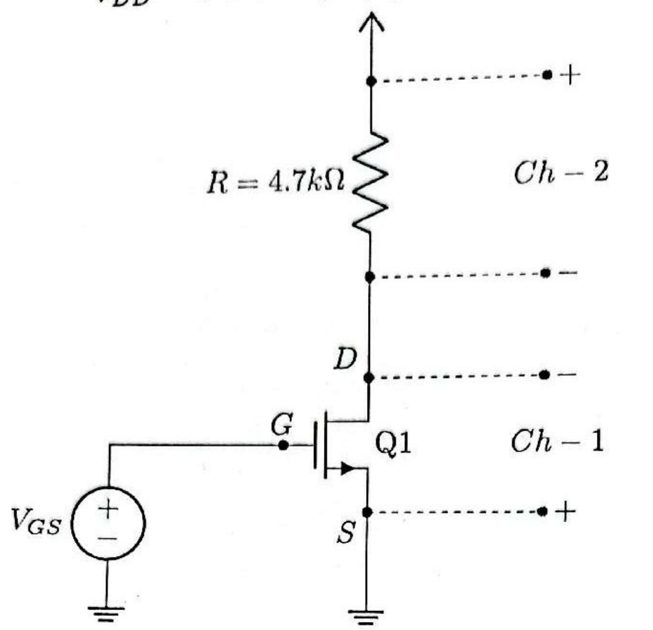
Task-01: I-V Characteristics of a MOSFET

$V_{DD} = 5 + 5\ \sin(2\pi f t)$ V [i.e. 0V to 10V]



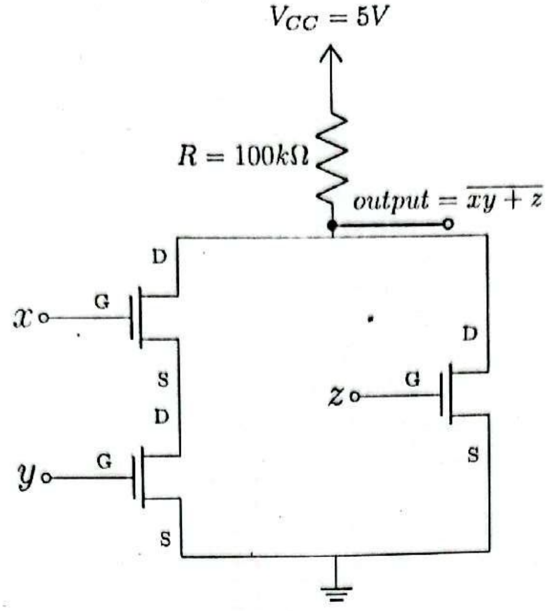
Procedure

1. Construct the circuit shown above. Use a data switch and connect it to the Gate of the MOSFET which will provide necessary voltage for V_{GS}. Use the function generator for $V_{DD} = 5 + 5\ \sin(2\pi f t)$ V [i.e. an AC voltage that varies from 0V to 10V] and set $f = 50$ Hz.
2. Set the oscilloscope in X-Y mode. Invert the Channel-1.
3. Observe the plot in the oscilloscope when the data switch is ON and OFF. This plot shows the I-V characteristics of a MOSFET as a switch. Capture the plots using your mobile camera.
4. Now, disconnect the data switch from the gate of the MOSFET and connect the dc power supply to the gate terminal so that we can increase or decrease V_{GS}.
5. Rotate the voltage knob of the dc power supply slowly from 0V to 5V. You should observe the change in the I-V characteristics.
6. Use your mobile camera to capture the image of the I-V characteristics graphs for 3 different V_{GS}. Measure the values of V_{GS} of the captured images and write them in Data Table 1.

