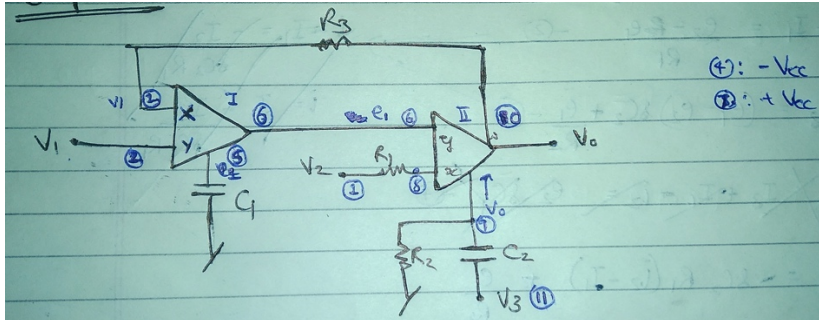


EXPERIMENT 8: Universal biquad using CFOA

1. Analyze the circuit shown below.
2. Choose the values of resistors and capacitors to have
 $\omega_0 = 10^6 \text{ rad/s}$, $Q_0 = \frac{1}{\sqrt{2}}$, $H_0 = 1$
3. Verify the workability of the circuit by determining magnitude and phase response all the 5 types of filters.

CIRCUIT:



Analysis:

$$I_{x1} = I_{z1} \Rightarrow \frac{V_0 - V_1}{R_3} = -C_1 \frac{dV_0}{dt} \quad (1)$$

$$I_{x2} = I_{z2} \Rightarrow \frac{V_2 - V_0}{R_1} = -\frac{V_0}{R_2} + (V_3 - V_0) C_2 \frac{d}{dt} \quad (2)$$

Substitute (1) into (2)

$$\begin{aligned} \frac{V_0}{R_1} + \frac{1}{R_1} \left[\frac{V_0 - V_1}{C_1 R_3} \right] &= -V_0 \left[\frac{1}{R_2} + C_2 \frac{d}{dt} \right] + C_2 \frac{dV_3}{dt} \\ \Rightarrow \frac{-V_1}{C_1 R_3 R_1} + \frac{V_0}{R_1} - C_2 \frac{dV_3}{dt} &= -V_0 \left[\frac{1}{R_2} + C_2 \frac{d}{dt} + \frac{1}{C_1 R_3 R_1} \right] \\ \Rightarrow \frac{V_1}{C_2 C_1 R_3 R_1} - \frac{C_2 V_0}{C_2 R_1} + \frac{C_2^2 V_0}{C_2} &= V_0 \left[\frac{1}{C_2 R_2} + \frac{C_2^2}{C_2} + \frac{1}{C_1 C_2 R_3 R_1} \right] \end{aligned}$$

$$\Rightarrow \left[\frac{C_2^2 V_0}{C_2 R_1} - \frac{C_2 V_0}{C_2 R_1} + \frac{V_1}{C_2 C_1 R_3 R_1} \right] = V_0 \left[\frac{1}{C_2 R_2} + \frac{C_2^2}{C_2} + \frac{1}{C_1 C_2 R_3 R_1} \right]$$

$$\omega_0 = \sqrt{\frac{1}{C_1 C_2 R_3 R_1}} = 10^6 \quad \left| \quad \frac{\omega_0}{Q_0} = \frac{1}{C_2 R_2} = \frac{10^6 \times \sqrt{2}}{1} \right.$$

$$\Rightarrow \frac{1}{C_1 C_2 R_3 R_1} = 10^{12}$$

$$\text{If } C_2 = 1 \text{ nF, then } R_2 = \frac{10^9}{10^6 \times \sqrt{2}} = 0.707 \times 10^3 = 707 \Omega$$

$$\text{and } \frac{1}{C_1 R_3 R_1} = 10^3$$

$$\text{If } C_1 = 1 \text{ nF, } R_1 = R_3 = 1 \text{ k}\Omega \text{ etc}$$

$$\left\{ \begin{aligned} \text{If } R_1 &= 707 \\ R_3 &= 1414.42 \Omega = 1.41 \text{ k}\Omega \end{aligned} \right\}$$

