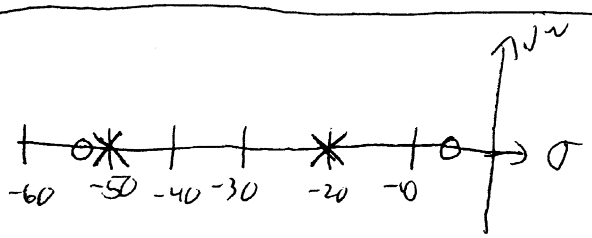
(a) $f(t) = \delta(t) + [5e^{-50t} - 15e^{-20t}]u(t)$

(b) $f(t) = [25 - 10\cos(500t)]u(t)$

$\boxed{9\text{-}8}$ (a) From Table 9-2, pg 442 & linearity priciple

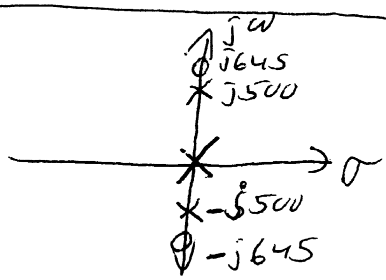
$\mathcal{L}[\delta(t)] = 1 \quad \mathcal{L}[5e^{-50t}u(t)] = \frac{5}{s+50} \quad \mathcal{L}[-15e^{-20t}u(t)] = \frac{-15}{s+20} \therefore$

$$\boxed{F(s) = 1 + \frac{5}{s+50} - \frac{15}{s+20} = \frac{(s^2+60s+350)}{(s+50)(s+20)} = \frac{(s+6.548)(s+53.45)}{(s+50)(s+20)}}$$



(b) $\mathcal{L}[25u(t)] = \frac{25}{s} \quad \mathcal{L}[-10\cos(500t)u(t)] = \frac{-10s}{s^2+500^2} \therefore$

$$\boxed{F(s) = \frac{25}{s} - \frac{10s}{s^2+500^2} = \frac{15(s^2+645.5^2)}{s(s^2+500^2)} = \frac{15(s+j645.5)(s-j645.5)}{s\cdot(s+j500)(s-j500)}}$$



9–14 **(a)** Write an expression for the waveform $f(t)$ in Figure P9–14 using only step functions and ramps.
(b) Use the time-domain translation property to find the Laplace transform of the waveform found in part (a).
(c) Verify your answer in (b) by applying the integral definition of the Laplace transformation to the $f(t)$ found in (a).

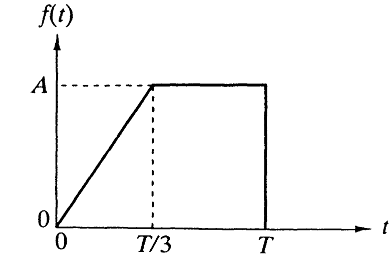


FIGURE P9–14

$\boxed{9\text{–}14}$ (a) $f(t) = \frac{3A}{T} \cdot t \cdot u(t) - \frac{3A}{T} \cdot t u(t - \frac{T}{3}) + A u(t - \frac{T}{3}) - A u(t - T$

$$\boxed{f(t) = \frac{3A}{T} t u(t) - \frac{3A}{T}\left(t - \frac{T}{3}\right)\left(u\left(t - \frac{T}{3}\right)\right) - A \cdot u(t - T)}$$

(

(b) $\mathcal{L}[\frac{3A}{T} \cdot t u(t)] = \frac{3A}{Ts^2}$ shifting by $t - \frac{T}{3}$ will multiply by $e^{-\frac{T}{3}s}$;

$\mathcal{L}[\frac{3A}{T} \cdot (t - \frac{T}{3}) \cdot u(t - \frac{T}{3})] = \frac{3A}{Ts^2}(e^{-T/3s})$. $\mathcal{L}[A u(t)] = \frac{A}{S}$;

$\mathcal{L}[A u(t - T)] = \frac{A}{s}(e^{-T \cdot s})$;

2

$$\boxed{F(s) = \frac{3A}{Ts^2} - \frac{3A}{Ts^2}(e^{-sT/3}) - \frac{A}{s}(e^{-Ts})}$$

(c) $F(s) = \int_0^{T/3} \frac{3At}{T} e^{-st} dt + \int_{T/3}^{T} A e^{-st} dt$

$$= \frac{3A}{T} e^{-st}\left[-\frac{1}{s^2} - \frac{t}{s}\right|_0^{T/3} + \frac{-A}{s} e^{-st}\Big|_{T/3}^{T}$$

$$= \frac{3A}{T}\left[e^{-sT/3}\left(\frac{-1}{s^2} - \frac{T}{3s}\right) + 1/s^2\right] - \frac{A}{s}\left(e^{-sT} - e^{-sT/3}\right)$$

1

$$= \frac{3A}{Ts^2} + e^{-sT/3}\left[\frac{-3A}{Ts^2} - \frac{A}{s} + \frac{A}{s}\right] - \frac{A}{s} e^{-st}$$

$$\boxed{F(s) = \frac{3A}{Ts^2} - \frac{3A}{Ts^2}(e^{-sT/3}) - A/s\, e^{-st}} \checkmark$$

Now, wasn't the other way a lot easier???

