Section 29
MOS Capacitor Signal Response

29.2 Small Signal Response

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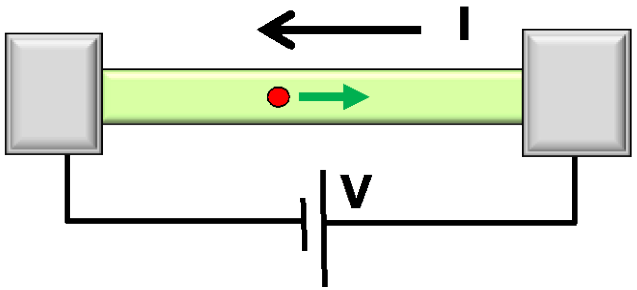
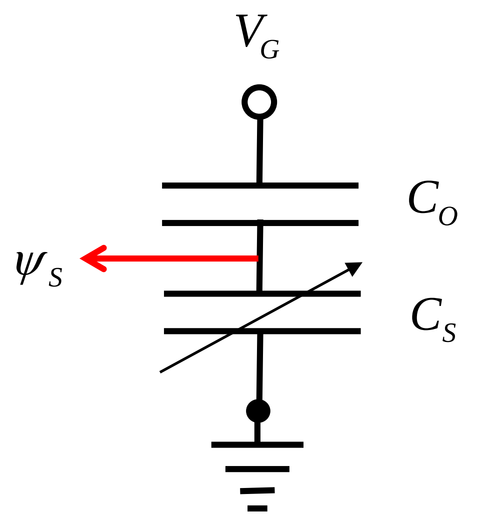


$I = G \times V$

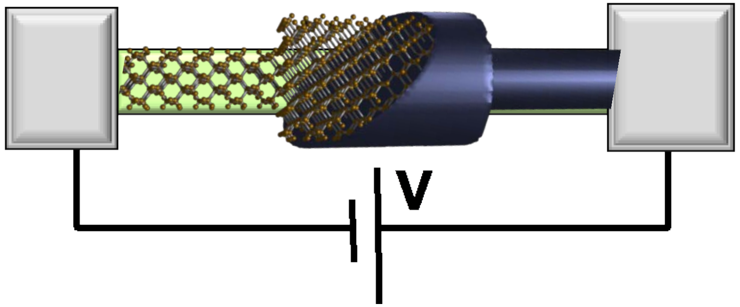
$= q \times n \times v \times A$

charge density velocity area

- 29.1 Introduction / Background
- 29.2 Small Signal Response ← status
- 29.3 Large Signal Response



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



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charge density velocity area

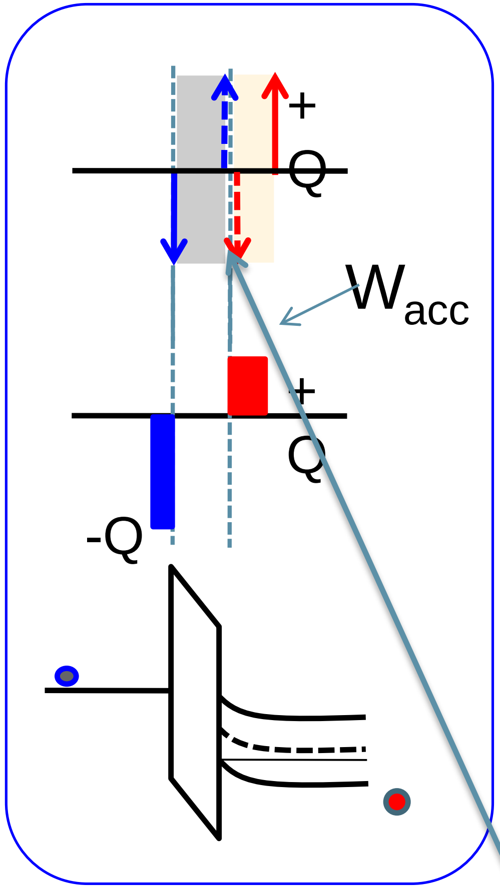
	Equilibrium	DC	Small signal	Large Signal	Circuits
PN Diode					
Schottky Diode					
BJT/ HBT					
MOScap MOScap					

