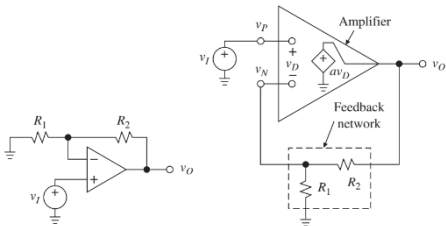
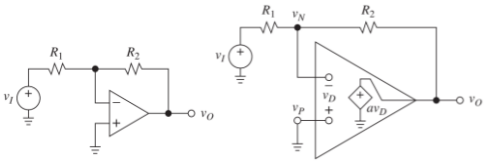
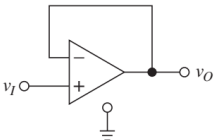


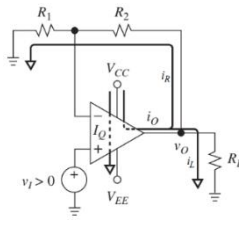
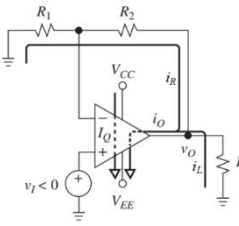
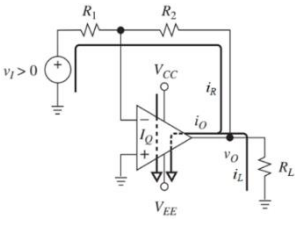
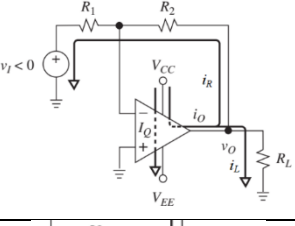
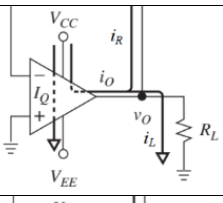
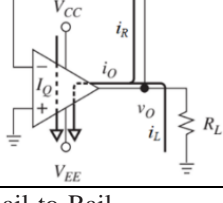
Configurații de bază realizate cu AO

Definiția AO	Amplificatorul operațional este un amplificator de tensiune cu câștig extrem de mare	
Configurația neinversoare		$v_O = a(v_P - v_N)$ $A = \frac{v_O}{v_I} = \left(1 + \frac{R_2}{R_1}\right) \frac{1}{1 + (1 + R_2/R_1)/a}$ $A_{ideal} = \lim_{a \rightarrow \infty} A = 1 + \frac{R_2}{R_1}$ $R_i \rightarrow \infty$ $R_o = 0$
Configurația inversoare		$v_O = a(v_P - v_N)$ $A = \frac{v_O}{v_I} = \left(-\frac{R_2}{R_1}\right) \frac{1}{1 + (1 + R_2/R_1)/a}$ $A_{ideal} = \lim_{a \rightarrow \infty} A = -\frac{R_2}{R_1}$ $R_i = R_1$ $R_o = 0$
Repetorul	<p>Este un caz particular de amplificator neinversor la care $R_1 \rightarrow \infty$ (se elimină și rămâne gol) și $R_2=0$ (se elimină și se pune în loc un scurtcircuit)</p> 	$A = 1 V/V$ $R_i \rightarrow \infty$ $R_o = 0$

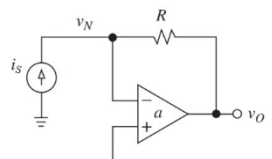
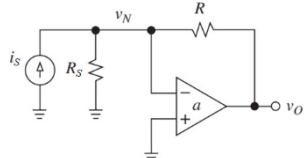
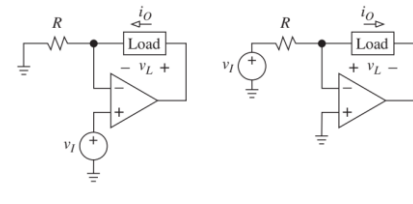
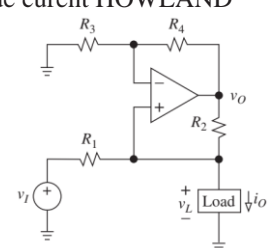
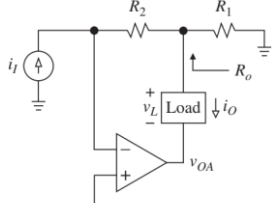
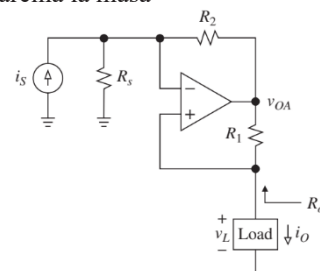
Circuite realizate cu AO ideal

