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EE1101: Circuits and Network Analysis

Lecture 12: Circuits with Three Terminal Elements
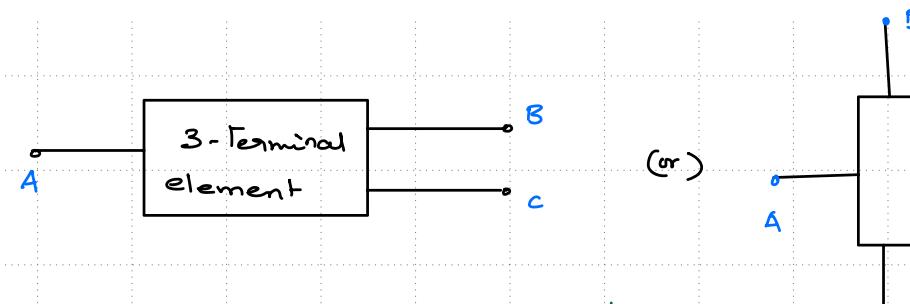
August 25, 2025

**Topics :**

1. Three Terminal Circuit Elements

2. Bipolar Junction Transistor (BJT)

Three Terminal Circuit Elements

Representation :-

3 - Terminal element

A   B   C

(or)

B   A   C

Clearly outline   a) control terminal|port

b) main ckt|port.

Typically two modes   a) Switch (ON & OFF State)

b) Amplifier

conditions that define the operating mode must be known:
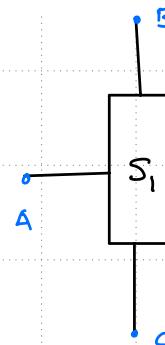
when operating as a Switch: ON → Very small Resistance (ideally SC)

OFF → Very large " (ideally OC)

when operating as an Amplifier → Model using dependent Sources.

Not every 3-terminal element exhibit both the modes.

Example: Three Terminal Circuit Elements

B

S_1 ← operating as a switch.

A

c

def of 3-terminal element

a) A–C : Control port

b) B–C : main ckt

c) $V_{AC} \leq 0$: OFF state (B–C is oc)

d) $V_{AC} \geq 5V$: ON state (B–C is Sc)

e) $0 < V_{AC} < 5$: Amplifier. &

from prev. Lec:

$\triangle$ + V_S

R_1

B

S_1

A

c

V_L
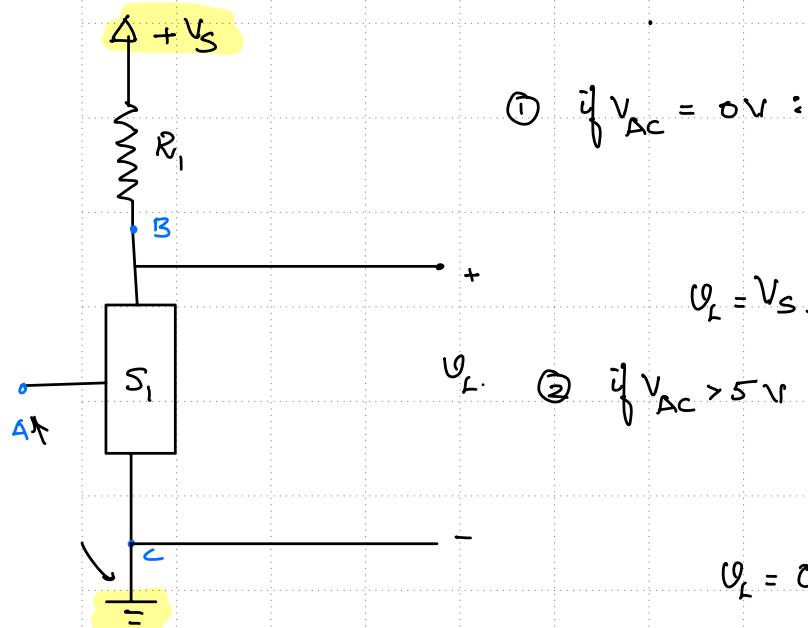
Eq. Circuit is

① if $V_{AC} = 0V$: S_1 is acting as a switch in OFF state (open ckt of B & C)

$V_L = V_S$.
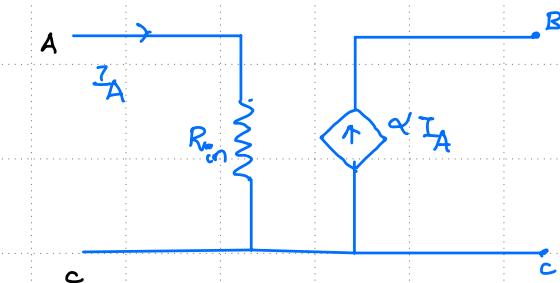
② if $V_{AC} > 5V$: S_1 is acting as a switch in ON state (short ckt of B & C)
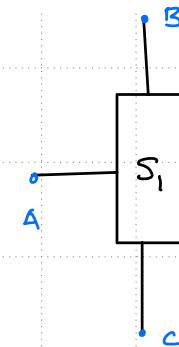
$V_L = 0$

