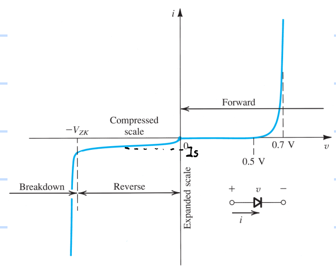
Quantity	Relationship	Value (T=300K for intrinsic Si)
Carrier concentration in intrinsic silicon (cm^{-3})	$n_i = BT^{\frac{3}{2}} e^{-\frac{E_g}{2kT}}$	$B = 7.3\times10^{15} cm^{-3}K^{-\frac{3}{2}}$, $E_g = 1.12eV$, $k = 8.62\times10^{-5} eV/K$, $n_i = 1.5\times10^{10}/cm^3$
Diffusion current density (A/cm^2)	$J_{drift} = q(p\mu_p + n\mu_n)E$	$\mu_p = 480 cm^2/V\cdot s$, $\mu_n = 1350 cm^2/V\cdot s$; μ_p, μ_n decrease when doping concentration increase
Resistivity ($\Omega\cdot cm$)	$\rho = \frac{1}{q(p\mu_p + n\mu_n)}$	
Relationship between mobility and diffusivity	$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T$	$V_T = \frac{kT}{q} \approx 25.9mV$
Carrier concentration in n-type silicon (cm^{-3})	$n_{no} \approx N_D$, $p_{no} = \frac{n_i^2}{N_D}$	
Carrier concentration in p-type silicon (cm^{-3})	$p_{po} \approx N_A$, $n_{po} = \frac{n_i^2}{N_A}$	
Junction built-in voltage (V)	$V_o = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$	
Width of depletion region (cm)	$\frac{x_n}{x_p} = \frac{N_A}{N_D}$, $W = x_n + x_p = \sqrt{\frac{2\varepsilon_s}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)(V_o+V_R)}$	$\varepsilon_s = 11.7\varepsilon_0$, $\varepsilon_0 = 8.854\times10^{-14} F/cm$
Charge stored in depletion layer (C)	$Q_J = q\frac{N_A N_D}{N_A+N_D}AW$	
Forward current (A)	$I = I_p + I_n$, $I_p = Aqn_i^2\frac{D_p}{L_p N_D}(e^{\frac{V}{V_T}}-1)$, $I_n = Aqn_i^2\frac{D_n}{L_n N_A}(e^{\frac{V}{V_T}}-1)$	
Saturation current (A)	$I_S = Aqn_i^2\left(\frac{D_p}{L_p N_D}+\frac{D_n}{L_n N_A}\right)$	
I-V relationship	$I = I_S(e^{\frac{V}{V_T}}-1)$	
Minority carrier lifetime (s)	$\tau_p = \frac{L_p^2}{D_p}$, $\tau_n = \frac{L_n^2}{D_n}$	$L_p, L_n = 1\mu m \sim 100\mu m$, $\tau_p, \tau_n = 1ns \sim 10^4 ns$
Minority carrier charge storage (C)	$Q_p = \tau_p I_p$, $Q_n = \tau_n I_n$, $Q = Q_p + Q_n = \tau_T I$	
Depletion capacitance (F)	$C_{jo} = A\sqrt{\left(\frac{\varepsilon_s q}{2}\right)\left(\frac{N_A N_D}{N_A+N_D}\right)\frac{1}{V_o}}$, $C_j = \frac{C_{jo}}{\left(1+\frac{V_R}{V_o}\right)^m}$	$m = \frac{1}{3} \sim \frac{1}{2}$
Diffusion capacitance (F)	$C_d = \left(\frac{\tau_T}{V_T}\right)I$	

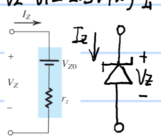


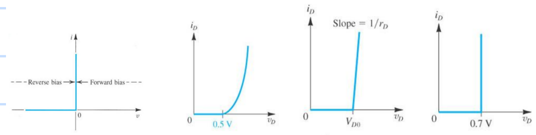
$i = I_S(e^{\frac{v}{V_T}}-1)$, $V_T = \frac{kT}{q}$

