Section 29
MOS Capacitor Signal Response

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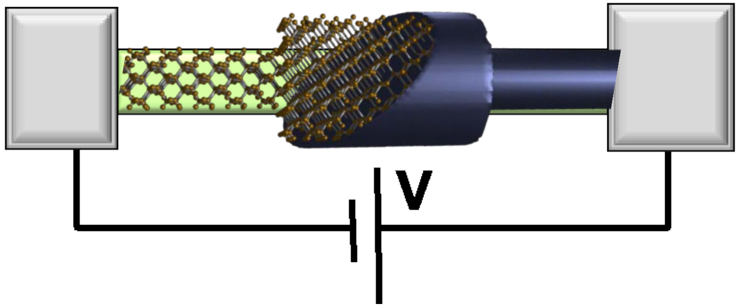
PURDUE UNIVERSITY

School of Electrical and Computer Engineering

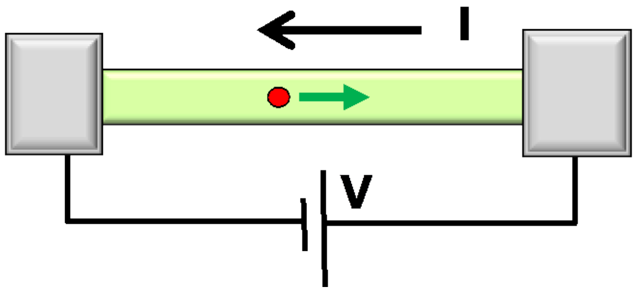
Section 27
Heterojunction Bipolar Transistor



$$I = G \times V$$
$$= q \times n \times v \times A$$

charge density velocity area

	Equilibrium	DC	Small signal	Large Signal	Circuits
PN Diode					
Schottky Diode					
BJT/ HBT					
MOScap MOScap					



$$I = G \times V$$
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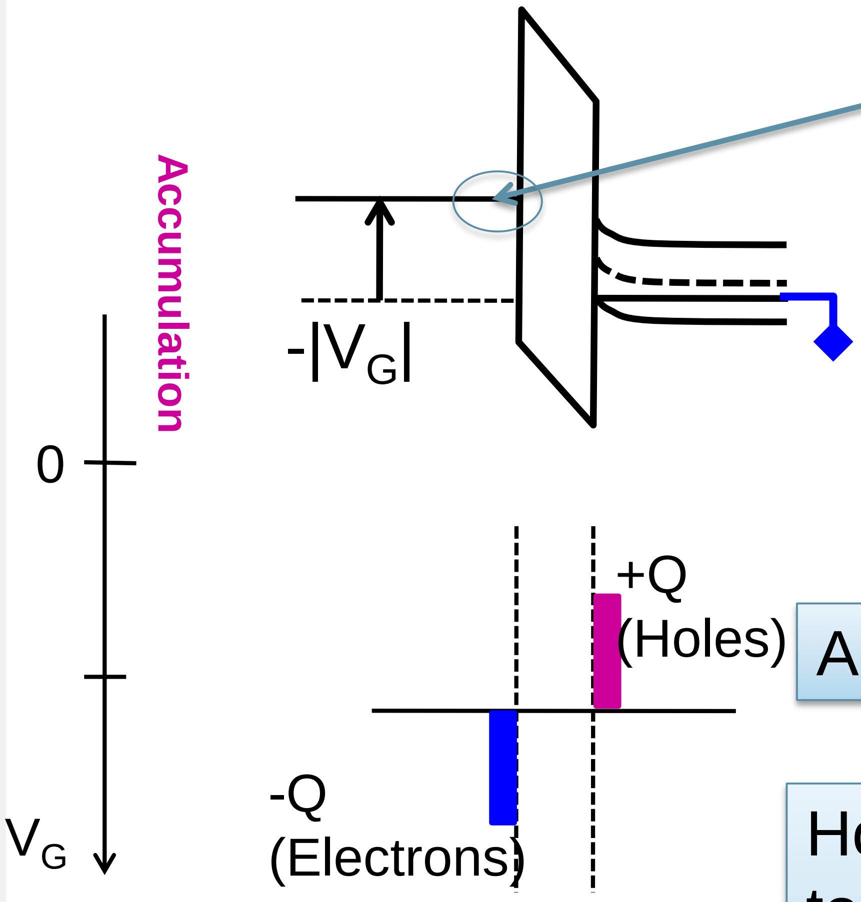
charge density (q, n) velocity (v) area (A)

- 1 • 29.1 Introduction / Background ← status
- 2 • 29.2 Small Signal Response
- 3 • 29.3 Large Signal Response

