ECE321 – Electronics I

Lecture 9: MOSFET Scaling Issues

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Review of Last Lecture

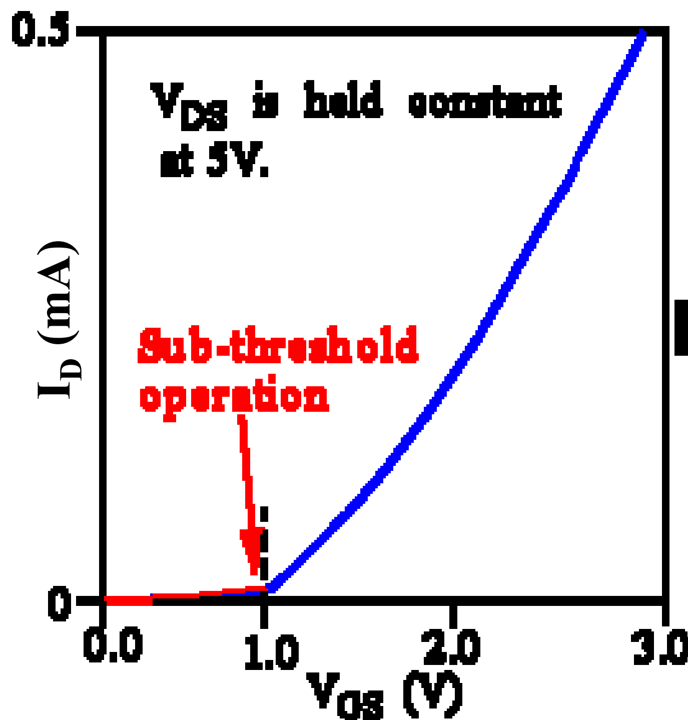
- "Dynamic Parameters of Long Channel MOSFET"
- MOSFET Parasitic Capacitances
  - Overlap capacitances
  - Channel capacitances
  - Junction capacitances

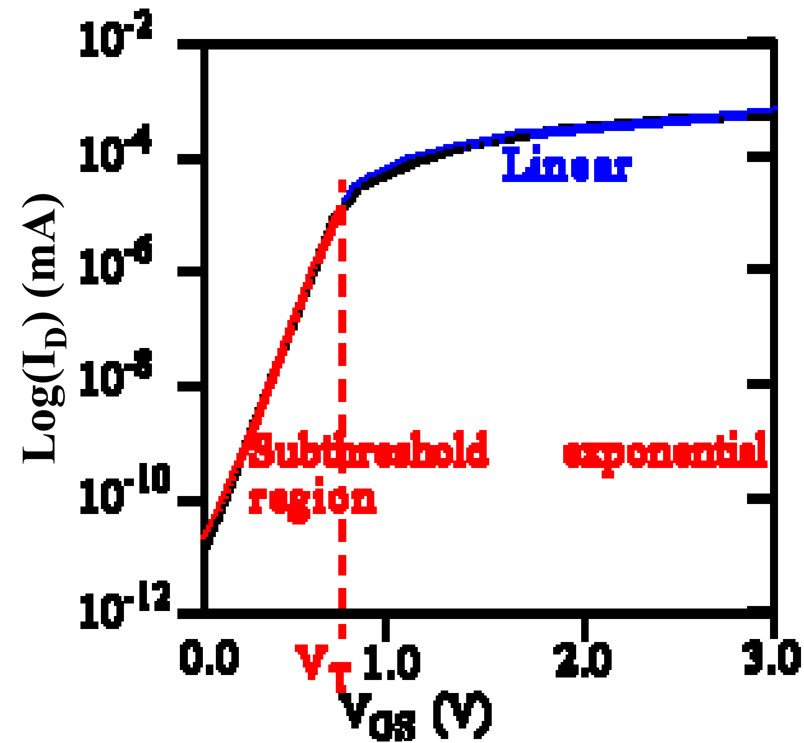
Today's Lecture

- Subthreshold Conduction (leakage)
- Velocity Saturation
- Threshold Voltage Roll-off
- Drain Induced Barrier Lower Effect (DIBL)
- Hot Electron