A →
I_A
R_{in} $\langle \uparrow \rangle \alpha I_A$
c   c

B

c

Example: Three Terminal Circuit Elements

B

S_1

A

C

from prev. Lec:

$+ V_S$

R_1

B

$+$

S_1 v_L

A

$-$

c

def of 3-terminal element

a) A-c : Control port
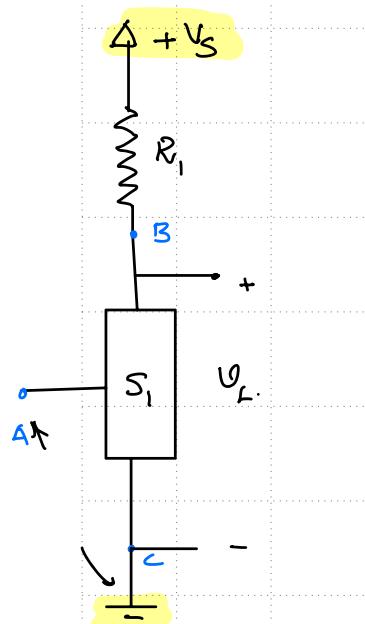
b) B-c : main ckt

c) $V_{AC} \leq 0$: OFF state (B-c is oc)
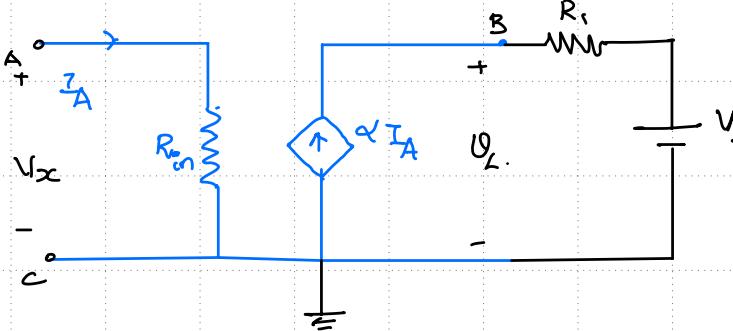
d) $V_{AC} \geq 5V$: ON state (B-c is sc)

e) $0 < V_{AC} < 5$: Amplifier &
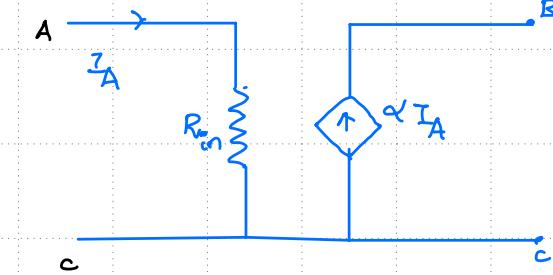
Eq. Circuit is
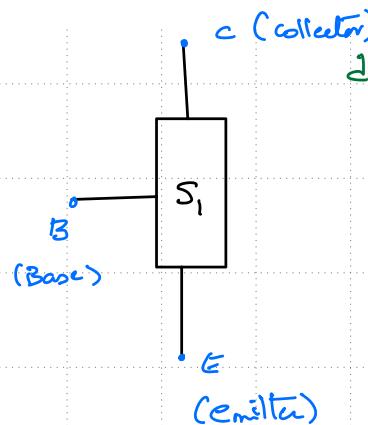
③ if $0 < V_{AC} < 5$ (operating as an amp)
(or)
V_x

A
$+$
I_A

V_x

R_{in} αI_A v_L

$-$
c

B R_1
$+$

V_S

$-$

A

I_A

R_{in} αI_A

B

c

derive v_L in terms of V_x

Example: Three Terminal Circuit Elements (leading to def of BJT from a ckt point of view)

c (collector)

S_1

B

(Base)