Electrostatics under Bias



Invisible band bending at metal side because of large DOS

Negative bias
Band bending
Flat Ef → no current

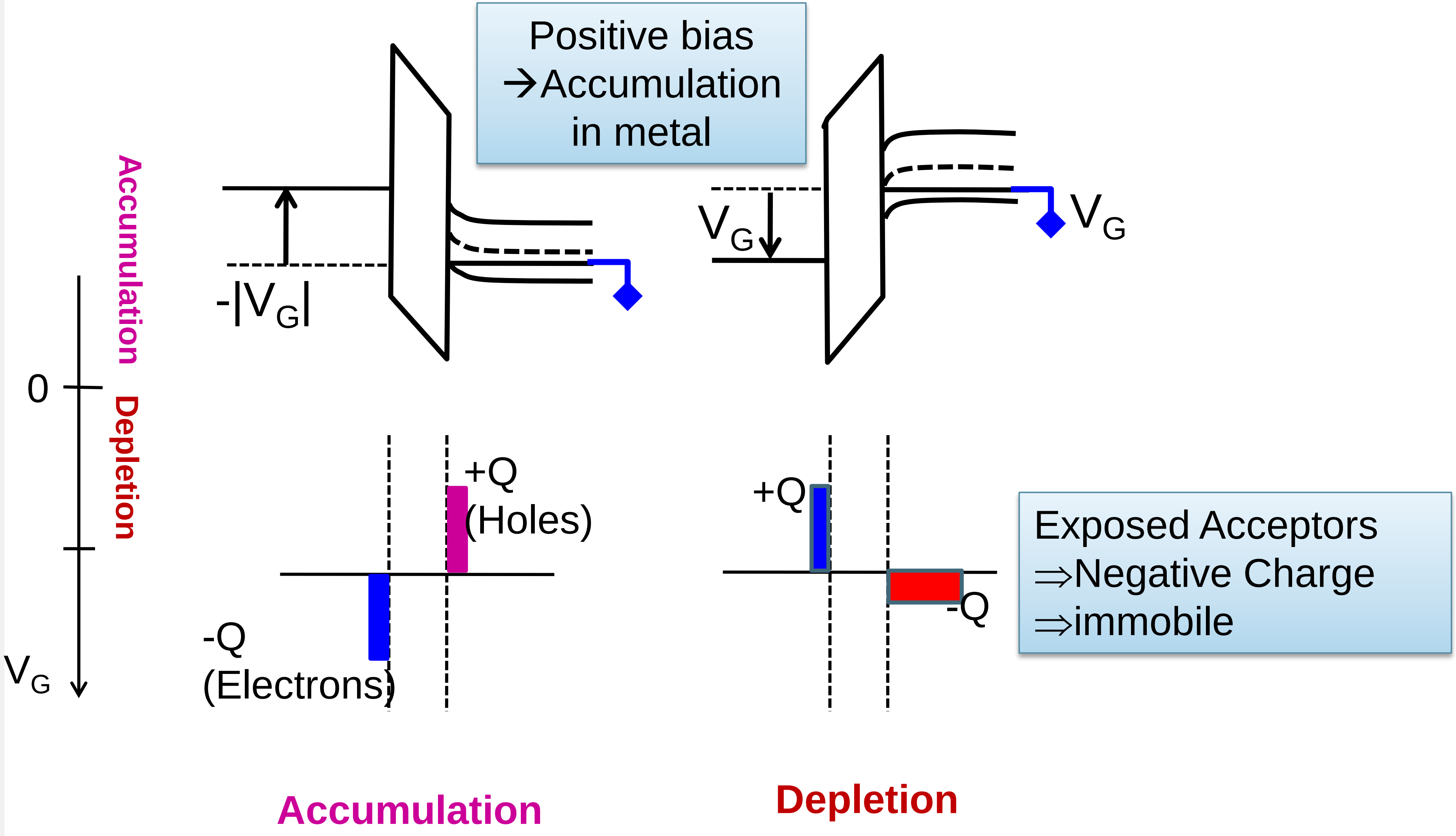
$j = n \mu \, dE_f/dx$

Accumulation

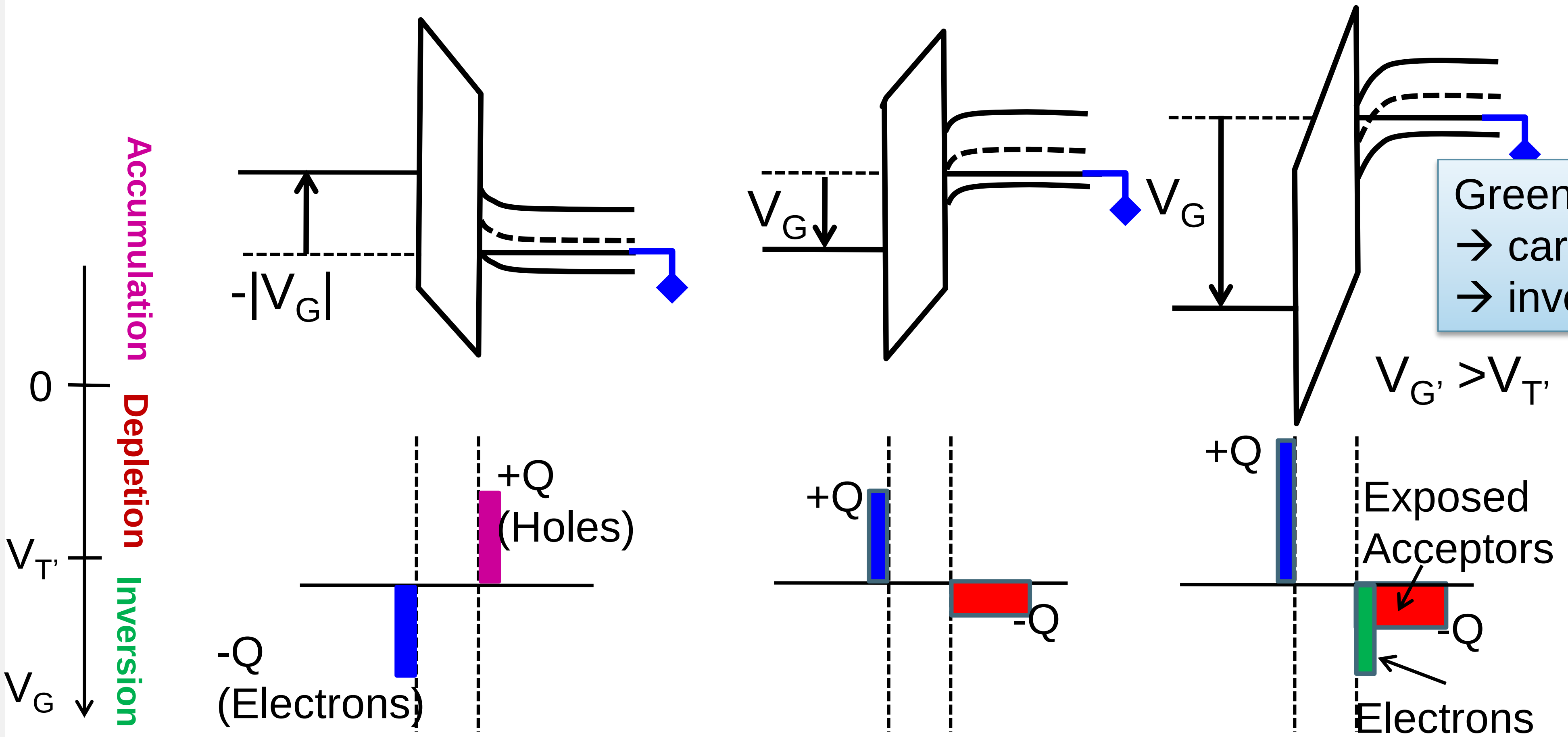
Holes are generated due to band bending/ Valence band come closer to Ef

