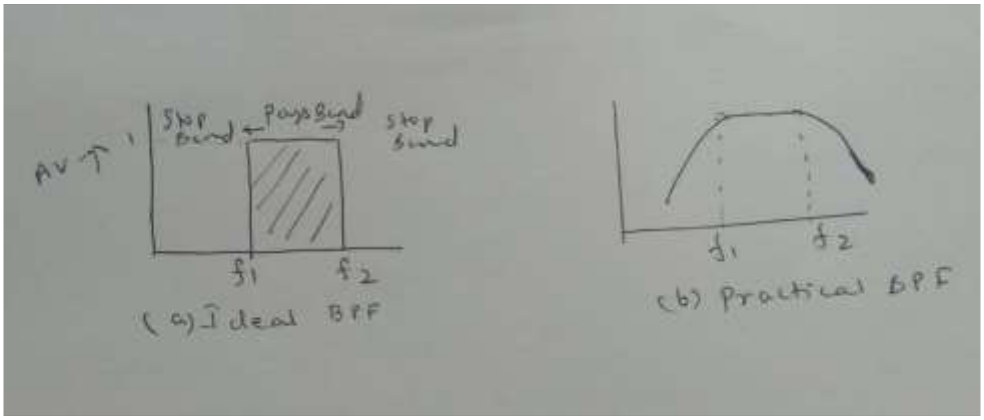
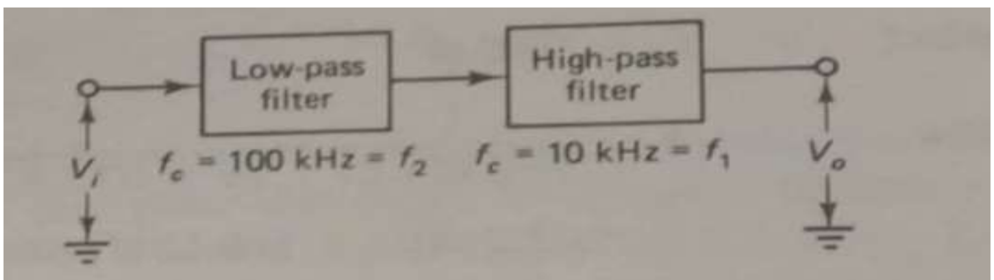
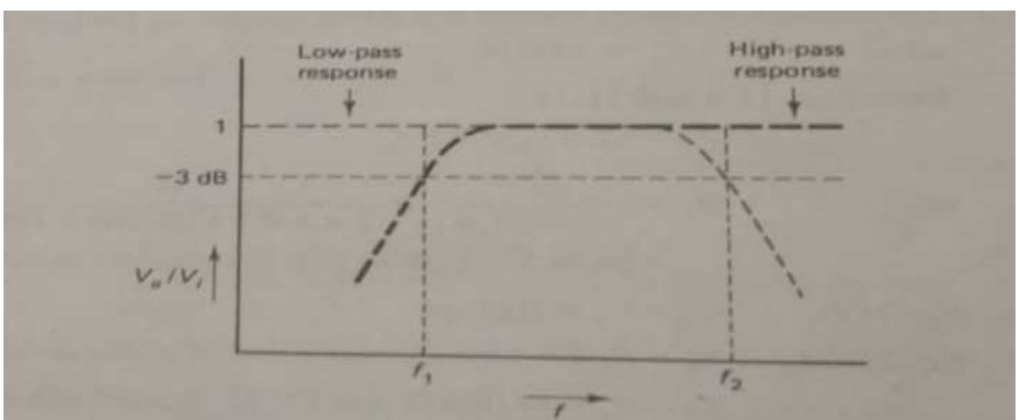
- **Band Pass Filters**



