FET

Wednesday, October 23, 2019 7:58 AM

//Field Effect Transistor (Transistor de Efecto de campo)

- Es un dispositivo electrónico que funciona como una fuente de corriente controlada por voltaje

//Características del FET

- El dispositivo tiene una alta impedancia a la entrada
  ∴ Inmune a las variaciones de entrada del dispositivo
- Inmune a las variaciones de temperatura
- Son sensibles a las descargas electroestáticas
  ↳ Teoría Electroestática
  - Materiales que disipan cargas electroestáticas
  - Teoría del transporte de materiales electrónicos
  - Manejo de materiales en
    * centros de producción
    * centros de servicio
    * centros de distribución

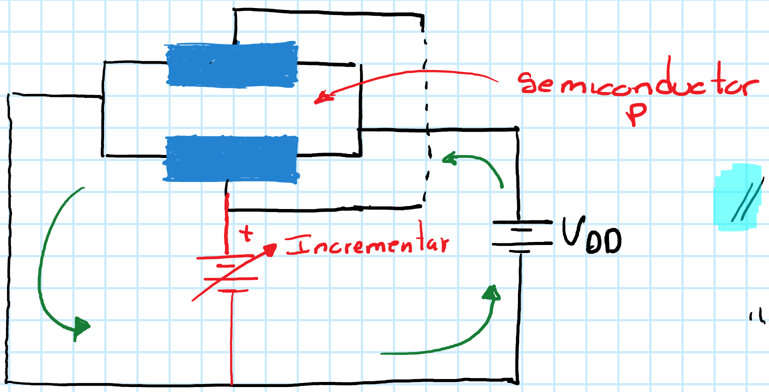
//Tipos de FET

- JFET $\triangleq$ Junction FET
- MOSFET $\triangleq$ Metal Oxide Semiconductor FET
  ↳ Circuitos Digitales
- Enhanced FET
- Depletion FET

• Depletion FET

• IGFET $\triangleq$ Isoleted Gate FET

▸ Principio de Operación (FET)



// La fuente de voltaje que controlará el "canal" reduciendo así la corriente

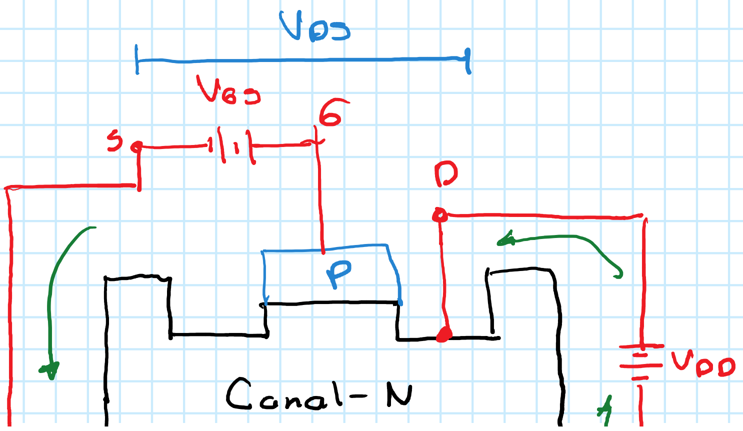
• Todos los FET son fuentes de corriente controladas por voltaje

• El Mosfet es un semiconductor de metal óxido

• Tienen 3 terminales:

① G - Gate (Base)
② D - Drain (Colector)
③ E - Emisor

• Esquema:

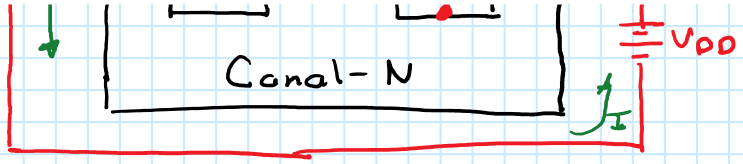


• $V_{pinchoff} \triangleq$ Voltaje Umbral

▸ Mientras que el $V_{GS} < V_{pinchoff}$

$\therefore I_D \neq 0$

▸ Cuando el ...

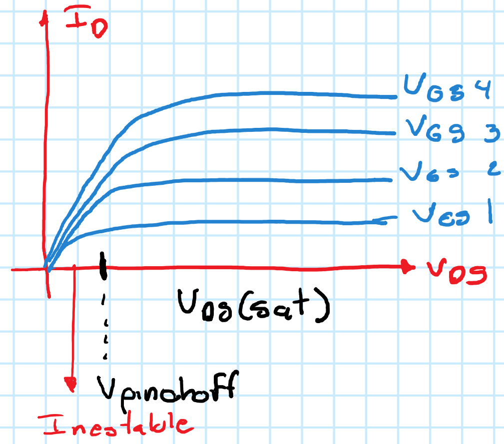


- Cuando el:

  $V_{GS} > V_{pinchoff}$

  $\therefore$ $I_D \triangleq$ Comienza flujo corriente.