Accumulation

Electrostatics under Bias



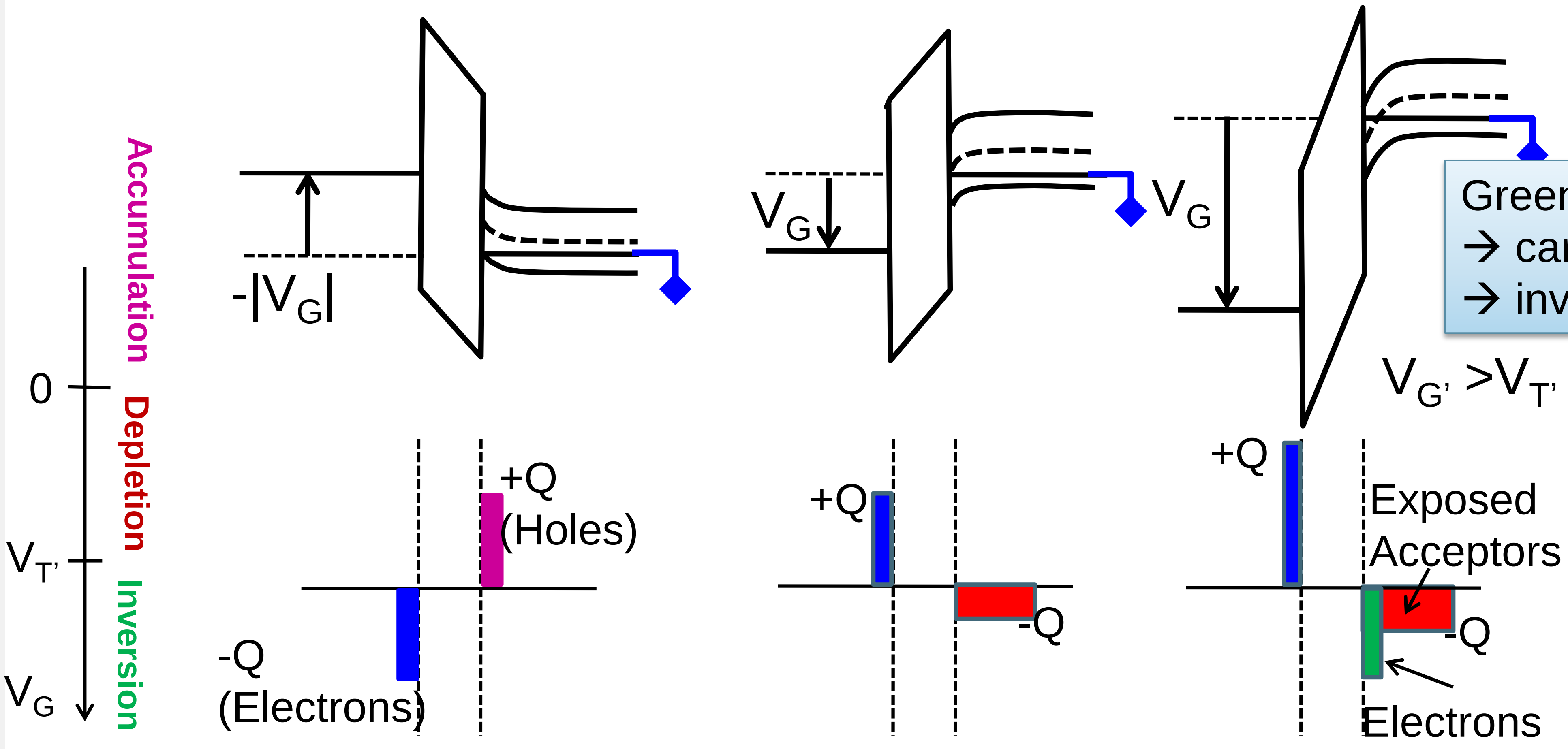
Electrostatics under Bias



Green : mobile electrons
→ carrier type are inverted
→ inversion

Accumulation **Depletion** **Inversion**

Electrostatics under Bias