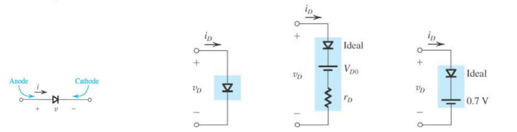
I_S doubles every 5°C rise

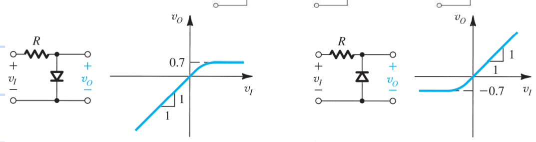
for fixed i, v drops 2mV every 1°C rise

$V_2 - V_1 = 2.3V_T \log\frac{I_2}{I_1}$



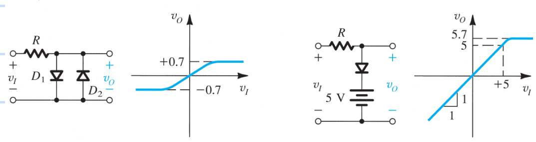






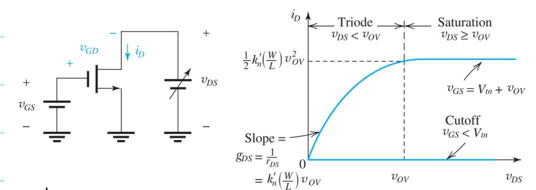
(a)

(b)



(c)

(d)



n-type

- $v_{GS} < V_{tn}$: no channel; transistor in cutoff; $i_D = 0$
- $v_{GS} = V_{tn} + v_{OV}$: a channel is induced; transistor operates in the triode region or the saturation region depending on whether the channel is continuous or pinched off at the drain end;

$k_n' = \mu_n C_{ox}$

$k_n = k_n'\left(\frac{W}{L}\right)$

Triode Region

Continuous channel, obtained by:

$v_{GD} > V_{tn}$

or equivalently:

$v_{DS} < v_{OV}$

Then,

$i_D = k_n'\left(\frac{W}{L}\right)\left[(v_{GS}-V_{tn})v_{DS} - \frac{1}{2}v_{DS}^2\right]$

or equivalently,

$i_D = k_n'\left(\frac{W}{L}\right)\left(v_{OV} - \frac{1}{2}v_{DS}\right)v_{DS}$

Saturation Region

Pinched-off channel, obtained by:

$v_{GD} \leq V_{tn}$

or equivalently:

$v_{DS} \geq v_{OV}$

Then

$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(v_{GS}-V_{tn})^2$

or equivalently,

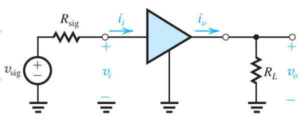
$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)v_{OV}^2$

p-type: use V_{SD}, V_{SG}, $|V_{OV}|$, $|V_{tp}|$, $|V_A|$, $|\lambda|$.

Channel-length modulation: $i_D = \frac{1}{2}k_n C_{ox}\left(\frac{W}{L}\right)V_{ov}^2(1+\lambda V_{DS})$

$V_A = \frac{1}{\lambda} = V_A' L$, $r_o = \frac{1}{\lambda I_D} = \frac{V_A}{I_D}$

$g_m = \mu_n C_{ox}\left(\frac{W}{L}\right)V_{ov} = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right)I_D} = \frac{2I_D}{V_{ov}}$



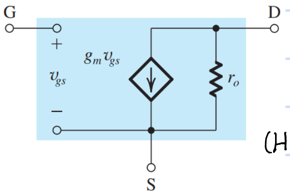
$R_{in} = \frac{V_i}{i_i}$

$R_{out} = \frac{V_t}{i_t}\Big|_{V_i=0}$

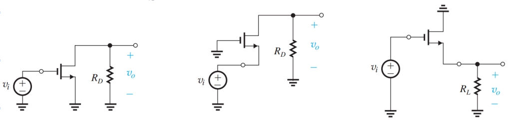
$A_v = \frac{V_o}{V_i}$

$A_i = \frac{i_o}{i_i}$

$G_m = \frac{i_o}{V_i}\Big|_{R_L=0}$



(Hybrid π model)



(a) Common Source (CS)

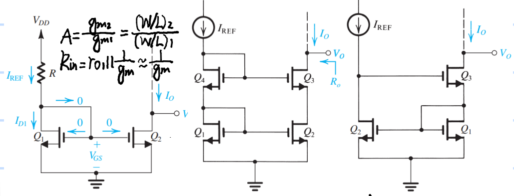
(b) Common Gate (CG)

(c) Common Drain (CD) or Source Follower

(r_o not included)

Characteristics[a]

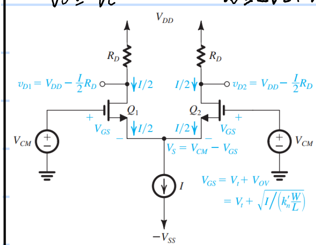
Amplifier type	R_{in}	A_{vo}	R_o	A_v	G_v
Common source (Fig. 7.35) gm stage	∞	$-g_m R_D$	R_D	$-g_m(R_D \parallel R_L)$	$-g_m(R_D \parallel R_L)$
Common source with R_s (Fig. 7.37)	∞	$-\frac{g_m R_D}{1+g_m R_s}$	R_D	$\frac{-g_m(R_D \parallel R_L)}{1+g_m R_s}$ $-\frac{R_D \parallel R_L}{1/g_m + R_s}$	$\frac{-g_m(R_D \parallel R_L)}{1+g_m R_s}$ $-\frac{R_D \parallel R_L}{1/g_m + R_s}$
Common gate (Fig. 7.39) current buffer	$\frac{1}{g_m}$	$g_m R_D$	R_D	$g_m(R_D \parallel R_L)$	$\frac{R_D \parallel R_L}{R_{sig}+1/g_m}$
Source follower (Fig. 7.42) voltage buffer	∞	1	$\frac{1}{g_m}$	$\frac{R_L}{R_L+1/g_m}$	$\frac{R_L}{R_L+1/g_m}$



