ANALOG ELECTRONIC CIRCUITS

LAB REPORT-7

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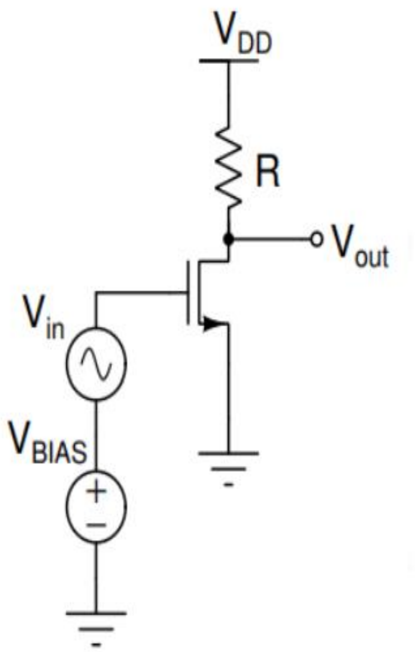
Common Source Amplifier

1) Effect of Body Effect on gain of CS Amplifier:



We built a circuit with V(dd) = 5V , V(BIAS) = 2.5 V , V(T) = 1.8 V , R(L) = 4.7 kΩ.

a) VDS=3.12 V
   Find Drain current

$$I_{DS} = \frac{VDD - V_{DS}}{R_L}$$

   And also find gm and

$$\mu_n C_{ox} \frac{W}{L}$$

$$g_m = \frac{\partial I_{DS}}{\partial V_{GS}} = \mu C_o \frac{W}{L}\left(V_{GS} - V_T\right)$$

$V_{DD} = 5V$, $V_B = 2.5$ $V_T = 1.8V$ $R_1 = 1K$

$\boxed{V_{DS} = 3.2}$

$$I_D = \frac{V_{DD} - V_{DS}}{R_L}$$

$$I_D = \frac{5 - 3.2}{1000} = 1.8 \times 10^{-3}$$

$$I_D = \frac{1}{2} \times \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)^2$$