Green : mobile electrons
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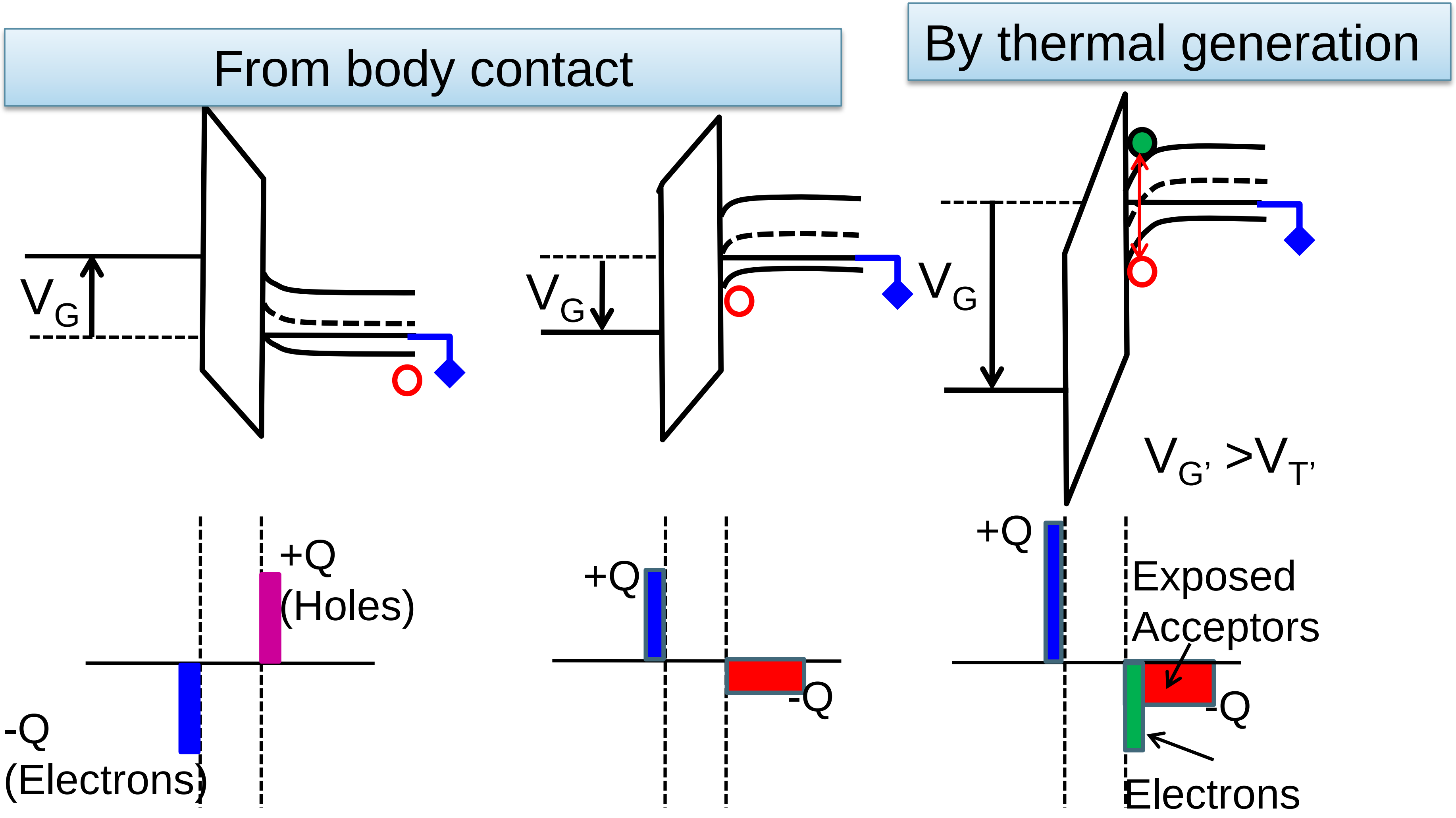
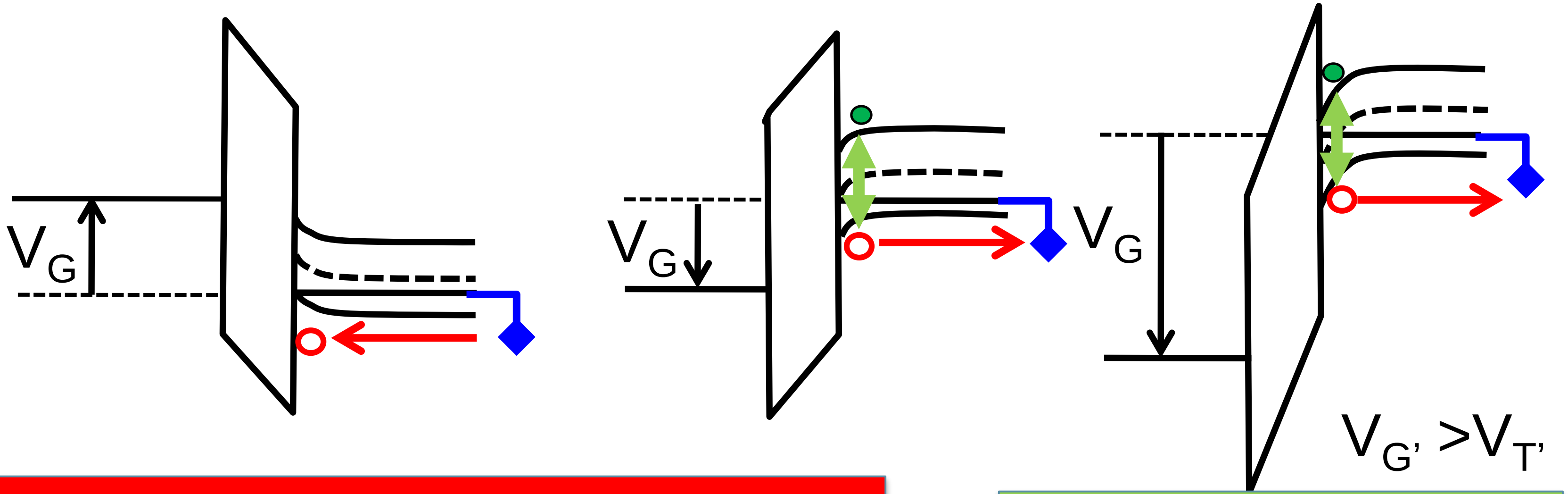
Accumulation **Depletion** **Inversion**

Where do charges come from?



- Integrate charge to find potential.