$A = \frac{g_{m2}}{g_{m1}} = \frac{(W/L)_2}{(W/L)_1}$

$R_{in} = r_{o1} \| \frac{1}{g_m} \approx \frac{1}{g_m}$

Current mirror	Cascode mirror	Wilson mirror
$\frac{I_O}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$	$\frac{I_O}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$	$\frac{I_O}{I_{REF}} = \frac{(W/L)_1}{(W/L)_2}$
$R_o = r_{o2}$	$R_o = g_{m3}r_{o3}r_{o2}$	$R_o = g_{m3}r_{o3}r_{o2}$
$V_o \geq V_t$	$V_o \geq 2V_t + V_{ov}$	$V_o \geq 2V_t + V_{ov}$



$V_S = V_{CM} - V_{GS}$

$V_{OV} = V_{GS} - V_t$

$\frac{I}{2} = \frac{1}{2}k_n'\left(\frac{W}{L}\right)V_{OV}^2$

$V_{OV} = \sqrt{\frac{I}{k_n'(W/L)}}$

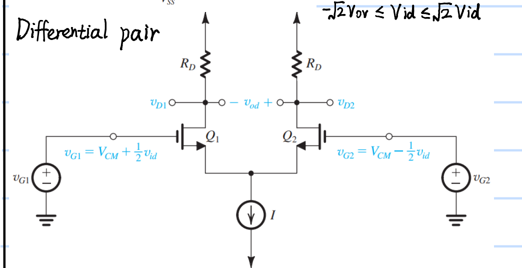
$V_{D1} = V_{D2} = V_{DD} - \frac{I}{2}R_D$

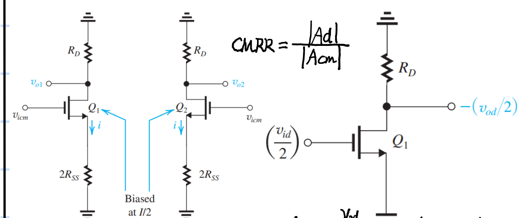
$V_{CMmax} = V_t + V_{DD} - \frac{I}{2}R_D$

$V_{CMmin} = -V_{SS} + V_{CS} + V_t + V_{OV}$

$-\sqrt{2}V_{OV} \leq V_{id} \leq \sqrt{2}V_{id}$

Differential pair





$CMRR = \frac{|A_d|}{|A_{cm}|}$

$A_d = \frac{V_{od}}{V_{id}} = g_m(R_D \| r_o)$

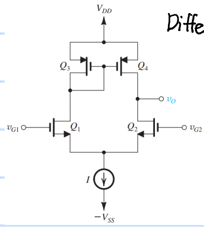
Differential ended: $A_{cm} = 0$ $\quad$ $CMRR = 0$

Single ended: $A_{cm} = \frac{V_{o1}}{V_{icm}} = -\frac{R_D}{2R_{SS}}$ $\quad$ $CMRR \approx 2g_m R_{SS}$

Mismatch ΔR_D, $\quad V_{od} = V_{o2} - V_{o1} = -\frac{\Delta R_D}{2R_{SS}}V_{icm}$

$A_{cm} = -\frac{\Delta R_D}{2R_{SS}}$, $CMRR \approx 2g_m R_{SS} \cdot \frac{R_D}{\Delta R_D}$

Mismatch Δg_m, $\quad A_{cm} \approx \frac{R_D}{2R_{SS}}\left(\frac{\Delta g_m}{g_m}\right)$, $CMRR = 2g_m R_{SS} \cdot \frac{g_m}{\Delta g_m}$



