EE2 – Final exam SOLUTION

Spring 2020

1. In passive filters amplitude-frequency character of pass band region have _______________
a) Positive slope
b) Negative slope
c) Zero slope
d) None of the mentioned

Ans.: c
Explanation: In passive filters, pass band of amplitude-frequency character is flat.

2. Passive filters have infinite attenuation in stop band region.
a) True
b) False

Ans.: b
Explanation: Attenuation in stop band region of passive filters are not infinite.

3. Which of the filters are lower order filters?
a) Butterworth filter
b) Chebychev filter
c) Bessel filter
d) None of the mentioned

Ans.: d
Explanation: Butterworth, Chebychev and Bessel filters are passive or active higher order filters.

4. Which of the following have pass band of low frequency range?
a) High pass filter
b) Band pass filter
c) Low pass filter
d) Band stop filter

Ans.: c
Explanation: Low pass filters have low frequency range as pass band.

5. Which of the following is known as equiripple filters?
a) Chebychev filter
b) Bessel filter
c) Butterworth filter
d) None of the mentioned

Ans.: a
Explanation: Pass band of chebychev have equal ripple value exhibition and known as equiripple filter.

7. Sharpness of cutoff in Butterworth filter __________ with increasing order.
a) Increases

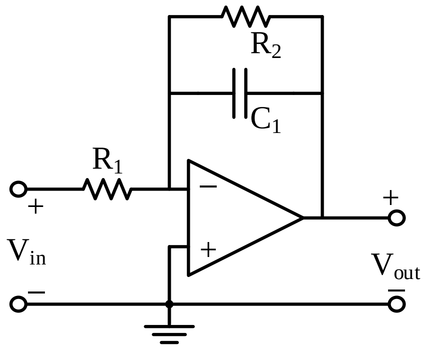
b) Decreases
c) Nothing happens
d) None of the mentioned

Ans.: a
Explanation: In Butterworth filter as order increases, cutoff and approach to ideal behavior increases.

8. Which is not a difference between active and passive filter?
a) A passive filter does not use op-amp while an active filter uses an op-amp
b) A passive filter can’t use an inductor while an active filter can
c) A passive filter performs only filtering while an active filter amplifies too
d) A passive filter is used at audio frequency and an active at radio frequency

Ans.: d
Explanation: A passive filter can consist of all R, L and C elements. An op-amp is used in an active filter, and it also provides amplification along with filtering. There are no inductors used in active filters because they are bigger in size and bulky. Active filters are used at audio frequency and passive filter at radio frequency.

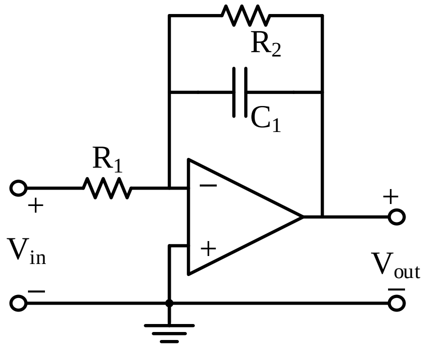
9. In a low pass filter as below, find the cut-off frequency for the following circuit.



Given that $R_1 = 20$ kΩ, $R_2 = 25$ kΩ, $C_1 = 10$ nF.
a) 640 kHz
b) 636 Hz
c) 5.5 kHz
d) 200 Hz

Ans.: b
Explanation: The cut-off frequency for the above filter is $f_c = 1/2\pi R_2 C_1$
$f_c = 1000000/(2\pi 25\times 10) = 636$ (Hz).

10. Given that the maximum gain of a low pass filter using op-amp is 5.5 and the resistor $R_1 = 10$ kΩ, find the value of R_2.



a) 220 kΩ
b) 55 kΩ
c) 50 Ω
d) -55 kΩ

Ans.: b
Explanation: The maximum gain is at low frequencies and at low frequencies, the capacitance reactance is infinite and thus the total feedback impedance $Z_F = R_F = R_2$
Thus gain = $-Z_F/Z = -R_2/R_1$
Amplitude = $5.5 = R_2/R_1 = R_2/10k$
R_2 = 55 kΩ.

11. Which filter attenuates any frequency outside the pass band?
a) Band-pass filter
b) Band-reject filter
c) Band-stop filter
d) All of the mentioned

Ans.: a
Explanation: A band- pass filter has a pass band between two cut-off frequencies f_H and f_L. So, any frequency outside this pass band is attenuated.

12. A band-pass filter has a bandwidth of 250 Hz and center frequency of 866 Hz. Find the quality factor of the filter?
a) 3.46
b) 6.42
c) 4.84
d) None of the mentioned

Ans.: a
Explanation: Quality factor of band-pass filter, Q $=f_c$/bandwidth= 566/250=3.46.

13. In Fourier Series Expansions, if the function $f(x)$ is even, then which of the following is zero?
a) a_n
b) b_n
c) a_v
d) nothing is zero

Ans.: b
Explanation: Since b_n includes sin(nx) term which is an odd function, odd times even function is always odd. So, the integral gives zero as the result.

