EXP NO: 6 DESIGN OF RF FILTERS AND AMPLIFIER USING COMPUTATIONAL TOOL

6.1 OBJECTIVE

To design and simulate the frequency response characteristics of RF filter and Amplifier using HSPICE simulation tool.

6.2 SIMULATION TOOL REQUIRED

Hspice and Cosmos scope

6.3 DESCRIPTON

The common source topology exhibits a relatively high input impedance while providing voltage gain and requiring a minimum voltage headroom. As such, it finds wide application in analog circuits and its frequency response is of interest.

6.3.1 COMMON SOURCE AMPLIFIER

DESIGN

By virtue of transconductance, a MOSFET converts variations in its gate-source voltage to a small-signal drain current, which can pass through a resistor to generate an output voltage. The common-source stage performs such operation.

If the input voltage increases from zero, M1 is off and $V_{out} = V_{DD}$. As V_{in} approaches V_{TH}, M1 begins to turn on, drawing current from R_D and lowering V_{out}. If V_{DD} is not excessively low, M1 turns on saturation, and we have

$$V_{out} = V_{DD} - R_D \frac{1}{2}\mu n\, Cox \left(\frac{w}{l}\right) \ (Vin - VTH)^2$$

Where the channel-length modulation is neglected. With further increase in V_{in}, V_{out} drops more and the transistor continues to operate in saturation until V_{in} exceeds V_{out} by V_{TH}. At this point,

$V_{in1} - V_{TH} = V_{DD} - R_D \frac{1}{2}\mu n\, Cox \left(\frac{w}{l}\right) \ (Vin1 - VTH)^2$

$V_{out} = V_{in1} - V_{TH}$, V_{out} can be obtained

For $V_{in} > V_{DD} - R_D \frac{1}{2}\mu n\, Cox \left(\frac{w}{l}\right) \ (2(Vin - VTH)Vout - Vout^2)$

R_1 and R_2 is chosen in such a way that V_{in} is high enough to drive M1 into deep triode region.

Thus R_1 =18k and R_2=8.2k

If V_{in} is high enough to drive M1 into deep triode region, $V_{out} << 2(V_{in} - V_{TH})$

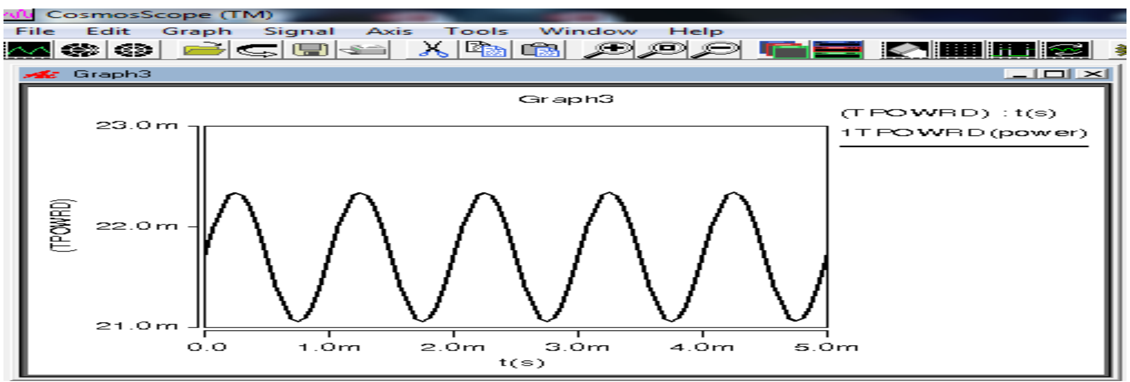
$$V_{out} = V_{DD} \frac{Ron}{Ron+RD} = \frac{VDD}{1+ RD\ \ \mu n\ Cox \left(\frac{w}{l}\right)\ \ (Vin-VTH)}$$