Data Table 1: Different Values of V_{GS} to observe the change in MOSFET I-V Characteristics

Values of V_{GS}	
1st Value	2.6
2nd Value	01.9
3rd Value	1.3

Task-02: Logic Function Implementation



Circuit-1
Logic Function, $f = \overline{xy+z}$ using MOSFET

Procedure

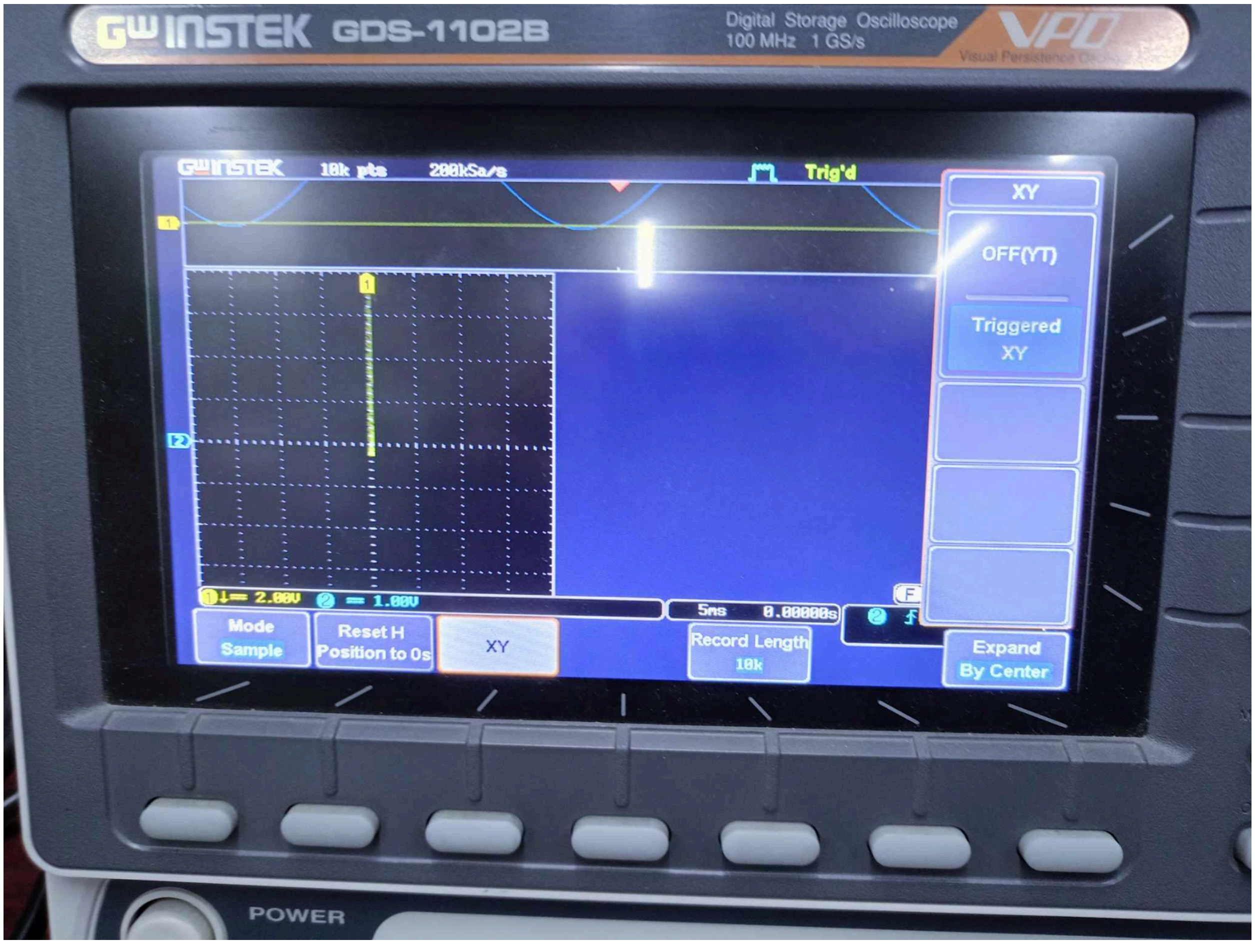
1. On a trainer board, setup the Circuit 1.
2. Connect the gate terminals (input x, y and z) to data switches. Those switches provide 5V approximately.
3. Keeping V_{CC} constant at 5V, at first turn off the data switches connected to the gate terminal. This implies you are now applying V_x= 0V, V_y= 0V and V_z= 0V. Measure the corresponding output voltage, V_{out} which should be approximately 5V which corresponds to boolean 1.
4. The boolean outputs can also be determined by the state of an LED. Connect V_{out} to one of the LEDs and check it. When the LED is ON, the boolean output is 1. Similarly, when the LED is OFF, the boolean output is 0.
5. Next, use the input voltage combinations of Data Table 2 and observe the state of LED again.
6. Verify the truth table of the Logic Function, f = $\overline{xy+z}$.

