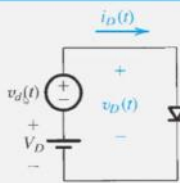


Small-Signal Model

ECE 214

Q: How is the small-signal diode model defined?

- **step #1:** Consider the conceptual circuit.
- DC voltage (V_D) is applied to diode
- Upon V_D , arbitrary time-varying signal v_d is super-imposed



- **DC only** – upper-case w/ upper-case subscript
- **time-varying only** – lower-case w/ lower-case subscript
- **total instantaneous** – lower-case w/ upper-case subscript
 - DC + time-varying

Small-Signal Model

ECE 2

- **step #2:** Define **DC current** as in (4.8).
 (eq4.8) $I_D = I_s e^{V_D/V_T}$
- **step #3:** Define **total instantaneous voltage** (v_D) as composed of V_D and v_d .
 (eq4.9) $v_D(t) = V_D + v_d(t)$
 $v_D(t)$ = total instantaneous voltage across diode
 V_D = dc component of $v_D(t)$
 $v_d(t)$ = time varying component of $v_D(t)$
- **step #4:** Define **total instantaneous current** (i_D) as function of v_D .
 (eq4.10) $i_D(t) = I_s e^{v_D/V_T}$
 note that this is different from (4.8)

total voltage
 $v_d = v_D(t)$

step 5: $i_D(t) = I_s e^{(V_D + v_d)/V_T} \Rightarrow i_D(t) = \underbrace{I_s e^{V_D/V_T}}_{I_D} e^{v_d/V_T} \Rightarrow i_D(t) = I_D \cdot e^{v_d/V_T}$

Small-Signal Model

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- **step #8:** Apply **power series expansion** to (4.12).

example: $e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \dots$

action: apply power series expansion to (4.12)
 because $v_d/V_T \ll 1$, these terms are assumed to be negligible

$$(eq4.12a) \quad i_D(t) = I_D \left[1 + \frac{v_d}{V_T} + \left[\left(\frac{v_d}{V_T} \right)^2 \frac{1}{2!} \right] + \left[\left(\frac{v_d}{V_T} \right)^3 \frac{1}{3!} \right] + \dots \right]$$

power series expansion of e^{v_d/V_T}

action: eliminate negligible terms

$$(eq4.14) \quad i_D(t) = I_D \left(1 + \frac{v_d}{V_T} \right)$$

$i_D(t) = I_D + \frac{I_D}{V_T} (v_d)$ [L.H. $i_D(t) = I_D + i_d(t)$]
 This is $i_d(t)$

so $i_d(t) = \frac{I_D}{V_T} v_d = \frac{1}{r_d} v_d$
 small signal resistance = $\frac{V_T}{I_D}$