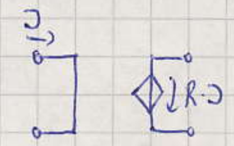
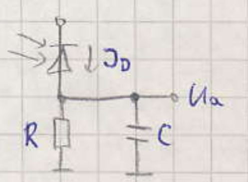
Stromgesteuerte Spannungsquellen



R - Übertragungswiderstand

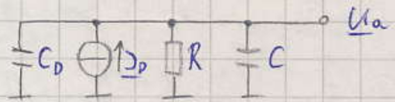
Motivation

Optische Datenübertragung, Empfänger mit Fotodiode



- sehr kleiner I_D, $\approx 10\,\mu A/lx$

KS-ESB

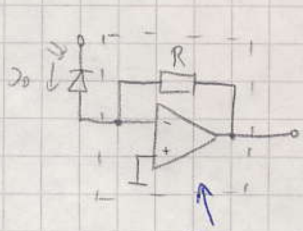


$$\omega_g = \frac{1}{R(C+C_D)} = \frac{I_{DA}}{U_{aA}(C+C_D)}$$

Bsp. $I_{DA} = 10\mu A$, $U_{aA} = 1V$, $C = 15pF$, $C_D = 10pF$

$\rightarrow f_g = 64\,kHz$

↳ Problem: Umladestrom der Kapazitäten
Abhilfe: U_a = konst., I_a ist Signal

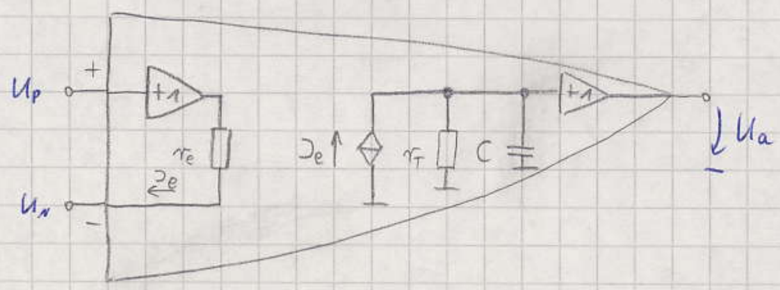


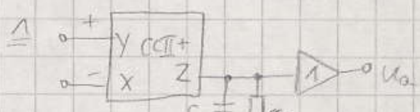
$U_a = -I_D \cdot R$, U_P = konst.

Transimpedanzverstärker (TIA)

