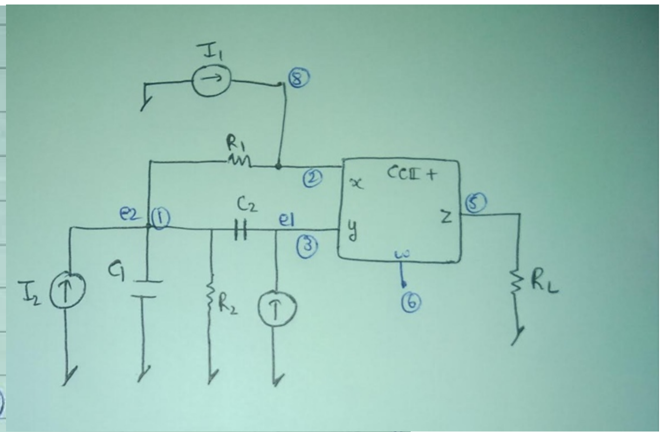
EXP 7: Current-mode biquad using a current conveyor (CC II+)

(Lab Report by Sanuj Kulshrestha, 2017UEC2053, ECD07, Semester 6)

AIM:

1. **Verify that the circuit shown in Figure 2 realizes a low pass, bandpass and high pass filter as follows:**
    a. **Low pass: i1 = i3 = 0, i2 = iin**
    b. **Band pass: i1 = i2 =0, i3 = iin**
    c. **High pass: i1 = -i2 and i3 = i1(R1/R2)(1 + C2/C1)**
2. **Discuss Limitations of the circuit**
3. **Comment upon if this is the only single CCII/single CFOA circuit which can realise an Universal filter?**
4. **Find out by searching the literature if there is any similar circuit known which can realise universal filter using a single CCII/CFOA in voltage mode i.e inputs and output both being voltages rather than currents?**



Ckt Analysis

- $V_{out} = -i_z R_L$ — (1)
- $i_z - I_1 = \dfrac{e_2 - e_1}{R_1}$ — (2)
- $I_3 = (e_1 - e_2)\, sC_2 + \dfrac{e_1}{R_2}$ — (3)

$= -sC_2 R_1 (i_z - I_1) + \dfrac{e_1}{R_2}$

$\Rightarrow e_1 = R_2 I_3 + sC_2 R_1 (i_z - I_1) R_2$ — (4)

and

$e_2 = R_1 (i_z - I_1) + e_1$

$= (R_1 + sC_2 R_1 R_2)\, i_z - (R_1 + sC_2 R_1 R_2) I_1 + R_2 I_3$ — (5)

- $I_2 + (e_1 - e_2)\, sC_2 = i_z - I_1 + e_2\, sC_1$

Subsituting e_2 from (5) & (2):

$\Rightarrow I_2 + -sC_2 R_1 (i_z - I_1) = i_z - I_1 + sC_1 \left[(R_1 + sC_2 R_1 R_2)(i_z - I_1) + R_2 I_3\right]$

$\Rightarrow I_1 \left[sC_2 R_1 + sC_1 R_1 + s^2 C_1 C_2 R_1 R_2 + 1\right] - I_3 \left[sC_1 R_2\right] + I_2 = i_z \left[sC_2 R_1 + sC_1 R_1 + s^2 C_1 C_2 R_1 R_2 + 1\right]$

$\Rightarrow \boxed{i_z = I_1 + \dfrac{I_2}{D(s)} - \dfrac{I_3\, sC_1 R_2}{D(s)}}$

