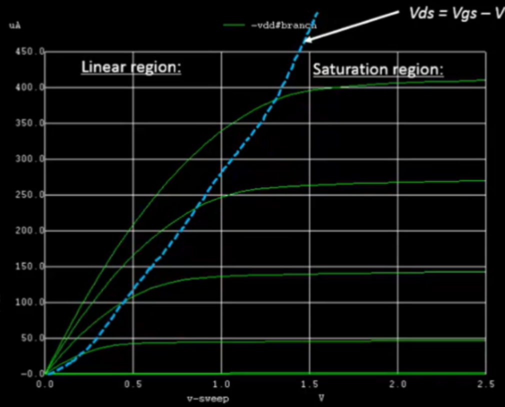
SPICE waveform : W=1.8u, L=1.2u device (W/L = 1.5)



Linear region:

$Id = kn \, . \, [(Vgs - Vt)Vds - \frac{Vds^2}{2}$

Saturation region:

$Id = \frac{Kn'}{2} \, . \, \frac{W}{L} \, . \, (Vgs - Vt)^2 \, [1 + \lambda \, Vds]$

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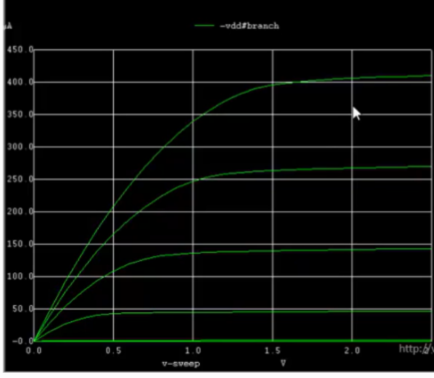
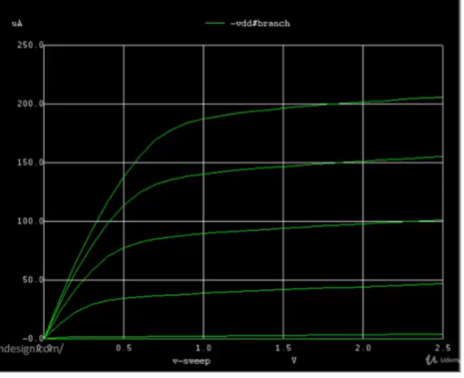
Observation 1:

W=1.8u, L=1.2u device



W=0.375u, L=0.25u device



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Observation 1:

Saturation region:

$Id = \frac{Kn'}{2} \, . \, \frac{W}{L} \, . \, (Vgs - Vt)^2 \, [1 + \lambda \, Vds]$

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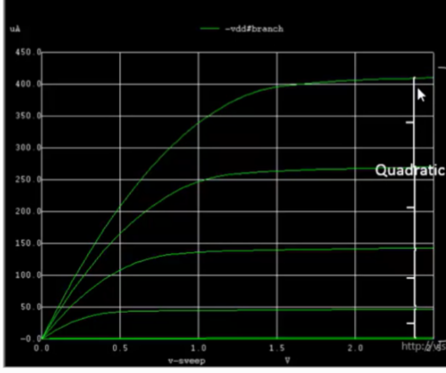
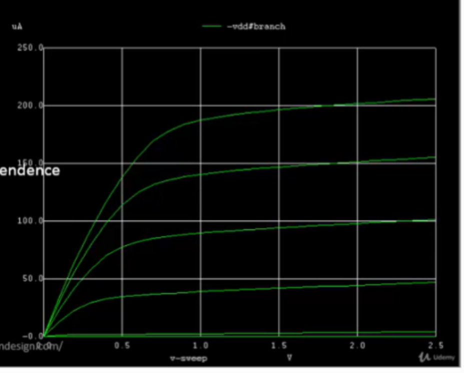