Transimpedanzverstärker

Modell



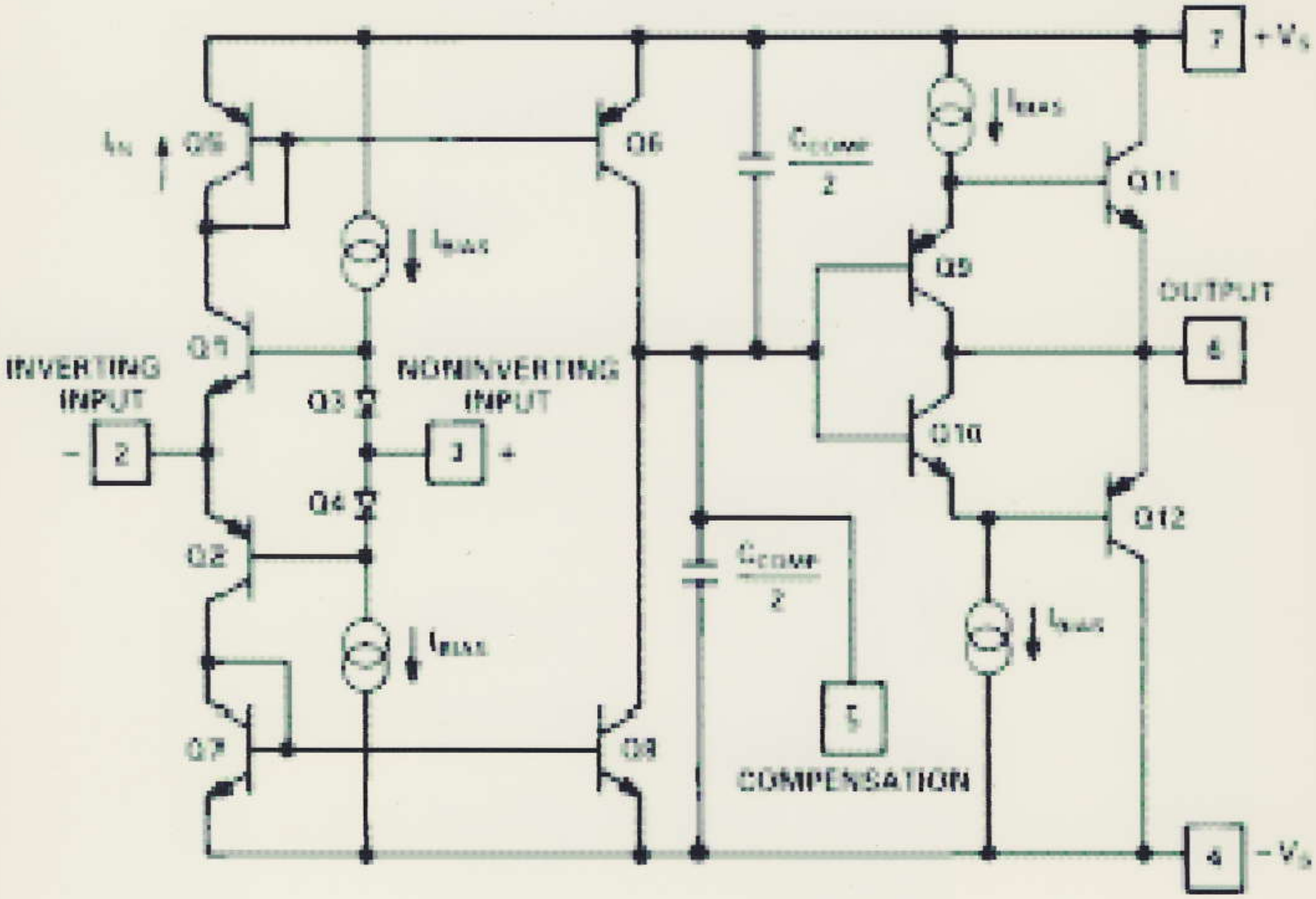


$$U_a = \frac{r_T}{1+sCr_T}\cdot I_E$$

r_T: Transimpedanz (sehr hoch, z.B. 200 MΩ)

$$I_E = \frac{U_P - U_N}{r_e} = \frac{U_d}{r_e}$$

r_e: Eingangsimpedanz (sehr klein, 50Ω)



7
+VS
Q5
Q6
Q11
Q9
Q1
Q3
Q4
Q2
Q10
Q12
Q7
Q8
INVERTING INPUT
NONINVERTING INPUT
OUTPUT
6
2
3
4
−VS
COMPENSATION

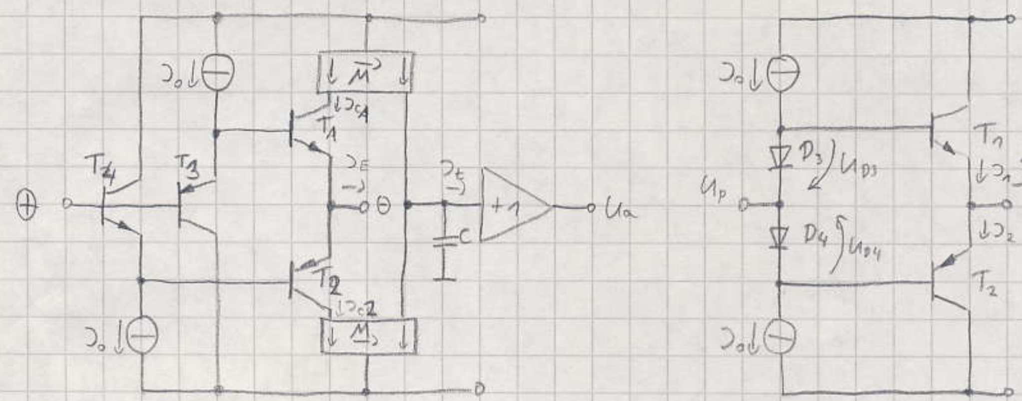
Spannungsverstärkung: $\underline{U}_a = Z_T \frac{\underline{U}_d}{r_e} = \underline{U}_d \cdot \underbrace{\frac{r_T}{r_e}}_{v_0} \cdot \frac{1}{1+sCr_T}$

$\approx 130\,dB$

- nichtinvertierender Eingang U_p hochohmig (Puffer)
- invertierender Eingang niederohmig
- dominanter Pol bei niedrigen Frequenzen
- niederohmiger Ausgang durch Puffer

