**Homework 2**

**P14.1.4** Given a lowpass *RL* filter having *R* = 1 kΩ and *L* = 20 mH. Determine: (a) the 3-dB cutoff frequency in krad/s; (b) the lowpass transfer function.

**Short solution:** (a) *ωc* = *R*/*L* = 1000/(20×10-3) rad/s ≡ 1000/20 = 50 krad/s.

(b) For the LP response, . If frequency is expressed as *ω*′ in krad/s, then *H*(*jω*) = .

**P14.1.14** (a) Determine NEC seen by the resistor in Figure P14.1.14; (b) *IO*(*jω*); (c) the 3-dB cutoff frequency.



**Solution:** It is convenient to determine the open-circuit voltage and *ZTh*. On open circuit, each branch has an impedance of *j*1.5*ω*, so that the 6 A divides equally between the two branches. It follows that *Vac* = *j*3*ω*; *Vbc* = *j*1.5*ω*; *Vba* = *VTh* = *Vbc* – *Vac* = *j*1.5*ω* – *j*3*ω* = -*j*1.5*ω*. When the current source is replaced by an open circuit, the impedance between terminals ‘ab’ is *j*1.5*ω* in parallel with *j*1.5*ω*, which is *j*0.75*ω*. TEC will be as shown. Hence, NEC consists of a current source *IN* = *Iba* =



-*j*1.5*ω*/(*j*0.75*ω*) = -2 A in parallel with *j*0.75*ω,* as shown. The current source -2 A is directed from terminal ‘b’ to terminal ‘a’ in accordance with the assumed polarity of *VTh*.

(b) It follows that = .

(c) ; ; , or, *ωc* =4000/3 rad/s ≡ 4/3 krad/s.



**P14.1.15** Determine, for the filter in Figure



P14.1.15, (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 angle as a function of frequency; (d) the maximum gain in the passband.



**Solution:** Since the circuit must reduce to an *RC* circuit, the equivalent circuit consisting of the dependent source and capacitor should be determined. By applying a test source, *VT*(*jω*) = 103(*jω*) + , or,  Ω, where *VT*(*jω*) is in V, *IO*(*jω*) is in A, and *ω* is in krad/s, or  kΩ. This is equivalent to a 1 kΩ resistor in series with a capacitor of impedance



100/*j*3*ω* kΩ. Alternatively, from the source absorption

theorem, the dependent source is equivalent to a resistance  Ω.

The next step is to derive TEC seen by the capacitor. *VTh*(*jω*) = 2×103*ISRC*(*jω*) in series with 3 kΩ.

1. It follows that , *ω* is in krad/s.
2. , or *ωc* = 1/0.09 = 100/9 krad/s.
3. Magnitude of the gain is , phase angle is -tan-1(0.09*ω*).
4. Maximum gain is 2×103 as *ω* → 0.

**P14.1.20** Reduce the circuit of Figure P14.1.20 to a first-order circuit and specify the values of the circuit elements.



**Short Solution:** Let the impedance of the lower branch be Z,

where *Z* = 6 + = 6 + ; the impedance of the upper branch is 30 + =

30 +  = 5*Z*; the impedance of the two branches in parallel is 5*Z*/6 = 5 +  = 5 + , which is equivalent to 5 Ω in series with 1/5 μF. This capacitance in series with 1 μF is  μF. hence the first order circuit is 5 Ω in series with 1/6 μF.

**P14.1.22** Determine the transfer functions *I*1(*jω*)/*VSRC*(*jω*) and *I*2(*jω*)/*VSRC*(*jω*). (Note that each is a first-order transfer function that is independent of the parameters of the other subcircuit.)



**Short Solution:**  A/V

 A/V

**P14.2.8** Determine *R* and *L* in Figure P14.2.8 so that the resonant frequency is 4 kHz, and *Q* = 5.



**Solution:** ;  H 3.17 mH.

;  Ω.



**P14.2.9** Determine in Figure P14.2.9: (a) the

minimum value of the transfer function |*VO*(*jω*)/*VSRC*(*jω*)|; (b) *Q* and BW.

**Solution:** The minimum value of *VO*(*jω*) occurs when the *LCR* branch has a minimum impedance. This occurs when *L* and *C* in series have a zero impedance, that is, at 

= 103 rad/s. At this frequency, 30||5 = 30/7 Ω.

1. From voltage division, the minimum value of the transfer function .
2. TEC seen by the *LCR* branch has *RTh* = (60)||(30) = 20 Ω. For the purpose of determining Q, *VTh* can be set to zero, the circuit reducing to that shown. This is a series *LCR* circuit with *R* = 25 Ω. Hence, 80; BW = 12.5 rad/s.

**P14.2.15** Determine the frequency at which *VO*(*jω*) = 0 in Figure P14.2.15



**Solution:** *VO*(*jω*) = 0 when the impedance of the *LC* branch is zero. The impedance of *L* in parallel with *C* is . This impedance in series with -*j*/*ωC* = 0, that is, , which gives , or , or  rad/s ≡  Mrad/s.