- **Multistage Band Pass Filter**

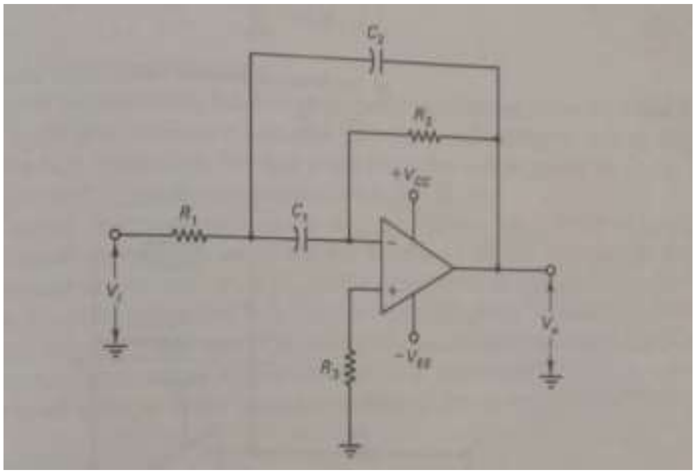


(a) Cascaded low-pass and high-pass filters

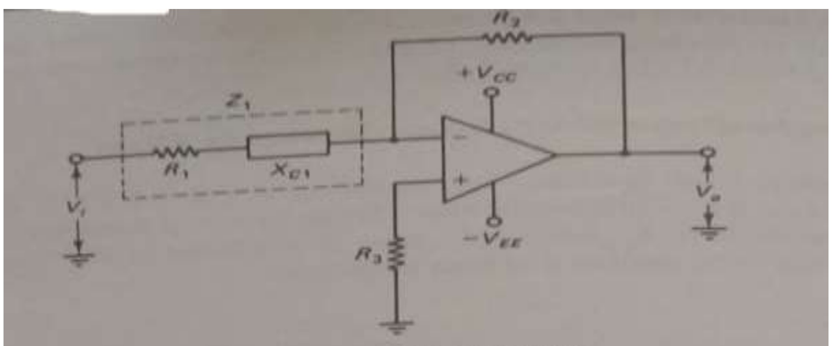


(b) Bandpass frequency response

- **Single Stage Band pass filter**



➢ At Low frequencies, X_{C2} is so large that it can be eliminated from the low frequency equivalent circuit.



(a) Low frequency equivalent circuit

$A_v = \frac{R_2}{Z_1}$

➢ As shown in the figure, the circuit is an inverting amplifier with voltage gain of

$$A_v = \frac{R_2}{Z_1} = \frac{R_2}{\sqrt{(R_1^2 + X_{C1}^2)}}$$

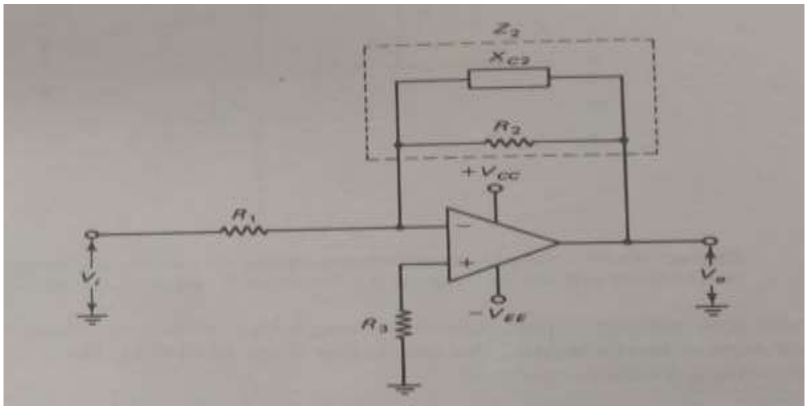
➢ At signal frequencies in the pass band of the circuit, X_{C1} becomes much smaller than R1, so the circuit gain becomes

$$A_v \approx \frac{R_2}{R_1}$$

➢ The above equations shows that for voltage gain to be down by 3dB,

$X_{C1}=R_1$ at f_1, Where f_1 is lower cutoff frequency.

- At High frequencies, X_{C1} becomes so small compared to R1 that can be neglected from the high frequency equivalent circuit.



- Therefore again the circuit is inverting amplifier and its voltage gain is,

$$A_v = \frac{X_{C2} \parallel R_2}{R_1} = \frac{1}{R_1\sqrt{[(1/R_2)^2 + (1/X_{C2})^2]}}$$

- At frequencies in the pass-band, X_{C2} is much larger than R1.
- So, the circuit voltage gain is once again,

$$A_v \approx \frac{R_2}{R_1}$$

- From the above equations, the voltage gain is down by 3dB from its mid-frequency value when,

$X_{C2}=R_2$ at f_2, Where f_2 is upper cutoff frequency.