Data Table 2: Verification of the Truth Tables of Logic Function, $f = \overline{xy+z}$

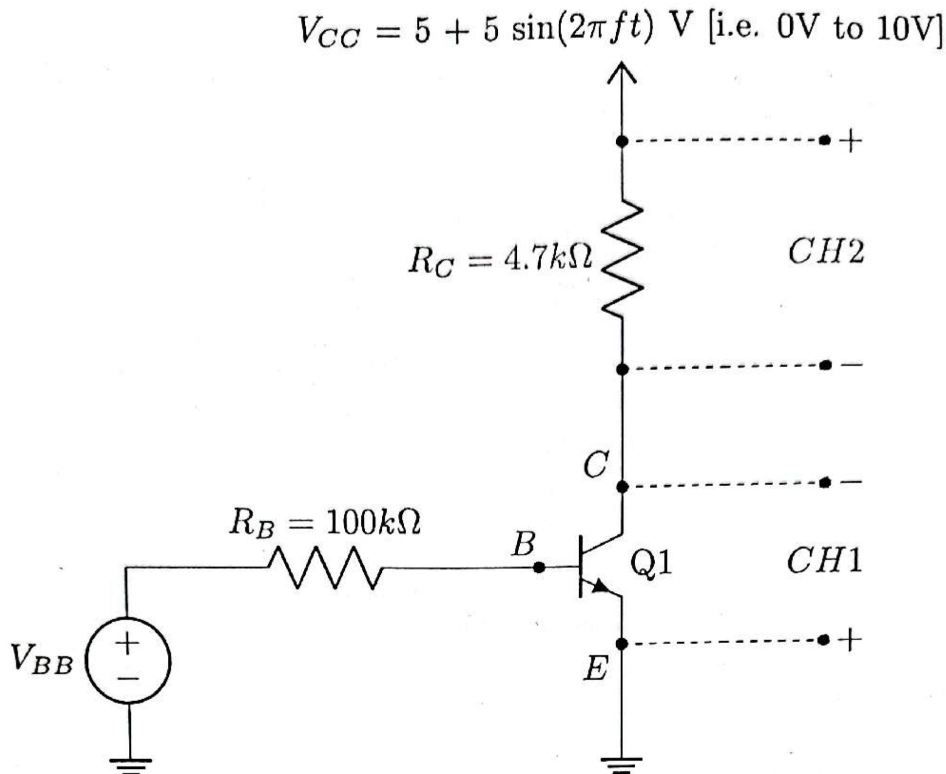
Input Voltage, V_x (volt)	Input Voltage, V_y (volt)	Input Voltage, V_z (volt)	State of LED (On/Off)	Boolean Output (0 or 1)
0V	0V	0V	ON	1
0V	0V	5V	OFF	0
0V	5V	0V	ON	1
0V	5V	5V	OFF	0
5V	0V	0V	ON	1
5V	0V	5V	OFF	0
5V	5V	0V	OFF	0
5V	5V	5V	OFF	0


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
HARDCOPY
10k pts
Trig'd
XY
OFF(YT)
Triggered
XY
2.00V
1.00V
5ms
Mode
Sample
Reset H
Position to 0s
XY
Record Length
10k
Expand
By Center