AO ideal		<p>Presupunerile de idealitate și consecințe:</p> $i_P = i_N = 0 \Rightarrow r_d \rightarrow \infty$ $r_o \rightarrow 0 \Rightarrow v_O = a v_D$ $\lim_{a \rightarrow \infty} v_D = \lim_{a \rightarrow \infty} \frac{v_O}{a} = 0$ $v_D = v_P - v_N$ $v_N = v_P - v_D = v_P - \frac{v_O}{a} \Rightarrow \lim_{a \rightarrow \infty} v_N = v_P$
Amplificatorul sumator		$i_1 + i_2 + i_3 = i_F$ $v_O = -\left(\frac{R_F}{R_1} v_1 + \frac{R_F}{R_2} v_2 + \frac{R_F}{R_3} v_3\right)$ $R_{ik} = R_k, k = 1, 2, 3$ $R_O = 0$ $R_3 = R_2 = R_1 \Rightarrow v_O = -\frac{R_F}{R_1} (v_1 + v_2 + v_3)$ $R_F = R_3 = R_2 = R_1 \Rightarrow v_O = -(v_1 + v_2 + v_3)$
Amplificatorul de diferență		$v_O = \frac{R_4}{R_3 + R_4} \left(1 + \frac{R_2}{R_1}\right) v_2 - \frac{R_2}{R_1} v_1$ $v_O = \frac{R_2}{R_1} \left(\frac{1 + R_1/R_2}{1 + R_3/R_4} v_2 - v_1\right)$ $R_{i1} = R_1$ $R_{i2} = R_3 + R_4$ $R_O = 0$ $\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow v_O = \frac{R_2}{R_1} (v_2 - v_1)$
Diferențiatorul		$C \frac{d(v_I - 0)}{dt} = \frac{0 - v_O}{R} \Rightarrow v_O(t) = -RC \frac{dv_I}{dt}$
Integratorul		$\frac{v_I - 0}{R} = C \frac{d(0 - v_O)}{dt}$ $v_O = -\frac{1}{RC} \int_0^t v_I(\xi) d\xi + v_O(0)$ $R_i = R$ $R_O = 0$

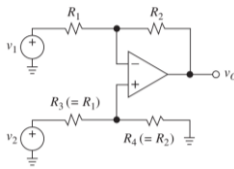
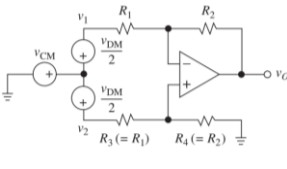
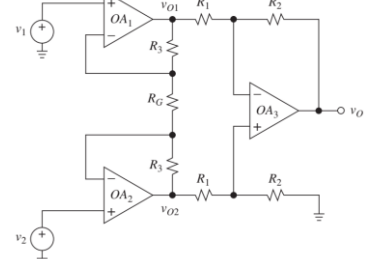
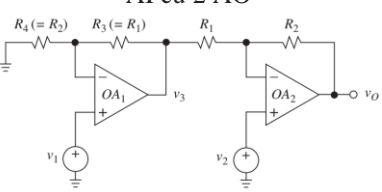
Alimentarea AO, puterea disipată, saturația

Amplificator neinversor, $v_I > 0$		$i_{CC} = i_{EE} + i_O = I_Q + i_O$ $i_{EE} = I_Q$ $i_O = i_L + i_R$ unde I_Q = curentul static de alimentare i_O = curentul de la ieșirea AO i_L = curentul prin sarcina R_L i_R = curentul prin rețeaua de reacție R_1, R_2 $i_L = \frac{v_O}{R_L}$ $i_R = \frac{v_O}{R_1 + R_2} = \frac{v_I}{R_1}$
Amplificator neinversor, $v_I < 0$		$i_{EE} = i_{CC} + i_O = I_Q + i_O$ $i_{CC} = I_Q$ $i_O = i_L + i_R$ $i_L = \frac{ v_O }{R_L}$ $i_R = \frac{ v_O }{R_1 + R_2} = \frac{ v_I }{R_1}$
Amplificator inversor, $v_I > 0$		$i_{EE} = i_{CC} + i_O = I_Q + i_O$ $i_{CC} = I_Q$ $i_O = i_L + i_R$ $i_L = \frac{ v_O }{R_L}$ $i_R = \frac{v_I}{R_1} = \frac{0 - v_O}{R_2}$
Amplificator inversor, $v_I < 0$		$i_{CC} = i_{EE} + i_O = I_Q + i_O$ $i_{EE} = I_Q$ $i_O = i_L + i_R$ $i_L = \frac{v_O}{R_L}$ $i_R = \frac{0 - v_I}{R_1} = \frac{v_O}{R_2}$
Puterea disipată		$v_O > 0$ $P_D = I_Q(V_{CC} - V_{EE}) + i_O(V_{CC} - v_O)$
		$v_O < 0$ $P_D = I_Q(V_{CC} - V_{EE}) + i_O(v_O - V_{EE})$
Saturația	AO de tipul Rail-to-Rail $V_{OH} \cong V_{CC}$ (sau V_{DD}) - saturația pozitivă $V_{OL} \cong V_{EE}$ (sau V_{SS}) - saturația negativă	AO obișnuite, fără capabilități Rail-to-Rail $V_{OH} = V_{CC}$ (sau V_{DD}) - 2V - saturația pozitivă $V_{OL} \cong V_{EE}$ (sau V_{SS}) + 2V - saturația negativă