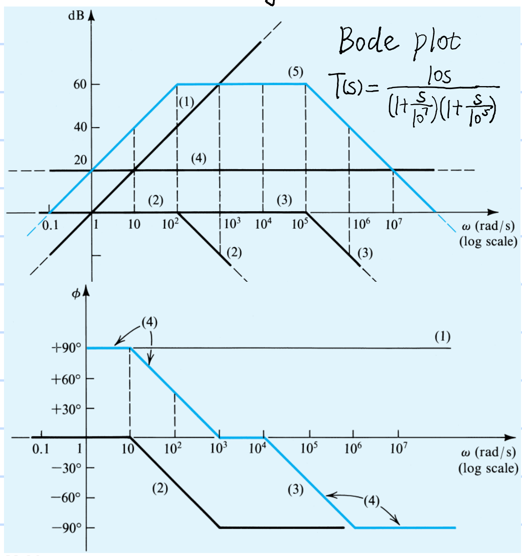
Differential pair with current mirror

$G_m = g_{m1,2}$

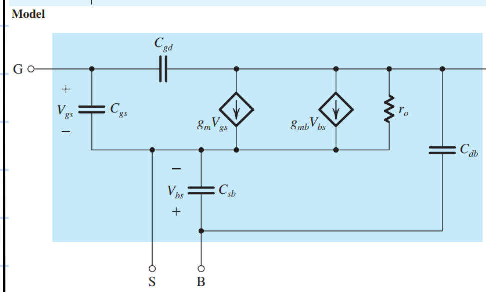
$R_o = r_{o1} \| r_{o2}$

$A_d = \frac{V_o}{V_{id}} = G_m R_o = g_{m1,2}(r_{o2} \| r_{o4})$

$A_d = \frac{1}{2}g_m r_o = \frac{1}{2}A_0$ $\quad (r_{o2} = r_{o4} = r_o)$



Model



Model Parameters

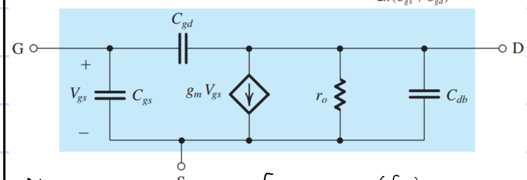
$g_m = \mu_n C_{ox}\frac{W}{L}|V_{OV}| = \sqrt{2\mu_n C_{ox}\frac{W}{L}I_D} = \frac{2I_D}{|V_{OV}|}$ $\qquad C_{sb} = \frac{C_{sb0}}{\sqrt{1+\frac{|V_{SB}|}{V_0}}}$

$g_{mb} = \chi g_m, \quad \chi = 0.1 \text{ to } 0.2$

$r_o = |V_A|/I_D$ $\qquad$ High frequency small signal model $\qquad C_{db} = \frac{C_{db0}}{\sqrt{1+\frac{|V_{DB}|}{V_0}}}$

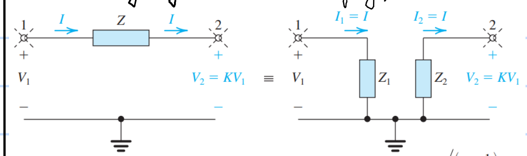
$C_{gs} = \frac{2}{3}WLC_{ox} + WL_{ov}C_{ox}$

$C_{gd} = WL_{ov}C_{ox}$ $\qquad f_T = \frac{g_m}{2\pi(C_{gs}+C_{gd})}$

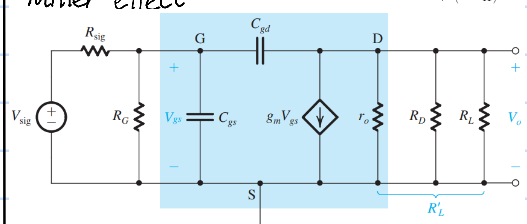


MOSFET unity-gain frequency (f_T)

$\left|\frac{I_o}{I_i}\right| = \frac{g_m}{s(C_{gs}+C_{gd})} = 1 \Rightarrow \omega_T = \frac{g_m}{\omega(C_{gs}+C_{gd})}$, $f_T = \frac{\omega_T}{2\pi}$



Miller effect $\qquad Z_1 = Z/(1-K)$, $\quad Z_2 = Z\Big/\left(1-\frac{1}{K}\right)$



CS amplifier

$A_M = -\frac{R_G}{R_G+R_{sig}}(g_m R_L')$ $\quad$ (set $C_{gs} = C_{gd} = 0$)

$\frac{V_o}{V_{sig}} = \frac{A_M}{1+\frac{s}{\omega_H}}$, where $\omega_H = C_{in}R_{sig}' = [C_{gs}+C_{gd}(1+g_m R_L')](R_{sig} \| R_G)$

When $R_{sig} \approx 0$, $\frac{V_o}{V_{sig}} = -g_m R_L' \frac{1-\frac{s C_{gd}}{g_m}}{1+s(C_L+C_{gd})R_L'}$

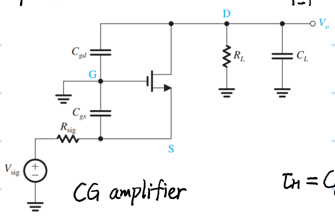
$f_Z = \frac{g_m}{2\pi C_{gd}}$, $f_H = \frac{1}{2\pi(C_L+C_{gd})R_L'}$, $f_t = |A_M| f_H = \frac{g_m}{2\pi(C_L+C_{gd})}$

