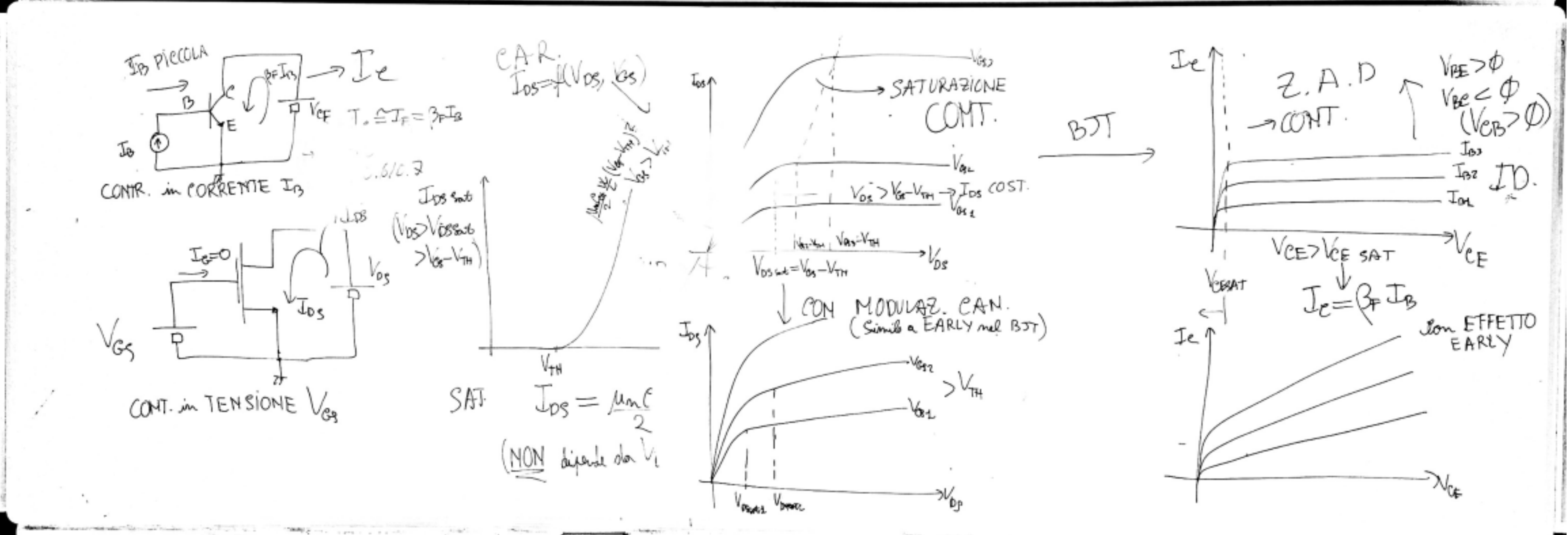
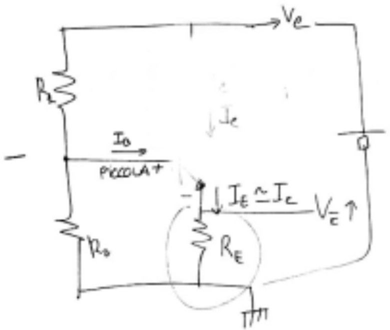

IB PICCOLA
Ic
VCE
CONTR. in CORRENTE IB
IG=0
IDS
VDS
VGS
CONT. in TENSIONE VGS
C.A.R.
IDS = f(VDS, VGS)
IDS sat
(VDS > VDS sat > VGS-VTH)
VTH
SAT. IDS = μnC/2
(NON dipende da V
SATURAZIONE
CONT.
VDS > VGS-VTH → IDS COST.
VDS sat = VGS-VTH
CON MODULAZ. CAN.
(Simile a EARLY nel BJT)
> VTH
BJT
Z.A.D
→ CONT.
VBE > 0
VBC < 0
(VCB > 0)
VCE > VCE SAT
VCESAT
Ic = βF IB
Con EFFETTO EARLY
VCE

$V_B = V_C \frac{R_2}{R_1+R_2}$ –



$I_C = \beta_F I_B$

β_F GRANDE

β_F MIN. GAR.