14. In Fourier Series Expansions, If the function $f(x)$ is odd, then which of the only coefficient is present?
a) a_n
b) b_n
c) a_v
d) everything is present

Ans.: b
Explanation: Since to find b_n we have sin(nx) and the function we have is also odd function,

the product of odd function and another odd function yields even function, the only coefficient which exists is b_n.

15. What are fourier coefficients?
a) The terms that are present in a fourier series
b) The terms that are obtained through fourier series
c) The terms which consist of the fourier series along with their sine or cosine values
d) The terms which are of resemblance to fourier transform in a fourier series are called fourier series coefficients

Ans.: c
Explanation: The terms which consist of the fourier series along with their sine or cosine values are called fourier coefficients. Fourier coefficients are present in both exponential and trigonometric fourier series.

16. Do exponential fourier series also have fourier coefficients to be evaluated.
a) True
b) False

Ans.: a

17. What is a line spectrum?
a) Plot showing magnitudes of waveforms are called line spectrum
b) Plot showing each of harmonic amplitudes in the wave is called line spectrum
c) Plot showing each of harmonic amplitudes in the wave is called line spectrum
d) Plot showing each of harmonic amplitudes called line spectrum

Ans.: b
Explanation: The plot showing each of harmonic amplitudes in the wave is called line spectrum. The line rapidly decreases for waves with rapidly convergent series.

18. An electrical filter is a
a) Phase-selective circuit
b) Frequency-selective circuit
c) Filter-selective circuit
d) None of the mentioned

Ans.: b
Explanation: An electric filter is often a frequency selective circuit that passes a specified band of frequencies and blocks or alternates signal of frequencies outside this band.

19. The problem of passive filters is overcome by using
a) Analog filter
b) Active filter
c) LC filter
d) A combination of analog and digital filters

Ans.: b
Explanation: The active filters enclose as a capacitor in the feedback loop and avoid using inductors, this way inductorless active filter are obtained.

20. Name the filter that has two stop bands?
a) Band-pass filter

b) Low pass filter
c) High pass filter
d) Band-reject filter

Ans.: a
Explanation: A band-pass filter has two stop bands: 1) $0 < f < f_L$ and 2) $f > f_H$.

Prob. 1: Calculate the center frequency, the bandwidth, and the quality factor of a bandpass filter that has an upper cutoff frequency of 121 krad/s and a lower cutoff frequency of 100 krad/s.

Sol.:

$$\omega_0 = \sqrt{\omega_{c1}\omega_{c2}} = \sqrt{121\times 100} = 110 \quad (krad/s)$$

$$f_0 = \frac{\omega_0}{2\pi} = 17.51 \qquad (kHz)$$

$$\beta = 121 - 100 = 21 \quad (krad/s) \qquad \text{or} \qquad 2.79 \quad (kHz)$$

$$Q = \frac{\omega_0}{\beta} = \frac{110}{21} = 5.24$$

Prob. 2: (30 points)

The op amp circuit in Fig. p2 is to be magnitude-scaled by 100 and frequency-scaled by 10^5. Find the resulting element values

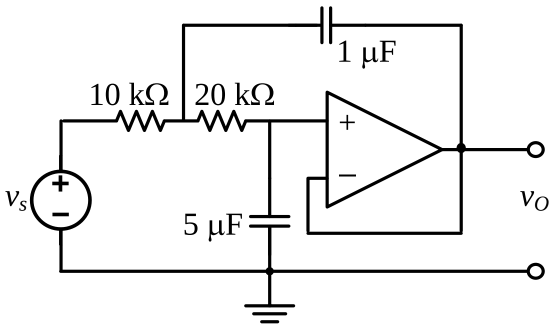


Fig. P2

Sol.:

$$1\mu F \longrightarrow \quad C' = \frac{1}{K_m K_f} C = \frac{10^{-6}}{100x10^5} = \underline{0.1\,pF}$$

$$5\mu F \longrightarrow \quad C' = \underline{0.5\,pF}$$

$$10\,k\Omega \longrightarrow \quad R' = K_m R = 100x10\,k\Omega = \underline{1M\Omega}$$

$$20\,k\Omega \longrightarrow \quad R' = \underline{2\,M\Omega}$$

Problem 3: (20 points)

Find the (response) steady-state voltage $v_O(t)$ in the circuit in right side of Fig. P3 if the input voltage is the waveform shown in left side of Fig. P3 with A = 1V.

