**Homework 2**



**P14.1.11** Determine, for the filter in Figure P14.1.11, (a) the transfer function *VO*(*jω*)/*ISRC*(*jω*); (b) the 3-dB cutoff frequency in krad/s; (c) the magnitude of the gain and the phase shift as a function of frequency; (d) the maximum gain in the passband.



**Solution:** (a) The impedance of the capacitor is  Ω, where *ω* is in rad/s. This can be expressed in terms of *ω*′ krad/s, where *ω* is replaced by (*ω*′×103): 

Ω  kΩ. When the source and 2 kΩ resistor are reflected to the secondary side, they become a source of 2*VSRC*(*jω*) in series with 8 kΩ. Hence, , or  . Response is highpass.

(b) The 3-dB cutoff frequency is = 1/1.8 = 5/9 krad/s,  = 5000/18*π* = 88.42 Hz

(c) It follows that , .

(d) Maximum gain as is 2/1.8 = 10/9; 20log10(10/9) = 0.915 dB.

**P14.1.13** (a) Determine NEC seen by the resistor in Figure P14.1.13; (b) *IO*(*jω*); (c) the 3-dB cutoff frequency.



**Solution:** (a) The admittance of the 1 μF capacitor is twice that of the 0.5 μF capacitor. Hence, *I*1(*jω*) is 2/3 of the source current and *I*2(*jω*) is 1/3 of the source current. It follows that *IN*(*jω*) *= I*1(*jω*) – *I*2(*jω*) = 1/3 of the source current = 6(*jω*)/3 = 2(*jω*) A. When the current source is replaced by an open circuit, the 1 μF capacitor in series with the 0.5 μF capacitor has a capacitance of 0.5/1.5 = 1/3 μF. The capacitance seen by the resistor is 2/3 μF. The impedance of this capacitor is 3×106/2*ω* Ω ≡ 1500/*ω* kΩ, where *ω* is in rad/s. NEC connected to the 1 kΩ resistor is as shown.



(b)  A; response is lowpass.

(c) *ωcl* = 1500 rad/s ≡ 1.5 krad/s.



**P14.1.18** Determine, for the filter in Figure

P14.1.18, (a) the transfer function *VO*(*jω*)/*VSRC*(*jω*); (b) the 3-dB cutoff frequency in krad/s; (c) the

magnitude of the gain and the phase

shift as a function of frequency; (d) the maximum gain in the passband.

**Solution:** (a) TEC, as seen by the



capacitor will be

derived. On open

circuit, *I*(*jω*) =  =

 mA, so that . This gives: . Alternatively, it follows from the source absorption theorem that the dependent source is equivalent to a resistance of  kΩ.



From voltage division,  . On short circuit,  mA. Hence, *RTh* kΩ. TEC seen by the capacitor is as shown, where the impedance of the capacitor is Ω. Since the resistances are in kΩ, the impedance can be expressed in kΩ by replacing *ω* in rad/s by (*ω*′×103), where *ω*′ is in krad/s. The impedance becomes:Ω  kΩ. Hence,  , or . Response is lowpass.

(b)  = 1/0.04 = 25 krad/s.

(c) . .

(d) Passband gain as  is |*H*(0)| = 0.8.

**P14.1.20** Reduce the circuit of Figure P14.1.20 to a first-order



circuit and specify the values of the circuit elements.

**Solution:** The impedance of the upper branch is 5 times that of the branch below it. Hence if the impedance of this lower branch is *Z*, that of the upper branch is 5*Z*, and the parallel impedance of the two branches is 5*Z*/6. This is equivalent to a resistance of 5×(6 Ω)/6 =

5 Ω, in series with a reactance of , equivalent to

a capacitance of (1/5) μF. This in series with 1 μF gives a capacitance of  μF.



**P14.1.21** Determine the transfer functions *VC*(*jω*)/*ISRC*(*jω*) and *VL*(*jω*)/*ISRC*(*jω*). Note that each is a first-order transfer function that is independent of the parameters of the other subcircuit.

**Solution:** *IC*(*jω*);



 .

*IL*(*jω*) ;

; .

**P14.2.3** For the circuit of Figure P14.2.3, determine: (a) the transfer function *VO*(*jω*)/*VSRC*(*jω*), (b) *ω*0; (c) *Q*; (d) BW; (e) *vO*(*t*) if *vSRC*(*t*) = 450cos(*ω*0*t*) V.



(a) Impedance of inductor = *jω*×40×10-3 = 4*s*×10-2; impedance of capacitor = ;  Multiplying by *s* and dividing by 4:  Multiplying numerator and denominator by 100:  This can be put in simpler form by expressing it in terms of *s*′ krad/s rather than *s* rad/s, where *s* is replaced by (*s*′)×103:  Multiplying numerator and denominator by 10-6: 

(b) *ω*0 =  25 krad/s.

(c) *Q* = .

(d) BW =  krad/s, which is also the coefficient of *s*′.

(e) *vO*(*t*) = 0.8×450cos(*ω*0*t*) = 360 cos(*ω*0*t*) V

**P14.2.5** A bandpass, series *RLC* circuit is required having *ω*0 = 106 rad/s, BW = 104 rad/s, *L* = 1mH, and a maximum gain of 0.5. Implement the circuit using 5 Ω resistors, 2 mH inductors, and 2 nF capacitors.



**Solution:** BW = , or *R* = *L*×BW = 10-3×104 = 10 Ω. Since the gain is 0.5, and 5 Ω resistors are to be used, the 10 Ω resistor is split into two 5 Ω resistors in series.  nF. This capacitor is obtained from two 2 nF capacitors in series. The 1 mH inductor is obtained from two 2 mH inductors in parallel. The circuit will be as shown.

**P14.2.17** Determine: (a) the nature of the response in



Figure P14.2.17; (b) *ω*0; (c) BW.

**Solution:** Denoting the resistance by *R* and

the impedance of the capacitor by 1/*sC*, the impedance of the parallel  branch is . The transfer function is:

. Multiplying numerator and denominator by *sC*(1 + *sCR*), =

. Dividing numerator and denominator by *C*2*R*2,

. Comparing with Table 10.5.1, it is clear that this is a bandpass response having  rad/s, , and a gain of  at *ω* = *ωn*. The bandwidth is:  rad/s.