High-frequency gain function $F_H(s)=\frac{(1+\frac{s}{\omega_{Z1}})(1+\frac{s}{\omega_{Z2}})\cdots(1+\frac{s}{\omega_{Zn}})}{(1+\frac{s}{\omega_{P1}})(1+\frac{s}{\omega_{P2}})\cdots(1+\frac{s}{\omega_{Pn}})}$

$A(s)=A_M F_H(s)$, dominant pole: $F_H(s)\approx\frac{1}{1+\frac{s}{\omega_{P1}}}$, $\omega_H\approx\omega_{P1}$

no dominant pole: $\omega_H\approx 1/\sqrt{(\frac{1}{\omega_{P1}^2}+\frac{1}{\omega_{P2}^2}+\cdots)-2(\frac{1}{\omega_{Z1}^2}+\frac{1}{\omega_{Z2}^2}+\cdots)}$

Open-circuit time constant $\tau_H=\sum_{i=1}^{n}C_iR_i$, $\omega_H\approx\frac{1}{\tau_H}$



CG amplifier

neglect r_o:

$f_{P1}=\frac{1}{2\pi C_{gs}(R_{sig}\|\frac{1}{g_m})}$

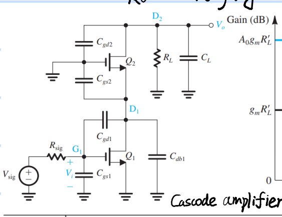
$f_{P2}=\frac{1}{2\pi(C_{gd}+C_L)R_L}$

$\tau_H=C_{gs}(R_{sig}\|\frac{1}{g_m})+(C_L+C_{gd})R_L$

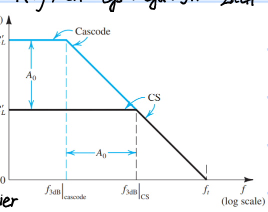
$f_H=\frac{1}{2\pi\tau_H}=\frac{1}{\frac{1}{f_{P1}}+\frac{1}{f_{P2}}}$

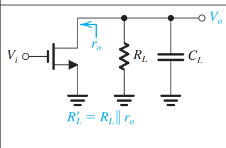
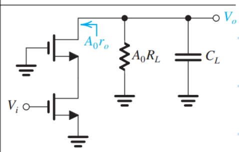
Consider r_o, $R_{gs}=R_{sig}\|R_{in}$, $R_{in}=\frac{r_o+R_L}{1+g_mr_o}\approx\frac{r_o+R_L}{g_mr_o}$, $R_{gd}=R_L\|R_o$

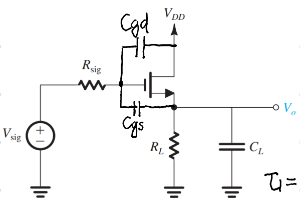
$R_o=r_o+R_{sig}+g_mr_oR_{sig}$, $\tau_H=\tau_{gs}+\tau_{gd}$, $f_H=\frac{1}{2\pi\tau_H}$



Cascode amplifier



	Common Source	Cascode
Circuit		
DC Gain	$-g_mR_L'$	$-A_0g_mR_L'$
f_{3dB}	$\frac{1}{2\pi(C_L+C_{gd})R_L'}$	$\frac{1}{2\pi(C_L+C_{gd})A_0R_L'}$
f_t	$\frac{g_m}{2\pi(C_L+C_{gd})}$	$\frac{g_m}{2\pi(C_L+C_{gd})}$



CD amplifier

$\frac{V_o}{V_{sig}}=A_M\frac{1+\frac{s}{\omega_Z}}{1+T_1s+T_2s^2}$

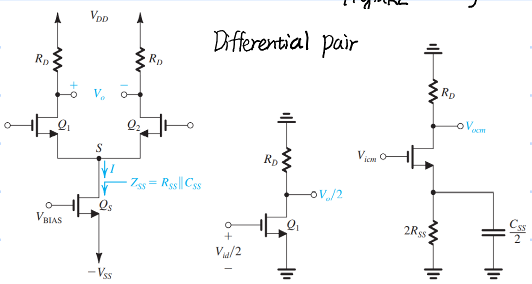
$A_M=\frac{g_mR_L'}{1+g_mR_L'}$

$\omega_Z=\frac{g_m}{C_{gs}}$

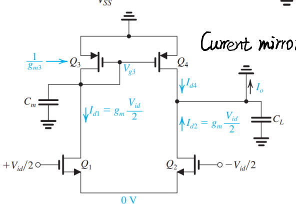
$T_1=(C_{gd}+\frac{C_{gs}}{1+g_mR_L'})R_{sig}+(\frac{C_{gs}+C_L}{1+g_mR_L'})R_L'$

