BIRZEIT UNIVERSITY

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Report for Experiment #10

Active Filters Analysis and Design

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Abstract:

The aim of this experiment:

The aim of this experiment is to find the response of the active filters by connecting different circuits for active filter.

The methods used:

In this experiment different types of active filters were connected by using (different values of "R" such as 1KΩ, 680Ω, 2.7KΩ", op-amp "active device", function generator, digital multimeter, and Oscilloscope.

Main result:

The results got in laboratory are acceptable, since when they were compared with the results got in PSPICE, MATLAB and by hand, they were found almost equal.

Theory:

Part A: First order low pass active filter:

In the first order low pass active filter, the low frequencies only allow to pass since that the impedance of the capacitor is affected, for example at low frequencies the capacitor is open circuit and the Op-Amp circuit is acts as like an inverting amplifier with gain $\frac{-R2}{R1}$.

In contrast, at high frequencies the capacitor is short circuit, thereby connecting the output of the op amp circuit to ground.

The op amp circuit in Fig. 1.1 thus functions as a low-pass filter with a passband gain of *–R2/R1.*

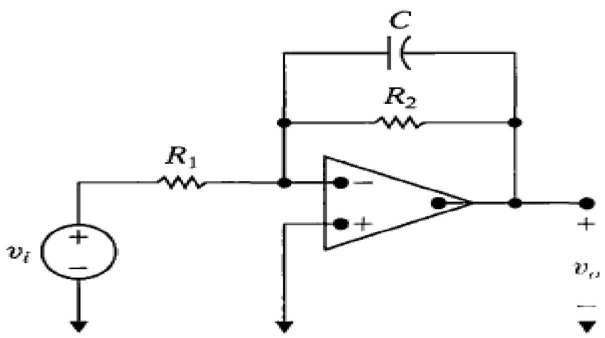

Figure 1.1

To analysis this circuit, we can compute the transfer function is $H(s)=V_o/V_i$, and we can need to replace Z_i at the input path "it is R1" and Z_f at the negative feedback "it is the parallel combination of the resistor R2 and the capacitor" it is show in the figure 1.2 shown below:

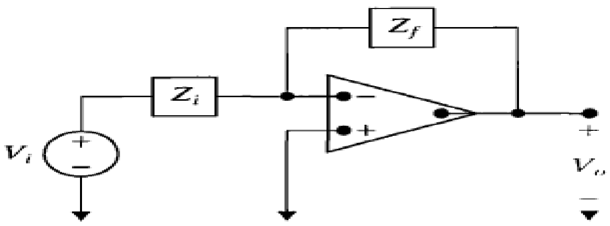

Figure 1.2

➔the transfer function of the circuit is

- **H(s)= -Zf/Zi**
- $\frac{-R2//(\frac{1}{sc})}{R1}$
- $-K\frac{Wc}{s+Wc}$

Where K= $\frac{R2}{R1}$ **and Wc=** $\frac{1}{R2C}$

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Part C: first order active high pass filter:

The figure 2.1 shown below is the general circuit of the high pass filter.

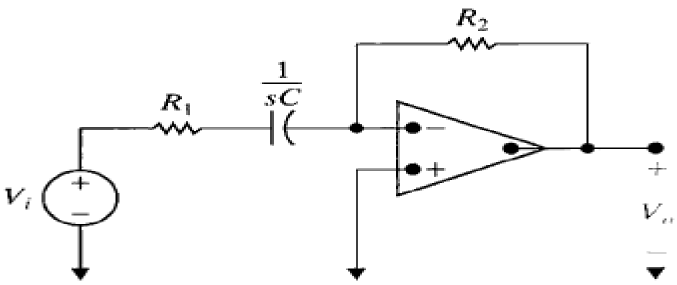

Figure 2.1

At high frequencies, the capacitor is short circuit, so the function of OP-Amp circuit is inverting amplifier with gain –R2/R1.

In contrast, at low frequencies the capacitors is open circuit thereby connecting the output of the op amp circuit to ground.

To analysis this circuit the impedance of the input path is the series combination of R1 and C and the impedance in the feedback path is the resistor R2.