1. Low Pass

```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*i. CFOAs:
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844
X2 6 8 7 4 10 9 AD844

*ii. Passive Componets
R1 1 8 707
R2 9 0 707
R3 3 10 1.41k
C1 5 0 1n
C2 9 11 1n

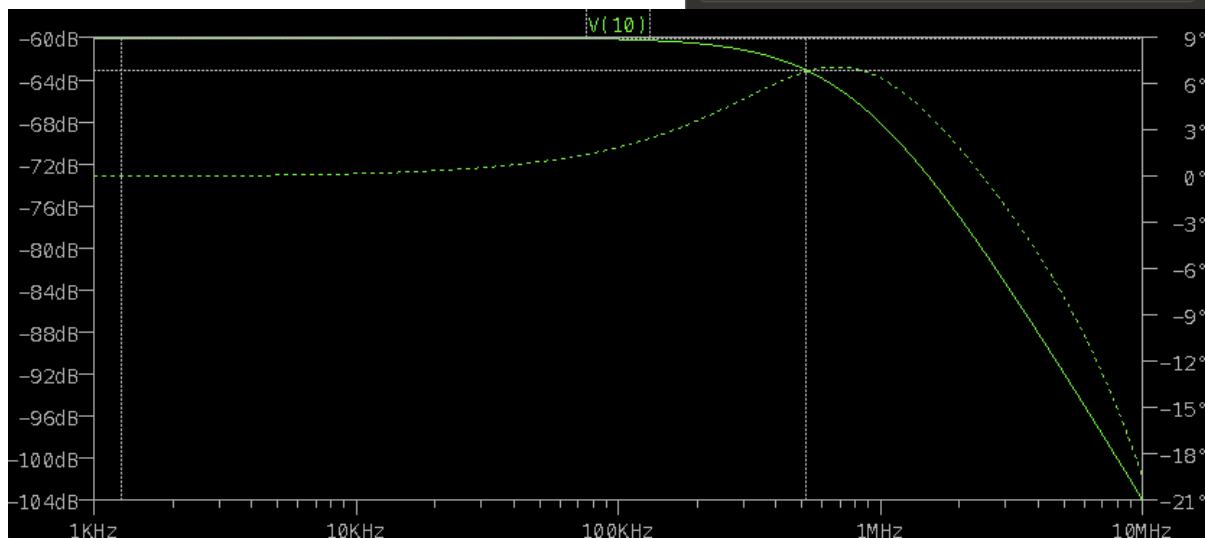
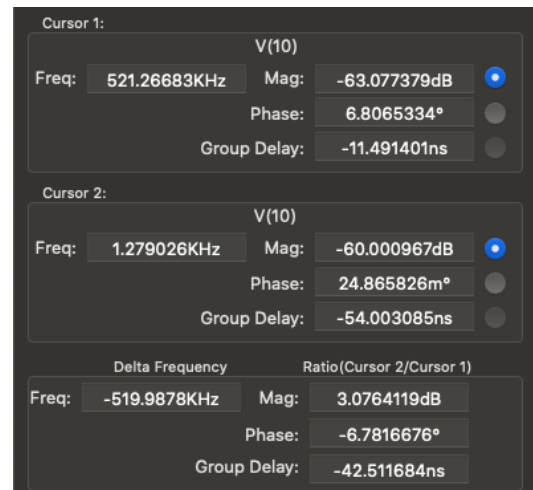
*iii. Power supplies:
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

*iv. Voltage inputs:
*LP: V2=V3=0, BP: V1=V3=0, HP:V2=V1=0
*AP: V1=V2=V3, R1=R2
V1 2 0 AC 1mV
V2 1 0 AC 0mV
V3 11 0 AC 0mV

***** OUTPUT CODES *****
*AC ANALYSIS
.AC DEC 50 1K 10MEG
```

Observation:

1. At DC, Mag = -60.00 dB
2. At freq = 521 KHz, Mag = -63.08dB
3. Therefore, 3 db BW = 521 KHz
4. At 1 MHz, Magnitude is equal to -66dB, hence there is drop of 6 dB from that of voltage at DC.