- It is seen that the circuit behaves as an inverting amplifier when the signal frequency is in the pass band, as a high-pass filter for low frequencies and as a low pass filter for high frequencies.
- Design Procedure:
    - C_2 is selected first (for both BIPOLAR and BIFET)
    - R_2 is obtained using **$X_{C2}=R_2$ at f_2**
    - $R_2=R_3$
    - For Av=1, $R_1=R_2$
    - C_1 is obtained using **$X_{C1}=R_1$ at f_1**

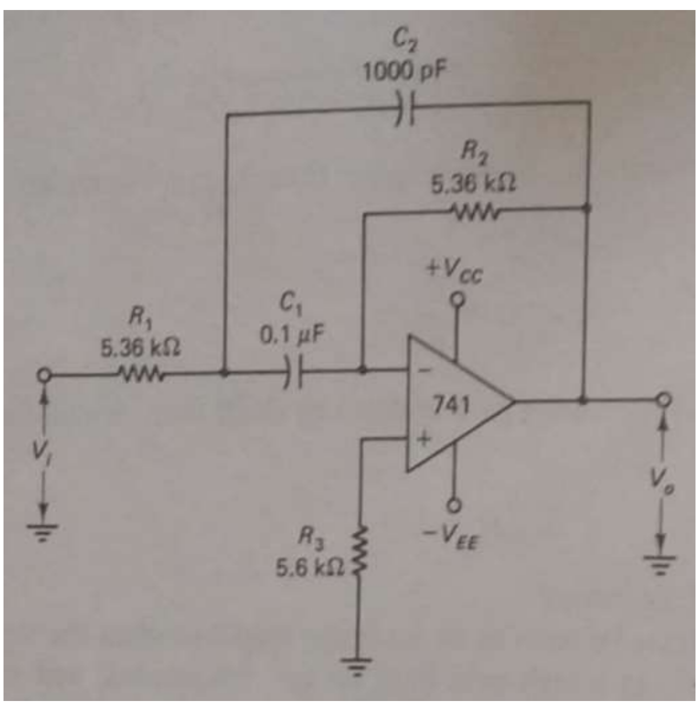
Problem

1. Design a single –stage bandpass filter to have a voltage gain of 1 and pass band from 300Hz to 30 kHz.

- Select C_2=1000pF
- R_2 is obtained using **$X_{C2}=R_2$ at f_2**

  $R_2=1/2\pi f_2 C_2$ = 5.6kΩ
- $R_2=R_3$ = 5.6kΩ
- For Av=1, $R_1= R_2$ =5.6kΩ
- C_1 is obtained using **$X_{C1}=R_1$ at f_1**

  $C_1=1/2\pi f_1 C_1$ = 0.1µF



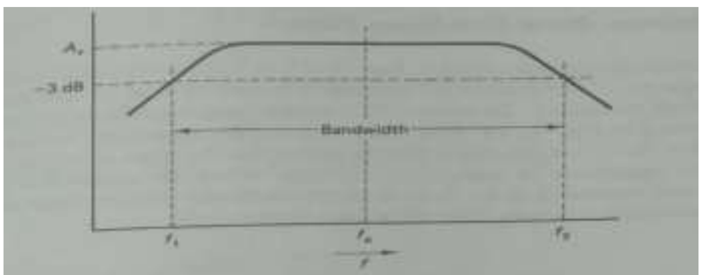
- **Wide-Band and Narrow-Band Bandpass Filters**

  - The bandwidth of the filter circuit is,

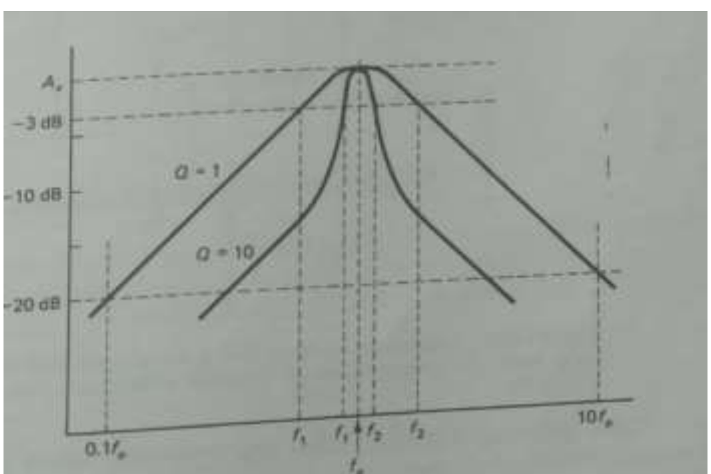
    $B = f_2 - f_1$
  - The center frequency f_0 is,