9–18 Find the inverse transforms of the following functions and sketch their waveforms for $\alpha > 0$:

$$\text{(a) } F_1(s) = \frac{\beta(s+2\alpha)}{(s+\alpha)^2+\beta^2}$$

9-18(a)

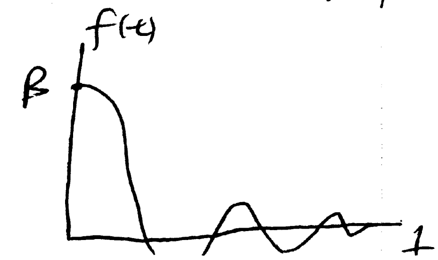
$$F(s) = \frac{\beta(s+2\alpha)}{(s+\alpha)^2+\beta^2} = \frac{\beta(s+\alpha)}{(s+\alpha)^2+\beta^2} + \frac{\alpha\beta}{(s+\alpha)^2+\beta^2}$$

$$\boxed{f(t) = e^{-\alpha t}u(t)[\beta\cos(\beta t)+\alpha\sin(\beta t)]}$$

2

*Note: The secret to doing these types of problems is knowing your 9-2 table, pg 442. Then, you need to re-arrange your expression algebraically until everything matches a term in the table. Just remember, $\frac{1}{s+\alpha} \neq \frac{1}{s}+\frac{1}{\alpha}$

f(t):



9–21 Plot the pole-zero diagrams of the following transforms, find the corresponding inverse transforms, and sketch their waveforms:

$$\text{(a) } F_1(s) = \frac{900}{s^2 + 65s + 900}$$

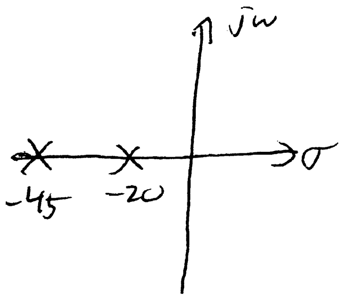
$\boxed{\text{9-21 (a)}}$

$$F(s) = \frac{900}{s^2+65s+900} = \frac{900}{(s+20)(s+45)} = \frac{K_1}{s+20} + \frac{K_2}{s+45}$$

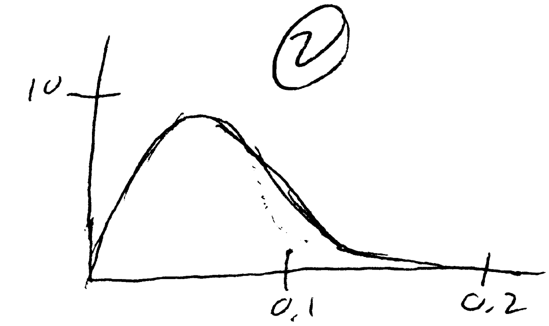
$$K_1 = \frac{900}{(-20+45)} = 36 \qquad K_2 = \frac{900}{(-45+20)} = -36 \;\therefore$$

$$F(s) = \frac{36}{(s+20)} - \frac{36}{s+45} \rightarrow \boxed{f(t) = 36\left(e^{-20t} - e^{-45t}\right)u(t)}$$

Pole-zero:



f(t) →



9–26 Find the inverse transforms for the following transforms:

$$\text{(b) } F(s) = \frac{s+1}{s^2 - 2s + 1}$$

9-26 (b)

$$F(s) = \frac{s+1}{(s^2-2s+1)} = \frac{s+1}{(s-1)^2} = \frac{K_1}{(s-1)^2} + \frac{K_2}{(s-1)}$$

$$\frac{K_1(s-1) + K_2(s-1)^2}{(s-1)^2(s-1)} = \frac{s+1}{(s-1)^2} \therefore K_1 + K_2(s-1) = s+1 \therefore \quad K_2 = 1 \quad K_1 = 2 \therefore$$

$$F(s) = \frac{2}{(s-1)^2} + \frac{1}{(s-1)} \rightarrow \boxed{f(t) = [2te^{t} + e^{t}]u(t)}$$

2

9–39 The switch in Figure P9–39 has been open for a long time and is closed at $t = 0$. The circuit parameters are $R = 1\ \text{k}\Omega$, $L = 200$ mH, $C = 0.5\ \mu\text{F}$, and $V_A = 10$ V.

(a) Find the differential equation for the circuit and the initial conditions.