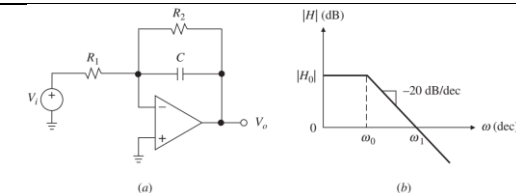
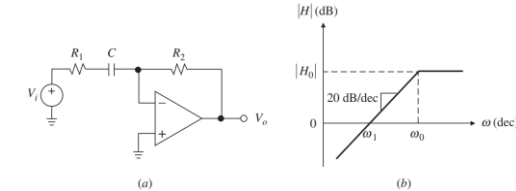
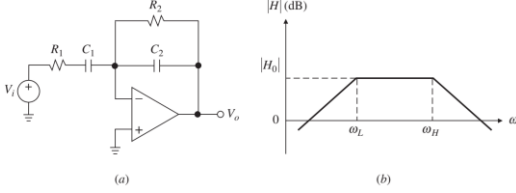
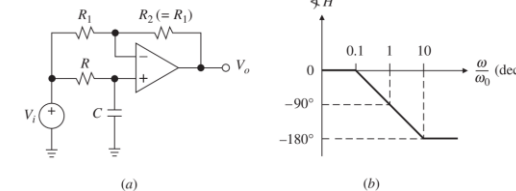
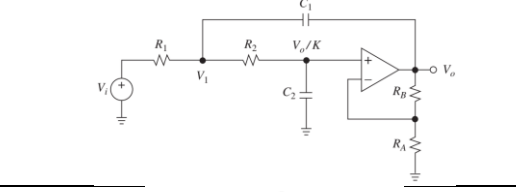
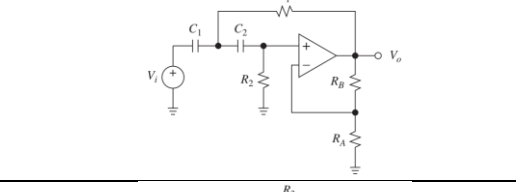
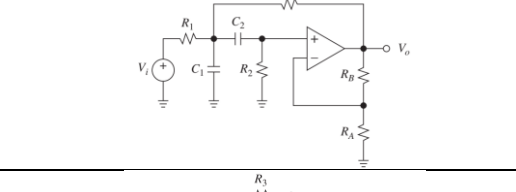
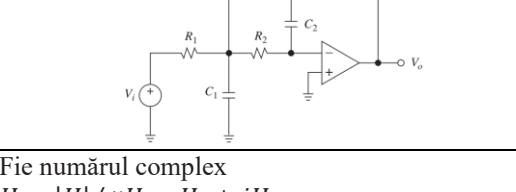
Circuite cu reacție negativă rezistivă – partea I

Convertisor I-V	<ul style="list-style-type: none"> i_S - sursă ideală de curent ($R_S \rightarrow \infty$) $a \rightarrow \infty$ 	$v_O = -R[1/(1 + 1/T)]i_S$ $T = a_\varepsilon b = (-aR)(-1/R) = a$ $a_\varepsilon = -aR$ $b = -\frac{1}{R}$ $A_r = v_O/i_S = (1/b)[1/(1 + 1/T)] = -R[1/(1 + 1/T)]$ $v_O \underset{a \rightarrow \infty}{=} -Ri_S$
	<ul style="list-style-type: none"> i_S - sursă reală de curent (R_S finită) a finită 	$v_O = -R[1/(1 + 1/T)]i_S$ $T = a_\varepsilon b = (-aR_S \parallel R) \times (-1/R) = a/(1 + R/R_S)$ $a_\varepsilon = -a(R_S \parallel R)$ $b = -\frac{1}{R}$ $A_r = v_O/i_S = (1/b)[1/(1 + 1/T)] = -R[1/(1 + 1/T)]$ $v_O \underset{a \text{ finit}, R_S \text{ finit}}{=} -R \frac{1}{1 + [(1 + R/R_S)/a]} i_S$
Convertoare V-I	<p>Cu sarcina flotantă</p> 	$i_O = \frac{v_I}{R}$ <p>Conformitatea tensiunii:</p> <p>(a) $(V_{OL} - v_I) < v_L < (V_{OH} - v_I)$ sau $v_L \leq V_{sat} - v_I$</p> <p>(b) $V_{OL} < v_L < V_{OH}$ sau $v_L \leq V_{sat}$</p> <p>V_{sat} este depărtat cu 2V de tensiunile de alimentare, deci pentru $V_{alim} = \pm 15V \Rightarrow V_{sat} = \pm 13V$</p>
	<p>Sursa de curent HOWLAND</p> 	$i_O = Av_I - \left(\frac{1}{R_o}\right)v_L$ $R_o = \frac{R_2}{\frac{R_2}{R_1} - \frac{R_4}{R_3}}$ $i_O = \frac{v_I}{R_1} \text{ dacă } R_o \rightarrow \infty \text{ când } \frac{R_4}{R_3} = \frac{R_2}{R_1}$ <p>Conformitatea tensiunii</p> $ v_L \leq \frac{R_1}{R_1 + R_2} V_{sat}$
Amplificatoare de curent	<p>cu sarcina flotantă</p> 	$i_O = Ai_I - \frac{1}{R_o} v_L \underset{R_o \rightarrow \infty}{=} Ai_I$ $A = 1 + \frac{R_2}{R_1}$
	<p>cu sarcina la masă</p> 	$i_O = Ai_I - \frac{1}{R_o} v_L$ $A = -\frac{R_2}{R_1}$ $R_o = -\frac{\bar{R}_1}{R_2} R_S$