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
VPO
Visual Persistence Oscilloscope
HARDCOPY
10k pts
200kSa/s
Auto
XY
OFF(YT)
Triggered
XY
2.00V
1.00V
5ms
0.00000s
Mode
Sample
Reset H
Position to 0s
XY
Record Length
10k
Expand
By Center
MENU OFF
OPTION
POWER
2V


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
10k pts
200kSa/s
Trig'd
XY
OFF(YT)
Triggered XY
2.00V
1.00V
5ms
0.00000s
Mode
Sample
Reset H Position to 0s
XY
Record Length
10k
Expand By Center
POWER

Task-03: I-V Characteristics of a BJT



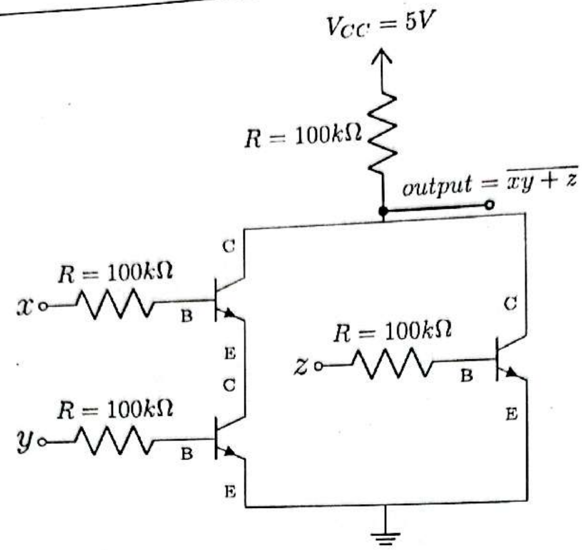
Procedure

1. Construct the circuit shown above. Use the function generator for $V_{CC} = 5 + 5\ \sin(2\pi f t)$ V [i.e. an AC voltage that varies from 0V to 10V]. Set $f = 50$ Hz. Use the dc power supply for V_{BB}.
2. Invert the CH1. Set the oscilloscope in the X-Y mode.
3. Now, rotate the voltage knob of the dc power supply slowly from 0V to 5V to vary V_{BB}. You should observe the change in the I-V characteristics.
4. Use your mobile camera to capture the image of the I-V characteristics graphs for 3 different values of V_{BB}. Measure the values of V_{BB} of the captured images and write them in Data Table 3:

Data Table 3: Different Values of V_{BB} to observe the change in BJT I-V Characteristics

Values of V_{BB}	
1st Value	0.3
2nd Value	0.8
3rd Value	1.3

Task-04: Logic Function Implementation



Circuit-1
Logic Function, $f = \overline{xy + z}$ using BJT

Procedure

1. On a trainer board, setup the Circuit 1.
2. Connect the gate terminals (input x and y) to data switches. Those switches provide 5V approximately.
3. Keeping V_{CC} constant at 5V, at first turn off the data switches connected to the gate terminal. This implies you are now applying V_x= 0V, V_y= 0V and V_z= 0V. Measure the corresponding output voltage, V_{out} which should be approximately 5V which corresponds to boolean 1.
4. The boolean outputs can also be determined by the state of an LED. Connect V_{out} to one of the LEDs and check it. When the LED is ON, the boolean output is 1. Similarly, when the LED is OFF, the boolean output is 0.
5. Next, use the input voltage combinations of Data Table 4 and observe the state of LED again.
6. Verify the truth table of the Logic Function, f = $\overline{xy + z}$.