$V_{BE} \cong V_\gamma = 0.7$

B–E DIR

$0.5 \leq V_{BE} \leq 0.75$

$V_{BE} = V_B - V_E$

Se I_E AUMENTA → V_E AUMENTA

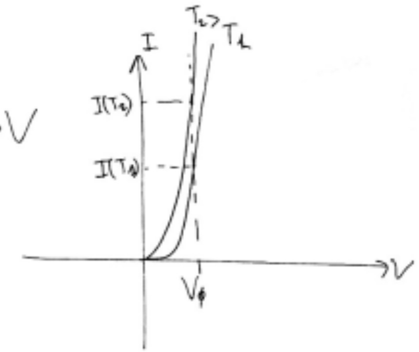
↓ V_{BE} DIM

↓ I_E DIM.

$I = I_S\left(e^{\frac{V}{V_T}} - 1\right)$ $\quad V_T = \frac{kT}{q}$

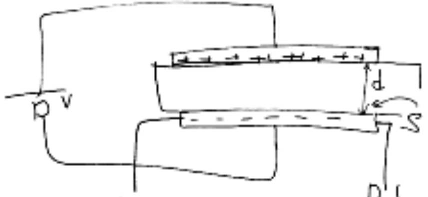
$I = I_S\left(e^{\frac{qV}{kT}} - 1\right)$

$I_S \propto e^{-\frac{qV_G}{kT}}$ ← 1.12V $\quad V_G > V$



Metal Oxide Si — MOS

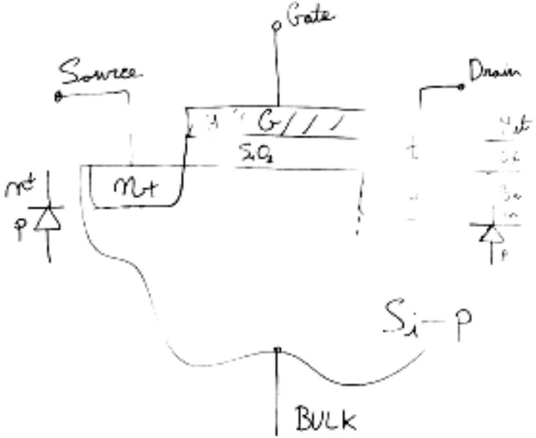
Field Effect Trans. — FET



$Q = C V$

$|Q^+| = |Q^-|$

$C = \varepsilon \cdot \frac{S}{d}$ F



$\varepsilon_r = 3.9$ (SiO_2)