Prinzipschaltung

Folie Schaltung



Transferkennlinie

$U_d = U_p - U_N$

$I_E = I_1 - I_2$ – getrennte Behandlung beider Ströme

oberer Schaltungsteil

KS: $I_0 = I_{D3} + I_{B1} = I_{D3} + \frac{I_1}{B+1}$

$I_1 = (I_0 - I_{D3})(B+1)$

$I_{D3} = I_S\, e^{\frac{U_{D3}}{U_T}}$; $I_1 = n I_S\, e^{\frac{U_{BE1}}{U_T}}$

$I_1 = (I_0 - I_S\, e^{\frac{U_{D3}}{U_T}})(B+1)$

MS: $U_{BE1} + \underbrace{U_N - U_p}_{-U_d} - U_{D3} = 0$

$I_1 = (I_0 - I_S\, e^{\frac{U_{BE1}-U_d}{U_T}})(B+1)$

mit $U_{BE1} = U_T \ln \frac{I_1}{n I_S}$

$I_1 = (I_0 - \frac{I_1}{n} e^{-\frac{U_d}{U_T}})(B+1)$

$I_1 = I_0 \frac{1}{\frac{1}{B+1} + \frac{1}{n} e^{-\frac{U_d}{U_T}}}$

unterer Schaltungsteil

$I_0 = I_{D4} + I_{B2} = I_{D4} + \frac{I_2}{B+1}$

$I_2 = (I_0 - I_{D4})(B+1)$

$\left(I_{D4} = I_S\, e^{\frac{U_{D4}}{U_T}} \right.$; $\left. I_2 = n I_S\, e^{\frac{U_{BE2}}{U_T}} \right)$

$(I_2 =$

$U_{BE2} + U_N - U_p - U_{D4} = 0$

$I_2 = I_0 \frac{1}{\frac{1}{B+1} + \frac{1}{n} e^{\frac{U_d}{U_T}}}$

$$I_E = I_0 \left(\frac{1}{\frac{1}{B+1} + \frac{1}{n} e^{-\frac{U_d}{U_T}}} - \frac{1}{\frac{1}{B+1} + \frac{1}{n} e^{\frac{U_d}{U_T}}} \right)$$

$$I_E = n \cdot I_0 \frac{e^{\frac{U_d}{U_T}} - e^{-\frac{U_d}{U_T}}}{1 + \left(\frac{n}{B+1}\right)^2 + \frac{n}{B+1}\left(e^{\frac{U_d}{U_T}} + e^{-\frac{U_d}{U_T}}\right)}$$

N: $\left(\frac{n}{B+1}\right)^2 \ll 1$; $\left(\frac{n}{B+1}\right)\left(e^{\frac{U_d}{U_T}} + e^{-\frac{U_d}{U_T}}\right) \ll 1$

$$I_E = n I_0 \left(e^{\frac{U_d}{U_T}} - e^{-\frac{U_d}{U_T}}\right)$$

↳ Folie Verlauf

Slew Rate: - ohne Übersteuerung der Eingangsstufe

$$SR = \left|\frac{d\,U_a}{dt}\right|_{max} = \frac{|I_t|}{C} = M \frac{|I_E|}{C}$$ M... Spiegelverhältnis

Slew Rate ist aussteuerungsabhängig wegen hochohmigem inneren Knoten und Nichtlinearität $I_E(U_d)$

- bei Übersteuerung der Eingangsstufe

$$SR = M \cdot B \cdot \frac{I_0}{C}$$

→ Folie AD 846 unten

$SR_{max} = 450\,V/\mu s$ (Diagramm) → sehr hohe Slew Rate

Kleinsignalverhalten ohne Gegenkopplung

a) Eingangswiderstand (an U_d)