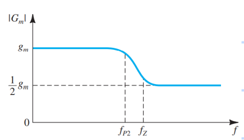
$T_2=\frac{(C_{gs}+C_{gd})C_L+C_{gs}C_{gd}}{1+g_mR_L'}R_{sig}R_L'$

Differential pair



Current mirror loaded differential pair





Feedback (negative)

$x_f=\beta x_o$

$x_i=x_s-x_f$

$A_f=\frac{x_o}{x_s}=\frac{A}{1+A\beta}$

for positive: $A_f=\frac{A}{1-A\beta}$

A: open loop gain, $A\beta$: loop gain, A_f: closed loop gain

$A\beta>>1$: deep feedback, $A_f\approx\frac{1}{\beta}$

Gain desensitivity: $\frac{dA_f}{A_f}=\frac{1}{(1+A\beta)}\frac{dA}{A}$, $\frac{1}{1+A\beta}$: desensitivity factor

Feedback effect: control input & output impedence

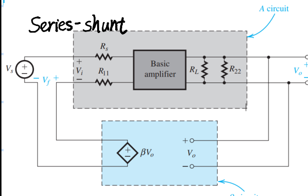
(stronger linearity) reduce non-linear distortion

$A(s)=\frac{A_M}{1+\frac{s}{\omega_H}}$ extend bandwidth $\omega_{Hf}=\omega_H(1+A_M\beta)$

Find $A\beta$: set $x_s=0$, cut off, give x_t, $A\beta=-\frac{x_r}{x_t}$

Feedback Amplifier	Feedback Topology	x_i	x_o	x_f	x_s	A	β	A_f	R_{if}	R_{of}	Refer to Figs.
Voltage	Series–shunt	V_i	V_o	V_f	V_s	$\frac{V_o}{V_i}$	$\frac{V_f}{V_o}$	$\frac{V_o}{V_s}$	$R_i(1+A\beta)$	$\frac{R_o}{1+A\beta}$	11.12 11.14
Current	Shunt–series	I_i	I_o	I_f	I_s	$\frac{I_o}{I_i}$	$\frac{I_f}{I_o}$	$\frac{I_o}{I_s}$	$\frac{R_i}{1+A\beta}$	$R_o(1+A\beta)$	11.25 11.26
Transconductance	Series–series	V_i	I_o	V_f	V_s	$\frac{I_o}{V_i}$	$\frac{V_f}{I_o}$	$\frac{I_o}{V_s}$	$R_i(1+A\beta)$	$R_o(1+A\beta)$	11.18 11.19
Transresistance	Shunt–shunt	I_i	V_o	I_f	I_s	$\frac{V_o}{I_i}$	$\frac{I_f}{V_o}$	$\frac{V_o}{I_s}$	$\frac{R_i}{1+A\beta}$	$\frac{R_o}{1+A\beta}$	11.22 11.23

Series-shunt

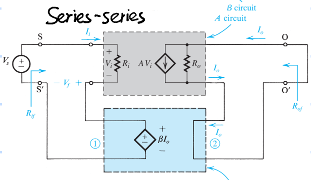


$A=\frac{V_o}{V_i}$, $\beta=\frac{V_f}{V_o}\Big|_{I_i=0}$

$R_{in}=R_{if}-R_s$

$R_{out}=\frac{1}{(\frac{1}{R_{of}}-\frac{1}{R_L})}$

Series-series

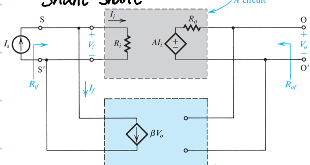


$A=\frac{I_o}{V_i}$, $\beta=\frac{V_f}{I_o}\Big|_{I_i=0}$

$R_{in}=R_{if}-R_s$

$R_{out}=R_{of}-R_L$

Shunt-shunt

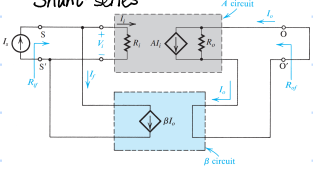


$A=\frac{V_o}{I_i}$, $\beta=\frac{I_f}{V_o}\Big|_{V_i=0}$

$R_{in}=\frac{1}{(\frac{1}{R_{if}}-\frac{1}{R_s})}$

$R_{out}=\frac{1}{(\frac{1}{R_{of}}-\frac{1}{R_L})}$

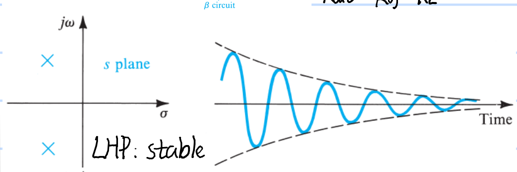
Shunt-series



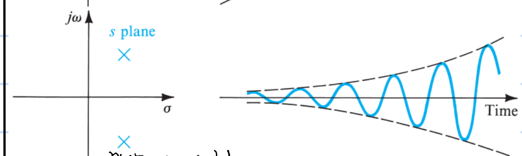
$A=\frac{I_o}{I_i}$, $\beta=\frac{I_f}{I_o}\Big|_{V_i=0}$