$C_{ox} = \frac{\varepsilon_0 \varepsilon_r}{t_{ox}}$ F/m^2

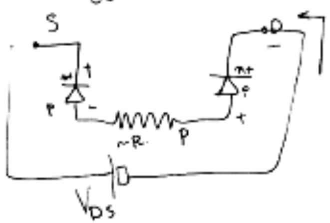
$Q = C_{ox} \cdot V$

C/m^2 F/m^2

NON è così

$V_{GB} < 0$

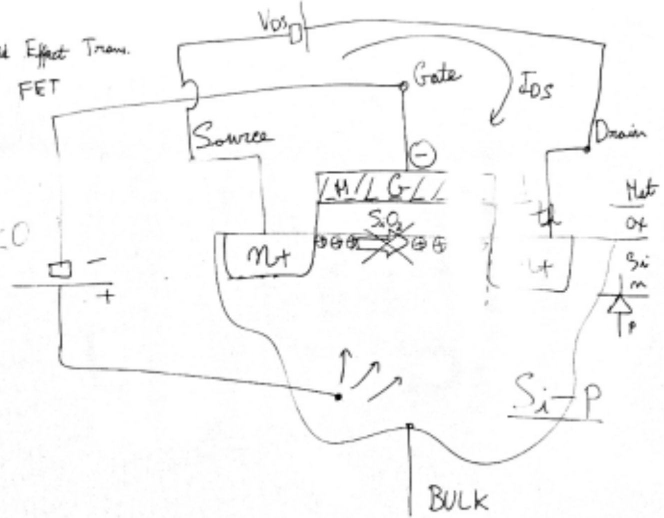
$V_{GB} = \emptyset$



$I_{DS} = \emptyset$

Metal Oxide Si
MOS

Field Effect Trans.
FET

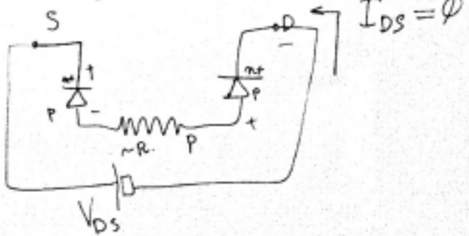


$\varepsilon_r = 3.9 \ (SiO_2)$

$$C_{ox} = \frac{\varepsilon_0 \varepsilon_r}{th} \quad F/m^2$$

$Q = C_{ox} \cdot V$ (C/m², F/m²) NON è così

$V_{GB} = \emptyset$



$V_{GB} < 0$

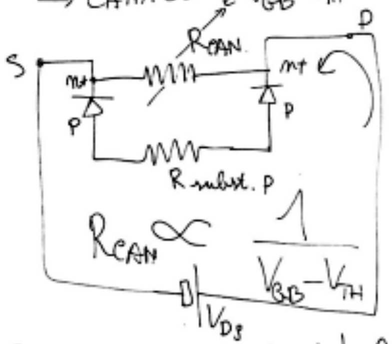
NON CAMBIA NIENTE!

Metal Oxide Si — MOS

Field Effect Trans. — FET

$V_{GB} > V_{TH}$

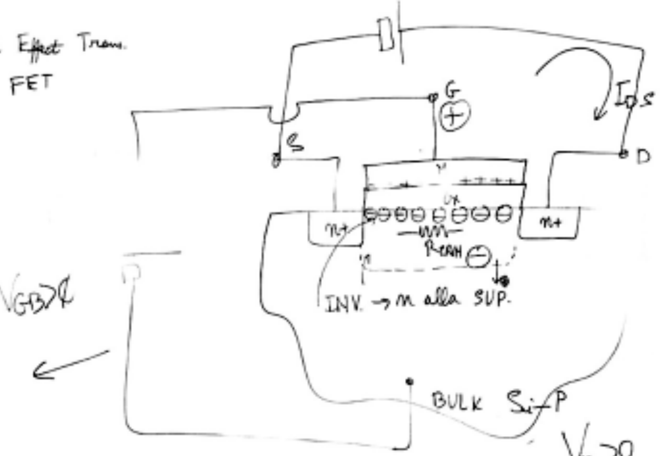
→ CANALE ← $V_{GB} - V_{TH}$



$R_{CAN} \propto \frac{1}{V_{GB} - V_{TH}}$

CONDUCE TANTO di PIU' QUANTO PIU' $V_{GB} - V_{TH}$ GRANDE

→ $I_{DS} \propto V_{GB}$



V_{GB} PICCOLA

V_{GB} SUFF. GRANDE

SOTTO il GATE il Si (ORIG. P) DIVENTA n → SI ACCUMULANO GLI ELETTRONI

$V_{THRESHOLD}$ → V_{TH}

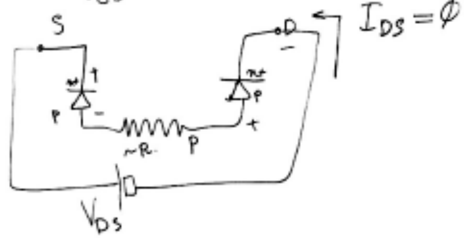
$V_{GB} > 0$ MA $V_{GB} < V_{TH}$ NO el. all' int. OX-Si

$V_{GB} > V_{TH}$ → ELETT. all' int OX-Si

→ INVERSIONE da p a n

→ CANALE di ELETTRONI

$V_{GB} = \emptyset$



$V_{GB} < 0$

NON CAMBIA NIENTE!

$V_{GB} > 0$ PICCOLA NON CAMBIA

$V_{GB} > 0$ SUFF. GRANDE ⟶ INVERSIONE

Metal Oxide Si

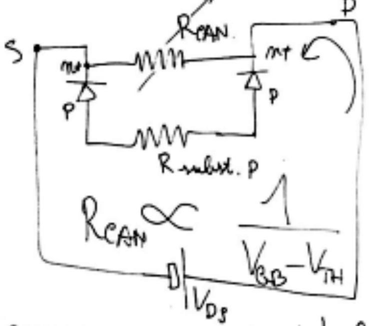
MOS

Field Effect Tran.

FET

$V_{GB} > V_{TH}$

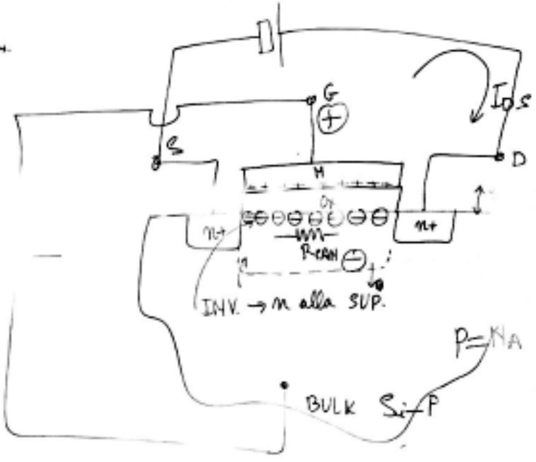
→ CANALE ← $V_{GB} - V_{TH}$



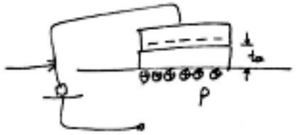
$$R_{CAN} \propto \frac{1}{V_{GB} - V_{TH}}$$

CONDUCE TANTO di PIU' QUANTO PIU' $V_{GB} - V_{TH}$ GRANDE

→ $I_{DS} \propto V_{GB}$



1) $V_{GB} < 0$ "+" al BULK "p"



$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{\varepsilon_0 \varepsilon_r}{t_{ox}}$$

2) $V_{GB} > 0$ MA $V_{GB} < V_{TH}$ NON SUCCEDE NIENTE

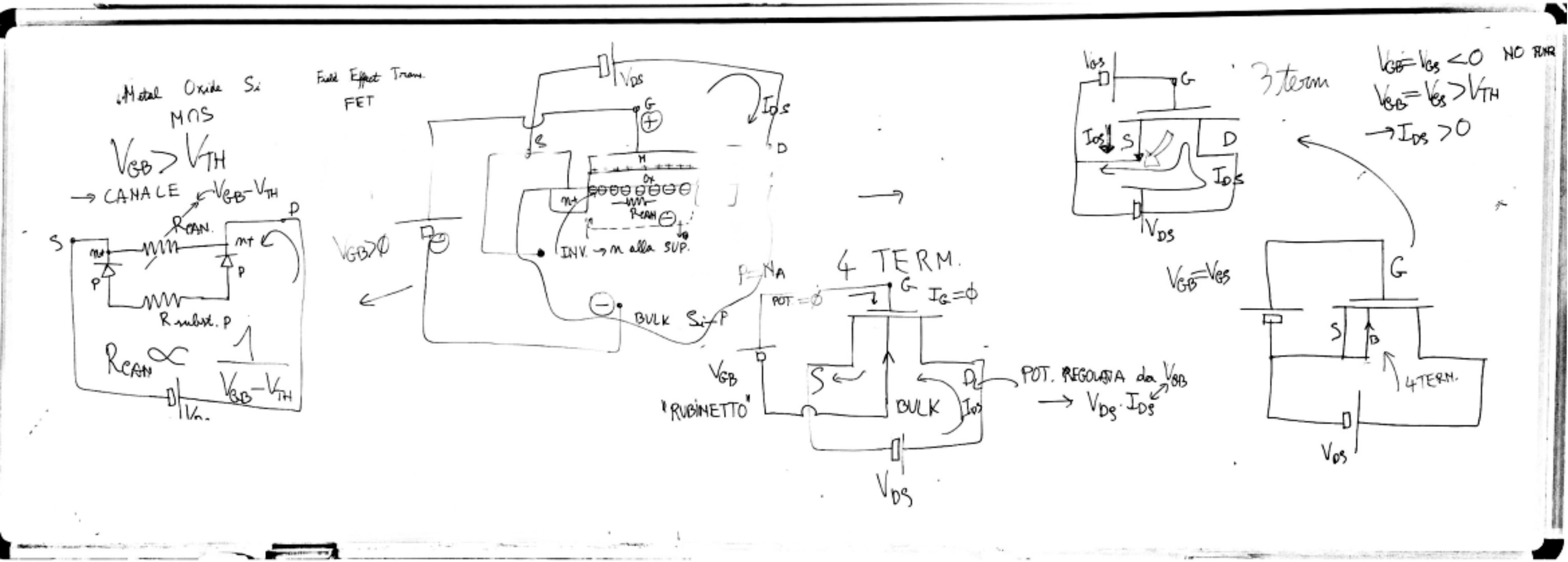
3) $V_{GB} > V_{TH}$ → COND. tra S e D

$$\rightarrow V_{TH}\text{ "ideale"} = \frac{\sqrt{2 \varepsilon_0 \varepsilon_{Si}\, q N_A\, 2\psi_B(N_A)}}{C_{ox}} + 2\psi_B(N_A)$$

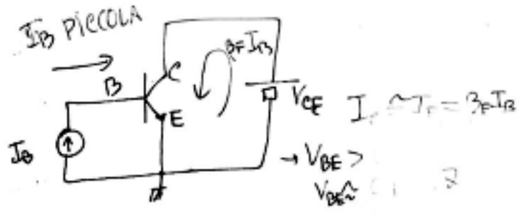
$$\psi_B = \frac{kT}{q} \ln \frac{N_A}{n_i}$$

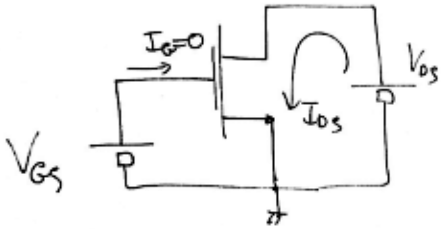
$n_i \cong 1.5 \times 10^{10}\ cm^{-3}$ $T = 300K$

CONC. di n (o p) Si NON DROGATO



Metal Oxide Si
MOS
Field Effect Tran.
FET
VGB > VTH
→ CANALE
VGB−VTH
RCAN.
S
D
n+
p
R subst. P
RCAN ∝ 1 / (VGB−VTH)
VDS
G
M
Ox
RCAN
IDS
INV. → n alla SUP.
BULK Si-P
VGB>0
4 TERM.
P=NA
POT=0
IG=0
VGB
"RUBINETTO"
BULK
POT. REGOLATA da VGB
→ VDS·IDS
3 term
VGB=VGS<0 NO PWR
VGB=VGS>VTH
→IDS>0
VGB=VGS
4TERM.