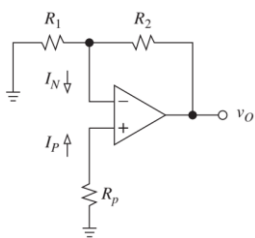
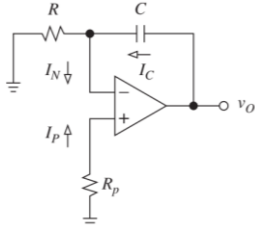
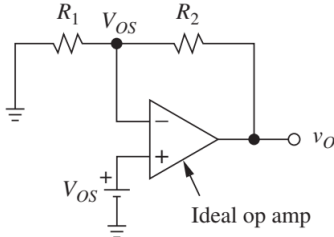
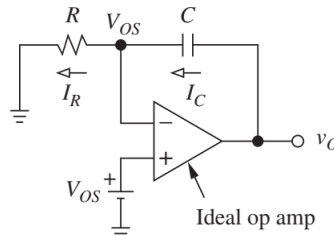
Circuite cu reacție negativă rezistivă – partea a II-a

Amplificatorul de diferență	 	$v_O = \frac{R_2}{R_1}(v_2 - v_1) \text{ dacă } \frac{R_3}{R_4} = \frac{R_1}{R_2}$ $v_{DM} = v_2 - v_1; v_{CDM} = \frac{v_1 + v_2}{2}$ $v_1 = v_{CM} - \frac{v_{DM}}{2}; v_2 = v_{CM} + \frac{v_{DM}}{2}$ $R_{id} = 2R_1; R_{ic} = \frac{R_1 + R_2}{2}$ $v_O = A_{dm}v_{DM} + A_{cm}v_{CM}$ $CMRR_{dB} = 20 \log_{10} \left \frac{A_{dm}}{A_{cm}} \right $
Amplificatoare de instrumentație (AI)	<p style="text-align: center;">AI cu 3 AO</p> 	$v_O = \left(1 + \frac{2R_3}{R_G}\right) \times \left(\frac{R_2}{R_1}\right)(v_2 - v_1)$
	<p style="text-align: center;">AI cu 2 AO</p> 	$v_O = \left(1 + \frac{R_2}{R_1}\right) \times \left(v_2 - \frac{1 + R_3/R_4}{1 + R_1/R_2} v_1\right)$ $v_O = \left(1 + \frac{R_2}{R_1}\right)(v_2 - v_1)$ <p>dacă</p> $\frac{R_3}{R_4} = \frac{R_1}{R_2}$

