VLSI Engineering Laboratory
Experiment 3
Common Source Amplifier with Active load

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AIM:

To study the transient response and frequency response of the common source amplifier with active load(i.e., considering current source load) using LT-spice software.

Circuit diagram :-

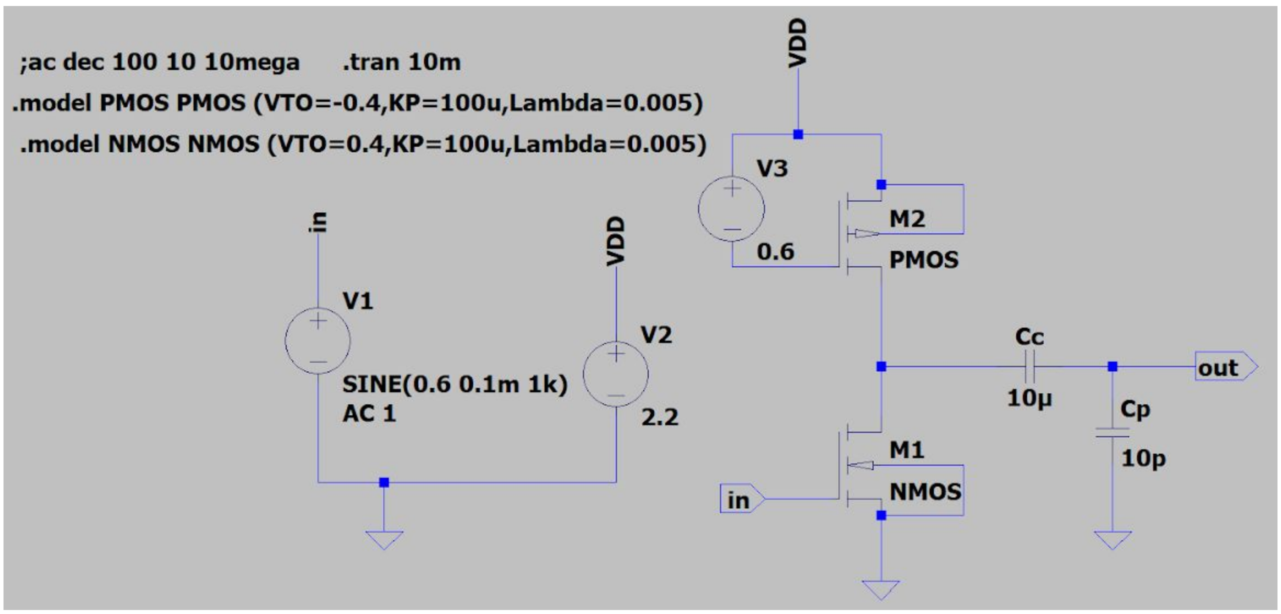

Fig.1:Circuit diagram of common source amplifier with the resistive load

Description:-

1. Common source amplifier with current source load(active load) is designed as shown above in the LT-spice simulator.
2. The first step of designing an amplifier circuit involves designing the biasing network of the transistor.
3. Current source load is made by using a PMOS transistor operated in saturation mode by using a Gate bias V_b
4. To get the linear amplification of the signal,it is necessary that the NMOS transistor operates in the saturation region i.e., $V_{ds} > V_{gs}$-V_{Th}.

5. To keep both the transistors in ON state we assigned a voltage source to the PMOS to provide 0.6 V difference between gate and source which is greater than our threshold voltage of 0.4V and in NMOS we used the property of voltage source in LT-spice simulator to provide DC offset value at the gate of NMOS.
6. We have to make sure that both the transistors to be in saturation region and as the current flow in both transistors equal we have to kept the width the KP value and the overdrive voltage of both the transistors equal,if we fail to keep those parameters equal then the PMOS will goes to triode region.

$0.5*Kp_n*(W/l)_n *(V_{gs}-V_{Th})^2 *(1+lambda_n*V_{DS}) =0.5*Kp_n*(W/l)_p*(V_{sg}-|V_{Th}|)^2 *(1+lambda_p*V_{SD})$

By making specified parameters equal we get,

$$(1+lambda_n*V_{DS})=(1+lambda_p*V_{SD})$$

7. So to make both the transistors work in saturation we will be taking W,KP,overdrive voltage of both the transistors equal,this will make the circuit to be sensitive to the lambda of both transistors.
8. To make the maximum swing at the output i.e., to set the DC voltage of the output point at $V_{DD}/2$ we will be making the lambda of both the transistors equal and from the above equation it is evident that $V_{DS} = V_{SD}$ (if lambda of both the transistors equal).
9. In the following all results we will consider W,KP,overdrive voltage and lambda of both the transistors equal.
10. We have used a coupling capacitor C_c to get only the AC part as output and remove the DC offset value.
11. A load capacitance is used which provides effective equivalent capacitance of the second stage.
12. Body of both the transistors are connected to the respective source so as to remove the body effect.
13. As we are working on 180nm technology node the length of the transistor was kept as 180nm and DC voltage supply is given as 2.2 except for the response of observing clipping effect.
14. We have found the transient response until 5m using the command tran.5m
15. We have found the frequency response from 10 Hz to 10 MHz using the command .ac dec 100 10 10mega