- Gráfica



- La $I_D \triangleq$ Corriente de Drain no depende de V_{DS}, depende del V_{GS}

- La ecuación característica del MOSFET es:

  if $V_{GS} > V_{pinchoff}$

  $$I_D = K_n (V_{GS} - V_{pinchoff})^2 \quad \therefore \; I_{DS} \triangleq \text{Constante en } V_{DS}$$

  $K_n \triangleq$ Valor dado por el fabricante $= \dfrac{W \mu_n C_{ox}}{2L}$

  $W \triangleq$ Ancho del dispositivo

  $\mu_n \triangleq$ Movilidad electrón

  $C_{ox} \triangleq$ Capacitor dispositivo

  $L \triangleq$ Longitud del canal

NOTA:

$K_n \triangleq$ Depende del fabricante

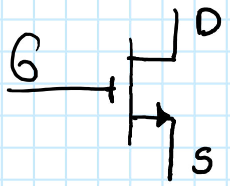
$V_{pinchoff} \triangleq$ Threshold

$\Big\}$ Datos Fabricante

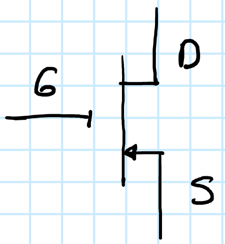
• Curva Característica del MOSFET

• If $V_{TH} \triangleq$ Empieza en el origen

// Simbología MOSFET



CANAL - N

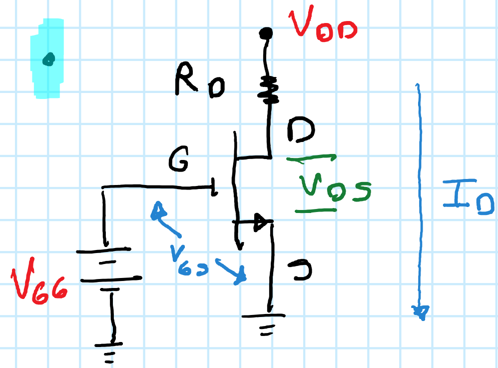


CANAL - P

$$I_D = I_{DDmax}\left(1 - \frac{V_{GS}}{V_{GSOFF}}\right)^2$$

$I_D \rightarrow$ EXTRA

•



$$\boxed{I_D} = k_n(V_{GS} - V_{TH})^2$$

$$\boxed{V_{DD}} = I_D R_D + V_{DS}$$

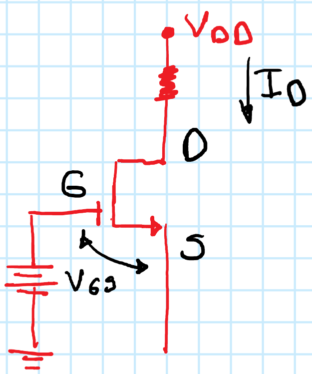
$\rightarrow$ Ecuación Carga

$$I_D = -\frac{V_{DS}}{R_D} + \frac{V_{DD}}{R_D}$$

• El V_{DS}, I_{DQ} y V_{DSQ} $\leftarrow$ DATOS A CALCULAR

Características

Wednesday, October 30, 2019 7:31 AM



$V_T \triangleq$ Voltaje de treshold (Umbral)

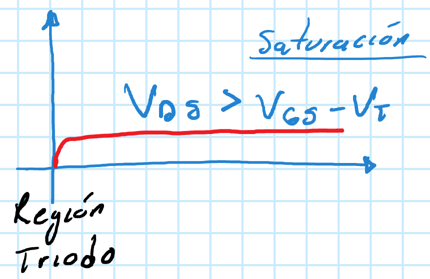
$K \triangleq$ Dado por fabricante

- Conduce cuando

$$V_{GS} \geq V_T$$

- El MOSFET está en una región llamada saturación cuando

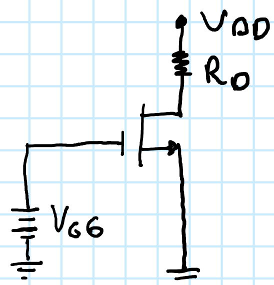
$$V_{DS} > V_{GS} - V_T$$



- El MOSFET a través del $V_{GS} \rightarrow I_{DQ}$, V_{DSQ}

$$I_D = K(V_{GS} - V_T)^2$$

① Ejemplo "Circuito MOSFET"



DATOS

$V_{GG} = 6\ V$

$R_D = 1\ K\Omega$

$V_T = 1.5\ V$

$K = 7.5\ \frac{mA}{V^2}$

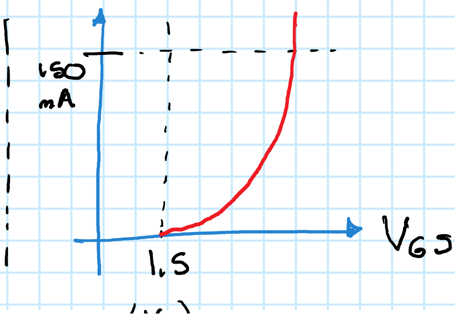
$V_{DD} = 20\ [V]$

- $V_{GG} = V_{GS}$

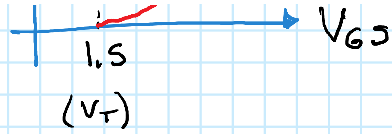
- $I_D = K(V_{GS} - V_T)^2$

$= 7.5 \times 10^{-3}(6 - 1.5)^2$

$= .151875\ [A]$



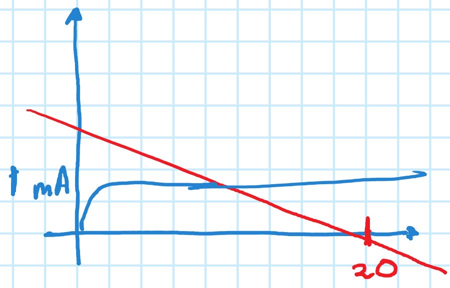
$= .151875\ [A]$



- $V_{DD} = I_{DQ} R_D + V_{DS}$;