E

(emitter)

def of 3-Terminal element

a) B-E: Control Port
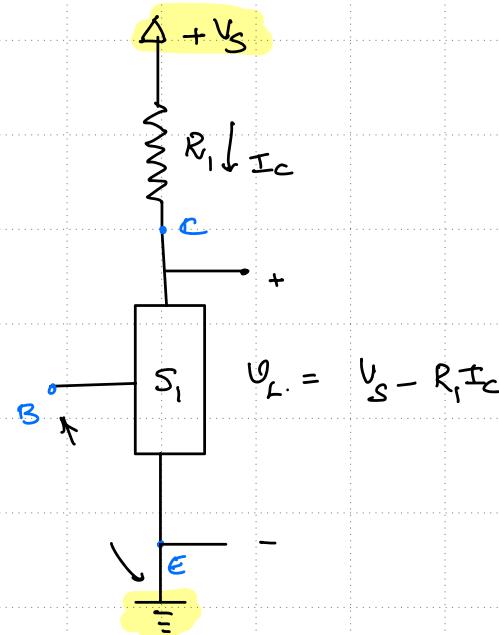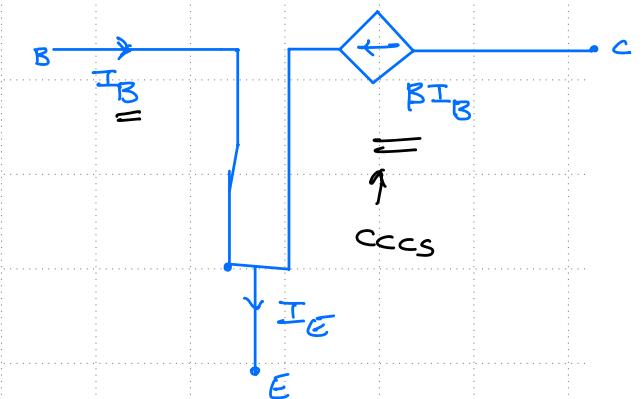
b) C-E: main ckt

c) $V_{BE} \leq 0$: OFF state (CE is OC)

d) $V_{BE} > V_{ON}$: ON state (CE is SC)
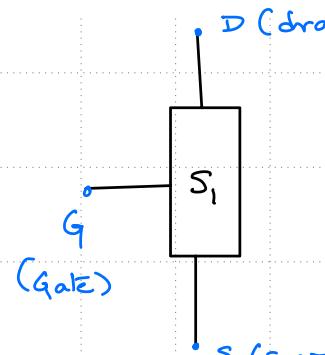
e) $0 \leq V_{BE} < V_{ON}$ Amplifier. &

Eq. Circuit is

B

I_B

βI_B

C

I_E

E

CCCS

$\triangle + V_S$

$R_1 \downarrow I_C$

C

+

S_1

$v_L = V_S - R_1 I_C$

B

E

−

Example: Three Terminal Circuit Elements (leading to def of MOSFET from a ckt point of view)

D (drain)

S_1

G
(Gate)

S (Source)

def of 3-Terminal element

a) G-S: Control port
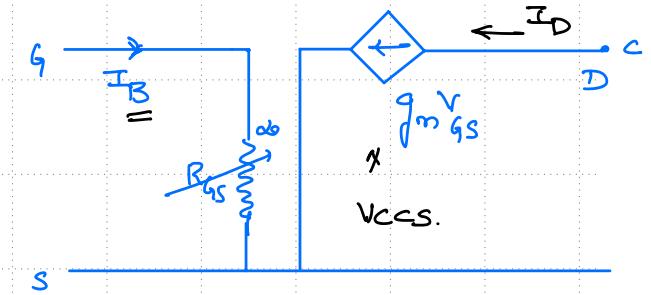
b) D-S : main ckt

c) $V_{GS} \leq 0$: OFF state (D-S)

d) $V_{GS} \geq V_{on}$: ON state (D-S is SC)

e) $0 \leq V_{GS} < V_{on}$ Amplifier. &

Eq. Circuit is

G ——— I_B ——— $g_m V_{GS}$ ——— $\leftarrow I_D$ ——— C

D

R_{GS}

VCCS.

S

△ + V_S

$R_1 \downarrow I_D$

D

+

S_1 $V_L =$

G

S

as $V_{GS} > 0 \implies I_D > 0$

$\Downarrow$
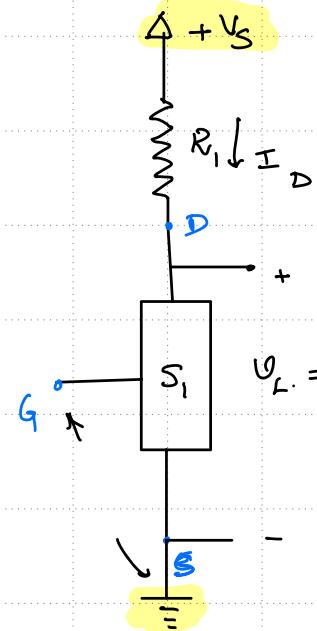
$V_L = V_S - R_1 I_d \rightarrow \downarrow$ when V_{GS} increases

$\downarrow$ beyond a threshold

$V_L \approx 0 \rightarrow SC \rightarrow$ ON State &

acts as a switch.