Data Table 4: Verification of the Truth Tables of Logic Function, $f = \overline{xy + z}$

Input Voltage, V_x (volt)	Input Voltage, V_y (volt)	Input Voltage, V_z (volt)	State of LED (On/Off)	Boolean Output (0 or 1)
0V	0V	0V	ON	1
0V	0V	5V	OFF	0
0V	5V	0V	ON	1
0V	5V	5V	OFF	0
5V	0V	0V	ON	1
5V	0V	5V	OFF	0
5V	5V	0V	OFF	0
5V	5V	5V	OFF	0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HARDCOPY
VARIABLE
Measure
Display
Select
Search
Set/Clear
VERTICAL
POSITION
MATH
M
REF
R
BUS
B
CH1
CH2
SCALE
POWER
Trig'd
XY
OFF(YT)
Triggered XY
Mode
Sample
Reset H
Position to 0s
XY
Record Length
Expand
By Center
5ms
2.00V


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
HARDCOPY
10k pts
200kSa/s
Auto
XY
OFF(YT)
Triggered XY
2.00V
2.00V
5ms
0.00000s
Mode
Sample
Reset H
Position to 0s
XY
Record Length
10k
Expand
By Center


GW INSTEK GDS-1102B
Digital Storage Oscilloscope
100 MHz 1 GS/s
VARIABLE
Measure
Display
Select
Search
Set/Clear
XY
OFF(YT)
Triggered XY
Mode Sample
Reset H Position to 0s
XY
Record Length 10k
Expand By Center
VERTICAL
POSITION
POSITION
CH1
CH2
SCALE
SCALE
POWER

Task-05: Report

1. Cover page [include course code, course title, name, student ID, group, semester, date of performance, date of submission]
2. Attach the signed Data Sheet.
3. Attach the captured photos of all the waveforms and measurements you have observed in the Oscilloscope. Each photo should contain necessary description.
4. Answer the questions of the Test Your Understanding section.
5. Add a brief Discussion at the end of the report. For the Discussion part of the lab report, you should include the answers of the following questions in your own words:
   - What did you learn from this experiment?
   - What challenges did you face and how did you overcome the challenges? (if any)
   - What mistakes did you make and how did you correct the mistakes? (if any)
   - How will this experiment help you in future experiments of this course?

Trasten

Signature of the lab faculty

Test Your Understanding

Answer the following questions:

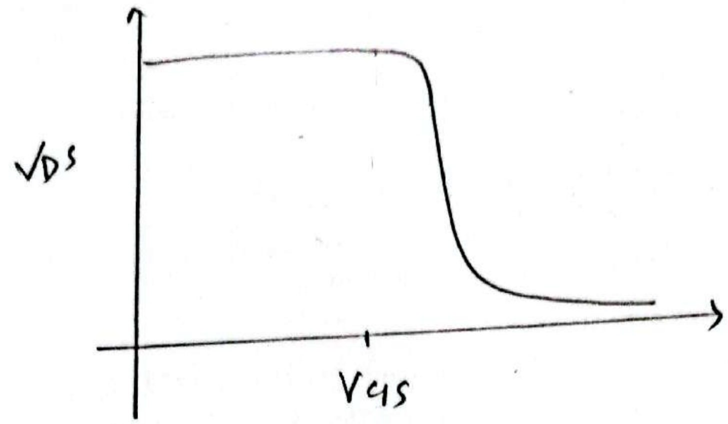
1. We can use the MOSFET as a switch. Which operating regions do we need for this purpose and why?
   Answer:

We need linear/triode region for MOSFET to behave as a switch.

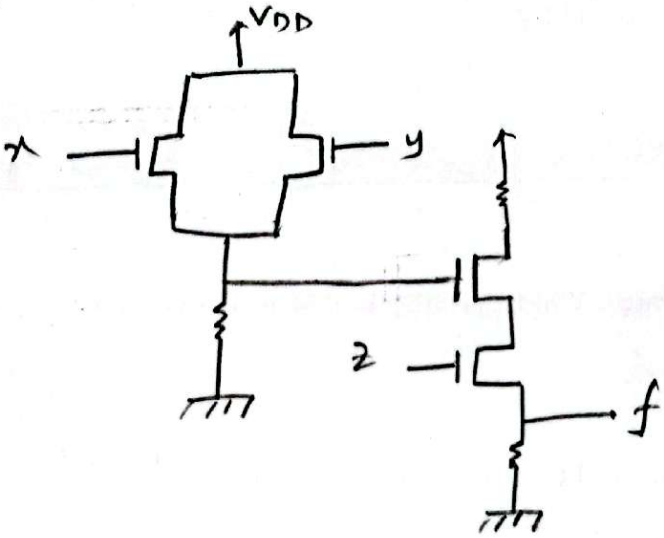
For linear region: $V_{GS} > V_T$, $V_{DS} < V_{OV}$

In this region the MOSFET allows current to flow freely between drain and source.