$$3.6 \times 10^{-3} = K(0.7)^2$$

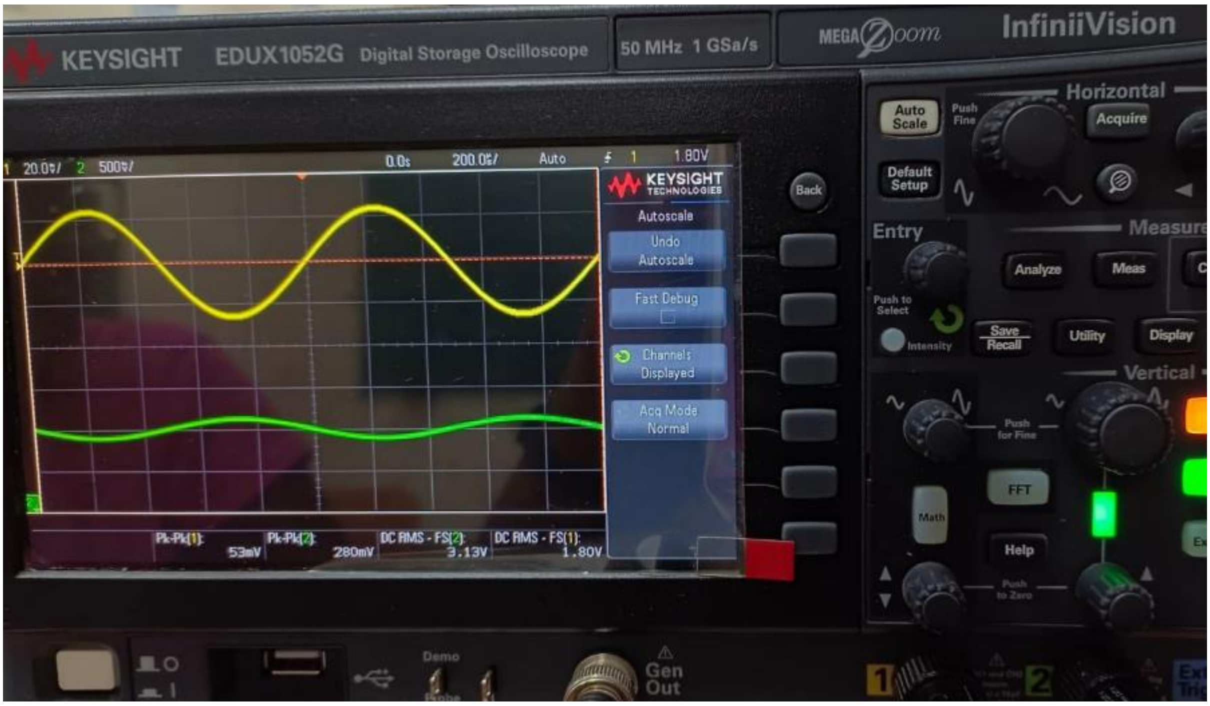
$$7.346 \times 10^{-3} = K$$

$$K = 0.007346$$

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_t)$$

$$= K \times 0.7$$

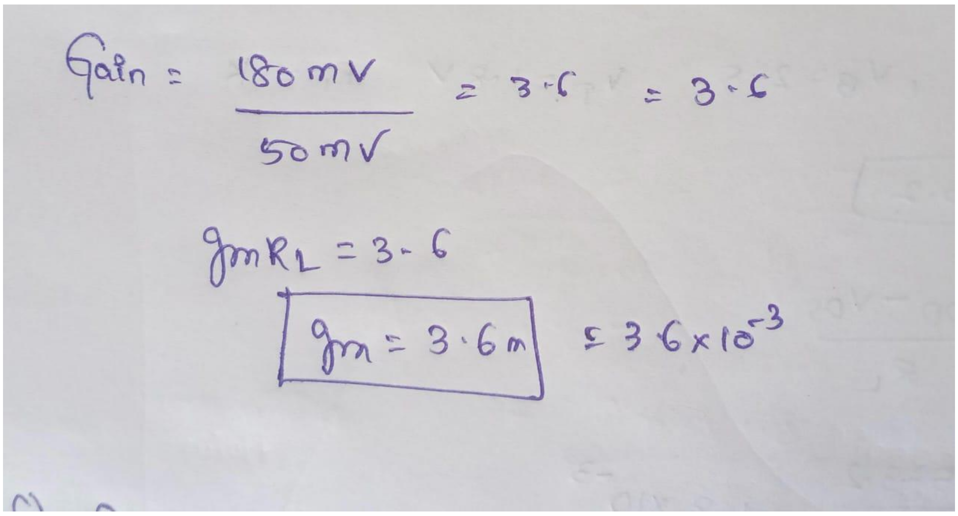
$$\boxed{g_m = 0.051422}$$



Gm=5.15m(approx.)

b)
We have applied an AC signal
Vin=50m Vpp(peak to peak)
Freq(f)=1k Hz

Vout =180mV (peak to peak)



$$\text{Gain} = \frac{180\,mV}{50\,mV} = 3.6 = 3.6$$

$$g_m R_L = 3.6$$

$$\boxed{g_m = 3.6m} \approx 3.6 \times 10^{-3}$$

The measured value of gm, which is 5.15 mA/V, is quite close to the calculated value of gm, which is 3.62 mA/V.

There are several possible factors that could contribute to this small difference, such as process variations, temperature effects, and parasitic resistances and capacitances.

c)

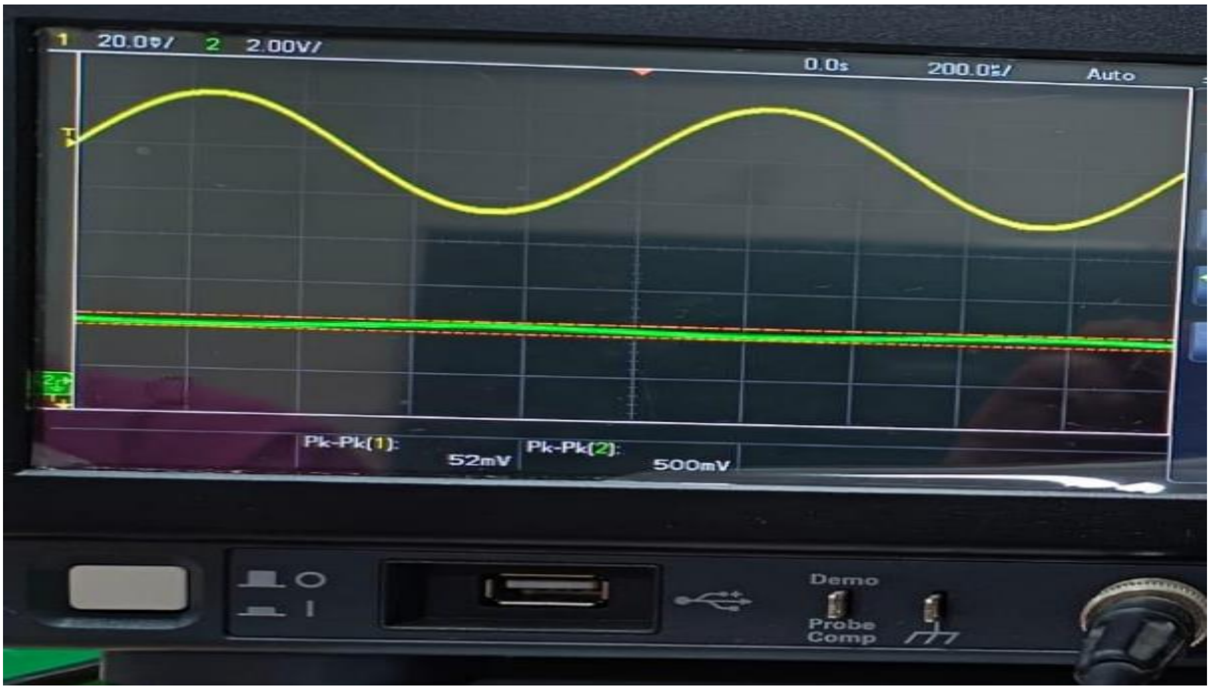
Vin=50m V(peak to peak)

Calculate gain and Gm effective

Check is it matching with previously calculated gm …?

$$A_v = \frac{v_{out}}{v_{in}} = g_m \times R_L$$


KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
50 MHz 1 GSa/s
Pk-Pk(1): 52mV
Pk-Pk(2): 177mV
Autoscale
Undo Autoscale
Fast Debug
Channels Displayed
Acq Mode Normal
Horizontal
Measure
Vertical
Trigger
Run Stop
Single
Gen Out
Ext Trig


2 2.00V/
0.0s
Auto
Pk-Pk(1): 52mV
Pk-Pk(2): 500mV
Demo
Probe Comp

Body Voltage (Vss)	Vout	Gain =(Vout/Vin)	Gm(effective)
0	280mV	5.5	0.00119
0.4	177mV	3.3	0.0007
-0.4	500mV	9.7	0.002

(c) $g_m(\text{effective}) = g_m + g_{mb}$

This is because if we consider body effect i.e, $V_B > V_S$.