Filtre active

FTJ cu amplificare		$H(j\omega) = H_0 \frac{1}{1 + j\omega/\omega_0}$ $H_0 = -\frac{R_2}{R_1}; \quad \omega_0 = \frac{1}{R_2 C}$
FTS cu amplificare		$H(j\omega) = H_0 \frac{j\omega/\omega_0}{1 + j\omega/\omega_0}$ $H_0 = -\frac{R_2}{R_1}; \quad \omega_0 = \frac{1}{R_1 C}$
FTB de bandă largă		$H(j\omega) = H_0 \frac{j\omega/\omega_L}{(1 + j\omega/\omega_L)(1 + j\omega/\omega_H)}$ $H_0 = -\frac{R_2}{R_1}; \quad \omega_L = \frac{1}{R_1 C_1}; \quad \omega_H = \frac{1}{R_2 C_2}$
Filtrul trece-tot		$H(j\omega) = \frac{1 - j\omega/\omega_0}{1 + j\omega/\omega_0} = 1\angle -2\tan^{-1}(\omega/\omega_0)$
Filtre KRC de tipul trece-jos		$H_0 = K$ $\omega_0 = \frac{1}{\sqrt{R_1 C_1 R_2 C_2}}$ $Q = \frac{1}{(1 - K)\sqrt{R_1 C_1 / R_2 C_2} + \sqrt{R_1 C_2 / R_2 C_1} + \sqrt{R_2 C_2 / R_1 C_1}}$
Filtre KRC de tipul trece-sus		$H_0 = K; \quad \omega_0 = \frac{1}{\sqrt{R_1 C_1 R_2 C_2}}$ $Q = \frac{1}{(1 - K)\sqrt{R_2 C_2 / R_1 C_1} + \sqrt{R_1 C_2 / R_2 C_1} + \sqrt{R_1 C_1 / R_2 C_2}}$
Filtre KRC de tipul trece-bandă		$R_1 = R_2 = R_3 = R \text{ și } C_1 = C_2 = C$ $H_{0BP} = \frac{K}{4 - K} \quad \omega_0 = \frac{\sqrt{2}}{RC} \quad Q = \frac{\sqrt{2}}{4 - K}$ <p>Relații de proiectare</p> $RC = \sqrt{2}/\omega_0 \quad K = 4 - \sqrt{2}/Q \quad R_B = (K - 1)R_A$
Filtru trece-jos cu reacție multiplă		$H_{0LP} = -\frac{R_3}{R_1} \quad \omega_0 = \frac{1}{\sqrt{R_2 R_3 C_1 C_2}}$ $Q = \frac{\sqrt{C_1 / C_2}}{\sqrt{R_2 R_3 / R_1^2} + \sqrt{R_3 / R_2} + \sqrt{R_2 / R_3}}$
Numere complexe	<p>Fie numărul complex</p> $H = H /\angle H = H_r + jH_i$ <p>unde</p> <p>H este modulul sau amplitudinea lui H,</p> <p>$\angle H$ argumentul lui H sau unghiul de fază,</p> <p>H_r partea reală iar</p> <p>H_i coeficientul părții imaginare</p>	$ H = \sqrt{H_r^2 + H_i^2}$ $\angle H = \tan^{-1}(H_i/H_r) \text{ dacă } H_r > 0$ $\angle H = 180^\circ - \tan^{-1}(H_i/H_r) \text{ dacă } H_r < 0$ <ul style="list-style-type: none"> Proprietăți $ H_1 \times H_2 = H_1 \times H_2 $ $\angle(H_1 \times H_2) = \angle H_1 + \angle H_2$ $ H_1/H_2 = H_1 / H_2 $ $\angle(H_1/H_2) = \angle H_1 - \angle H_2$

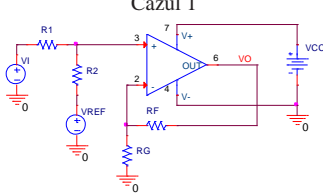
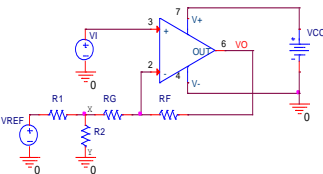
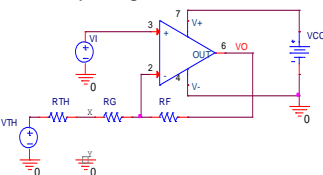
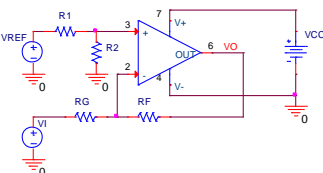
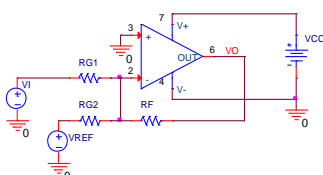
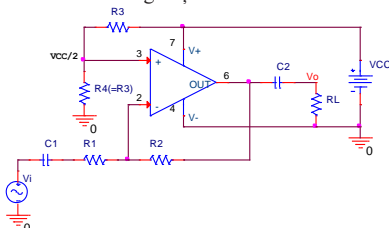
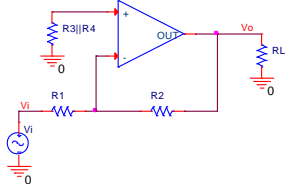
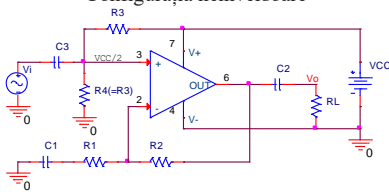
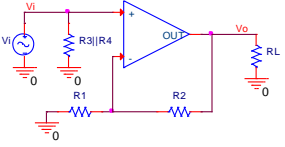
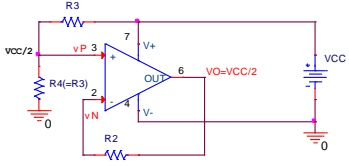
Limitări statice ale AO