Response Time



Fast as sigma is large

Slower process

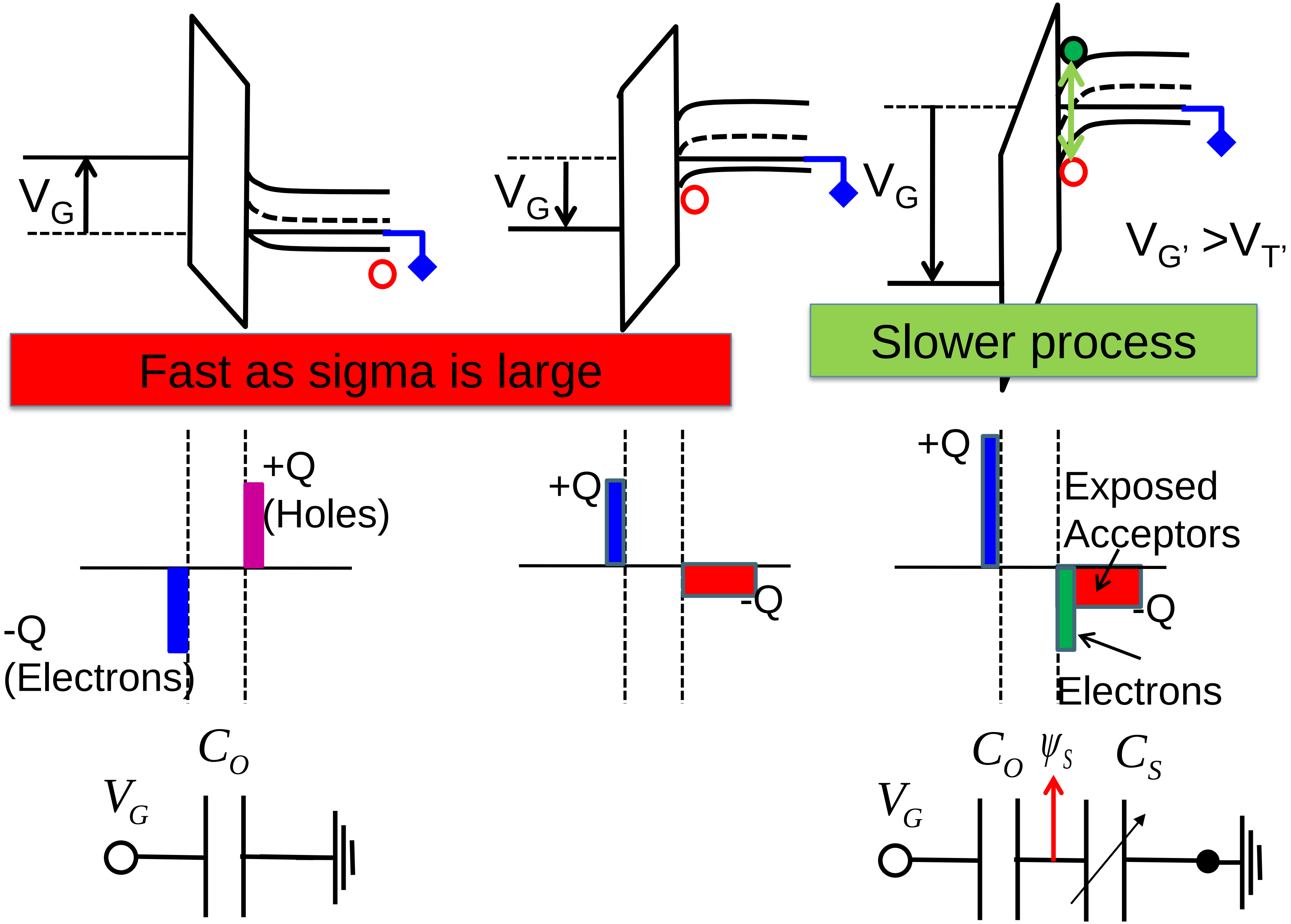
Dielectric Relaxation

$$\tau = \frac{\sigma}{\kappa_s \varepsilon_0}$$

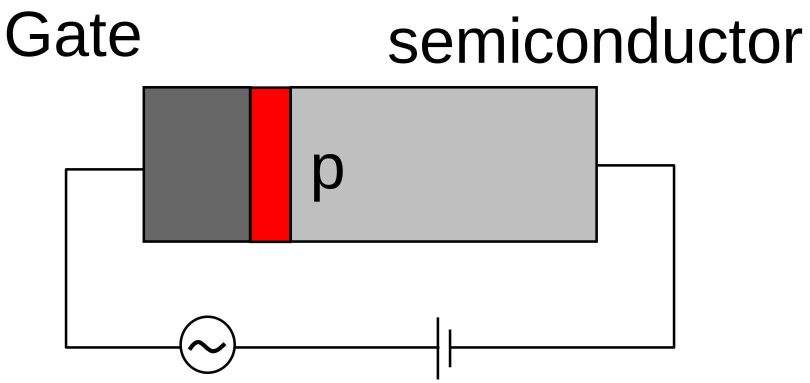
SRH Recombination-Generation

$$R = \frac{np - n_i^2}{\tau_n (p + p_1) + \tau_p (n + n_1)} \rightarrow \frac{-n_i}{\tau_n + \tau_p}$$