W=0.375u, L=0.25u device



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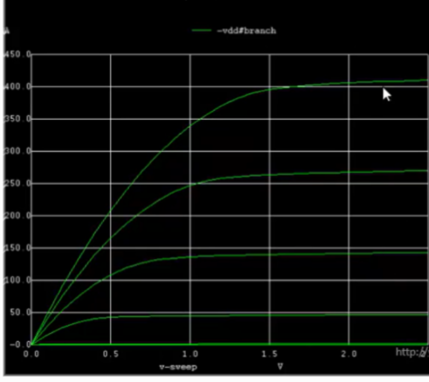
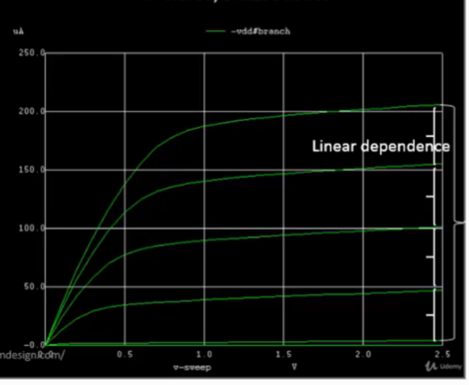
Observation 1:

Velocity Saturation Effect

W=1.8u, L=1.2u device



W=0.375u, L=0.25u device



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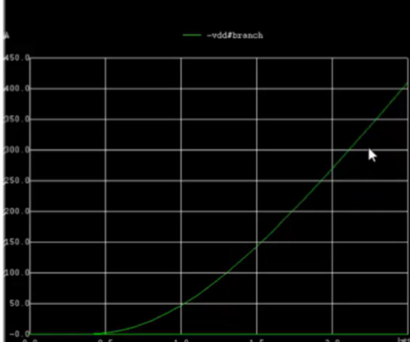
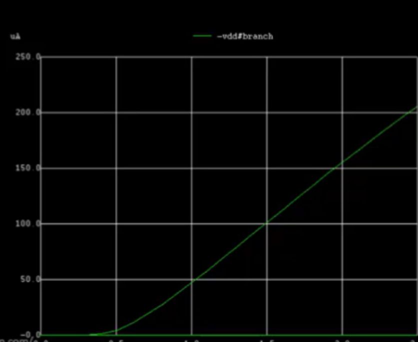


W=0.375u, L=0.25u device



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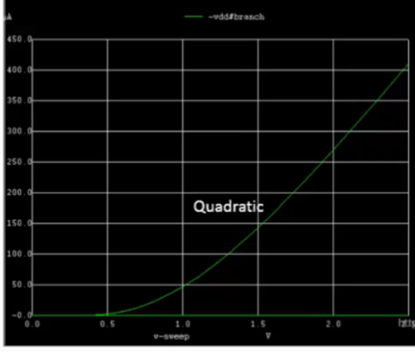
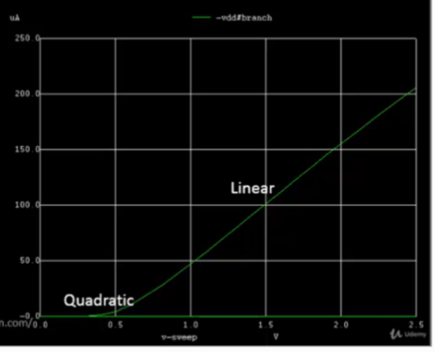


W=0.375u, L=0.25u device



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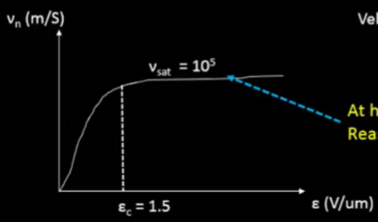
Velocity Saturation Effect