(b) Use Laplace transforms to solve for the $i_L(t)$ for $t \geq 0$.

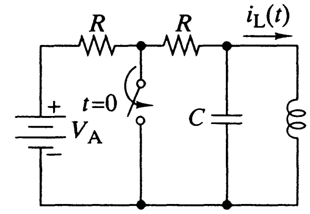
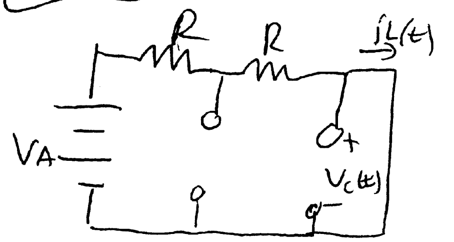


FIGURE P9–39

9-39 First, let's find the initial conditions. DC ckt:

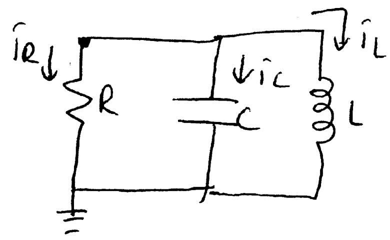


$V_C(0) = 0$

$i_L(0) = \frac{V_A}{2R} = \frac{10}{2000}$ $\quad i_L(0) = 5 \times 10^{-3} A$

$\frac{d}{dt} I_L(0) = \frac{1}{L} V_C(0) = 0$

At $t=0$, V_A is shorted out:



$i_R + i_C + i_L = 0$ (KCL at gnd)

$i_R = V_R/R = V_L/R = \frac{L}{R}\frac{di_L}{dt}$ $\quad (V_L = L\frac{di_L}{dt})$

$i_C = C\frac{dv_C}{dt} = C\frac{dV_L}{dt} = LC\frac{d i_L^2}{dt^2}$

diffeqn: $LC\frac{d^2}{dt^2} i_L + \frac{L}{R}\frac{d}{dt} i_L + i_L = 0$ (2)

$$\boxed{10^{-7}\frac{d^2}{dt^2} i_L + 2\cdot\times 10^{-4}\frac{d}{dt} i_L + i_L = 0, \quad V_C(0)=0 \quad \frac{d}{dt}I_L(0) = 0 \quad i_L(0) = 5mA \quad \frac{1}{L}V_C(0) = 0}$$

(b) From differentiation property,

$$10^{-7}(s^2 I_L(s) - 5\cdot 10^{-3}s) + 2\cdot 10^{-4}(s\cdot I_L(s) - 5\cdot 10^{-3}) + I_L(s) = 0$$

$$I_L(s)[10^{-7}s^2 + 2\times 10^{-4}s + 1] = (10^{-7})(5\times 10^{-3}s) + (2\times 10^{-4})(5\times 10^{-3})$$

$$I_L(s) = \frac{(5\times 10^{-3})(s+2000)}{s^2 + 2000s + 10^7} = \frac{1}{200}\left(\frac{s+2000}{(s+1000)^2 + 3000^2}\right)$$

$s^2 + 2000s + 10{,}000{,}000$

$s^2 + 2{,}000s + 1{,}000{,}000 + 9{,}000{,}000$

$(s+1{,}000)^2 + 3{,}000^2$

$$I_L(s) = \frac{1}{200}\left[\frac{s+1{,}000}{(s+1{,}000)^2 + 3000^2} + \frac{1}{3}\cdot\frac{3{,}000}{(s+1{,}000)^2 + 3{,}000^2}\right]$$

$$\boxed{i_L(t) = \frac{1}{200}\left(e^{-1{,}000t}u(t)\right)\left(\cos(3{,}000t) + \tfrac{1}{3}\sin(3{,}000t)\right)}$$ (2)

9–47 Use the initial and final value properties to find the initial and final values of the waveform corresponding to the following transforms. If either property is not applicable, explain why.

$$\text{(a) } F_1(s) = \frac{(s^2 + 15s + 12)}{s(s^2 + 6s + 12)}$$

$\boxed{9\text{-}47(a)}$ Both the initial & final value theorems apply; this is a proper rational function w/ negative poles.

$$sF(s) = \frac{s^2+15s+12}{s^2+6s+12} \quad f(0) = \lim_{s\to\infty} sF(s) = \lim_{s\to\infty} \frac{1+\cancel{15/s}+\cancel{12/s^2}}{1+\cancel{6/s}+\cancel{12/s^2}} = \boxed{1 = f(0)}$$

$$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s) = \frac{12}{12} = \boxed{1 = \lim_{t\to\infty} f(t)}$$

2

9–53 OP AMP *RC* CIRCUIT

In Chapter 6 we learned how to analyze and design the input-output relationships of dynamic OP AMP circuits in the time domain. In this problem we explore the same problem in the *s* domain.