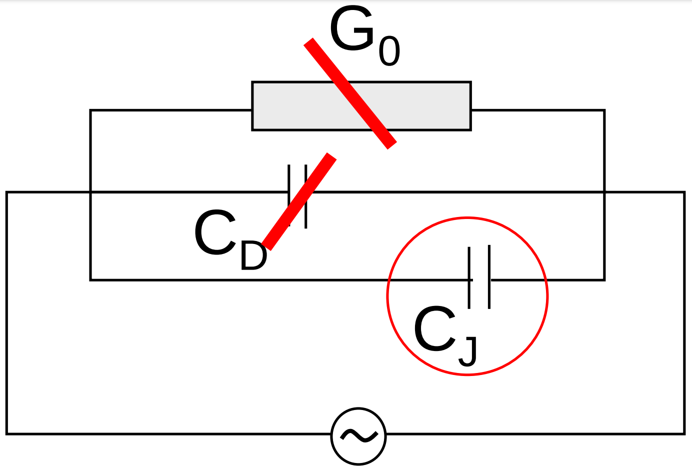
Capacitance Model

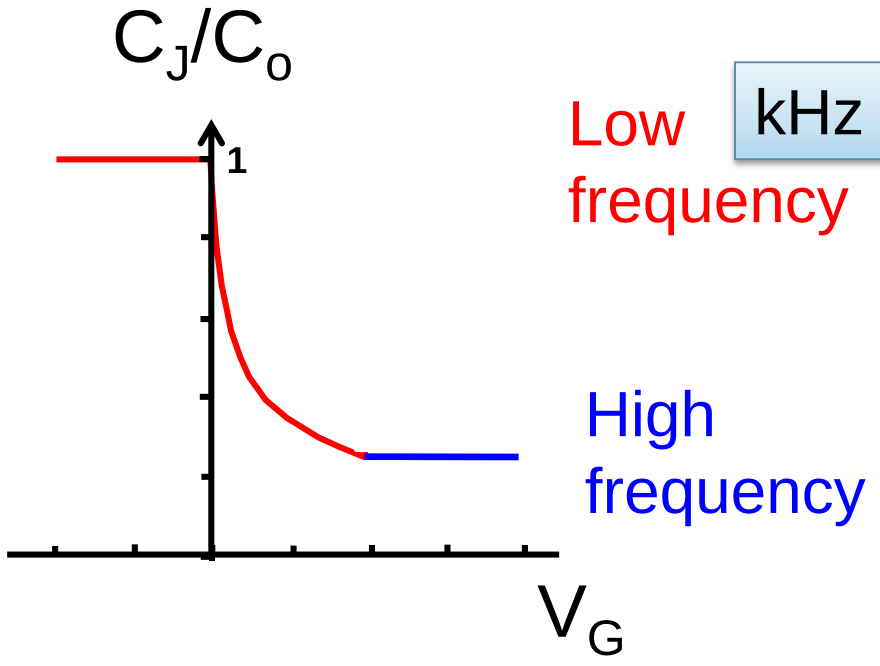


Small Signal Equivalent Circuit



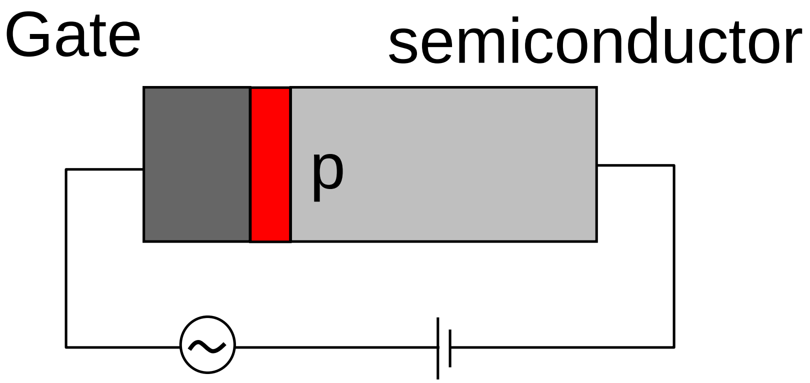
G_0 is small (only tunelling current)





For insulated devices, consider only majority carrier junction capacitance C_J

Small Signal Equivalent Circuit



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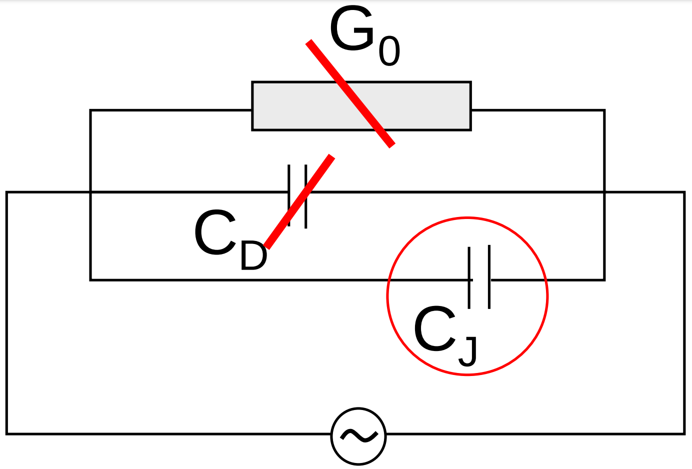
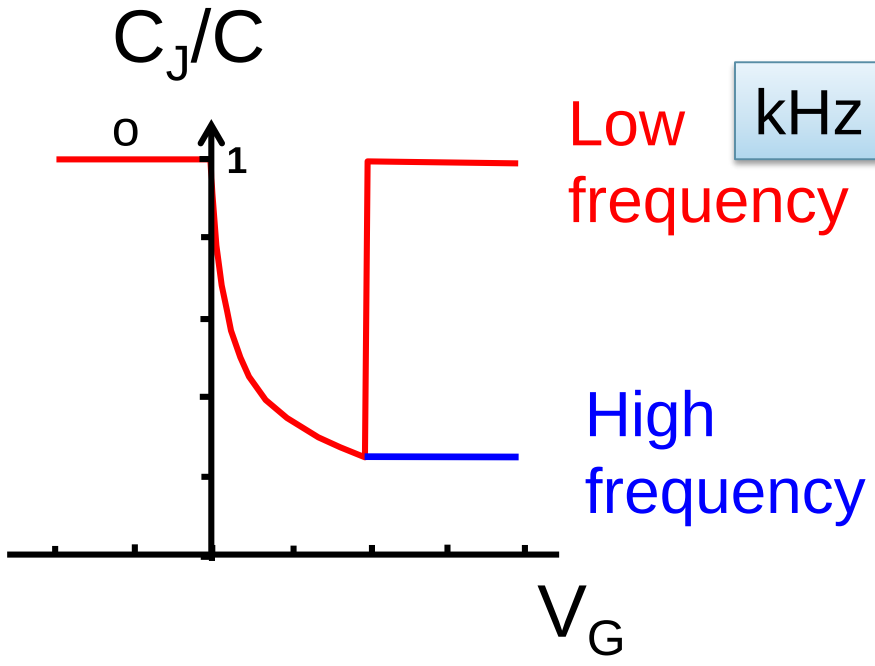


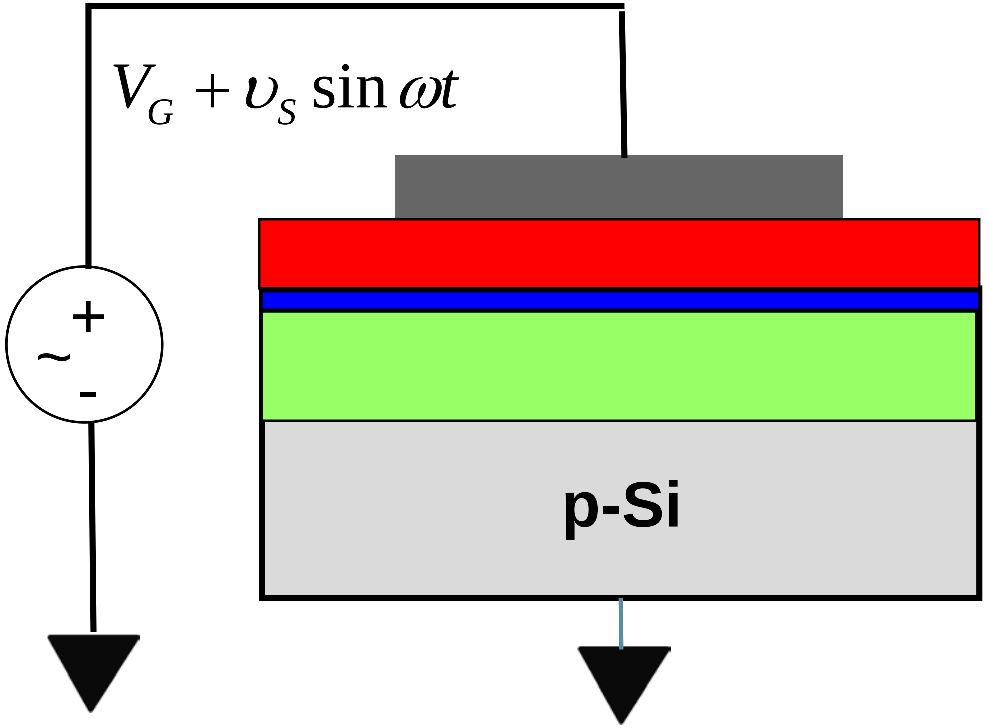


For insulated devices, consider only majority carrier junction capacitance C_J

Junction Capacitance

$$V_G = V_{ox} + \psi_s \qquad V_{ox} = \frac{Q_G}{C_O} = -\frac{Q_S}{C_O}$$

Grey: gate
Red: oxide
Blue: inversion
Green: depletion



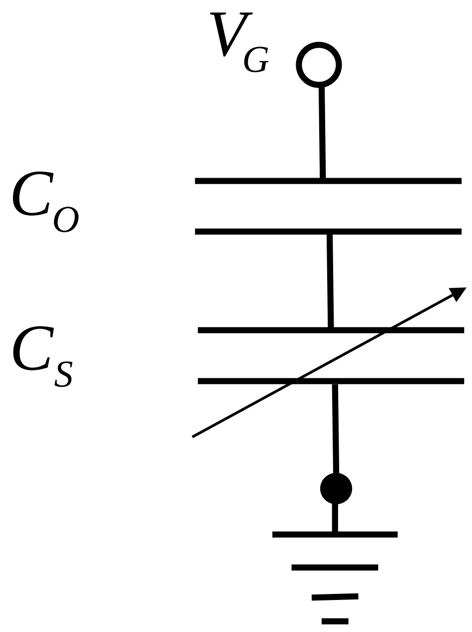
$$C_G \equiv \frac{dQ_G}{dV_G} = \frac{d(-Q_S)}{dV_G}$$

$$V_G = \psi_S - \frac{Q_S}{C_O}$$

$$\frac{dV_G}{d(-Q_S)} = \frac{d\psi_S}{d(-Q_S)} + \frac{1}{C_O}$$

$$\frac{1}{C_G} = \frac{1}{C_S} + \frac{1}{C_O}$$

Junction Capacitance



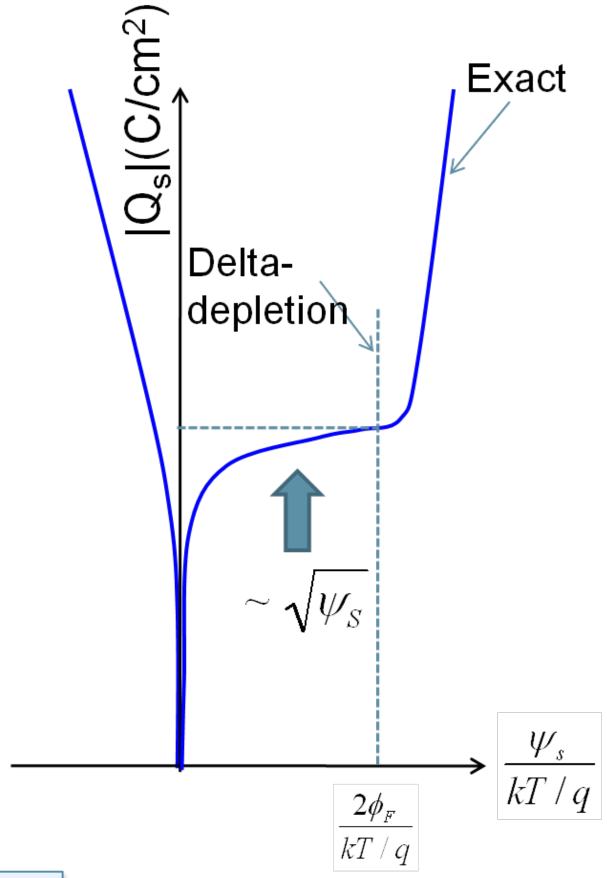
$$\frac{1}{C_G} = \frac{1}{C_S} + \frac{1}{C_O}$$

$$C_S \equiv \frac{d(-Q_S)}{d\psi_S}$$

C_s is not fixed

$Q_S(\psi_S)$

which we already understand!



Remember the Qs vs Ψ_S figure we explored in the previous lecture

Definition of *m* for later use

$$m = \left(1 + C_S / C_O\right)$$

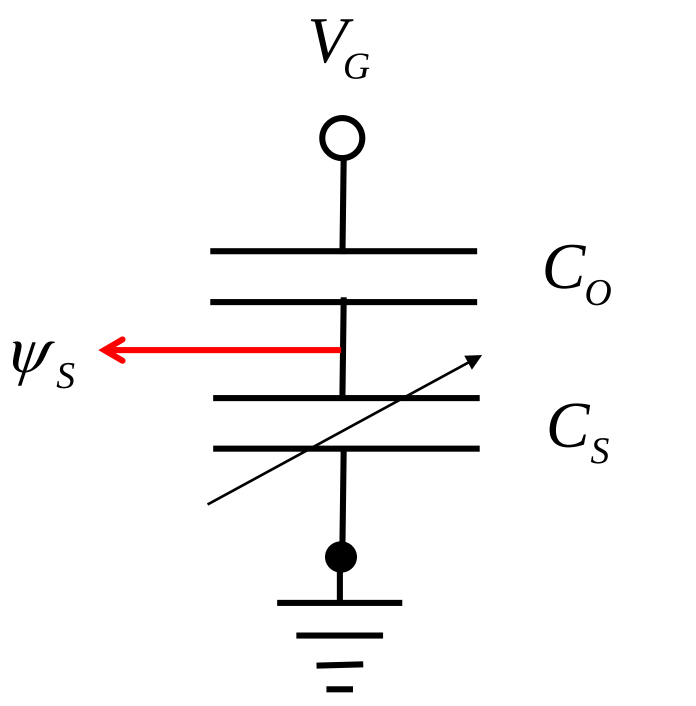
'body effect coefficient'