$$r_e = \frac{1}{2g_m} = \frac{U_T}{4n \cdot I_0} = \frac{K_{re}}{I_0}$$

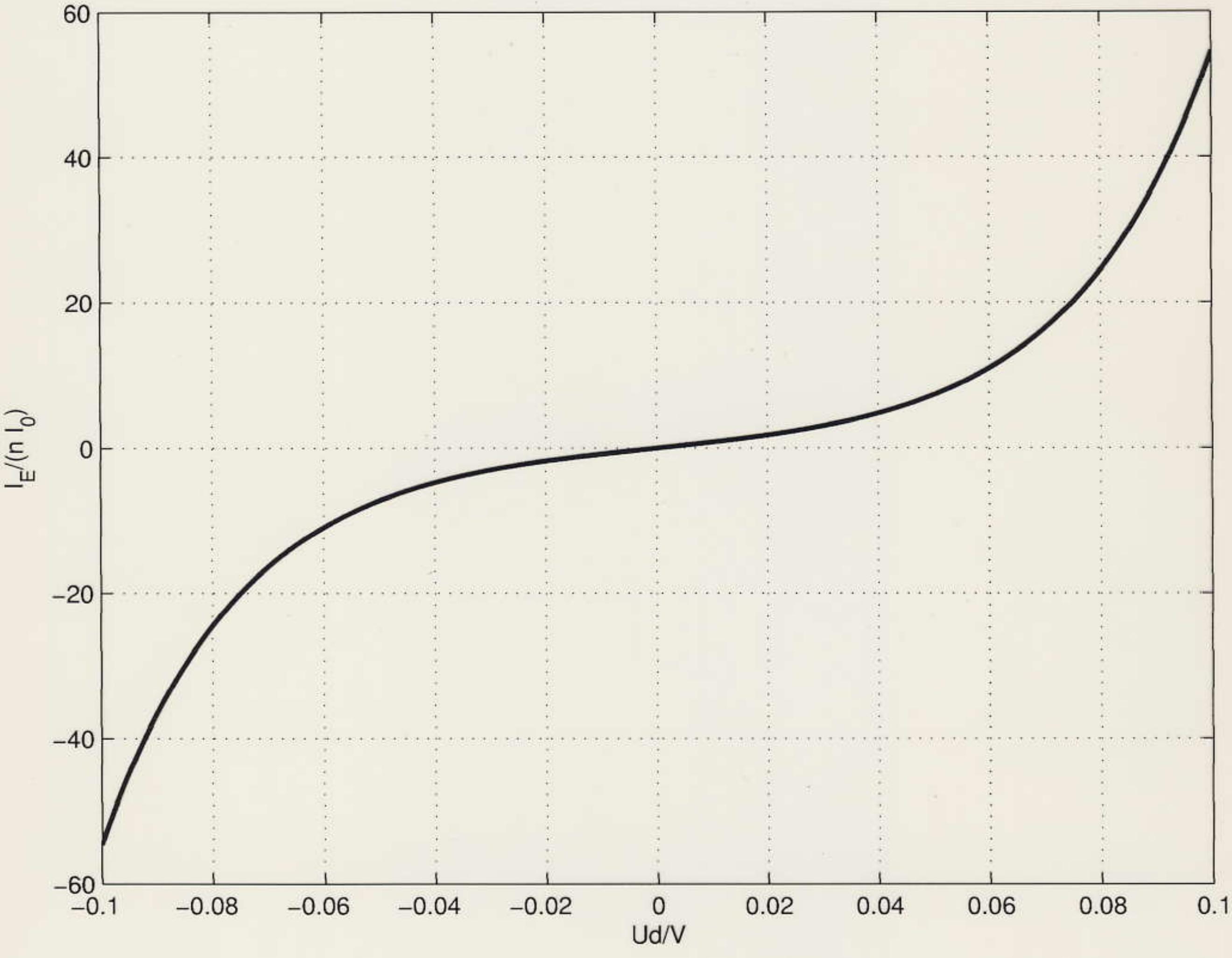
↓ für $B \gg 1$

b) Transferwiderstand

$$r_t = M(r_{ass1} \| r_{ass2}) = \frac{U_Y}{2 I_0 \cdot n} = \frac{K_{rt}}{I_0}$$

c) Leerlaufverstärkung

$$\underline{V} = \frac{\underline{Z}_t}{r_e} = \frac{K_{rt}}{K_{re}} \cdot \frac{1}{1+s\tau} = \frac{2U_Y}{U_T} \cdot \frac{1}{1+s\tau}$$



60
40
20
0
−20
−40
−60
$I_E/(n\,I_0)$
−0.1
−0.08
−0.06
−0.04
−0.02
0
0.02
0.04
0.06
0.08
0.1
Ud/V