Erori datorate I_B și I_{OS}	Amplificatoarele inversoare și neinversoare, amplificatoarele de sumă și diferență, convertoarele I-V		$E_O = \left(1 + \frac{R_2}{R_1}\right) [(R_1 \parallel R_2) I_N - R_p I_P]$ $E_O = \left(1 + \frac{R_2}{R_1}\right) \{[(R_1 \parallel R_2) - R_p] I_B - [(R_1 \parallel R_2) + R_p] I_{OS}/2\}$ <p>Dacă $R_p = R_1 \parallel R_2$, atunci</p> $E_O = \left(1 + \frac{R_2}{R_1}\right) [- (R_1 \parallel R_2)] I_{OS}$ <p>Dacă I_P și I_N au sensuri opuse celor figurate, atunci</p> $E_O = \left(1 + \frac{R_2}{R_1}\right) (R_1 \parallel R_2) I_{OS} = \left(1 + \frac{R_2}{R_1}\right) R_p I_{OS}$
	Integrator		$I_C = \frac{1}{R} (R I_N - R_p I_P) = \frac{1}{R} [(R - R_p) I_B - (R + R_p) I_{OS}/2]$ $v_O(t) = E_O(t) + v_O(0)$ $E_O(t) = \frac{1}{RC} \int_0^t [(R - R_p) I_B - (R + R_p) I_{OS}/2] dx$ <p>Dacă $R_p = R$, atunci</p> $E_O(t) = \frac{1}{RC} \int_0^t -R I_{OS} dx$
Erori datorate V_{OS}	Amplificatoarele inversoare și neinversoare, amplificatoarele de sumă și diferență, convertoarele I-V		$E_O = \left(1 + \frac{R_2}{R_1}\right) V_{OS}$
	Integrator		$E_O(t) = \frac{1}{RC} \int_0^t V_{OS} dx$
Eroarea cumulată	Amplificatoarele inversoare și neinversoare, amplificatoarele de sumă și diferență, convertoarele I-V	Este mai corect să se adune cele 2 componente datorate I_B și I_{OS} , respectiv V_{OS}	<p>Dacă $R_p = R_1 \parallel R_2$, atunci</p> $E_O = \left(1 + \frac{R_2}{R_1}\right) (V_{OS} + R_p I_{OS})$

Limitări dinamice ale AO

Căștigul în buclă deschisă având un pol		$a(jf) = \frac{a_0}{1 + jf/f_a}$ $ a(jf) = \text{mag } a(jf) = \frac{a_0}{\sqrt{1 + (f/f_a)^2}}$ $\angle a(jf) = \text{ph } a(jf) = -\tan^{-1}(f/f_a)$ $\frac{a_0}{\sqrt{1 + (f_t/f_a)^2}} = 1 \Rightarrow f_t = a_0 f_a$ $a(jf) _{f \ll f_a} \rightarrow a_0 \angle 0^\circ$ $a(jf) _{f=f_a} \rightarrow \frac{a_0}{\sqrt{2}} \angle -45^\circ$ $a(jf) _{f \gg f_a} \rightarrow \frac{f_t}{f} \angle -90^\circ$ $GBP = f_t$
Răspunsul în frecvență în buclă închisă		$A(jf) = A_0 \frac{1}{1 + jf/f_A} \cong A_{ideal} \frac{1}{1 + jf/f_A}$ $f_A = (1 + a_0 b) f_a \cong a_0 b f_a = b f_t$
Graficul răspunsului în buclă închisă $ A(jf) $	<p>Amplificatorul neinversor</p> <p>Amplificatorul inversor</p>	$b = \frac{R_1}{R_1 + R_2} = \frac{1}{1 + R_2/R_1}$ $f_A \cong b f_t = \frac{f_t}{1 + R_2/R_1}$ <div> <div> <p>Neinversor</p> $A_0 \cong 1 + \frac{R_2}{R_1}$ $GBP_{neinv} \cong f_t$ </div> <div> <p>Inversor</p> $A_0 \cong -\frac{R_2}{R_1}$ $A_0 < 1 + \frac{R_2}{R_1}$ $GPB_{inv} \cong (1 - b) f_t$ </div> </div>
Impedanțele de intrare și ieșire		$Z_{se} = z_0(1 + T)$ $Z_{sh} = \frac{z_0}{1 + T}$ <div> <div> <p>Neinversor (în c.c. și la foarte joasă frecvență)</p> $R_i = r_a(1 + a_0 b)$ $R_o = \frac{r_o}{1 + a_0 b}$ $b = \frac{R_1}{R_1 + R_2}$ </div> <div> <p>Inversor (în c.c. și la foarte joasă frecvență)</p> $R_i = R_1 + \frac{R_2}{1 + a_0}$ $R_o = \frac{r_o}{1 + a_0 b}$ $b = \frac{R_1}{R_1 + R_2}$ </div> </div>
Timpul de creștere, t_R		$A(jf) = \frac{1}{1 + jf/f_t}$ $v_o(t) = V_m(1 - e^{-t/\tau})$ $\tau = \frac{1}{2\pi f_t}$ $t_R = \tau(\ln 0,9 - \ln 0,1) = \frac{0,35}{f_t}$
Limitarea de SR		$V_{om(crit)} = \frac{SR}{2\pi f_t}$ <p>Full-Power Bandwidth (FPB)</p> $FPB = \frac{SR}{2\pi V_{sat}}$ <p>Legătura dintre banda liniară și SR</p> $\begin{cases} f \ll f_A \\ f < f_{SR} \end{cases}$ <p>unde</p> $f_A \cong b f_t$ $f_{SR} \leq \frac{SR}{2\pi V_{om}} = \frac{SR}{2\pi A V_{im}}$