$$V_{DS} = V_{DD} - I_{DQ} R_D$$
$$= 20 - (.150)(1000)$$
$$= \underbrace{-130\ [V]}_{\text{(Esta saturado)}}$$

Modelo $I_D = -\dfrac{V_{DS}}{R_D} + \dfrac{V_{DD}}{R_D}$



EXTRA

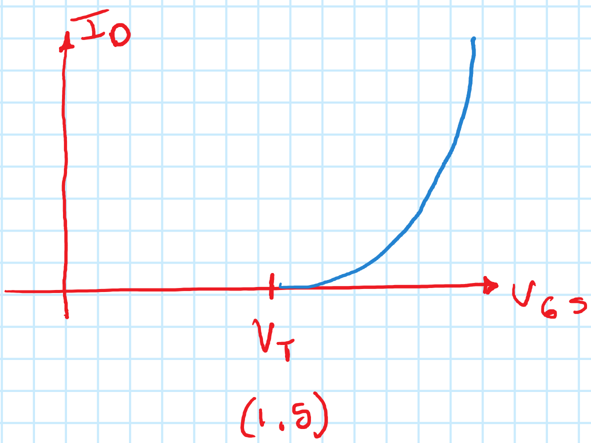
Arbitrario *

$$V_{GS} = V_T + \sqrt{\frac{I_D}{K}} = \sqrt{\frac{10\times10^{-3}}{7.5\times10^{-3}}} + 1.5 = 2.65\ [V]$$

$I_D = 10\ [mA]$

$V_{DSQ} = 10\ [V]$

* Mitad del máximo



- $I_D = K(V_{GS} - V_T)^2$

if $V_{GS} < V_T \therefore I_D = 0$

- Máxima Corriente

$$I_D = -\frac{V_{DS}}{R_D} + \frac{V_{DD}}{R_D}$$

$$\frac{V_{DD}}{R_D} = \frac{20}{1000} = .020\ [A]$$

Ecuación Característica

Monday, November 4, 2019 7:35 AM

• Ecuación Características

- $I_D = K_n (V_{GS} - V_{TH})^2$

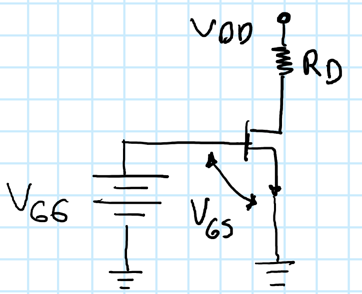
- El V_{TH} → Lo obtenemos de la hoja de datos característicos

- Para obtener K → gfs → Valor Dado a una corriente dada

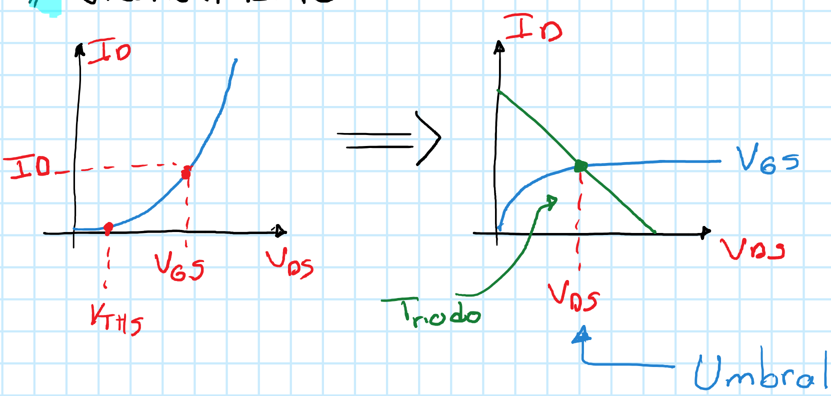
$g_m = \frac{I_d}{V_{gs}}$

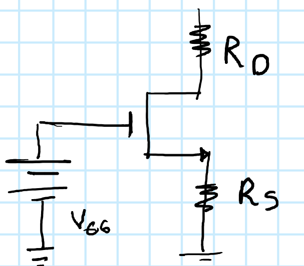
$$K_n = \frac{gfs^2}{(4)(I_D)} = \frac{100 \times 10^{-6}\ [mOhs]}{(4)(200 \times 10^{-3})} = 12.5 \times 10^{-9}$$

$I_D = 200\ [mA]$



// Gráficamente





$V_{GG} = V_{GS} + I_D R_S$; $V_{GS} = V_{GG} - I_D R_S$

// Ecuación Característica

$$I_D = K_n (V_{GS} - V_{TH})^2$$

$$= K_n \left[(V_{GG} - I_D R_S) - V_{TH} \right]^2$$

$$= K \left[(V \ldots - I \ldots)^2 + V^2 \right.$$

$$= K_n\left[(V_{GG} - I_D R_S)^2 + V_{TH}^2 - 2(V_{GG} - I_D R_S)V_{TH}\right]$$

$$\therefore \frac{I_D}{K_n} = K_n\left[V_{GG}^2 - 2 I_D R_S V_{GG} + I_D R_S^2 + V_{TH}^2 - 2 V_{GG} V_{TH} + 2 I_D R_S V_{TH}\right]$$

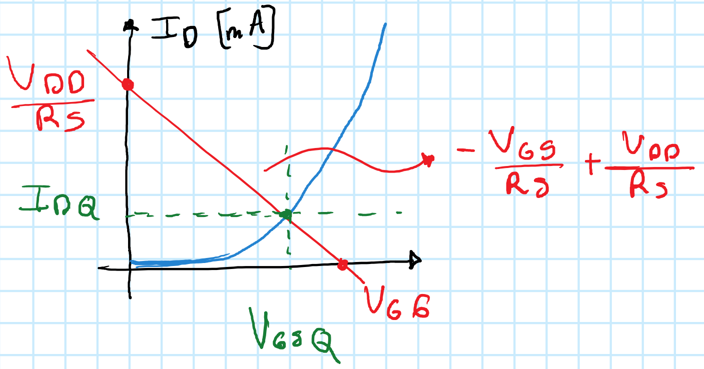
$$0 = (I_D R_S)^2 - 2R_S I_D (V_{GG} + V_{TH}) - \frac{I_D}{K} + (V_{GG} - V_{TH})^2$$

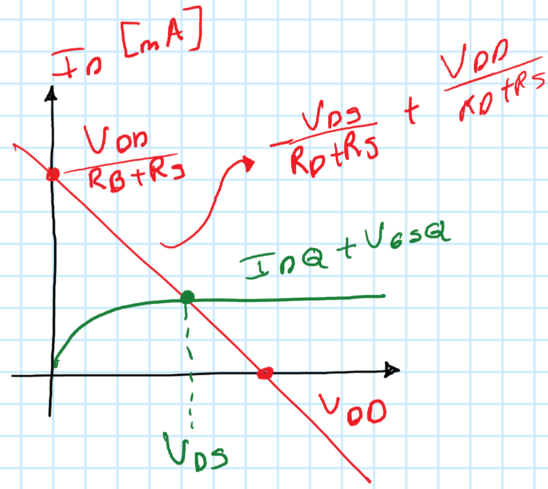
$A = R_S^2$ $\qquad B = -\left[2R_S(V_{GG} - V_{TH}) + \frac{1}{K_n}\right]$

$C = (V_{GG} - V_{TH})^2$

Forma: $0 = Ax^2 + Bx + C$

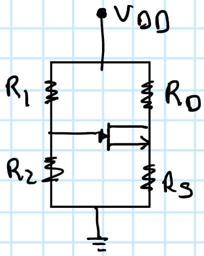
// Graficamente



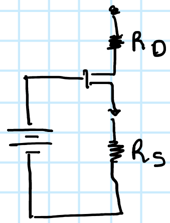


Ejercicio

miércoles, 6 de noviembre de 2019 7:31



$$V_{GG} = \frac{V_{DD} R_2}{R_1 + R_2}$$



$$V_{GG} = V_{GS} + I_D R_S$$

$$V_{GS} = V_{GG} - I_D R_S$$

// Calcular el valor de K (A partir hoja datos)

V_T, gfs | $K = \dfrac{gfs^2}{I_D}$ ← Hoja de datos

if tenemos el valor de k_n

$$I_d = k_n (V_{GS} - V_{TH})^2 \; ; \quad I_d = k_n \left([V_{GG} - I_D R_S] - V_{TH} \right)^2$$

$$A = R_S^2 \qquad C = (V_{GG} - V_{TH})^2$$

$$B = - \left[2 R_S (V_{GG} - V_{TH}) + \frac{1}{k_n} \right]$$

$$\therefore \; I_D = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

▶ I_{D1}, I_{D2}

$$V_{GS1} = V_{GG} - I_{D1} R_S$$

$$V_{GS2} = V_{GG} - I_{D2} R_S$$

$V_{GS} > V_{TH}$

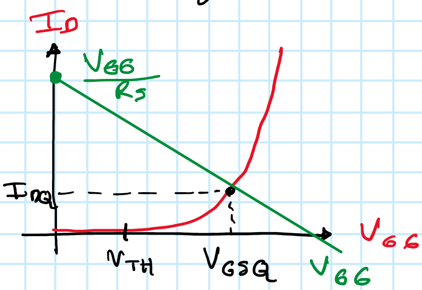
// Calculamos V_{DS}

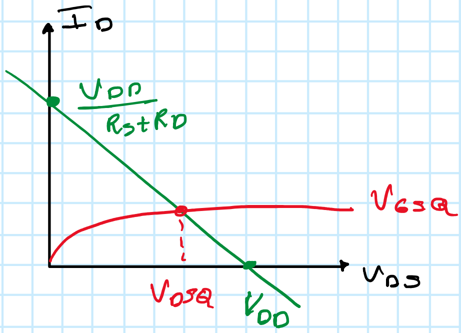
$$V_{DSQ} = V_{DD} - I_{DQ}(R_D + R_S)$$

// Saturación del MOSFET

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

// Apartado gráfico





// Para obtener V_{GS} gráfico

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

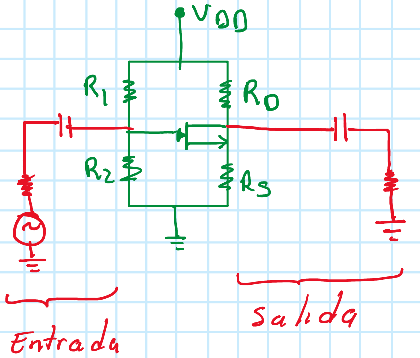
// Para obtener V_{GS} gráfico

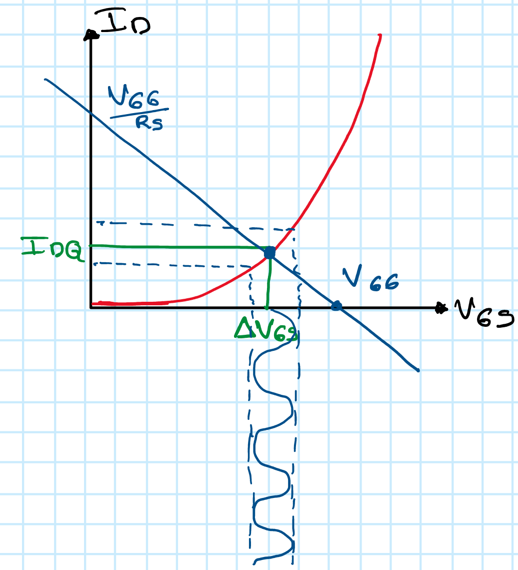
$$V_{GG} = V_{GS} + I_D R_S$$

$$\to I_D = -\frac{V_{GS}}{R_S} + \frac{V_{GG}}{R_S}$$

$$V_{DS} = V_{DD} - I_D(R_D + R_S)$$

$$I_D = -\frac{V_{DS}}{R_D + R_S} + \frac{V_{DD}}{R_D + R_S}$$





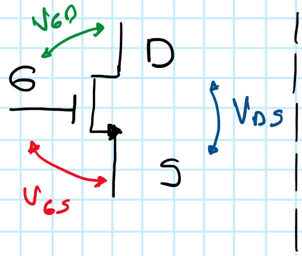
$$\frac{\Delta I_d}{\Delta V_{GS}} = \frac{dI_d}{dV_{GS}} = \underbrace{2K_n(V_{GS} - V_{TH})}_{gm}$$

$gm \triangleq$ Transconductancia del MOSFET

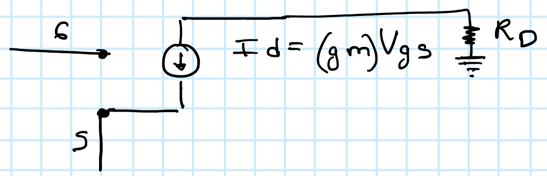
$$\to I_d = K_n(V_{GS} - V_{TH})^2$$

$$I_d = x V_{gs} \quad ; \quad I_d = (gm) V_{gs}$$

// Modelo con señal pequeña



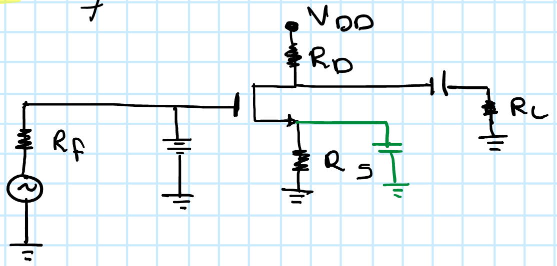
$$V_{in} = V_{GS}$$



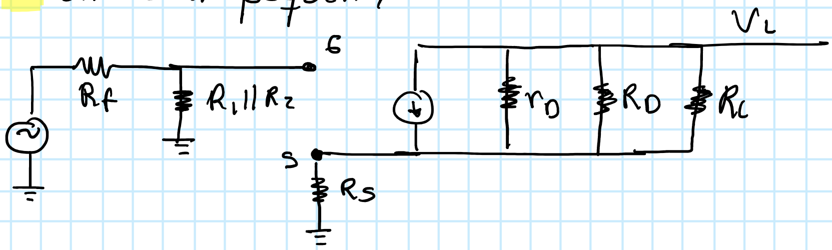
$$\left.\begin{aligned} V_{in} &= V_{GS} \\ V_o &= I_d R_D \\ V_o &= (gm) V_{gs} R_D \end{aligned}\right\} \quad \frac{V_o}{V_{in}} = \frac{\cancel{V_{gs}}(gm) R_D}{\cancel{V_{gs}}}$$

$$\therefore \frac{V_o}{V_{in}} = (gm) R_D$$

// Esquema



// En señal pequeña



$$V_{in} = V_{GS} + i_D R_S$$

$$V_L = (\underbrace{r_D \| R_D}_{R_D} \| R_L)\, i_D$$

$$\frac{V_L}{V_{in}} = \frac{(gm)V_{GS}(R_D \| R_L)}{V_{GS} + gm(V_{GS}R_S)} = \frac{V_{GS}(gm)(R_D \| R_L)}{V_{GS}(1 + gm R_S)}$$

$$\frac{V_L}{V_{in}} = \frac{(R_D \| R_L)}{\frac{1}{gm} + \cancel{R_S}}$$ Capacitor ; $$\frac{V_L}{V_{in}} = gm(R_D \| R_L)$$

NOTA!

$$gm = 2K_n(V_{GS} - V_{TH})$$

$$I_d = K_n(V_{GS} - V_{TH})^2 \; ; \; \frac{I_d}{K_n} = (V_{GS} - V_{TH})^2$$

$$V_{GS} - V_{TH} = \sqrt{\frac{I_d}{K_n}}$$

$$gm = 2K_n\left(\sqrt{\frac{I_d}{K_n}}\right) \; ; \; gm^2 = 4K_n^2\left(\frac{I_d}{K_n}\right)$$

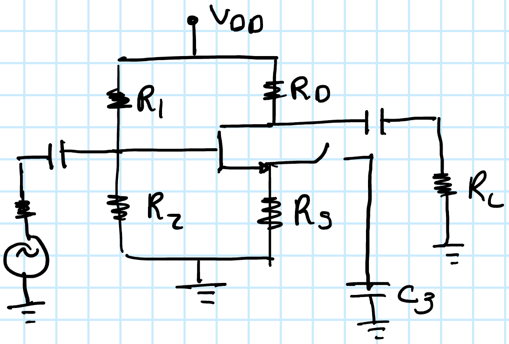
$$gm = 4K_n I_d \; ; \; K_n = \frac{gm^2}{4I_D}$$

$$gm = gfs$$

Ejercicio

lunes, 11 de noviembre de 2019 7:54

▸ Ejercicio Mosfet



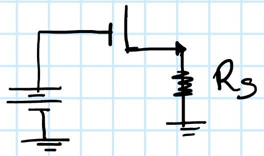
Valores

$V_{DD} = 30\ V$ | $R_S = 250\ \Omega$
$R_1 = 27\ k\Omega$ | $R_L = 1K$
$R_2 = 3\ k\Omega$ | $R_f = 500\ \Omega$
$R_D = 1150\ \Omega$ | $V_T = 4\ V$
 | $K_n = 0.125 \left[\frac{A}{V^2}\right]$

a) I_{DQ}, V_{GSQ}, V_{DSQ}

$$V_{GG} = \frac{(V_{DD})(R_2)}{V_{DD}} = \frac{(30)(3)}{(30)} = \cancel{3}$$

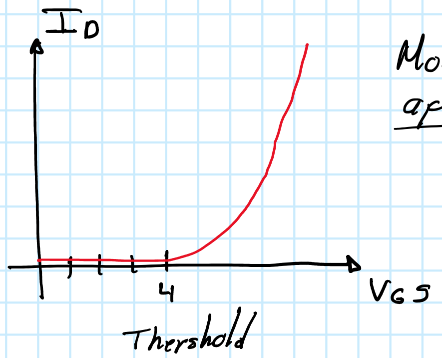
→ En DC



$$V_{GG} = V_{GS} + I_D R_S$$

$$\therefore I_D = -\frac{V_{GS}}{R_S} + \frac{V_{GG}}{R_S}$$

• Solución gráfica



Mosfet está apagado //

if $R_1 = 21\ k$ y $R_2 = 9\ K$ y $V_{GG} = 9$ // Cambiar valores

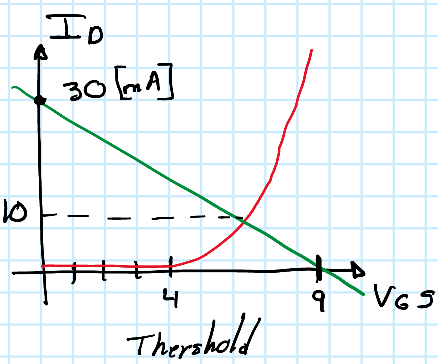
• $V_{GG} = \frac{(30)(9000)}{21000 + 9000}$

$= 9$

• $I_D = -\frac{V_{GS}}{R_S} + \frac{V_{GG}}{R_S}$

if $V_{GS} = 0$ | if $V_{GG} = 0$

$\therefore \frac{V_{GG}}{\cancel{R_S}}$ 250 | $\therefore \frac{V_{GS}}{R_S}$



$A = R_S^2$

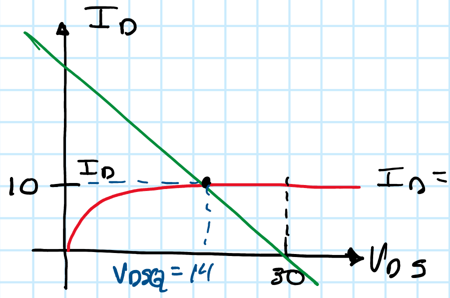
$B = -\left[2R_S(K_n - V_{GG}) + \frac{1}{m}\right]$

• $I_D = \frac{9}{...} = 30$ [mA]

- $I_D = \frac{9}{250} = 30\ [mA]$

$B = -\left[2R_S(K_n - V_{GG}) + \frac{1}{m}\right]$

$C = (V_{TH} - V_{GG})^2$



$I_D = 10\,mA$ @ $V_{GSQ} = 7\,V$

$V_{DS} = V_{DD} - I_D(R_D + R_S)$

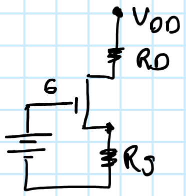
$I_D = -\frac{V_{DS}}{R_D + R_S} + \frac{V_{DD}}{R_D + R_S}$

$I_{Dmax} = \frac{30}{1400} = 21.42\ [mA]$

b) Calcular g_m

c) $\frac{V_L}{V_f}$

a) I_{DQ}, V_{GSQ}
V_{DSQ}



$V_{GG} = 9V$

$V_{GG} = V_{GS} + I_D R_S$; $V_{GS} = V_{GG} - I_D R_S$

$I_D = K_n(V_{GS} - V_{TH})^2$

$I_D = k_n([V_{GG} - I_D R_S]^2 - 2(V_{GG} - I_D R_S)V_{TH} + V_{TH}^2)$

Magia Algebraica ...

$0 = I_D^2 R_S^2 - 2V_{GG} I_D R_S + 2V_{TH} I_D R_S + V_{TH}^2 - 2V_{GG}V_{TH} + V_{GG}^2 - \frac{I_D}{k_n}$

// Reducción

$A = R_S^2$

$B = -2V_{GG}R_S + 2V_{TH}R_S - \frac{1}{k_n}$

$C = (V_{GG} - V_{TH})^2$
$= V_{GG}^2 - 2V_{GG}V_{TH} + V_{TH}^2$

// Valore del circuito

- $V_{DD} = 30$ · $R_1 = 21K\Omega$ $R_2 = 9\ K\Omega$
- $R_D = 1150\Omega$ · $R_S = 250\Omega$ $R_L =$

$V_{TH} = 4\ V$ $V_{GG} = 9$

$k_n = .125\ \frac{A}{V^2}$

$A = (250)^2$

$A = (250)^2$

$B = -2(4)(250) + (2)(4)(250)\left(-\frac{1}{.125}\right) = -2508$

$C = 25$

$$I_D = \frac{-B \pm \sqrt{(-B)^2 - 4AC}}{2A} \quad \begin{cases} I_{D_1} = 21.6 \text{ [mA]} \\ I_{D_2} = 18.4 \text{ [mA]} \end{cases}$$

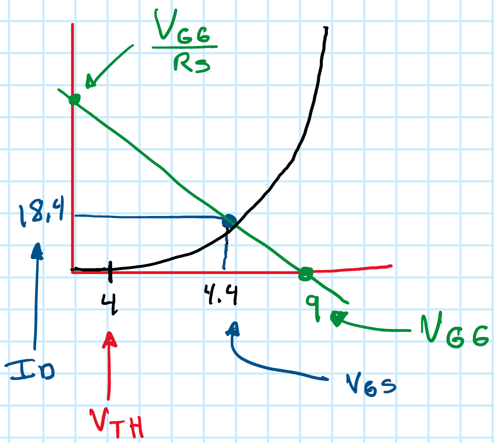
NOTA: Tomar la corriente positivo o la más pequeña

$V_{GS} = V_{GG} - I_D R_S = 9 - (18.4 \times 10^{-3})(250) = 4.4$ [V]

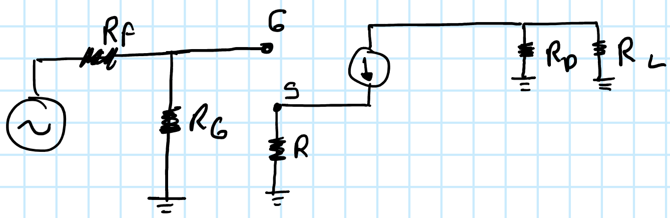
Is $V_{GS} > V_{TH}$

$\therefore V_{DS} = V_{DD} - I_D(R_D + R_S)$

$= 30 - (18.4 \times 10^{-3})(1400) = 4.24$ [V]



b) Calcular gm



$gm = Km(V_{GSQ} - V_{TH})$

$= .125(4.4 - 4) =$

$= 0.05$ [mOhs]

$R_{in} = R_G = R_1 // R_2$

c) $\frac{V_c}{V_f}$

SIN CAPACI

$A = (R_D // R_L)$

(1000)(1150)

V_f

SIN CAPACI

$$A_v = \frac{(R_D \parallel R_L)}{\frac{1}{g_m} + R_L} = \frac{\frac{(1000)(1150)}{1000+1150}}{\frac{1}{.05} + 1000} = 1.98$$

sólo una parte

CON CAPACITOR

$$A_v = g_m (R_D \parallel R_L) = (.05)(534.88) = 26.74$$

$$\frac{V_L}{V_f} = \left(\frac{R_{in}}{R_f + R_{in}}\right)(A_v) = \left(\frac{534.88}{500 + 534.88}\right)(26.74) = 13.68$$

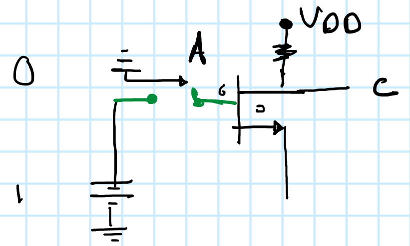
con capacitor

Total

MOSFETas switch

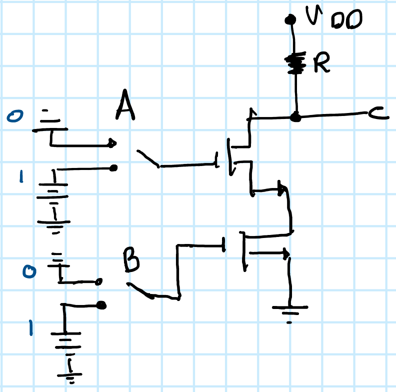
viernes, 15 de noviembre de 2019 7:32

Circuito Inversor

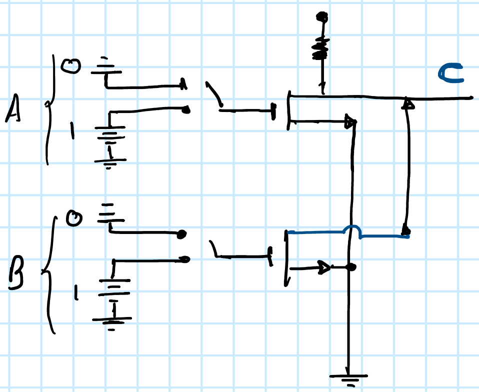


A	C
0	1
1	0

Compuerta NAND

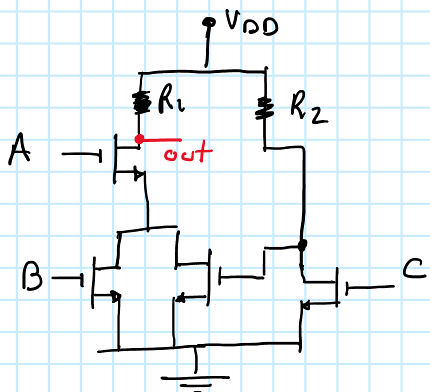


B	A	C
0	0	1
1	0	1
0	1	1
1	1	0



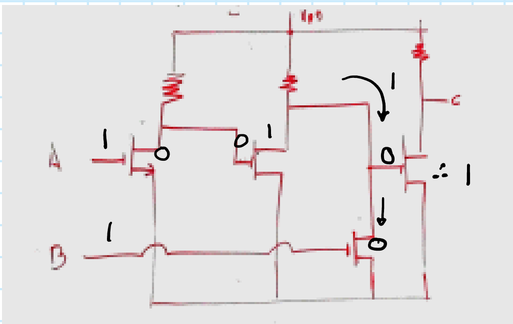
Compuerta NOR

B	A	C
0	0	1
1	0	0
0	1	0
1	1	0



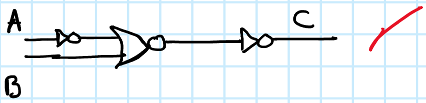
C	B	A	OUT
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

TAREA



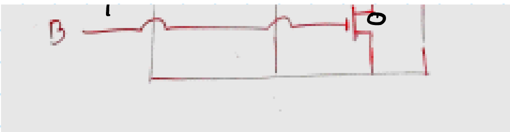
// A que circuito lógico corresponde

1



B	A	Ā	NOR	Result
0	0	1	0	1
0	1	0	1	0
1	0	1	0	1
1	1	0	0	1

NOR	
0 0	1
0 1	0
1 0	0
1 1	0

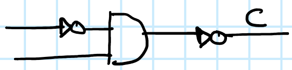


0	1	0	1	0
1	0	1	0	1
1	1	0	0	1

1	0	0
1	1	0

B	A	C
0	0	1
0	1	0
1	0	1
1	1	1

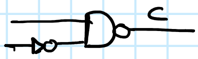
② A B



B	$\bar{A}$	AND	Result
0	1	0	1
0	0	0	1
1	1	1	0
1	0	0	1

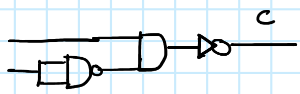
AND		
0	0	0
0	1	0
1	0	0
1	1	1

③



B	A	$\bar{B}$	NAND
0	0	1	1
0	1	1	0
1	0	0	1
1	1	0	1

④



B	A	NOR		AND	Result
0	0	1	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	1	0	1	0	1