➔the transfer function of the circuit is:

- **H(s)=** $\frac{-Zf}{Zi}$
- **=**$\frac{-R2}{R1+\frac{1}{SC}}$
- **=-K** $\frac{S}{S+WC}$

Where K is R2/R1 and Wc=$\frac{1}{R2C}$**.**

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Part E: Active band-pass filter:

The general form of block diagram of the band pass filter is shown in the figure 3.1 shown below

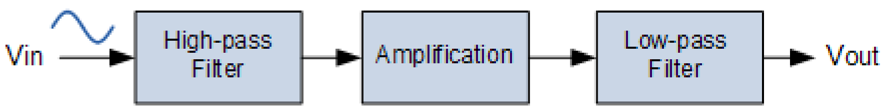


Figure 3.1

The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF) and the difference between the frequencies at the -3dB point will determine the "bandwidth" of the band pass filter while attenuating any signals outside of these points. One way of making a very simple Active Band Pass Filter is to connect the basic passive high and low pass filters we look at previously to an amplifying op-amp circuit as shown in the figure 3.2 shown below.

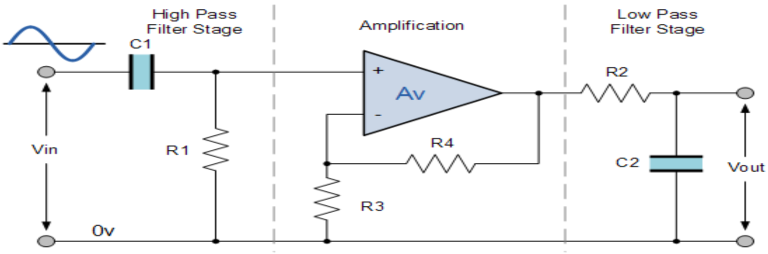


Figure 3.2

This cascading together of the individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively flat asymmetrical pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown in the figure 3.3 shown below.

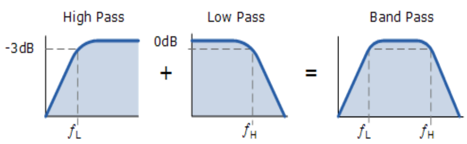
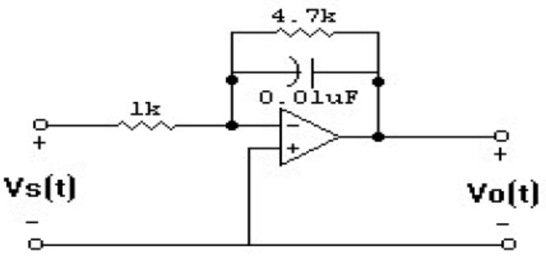


Figure 3.3

Procedure:

Part A: first order active low pass filter:

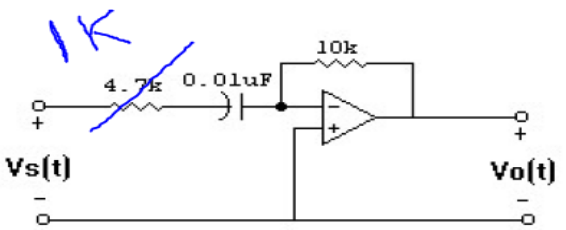
1) The circuit shown below was connected, and the input voltage($V_s(t)$) was put to be 1Vrms.



2) Low frequencies were used at first, and then the frequency was increased to observe the filter response.
3) The cut of frequency was determined by changing the frequency until Vo is around $Vm/\sqrt{2}$, hence the frequency shown is fc.
4) The DMM was connected across Vo, and frequency was changed step by step, so that Vo equals the values listed in Table 10.1, and the corresponding values of (f) were recorded in Table 10.1.

Part C: First order active high -pass filter:

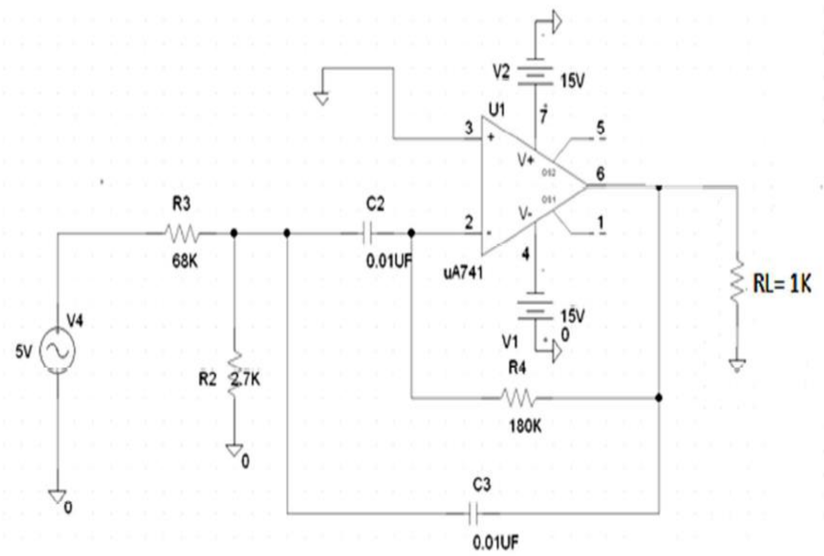
1) The circuit shown below was connected, and the input voltage($V_s(t)$) was put to be 1Vrms.



2) The same steps in Part A were repeated, and the results were recorded in Table 10.3.

Part E: Active band-pass filters:

1) The circuit shown below was connected, and the input voltage($V_s(t)$) was put to be 2.2Vrms.



2) In the first low frequencies were used, and then the frequency was increased to observe the filter response.

3) The center frequency "fo" was determined experimentally by changing the frequency until Vo is around Vmax=2.26, at this point "f" is the center frequency, the results were recorded in Table 10.5.

4) The cut of frequencies "f_{c1} , f_{c2} " were determined experimentally by changing the frequency until Vo is around (Vmax / $\sqrt{2}$), at this point, there would be two points of "f", they were recorded in Table 10.5.

5) The DMM was connected across Vo, then frequency was increased step by steps, so that Vo is equal to the values listed in Table 10.5, the corresponding values of frequency were recorded in Table 10.5.

Data and calculation:

Data Tables:

Part A: First order active low-pass filter

Table 10.1

V_o [V_{RMS}]	V_{max} 4.4	V_{max} 5	V_{max} 4.6	4.36	3.75	$V_{max}/\sqrt{2}$ 3.6	2.45	2	1.6	V_{min} 0.36	V_{min} 0.108
f [kHz]	50Hz	500Hz	1590Hz	2KHz	3KHz	f_c 3.3K	6KHz	8KHz	10KHz	50KHz	100KHz
V_i [V_{RMS}]	1	1	1	1	1	1	1	1	1	1	1
$20\log(\frac{V_o}{V_i})$ [**dB**]	12.86	13.9	13.2	12.7	11.4	11.1	7.78	6.02	4.08	-8.8	-19.33

f	**50Hz**	**500HZ**	**1590hz**	**2K**	**3K**	**3.3K**	**6K**	**8K**	**10K**	**50K**	**100K**
Logf	**1.69**	**2.6**	**3.2**	**3.30**	**3.47**	**3.518**	**3.77**	**3.90**	**4**	**4.69**	**5**

The Table need to graph

Logf	**1.69**	**2.6**	**3.2**	**3.30**	**3.47**	**3.518**	**3.77**	**3.90**	**4**	**4.69**	**5**
$20\log(\frac{V_o}{V_i})$ [**dB**]	12.86	13.9	13.2	12.7	11.4	11.1	7.78	6.02	4.08	-8.8	-19.33

Part C: First order active high -pass filter

In this part, we use resistor 1K not 4.7K.

Table 10.3

V_o [V_{RMS}]	V_{min} 0.035	V_{min} 0.356	1.095	1.42	1.95	$V_{max}/\sqrt{2}$ 5.1	4	5	V_{max} 6.3	V_{max} 7	V_{max} 7.3
f [kHz]	50Hz	500Hz	1590Hz	2KHz	3KHz	f_c 8.2KHz	6KHz	8KHz	10KHz	11.5KHz	12KHz
V_i [V_{RMS}]	1	1	1	1	1	1	1	1	1	1	1
$20\log(\frac{V_o}{V_i})$ [**dB**]	-29.1	-8.9	0.78	3.04	5.80	14.15	12.04	13.97	15.98	16.9	17.2

f	50Hz	500HZ	1590hz	2K	3K	8.2K	6K	8K	10K	11.5K	12K
Logf	**1.69**	**2.69**	**3.20**	**3.30**	**3.47**	**3.91**	**3.77**	**3.90**	**4**	**4.06**	**4.07**