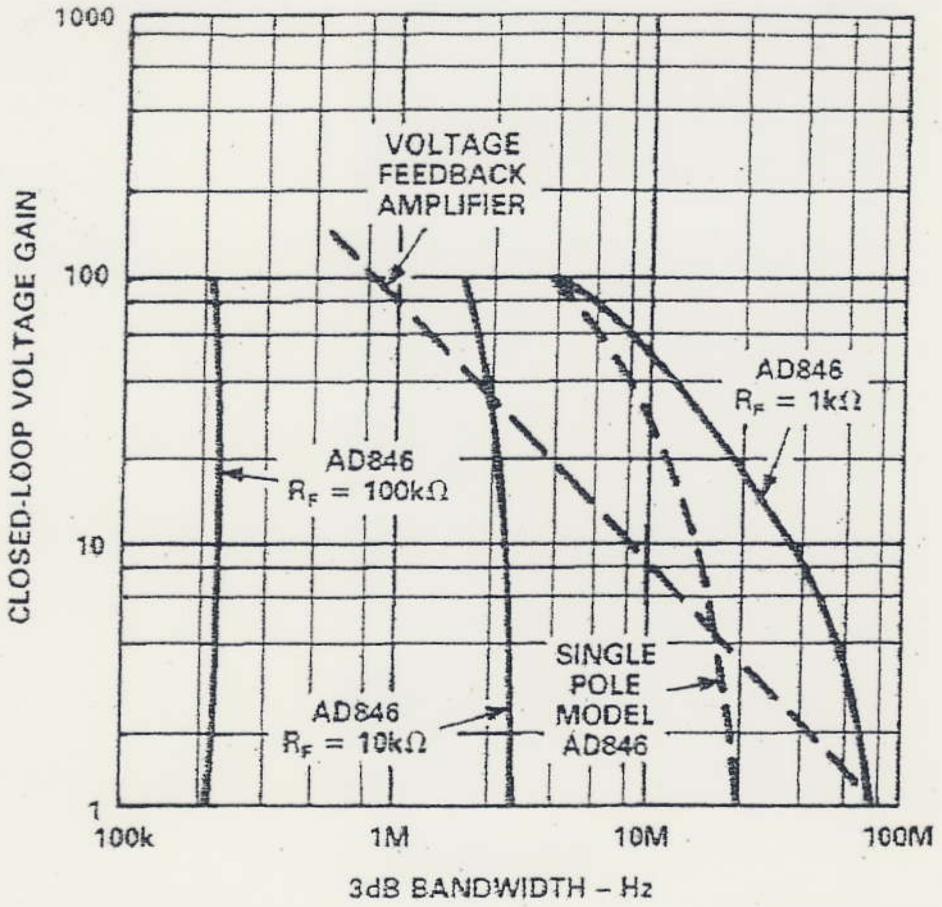


Figure 41. Closed-Loop Voltage Gain vs. Bandwidth for Various Values of R_F

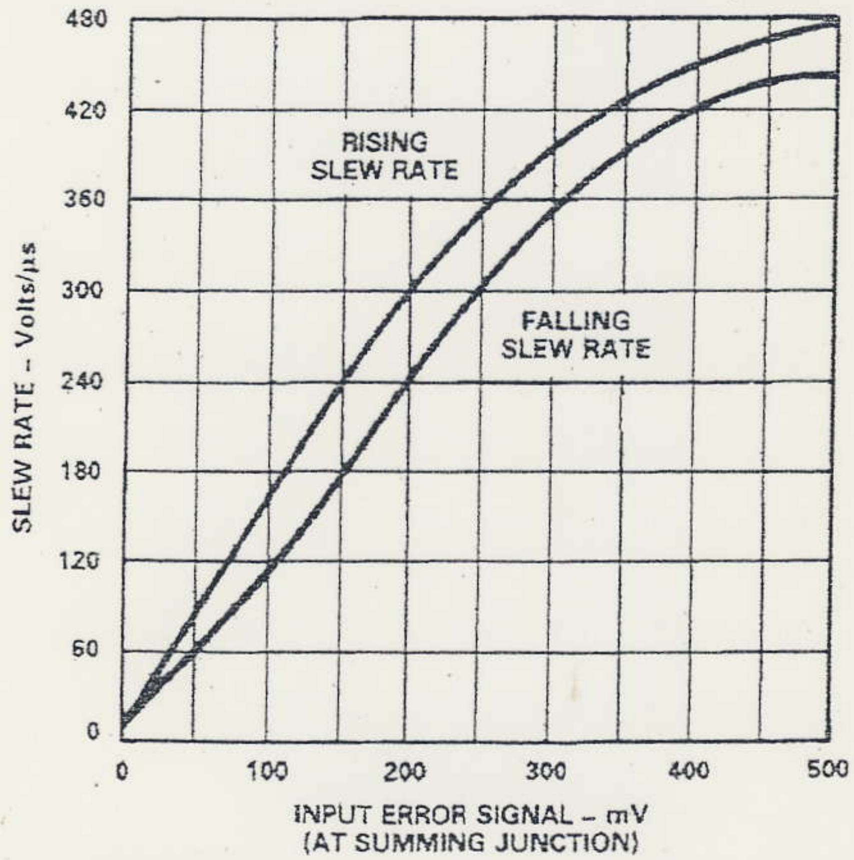
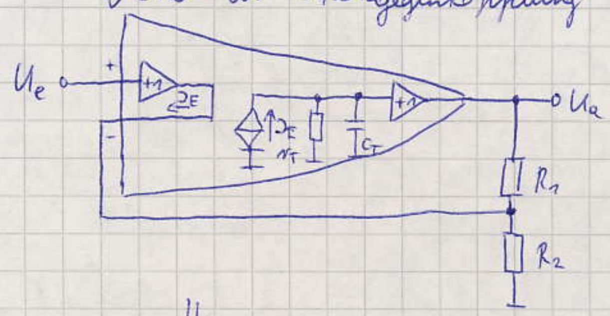