where $D(s) = s^2 C_1 C_2 R_1 R_2 + s\left[C_2 R_1 + C_1 R_1\right] + 1$

1. SPICE ANALYSIS

a. LOW PASS

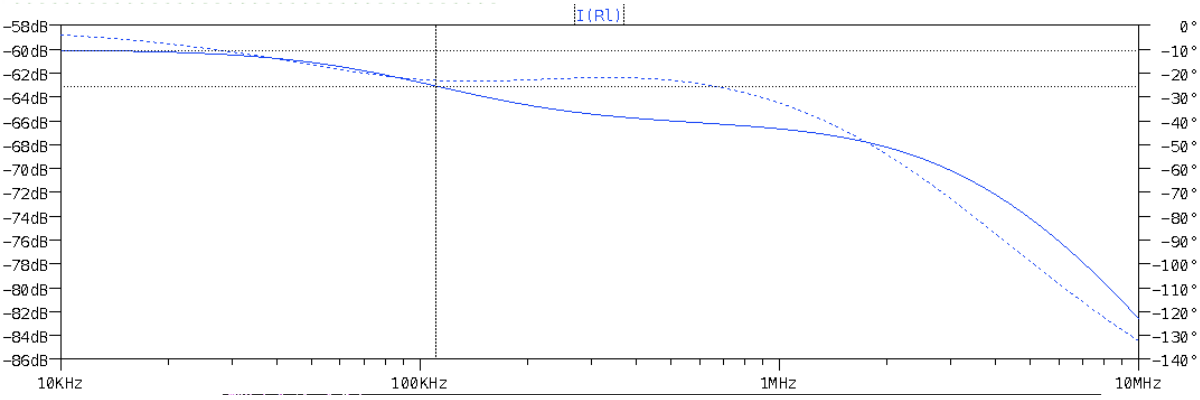
```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844

R1 2 1 1k
R2 3 0 500
RL 0 5 10k

C1 1 0 1n
C2 1 3 1n

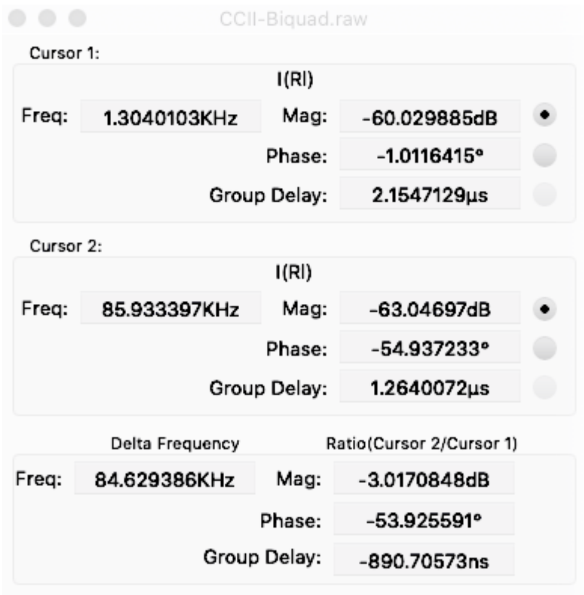
I1 0 8 AC 0m
I2 0 1 AC 1m
I3 0 3 AC 0m
*For HIGH PASS I3 needs to be i1(R1/R2)(1 + C2/C1) = 4*I1
*F3 0 3 VI1 4
*0V voltage source for current dependent(I1) current source(I3)
VI1 8 2 DC 0V
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

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



Observation:

1. At DC, Mag = -60.08 dB
2. At freq = 111 KHz, Mag = -63.08dB
3. Therefore, 3 db BW = 111 KHz
4. At 225 KHz, Magnitude is equal to -64dB, hence there is drop of 4dB from that of voltage at DC.



b. BAND PASS

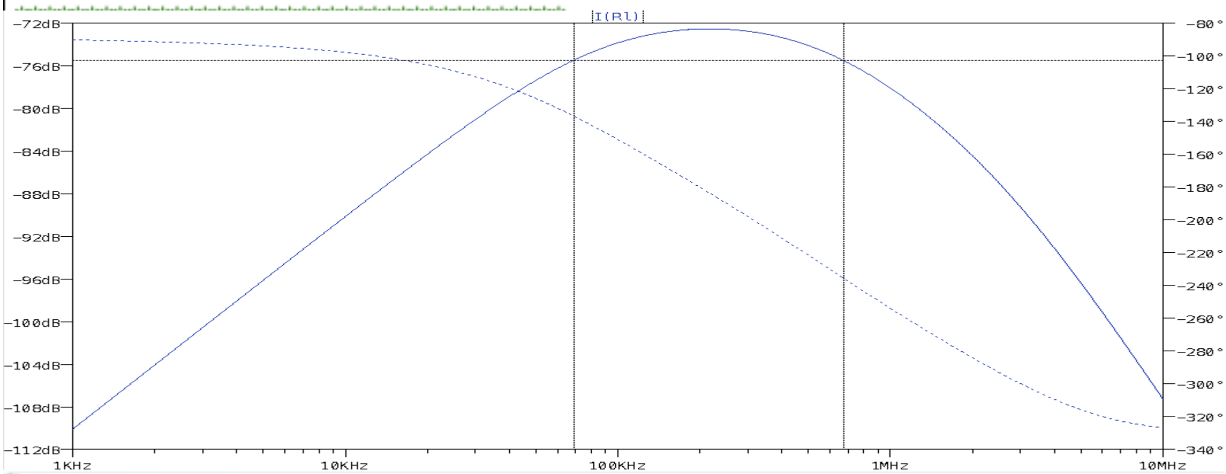
```
.include /Users/sanujkul/Documents/LTspice/libraries/ad844.cir
*Xn Y X +V -V W Z MODELNAME
X1 3 2 7 4 6 5 AD844

R1 2 1 1k
R2 3 0 500
RL 0 5 10k

C1 1 0 1n
C2 1 3 1n

I1 0 8 AC 0m
I2 0 1 AC 0m
I3 0 3 AC 1m
*For HIGH PASS I3 needs to be i1(R1/R2)(1 + C2/C1) = 4*I1
*F3 0 3 VI1 4
*0V voltage source for current dependent(I1) current source(I3)
VI1 8 2 DC 0V
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

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



Observations:

1. Centre frequency = 217 kHz
2. Left -3dB freq = 68 kHz
3. Right -3db freq = 68 kHz
4. BW = 603 kHz

Cursor 1:

I(Rl)

Freq:	672.00787KHz	Mag:	-75.465946dB
		Phase:	-235.39705°
		Group Delay:	194.71401ns

Cursor 2:

I(Rl)

