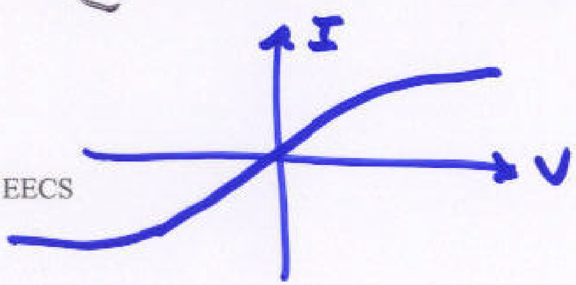
• NO LECTURE MONDAY ...

Lecture 11

• PS 4 IS DUE THURSDAY AT 4 PM

- Last time:
  - pn junctions: thermal equilibrium
  - pn junctions: charge-voltage characteristic
- Today :
  - pn junction *small-signal* capacitance (attention: this concept is difficult)



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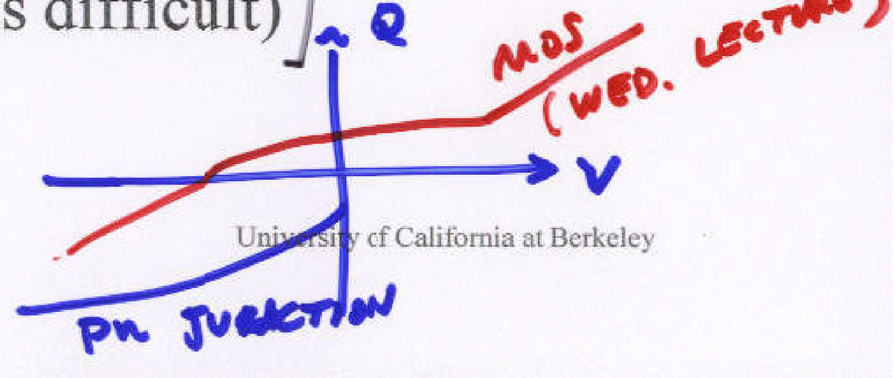
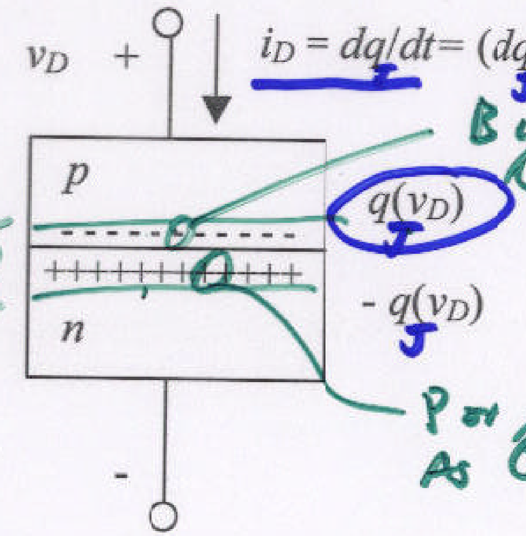


Charge Storage in pn Junction

- Circuit element:

q_J = NOT DC NECESSARILY.. (varying)

$i_D = dq/dt = (dq/dv)(dv/dt)$ … $q_J \neq C v_D$



Signs:

- $v_D < 0$ [reverse bias only] ⇒ $q(v_D) < 0$ [on p-side of the junction]

- Can't handle non-linearity in KCL, KVL

$q_J(v_D) = Q_{J0}\sqrt{1 - v_D/\phi_B}$; $v_D \leq 0V$, $Q_{J0} < 0$

$v_D \lesssim +0.3V$

Linearizing the Charge Storage !

- Symbol conventions

$$q_J = Q_J + q_j$$

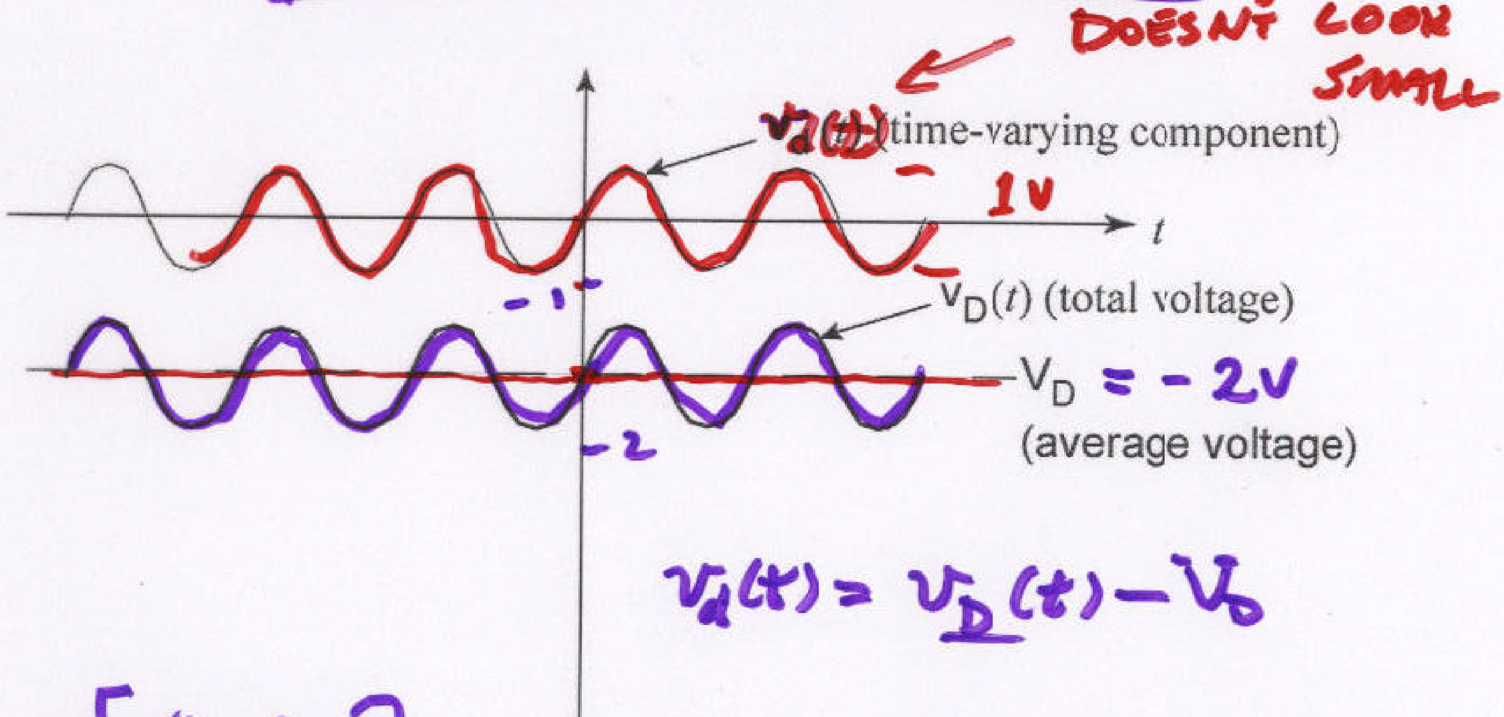
TOTAL | AVERAGE (DC) | SMALL-SIGNAL... IT'S SMALL!] LINEAR ENOUGH ...

$$v_D = V_D + v_d$$

[lower case lower case]

TOTAL | AVERAGE | SMALL-SIGNAL

Diode Voltage $v_D(t)$



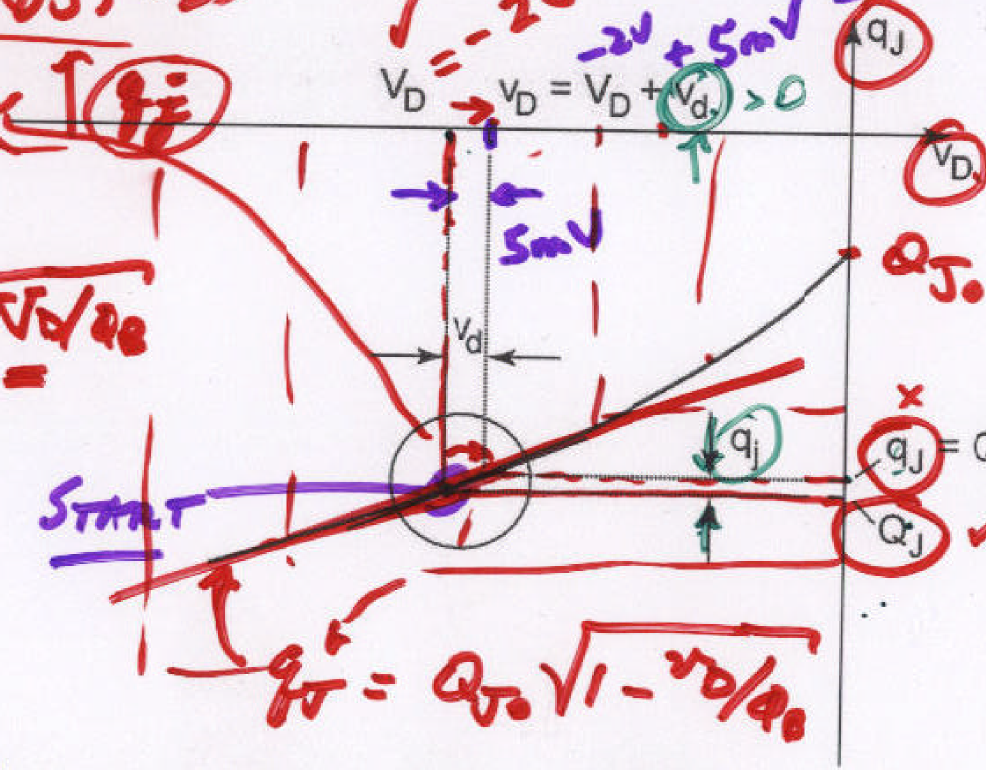
$$v_d(t) = v_D(t) - V_D$$

$\begin{bmatrix} v_D(t) \\ V_D \\ v_d(t) \end{bmatrix}$ "Δ" ≡

$$\underbrace{v_d(t)}_{\text{SMALL}} = \Delta \underbrace{v_D(t)}_{\text{TOTAL}}$$

R. T. Howe

Incremental Charge q_j

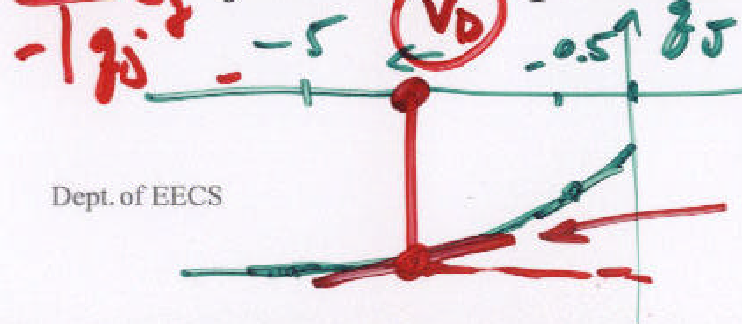


Junction Capacitance C_j

- Slope of charge-voltage plot is the ratio of the small-signal charge to the small-signal voltage

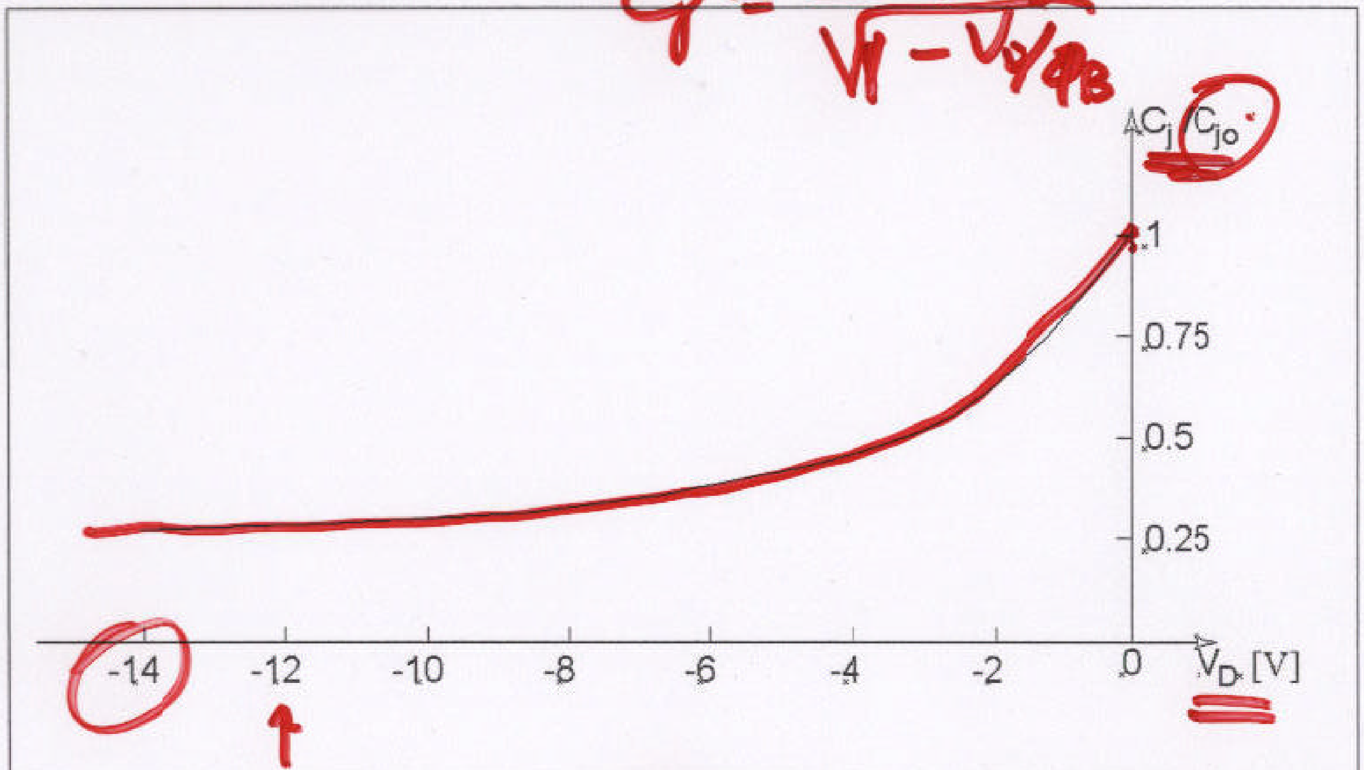
$$slope = \left.\frac{dq_J}{dv_D}\right|_{V_D} = \frac{q_j}{v_d} = C_j$$

- Define the slope (units: C/V = F) to be the *junction capacitance* C_j



Junction Capacitance vs. DC Bias

$C_j = \frac{C_{j0}}{\sqrt{1 - V_D/\phi_B}}$

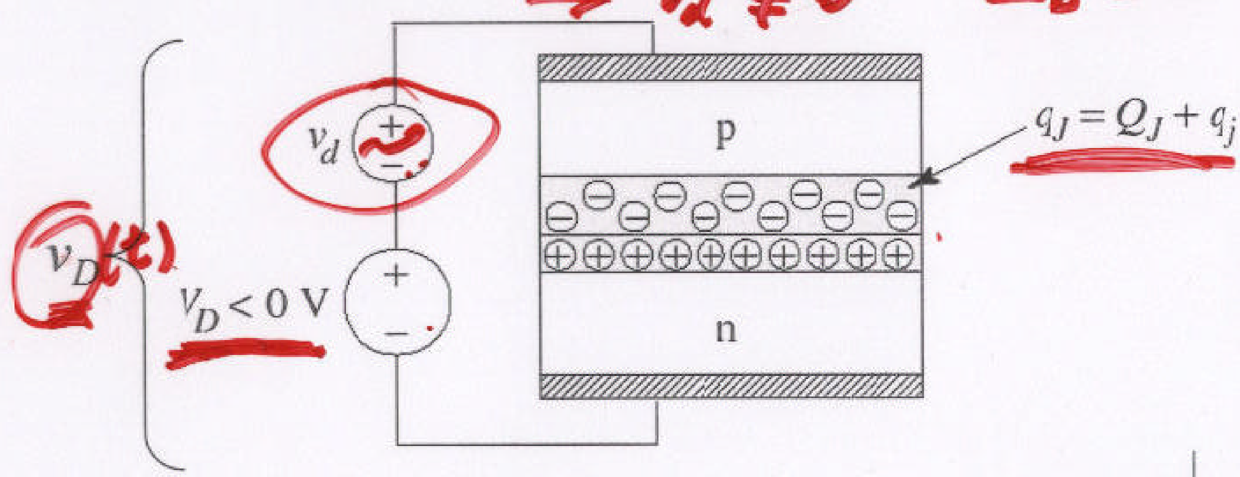


$C_j(V_D) = \frac{dq_J}{dv_D}\Big|_{V_D} = \frac{d}{dv_D}\left\{Q_{J0}\sqrt{1 - \frac{v_D}{\phi_B}}\right\}\Big|_{V_D}$

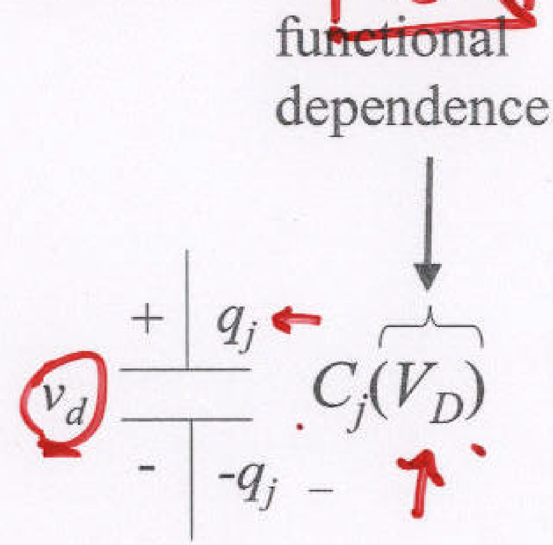
Small-Signal Circuit Model

- total voltage and total charge:

$I_D = 0$

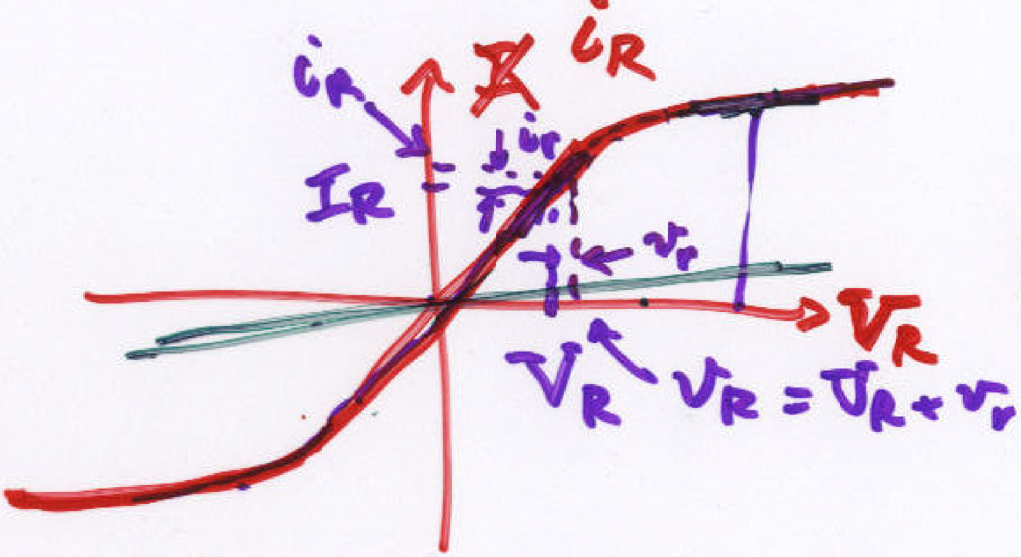


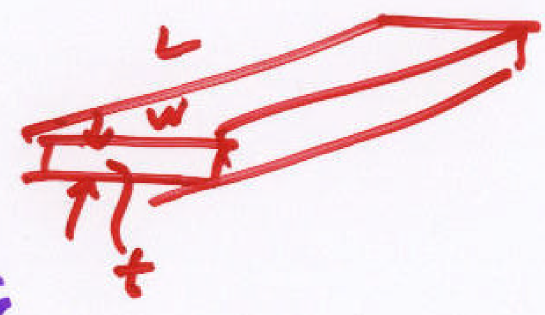
- small-signal variables *only* →

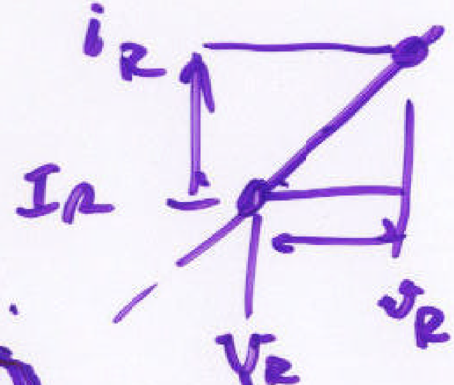


LINEAR CAPACITOR!!

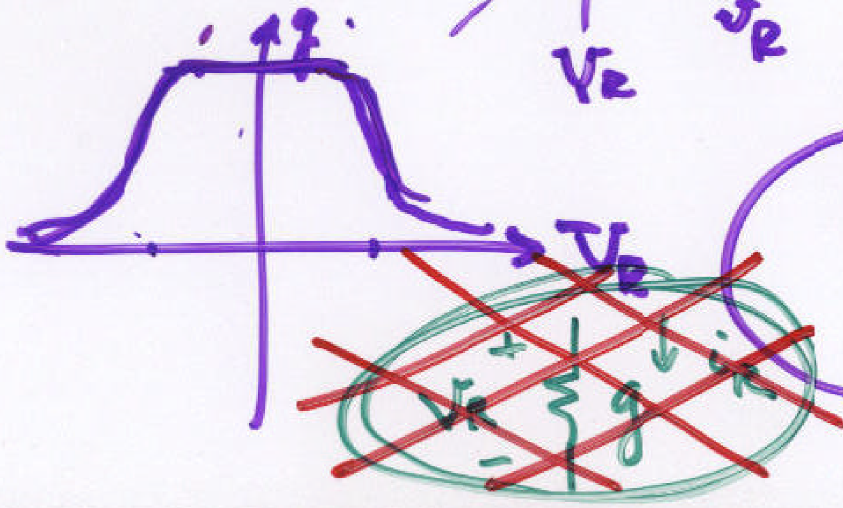
PHASORS..







$$\left.\frac{di_R}{dv_R}\right|_{V_R} = S = \frac{1}{\Omega} = g(V_R)$$



$$i_r = g(V_R) \cdot v_r$$

↑ fn.