2. HIGH PASS

```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*1. CFOAs:
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844
X2 6 8 7 4 10 9 AD844

*ii. Passive Componets
R1 1 8 707
R2 9 0 707
R3 3 10 1.41k
C1 5 0 1n
C2 9 11 1n

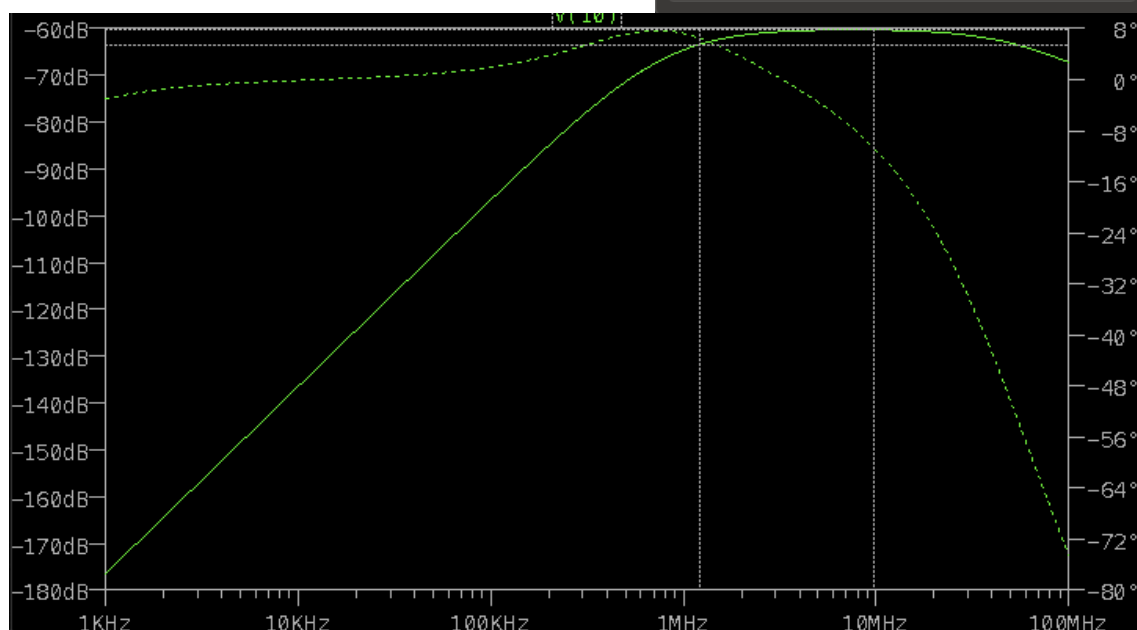
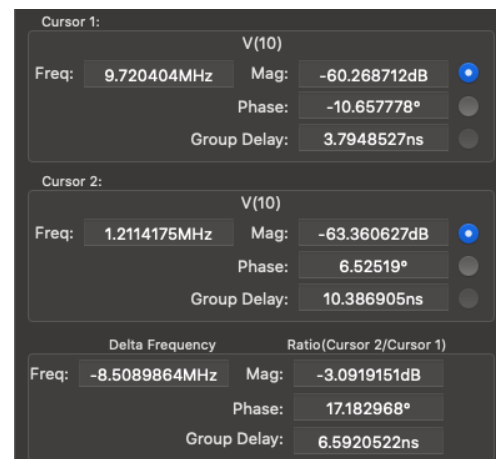
*iii. Power supplies:
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

*iv. Voltage inputs:
*LP: V2=V3=0, BP: V1=V3=0, HP:V2=V1=0
*AP: V1=V2=V3, R1=R2
V1 2 0 AC 0mV
V2 1 0 AC 0mV
V3 11 0 AC 1mV

***** OUTPUT CODES *****
*AC ANALYSIS
.AC DEC 50 1K 100MEG
```

