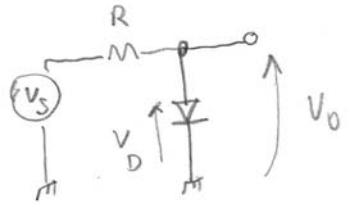
SMALL SIGNAL MODEL (PERTURBATION THEORY FOR SOLVING NONLINEAR DIFF EQU.)

FIRST DIODE CIRCUITS,
THEN TRANSISTOR CIRCUITS



$V_O = V_D$

$I_D = I_S \exp(V_D / V_T)$

LET $V_S = DC + v_{in} = 5V. + v_{in}$

v_{in} is AC, $A \sin \omega t$

KCL at V_O NODE: $\dfrac{5 + v_{in} - V_D}{R} = I_D = I_S \exp(V_D / V_T)$

LET $v_D = V_D + v_d = DC + AC$ $\quad I_D = I_S \exp\left(\frac{V_D}{V_T}\right) \cdot \exp v_d / V_T$

(USE v_d vs v_O FOR BETTER NOTATION) $\quad = I_B \exp(v_d / V_T)$

$$\frac{5 + v_{in} - V_D - v_d}{R} = I_B \exp(v_d / V_T) = I_B + I_B \frac{v_d}{V_T} \quad \text{when } \frac{v_d}{V_T} \ll 1$$

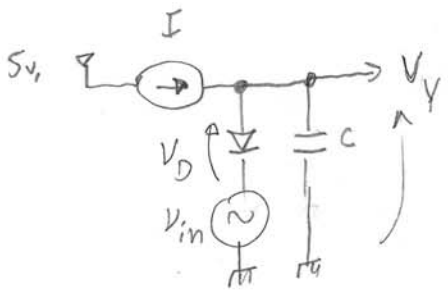
DIVIDE INTO TWO EQUS. (AND TWO CIRCUITS) I_B is DIODE DC CURRENT
ONE DC, ONE AC (LINEAR, SMALL SIGNAL)

$\dfrac{5 - V_D}{R} = I_B$ $\qquad \dfrac{v_{in} - v_d}{R} = \dfrac{v_d}{r_d}$ $\qquad r_d = \dfrac{V_T}{I_B}$ $\qquad v_d = \dfrac{r_d}{r_d + R} v_{in}$

SOLVE FOR V_D, THUS I_B ⇒ FIND r_d, SOLVE AC EQU. FOR v_d

$v_O = v_D$

NEED C, L, etc. to actually get NONLINEAR DIFF EQU.



↙ USE V_y vs V_o FOR SMALL SIGNAL NOTATION

$$I_D = I_S \exp(V_D/V_T)$$

$$I = I_S \exp(V_D/V_T) + C\frac{dV_y}{dt} \quad \text{KCL at } V_y$$

$$v_{in} + V_D = V_y \quad \text{KVL}$$

USE SMALL SIGNAL APPROACH FOR EACH KCL, KVL, THEN SOLVE DC & AC CIRCUITS SEPERATELY! SOLVE DC FIRST (WHY?)

KCL

$$I = I_S \exp[(V_D + v_d)/V_T] + C\frac{d}{dt}(V_y + v_y) = I_B + \frac{v_d}{r_d} + C\frac{d}{dt}v_y$$

$I_B = I_S \exp V_D/V_T$ as before. DC equ. $I = I_B$

AC equ. $0 = v_d/r_d + C\frac{d}{dt}v_y$

KVL

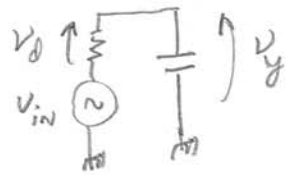
$$v_{in} + V_D + v_d = V_y + v_y$$

DC equ $V_D = V_y$

AC equ. $v_{in} + v_d = v_y$

DC only $I = I_S \exp(V_D/V_T)$ $V_y = V_D$ FIND V_D, V_y FOLLOWS

AC CIRCUIT



v_y is a LOW PASS FILTER OF v_{in}

$$v_y = \frac{1/j\omega C}{1/j\omega C + r_d} v_{in} = \frac{v_{in}}{1 + j\omega r_d C}$$