Freq:	68.761KHz	Mag:	-75.466332dB
		Phase:	-136.41702°
		Group Delay:	1.4603406µs

	Delta Frequency		Ratio(Cursor 2/Cursor 1)
Freq:	-603.24687KHz	Mag:	-386.58463µdB
		Phase:	98.980032°
		Group Delay:	1.2656265µs

c. HIGH PASS

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

R1 2 1 1k
R2 3 0 500
RL 0 5 10k

C1 1 0 1n
C2 1 3 1n

I1 0 8 AC 1m
I2 0 1 AC -1m
*I3 0 3 AC 1m
*For HIGH PASS I3 needs to be i1(R1/R2)(1 + C2/C1) = 4*I1
F3 0 3 VI1 4
*0V voltage source for current dependent(I1) current source(I3)
VI1 8 2 DC 0V
VccPositive 7 0 DC 12V
VccNegative 4 0 DC -12V

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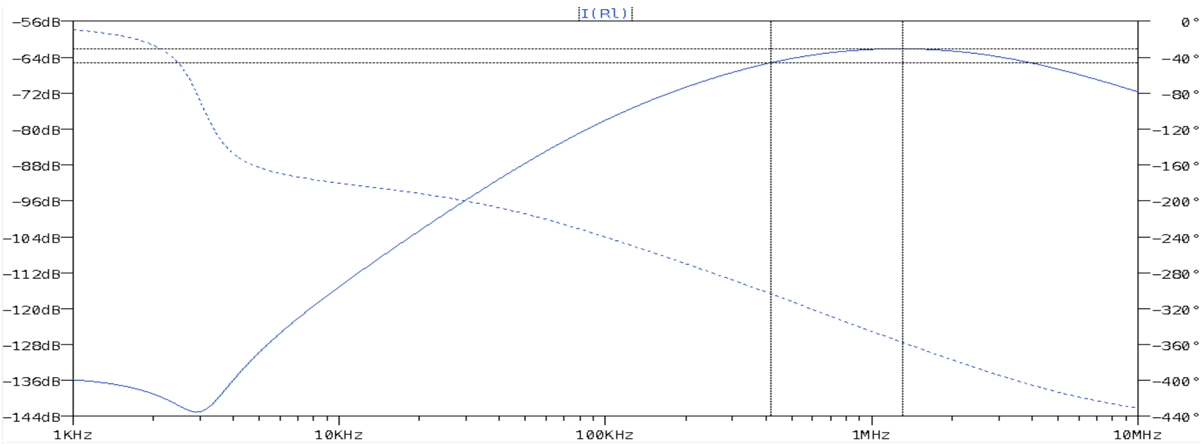
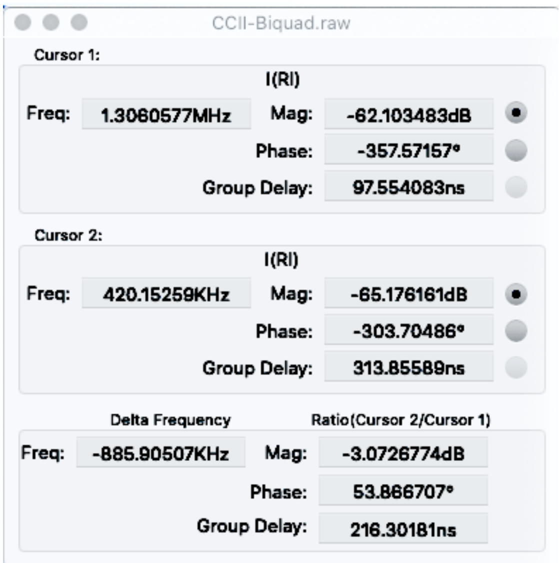


Observations:

1. 3dB cutoff frequency = 420 KHz



Limitations of the circuit:

1. For High pass response, there is too much dependencies among current sources.
2. Not adjustable filter parameters.
3. No feedback.

Comment upon if this is the only single CCII/single CFOA circuit which can realise an Universal filter?

No this is not the only single CCII/single CFOA based Universal filters. Some of other examples can be found in:

1. SUN, Y .-CH., HE, Y .-G. (2003) Active filters using single current conveyor.
2. Sharma, R. K., & Senani, R. (2004). *Universal current mode biquad using a single CFOA. International Journal of Electronics.*
3. Sharma, R. K., & Senani, R. (2004). *On the Realization of Universal Current Mode Biquads Using a Single CFOA. Analog Integrated Circuits and Signal Processing.* (This paper has 8 Current mode universal filters using single CFOA)

Find out by searching the literature if there is any similar circuit known which can realise universal filter using a single CCII/CFOA in voltage mode i.e inputs and output both being voltages rather than currents?

1. Kaçar, F., & Yeşil, A. (2009). *Voltage mode universal filters employing single FDCCII. Analog Integrated Circuits and Signal Processing.*
   (This paper has 4 Voltage mode universal biquads using single Fully Differencial CCII)
2. Chen, H.-P. (2009). *Single CCII-based voltage-mode universal filter. Analog Integrated Circuits and Signal Processing*