Observations:

1. 3dB cut off frequency = 1.21 MHz



3. Band Pass

```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
```

```
*i. CFOAs:
```

```
*Xn Y X +V -V W Z MODELNAME
```

```
X1 3 2 7 4 6 5 AD844
```

```
X2 6 8 7 4 10 9 AD844
```

```
*ii. Passive Componets
```

```
R1 1 8 707
```

```
R2 9 0 707
```

```
R3 3 10 1.41k
```

```
C1 5 0 1n
```

```
C2 9 11 1n
```

```
*iii. Power supplies:
```

```
VccPositive 7 0 DC 12V
```

```
VccNegative 4 0 DC -12V
```

```
*iv. Voltage inputs:
```

```
*LP: V2=V3=0, BP: V1=V3=0, HP: V2=V1=0
```

```
*AP: V1=V2=V3, R1=R2
```

```
V1 2 0 AC 0mV
```

```
V2 1 0 AC 1mV
```

```
V3 11 0 AC 0mV
```

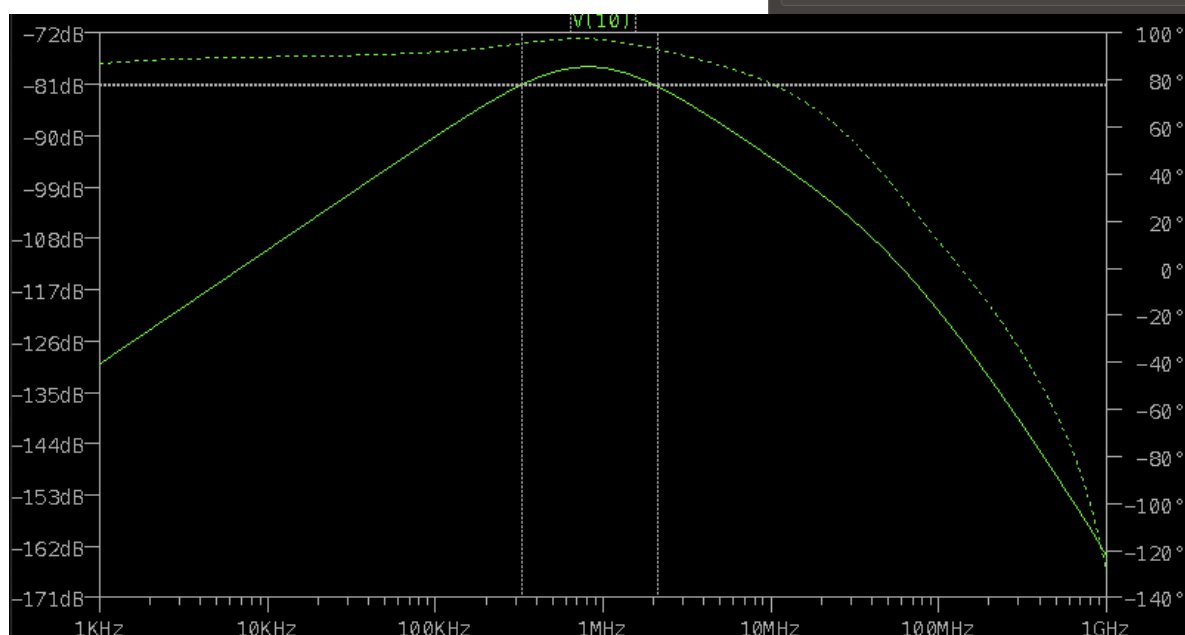
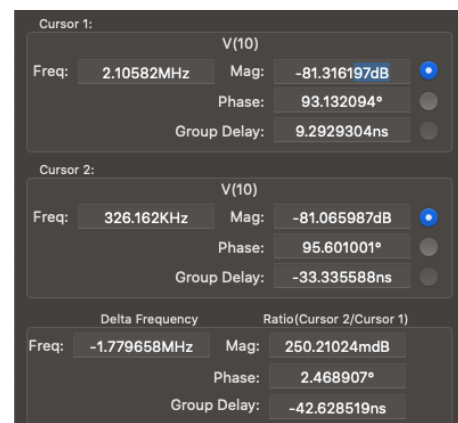
```
***** OUTPUT CODES *****
```

```
*AC ANALYSIS
```

```
.AC DEC 50 1K 1G
```