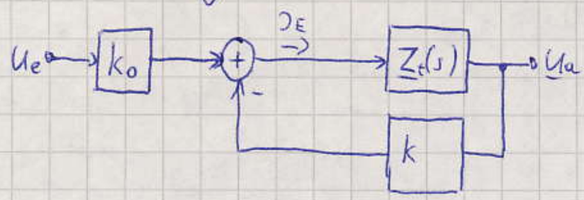
Figure 18. Slew Rate vs. Input Error Signal

Kleinsignalverhalten mit Gegenkopplung

Modell der Stromgegenkopplung



⇓



$$k = -\frac{\mathfrak{I}_E}{U_a}\bigg|_{U_e=0} = \frac{1}{R_1} \qquad \neq f(R_2)!$$

$$k_0 = \frac{\mathfrak{I}_E}{U_e}\bigg|_{U_a=0} = \frac{1}{R_1 \| R_2}$$

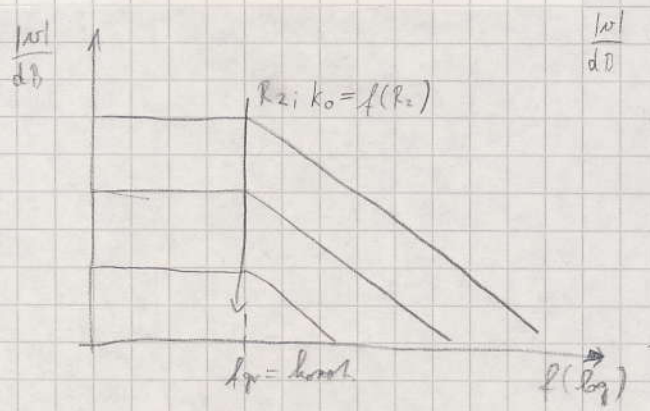
$$\underline{g} = 1 + k\,\underline{Z}_t(s) = 1 + \frac{\underline{Z}_t(s)}{R_1} \quad \neq f(R_2)!$$

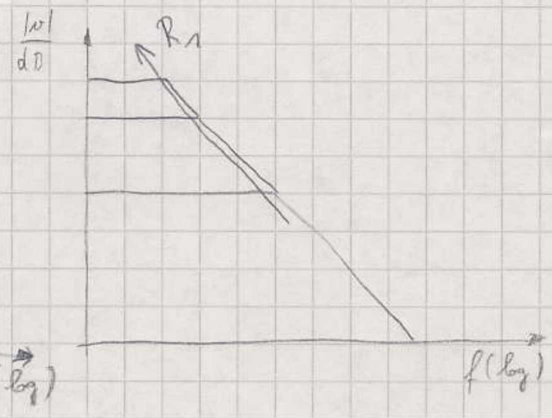
$$g = 1 + k\,r_T = 1 + r_T / R_1$$

$$\underline{V}'(s) = k_0 \frac{\underline{Z}_t(s)}{1 + k\,\underline{Z}_t(s)} = \frac{R_1 + R_2}{R_1 \cdot R_2} \cdot \frac{\underline{Z}_t(s)}{1 + \frac{\underline{Z}_t(s)}{R_1}} \approx 1 + \frac{R_1}{R_2} \qquad \text{für } \underline{Z}_t(s) \gg R_1$$