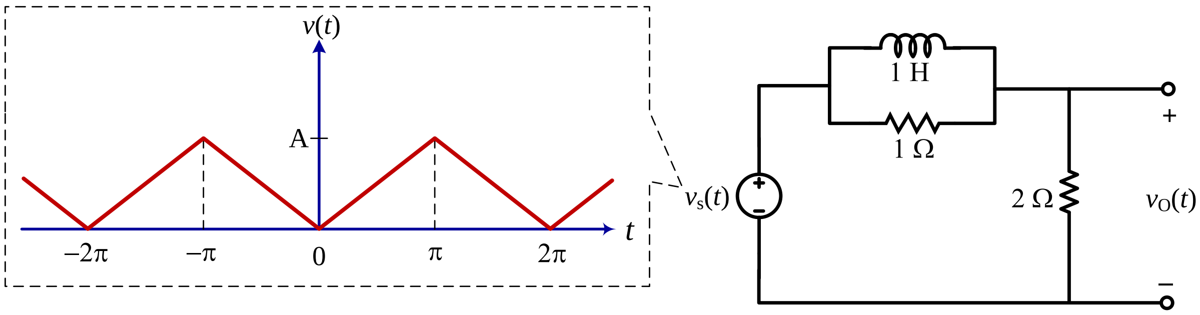


Fig. P3

Sol.:

The Fourier series: $f(t) = a_v + \sum_{n=1}^{\infty}\left(a_n \cos n\omega_0 t + b_n \sin n\omega_0 t\right)$

Note that the waveform is an **even function** and therefore $b_n = 0$ for all n. Thus, we need to find only the a_v and a_n coefficients.

For this waveform, we note that T = 2 π and $\omega_0 = \dfrac{2\pi}{T} = 1$

And a_v is $a_v = \dfrac{2}{T}\int_0^{T/2} f(t)dt = \dfrac{2}{2\pi}\int_0^{2\pi/2} \dfrac{A}{\pi} tdt = \dfrac{A}{\pi^2}\int_0^{\pi} tdt = \dfrac{A}{\pi^2}\times\dfrac{1}{2}t^2\Big|_0^{\pi} = \dfrac{A}{2}$

$$a_n = \frac{4}{T}\int_0^{T/2} f(t)\cos ntdt = \frac{4}{2\pi}\int_0^{T/2}\frac{A}{\pi}t\cos ntdt = \frac{4}{2\pi}\times\frac{A}{\pi}\int_0^{T/2} t\cos ntdt = \frac{2A}{\pi^2}\left[\frac{t}{n}\sin nt + \frac{1}{n^2}\cos nt\right]_0^{\pi}$$

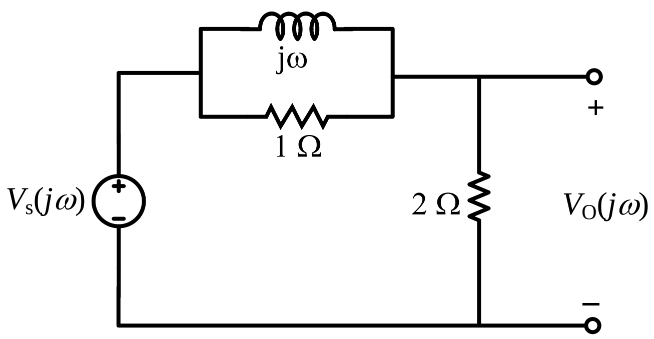
$$= \frac{2A}{(n\pi)^2}(\cos n\pi - 1) = \begin{cases} 0 & \text{for } n \text{ odd} \\ -\dfrac{4A}{(n\pi)^2} & \text{for } n \text{ even} \end{cases}$$

Therefore, the Fourier series is:

$$v(t) = \frac{A}{2} + \sum_{\substack{n=1 \\ n\ odd}}^{\infty} \frac{-4A}{(n\pi)^2}\cos nt \quad \text{(V)}$$

With A = 1 V, so $v(t) = \dfrac{1}{2} + \sum_{\substack{n=1 \\ n\ odd}}^{\infty} \dfrac{-4}{(n\pi)^2}\cos nt$ where $\omega_0 = 1$

Besides, the output voltage for the network can be derived using voltage division as (in s domain)



$$V_O(j\omega)=\frac{2}{2+\dfrac{1\times j\omega}{1+j\omega}}\times V_s(j\omega)=\left[\frac{2(1+j\omega)}{2+3j\omega}\right]\times V_s(j\omega)$$

Since $\omega_0 = 1$ ➔ $V_O(n)=\left[\dfrac{2(1+jn)}{2+3jn}\right]V_s(n)$

Since $V_s(\mathrm{dc}) = a_v = 1/2$ V → $V_O(dc)=\dfrac{2}{2}\times\dfrac{1}{2}=\dfrac{1}{2}\qquad (V)$

Furthermore,

$$V_o(\omega_0)=\frac{-4}{\pi^2}\left[\frac{2(1+j)}{2+3j}\right]=0.318\angle 168.69°$$

$$V_o(3\omega_0)=\frac{-4}{9\pi^2}\left[\frac{2(1+j3)}{2+j9}\right]=3.09\times 10^{-2}\angle 174.09°$$

$$V_o(5\omega_0)=\frac{-4}{25\pi^2}\left[\frac{2(1+j5)}{2+j15}\right]=1.09\times 10^{-2}\angle 176.28°$$

Thus, in the time domain, the steady-state output voltage of the circuit is

$$v_O(t)=\frac{1}{2}+0.318\cos(t+168.69°)+3.09\times 10^{-2}\cos(3t+174.09°)+$$
$$+1.09\times 10^{-2}\cos(5t+176.28°)+\ldots\qquad (V)$$