IEC 103 — Assignment-3 — IEC 103/ Ass 3/BEC

Operational Amplifiers-2.

Filters

1. A Miller integrator incorporates an ideal op-amp, a resistor R of 100KΩ and a capacitor C of 10nF. A sine wave signal is applied to its input.

   (a) At what frequency (in Hz) are the input and output signals equal in amplitude?

   (b) At that frequency how does the phase of the output sine wave relate to that of the input?

   (c) If the frequency is lowered by a factor of 10 from that found in (a), by what factor does the output voltage change, and in what direction (smaller or larger)?

   (d) What is the phase relation between the input and output in situation (c)?

2. Design a Miller integrator with a time constant of one second and an input resistance of 100KΩ. For a dc voltage of −1V applied at the input at time 0, at which moment $V_0 = -10V$, how long does it take for the output to reach 0V and +10V?

3. An op amp based inverting integrator is measured at 1KHz to have a voltage gain of −100V/V. What is the frequency at which its gain is reduced to −1V/V? What is the integrator time constant?

4. Design a Miller integrator that has a unity gain frequency of 1 Krad s^{-1} and an input resistance of 100 KΩ. Sketch the output you would expect for the situation in which, with output initially at 0V, a 2V 2ms pulse is applied to the input. Characterize the output that results when a sine wave 2 sin1000t is applied to the input?

5. Design a Miller integrator whose input resistance is 20KΩ and unity gain frequency is 10 Hz. What components are needed? For long term stability, a feedback resistor is introduced across the capacitor, which limits the dc gain to 40dB. What is its value? What is the associated lower 3-dB frequency? Sketch and label the output which results with a 0.1ms, 1-V positive input pulse (initially at 0V) with (a) no dc stabilization (but with output initially at 0V) and (b) the feedback resistor connected.

6. A Miller integrator whose input, ~~output~~ voltages are initially zero and whose time constant is 1ms is driven by the signal shown in figure 1. Sketch and label the output waveform that results. Indicate what happens if the input levels are ±2V, the ~~time~~ constant remaining the same and the time constant raised to 2ms?

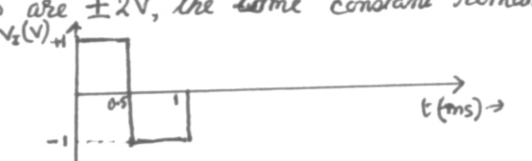

Figure 1.

7. A Miller integrator with $R = 10K\Omega$ and $C = 10nF$ is implemented using an op-amp with $V_{os} = 3mV$, $I_B = 0.1\mu A$, and $I_{os} = 10nA$. To provide a finite dc gain, a $1M\Omega$ resistor is connected across the capacitor.

(a) To compensate for the effect of I_B, a resistor is connected in series with the positive input terminal of the op-amp. What should its value be?

(b) With the resistor of (a) in place, find the worst case dc output voltage of the integrator when the input is grounded.

8. A differentiator utilizes an ideal op-amp, a $10K\Omega$ resistor and a $0.01\mu F$ capacitor. What is the frequency f_0 (in Hz) at which its input and output sine wave signals have equal magnitude? What is the output signal for a $1V_{p-p}$ sine wave input with frequency equal to $10f_0$?

9. An op-amp differentiator with 1ms time constant is driven by the rate controlled step shown in figure 2. Assuming V_o to be zero initially, sketch and label its waveform.

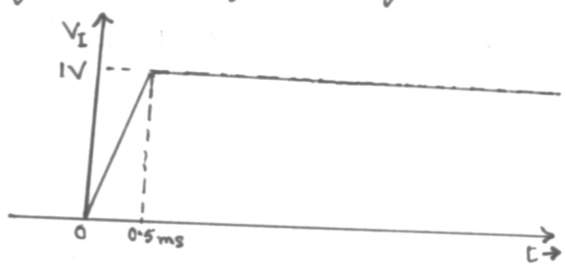

Figure 2

10. An op-amp differentiator has $R = 10K\Omega$ and $C = 0.1\mu F$. When a triangle wave of ± 1-V peak amplitude at 1KHz is applied to the input, what form of output results? What is its frequency? What is its peak amplitude? What is its average value? What value of R is needed to cause the output to have a 10V peak amplitude? When a 1-V peak sine wave at 1KHz is applied to the original circuit, what output waveform is produced? What is its peak amplitude?

11. Using an ideal op-amp, design a differentiation circuit for which the time constant is $10^{-3}s$ using a 10 nF capacitor. What are the gains and phase shifts found for this circuit at one-tenth and 10 times the unity gain frequency? A series input resistor is added to limit the gain magnitude at high frequencies to 100V/V. What is the associated 3-dB frequency? What gain and phase shift result at 10 times the unity gain frequency?

12. Consider the circuit shown in figure 3. Derive the transfer function and show that the high frequency gain is $-(R_2/R_1)$ and the 3 dB frequency $\omega_0 = \frac{1}{CR}$. Design the circuit to obtain a high frequency input resistance of $10K\Omega$, a high frequency gain of 40dB and a 3dB frequency of 1000Hz. At what frequency, does the magnitude of the transfer function reduce to unity?

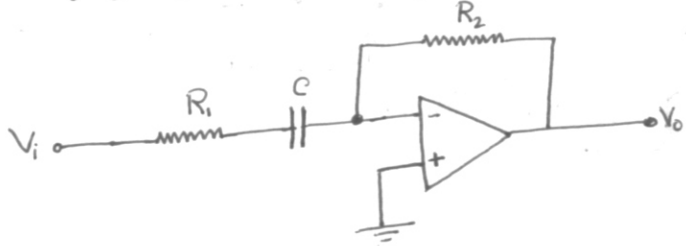

Figure 3.

13. Consider the circuit shown in figure 4. Show that the output V_o is proportional to the inverse logarithm of input V_I.

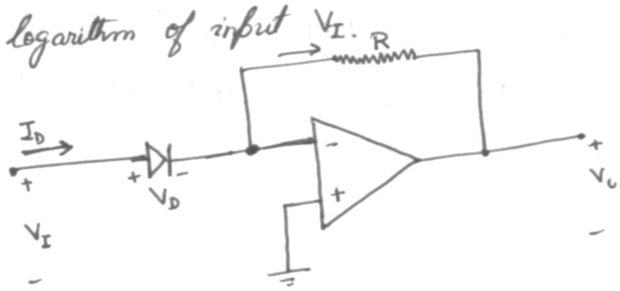

Figure 4.

14. Design a circuit that will multiply two inputs together.

15. Show that the circuit in figure 5 uses an analog multiplier to perform analog division.

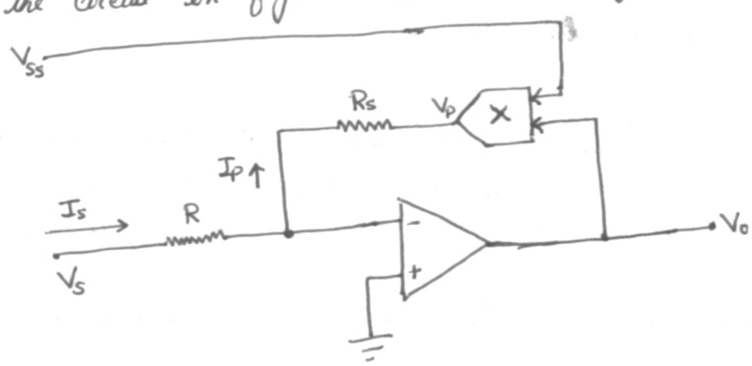

Figure 5

16. Consider the circuit shown in figure 6. The analog multiplier has the characteristic $V_p = V_1 V_2$. Determine the output V_o.

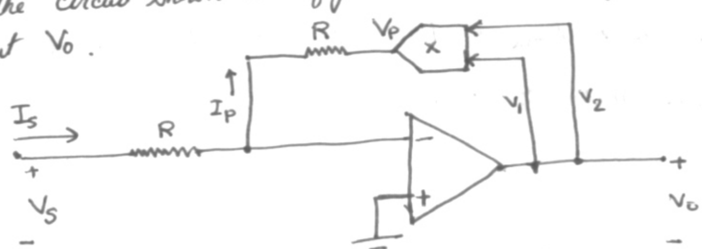

Figure 6

17. Determine the output V_o for the circuit in figure 7.

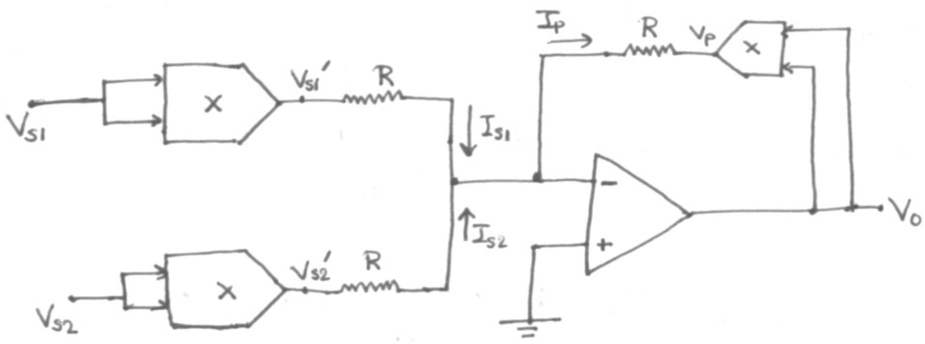

Figure 7

18. The transfer function of a first order low pass filter can be expressed as $T(s) = \frac{\omega_0}{s+\omega_0}$, where ω_0 is the 3dB frequency of the filter. Give in table form the values of $|T|$, ϕ, G and A at $\omega = 0, 0{\cdot}5\omega_0, \omega_0, 2\omega_0, 5\omega_0, 10\omega_0$ and $100\omega_0$.

19. A filter has the function $T(s) = \frac{1}{(s+1)(s^2+s+1)}$. Show that $|T| = \sqrt{1+\omega^6}$ and find an expression for its phase response $\phi(\omega)$. Calculate the values of $|T|$ and ϕ for $\omega = 0{\cdot}1, 1$ and 10 rads^{-1} and then find the output corresponding to each of the following input signals:

(a) $2 \sin 0{\cdot}1t$ (volts)
(b) $2 \sin t$ (volts)
(c) $2 \sin 10t$ (volts)

20. A low pass filter is required to pass all signals within its pass-band, extending from 0 to 4 KHz, with a transmission variation of at most 10% (i.e. the ratio of the maximum to minimum transmission in the passband should not exceed 1·1). The transmission in the stop-band, which extends from 5 KHz to ∞, should not exceed 0·1% of the maximum passband transmission. What are the values of A_{max}, A_{min} and the selectivity factor for this filter?

21. A low pass filter is specified to have $A_{max} = 1$dB and $A_{min} = 10$dB. It is found that these specifications can just be met with a single time constant RC circuit having a time constant of 1s and a dc transmission of unity. What must ω_p and ω_s of this filter be? What is the selectivity factor?

22. Sketch transmission specifications for a high pass filter having a pass-band defined by $f \geq 2$KHz and a stop band defined by $f \leq 1$KHz. $A_{max} = 0{\cdot}5$dB and $A_{min} = 50$dB.

23. Sketch transmission specifications for a bandstop filter that is required to pass signals over the bands $0 \leq f \leq 10$KHz and $20\text{KHz} \leq f \leq \infty$ with A_{max} of 1dB. The stopband extends from $f = 12$KHz to $f = 16$KHz, with a minimum required attenuation of 40dB.

24. By cascading a first order op-amp RC low pass circuit with a first order op-amp RC high pass circuit one can design a wideband bandpass filter. Provide such a design for the case in which the mid-band gain is 12 dB and the 3-dB bandwidth extends from 100 Hz to 10 KHz. Select appropriate component values under the constraint that no resistors higher than 100 KΩ are to be used, and that the input resistance is to be as high as possible.

25. Show that the magnitude response of a second order bandpass function is geometrically symmetrical around the centre frequency ω_0. That is, the members of each pair of frequencies ω_1 and ω_2 for which $|T(j\omega_1)| = |T(j\omega_2)|$ are related by $\omega_1\omega_2 = \omega_0^2$.

26. For a maximally flat second order low pass filter $(Q = 1/\sqrt{2})$, show that at $\omega = \omega_0$, the magnitude response is 3 dB below the value at dc.

27. Find the transfer function of a second order bandpass filter with a centre frequency of 10^5 rad s^{-1}, a centre frequency gain of 10, and a 3-dB bandwidth of 10^3 rad s^{-1}.