Grenzfrequenz der gegengekoppelten Schaltung:

$$f_{gr}' = g\,f_{gr0} = f_{gr0}(1 + r_t / R_1)$$





800 MHz, 50 mW Current Feedback Amplifier

AD8001

FEATURES

Excellent Video Specifications (R_L = 150 Ω, G = +2)
- **Gain Flatness 0.1 dB to 100 MHz**
- **0.01% Differential Gain Error**
- **0.025° Differential Phase Error**

Low Power
- **5.5 mA Max Power Supply Current (55 mW)**

High Speed and Fast Settling
- **880 MHz, –3 dB Bandwidth (G = +1)**
- **440 MHz, –3 dB Bandwidth (G = +2)**
- **1200 V/μs Slew Rate**
- **10 ns Settling Time to 0.1%**

Low Distortion
- **–65 dBc THD, f_C = 5 MHz**
- **33 dBm 3rd Order Intercept, F_1 = 10 MHz**
- **–66 dB SFDR, f = 5 MHz**

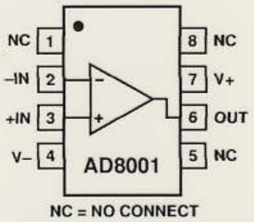
High Output Drive
- **70 mA Output Current**
- **Drives Up to Four Back-Terminated Loads (75 Ω Each) While Maintaining Good Differential Gain/Phase Performance (0.05%/0.25°)**

APPLICATIONS

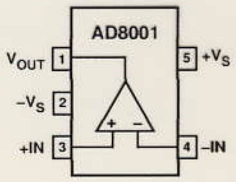
A-to-D Driver
Video Line Driver
Professional Cameras
Video Switchers
Special Effects
RF Receivers

FUNCTIONAL BLOCK DIAGRAMS

8-Lead DIP (N-8, Q-8) and SOIC (SO-8)



5-Lead SOT-23-5



PRODUCT DESCRIPTION

The AD8001 is a low power, high-speed amplifier designed to operate on ±5 V supplies. The AD8001 features unique transimpedance linearization circuitry. This allows it to drive video loads with excellent differential gain and phase performance on only 50 mW of power. The AD8001 is a current feedback amplifier and features gain flatness of 0.1 dB to 100 MHz while offering differential gain and phase error of 0.01% and 0.025°. This makes the AD8001 ideal for professional video electronics such as cameras and video switchers. Additionally, the AD8001's low distortion and fast settling make it ideal for buffer high-speed A-to-D converters.

The AD8001 offers low power of 5.5 mA max (V_S = ±5 V) and can run on a single +12 V power supply, while being capable of delivering over 70 mA of load current. These features make this amplifier ideal for portable and battery-powered applications where size and power are critical.

The outstanding bandwidth of 800 MHz along with 1200 V/μs of slew rate make the AD8001 useful in many general purpose high-speed applications where dual power supplies of up to ±6 V and single supplies from 6 V to 12 V are needed. The AD8001 is available in the industrial temperature range of –40°C to +85°C.

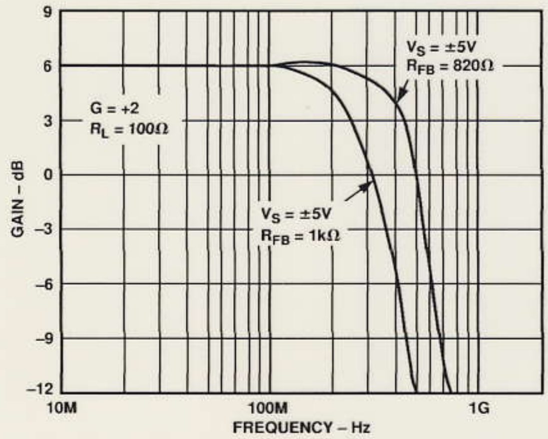


Figure 1. Frequency Response of AD8001

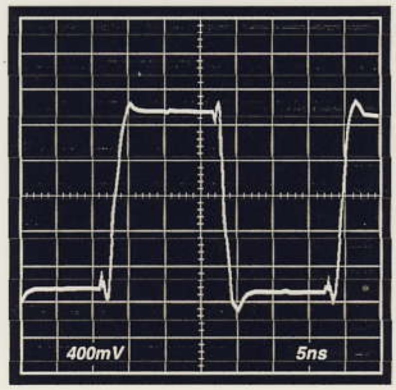


Figure 2. Transient Response of AD8001; 2 V Step, G = +2

REV. C

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD8001–SPECIFICATIONS (@ T_A = + 25°C, V_S = ±5 V, R_L = 100 Ω, unless otherwise noted)