Results :-

a.transient response:-

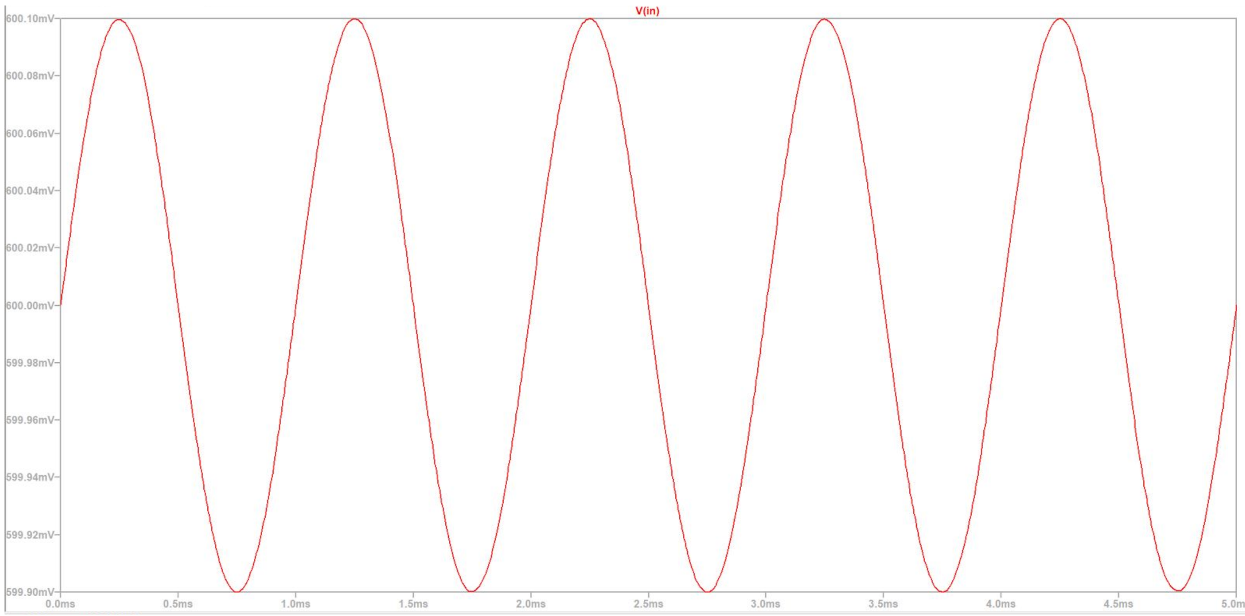

Fig.2:-input signal for the above circuit
amplitude=0.1mV

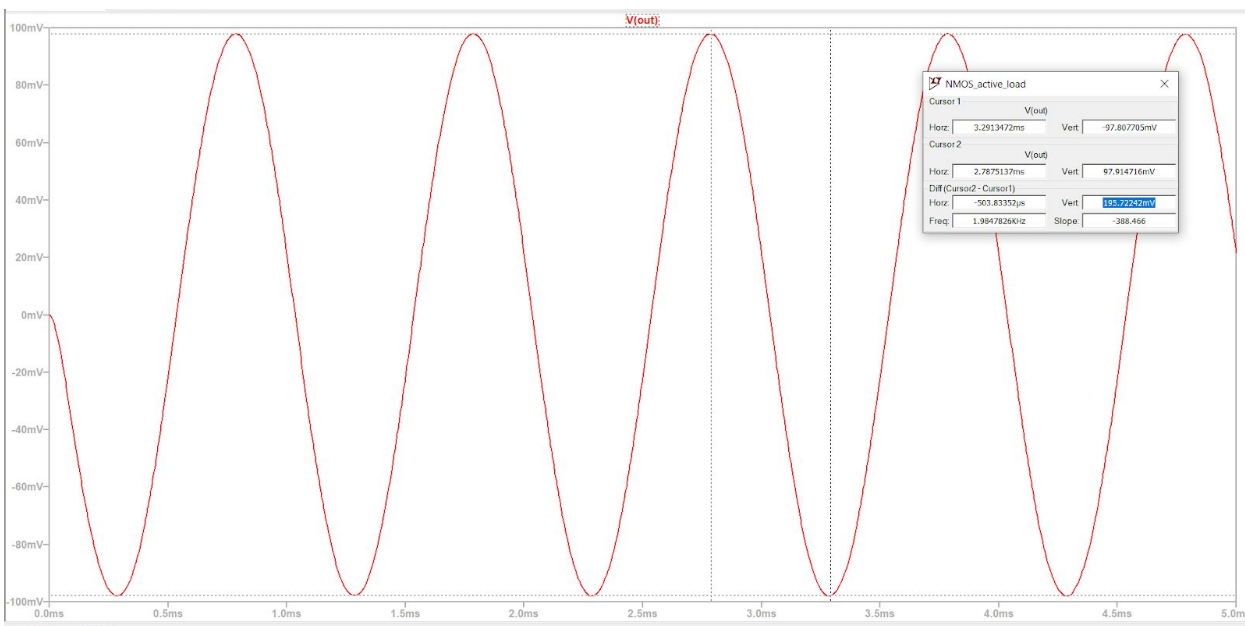

Fig.3:-transient response of the Fig.1 with W=2.5um L=180nm
Gain = 195.72/(2*0.1) = 978.6

