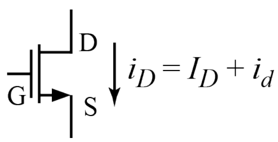
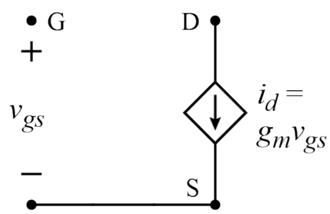
TOOL: AC Model of enhancement-mode NMOS FET with channel modulation.

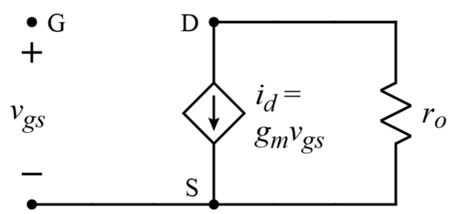
Transconductance parameter	k_n	A/V^2	$k_n = \sqrt{\mu_n C_{ox} \dfrac{W}{L}}$
Threshold	V_{TH}	V	
Channel modulation	λ	/V	
Early voltage	V_A	/V	
Channel modulation R	r_o	Ω	$r_o = \dfrac{1}{\lambda I_D} = \dfrac{V_A}{I_D}$
Over-voltage	V_{OV}	V	$V_{OV} = V_{GS} - V_{TH}$
DC Drain current	I_D	A	
AC drain current	i_d	A	
AC transconductance	g_m	A/V	



FET



AC model



AC model with channel modulation

MODEL: Without channel modulation: $I_D = \dfrac{k_n}{2}(V_{GS} - V_{TH})^2$

$i_d = g_m v_{gs}$

$\boxed{g_m = k_n(V_{GS} - V_{TH})}$ $\boxed{g_m = \dfrac{2I_D}{V_{GS} - V_{TH}}}$ $\boxed{g_m = \sqrt{2\mu_n C_{ox} \dfrac{W}{L} I_D}}$

$r_o = \infty\,\Omega$ (omitted from schematic)

With channel modulation: $I_{Dmod} = \dfrac{k_n}{2}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$

$i_{dmod} = g_m v_{gs} + v_{ds}/r_o$

$g_m = \dfrac{dI_{Dmod}}{dV_{GS}}$ $g_m = k_n(V_{GS} - V_{TH})(1 + \lambda V_{DS})$ $g_m = \dfrac{2I_{modD}}{V_{GS} - V_{TH}}$

$r_o = \dfrac{1}{\frac{dI_{Dmod}}{dV_{DS}}} = \dfrac{1}{\lambda I_{Dmod}} = \dfrac{V_A}{I_{Dmod}}$ where V_A is from data sheet

REF: [1] Adel S. Sedra and Kenneth C. Smith, *Microelectronic Circuits, 5th Ed.,* New York, NY: Oxford University Press, 2004.

[2] Behzad Razavi, *Fundamentals of Microelectronics with Robotics and Bioengineering Applications, 3rd Ed., Enhanced eText,* New York, NY: Wiley, 2021. ISBN: 9781119694397

[3] Becker (https://electronics.stackexchange.com/users/309451/becker), Does channel length modulation take effect in triode region of MOSFET?, URL (version: 2024-10-09): https://electronics.stackexchange.com/q/727466

[4] Hearth (https://electronics.stackexchange.com/users/57556/hearth), Does channel length modulation take effect in triode region of MOSFET?, URL (version: 2024-10-09): https://electronics.stackexchange.com/q/727468