Model		Conditions	AD8001A Min	Typ	Max	Units
DYNAMIC PERFORMANCE						
–3 dB Small Signal Bandwidth,	N Package	G = +2, < 0.1 dB Peaking, R_F = 750 Ω	350	440		MHz
		G = +1, < 1 dB Peaking, R_F = 1 kΩ	650	880		MHz
	R Package	G = +2, < 0.1 dB Peaking, R_F = 681 Ω	350	440		MHz
		G = +1, < 0.1 dB Peaking, R_F = 845 Ω	575	715		MHz
	RT Package	G = +2, < 0.1 dB Peaking, R_F = 768 Ω	300	380		MHz
		G = +1, < 0.1 dB Peaking, R_F = 1 kΩ	575	795		MHz
Bandwidth for 0.1 dB Flatness						
	N Package	G = +2, R_F = 750 Ω	85	110		MHz
	R Package	G = +2, R_F = 681 Ω	100	125		MHz
	RT Package	G = +2, R_F = 768 Ω	120	145		MHz
Slew Rate		G = +2, V_O = 2 V Step	800	1000		V/µs
		G = –1, V_O = 2 V Step	960	1200		V/µs
Settling Time to 0.1%		G = –1, V_O = 2 V Step		10		ns
Rise and Fall Time		G = +2, V_O = 2 V Step, R_F = 649 Ω		1.4		ns
NOISE/HARMONIC PERFORMANCE						
Total Harmonic Distortion		f_C = 5 MHz, V_O = 2 V p-p		–65		dBc
		G = +2, R_L = 100 Ω				
Input Voltage Noise		f = 10 kHz		2.0		nV/√Hz
Input Current Noise		f = 10 kHz, +In		2.0		pA/√Hz
		–In		18		pA/√Hz
Differential Gain Error		NTSC, G = +2, R_L = 150 Ω		0.01	0.025	%
Differential Phase Error		NTSC, G = +2, R_L = 150 Ω		0.025	0.04	Degree
Third Order Intercept		f = 10 MHz		33		dBm
1 dB Gain Compression		f = 10 MHz		14		dBm
SFDR		f = 5 MHz		–66		dB
DC PERFORMANCE						
Input Offset Voltage				2.0	5.5	mV
		T_{MIN}–T_{MAX}		2.0	9.0	mV
Offset Drift				10		µV/°C
–Input Bias Current				5.0	25	±µA
		T_{MIN}–T_{MAX}			35	±µA
+Input Bias Current				3.0	6.0	±µA
		T_{MIN}–T_{MAX}			10	±µA
Open Loop Transresistance		V_O = ±2.5 V	250	900		kΩ
		T_{MIN}–T_{MAX}	175			kΩ
INPUT CHARACTERISTICS						
Input Resistance		+Input		10		MΩ
		–Input		50		Ω
Input Capacitance		+Input		1.5		pF
Input Common-Mode Voltage Range				3.2		±V
Common-Mode Rejection Ratio						
Offset Voltage		V_{CM} = ±2.5 V	50	54		dB
–Input Current		V_{CM} = ±2.5 V, T_{MIN}–T_{MAX}		0.3	1.0	µA/V
+Input Current		V_{CM} = ±2.5 V, T_{MIN}–T_{MAX}		0.2	0.7	µA/V
OUTPUT CHARACTERISTICS						
Output Voltage Swing		R_L = 150 Ω	2.7	3.1		±V
Output Current		R_L = 37.5 Ω	50	70		mA
Short Circuit Current			85	110		mA
POWER SUPPLY						
Operating Range			±3.0		±6.0	V
Quiescent Current		T_{MIN}–T_{MAX}		5.0	5.5	mA
Power Supply Rejection Ratio		$+V_S$ = +4 V to +6 V, $–V_S$ = –5 V	60	75		dB
		$–V_S$ = – 4 V to –6 V, $+V_S$ = +5 V	50	56		dB
–Input Current		T_{MIN}–T_{MAX}		0.5	2.5	µA/V
+Input Current		T_{MIN}–T_{MAX}		0.1	0.5	µA/V

Specifications subject to change without notice.