Here V_{DD} = 10v, w=122u, l=180n, V_{in}=10mv from this R_D=3.3k

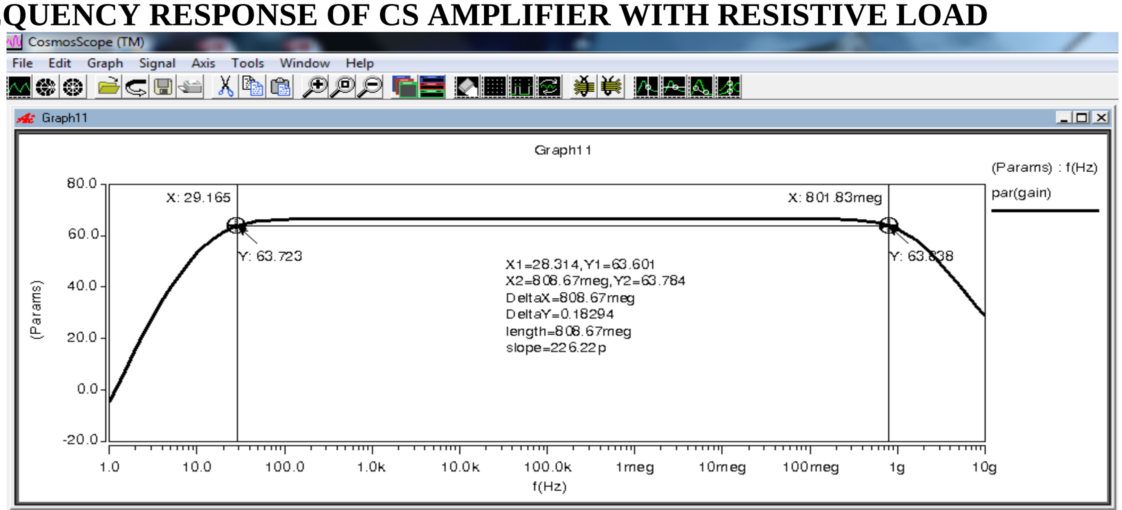
Voltage gain, $A_v = \frac{\partial Vout}{\partial Vin}$ = - $RD\ \ \mu n\ Cox\ \left(\frac{w}{l}\right)\ \ (Vin - VTH)$ = $-g_m R_D$

Operating frequency is 1k there for capacitance values are 10u from

POWER CS AMPLIFIER WITH RESISTIVE LOAD

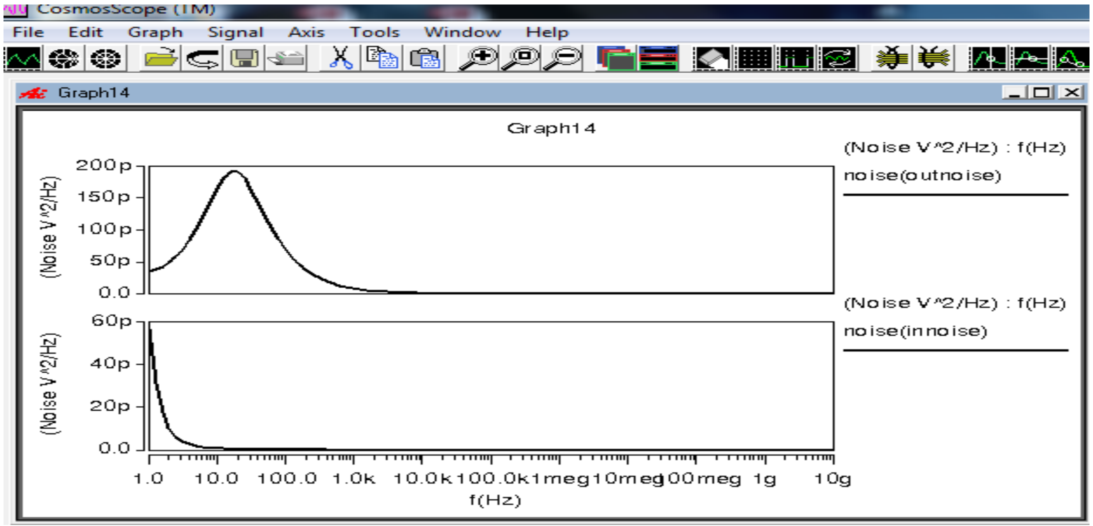


FREQUENCY RESPONSE OF CS AMPLIFIER WITH RESISTIVE LOAD



INFERENCE: Gain of 63.72 dB is obtained and bandwidth of 808.67 MHz is obtained

NOISE ANALYSIS



$V_{out} = V_{DD} - R_D \frac{1}{2}\mu n\, Cox \left(\frac{w}{l}\right) \ (Vin - VTH)^2\ (1+\lambda V_{out})$

$F = \dfrac{1}{2\pi RXc}$

For large values of R_D the effect of channel length modulation in M1 becomes significant.

Modifying

$\dfrac{\partial Vout}{\partial Vin} = -\ RD\ \ \mu n\ Cox\ \left(\frac{w}{l}\right)\ \ (Vin - VTH)\ (1+\lambda V_{out}) - R_D\ \frac{1}{2}\mu n\ Cox\ \left(\frac{w}{l}\right)\ \ (Vin - VTH)^2 \lambda \frac{\partial Vout}{\partial Vin}$

$A_v = -g_m R_D - R_D I_D \lambda A_V$

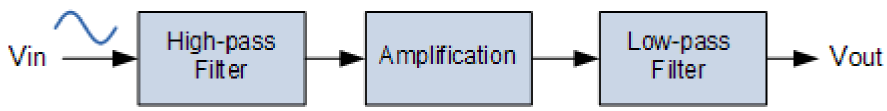
$I_D \lambda = 1/r_0$

$A_v = g_m \dfrac{r0\ RD}{r0+RD}$

6.3.2 RF BAND PASS FILTER

The principal characteristic of a **Band Pass Filter** or any filter for that matter, is its ability to pass frequencies relatively unattenuated over a specified band or spread of frequencies called the “Pass Band”.