$$m = \left(1 + \kappa_S x_O / \kappa_0 W_T\right)$$

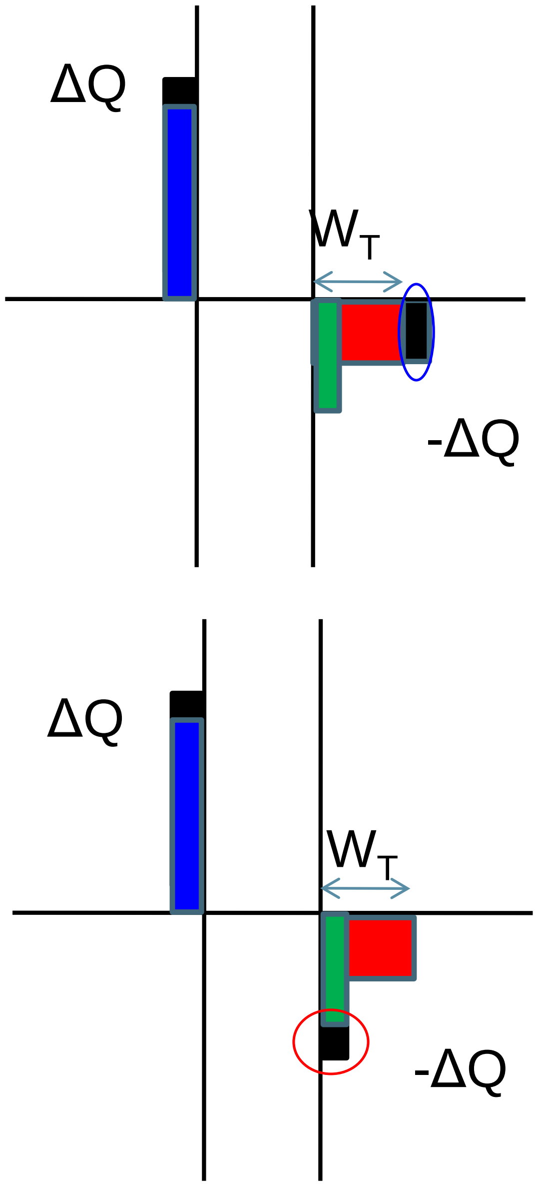
W_T depends on the voltage

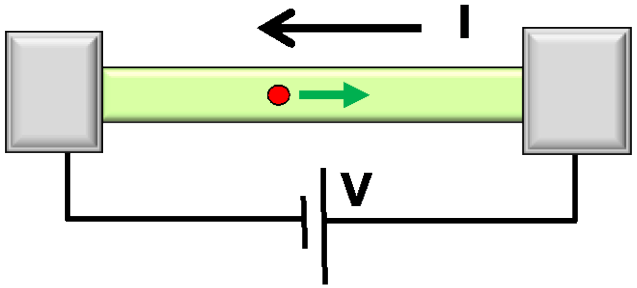
in practice:

$$1.1 \le m \le 1.4$$



$$\psi_S = \frac{C_O}{C_O + C_S} V_G \equiv \frac{V_G}{m}$$





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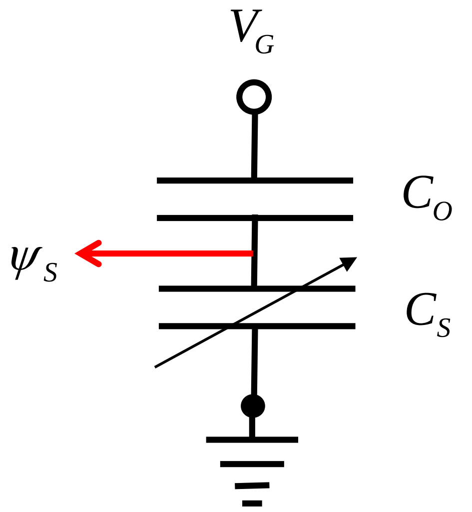
status



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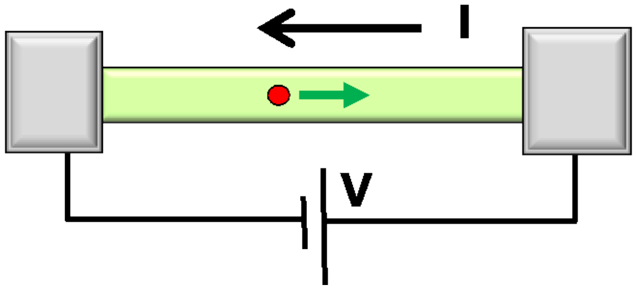

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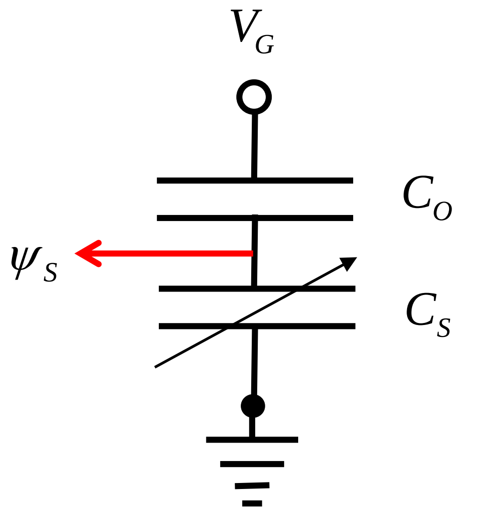

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