More V_{GS} is required for channel formation i.e, V_T Increases.

This is reciprocated in eqn :

$$V_T = V_{T0} + \gamma\left[\sqrt{2\phi_s + V_{SB}} - \sqrt{2\phi_s}\right]$$

* $\phi_s = 2V_T \ln\left(\frac{N_A}{n_T}\right)$

V_T = Thermal Voltage

When $V_{SB} = 0$

$V_T = V_{T0}$

when we consider body effect, V_T is of func^n of V_{SB}.

$$\boxed{I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{th})^2}$$

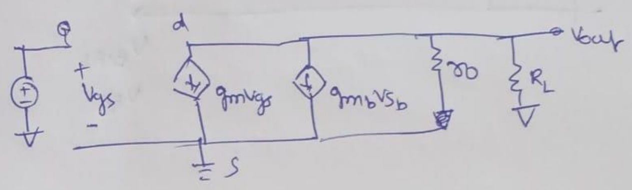
I_D is a function of V_T

Indirectly, I_D is a function of V_{SB}

$\frac{\partial I_D}{\partial V_{SB}}$ is finite value

$\therefore$ We can say

$$I_{D2} = -g_{mb} V_{sb}$$



$$\frac{V_{out}}{R_L} + \frac{V_{out}}{r_o} + g_m v_{sb} + g_m V_{gs} = 0$$

$$V_{out}\left(\frac{1}{R_L} + \frac{1}{r_o}\right) = -(g_m V_{sb} + g_m v_{in})$$

($\because$ as $V_S = 0$)

$$\frac{V_{out}}{V_{in}} = \frac{-(g_{mb} + g_m)}{\frac{1}{r_o} + \frac{1}{R_L}}$$

r_o is very high if we ignore CLM.

$$\boxed{A_V = -(g_{mb} + g_m) R_L}$$

$$\boxed{\therefore\ g_m(\text{effective}) = g_m + g_{mb}}$$

When the body voltage is increased in an NMOS (n-channel MOSFET), the conductivity of the channel increases. As the body voltage is raised, the p-substrate reaches a higher potential. This positive charge accumulation at the bottom of the substrate causes more electrons to be attracted out of the n+ regions. Consequently, a lower threshold voltage (Vth) is required to fill the channel with electrons and enable conduction.

Since transconductance (gm) is directly proportional to the difference between the gate-to-source voltage (Vgs) and the threshold voltage

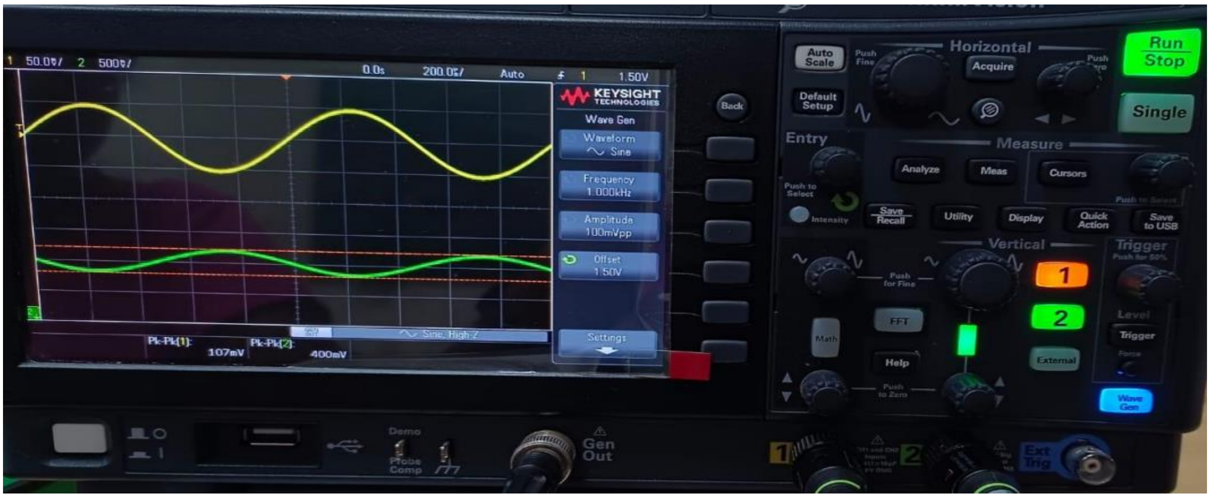
(Vth), an increase in gm is observed. This is because the decreased Vth leads to a larger Vgs-Vth value, resulting in higher transconductance.

On the other hand, if the body voltage is decreased (Vbs < 0), the n+ regions and the p-substrate are in reverse bias. This reverse biasing causes electrons to be pushed further into the n+ regions, resulting in an increased threshold voltage. Consequently, a higher Vth is needed to fill the channel with electrons and allow conduction, leading to a reduction in transconductance (gm).