Simple **Band Pass Filter** can be easily made by cascading together a single Low Pass Filter with a single High Pass Filter as shown.



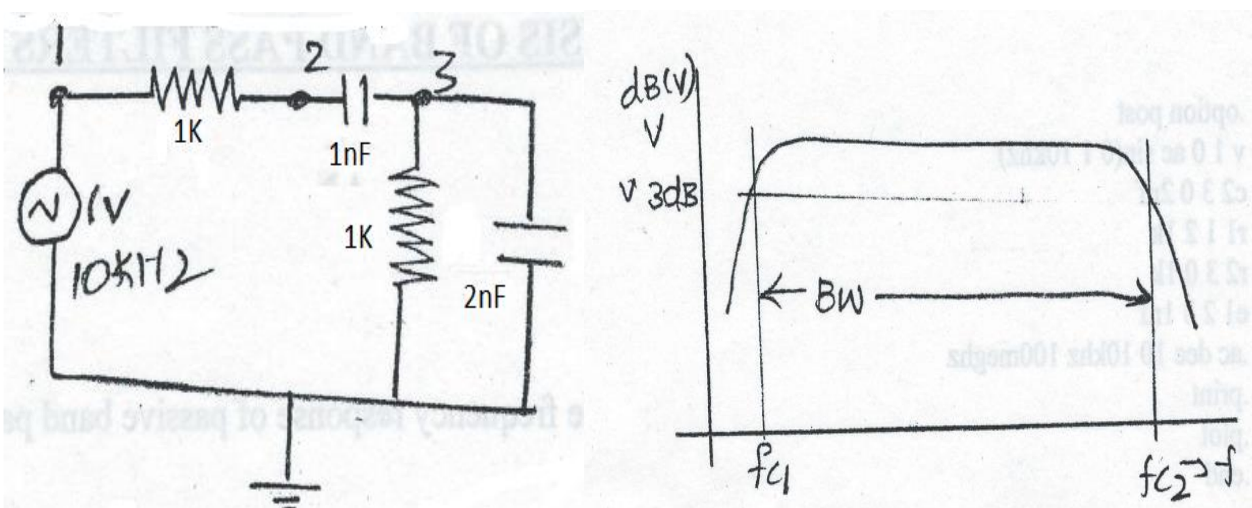
The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF) and the difference between the frequencies at the -3dB point will determine the "bandwidth" of the band pass filter while attenuating any signals outside of these points

$$f_r = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \qquad Q_{BP} = \frac{f_r}{BW_{(3dB)}} = \frac{1}{2}\sqrt{\frac{R_2}{R_1}}$$

$$\text{Maximum Gain, } (Av) = -\frac{R_2}{2R_1} = -2Q^2$$

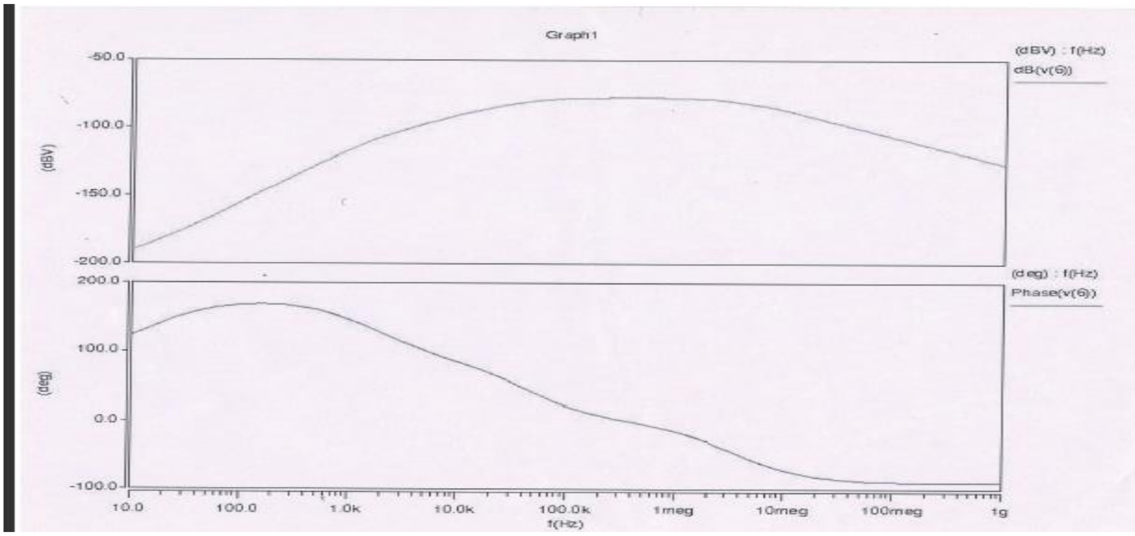
The relationship between resistors, R_1 and R_2 determines the band pass "Q-factor" and the frequency at which the maximum amplitude occurs, the gain of the circuit will be equal to $2Q^2$.

