**EECE 290 Analog Signal Processing**

**Quiz 2 – March 20, 2017**

32%

1. A wideband bandpass filter is required to meet the following specification:
2. Nominal 3 dB frequencies of 10 rad/s and 100 krad/s
3. Maximum passband gain of 40 dB, divided equally between the stages
4. The largest resistor not to exceed 1 MΩ and the smallest resistor not to be less than 10 Ω.
5. Capacitors to be 0.1 μF or 1 μF.
6. Input impedance to be at least 50 kΩ.

Draw the circuit of the filter, indicating the values of all components, assuming ideal op amps.

**Solution:** The overall gain is 100, or 10 per stage. The largest time constant is that of the highpass filter, *RrhCrh*, since his has the lower 3 dB cutoff frequency of 10 rad/s. If a 1 μF capacitor is used, *Rrh* = 1/(*ωc*1*Crh*) = 1/(10×10-6) = 105 ≡ 100 kΩ. The largest resistor is therefore *Rfh* = 10*Rrh* = 1 MΩ. For the lowpass filter, if *Cfl* = 0.1 μF, *Rfl* = 1/(*ωc*2*Rfl*) = 1/(105×10-7) 100 Ω and *Rrl* = 100/10 Ω. To have an input impedance of at least 50 kΩ, the highpass filter should precede the lowpass filter. The circuit will be as shown.



34%

1. *f*(*t*) is periodic of period 8 s, described by:

*f*(*t*) = , 0 ≤ *t* ≤1 s and 7 ≤ *t* ≤ 8 s; *f*(*t*) = , 3 ≤ *t* ≤ 5 s; *f*(*t*) = *A*, 1 ≤ *t* ≤ 3 s; and *f*(*t*) = -*A*, 5 ≤ *t* ≤ 7 s. Assuming *A* = 1, determine:

(a) *a*0, *an*, and *bn* (22 grades),

(b) the rms value of *f*(*t*) (12 grades).

**Solution:** (a) The function is odd and quarter-wave symmetric. *a*0 = *a*n = 0 and *b*n = 0 for *n* even.For *n* odd,   +  = + ; , ,  for odd *n*. Hence, *bn* = 

, *n* odd.

(b) The rms value will be determined over quarter of a period. The square of the function over the first interval is: . The area under the square for a quarter period is: *dt* + *A*2 = . The mean square is  and the rms value is . Alternatively, the sine function and the square wave extend over half a period. The mean square of the sine function is *A*2/2, over a full period and *A*2/4 over a half-period. The mean square of the square wave over a half-period is *A*2/2. The sum is *A*2/4, as before.

**Version 1:** *A* = 1, (a) , (b) .

**Version 2:** *A* = 2, (a) , (b) .

**Version 3:** *A* = 3, (a) , (b) .

**Version 4:** *A* = 4, (a) , (b) .

**Version 5:** *A* = 5, (a) , (b) .

34%

1. (a) Determine *L* and *C*, assuming: (i) the complex power delivered by the source has a magnitude of 100 VA, (ii) the magnitude of reactive power absorbed by *L* is twice the magnitude of the reactive power absorbed by *C*, and (iii) *ω* = 100 rad/s (22 grades).

(b) If the current source is replaced by an ideal voltage source of 1∠0° V rms*,* and if *LS* = 4 H, *L* = 6 H, and *C* = 0.1 μF, determine the frequency at which maximum power is transferred to the 50 Ω resistor (12 grades).

**Solution:** (a) The real power absorbed by the two resistors is (10 + 50)(1)2 = 60 W. It follows from the power triangle that the reactive power *QS* delivered by the source is given by: (100)2 = (60)2 + (*QS*)2, or  VAR, where the p00ositive sign is retained because both the reactive power of *LS* and that of *L* in parallel with *C* are inductive. It follows that the reactive power of *L* in parallel with *C* is 80 – 30 = 50 = |*QL*| – 0.5|*QL*|, so that *QL* = 100 VAR and *QC* = -50 VAR. The 50 VAR of the parallel combination equals |*VLC*|×1, or |*VLC*| = 50 V. Hence, *QL* = 100 = , or *L* = 25/*ω*; and , or *C* = 1/50*ω*.

(b) Maximum power is transferred when the total impedance is zero, that is, when , or *LS* – *ω*2*LSLC + L =* 0, or .

**Version 1:** *ω* = 100 rad/s and *C* = 0.1 μF; (a) *L* = 0.25 H, *C* = 0.2 mF; (b) *ω* = 2041.2 rad/s.

**Version 2:** *ω* = 200 rad/s and *C* = 0.4 μF; (a) *L* = 0.125 H, *C* = 0.1 mF; (b) *ω* = 1020.6 rad/s.

**Version 3:** *ω* = 400 rad/s and *C* = 1.6 μF; (a) *L* = 62.5 mH, *C* = 50 μF; (b) *ω* = 510.3 rad/s.

**Version 4:** *ω* = 500 rad/s and *C* = 2.5 μF; (a) *L* = 50 mH, *C* = 40 μF; (b) *ω* = 408.2 rad/s.

**Version 5:** *ω* = 1000 rad/s and *C* = 10 μF; (a) *L* = 25 mH, *C* = 20 μF; (b) *ω* = 204.1 rad/s.