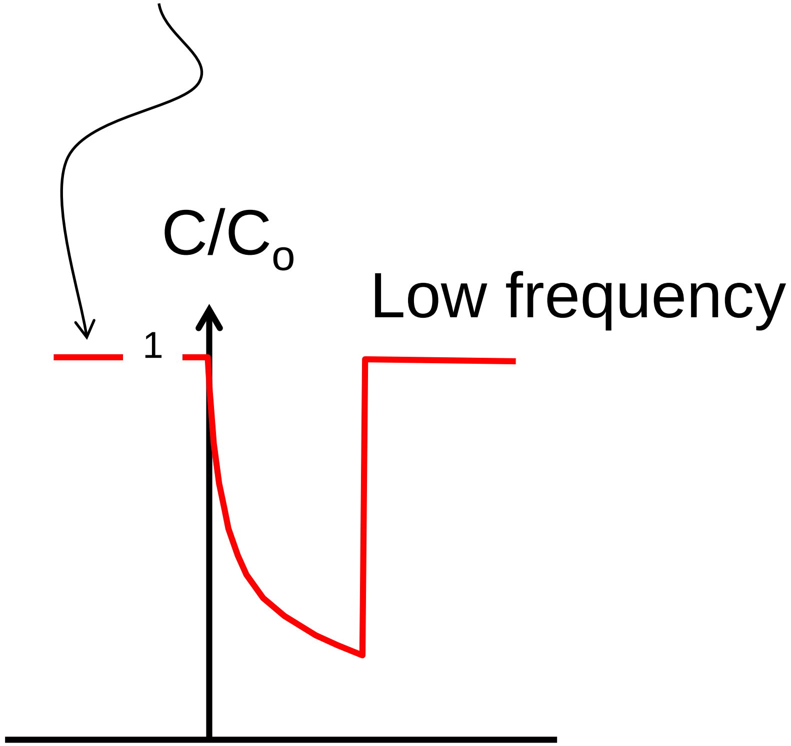
Junction Capacitance *in accumulation*

$$C_{j,acc} \approx \frac{\kappa_{ox}\mathcal{E}_0}{x_0} \equiv C_0$$

$$C_{j,acc} = \frac{C_o C_{s,acc}}{C_o + C_{s,acc}}$$

$$C_{s,acc} \equiv \frac{\kappa_s \mathcal{E}_0}{W_{acc}}$$





Arrows is the charge induced by small signal
Two blue arrow→ C_0
Two red arrow → C_s
These two capacitors are in series

Junction Capacitance *in depletion*

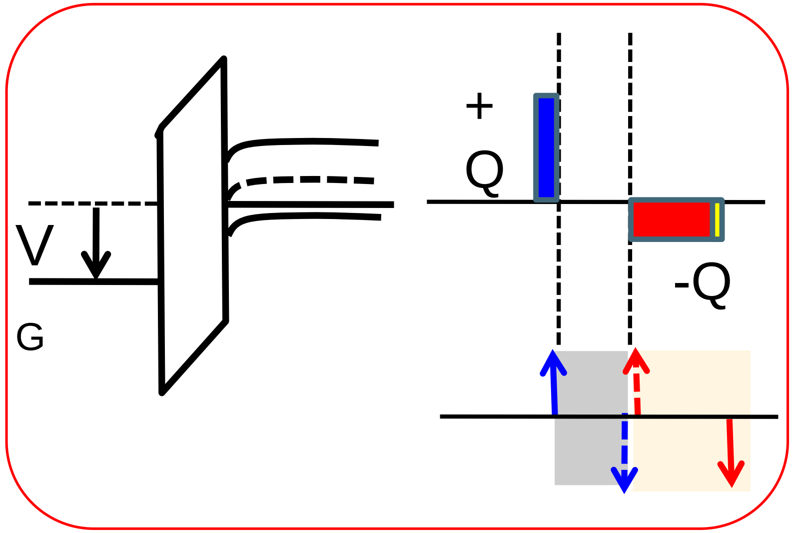
$$C_{j,dep} = \frac{C_0 C_s}{C_0 + C_s} = \frac{C_0}{1 + C_0/C_s}$$

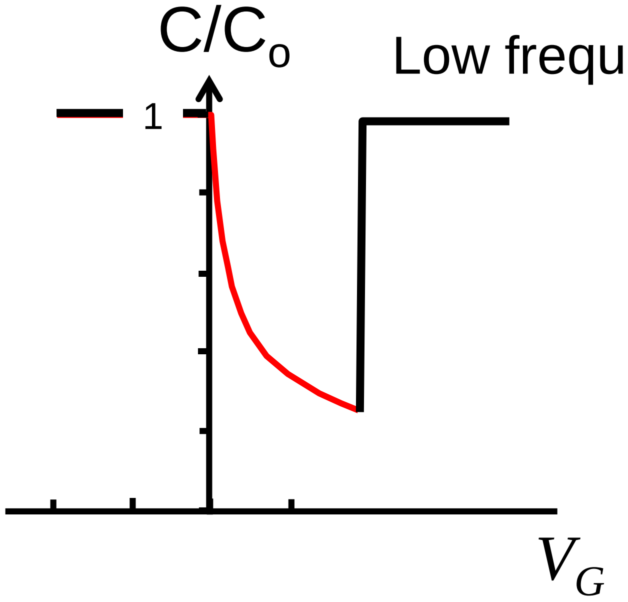
$$= \frac{C_0}{1 + \dfrac{\kappa_o \varepsilon_0}{x_0} \Big/ \dfrac{\kappa_s \varepsilon_0}{W}} \qquad = \frac{C_o}{\sqrt{1 + \dfrac{V_G}{V_\delta}}}$$

$$V_G = \frac{qN_A W}{\kappa_o \varepsilon_0} x_0 + \left(\frac{qN_A W^2}{2\kappa_s \varepsilon_0} \right)$$

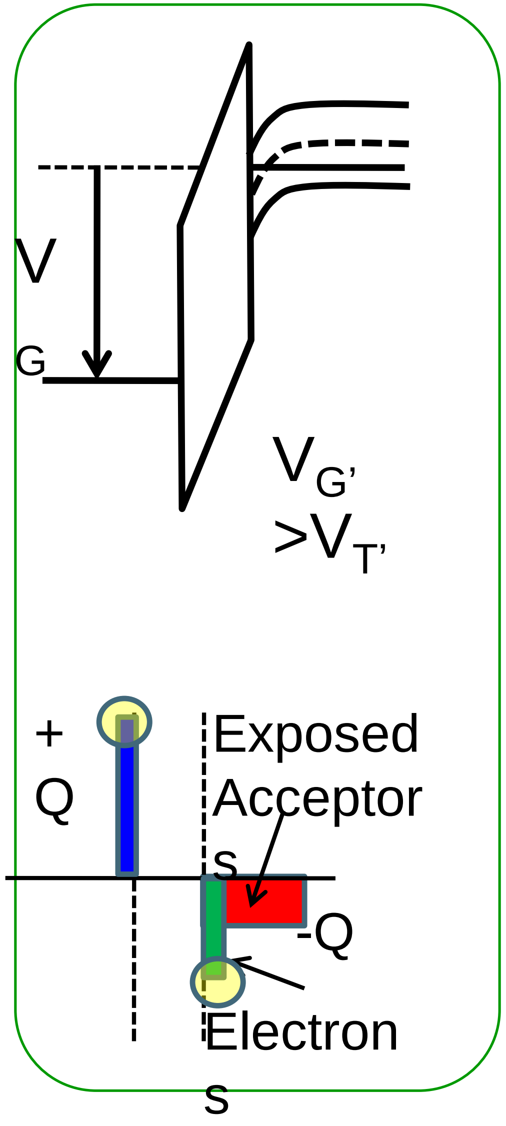
First term is the V drops on oxide
Second term is band bending
Solve for W V_δ is some constant

$$\frac{\kappa_o}{\kappa_s} \frac{W}{x_0} = \sqrt{1 + \frac{V_G}{V_\delta}} - 1$$





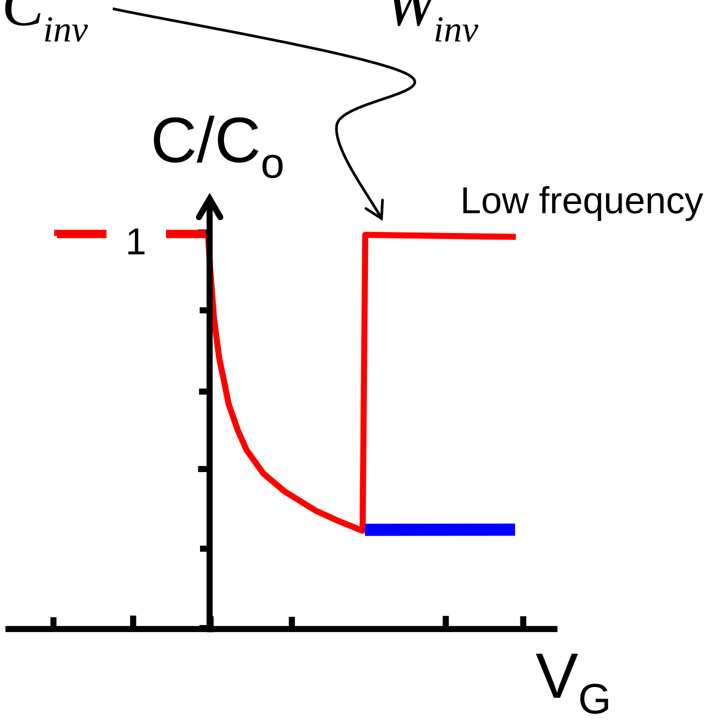
Junction capacitance *in inversion*



$$C_{j,inv} \approx \frac{\kappa_s \varepsilon_0}{x_0} \equiv C_0$$

Time to generate inversion charge. ms to μs

$$C_{j,inv} = \frac{C_o C_{inv}}{C_o + C_{inv}} \qquad C_{inv} \equiv \frac{\kappa_s \varepsilon_0}{W_{inv}}$$



Equivalent Oxide Thickness

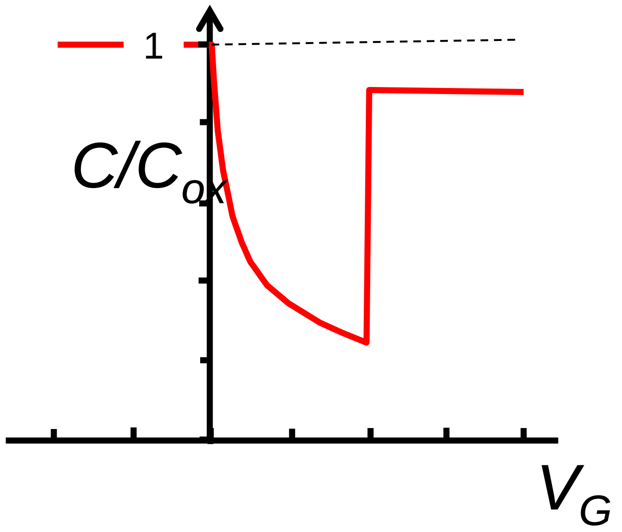
$$Q_i = -C_G\left(V_G - V_T\right)$$

$$C_G = C_{j,inv} = \frac{C_o C_{inv}}{C_{inv} + C_o} < C_o$$

$$C_o = \frac{\kappa_o \varepsilon_o}{x_0} \qquad C_{inv} \equiv \frac{\kappa_s \varepsilon_o}{W_{inv}}$$

$$C_G = \frac{\kappa_{ox}\varepsilon_O}{EOT_{elec}} \qquad EOT_{elec} = x_O + \left(\frac{\kappa_{ox}\varepsilon_O}{\kappa_s \varepsilon_O}\right) W_{inv} > x_O$$

Low frequency

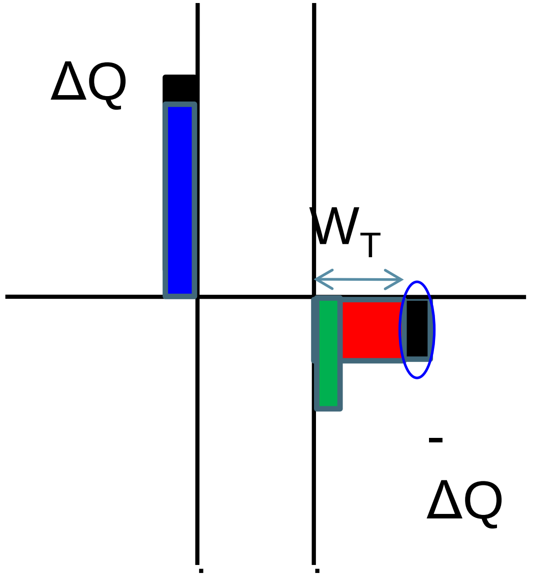


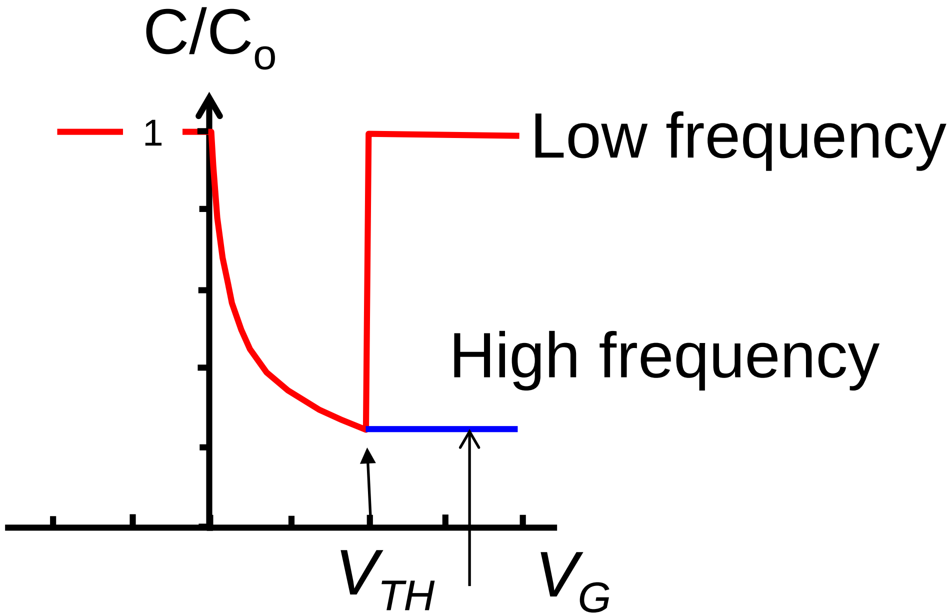
'Equivalent oxide thickness - electrical '

High frequency curve *at inversion*

$$C_{j,inv} \approx \frac{\kappa_s \varepsilon_0}{x_0} \equiv C_0$$

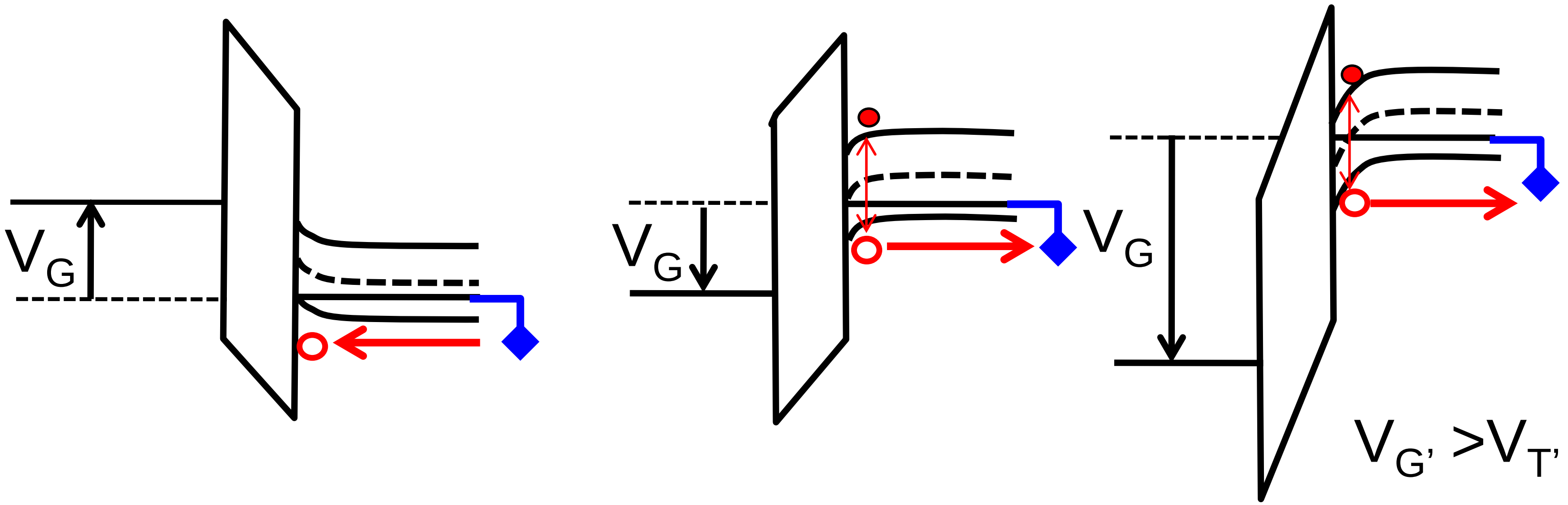
High Frequency





The red region contribute to the C, as if it is still in depletion

What about high frequency part of the curve?



Dielectric Relaxation

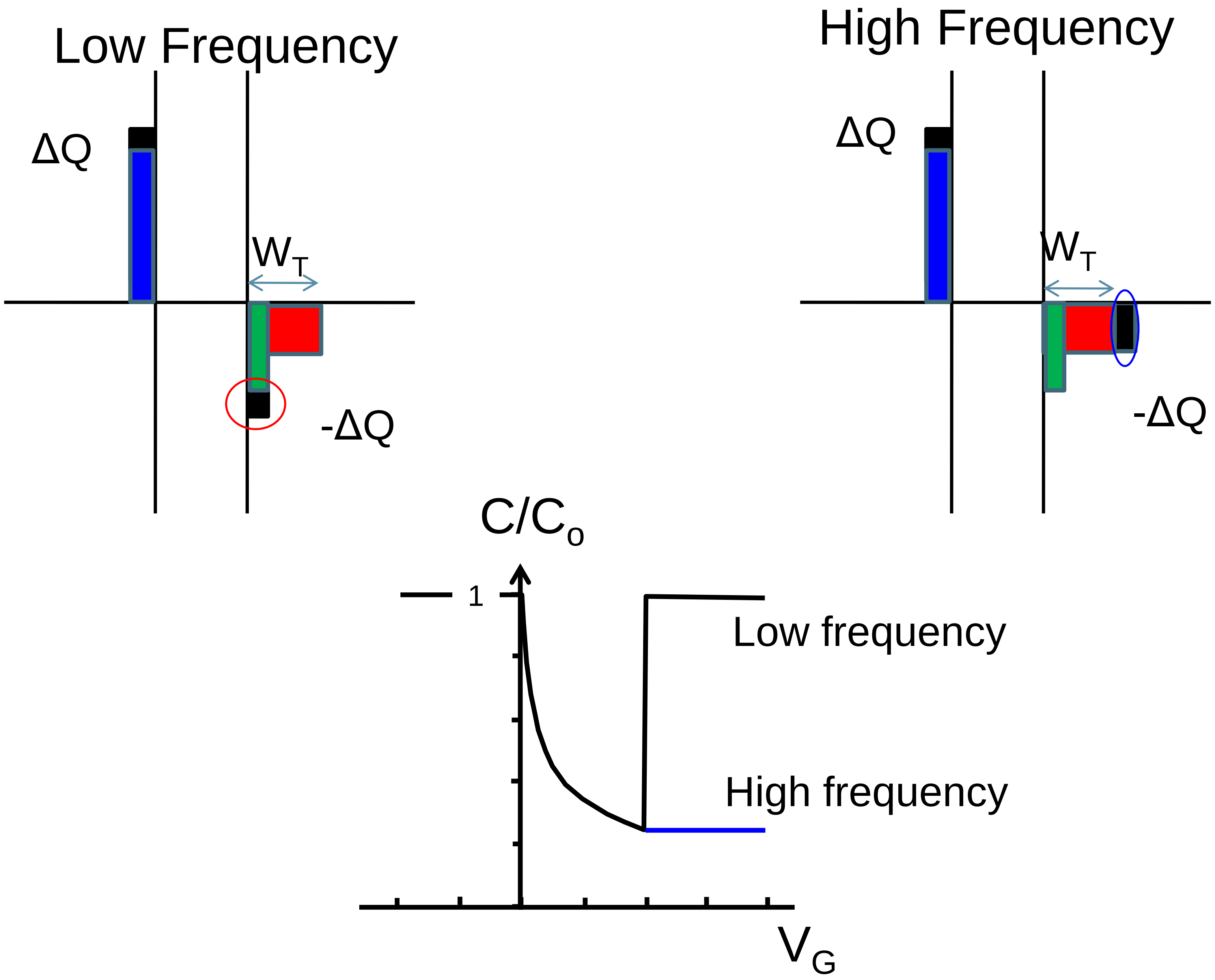
$$\tau = \frac{\sigma}{\kappa_s \varepsilon_0}$$

SRH Recombination-Generation

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

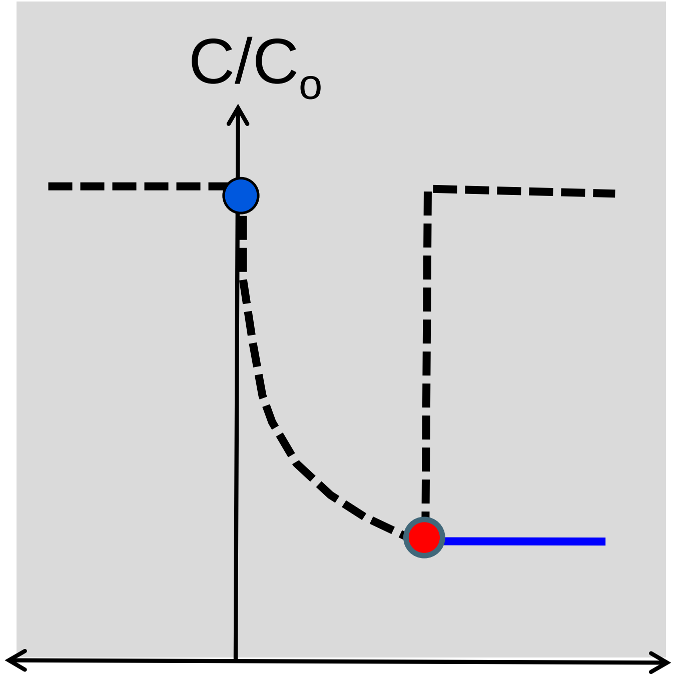
Ref. Lecture no. 15

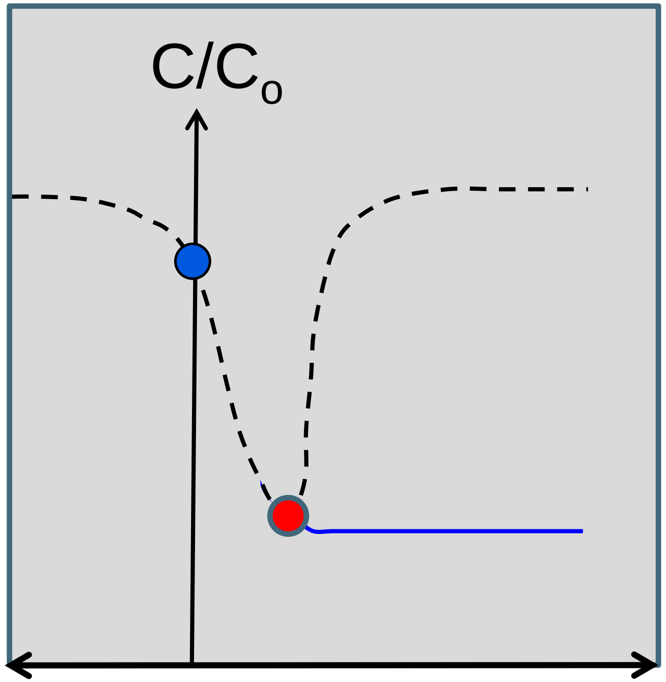
High frequency response in MOS-C



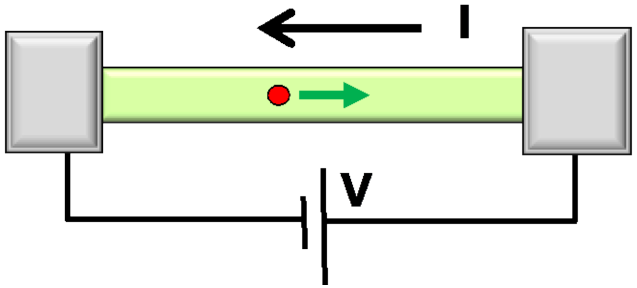
Ideal vs. Real C-V Characteristics

Blue dot: Flat band voltage …





Red dot: Threshold voltage …



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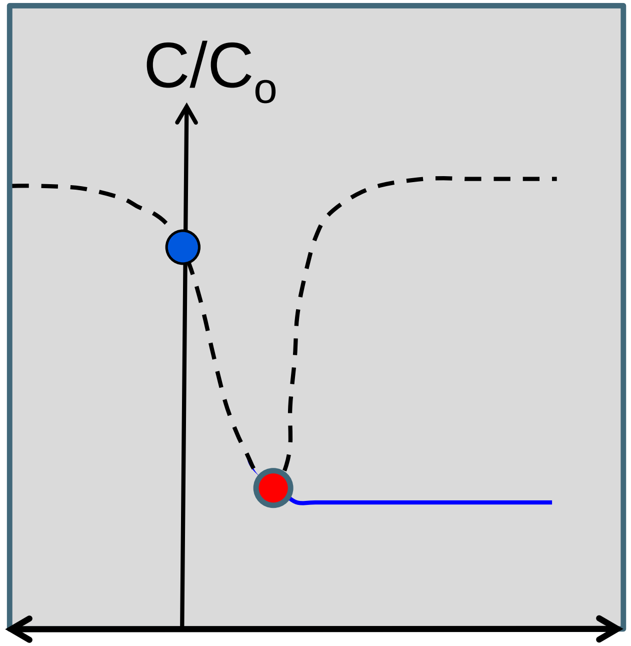

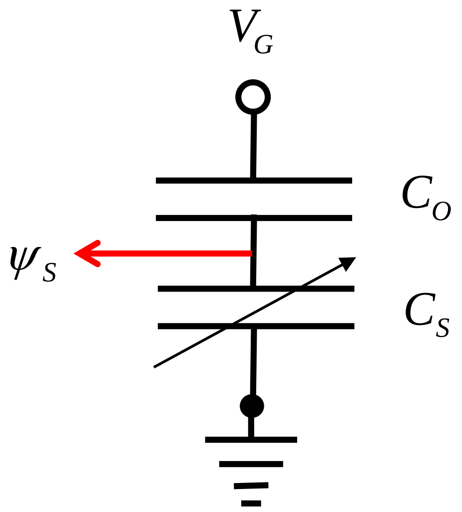

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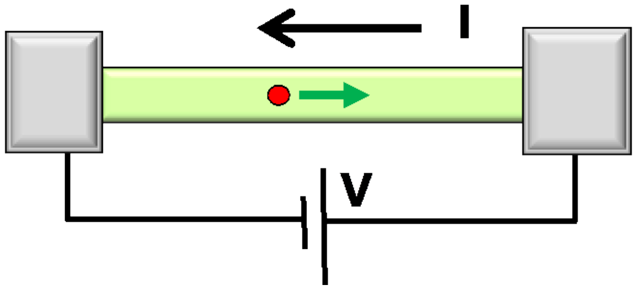

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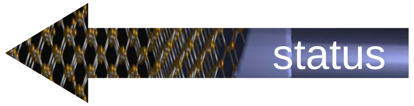

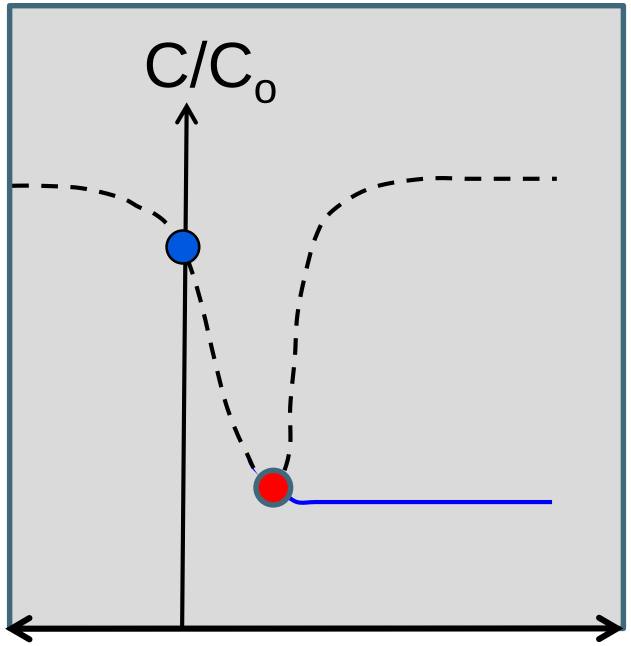

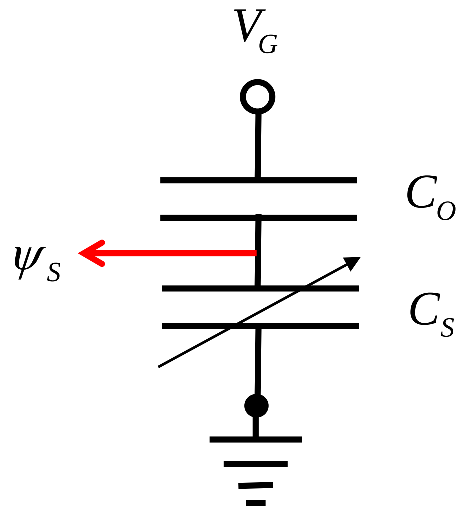

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