Observations

1. Centre frequency = 1 MHz
2. Left -3dB freq = 326 kHz
3. Right -3db freq = 2.105 MHz
4. BW = 1.779 MHz



4. ALL Pass

```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*1. CFOAs:
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844
X2 6 8 7 4 10 9 AD844

*ii. Passive Componets
R1 1 8 707
R2 9 0 707
R3 3 10 1.41k
C1 5 0 1n
C2 9 11 1n

*iii. Power supplies:
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

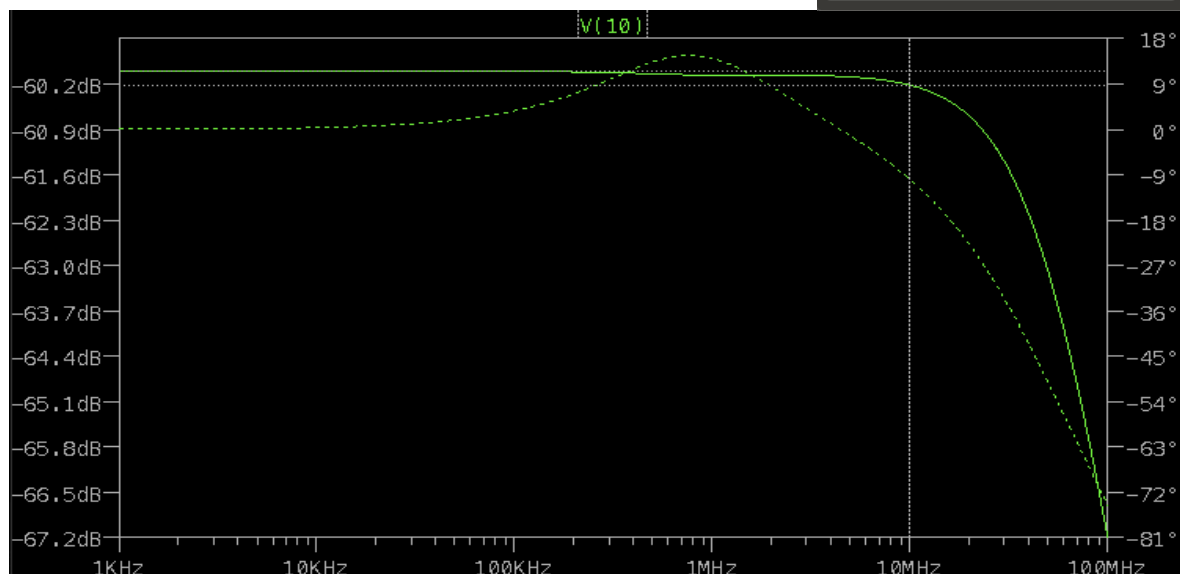
*iv. Voltage inputs:
*LP: V2=V3=0, BP: V1=V3=0, HP: V2=V1=0
*AP: V1=V2=V3, R1=R2, BR: V2=0
V1 2 0 AC 1mV
V2 1 0 AC 1mV
V3 11 0 AC 1mV

***** OUTPUT CODES *****
*AC ANALYSIS
.AC DEC 50 1K 100MEG
```

Observations:

1. Curve has output signal of value -60dB (or the gain 0 db) until 10 MHz and then starts to deteriorate because of parasitic capacitances.