    $f_0 = \sqrt{f1\ f2}$
  - The circuit Q factor is

    $Q = f_0/B$
  - The Q factor is a figure of merit for a filter circuit. It defines the selectivity of the filter in passing the center frequency and rejecting other frequencies.
  - Wideband filters will have Q less than 5, whereas Narrow band filter will have Q greater than 5.



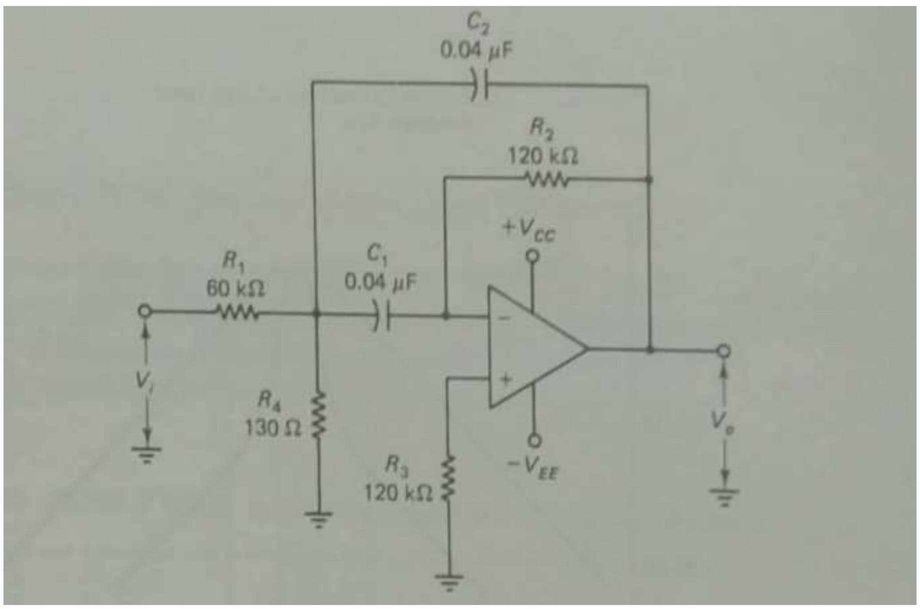
(a) Frequency response of wide band bandpass filter



(b) Frequency response of narrow-band bandpass filters

- **Narrow-Band Bandpass Filter**

  - If f_1 and f_2 are brought closer together, C_2 will affect low cutoff frequency and C_1 will interfere with high cutoff frequency. To avoid this resistor R_4 is included in the circuit, as shown below.
  - This additional resistor makes the circuit analysis very complex, but it can be stated that R_4 attenuates the input signal at frequencies at which the impedance of C_1 is high. When the impedance of C_1 becomes very small compared to R_1, R_4 is in parallel with the opamp input terminals and in this position it has very little effect.



  - Design Equations:

    $C_1 = C_2 = C$,

    $R_1 = R_2/2$,

    $R_2 = 2\,Q\,X_c$ at f_0,

    $R_4 = R_1/2Q^2 - 1$

Problem

1. Design a band pass filter using 741 opamp with center frequency is to be 1 kHz and the pass band is to be approximately ±33Hz on each side of 1 kHz.

Soln.

$B = 33Hz + 33Hz = 66Hz$

$Q = f_0/B = 15.2$

$R_2 = R_3 = 0.1\ V_{BE}/I_{Bmax} = 120k\Omega$

$R_2 = 2\ Q\ X_c$ at f_0,

$C = 2\ Q\ /2\pi\ f_0\ R_2 = 0.04\mu F$

$C_1 = C_2 = C = 0.04\mu F$

$R_1 = R_2/2 = 60k\Omega$

$R_4 = R_1/(2Q^2 - 1) = 130\Omega$