Alimentarea AO cu o singură tensiune

Circuite de condiționare a semnalului	<p>Cazul 1</p> 	$V_O = \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_2}{R_1 + R_2} \cdot V_I + \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_1}{R_1 + R_2} \cdot V_{REF}$ $m = \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_2}{R_1 + R_2}$ $b = \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_1}{R_1 + R_2} \cdot V_{REF}$					
	<p>Cazul 2</p>  <p>Schema obținută prin echivalare Thévenin</p> 	$V_{TH} = \frac{R_2}{R_1 + R_2} \cdot V_{REF}$ $R_{TH} = R_1 R_2$ $V_O = -\frac{R_F}{R_G + R_{TH}} V_{TH} + \left(1 + \frac{R_F}{R_G + R_{TH}}\right) V_I$ $V_O = \left(1 + \frac{R_F}{R_G + R_{TH}}\right) V_I - \frac{R_F}{R_G + R_{TH}} \cdot \frac{R_2}{R_1 + R_2} V_{REF}$ $m = 1 + \frac{R_F}{R_G + R_{TH}}$ $b = -\frac{R_F}{R_G + R_{TH}} \cdot \frac{R_2}{R_1 + R_2} \cdot V_{REF}$					
	<p>Cazul 3</p> 	$V_O = -\frac{R_F}{R_G} \cdot V_I + \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_2}{R_1 + R_2} \cdot V_{REF}$ $m = -\frac{R_F}{R_G}$ $b = \left(1 + \frac{R_F}{R_G}\right) \cdot \frac{R_2}{R_1 + R_2} \cdot V_{REF}$					
	<p>Cazul 4</p> 	$V_O = -\frac{R_F}{R_{G1}} \cdot V_I - \frac{R_F}{R_{G2}} \cdot V_{REF}$ $m = -\frac{R_F}{R_{G1}}$ $b = -\frac{R_F}{R_{G2}} \cdot V_{REF}$					
Amplificatoare de tensiune alternativă	<p>Configurația inversoare</p> 	 $A_v = \frac{V_o}{V_i} = -\frac{R_2}{R_1}$ $R_i = R_1$					
	<p>Configurația neinversoare</p> 	 $A_v = \frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}$ $R_i = R_3 R_4$					
	<p>Schema echivalentă de c.c. (la ambele configurații)</p> 	$V_O = v_P = V_{CC}/2 \text{ (repetor în c.c.)}$ $v_N = v_P = V_{CC}/2$					
	<p>Dimensionarea condensatoarelor</p>	<table><tr><td>Inversor: $f^* = f_L \sqrt{2^{1/2} - 1}$</td><td>Neinversor: $f^* = f_L \sqrt{2^{1/3} - 1}$</td></tr><tr><td>$C_1 \geq \frac{1}{2\pi f^* R_1}$</td><td>$C_2 \geq \frac{1}{2\pi f^* R_L}$</td></tr><tr><td>$C_3 \geq \frac{1}{2\pi f^* (R_3 R_4)}$</td><td></td></tr></table>	Inversor: $f^* = f_L \sqrt{2^{1/2} - 1}$	Neinversor: $f^* = f_L \sqrt{2^{1/3} - 1}$	$C_1 \geq \frac{1}{2\pi f^* R_1}$	$C_2 \geq \frac{1}{2\pi f^* R_L}$	$C_3 \geq \frac{1}{2\pi f^* (R_3 R_4)}$
Inversor: $f^* = f_L \sqrt{2^{1/2} - 1}$	Neinversor: $f^* = f_L \sqrt{2^{1/3} - 1}$						
$C_1 \geq \frac{1}{2\pi f^* R_1}$	$C_2 \geq \frac{1}{2\pi f^* R_L}$						
$C_3 \geq \frac{1}{2\pi f^* (R_3 R_4)}$							