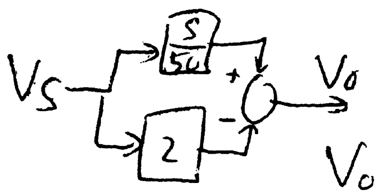
(a) With zero initial conditions, transform the time-domain input-output relationship

$$v_O(t) = -2v_S(t) + \frac{1}{50}\frac{dv_S(t)}{dt}$$

into the *s* domain and draw a block diagram of the relationship between the output transform $V_O(s)$ and input transform $V_S(s)$. How does the time-domain differentiation involved show up in the *s*-domain block diagram? How are the poles of the output transform related to the poles of the input transform?

9-53

(a) $V_o(s) = \mathcal{L}\left(-2V_s(t) + \frac{1}{50}\frac{d}{dt}V_s(t)\right) = -2V_s(s) + \frac{s}{50}V_s(s) = \left(\frac{s-100}{50}\right)V_{s(}$



The time differentiation translates to the $s/50$ block in the diagram. Since $V_o(s) = \left(\frac{s-100}{50}\right)V_s(s)$, V_o has all of the poles/zeros that V_s does, plus an additional zero at $s = 100$. Thus, the differentiation adds a zero, or in other words, to retrieve the input from the output, a pole must be added at $s = 100$

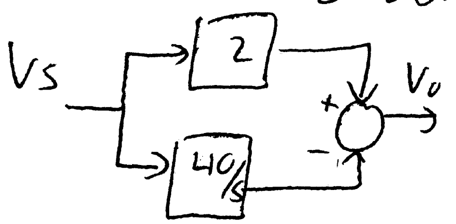
2

(b) Draw a block diagram of the s-domain input-output relationship

$$V_O(s) = 2\,V_S(s) - \frac{40}{s}V_S(s)$$

How are the poles of the output transform related to the poles of the input transform? Perform the inverse Laplace transform to obtain the t-domain input-output relationship. How do the time-domain signal processing functions show up in the s-domain block diagram?

(b) $V_o(t) = \mathcal{L}^{-1}\left[2\cdot V_s(s) - \frac{40}{s}V_s(s)\right] = 2V_s(t) - 40\int_0^t V_s(x)\,dx$



As seen from the inverse transform, the time-domain signal is integrated, shown by 40/s block. $V_o(s) = \frac{2s-40}{s}$. Thus, integration adds a pole at $s=0$, and a zero at $s=20$.

This is an important analysis if Vs/Vo are high frequency. The low-frequency poles & zeros added will alter the circuit's performance dramatically.

2

10–15 The switch in Figure P10–15 has been closed for a long time and is opened at $t = 0$. Transform the circuit into the s domain and solve for $I_L(s)$ and $i_L(t)$.

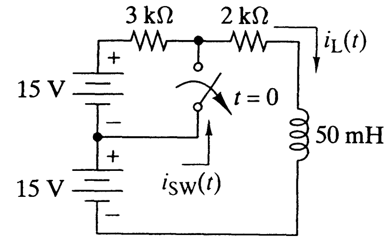
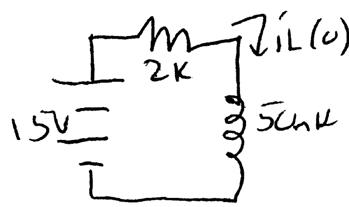


FIGURE P10–15

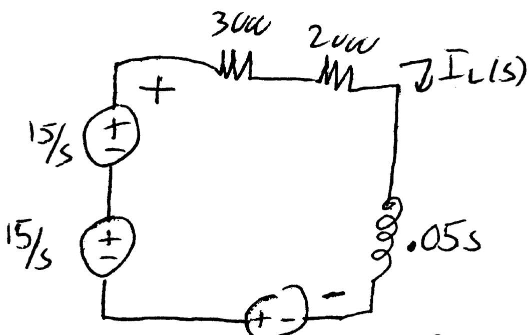
10.15

With the switch closed, the circuit reduces to that shown.

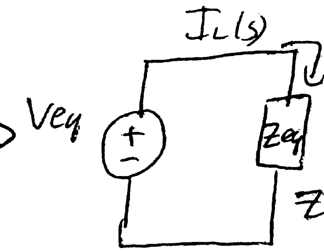


$i_L(0) = \frac{15V}{2000} = \underline{7.5mA}$

s-domain circuit:



$\Rightarrow$



$$V_{eq} = \frac{15}{s} + \frac{15}{s} + 3.75\times10^{-4} = \frac{30 + s(3.75\times10^{-4})}{s}$$

$$Z_{eq} = 3{,}000 + 2{,}000 + .05s = 5{,}000 + .05s$$

$$I_L(s) = \frac{V_{eq}}{Z_{eq}} = \frac{30 + s(3.75\times10^{-4})}{s(.05s + 5{,}000)} = \frac{600 + .0075s}{s(s + 100{,}000)} = \frac{K_1}{s} + \frac{K_2}{s + 100000}$$

$$K_1 s + 100000\,K_1 + K_2 s = 600 + .0075s \qquad K_1 = \frac{3}{500} \quad K_2 = \frac{3}{2{,}000}$$

$$\boxed{I_L(s) = s\left(\frac{3}{500}\right) + \left(\frac{3}{2{,}000}\right)\left(\frac{1}{s + 100000}\right)}$$

$$\boxed{i_L(t) = \frac{3}{500}\left(1 + \frac{1}{4}e^{-100{,}000t}\right) A}$$ ← standard inverse Laplace using table 9-2.