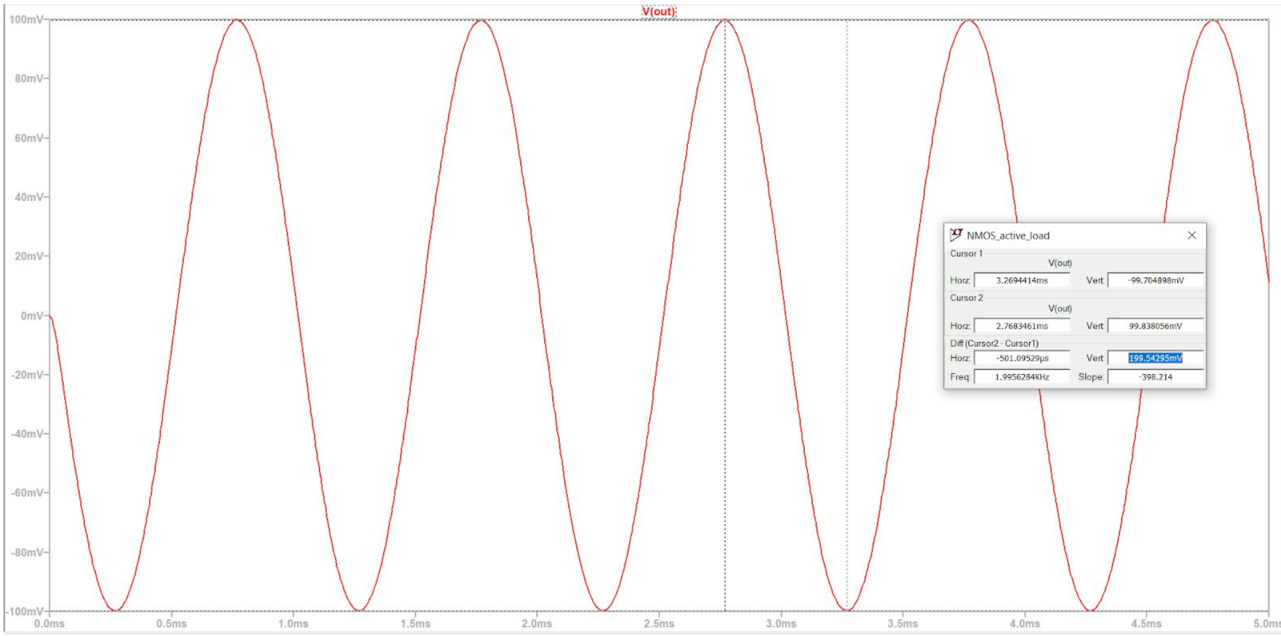

Fig.4:-Circuit with W=5um ; KP=100u ; lambda=0.005 ; V_{GS}-V_{Th} =0.2

Gain = 199.54/(2*0.1)= 997.7

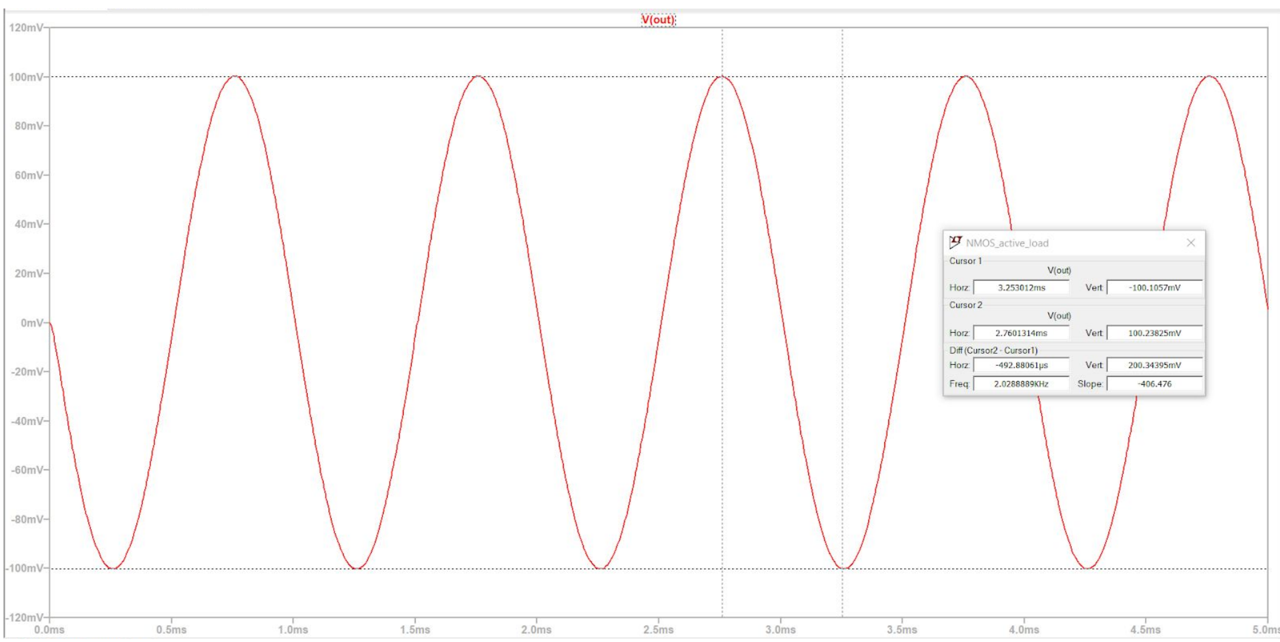

Fig.5:-Circuit with W=5um ; KP=200u ; lambda=0.005 ; V_{GS}-V_{Th} =0.2

Gain = 200.34/(2*0.1)= 1001.7