Velocity Vn(x) = mobility . electric field
= μn . dV/dx

At higher fields, velocity becomes constant
Reason = Scattering Effects

$$v_n\,(m/S) = \mu n \,.\, \varepsilon / 1 + (\varepsilon/\varepsilon_c) \quad \text{for } \varepsilon \le \varepsilon_c$$
$$= v_{sat} \quad \text{for } \varepsilon \ge \varepsilon_c$$

$$\varepsilon_c = 2\, v_{sat} / \mu n$$

Observation 1:

Velocity Saturation Effect

Qi(x) = -Cox ([Vgs – V(x)] -Vt)

Velocity Vn(x) = mobility . electric field
= μn . dV/dx

Re-deriving drain current using below boundary condition $\boxed{\text{Id = -Vn(x) . Qi(x) . W}}$ ➡ $\text{Id} = \underbrace{\dfrac{\mu n \,.\, Cox}{1 + \left(\dfrac{Vds}{\varepsilon_c L}\right)} \,.\, (W/L)\,[(Vgs - Vt)Vds - Vds^2/2]}_{\text{Too complex}}$

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Observation 1:

Velocity Saturation Effect

Let's come up with one model

Operation modes

Let's call (Vgs - Vt) = Vgt

Long Channel (>250nm)	Short Channel (<250nm)
Cutoff	Cutoff
Resistive	Resistive
	Velocity Saturation
Saturation	Saturation

Id = 0, for Vgt < 0, cutoff mode

For all other modes, let's use below model

$$Id = kn \cdot \left[(Vgt \cdot Vmin) - \frac{Vmin^2}{2}\right] \cdot [1 + \lambda\, Vds]$$

Where Vmin = min (Vgt, Vds, Vdsat)

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Velocity Saturation Effect

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Where Vmin = min (Vgt, Vds, Vdsat)

Technology parameter
Saturation voltage i.e. voltage at which device velocity saturates and is independent of Vgs or Vds

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Velocity Saturation Effect

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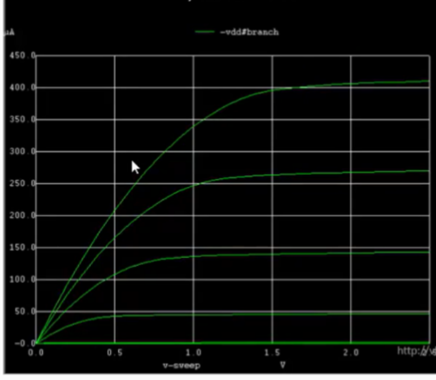
Where Vmin = min (Vgt, Vds, Vdsat)

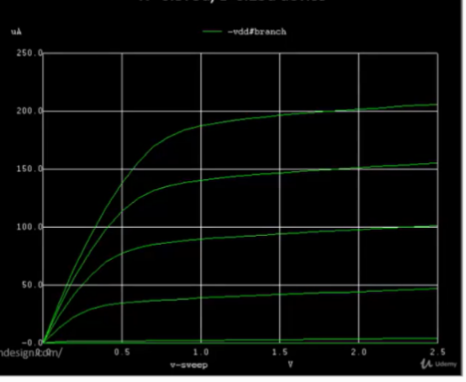
For eg., If Vds = minimum value

Observation 2:

W=1.8u, L=1.2u device



W=0.375u, L=0.25u device

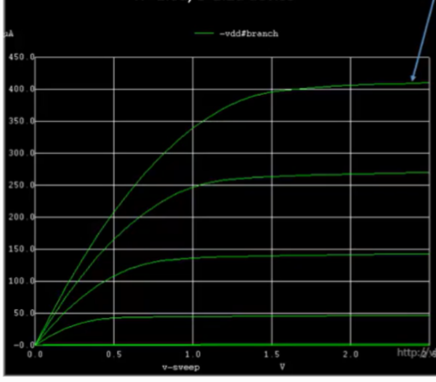


Observation 2:

Velocity Saturation causes device to saturate early

Peak current = 410um

W=1.8u, L=1.2u device



W=0.375u, L=0.25u device

Peak current = 210um