10–21 There is no initial energy stored in the circuit in Figure P10–21.

(a) Transform the circuit into the s domain and use voltage division to solve for $V_C(s)$.

(b) Identify the forced and natural poles in $V_C(s)$ when $v_S(t) = 100\,u(t)$ V, $L = 50$ mH, $C = 0.05$ μF, and $R = 5$ kΩ.

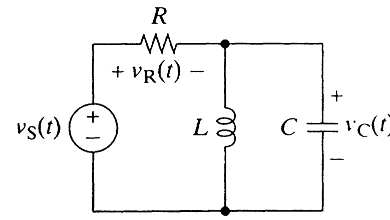
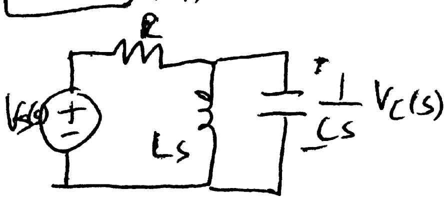
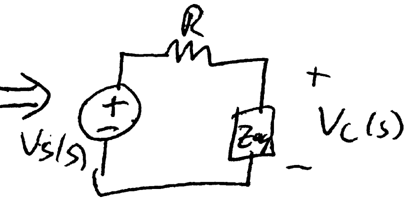


FIGURE P10–21

10, 21 (a)



$\Rightarrow$



$$Z_{eq} = Ls \,//\, \frac{1}{Cs} = \frac{Ls\left(\frac{1}{Cs}\right)}{Ls + 1/Cs} = \frac{Ls}{LCs^2+1}$$

By voltage division, $Vc(s) = \dfrac{Vs(s)\,Z_{eq}}{R + Z_{eq}}$

$$Vc(s) = Vs(s)\,\frac{\frac{Ls}{LCs^2+1}}{R + \frac{Ls}{LCs^2+1}}$$

$$\boxed{Vc(s) = Vs(s)\left[\frac{Ls}{RLCs^2 + R + Ls}\right]}$$

b) $\mathcal{L}[100u(t)] = \frac{100}{s}$ ∴ $Vc(s) = \left(\dfrac{s \quad .05}{1.25\times10^{-6}s^2 + .05s + 5{,}000}\right)\left(\dfrac{100}{s}\right)$

$$Vc(s) = \frac{4\times10^5}{s^2 + 4000s + 4\times10^8}$$

Solving $s^2 + 4{,}000s + 4\times10^8$

$s = -2{,}000 \pm j20{,}000$

$\boxed{\text{Natural poles: } -2{,}000 \pm j20{,}000}$ $\boxed{\text{Forced-poles: none}}$

* The $s=0$ pole caused by the step function is cancelled by a natural zero

11–1 Connect a voltage source $v_1(t)$ at the input port and an open circuit at the output port of the circuit in Figure P11–1.

(a) Transform the circuit into the s domain and find the driving-point impedance $Z(s) = V_1(s)/I_1(s)$ and the transfer function $T_V(s) = V_2(s)/V_1(s)$.

(b) Find the poles and zeros of $Z(s)$ and $T_V(s)$ for $R_1 = R_2 = 2\ \text{k}\Omega$, $L = 100$ mH, $C = 250$ nF.

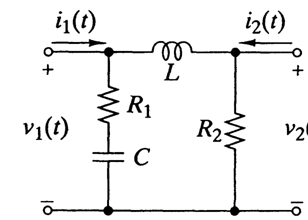
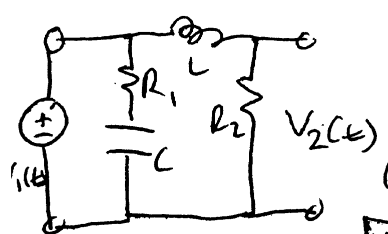


FIGURE P11–1

$\boxed{1.1}$ (a)



$T_V(s) = \dfrac{V_2(s)}{V_1(s)}$ By simple voltage division, $V_2(s) = \dfrac{R_2}{Ls+R_2} V_1(s)$

$$\boxed{T_V(s) = \frac{R_2}{Ls+R_2}}$$

(b) $T_V(s) = \dfrac{2000}{.1s+2000} = \dfrac{20{,}000}{s+20{,}000}$ ∴

$\boxed{T_V(s) \text{ has a pole at } s = -20{,}000}$

11–4 Connect a current source $i_1(t)$ at the input port and a short circuit at the output port of the circuit in Figure P11–3.