Subthreshold Conduction

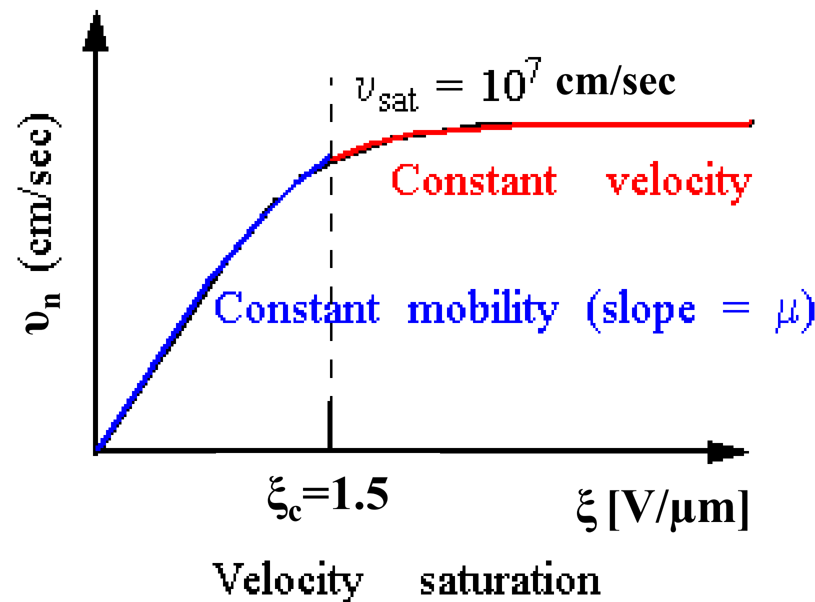
- I_{DS} does not equal to zero even with $V_{GS} = 0$
  - To get I_{DS}=0 need V_{DS}=0
- This is known as subthreshold conduction
- To reduce subthreshold leakage, threshold voltage needs to be increased





Velocity Saturation

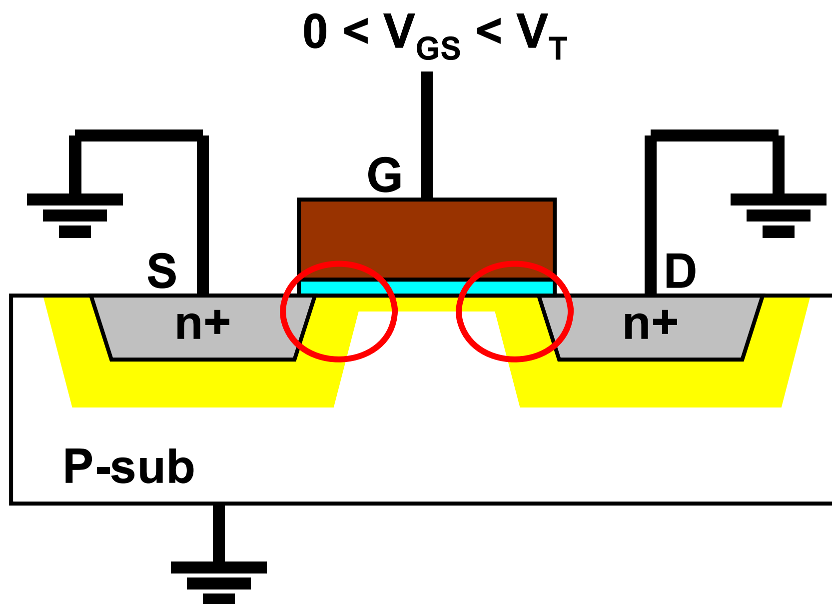
- Velocity of carriers (*v*) proportional to the electric field (ξ) is true only for values of ξ less than 1.5V/μm.
- Consider a 0.6μ device velocity saturation will start to occur for a V_{DS} of 1V.
- Velocity saturation results in "early saturation of device" and therefore lower I_{DS} current and lower performance