$R_{in}=\frac{1}{(\frac{1}{R_{if}}-\frac{1}{R_s})}$

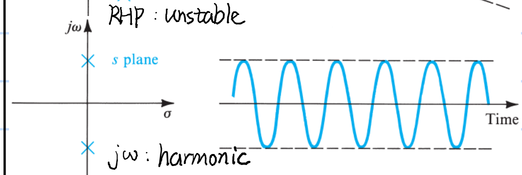
$R_{out}=R_{of}-R_L$



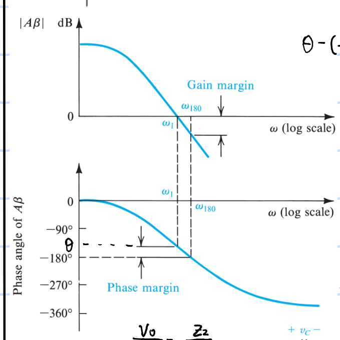
LHP: stable



RHP: unstable



$j\omega$: harmonic



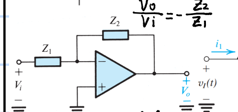
$\theta-(-180°)$ = phase margin

If $|A\beta|=0dB/1dB$, oscillation happens.

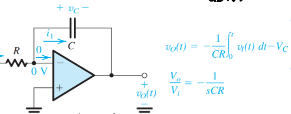
For good stability, phase margin $>60°$

$PM=90°-\arctan(\frac{GBW}{f_{P2}})=\arctan(\frac{f_{P2}}{GBW})$

$\frac{V_o}{V_i}=-\frac{Z_2}{Z_1}$



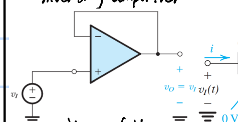
inverting amplifier



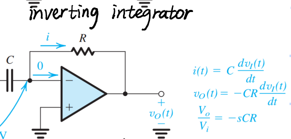
$v_O(t)=-\frac{1}{CR}\int_0^t v_I(t)\,dt-V_C$

$\frac{V_o}{V_i}=-\frac{1}{sCR}$

inverting integrator



voltage follower



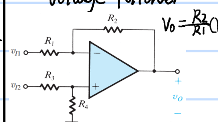
$i(t)=C\frac{dv_I(t)}{dt}$

$v_O(t)=-CR\frac{dv_I(t)}{dt}$

$\frac{V_o}{V_i}=-sCR$

inverting differentiator

$V_o=\frac{R_2}{R_1}(V_{I2}-V_{I1})$



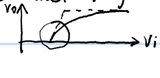
difference amplifier

PSRR: power supply rejection ratio

dependency on power supply change

$PSRR_{dd}=\frac{A_{dm}}{A_{dd}}$, $PSRR_{ss}=\frac{A_{dm}}{A_{ss}}$

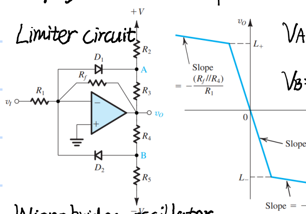
Slew rate: large signal behavior



Oscillator: positive feedback $A_f(s)=\frac{A(s)}{1-A(s)\beta(s)}$

Loop gain $L(s)=A(s)\beta(s)$, then $1-L(s)=0$

Limiter circuit



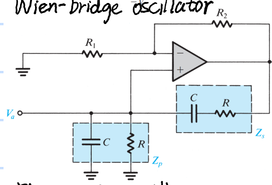
$V_A=V\frac{R_3}{R_2+R_3}+V_D\frac{R_2}{R_2+R_3}$

$V_B=-V\frac{R_4}{R_4+R_5}+V_D\frac{R_5}{R_4+R_5}$

$V_A=-V_D$, L_-

$V_B=V_D$, L_+

Wien-bridge oscillator

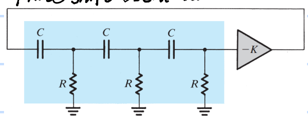


$L(s)=(1+\frac{R_2}{R_1})\frac{Z_p}{Z_p+Z_s}=\frac{1+\frac{R_2}{R_1}}{3+sCR+\frac{1}{sCR}}$