(a) Transform the circuit into the s-domain and find the driving-point impedance $Z(s) = V_1(s)/I_1(s)$ and the transfer impedance $T_I(s) = I_2(s)/I_1(s)$.

(b) Find the poles and zero of $Z(s)$ and $T_I(s)$ for $R_1 = 500\ \Omega$, $R_2 = 2000\ \Omega$, and $L_1 = 0.4$ H.

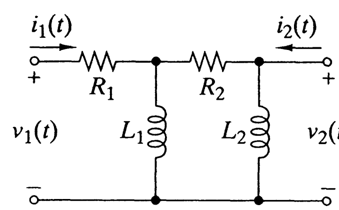
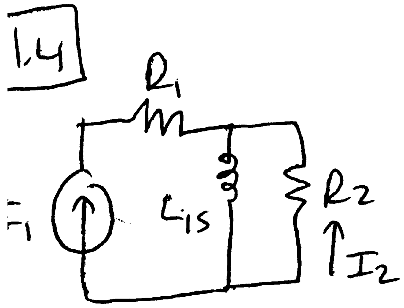


FIGURE P11–3

$\boxed{1.4}$



(a) By current division, $I_2 = \dfrac{-L_1s}{L_1s+R_2} \cdot I_1(s)$ ∴

$$\boxed{T_i(s) = \frac{I_2(s)}{I_1(s)} = \frac{-L_1s}{L_1s+R_2}}$$

L_2s is shorted out

[illegible]y the short over $V_2(t)$)

(b) $T_i(s) = \dfrac{-.4s}{.4s+2{,}000} = \dfrac{-s}{s+5{,}000}$

$\boxed{T_i(s) \text{ has a zero at } s=0 \text{ and a pole at } s=-5{,}000}$

11–27 Find the transfer function and the impulse-response waveform corresponding to each of the following step responses:
(a) $g(t) = [-e^{-2000t}]u(t)$
(b) $g(t) = [1 - e^{-2000t}]u(t)$

$\boxed{11.27}$ Just find the transfer functions $T(s) = sG(s)$ by eqn 11-15

(a) $g(t) = -u(t)e^{-2,000t}$ $T(s) = sG(s) = s\,\mathcal{L}\{g(t)\}$ $\boxed{T(s) = \dfrac{-s}{s+2,000}}$

b) $T(s) = sG(s) = s\,\mathcal{L}\{u(t) - u(t)e^{-2,000t}\} = s\left(\dfrac{1}{s} - \dfrac{1}{s+2,000}\right)$

$\boxed{T(s) = \dfrac{2,000}{s+2,000}}$

11–28 Find the step response waveforms corresponding to each of the following impulse responses.
(a) $h(t) = [-1000e^{-2000t}]u(t)$
(b) $h(t) = \delta(t) - [2000e^{-2000t}]u(t)$

$\boxed{11.28}$ $T(s) = H(s)$ by eqn. 11-14

(a) $\boxed{H(s) = \dfrac{-1,000}{s+2,000} = T(s)}$ (b) $H(s) = 1 - \dfrac{2,000}{s+2,000}$ $\boxed{T(s) = \dfrac{s}{s+2,000}}$

11–37 The step response of a linear circuit is $g(t) = [e^{-1000t}]u(t)$. Find the amplitude and phase angle of the sinusoidal steady-state output for the sinusoidal input $x(t) = 5 \cos 2000t$.

$\boxed{11.37}$ $G(s) = \mathcal{L}[e^{-1,000t}]u(t) = \dfrac{1}{s+1,000}$ $T(s) = sG(s) = \dfrac{s}{s+1,000}$

$x(t) = 5\cos 2,000t$ by eqn 11-24:

Amplitude $= 5\,|T(j\cdot 2,000)| = 5\left|\dfrac{j\cdot 2,000}{j\cdot 2,000+1,000}\right|$ $\boxed{\text{Amplitude} = 4.472}$

Phase angle $= \phi + \theta = 0 + \text{angle}\left(\dfrac{j\cdot 2,000}{j\,2,000+1,000}\right)$ $\boxed{\phi = 26.565^\circ}$

11–40 The impulse response of a linear circuit is $h(t) = 400[e^{-100t} - e^{-5000t}]u(t)$. Find the amplitude and phase angle of the sinusoidal steady-state output for the sinusoidal input $x(t) = 5\cos 700t$.