2) Effect of BIAS points on Gain of common source Amplifier:

a)

Vbias=1.5 V

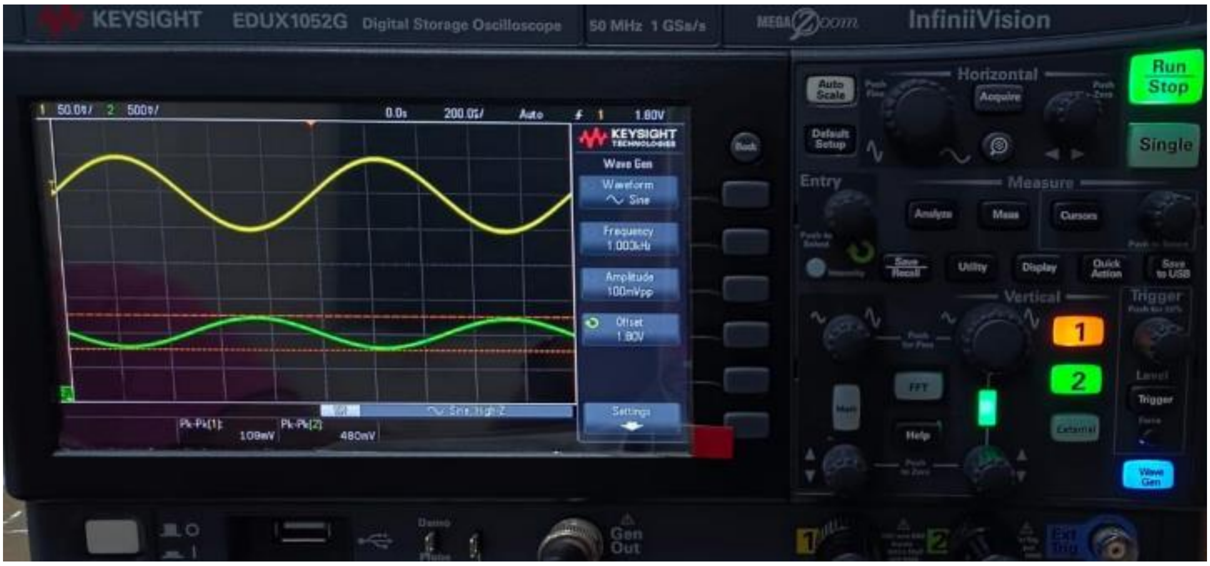


Vbias=1.8 V

Vbias=2.5 V

b)

When Vbias=1.8V .



At this point, the device is just turning on and is on the verge of entering the saturation mode. As a result, the drain current Id is slightly greater than zero.

The measured value of the output voltage (Vout) is 1mV. The gain of the amplifier is calculated as the ratio of Vout to the input voltage (Vin), which is 1mV divided by 100mV, resulting in a gain of 0.01. And gm=gain/RD=2.125uA/V

Vbias=2.5

The device is turned on, and the gate-to-source voltage Vgs exceeds the threshold voltage Vth (1.8V). As a result, the device enters the saturation mode.

Vout=100mV, gain=Vout/Vin=100/100=1=>

gain=1 And gm=gain/Rd=1/4.7k=0.212mA/V => gm=0.212mA/v

Vbias=3.1V

In the given scenario, the measured value of Vds (drain-to-source voltage) is 3.92V. Since Vds is greater than Vbias-Vth, the device remains in saturation mode, and no clipping of the output is observed.

Vout=200mV, gain=Vout/Vin=200mV/100mV=2 =>gain=2, gm=gain/Rd=2/4.7=0.4255mA/V =>gm=0.4255mA/v

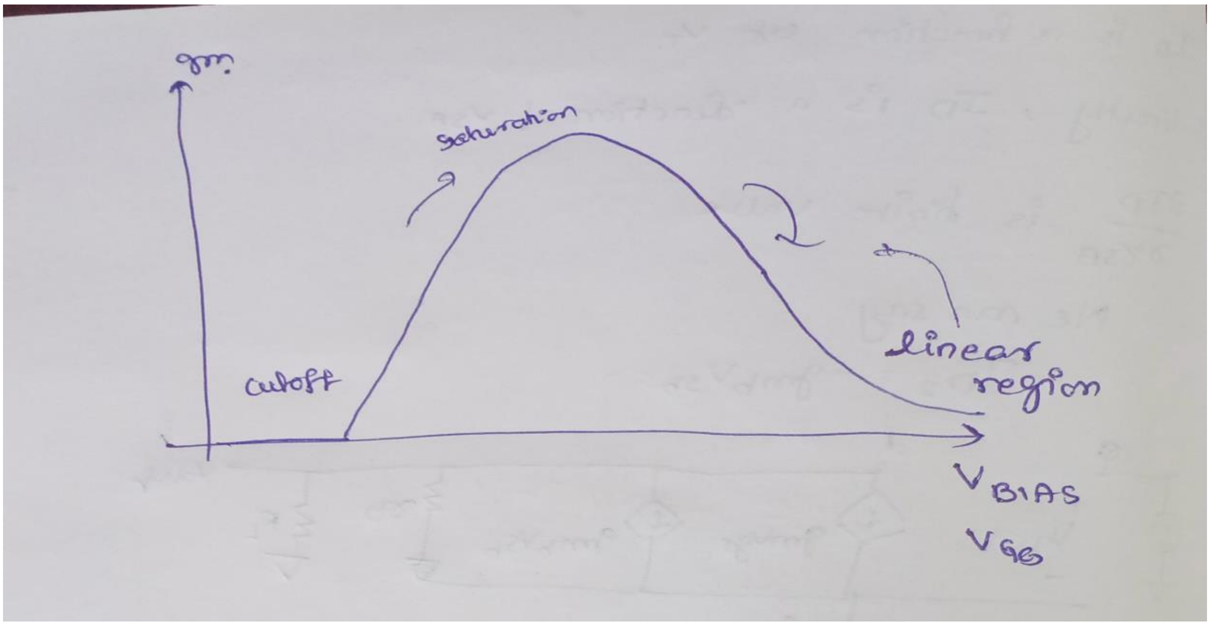
Vbias=4V

The measured value of Vds (drain-to-source voltage) is 2.93V. Since Vds is still greater than Vgs-Vth, the device continues to operate in saturation mode, and no clipping of the output signal is observed.