2. Draw the VTC (V_{DS} vs V_{GS}) graph of a MOSFET operating as a switch.
Answer:



3. Draw a circuit using MOSFETs that implements the following logic function, $f = (x+y)z$
Answer:



4. When a MOSFET is in triode mode, does it display zero, finite or infinite resistance? Justify your answer.
Answer:

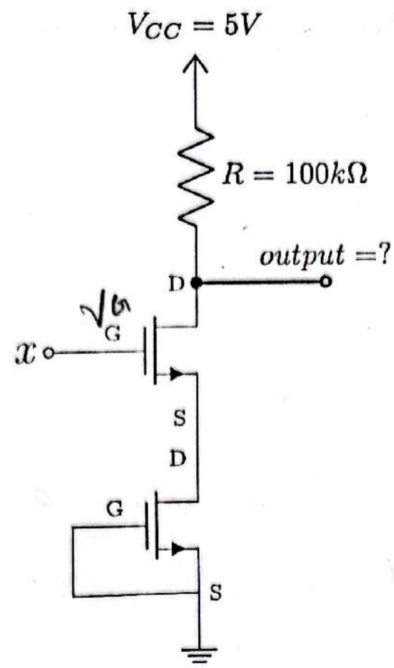
When a MOSFET is in triode mode, it displays finite resistance.

In linear mode, $V_{GS} > V_T$ and $V_{ds} < V_O$

$$I_D = k_n' \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$\therefore R_{DS} = \frac{V_{DS}}{I_D} = \frac{V_{DS}}{k_n' \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right]}$$

So R_{DS} is not infinite nor zero. It



5. What is the value of the output of the circuit above?
<u>Answer:</u> Output depends on gate Voltage, $V_G = X$

if x is 0; no current flows from drain to source,
(OFF) output is high through resister.
Output = 5V

if x is 1; current flows from drain to ground.
(ON) out put is pulled low.

. Output = 0V

6. If $V_{DS} = 3V$, $V_{GS} = 3V$ and $V_T = 1V$, find the gate current (I_G), drain current (I_D) and source current (I_S) of a MOSFET given that $k = 0.5mA/V^2$.
<u>Answer:</u>

$V_0 = V_{GS} - V_T = (3-1) = 2V$

$V_{DS} = 3V$

$V_0 < V_{DS}$
$\therefore$ saturation

$I_G = 0$

$I_D = \frac{1}{2} k_n (V_{GS} - V_T)^2$
$= \frac{1}{2} \times 0.5 \times (3-1)^2$
$= 1 \text{ mA}$

$I_S = 1 \text{ mA}$

7. We can use the BJT as a switch. Which operating regions do we need for this purpose and why?
Answer:

To use BJT as a switch, we need to use i) cutoff & ii) saturation region.

Cutoff region for the OFF state and saturation region for the ON state.
We do not need to use active region because it's for amplification, not switching.