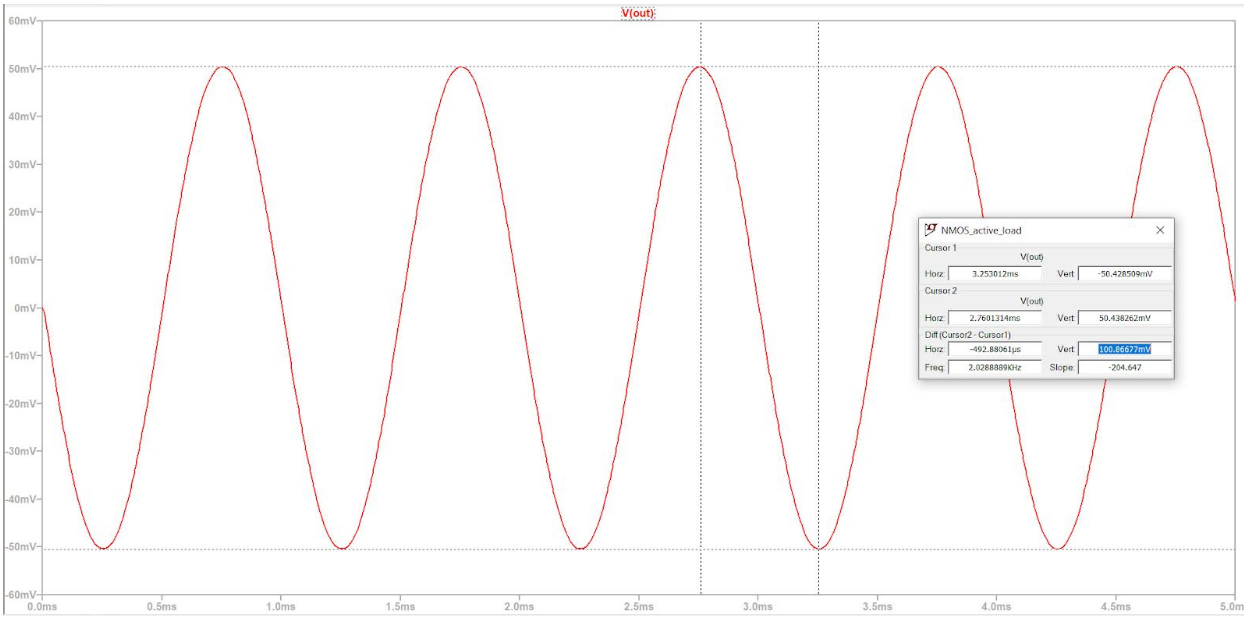

Fig.6:-Circuit with W=5um ; KP=200u ; lambda=0.01 ; V_{GS}-V_{Th} =0.2
Gain = 100.87/(2*0.1)= 504.35

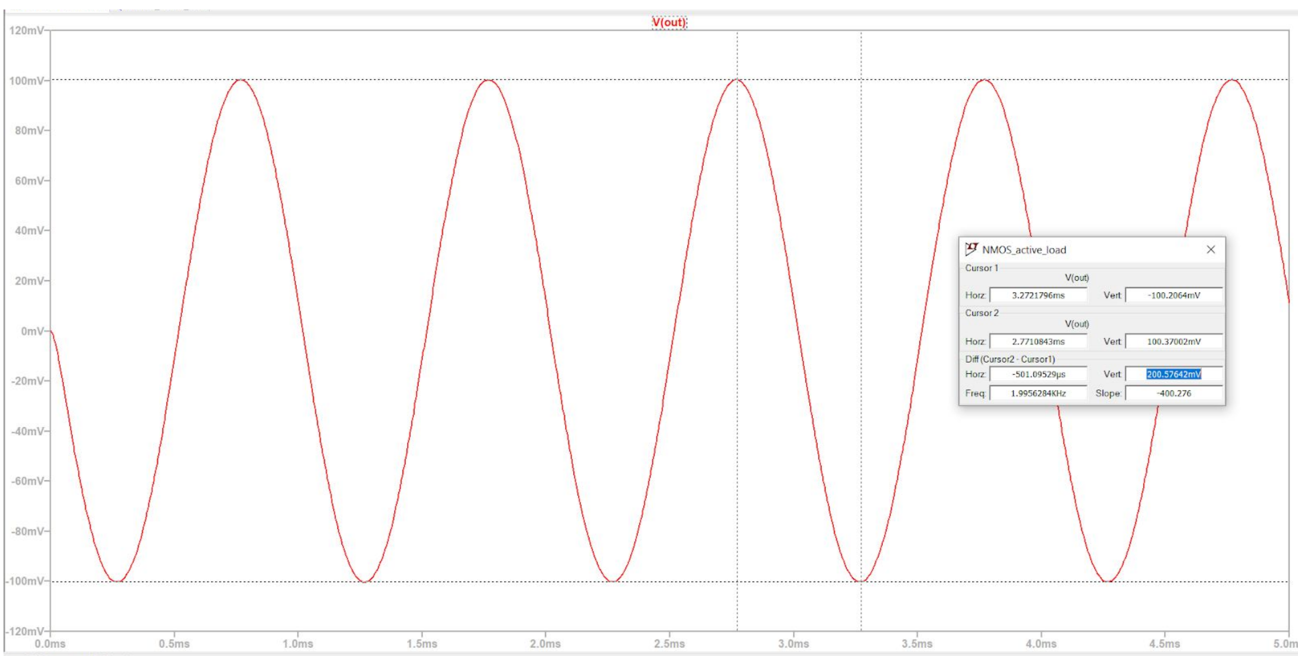

Fig.7:-Circuit with W=5um ; KP=200u ; lambda=0.01 ; V_{GS}-V_{Th} =0.1
Gain = 200.57/(2*0.1)= 1002.85

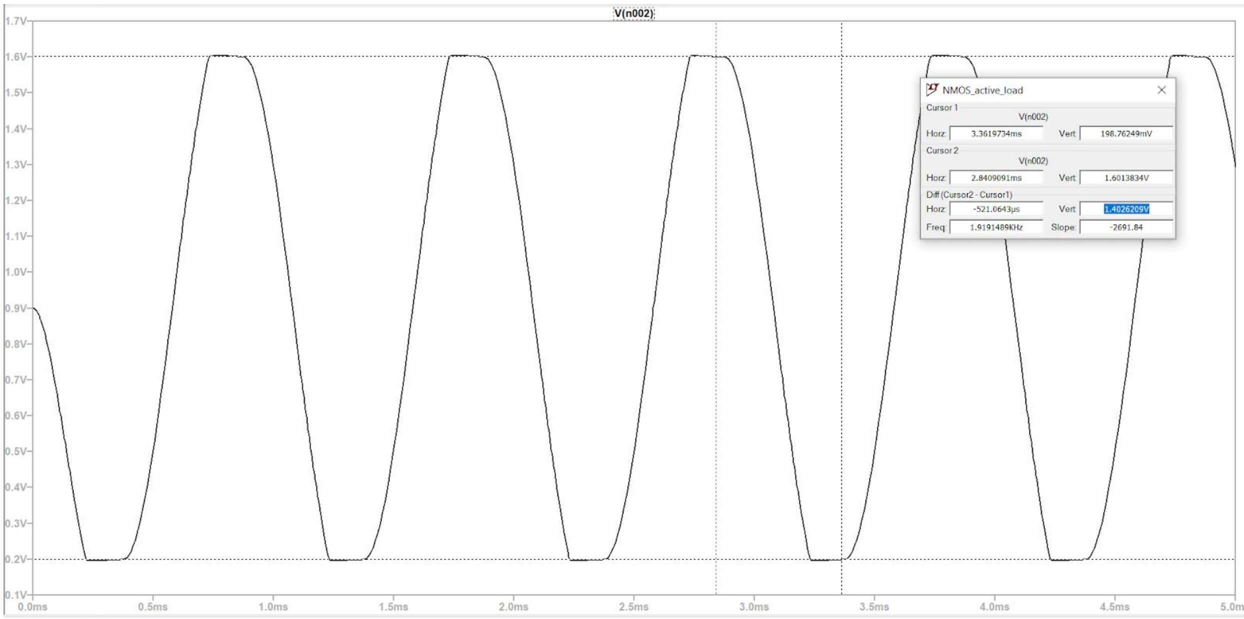

Fig.8:-Circuit with W=5um ; KP=200u ; lambda=0.0005 ; V_{GS}-V_{Th} =0.2 ; V_{DD} =1.8V
Maximum swing=1.4 V
Clipping of the output

b.Frequency response:-

Cursor 1 gives gain in db and cursor 2 gives bandwidth of the response

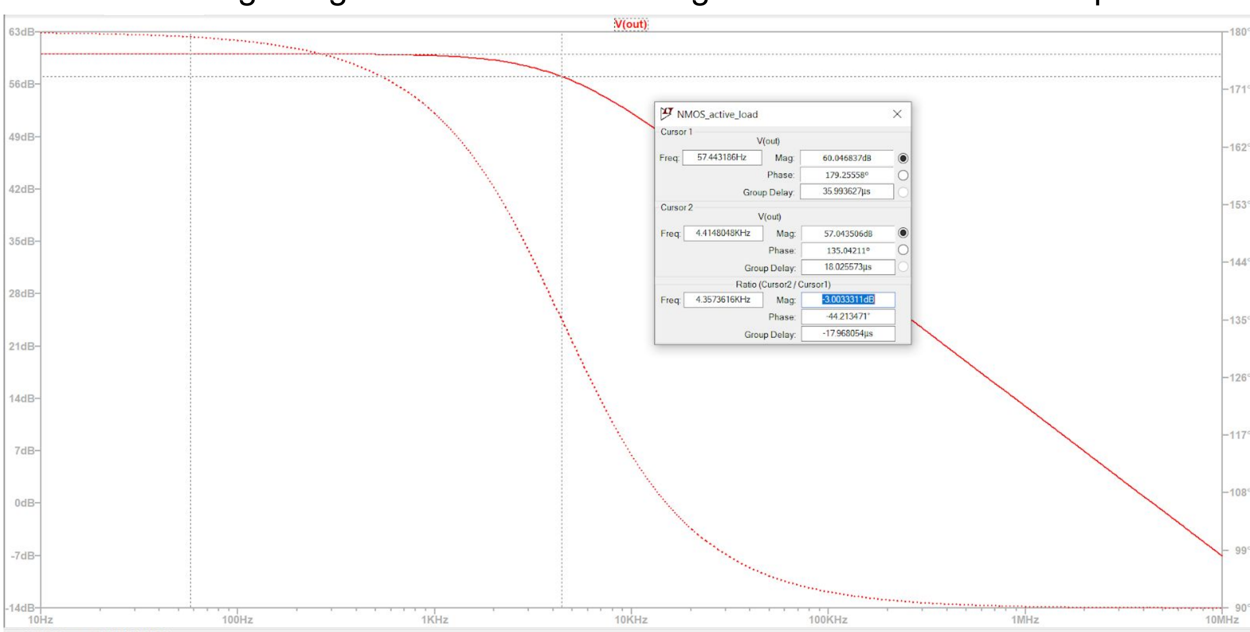

Fig.9 :- Frequency response of the circuit shown(Fig.1)
with W=2.5um ; KP=100u ; lambda=0.005 ; V_{GS}-V_{Th} =0.2 ; C_p=10 pF
Gain =60.04 dB ; Fh=4.415 KHz ;

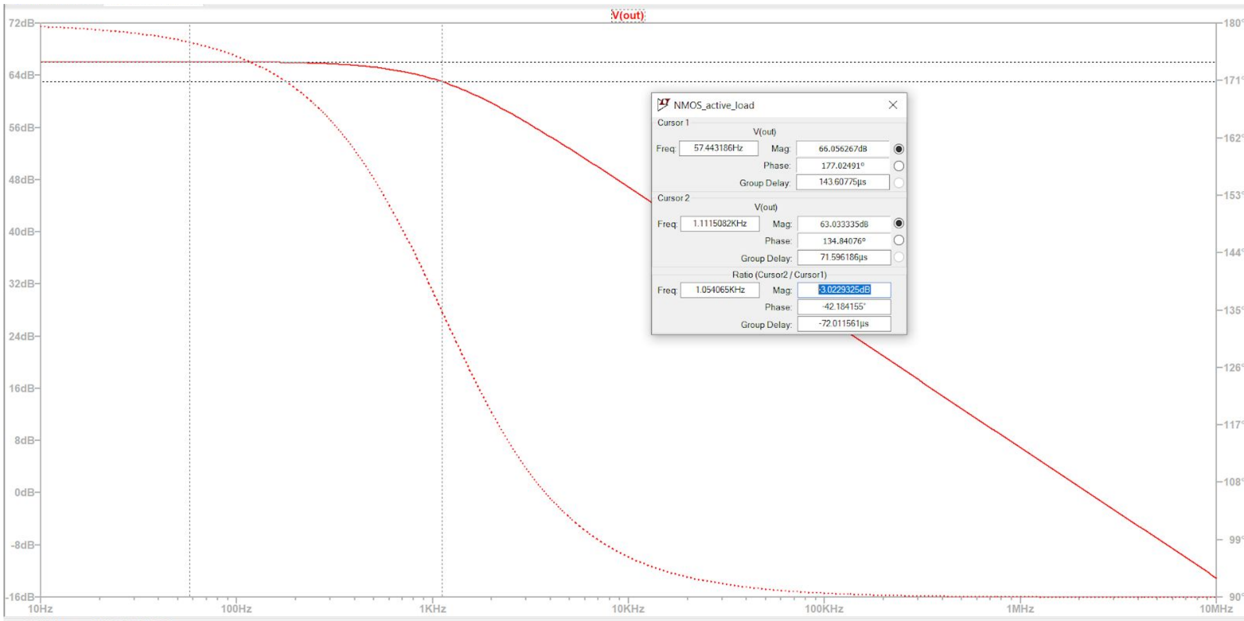

Fig.10 :- Frequency response of the circuit shown(Fig.1)
with W=2.5um ; KP=100u ; lambda=0.005 ; V_{GS}-V_{Th} =0.1 ; C_p=10 pF
Gain =66.06 dB ; Fh=1.112 KHz ;

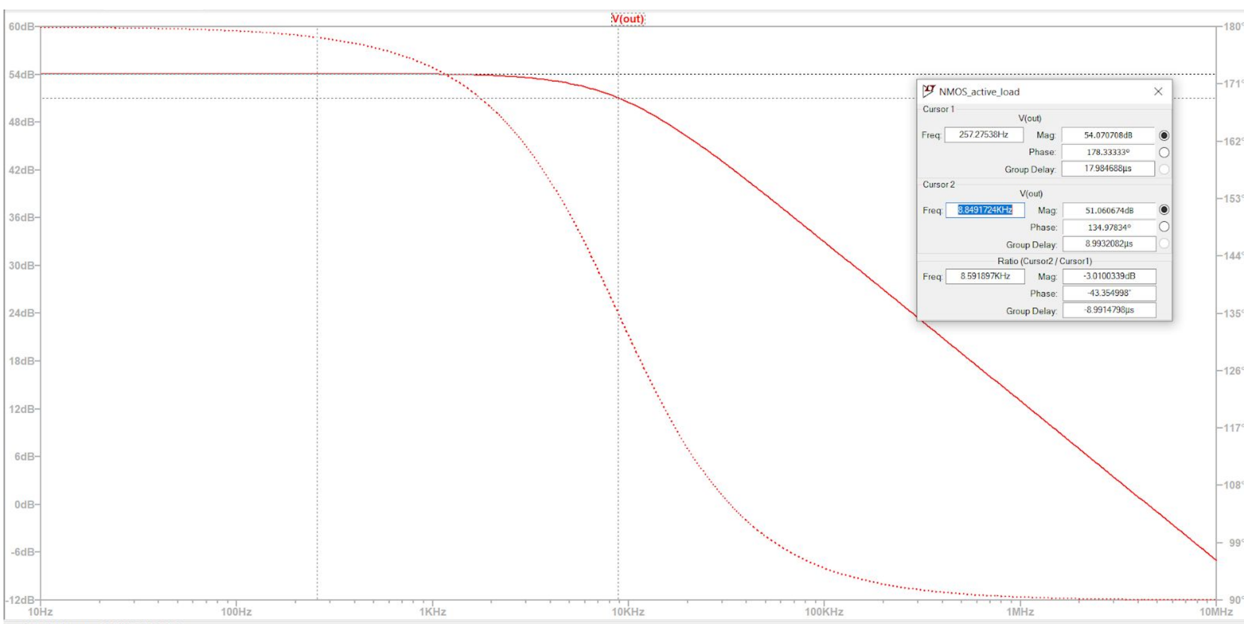

Fig.11 :- Frequency response of the circuit shown(Fig.1)
with W=2.5um ; KP=100u ; lambda=0.01 ; V_{GS}-V_{Th} =0.2 ; C_p=10 pF
Gain =54.07 dB ; Fh=8.849 KHz ;

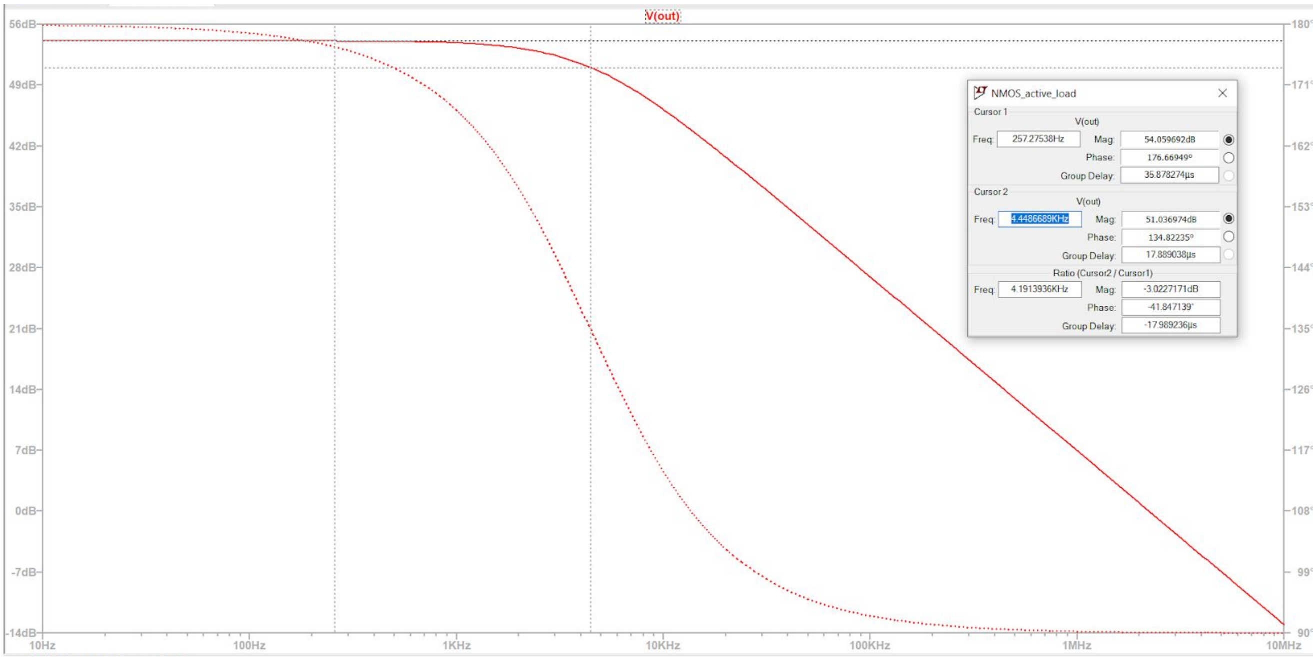

Fig.12 :- Frequency response of the circuit shown(Fig.1)
with W=2.5um ; KP=100u ; lambda=0.01 ; V_{GS}-V_{Th} =0.2 ; C_p=20 pF
Gain =54.06 dB ; Fh=4.45 KHz ;

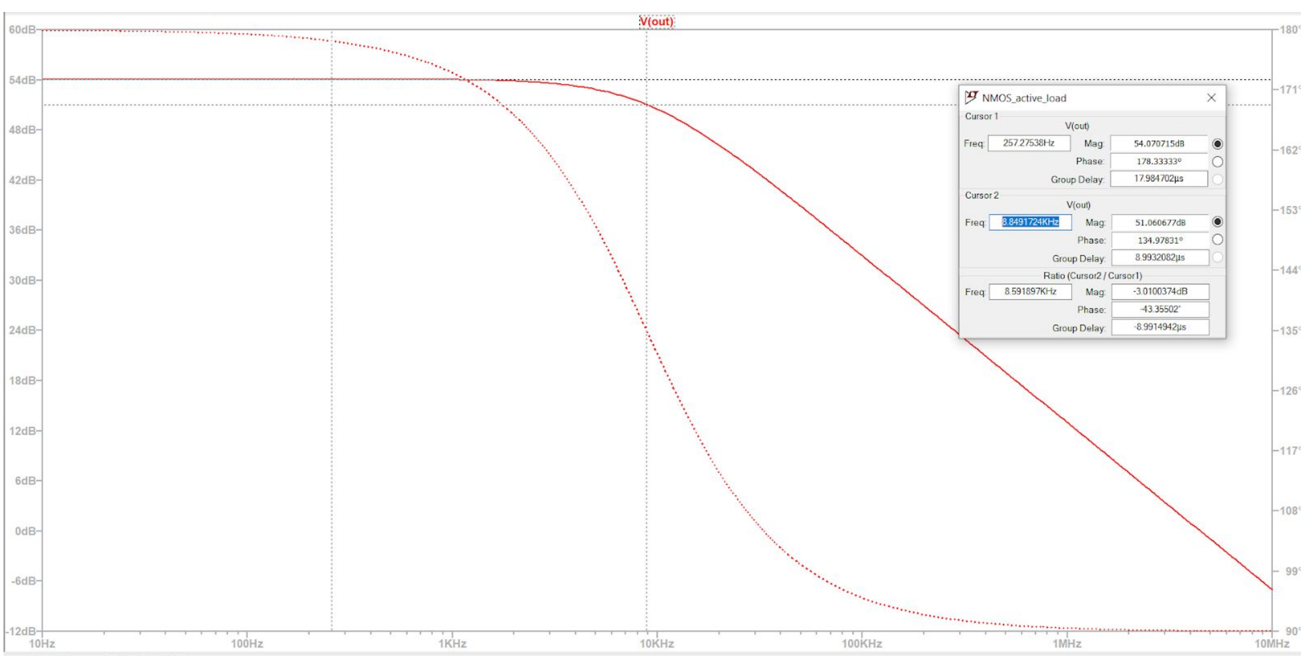

Fig.13 :- Frequency response of the circuit shown(Fig.1)
with W=5um ; KP=100u ; lambda=0.01 ; V_{GS}-V_{Th} =0.2 ; C_p=20 pF
Gain =54.07 dB ; Fh=8.849 KHz ;

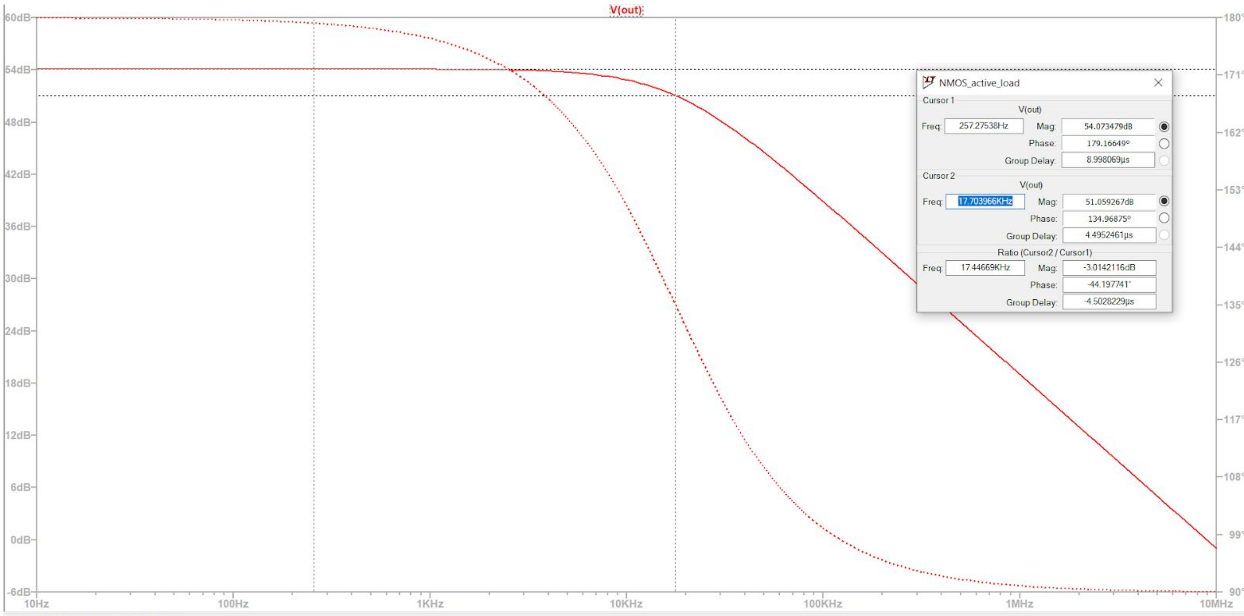

Fig.14 :- Frequency response of the circuit shown(Fig.1)
with W=5um ; KP=200u ; lambda=0.01 ; V_{GS}-V_{Th} =0.2 ; C_p=20 pF
Gain =54.07 dB ; Fh=17.704 KHz ;

Observation and discussion:-

1. In this experiment, we simulated a common source MOS amplifier and observed the effect of various circuit parameters and device parameters on the output signal,the gain of the amplifier and the bandwidth of the amplifier.
2. The advantages of using active load(current source load) over passive load(resistive load):
    a. The implementation of a resistor on the chip takes a lot of space when compared to that of a transistor,so to minimise the space consumption this circuit will be very helpful.
    b. To increase gain,to increase gain in a passive load circuit we have to increase the value of resistance which will make problems in space consumption,so to avoid that, in the active load we increase the gain with the decrease in lambda.
3. Here we analysed the output waveform by considering a sine wave as an input pulse with amplitude of 0.1m(Fig.1).
4. In Fig 3 we can see,we obtain a sine wave as output with a phase shift of 180^{o} and having amplitude around 1000 times of the input,i.e., there by having a gain of around -1000.
5. We plotted the transient response of the amplifier with varying circuit parameters and device parameters.

6. In Fig.4 from Fig 3 to Fig 4,we increased the width of both the transistors by 2 times and we can see there is almost no change in the gain which implies the gain of the circuit does not depend on the width of the transistor.
7. In Fig.5 from Fig 4 to Fig 5,we increased the KP of both the transistors by 2 times and we can see there is almost no change in the gain which implies the gain of the circuit does not depend on the width of the transistor.
8. In Fig.6 from Fig 5 to Fig 6,we increased the lambda of both the transistors by 2 times and we can see the gain is almost dropped by half which shows the transistor gain is inversely proportional to the lambda of the transistor.
9. In Fig.7 from Fig 6 to Fig 7,we decreased the overdrive voltage of both the transistors by 2 times and we can see the gain is almost doubled which shows the transistor gain is inversely proportional to the overdrive voltage of the transistor.
10. From above results we can say that:

    Gain = -K / (lambda * (V_{GS}-V_{Th}))

    From the theory we can obtain:

    Gain = -4 / (lambda * (V_{GS}-V_{Th}))   (by using Gm * Rout analysis)
11. In Fig.8 we made the gain of the circuit very large such that the circuit gets clipped.
12. We plotted the frequency response of the amplifier with varying circuit parameters and device parameters.
13. The bandwidth of the circuit is given by

    1 /(Rout * C_p) = lambda * KP *W/L * (V_{GS}-V_{Th} $)^2$ / C_p
14. In Fig.10 from Fig 9 to Fig 10,we made the overdrive voltage of both the transistors half so we can see the bandwidth decrease by 4 times.
15. In Fig.11 from Fig 9 to Fig 11,we increased the lambda of both the transistors by 2 times,so we can see the bandwidth increase by 2 times.
16. In Fig.12 from Fig 11 to Fig 12,we increased load capacitance by 2 times,so we can see the bandwidth decrease by 2 times.
17. In Fig.13 from Fig 12 to Fig 13,we increased the width of both the transistors by 2 times,so we can see the bandwidth increase by 2 times.
18. In Fig.14 from Fig 13 to Fig 14,we increased the KP of both the transistors by 2 times,so we can see the bandwidth increase by 2 times.
19. In all the frequency responses we can see that we didn't get any lower cut-off frequencies,this is because we have not used input coupling capacitance and the source bypassing capacitor.

Conclusion:-

The common source MOS amplifier which has active load is a very important system which can be used for amplifying the strength of weak signals and occupies a very small area as compared to the amplifier with passive load(resistive load).