$L(j\omega)=\frac{1+\frac{R_2}{R_1}}{3+j(\omega CR-\frac{1}{\omega CR})}$

so $\omega=\frac{1}{CR}$, $\frac{R_2}{R_1}=2$

Phase-shift oscillator

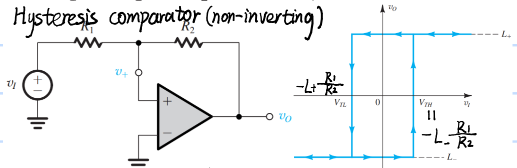


$\frac{V_{k+1}}{V_k}=\frac{R}{R+\frac{1}{sC}}$

Each shift $<90°$

Three make $180°$

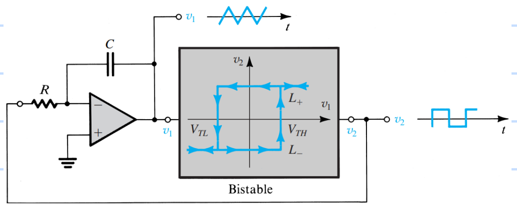
Hysteresis comparator (non-inverting)

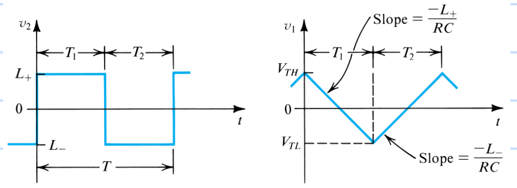


$V_{TL}=-L_+\frac{R_1}{R_2}$

$V_{TH}=-L_-\frac{R_1}{R_2}$

$V_+=V_I\frac{R_2}{R_1+R_2}+V_O\frac{R_1}{R_1+R_2}$, $V_+>0$, $V_O=L_+\Rightarrow V_{TH}$





$\frac{V_{TH}-V_{TL}}{T_1}=\frac{L_+}{CR}$, $T_1=CR\frac{V_{TH}-V_{TL}}{L_+}$

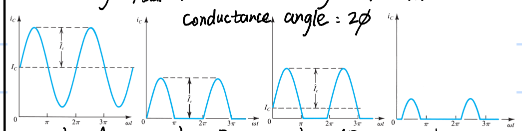
$\frac{V_{TH}-V_{TL}}{T_2}=\frac{-L_-}{CR}$, $T_2=CR\frac{V_{TH}-V_{TL}}{-L_-}$

Power amplifier efficiency

drain: $\eta_{drain}=\frac{P_{RFout}}{P_{DC}}$, power added: $\eta=\frac{P_{RFout}-P_{RFin}}{P_{DC}}$

ideal: $\eta=\frac{P_{out}}{P_{total}}=1$, overall: $\eta=\frac{P_{RFout}}{P_{DC}+P_{RFin}}$

Conductance angle: 2ϕ



class A 360°, class B 180°, class AB >180° slightly, class C <180°

	NMOS	BJT (npn)
Transconductance g_m	$g_m=I_D/(V_{OV}/2)$ $g_m=(\mu_nC_{ox})\left(\frac{W}{L}\right)V_{OV}$ $g_m=\sqrt{2(\mu_nC_{ox})\left(\frac{W}{L}\right)I_D}$	$g_m=I_C/V_T$
Output Resistance r_o	$r_o=V_A/I_D=\frac{V_A'L}{I_D}$	$r_o=V_A/I_C$
Intrinsic Gain $A_0\equiv g_mr_o$	$A_0=V_A/(V_{OV}/2)$ $A_0=\frac{2V_A'L}{V_{OV}}$ $A_0=\frac{V_A'\sqrt{2\mu_nC_{ox}WL}}{\sqrt{I_D}}$	$A_0=V_A/V_T$
Input Resistance with Source (Emitter) Grounded	∞	$r_\pi=\beta/g_m$
Capacitances	$C_{gs}=\frac{2}{3}WLC_{ox}+WL_{ov}C_{ox}$ $C_{gd}=WL_{ov}C_{ox}$	$C_\pi=C_{de}+C_{je}$ $C_{de}=\tau_Fg_m$ $C_{je}\simeq 2C_{je0}$ $C_\mu=C_{\mu0}/\left[1+\frac{V_{CB}}{V_{C0}}\right]^m$
Transition Frequency f_T	$f_T=\frac{g_m}{2\pi(C_{gs}+C_{gd})}$ For $C_{gs}\gg C_{gd}$ and $C_{gs}\simeq\frac{2}{3}WLC_{ox}$, $f_T\simeq\frac{1.5\mu_nV_{OV}}{2\pi L^2}$	$f_T=\frac{g_m}{2\pi(C_\pi+C_\mu)}$ For $C_\pi\gg C_\mu$ and $C_\pi\simeq C_{de}$, $f_T\simeq\frac{2\mu_nV_T}{2\pi W_B^2}$