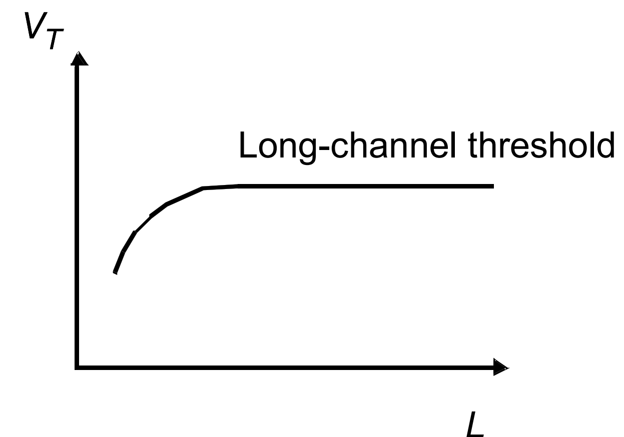


Velocity saturation

Threshold Voltage Roll-off

- **Because of the partial channel depletion caused by Source and Drain, a smaller threshold is enough to create strong inversion.**
- **Therefore, the threshold voltage is a function of channel length, L.**

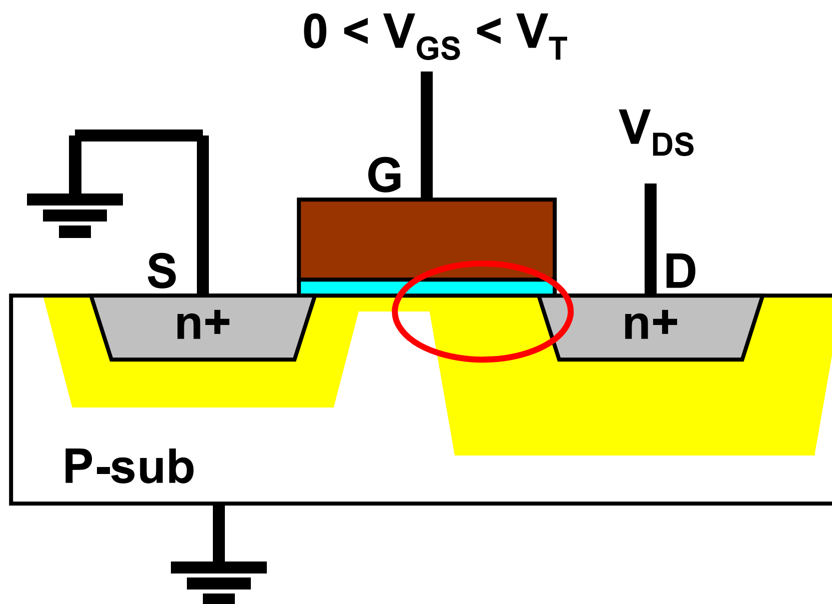


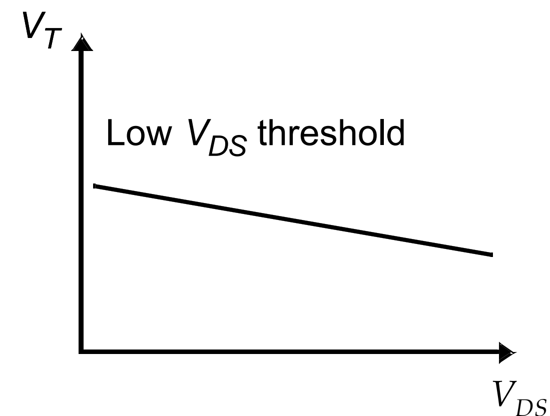


Threshold as a function of the length (for low V_{DS})

DIBL Effect

- Raising the drain potential increases the drain junction depletion region, reducing threshold voltage furthermore.
- This is called Drain Induced Barrier Lowering (DIBL).
- Therefore, threshold voltage in short channel device becomes a function of operating voltages.





Drain-induced barrier lowering (for low L)

Hot Electrons

- Increase in lateral electric field causes an increasing velocity of electron
- The lateral field is strongest in the pinch off region where V_{DS}-V_{DSAT} is dropped over the distance of the channel that is pinched off.
- This high energy electrons (hot electrons) can leave channel and tunnel into the gate oxide
- Electrons trapped in the gate oxide creates a fixed charge that increases the threshold voltage of NMOS, which result is degradation of device transcoductance