Vout=300mV, gain=Vout/Vin=300mv/100mV=3 =>

gain=3, gm=gain/Rd=3/4.7k=0.6382mA/V => gm=0.6382mA/v

c)



d)

Vbias(V)	Vout	Gain	gm
0.9	8mV	0.08	0.017
1.5	480mV	3.73	0.795m
1.8	480mV	4.40	0.936m
2.5	63mV	0.16	0.034m
3.1	15.7mV	0.03	0.0066
4	7.6mV	0.01	0.0026

Upto Vbias=2V MOSFET is in SATURATION MODE. After 2V the MOSFET wents to LINEAR/TRIODE MODE .

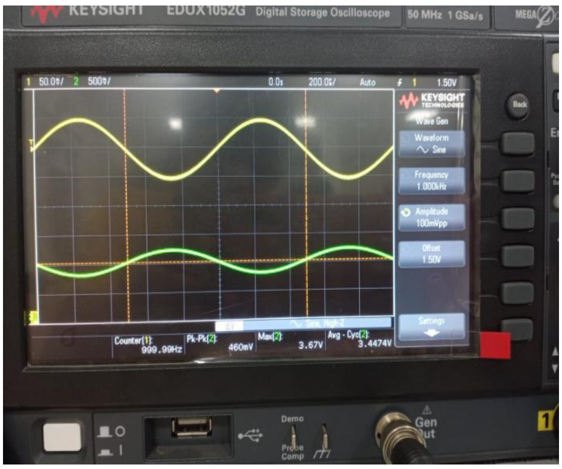
Till 2V the MOSFET acts as voltage dependent current source.

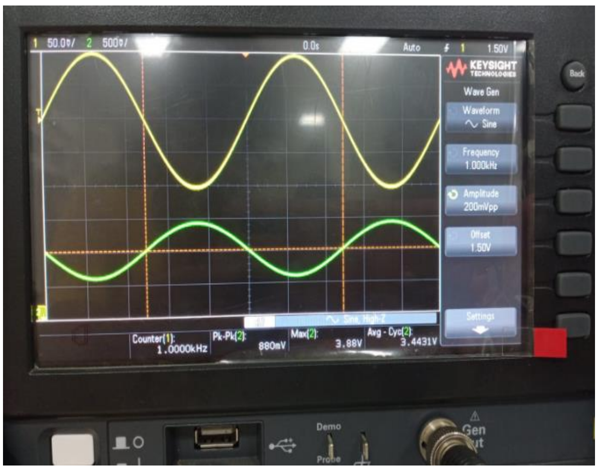
Due to linear region after 2V gain is decreasing because MOSFET acts as voltage dependent RESISTOR in TRIODE MODE.

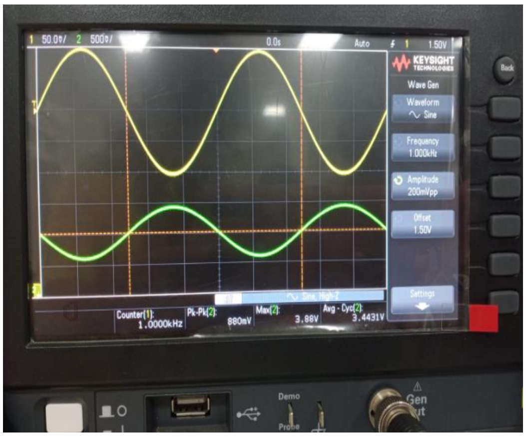
3) Effect of small signal input swing on gain of common source Amplifier :

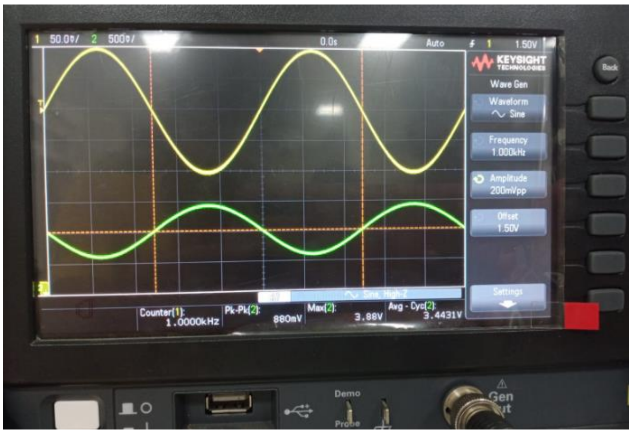
a)