The Table need to graph

logf	**1.69**	**2.69**	**3.20**	**3.30**	**3.47**	**3.91**	**3.77**	**3.90**	**4**	**4.06**	**4.07**
20log($\frac{Vo}{}$) [**dB**]	-29.1	-8.9	0.78	3.04	5.80	14.15	12.04	13.97	15.98	16.9	17.2

Part E: Active band-pass filters

Table 10.5

Vo [V_{RMS}]	V_{min} 0.03	0.54	0.83	1.5	$V_{max}/\sqrt{2}$ 1.57	V_{max} 2.26	$V_{max}/\sqrt{2}$ 1.61	1.33	0.52	0.31	V_{min} 0.08
f [kHz]	50Hz	400Hz	500Hz	600Hz	f_{c1} 614Hz	f_0 738Hz	f_{c2} 860Hz	900Hz	1.3KHz	1.8KHz	5KHz
Vi [V_{RMS}]	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22
20log($\frac{Vo}{Vi}$) [**dB**]	-37.3	-12.2	-8.54	-3.40	-3	0.155	-2.7	-4.45	-12.6	-17.09	-28.86

f	50Hz	400HZ	500hz	600Hz	614Hz	738HzK	860Hz	900Hz	1.3K	1.8K	5K
Logf	**1.69**	**2.60**	**2.69**	**2.77**	**2.78**	**2.86**	**2.93**	**2.95**	**3.11**	**3.25**	**3.69**

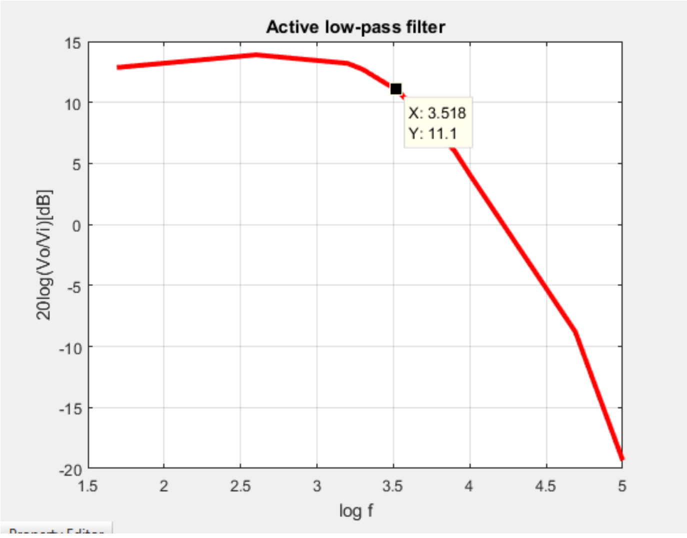
The table need to graph:

logf	**1.69**	**2.60**	**2.69**	**2.77**	**2.78**	**2.86**	**2.93**	**2.95**	**3.11**	**3.25**	**3.69**
20log($\frac{Vo}{}$) [**dB**]	-37.3	-12.2	-8.54	-3.40	-3	0.155	-2.7	-4.45	-12.6	-17.09	-28.86

Conclusion:

Part A: First order active low pass filter:

The response graph of this part using MATLAB:



From the graph of the response, some notes can be noticed:

- ✓ **The magnitude decreases when the frequency increases.**
- ✓ **The curve is not smooth, since that the points got are not enough to draw a smooth curve.**

- **The value of *fc* theoretically is:**

fc= 1/(2πRC)

= 1/(4.7k*.01u*2*3.14)

✓ = 3.38kHz

- **The value of fc practically is:**

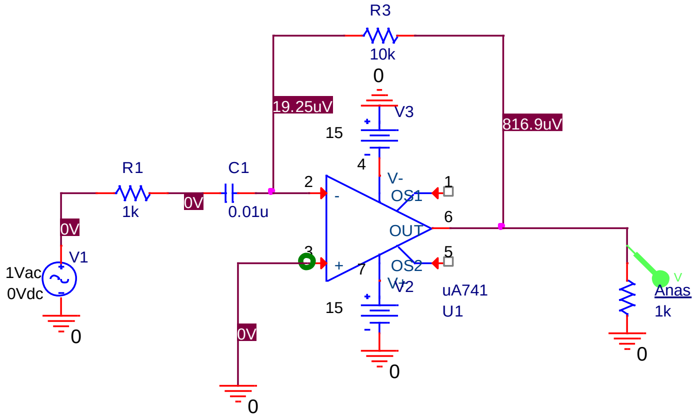
✓ **3.3kHz .**

This values are almost equal since the frequency used was small so the internal resistance of the components such as C, L do not appear.