Circuite neliniare

Circuitul de logaritmare		$v_{BE} = V_T \ln \left(\frac{i_C}{I_S} \right)$ $i_C = I_S \exp \left(\frac{v_{BE}}{V_T} \right)$ $v_O = -v_{BE} = -V_T \ln \frac{I_C}{I_S} = -V_T \ln \frac{v_I}{RI_S}$
Circuitul de exponențiere		$v_O = Ri_C = RI_S \exp \left(\frac{v_{BE}}{V_T} \right) = RI_S \exp \left(\frac{-v_I}{V_T} \right)$
Redresorul de precizie monoalternanță neînversor		$\begin{cases} v_O = v_I, & v_I > 0 \\ v_O = 0, & v_I < 0 \end{cases}$
Redresorul de precizie monoalternanță inversor		$\begin{cases} v_O = -\frac{R_2}{R_1} v_I, & v_I < 0 \\ v_O = 0, & v_I > 0 \end{cases}$
Redresorul de precizie dublă-alternanță		$\begin{cases} v_O = v_I & \text{pentru } v_I < 0 \\ v_O = v_I & \text{pentru } v_I > 0 \end{cases}$ $v_O = -v_I - 2v_A = -v_I - 2(-v_I) = v_I$
Comparatoare saturate cu prag 0	<p>Comparatorul neînversor</p>	$\begin{cases} v_O = +V_{sat} & \text{pentru } v_I > 0 \\ v_O = -V_{sat} & \text{pentru } v_I < 0 \end{cases}$
	<p>Comparatorul inversor</p>	$\begin{cases} v_O = -V_{sat} & \text{pentru } v_I > 0 \\ v_O = +V_{sat} & \text{pentru } v_I < 0 \end{cases}$
Comparatoare saturate cu prag ≠ 0	<p>Comparatorul neînversor cu prag pozitiv</p>	$\begin{cases} v_O = -V_{sat} & \text{pentru } v_I < V_{th} \\ v_O = +V_{sat} & \text{pentru } v_I > V_{th} \end{cases}$
	<p>Comparatorul neînversor cu prag negativ</p>	$\begin{cases} v_O = -V_{sat} & \text{pentru } v_I < (-V_{th}) \\ v_O = +V_{sat} & \text{pentru } v_I > (-V_{th}) \end{cases}$
	<p>Comparatorul inversor cu prag pozitiv</p>	$\begin{cases} v_O = +V_{sat} & \text{pentru } v_I < V_{th} \\ v_O = -V_{sat} & \text{pentru } v_I > V_{th} \end{cases}$
	<p>Comparatorul inversor cu prag negativ</p>	$\begin{cases} v_O = +V_{sat} & \text{pentru } v_I < (-V_{th}) \\ v_O = -V_{sat} & \text{pentru } v_I > (-V_{th}) \end{cases}$

Stabilizatoare de tensiune

Stabilizator serie cu reacție		<p>Elemente componente:</p> <p>ERS = element de reglare serie</p> <p>COMP = circuit de comparare</p> <p>CE = circuit de eșantionare</p> <p>REF = referința de tensiune</p> <p>VI = tensiunea nestabilizată</p> <p>VO = tensiunea stabilizată</p>
Stabilizator paralel cu reacție		<p>Elemente componente:</p> <p>ERS = element de reglare serie</p> <p>COMP = circuit de comparare</p> <p>CE = circuit de eșantionare</p> <p>REF = referința de tensiune</p>
Stabilizator de tensiune serie realizat cu AO		<p>Descriere:</p> <ul style="list-style-type: none"> ERS = Q1 REF = R1, D1 COMP = AO CE = R2, R3 $v_P = v_N \Rightarrow V_{REF} = \frac{R_2}{R_2 + R_3} V_O$ $V_O = \left(1 + \frac{R_3}{R_2}\right) \cdot V_{REF}$
Protecție prin limitare		$I_{Olim} = I_{sc} = \frac{V_{BE,Q2}}{R_{sc}} \approx \frac{0,65V}{R_{sc}}$ $P_{d(Q1)} = (V_I - V_{BE,Q2}) \times I_{sc}$ $P_{d(Q1)} \approx V_I \times I_{sc}$
Protecție prin întoarcerea caracteristicii		$V_{BE} = V_B - V_E$ $V_{BE} = \frac{R_B}{R_A + R_B} V_A - V_O$ $V_A = V_O + I_O R_{sc}$ $I_O = \frac{R_A}{R_B R_{sc}} V_O + \frac{R_A + R_B}{R_B R_{sc}} V_{BE}$ $V_{BE,Q2} = 0,65V \Rightarrow I_{Omax} = \frac{R_A}{R_B R_{sc}} V_O + \frac{R_A + R_B}{R_B R_{sc}} \times 0,65V$ $V_O = 0 \Rightarrow I_{sc} = \frac{R_A + R_B}{R_B R_p} \times 0,65V$
Parametrii principali ai stabilizatoarelor	Stabilizarea de intrare (linie) S_V - Line Regulation	$S_V = \frac{\Delta V_O}{\Delta V_I} \left[\frac{mV}{V} \right] \text{ sau } \left[\frac{\mu V}{V} \right]$ $S_V \left(\frac{\%}{V} \right) = 100 \frac{\Delta V_O / V_O}{\Delta V_I} = 100 \frac{\Delta V_O / \Delta V_I}{V_O} \left[\frac{\%}{V} \right]$
	Stabilizarea de sarcină S_L - Load Regulation	$S_L = \frac{\Delta V_O}{\Delta I_O} \left[\frac{mV}{mA} \right] \text{ sau } \left[\frac{mV}{A} \right]$ $S_L \left(\frac{\%}{A} \right) = 100 \frac{\Delta V_O / V_O}{\Delta I_O} = 100 \frac{\Delta V_O / \Delta I_O}{V_O} \left[\frac{\%}{mA} \right] \text{ sau } \left[\frac{\%}{A} \right]$
	Rejecția tensiunii de undulație (pulsatie) RRR - Ripple Rejection Ratio	$RRR = 20 \log_{10} \frac{V_{ri}}{V_{ro}} \text{ [dB]}$