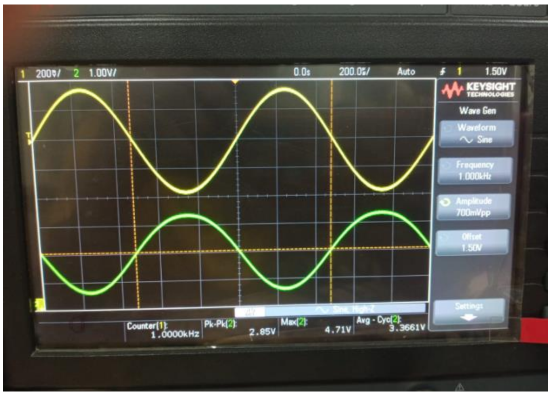
CHANGING VALUES OF Vin for constant BIAS voltage:

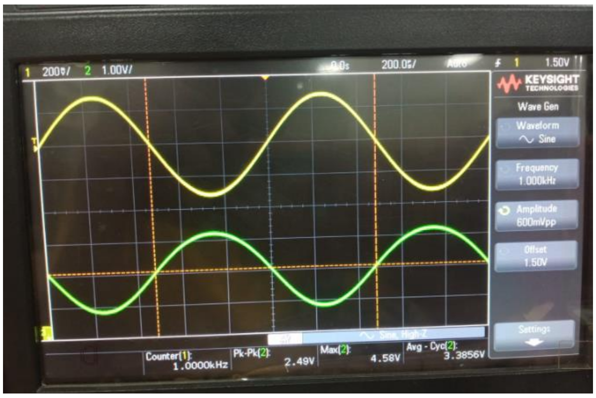


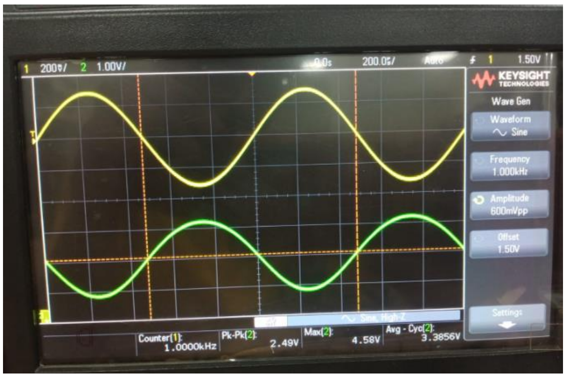


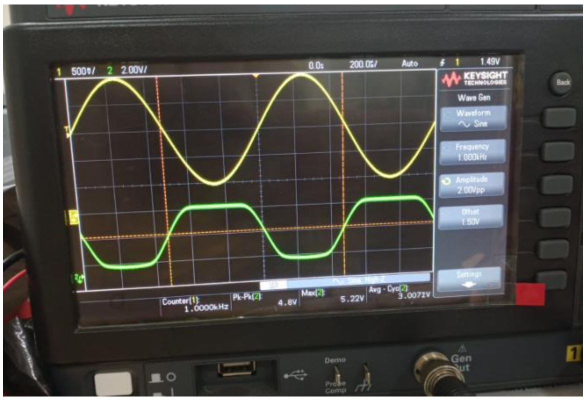












V(input)	V(output)	Gain	Gm
100mV	480mV	4.8	1.021m
200mV	900mV	4.5	0.958m
300mV	1.33V	4.43	0.945m
400mV	1.71 V	4.27	0.909m
500mV	2.17V	4.34	0,923m
600mV	2.57V	4.28	0.91m
700mV	2.6V	3.57	0.895m

900mV	3.14V	3.48	0.874m
1V	4V	4	0.85m
1.2V	4.4V	3.66	0.778m
1.3V	4.5V	3.46	0.73m
1.4V	4.6V	3.28	0.69m
1.5V	4.7V	3.14	0.66m

Clipping is observed in the output signal when the input voltage Vin exceeds a threshold between 1.2V and 1.3V. Beyond this threshold, the output signal exhibits distinct clipping, indicating that the device is entering the cutoff region and cannot fully amplify the input signal.

When observing the gain with respect to Vgs (gate-to-source voltage), it is noticed that the gain generally increases as Vgs increases when the device is operating in the saturation region. This implies that the overall gain of the amplifier increases in a consistent manner. However, it is important to note that linearity in the gain is maintained only when Vgs is greater than Vth (threshold voltage).

On the other hand, when Vgs is less than Vth, the gain continues to increase, but linearity is not preserved on the negative side of the output signal.

This is due to clipping, where the output signal is unable to fully amplify the input signal and gets truncated, resulting in distortion and a loss of linearity.While the gain increases steadily with increasing Vgs in the saturation region, linearity is only maintained up to Vgs exceeding Vth. For Vgs less than Vth, there is an increase in gain but with the presence of clipping, leading to a loss of linearity on the negative side of the output signal.

4)CS Amplifier with external coupling:

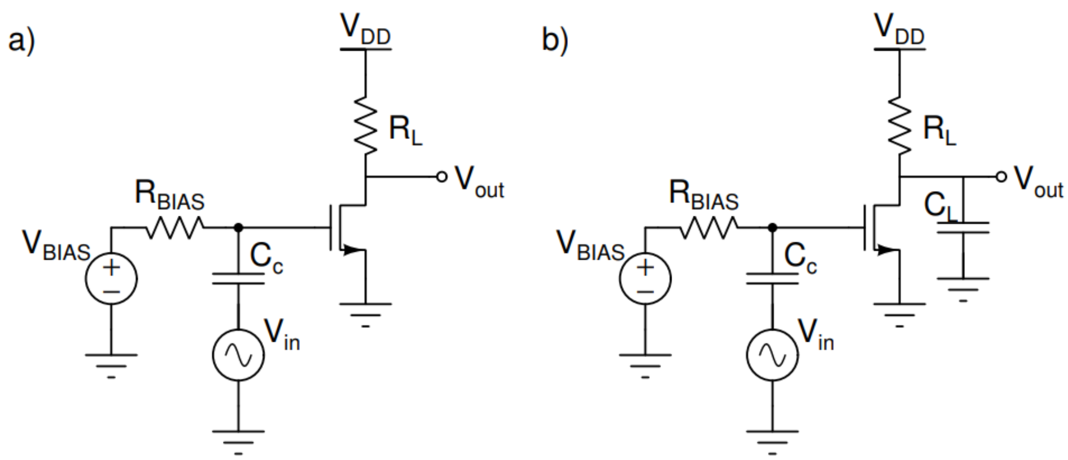


Figure 2: CS amplifier with external coupling capacitance and resistor

a)

In the circuit, an external coupling capacitance Cc of 10uF and a bias resistor Rbias of 100 ohms are connected.

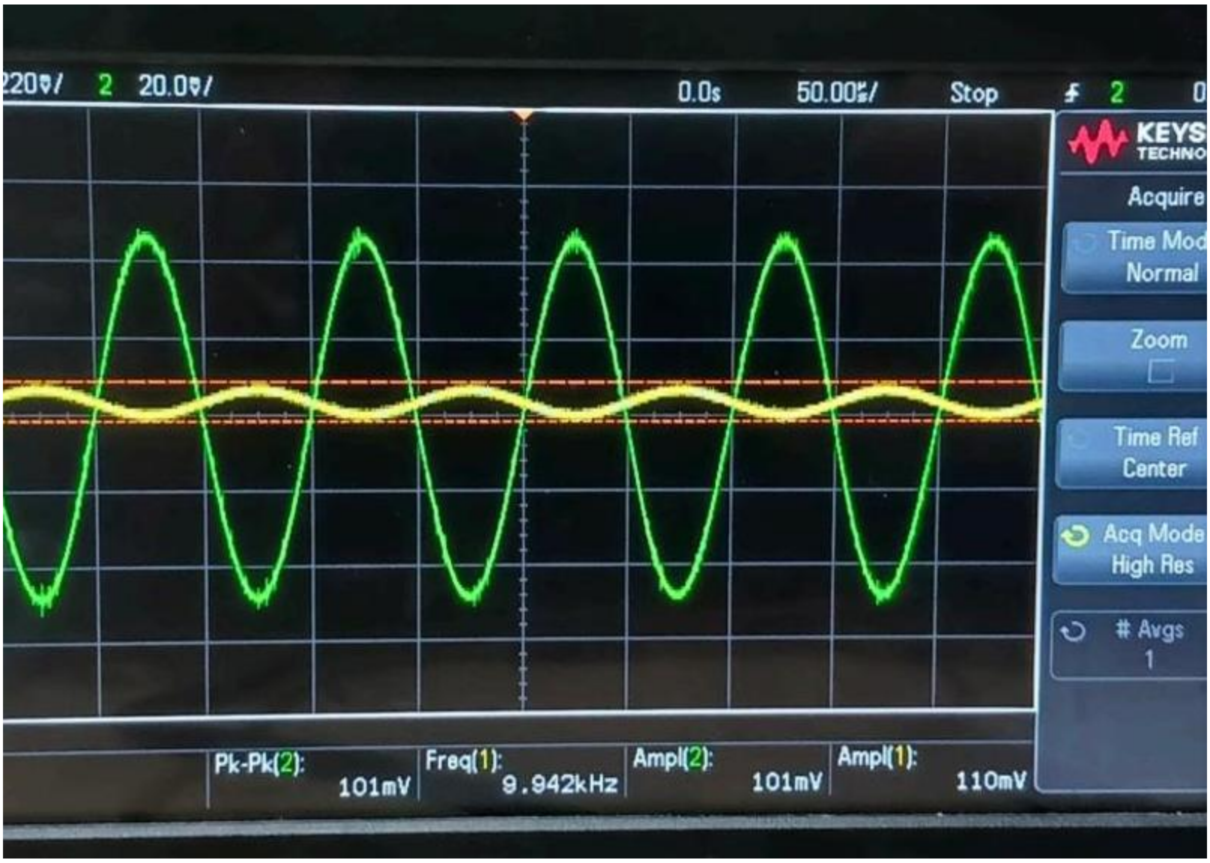
The coupling capacitance Cc is used to block any DC component of the signal, allowing only the AC component to pass through. It helps to prevent any unwanted DC bias from affecting the subsequent stages of the circuit.

The bias resistor Rbias is employed to establish a DC bias point in the circuit. It ensures that the amplifier operates within the desired range and provides a stable operating point for the active components.

b)