PASSIVE BAND PASS FILTER CIRCUIT



$$Voltage\ Gain = -\frac{R_2}{R_1}, \quad fc_1 = \frac{1}{2\pi R_1 C_1}, \quad fc_2 = \frac{1}{2\pi R_2 C_2}$$

Frequency Response of passive Band Pass Filter



6.4

HSPICE PROGRAM

6.4.1 CMOS RF AMPLIFIER

```
.option post
.include c:\synopsys\tsmc018.lib
vdd 1 0 dc 10
vin 3 0  ac sin(0 10m 1k 2n 0 0)
m0 5 2 4 4 cmosn w=122u l=180n
r1 1 2 r=18k
r2 2 0 r=8.2k
rs 4 0 r=1.42k
rd 1 5 r=3.3k
r0 6 0 r=33k
c1 3 2 c=10u
c2 4 0 c=100u
c3 5 6 c=10u
.tran 1m 5m
.ac dec 10 1 10g
.tf v(6) vin
.meas tran avgpower AVG POWER from=1n to=100n
.net v(6) vin
.noise v(6) vin
.plot z11(db) z11(m) z11(p) z11(i) z11(r)
.plot z22(db) z22(m) z22(p) z22(i) z22(r)
.plot ac gain=par('20*log(v(6)/v(3))')
.end
```

6.4.2 PASSIVE BAND PASS FILTER

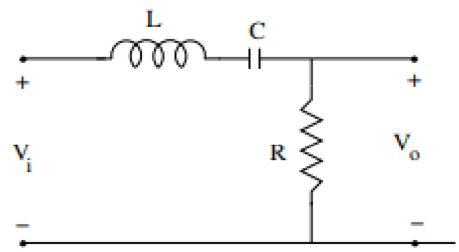
```
.GLOBAL 1
.OPTION POST
.include c:\synopsys\tsmc018.lib
V 1 0 ac sin(0 1 10Khz)
C2 3 0 2nf
R1 1 2 1k
R2 3 0 1k
C1 2 3 1nf
.ac dec 10 10khz 100meghz
.print
.plot
.end
```

6.5 PRE LAB QUESTIONS

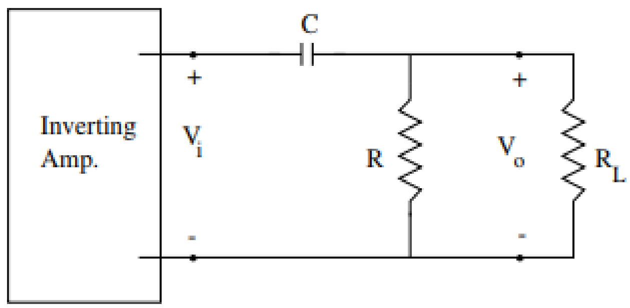
1. Write the limitations of the active filters over the passive filters.
2. What is filter? Discuss the types of filters.
3. Define transconductance of an amplifier.
4. What is the gain of an amplifier if g_m=50mA/v and r_d=10k
5. Write short notes on transient and ac analysis of an amplifier.
6. What is meant by order of the filter?

6.6 POST LAB QUESTIONS

1. A second-order **band pass filter** is to be constructed using RC components that will only allow a range of frequencies to pass above 1 kHz (1,000Hz) and below 30kHz (30,000Hz). Assuming that both the resistors have values of 10kΩ, calculate the values of the two capacitors required.
2. The tuner for an FM radio requires a band-pass filter with a central frequency of 100 MHz (frequency of a FM station) and a bandwidth of 2 MHz. a) Design such a filter. b) What are its cut-off frequencies?



3. We have an amplifier that amplifies a 1 kHz signal from a detector. The load for this amplifier can be modeled as a 50 kΩ resistor. The amplifier output has a large amount of 60 Hz noise. We need to reduce the amplitude of noise by a factor of 10. Design a first-order passive filter which can be placed between the amplifier and the load and does the job. Would this filter affect the 1 kHz signal that we are interested in? If so, by how much?



Result:

Thus the frequency response RF amplifier and filter have been simulated using HSPICE.

Cut off frequencies and Bandwidth of Band pass filter:

Gain and bandwidth of the CMOS RF amplifier: