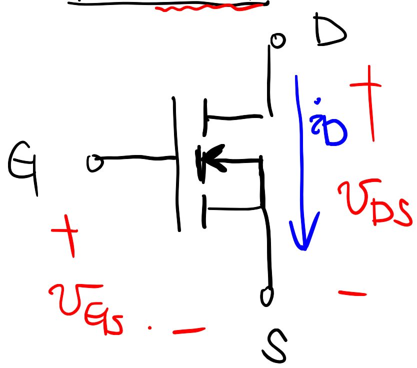
L23 – Power Electronics: Switching Amplifier

- MOSFET.



· Gate is AC coupled. : $\bar{i}_G = 0$

· Arrow : p-type body → n-channel.

· Body-source short : "Body diode"

· Dot - enhancement mode (normally off)

Terminal vars

· Voltages : v_{GS}, v_{DS}

· Current : i_G, i_D, i_S ($i_G = 0$ at DC $\Rightarrow$ $i_D = i_S$)

Terminal Relations

① Cutoff. ($v_{GS} < V_{th}$).

$i_D = 0$

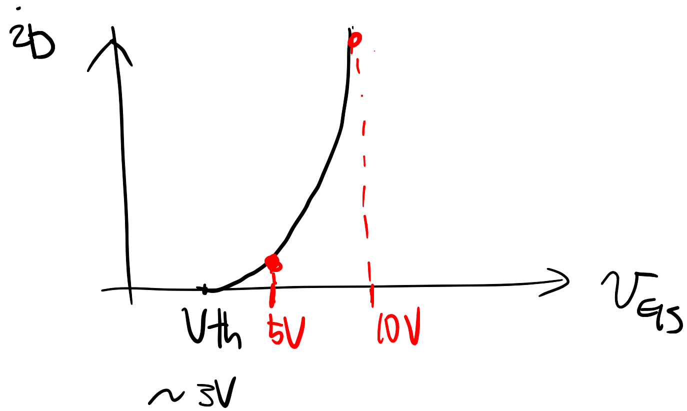
$v_{DS} > v_{GS} - V_{th} > 0.$

② Saturation. ($v_{GS} > V_{th}$, $v_{DS} > v_{GS} - V_{th}$).

$$i_D = \frac{1}{2} K (v_{GS} - V_{th})^2 . \longrightarrow g_m \triangleq \frac{d i_D}{d v_{GS}} = K (v_{GS} - V_{th})$$

· VCCS

· i_D . insensitive to v_{DS} . → BJT in "Active region"



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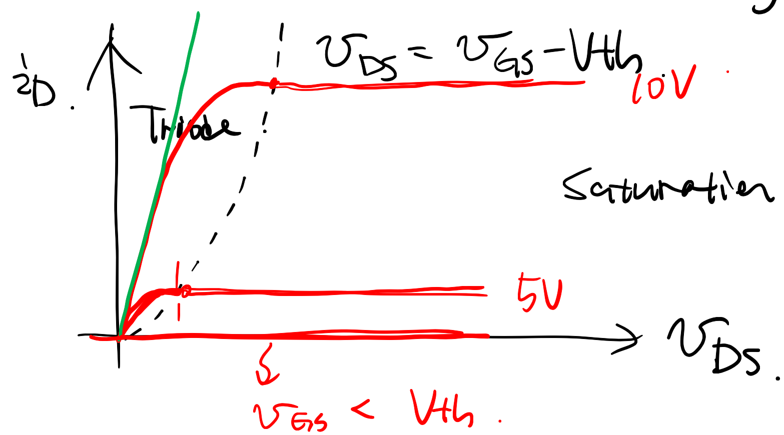

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③ Triode . ($v_{GS} > V_{th}$, $v_{DS} < v_{GS} - V_{th}$)

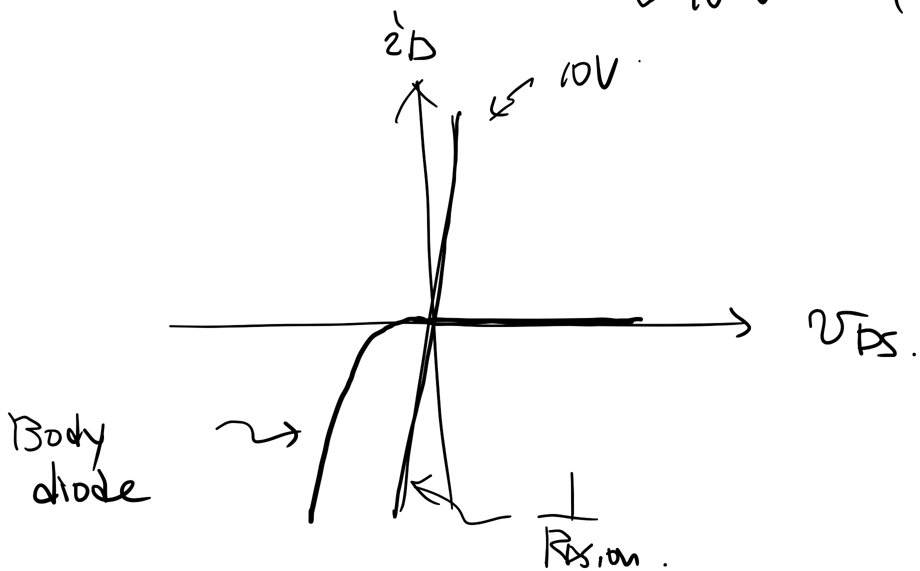
$$i_D = K \left\{ (v_{GS} - V_{th}) v_{DS} - \cancel{\frac{1}{2} v_{DS}^2} \right\}.$$

$$\simeq \underbrace{K (v_{GS} - V_{th})}_{\triangleq \frac{1}{R_{DS,on}}} v_{DS}.$$

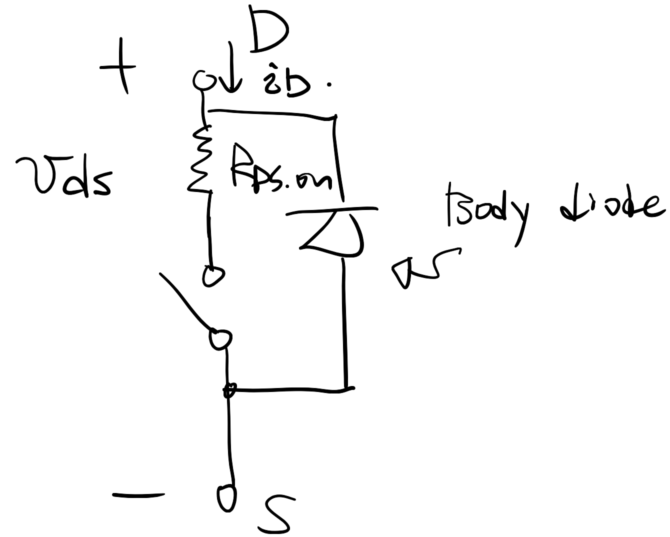
$$R_{DS,on} = \frac{1}{K (v_{GS} - V_{th})}. \downarrow$$

○ MOSFET as a power switch.

Suppose $v_{GS} = \begin{cases} 0 & \text{(switch off)} \\ 10\,V & \text{(switch on)} \end{cases}$



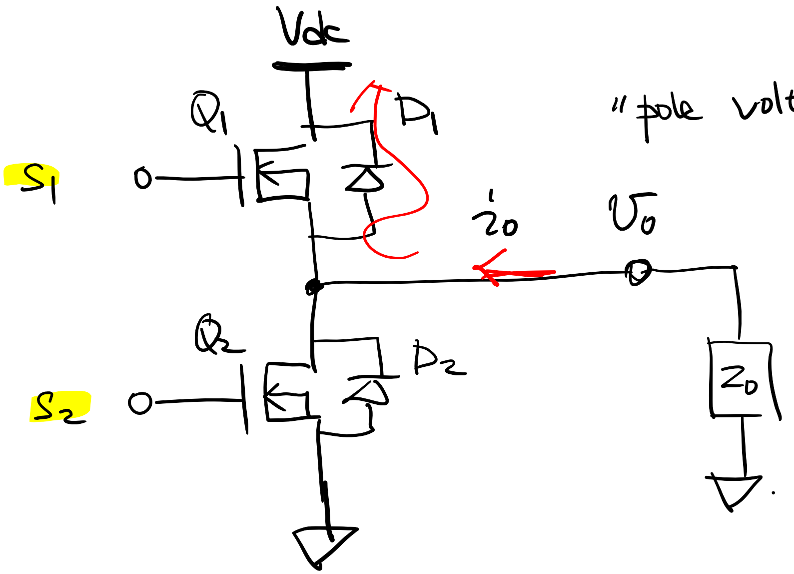
$\Rightarrow$



· Block $+v$.

· Conduct $\pm i$ //

- Half-bridge Stage (Totem pole circuit).



"pole voltage"

- Unipolar $(+v_o)$. / two-quadrant $(\pm i_o)$.

- State table.

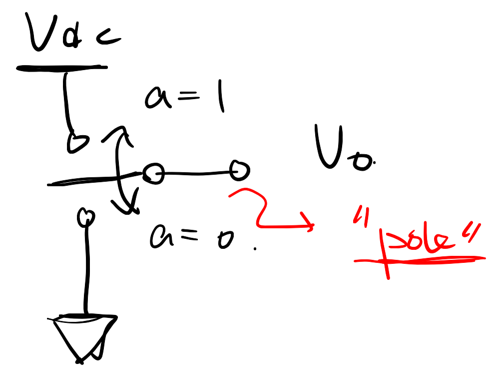
k	S_1	S_2	v_o	Conduction.
0	0	0	0 / Vdc	D_2 $(i_o>0)$ / D_1 $(i_o<0)$.
1	1	0	Vdc	Q1
2	0	1	0	Q2.
3.	1	1	X	Shoot through.

- $k=1 \longleftrightarrow k=2$. "Complementary Switching"

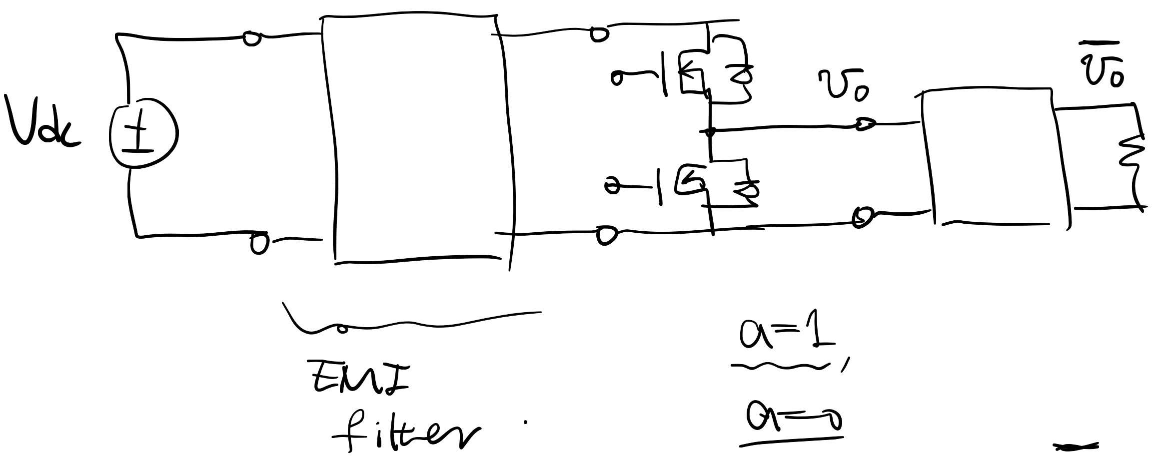
- Never use $k=3$ "Shoot through"
- ✓ $\boxed{\text{Insert } k=0}$ between $k=1 \leftrightarrow k=2$. "Dead time"

- State var.

"a". $a = S_1 = \bar{S}_2 \Rightarrow \begin{cases} a=0: & v_o = 0. \\ a=1: & v_o = V_{dc} \end{cases}$



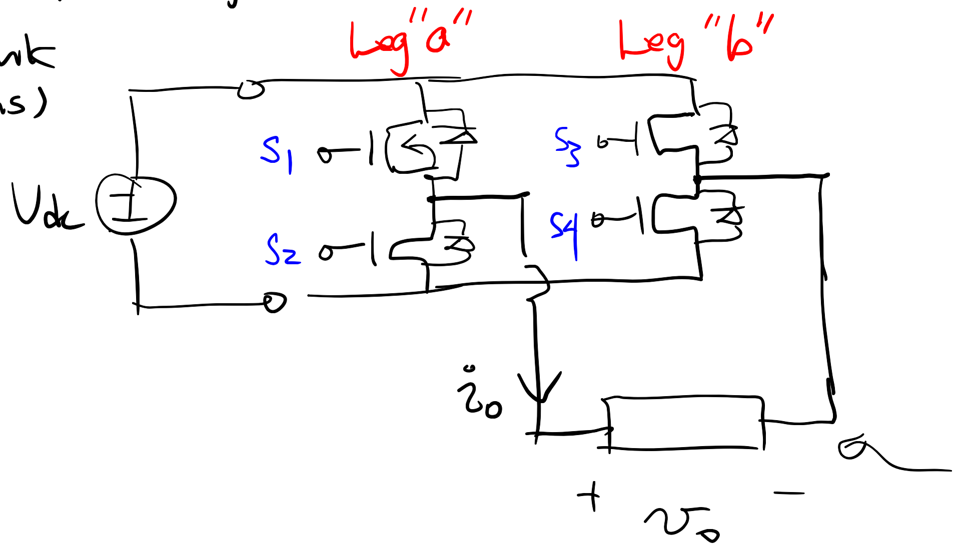
- Sync. Buck Conv.



$$\bar{v} = \frac{1}{T}\int_T v_o \, dt = D \cdot V_{dc}$$

- H-bridge (dc / ac).

DC Link (Bus)



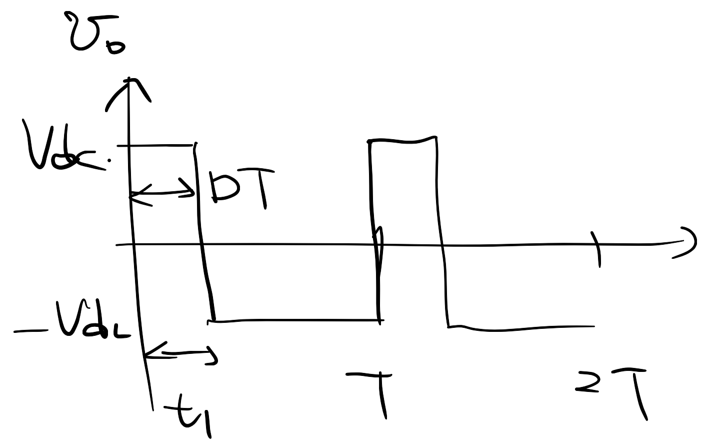
"Bridge"

"Four quad"

$\pm v_o$, $\pm i_o$.

- State table.

	n	a	b	v_o
	0	0	0	0
$V_1=[1\ 0]^T$	1	1	0	V_{dc}
	2	0	1	$-V_{dc}$
	3	1	1	0



- Duty Ratio Control. $D \triangleq \dfrac{t_1}{T}$.

$$\bar{v}_o = \frac{1}{T} V_{dc}\left(DT + (D-1)T\right) = (2D-1)V_{dc}.$$

$D = 0.5 \rightarrow \underline{\bar{v}_0 = 0}$