**EECE 290 Analog Signal Processing**

**Quiz 1 – Feb 20, 2017**

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1. Determine the power absorbed or delivered by *VSRC* and each of the op amps, assuming *VSRC* = 3 V.

**Solution:**

**1 –**

**Initialize:** virtual short circuit and virtual ground are indicated and zero current connections are marked with an x.

**2 – Simplify:** circuit is in simple enough form.

**3 – Deduce:** i) From virtual short circuit, *Va* = 15 V.

ii) From virtual ground, current in 2 kΩ resistor is 3 mA. This current flows through the 4 kΩ resistor, so that *Vc* = -12 V.

**4 – Explore:** If a voltage *Vb* is assigned to the middle node, then *Vb* can be determined from KCL at this node: , so that  V. It follows that *Iab* = (15 – *Vb*)/1 = (14 – *VSRC*/3) mA, which is also the output current of op amp (1), and *VO*1 = 15 + (14 – *VSRC*/3) = (29 – *VSRC*/3) V. Op amp (1) therefore delivers a power (29 – *VSRC*/3)(14 – *VSRC*/3) mW.

*Ibc* = (*Vb* – (-12)/1 = (13 + *VSRC*/3) mA; the current flowing from node ‘c’ towards the output of the op amp is 3 + *Ibc* = (16 + *VSRC*/3) mA; *VO*2 = -12 – (16 + *VSRC*/3) = -28 – *VSRC*/3 V. The current entering the output of op amp (2) is 16 + *VSRC*/3 + 28 + *VSRC*/3 V = (44 + 2*VSRC*/3) mA. The op amp therefore absorbs a power (-28 – *VSRC*/3)(44 + 2*VSRC*/3) mW, or delivers a power (28 + *VSRC*/3)(44 + 2*VSRC*/3) mW.

The current flowing out of *VSRC* is (-1 + 2*VSRC*/3) mA, and the power delivered by *VSRC* is (-1 + 2*VSRC*/3)*VSRC* mW.

**Version 1:** *VSRC* = 3 V; power delivered by *VSRC* = (-1 + 2*VSRC*/3)*VSRC* = (1)×3 = 3 mW, power delivered by op amp (1) is (29 – *VSRC*/3)(14 – *VSRC*/3) = (28)(13) = 364 mW, power delivered by op amp (2) is (28 + *VSRC*/3)(44 + 2*VSRC*/3) = (29)(46) = 1334 mW.

**Version 2:** *VSRC* = 6 V; power delivered by *VSRC* = (-1 + 2*VSRC*/3)*VSRC* = (3)×6 = 18 mW, power delivered by op amp (1) is (29 – *VSRC*/3)(14 – *VSRC*/3) = (27)(12) = 324 mW, power delivered by op amp (2) is (28 + *VSRC*/3)(44 + 2*VSRC*/3) = (30)(48) = 1440 mW.

**Version 3:** *VSRC* = 9 V; power delivered by *VSRC* = (-1 + 2*VSRC*/3)*VSRC* = (5)×9 = 45 mW, power delivered by op amp (1) is (29 – *VSRC*/3)(14 – *VSRC*/3) = (26)(11) = 286 mW, power delivered by op amp (2) is (28 + *VSRC*/3)(44 + 2*VSRC*/3) = (31)(50) = 1550 mW.

**Version 4:** *VSRC* = 12 V; power delivered by *VSRC* = (-1 + 2*VSRC*/3)*VSRC* = (7)×12 = 84 mW, power delivered by op amp (1) is (29 – *VSRC*/3)(14 – *VSRC*/3) = (25)(10) = 250 mW, power delivered by op amp (2) is (28 + *VSRC*/3)(44 + 2*VSRC*/3) = (32)(52) = 1664 mW.

**Version 5:** *VSRC* = 15 V; power delivered by *VSRC* = (-1 + 2*VSRC*/3)*VSRC* = (9)×15 = 135 mW, power delivered by op amp (1) is (29 – *VSRC*/3)(14 – *VSRC*/3) = (24)(9) = 216 mW, power delivered by op amp (2) is (28 + *VSRC*/3)(44 + 2*VSRC*/3) = (33)(54) = 1782 mW.

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1. (a) Determine the response *VO*(*jω*)/*VSRC*(*jω*) assuming *Cf* = 0.5 μF (5 grades), and sketch the Bode magnitude plot showing the maximum gain in dB and the 3 dB cutoff frequency in rad/s (7 grades).

(b) Choose *C* so that the response *IO*(*jω*)/*VSRC*(*jω*) is a bandpass response having the center frequency the same as the 3 dB cutoff frequency in (a) (10 grades).

(c) Determine *Q* of the response in (b) (5 grades) and the maximum gain in dB (7 grades).

**Solution:** (a) Let the 10 kΩ resistor be denoted by *R*. The parallel impedance of *R* and *Cf* is .  . This is a low-pass response having a maximum gain of

10, equivalent to 20log10(10) = 20

dB,

and

a 3 dB cutoff frequency *ωcl* = 1/(104×0.5×10-6) =

200 rad/s. The Bode magnitude plot will be as shown.

(b) In terms of *s*:  and  . Hence, ×= .It follows that , so that *CR* = 1/200 and *C* = 1/(200×104) = 0.5×10-6 μF = *Cf*.

(c) . It follows that BW = 400 rad/s, so that *Q* = 200/400 = 0.5. The maximum gain is 10-3/2 ≡ 20log10(10-3) – 20log10(2) = -60 – 6 ≅ -66 dB.

**Version 1:** (a) *Cf* = 0.5 μF; *ωcl* = 1/(*CfR*) = 1/(0.5×10-6×104) = 200 rad/s, (b) *C* = *Cf* = 0.5 μF, (c) *Q* = 0.5, gain = -66 dB.

**Version 2:** (a) *Cf* = 1 μF; *ωcl* = 1/(*CfR*) = 1/(1×10-6×104) = 100 rad/s, (b) *C* = *Cf* = 1 μF, (c) *Q* = 0.5, gain = -66 dB.

**Version 3:** (a) *Cf* = 2 μF; *ωcl* = 1/(*CfR*) = 1/(2×10-6×104) = 50 rad/s, (b) *C* = *Cf* = 2 μF, (c) *Q* = 0.5, gain = -66 dB.

**Version 4:** (a) *Cf* = 5 μF; *ωcl* = 1/(*CfR*) = 1/(5×10-6×104) = 20 rad/s, (b) *C* = *Cf* = 5 μF, (c) *Q* = 0.5, gain = -66 dB.

**Version 5:** (a) *Cf* = 10 μF; *ωcl* = 1/(*CfR*) = 1/(10×10-6×104) = 10 rad/s, (b) *C* = *Cf* = 10 μF, (c) *Q* = 0.5, gain = -66 dB.

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1. Assuming *R* = 2 Ω,
2. Derive the transfer function *IR*(*jω*)/*ISRC*(*jω*) (8 grades), specify the type of response (2 grades), and determine the 3 dB cutoff frequencies in krad/s (6 grades).
3. Derive the transfer function *IL*(*jω*)/*ISRC*(*jω*) (8 grades), specify the type of response (2 grades), and determine the 3 dB cutoff frequencies in krad/s (6 grades).

**Solution:** (a) From current division: , where  krad/s. The response is bandstop, with BW = *R*/*L* = *R*/10-3 ≡ *R* krad/s. It follows that *ω*2 – *ω*1 = *R* and . Hence, , or , or  krad/s, and , or , or  krad/s.

1. From current division: .the response is bandpass having the same *ω*0, *ω*1 and *ω*2.

**Version 1:** *R* = 2 Ω;  = 2.414 krad/s and  = 0.414 krad/s

**Version 2:** *R* = 3 Ω;  = 3.303 krad/s and  = 0.303 krad/s

**Version 3:** *R* = 4 Ω;  = 4.236 krad/s and  = 0.236 krad/s

**Version 4:** *R* = 5 Ω;  = 5.193 krad/s and  = 0.193 krad/s

**Version 5:** *R* = 6 Ω;  = 6.162 krad/s and  = 0.162 krad/s