8. What's the primary difference between a MOSFET and a BJT when they are both acting as switches?
Answer:

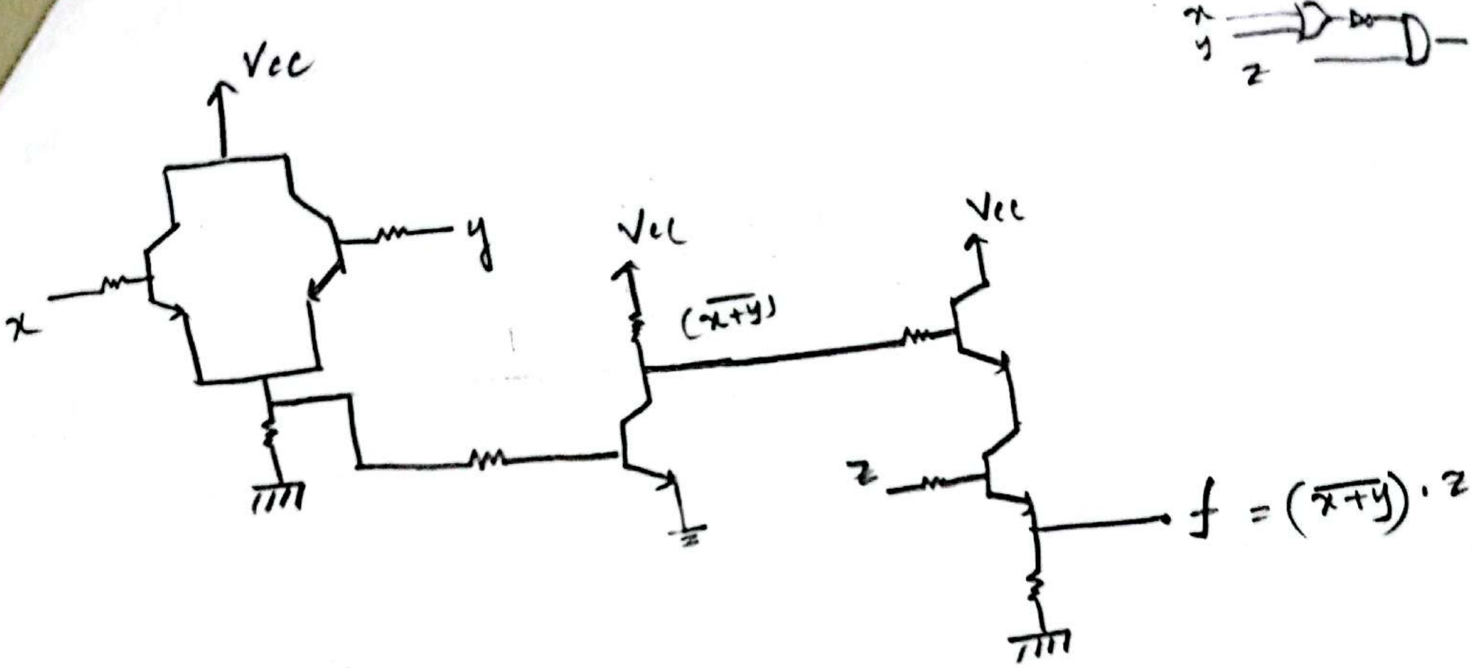
MOSFET is a voltage controlled transistor while BJT is a current controlled transistor.
MOSFET requires voltage at the gate to turn ON.
BJT requires base current to stay ON.
MOSFET's switching speed is faster than BJT and its efficiency is higher at high speed compared to BJT

9. Suppose we want to cascade two BJT logic gates (use the output of the first logic gate as one of the inputs of the second one). Why do we need to add a resistor at the input of the second logic gate?
Answer:

The output of the first BJT is the input of the second BJT. The Base-emitter junction behaves like a diode. Without a resistor the output of the first gate could sink excessive current and damage logic levels. The resistor limits the base current to a safe value.

10. Draw a circuit using BJTs that implements the following logic function, $f = (\overline{x+y}).z$

Answer:



11. Suppose, a BJT is operating in the active region where, $I_B = 0.01mA$. If $\beta = 100$, find the value of I_C and I_E.

Answer:

$\beta = 100$

$\Rightarrow \dfrac{I_c}{I_B} = 100$

$\Rightarrow I_c = (100 \times 0.01)$

$\therefore I_C = 1 \text{ mA}$

$\therefore I_E = I_B + I_C = (0.01 + 1) = 1.01 \text{ mA}$