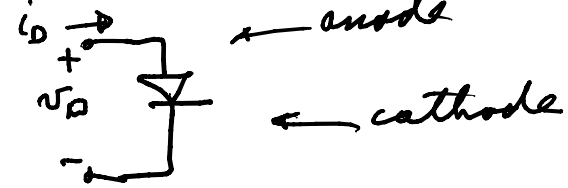
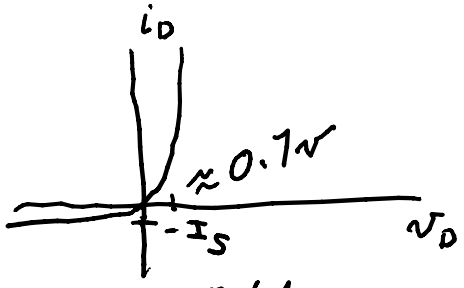
P. 213 = Spice, key D model parameters

D 1N4148

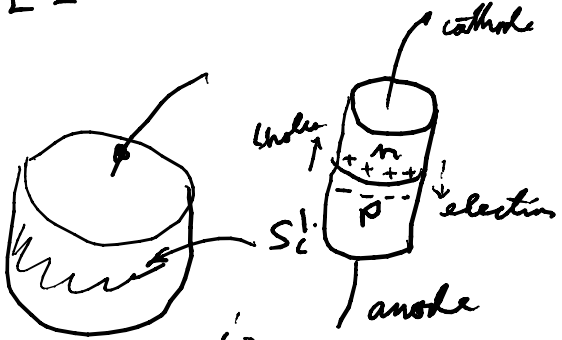
Spice designators:
- D = diode
- Q = bipolar junction transistor
- M = MOS transistor
- G = VCCS
- F = CCCS
- E = VCVS

silicon diode



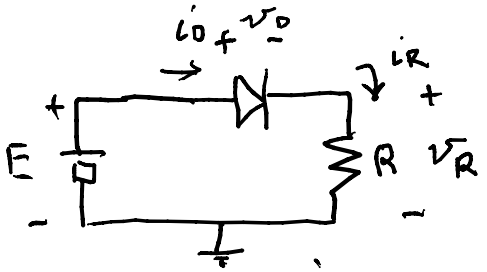


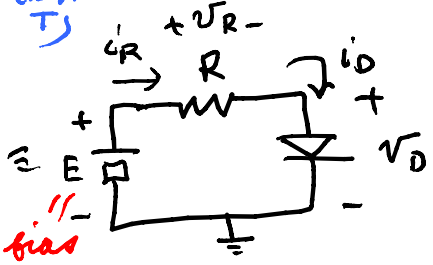
$$i_D = I_S\left(e^{v_D/nV_T} - 1\right)$$

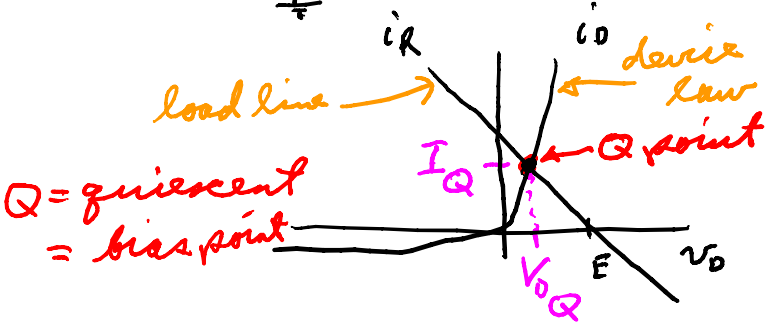


$n \approx 1$ $0.026_v \approx V_T$ = thermal voltage $= kT/|Q|$ electron

Cat room T)



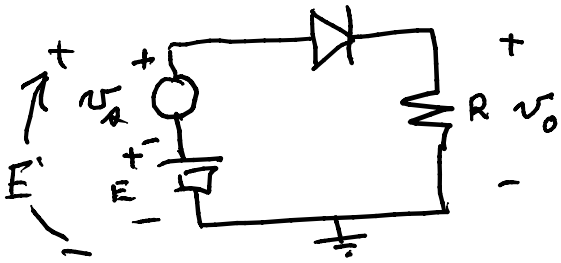


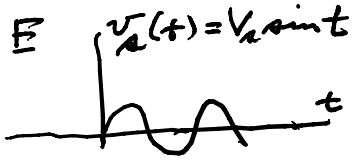


$$0 = -v_D - v_R + E$$
$$= -v_D - Ri_R + E$$
$$Ri_R = -v_D + E$$
$$i_R = G(-v_D + E);\quad G = 1/R$$

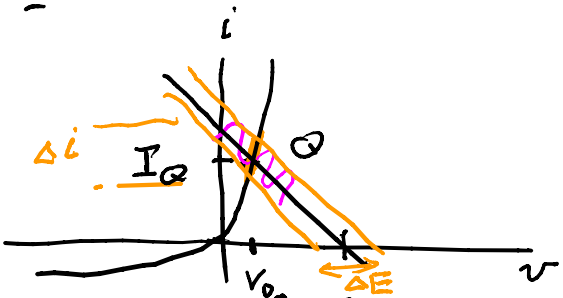
add in signal:

$|v_s| << E$ $\quad v_s(t) = V_s \sin t$



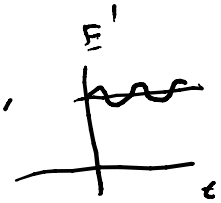


Look for signal at v_o



Make a power series expansion about Q-point

$E \rightarrow E + v_s = E'$



$$\circledast \quad i_D(v_D) = i_D(V_{DQ}) + \left.\frac{\partial i_D}{\partial v_D}\right|_Q (v_D - V_{DQ}) + \underbrace{\frac{1}{2!}\frac{\partial^2 i_D}{\partial v_D^2}(v_D - V_{DQ})^2 + \cdots}_{\text{ignore as } |v_D - V_{DQ}| << E}$$

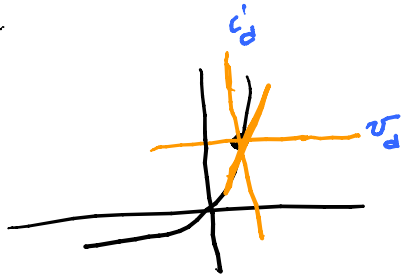
i_D = total current

$i_D(V_{DQ}) = I_D$ = bias current

v_D = total voltage, $V_{DQ} = V_D$ = bias voltage on diode

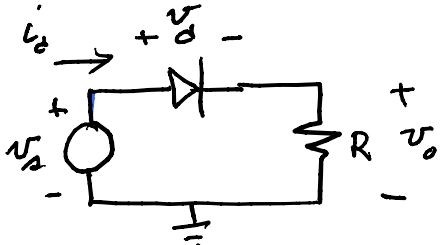
$v_d = v_D - V_D$ = signal component

$= i_D - I_D = i_d$



rewrite $\circledast$ $\quad i_d = \left.\frac{\partial i_D}{\partial v_D}\right|_Q \cdot v_d$

set $\frac{\partial i_D}{\partial v_D} = g_d$ = diode conductance

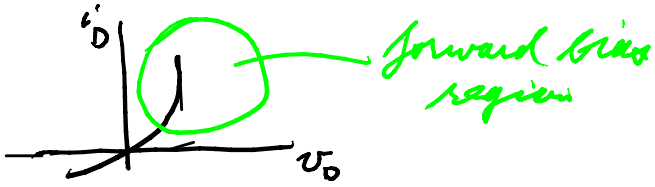


a signal diagram valid for $|v_s| << E$

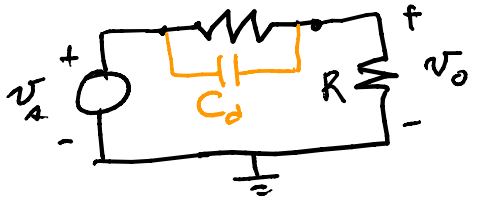
$$i_D = I_S(e^{v_D/V_T} - 1) \Rightarrow \left.\frac{\partial i_D}{\partial v_D}\right|_Q = \left.\frac{I_S}{V_T} e^{v_D/V_T}\right|_Q = \frac{I_S}{V_T} e^{V_D/V_T} \approx \frac{I_D}{V_T} = G_D$$

if forward bias "enough"

$i_D \approx I_S e^{v_D/V_T}$



$R_d = V_T/I_D = \frac{1}{G_D}$



find $\frac{v_o}{v_s} = \frac{R}{R+R_d} = \frac{R}{R+V_T/I_D}$

C_d adds dynamics

replace C_d by its admittance sC_d, $i_{cap} = C_d \frac{dv_o}{dt}$

diode admittance is

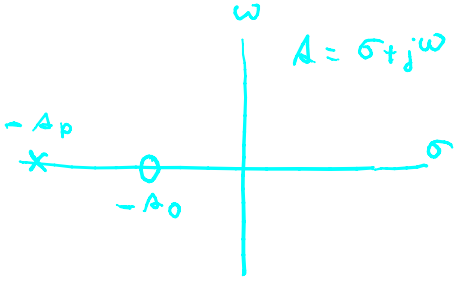
$y_{diode}(s) = G_d + sC_d = \frac{I_D}{V_T} + sC_d$ $\Rightarrow$ impedance $z_{diode}(s) = \frac{1}{y_{diode}(s)} = \frac{1}{sC_d+G_d}$

$\frac{v_o}{v_s}(s) = \frac{R}{R+\frac{1}{sC_d+G_d}} = \frac{R(sC_d+G_d)}{R(sC_d+G_d)+1}$

has zeros & poles

zero at $s_o = -G_d/C_d$

pole at $s_p = -\frac{(1+G_dR)}{RC_d} = -s_o - \frac{1}{RC_d}$



$\frac{v_o}{v_s}(s) = \frac{s-s_o}{s-s_p}$