$\boxed{1.40}$ $h(t) = [400e^{-100t} - 400e^{-5{,}000t}]u(t)$ $H(s) = T(s) = 400\left(\frac{1}{s+100} - \frac{1}{s+5000}\right)$

$T(s) = \frac{1.96 \times 10^6}{(s+100)(s+5{,}000)}$ Amplitude $= 5\left|\frac{1.96\times10^6}{(700j+100)(700j+5{,}000)}\right| = \boxed{2.745}$

$\phi = \text{angle}\left|\frac{1.96\times10^6}{(700j+100)(700j+5{,}000)}\right|$ $\boxed{\phi = -89.84^\circ}$

12–3 **(a)** Find the transfer function $T_V(s) = V_2(s)/V_1(s)$ for the *RC* OP AMP circuit in Figure P12–3.

(b) Determine the dc gain, infinite-frequency gain, and the cutoff frequency ω_C. Is the gain response low-pass, high-pass, or bandpass?

(c) Draw the straight-line approximations of the gain and phase of $T_V(j\omega)$.

(d) Use the straight-line approximations to estimate the gain at $\omega = 0.5\omega_C$, ω_C, and $2\omega_C$. Compare these straight-line gains to the value of $|T_V(j\omega)|$ at the same frequencies.

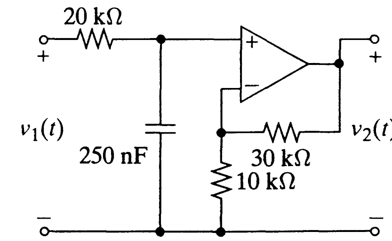
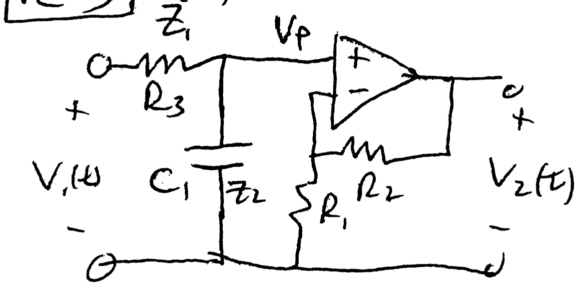


FIGURE P12–3

12-3 (a)



From OP-Amps, $V_2(t) = V_P\left(\frac{R_1+R_2}{R_1}\right)$

(standard non-inverting OP-Amp amplifier)

$V_P = V_1(t)\left[\frac{Z_2}{Z_1+Z_2}\right]$ ∴

$$V_2(s) = \left(\frac{R_1+R_2}{R_1}\right)\left(\frac{\frac{1}{C_1 s}}{R_3+1/C_1 s}\right)V_1(s)$$

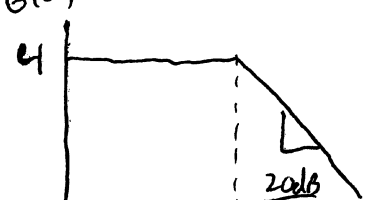
$$V_2(s) = \left(\frac{10+30}{10}\right)\left(\frac{1}{.005s+1}\right)V_1(s) \qquad \frac{V_2(s)}{V_1(s)} = \boxed{T_V(s) = \frac{800}{s+200}}$$

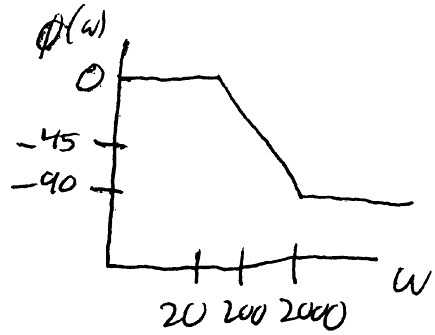
(b) • DC gain $= T_V(0) = \frac{800}{200} = \boxed{4}$

• ∞ frequency gain $= T_V(\infty) = \frac{800}{\infty} = \boxed{0}$

Cutoff frequency & type of filter: Circuit is of type shown in eqn 12-4; $\boxed{\text{low-pass filter w/ } \omega_C = 200}$

(c) $G(\omega)$





12–7 The circuit in Figure P12–7 is a small-signal model of a transistor circuit. Determine the gain of $T_V(s) = V_2(s)/V_1(s)$ at $\omega = 0$ and $\omega = \infty$. Is this a low-pass, bandpass, or high-pass circuit? What are the passband gain and the cutoff frequency for $R_S = 1\ k\Omega$, $R_g = 500\ k\Omega$, $R_O = 10\ k\Omega$, $R_L = 5\ k\Omega$, $C_L = 5$ pF, and $\beta = 100$?