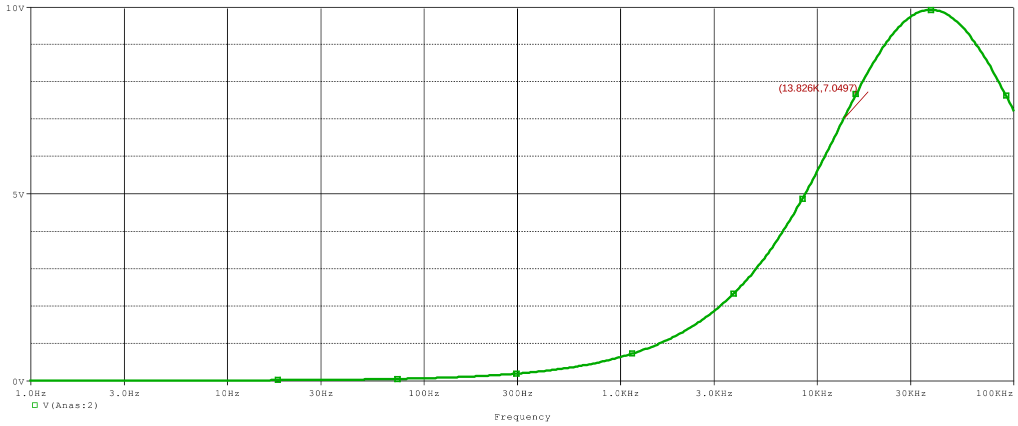
✓ **The error in this part is negligible since the value of frequency used is not enough to shown the internal resistance of the components.**

Part C: First order active high pass-filter:

We need to make a new simulation for part C with resistor 1K:

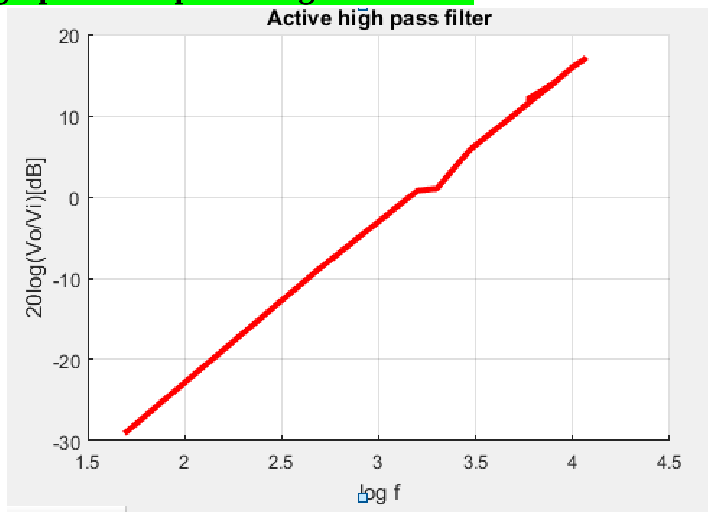


The result:



➔ $fc=\frac{1}{2*3.14*1K*0.01U}$ = 15.9KHz

✓ **The response graph of this part using MATLAB:**

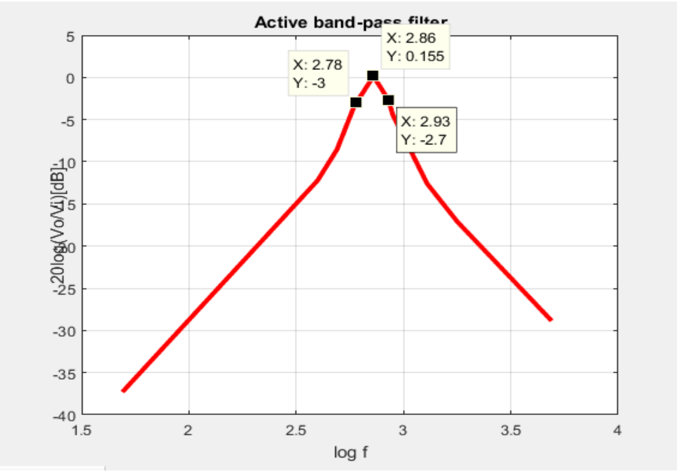


- From the graph of the response, some notes can be noticed:
  - ✓ The magnitude increases when the frequency increases.
  - ✓ The curve is not smooth since the points got is not enough to graph a smooth curve.

- The value of *fc* theoretically:
  - ✓ $fc = \frac{1}{2*3.14*1K*0.01U}$ = 15.9KHz
- the value of *fc* practically:
  - ✓ 8.2K Hz
- The causes of error are:
  - ✓ The tolerance in the components.
  - ✓ The internal resistor of the DMM and another devices used.
  - ✓ The choosing frequencies can not be generated exactly as desired.
  - ✓ In this part we was used 1K resistor not 4.7K this is an error.

Pare E: Active band-pass filter:

- ✓ The response graph of this part using MATLAB:



- From the graph of the response, some notes can be noticed:
  - ✓ The magnitude increases till the resonance frequency, then decreases again.
  - ✓ The curve is not smooth since that the points got is not enough to graph a smooth curve.

- The value of *fc1, fc2, fo* practically is:

  fc1=614 Hz fo= 738 Hz

  fc2=860 Hz

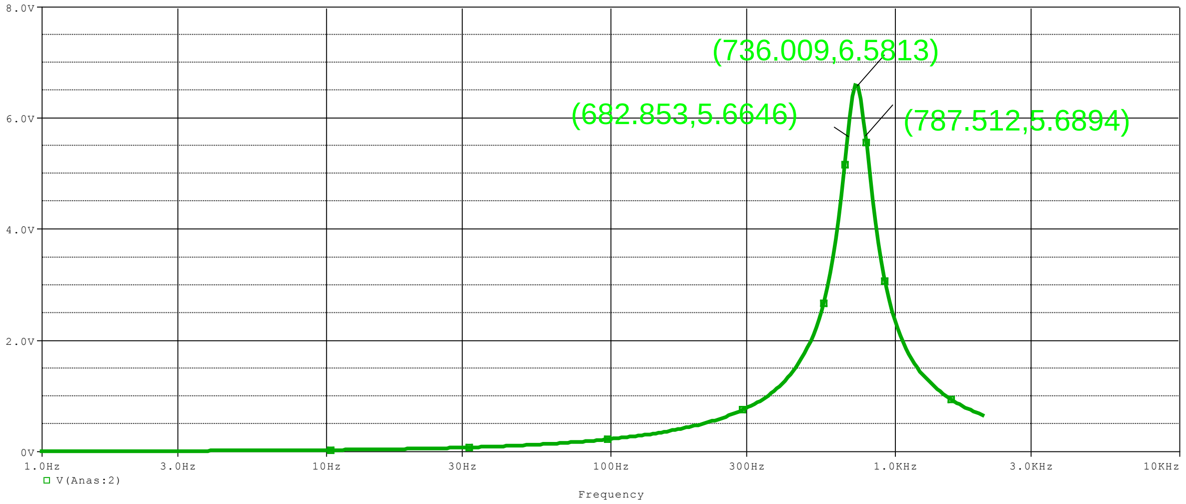
- **The value of *fc1 ,fc2 ,fo* theoretically is:**

fo= 1/(2π*$\sqrt{R1R2C1C2}$) **R1= 2.7ll68 = 2.6k**

fo=1/(2*3.14*$\sqrt{2.6K * 180K *.01u *.01u}$) = 736Hz

B.W=$\frac{2}{R_3c}$ = 1111.

The result was obtained in ORCAD:



The result is acceptable with some of little error for example:

- ✓ **The tolerance in the components.**
- ✓ **The internal resistor of the DMM and another devices used.**
- ✓ **The problem of unstable frequency (Although it's a little unitability but it still affects the results)**
- ✓ **The value got in this part is very logical value**

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