I_{DS} per $V_{GS} > V_{TH}$

V_{DS} piccole, $\frac{V_{DS}^2}{2}$ piccolissimo

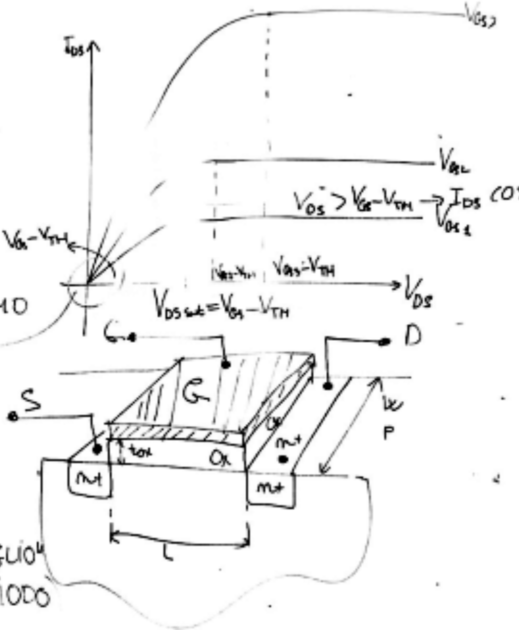
$I_{DS} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH}) V_{DS}$

$R_{CAN} = \frac{1}{\mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})}$

↓

$I_{DS} = \frac{V_{DS}}{R_{CAN}}$ (ZONA LIN.

è un "DETTAGLIO" della ZONA TRIODO



$V_{GS} > V_{TH}$

per una certa V_{GS}

$V_{DS} < V_{GS} - V_{TH} = V_{DS\,sat}$

$\rightarrow I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]$

AND. PARABOLICO

(ZONA TRIODO)

$\rho = \frac{1}{\sigma}, \sigma = q \mu_n n \uparrow$

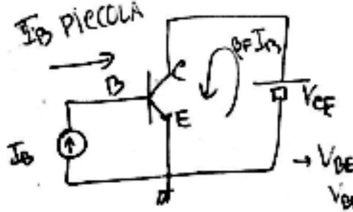
$V_{DS} > V_{GS} - V_{TH}$

$\rightarrow$ SATURAZIONE

$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$

DIPENDE da $V_{GS} > V_{TH}$

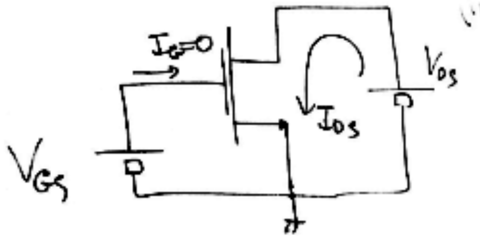
NON DIPENDE da V_{DS}



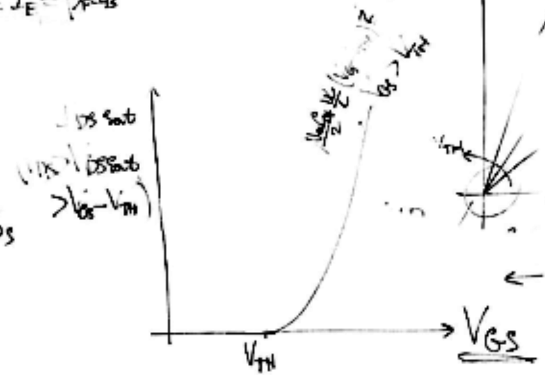
$I_C \cong I_E = \beta_F I_B$

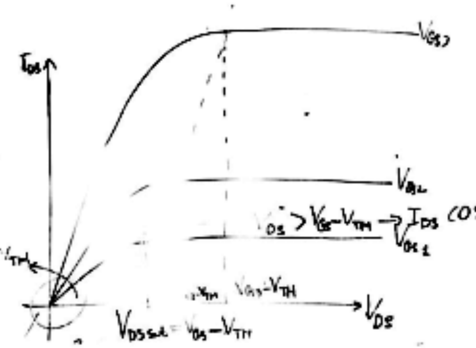
→ $V_{BE} > 0$

$V_{BE} \cong 0$



CAR. $I_{DS} = f(V_{DS}, V_{GS})$





SAT. $I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$

(NON dipende da V_{DS}, se $V_{DS} > V_{GS} - V_{TH} = V_{DSsat}$)

← TRANS-CAR. $I_{DS} = f(V_{GS})$

$V_{DS} > V_{DSsat}$

$V_{GS} > V_{TH}$

per una certa V_{GS}

$V_{DS} < V_{GS} - V_{TH} = V_{DSsat}$

→ $I_{DS} = \mu_n C_{ox} \frac{W}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]$