Cursor 1:			
V(10)			
Freq:	9.9579217MHz	Mag:	-60.214111dB
		Phase:	-9.8351728°
		Group Delay:	4.0856617ns
Cursor 2:			
V(10)			
Freq:	1KHz	Mag:	-60.000799dB
		Phase:	37.582231m°
		Group Delay:	-104.39478ns
Delta Frequency			
Ratio(Cursor 2/Cursor 1)			
Freq:	-9.9569217MHz	Mag:	213.31128mdB
		Phase:	9.8727551°
		Group Delay:	-108.48042ns



5. Band reject

```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*i. CFOAs:
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844
X2 6 8 7 4 10 9 AD844

*ii. Passive Componets
R1 1 8 707
R2 9 0 707
R3 3 10 1.41k
C1 5 0 1n
C2 9 11 1n

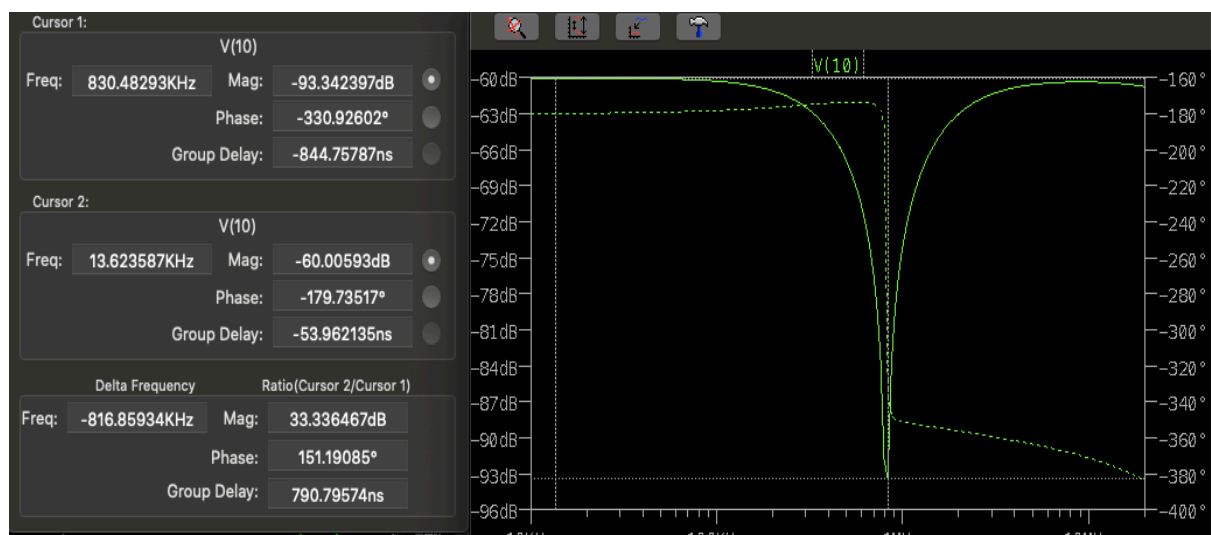
*iii. Power supplies:
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

*iv. Voltage inputs:
*LP: V2=V3=0, BP: V1=V3=0, HP: V2=V1=0
*AP: V1=V2=V3, R1=R2, BR: V2=0
V1 2 0 AC -1mV
V2 1 0 AC 0mV
V3 11 0 AC 1mV

***** OUTPUT CODES *****
*AC ANALYSIS
.AC DEC 50 10K 20MEG
```

Observations:

1. The minima of notch is at 830.4 KHz.
2. In LTSpice, $V1 = V3$ didn't give the desired result, but $V1 = -V3$ did. Though mathematically this will make zeros imaginary. Trying to find the reason why this worked.



Conclusions

1. This is a voltage mode **universal filter using 2 CFOAs**.
2. This circuit has a **current feedback**.
3. The circuit can **realize all the 5 filters**.
4. DC gain cant be varied by keeping bandwidth constant. They are interdependent.