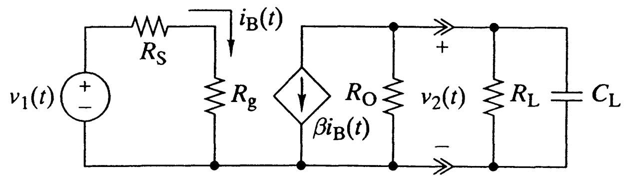
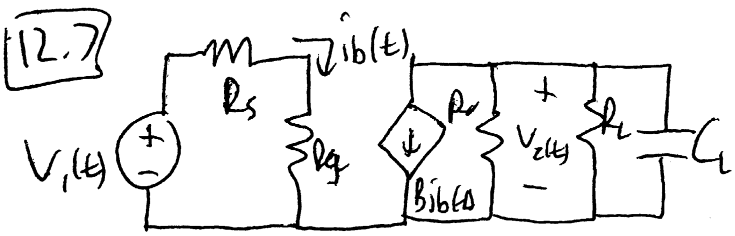


FIGURE P12–7

$\boxed{12.7}$



$$I_B(s) = \frac{V_1(s)}{R_s + R_g}$$

$$V_2(s) = (-\beta I_B(s))(R_o // R_L // C_L)$$

$$V_2(s) = \left(\frac{R_o R_L}{R_L + R_o + C_L s R_o R_L}\right)\left(-\beta \frac{V_1(s)}{R_s + R_g}\right)$$

$$\boxed{T_V(s) = \left(\frac{-\beta R_o R_L}{R_s + R_g}\right)\left(\frac{1}{s(R_o \cdot R_L \cdot C_L) + R_o + R_L}\right)}$$

$$\boxed{|T_V(0)| = \frac{\beta}{R_s + R_g}\left(\frac{R_o R_L}{R_o + R_L}\right)} = 0.665$$

$$T_V(s) = \frac{-9980}{s(2.5 \times 10^{-4}) + 15{,}000}$$

$$\boxed{|T_V(j\omega = \infty)| = 0}$$

Pass-band gain: $\boxed{K = T_V(0) = 0.665}$

$$\omega_c = \frac{R_o + R_L}{R_o \cdot R_L \cdot C_L} \qquad \boxed{\omega_c = 6 \times 10^7}$$

$\boxed{\text{Circuit is low-pass}}$

12–8 The circuit in Figure P12–8 is a small-signal model of a transistor circuit. Determine the gain of $T_V(s) = V_2(s)/V_1(s)$ at $\omega = 0$ and $\omega = \infty$. Is this a low-pass, bandpass, or high-pass circuit? What are the pass-band gain and the cutoff frequency for $R_S = 0.1$ kΩ, $R_g = 500$ kΩ, $R_D = 10$ kΩ, $R_L = 5$ kΩ, $C_C = 0.05$ μF, and $g = 0.01$ S?

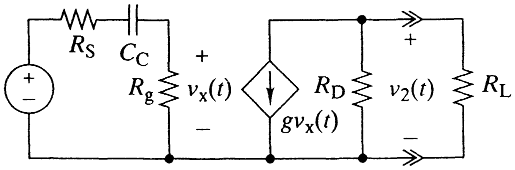
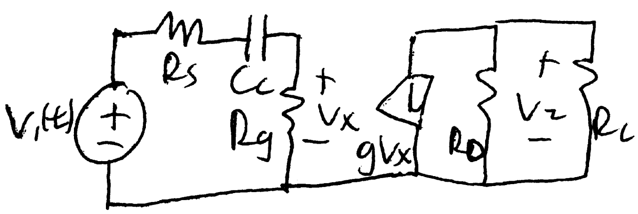


FIGURE P12–8

$\boxed{12.8}$



$$V_x(s) = \frac{V_1(s) R_g}{R_g + R_s + \frac{1}{C_c s}} = \frac{V_1(s) R_g C_c s}{C_c s (R_g + R_s) + 1}$$

$$V_2(s) = \left(\frac{R_D R_L}{R_D + R_L}\right)(-g \cdot V_x(s)) \therefore$$

$$\boxed{T_V(s) = \frac{-g R_D R_L}{R_D + R_L}\left[\frac{R_g C_c s}{(R_g + R_s) C_c s + 1}\right]} = \frac{-.83\bar{3}\, s}{.025 s + 1}$$

$$\boxed{|T_V(0)| = 0} \quad \boxed{|T_V(\infty)| = \left[\frac{g R_D R_L}{R_D + R_L}\right]\left[\frac{R_g C_c}{(R_g + R_s) C_c}\right]} = 33.?$$

$$\boxed{K = T_V(\infty) = 33.2} \quad \omega_c = \frac{1}{(R_g + R_s) C_c} \quad \boxed{\omega_c = 39.992}$$

Take all terms in $\frac{R_g C_c s}{(R_g + R_s) C_c s + 1}$ & divide by $s \rightarrow$ $R_g C_c / (R_g + R_s) C_c + 1/s$ $\quad 1/\infty = 0$

$\boxed{\text{Circuit is high pass}}$