AND. PARABOLICO

(ZONA TRIODO)

$\rho = \frac{1}{\sigma}$, $\sigma = q \mu_n n$ ↑

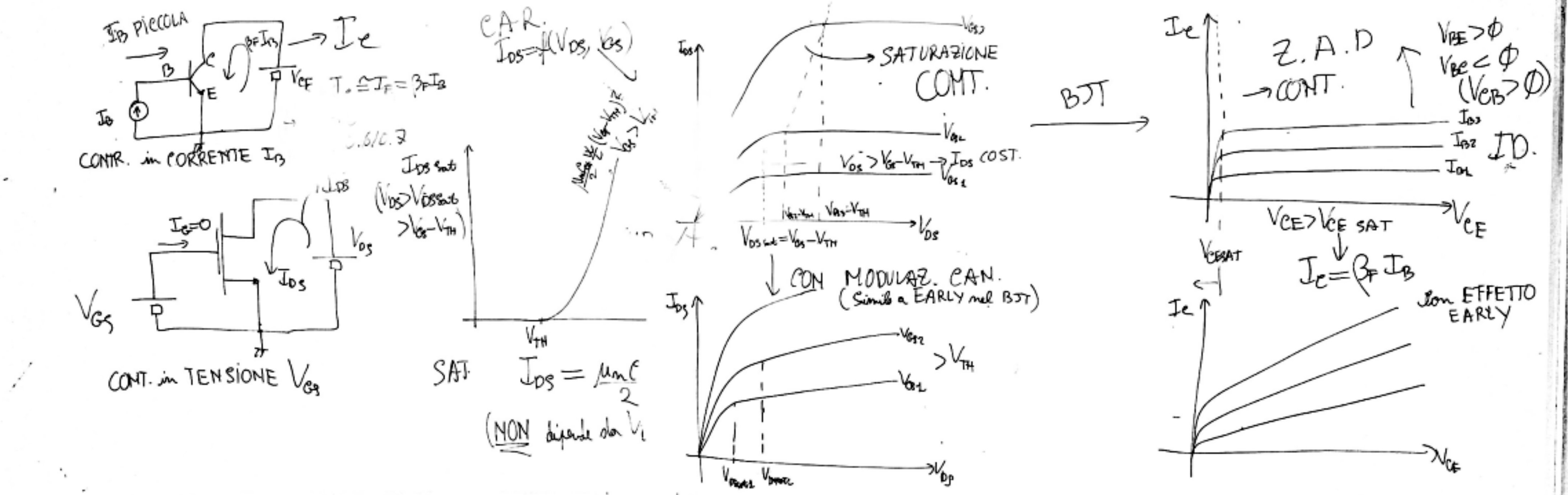
$V_{DS} > V_{GS} - V_{TH}$

→ SATURAZIONE

$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$

DIPENDE da $V_{GS} > V_{TH}$

NON DIPENDE da V_{DS}



IB PICCOLA
B
C
E
IB
βF IB
→ IC
VCE
IC ≅ IF = βF IB
CONTR. in CORRENTE IB
IG=0
IDS
VGS
VDS
CONT. in TENSIONE VGS
CAR.
IDS = f(VDS, VGS)
IDS sat
(VDS > VDSsat > VGS − VTH)
VTH
SAT. IDS = μnC/2
(NON dipende da V
IDS
VGS3
SATURAZIONE
CONT.
VGS2
VDS > VGS − VTH → IDS COST.
VGS1
VDS sat = VGS − VTH
VDS
CON MODULAZ. CAN.
(Simile a EARLY nel BJT)
VGS2
> VTH
VGS1
VDS
BJT
IC
Z.A.D
→ CONT.
VBE > 0
VBC < 0
(VCB > 0)
IB3
IB2
IB1
I.D.
VCE
VCE > VCE SAT
VCESAT
IC = βF IB
IC
Con EFFETTO EARLY
VCE