Vin(Vpp)=100mV, Vbias=2.5V and VDD=5V

MEASURED gain:



gm =gain/R=1.0891/4.7k=0.2317mA/V

Gain=Vout/Vin=110/101=1.089

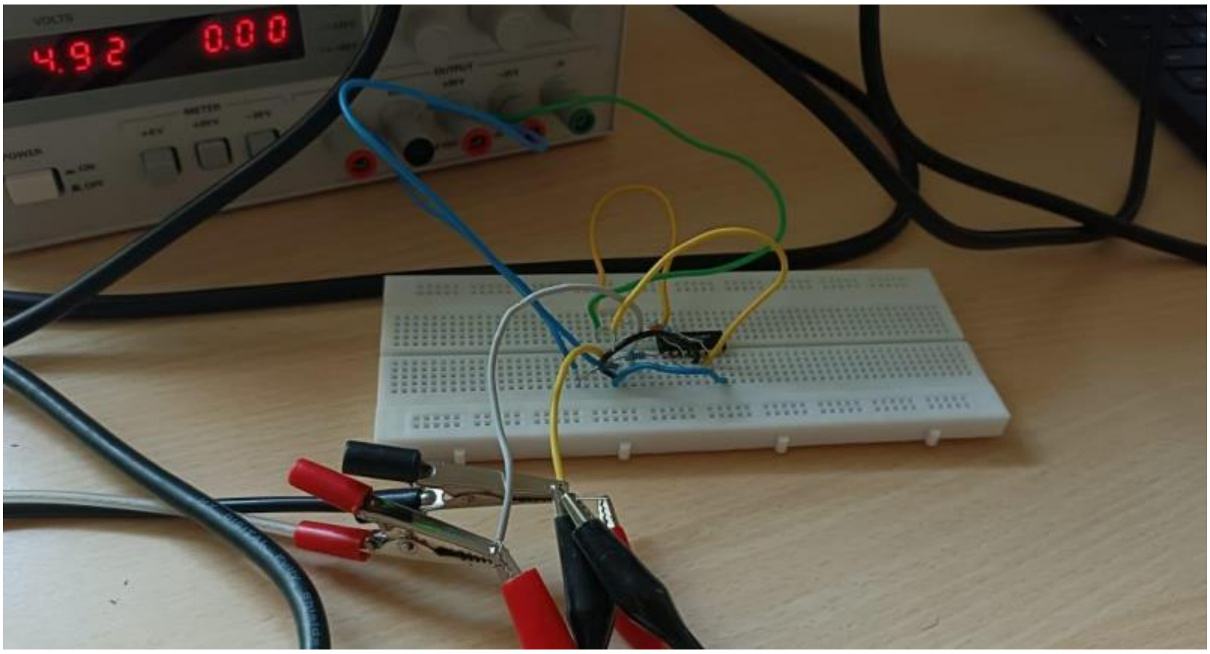
In the current configuration with the addition of external coupling, there is only a slight increase in gm. This can be attributed to the effect of the external coupling on the circuit.

By connecting the Vbias and small input signal separately, the small AC signal is prevented from passing towards the Vbias side branch due to the presence of the bias resistor Rbias. Additionally, the DC bias voltage Vbias is blocked from passing through the coupling capacitor Cc. As a result, a proper mixing of the DC and AC signals is achieved, which leads to a slight increase in transconductance (gm).

In summary, the introduction of external coupling in the circuit results in a small increase in gm. This can be attributed to the isolation of the AC and DC components of the signal, allowing for a more accurate mixing of the signals and enhancing the transconductance.

c)

MEASURED VALUE OF VDS:



Measured VDS= 4.42 which is close to previous observed value which was 4.4v.

d) LOAD CAPACITANCE CL=470pF

And -3db cut-off frequencies are F1=588Hz and F2=100KHz

(C) $V_{DS} = 4.42V$

$$I_{DS} = \frac{V_{DD} - V_{DS}}{R} = \frac{5 - 4.42}{4.7K}$$

$$= 0.123\ mA$$

$$\boxed{I_{DS} = 0.123\ mA}$$

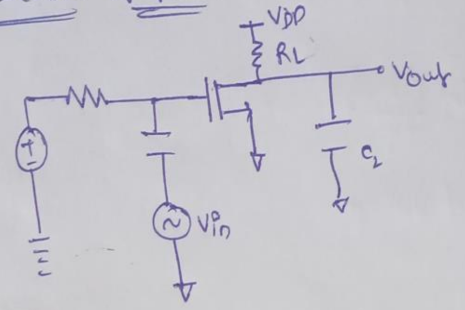
And $g_m = 0.2382\ mA/V$

As $g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{th})$

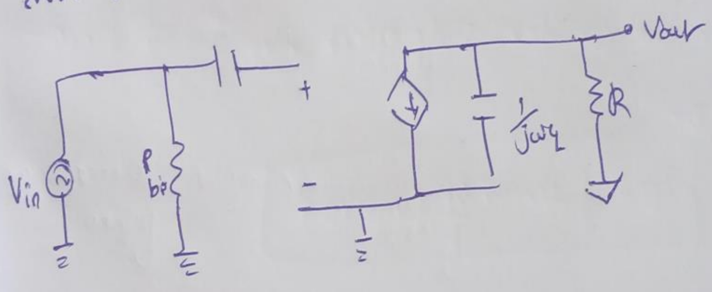
$$= 0.2382 = \mu_n C_{ox} \frac{W}{L} (2.5 - 1.8)$$

$$\boxed{\therefore \mu_n C_{ox} \frac{W}{L} = 0.331\ mA/V^2}$$

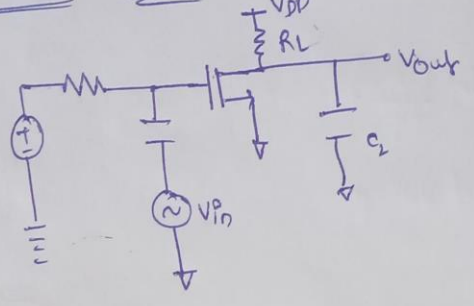
* Calculation of poles:



Small signal:



* Calculation of poles:



Small signal: