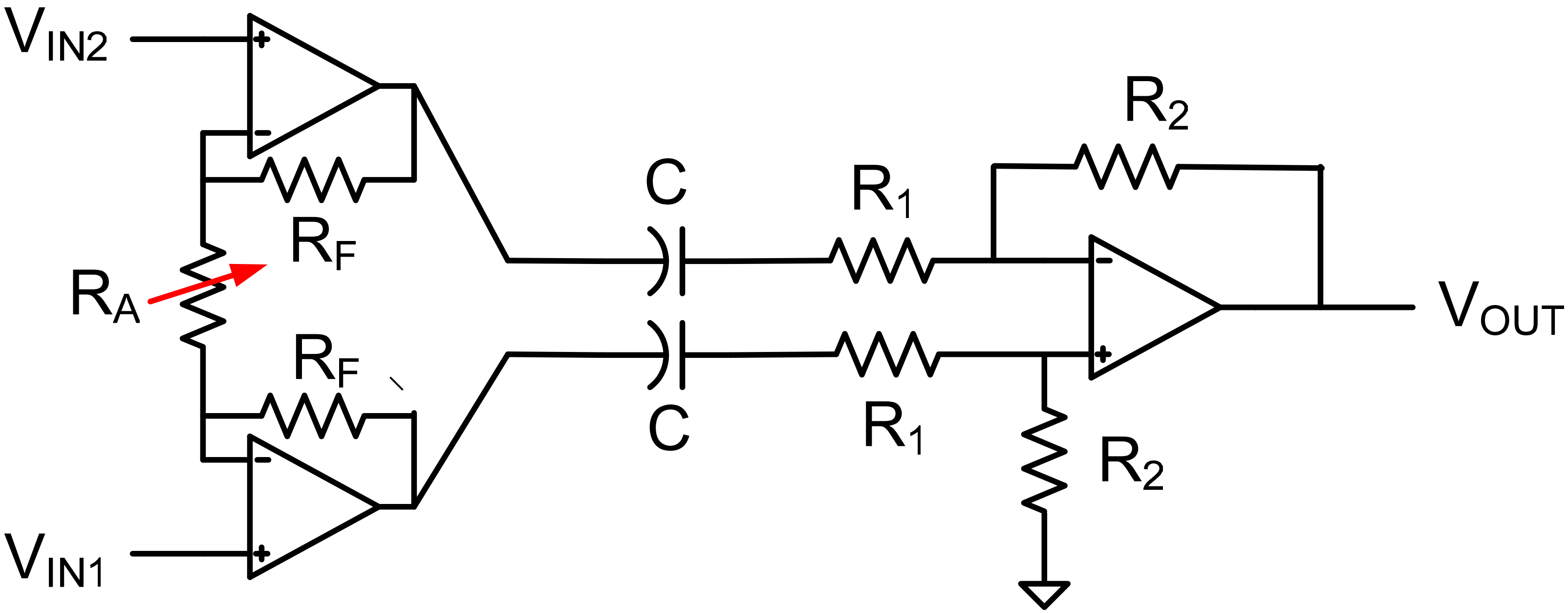
EE 230
Lecture 16

Nonideal Op Amp Characteristics

Differential Amplifiers

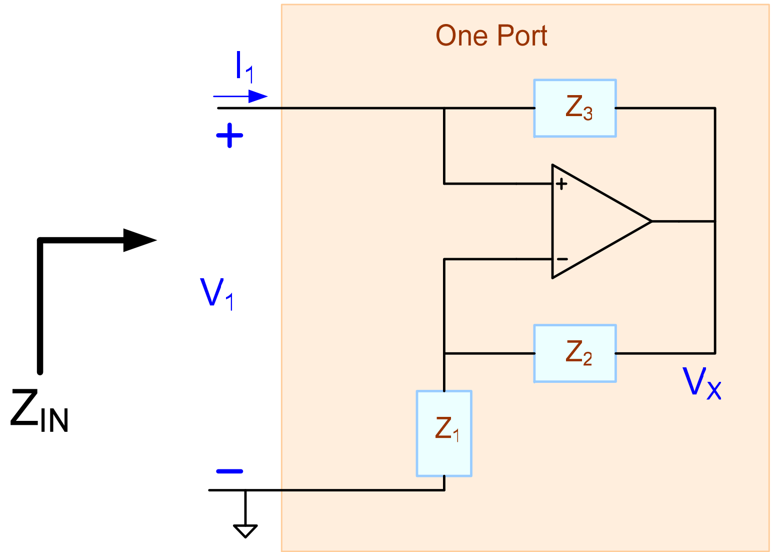
Instrumentation Amplifier



- Can reduce effects of dc offset if gain must be very large
- Must pick C to that frequencies of interest are in passband

Review from Last Time

Impedance Converters



$$V_1(G_1+G_2) = V_X G_2$$

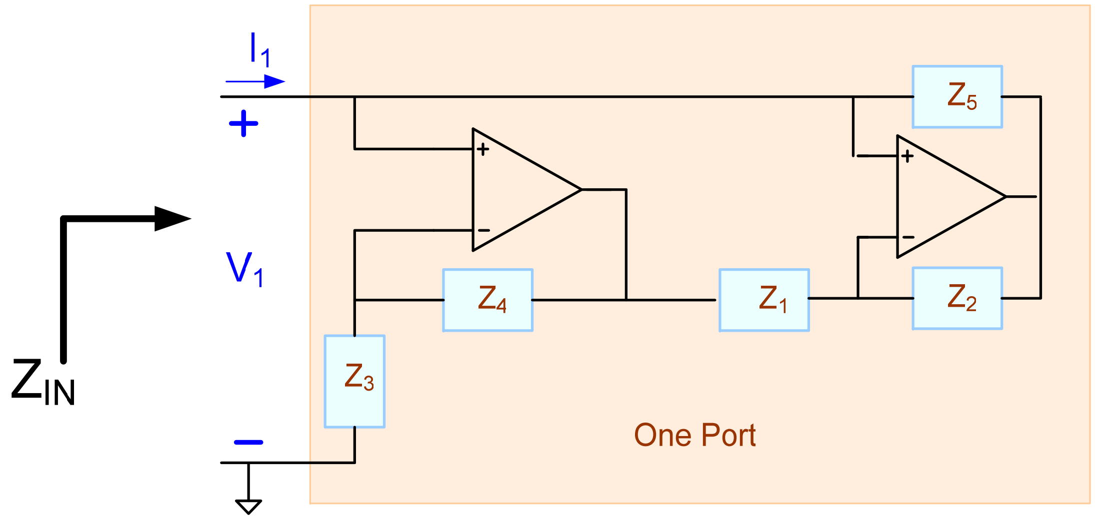
$$I_1=(V_1-V_X)G_3$$

$$Z_{IN} = -\frac{Z_2}{Z_1 Z_3}$$

Observe this input impedance is negative!

Review from Last Time

Impedance Converters



$$Z_{IN} = \frac{Z_1 Z_3 Z_5}{Z_2 Z_4}$$

If $Z_1=Z_3=Z_4=Z_5=R$ and $Z_2=1/sC$ $\quad Z_{IN} = \left(R^2C\right)s \quad$ This is an inductor of value $L=R^2C$

If $Z_2=R_2$, $Z_3=R_3$, $Z_4=R_4$, $Z_5=R_5$ and $Z_1=1/sC$ $\quad Z_{IN} = \dfrac{R_3R_5}{sCR_2R_4}$

This is a capacitor of value $\quad C_{EQ} = C\dfrac{R_2R_4}{R_3R_5} \quad$ (can scale capacitance up or down)

If $Z_2=Z_4=Z_5=R$ and $Z_1=Z_3=1/sC$ $\quad Z_{IN} = \left(R^3C^2\right)s^2 \quad$ This is a "super" capacitor of value R^3C^2

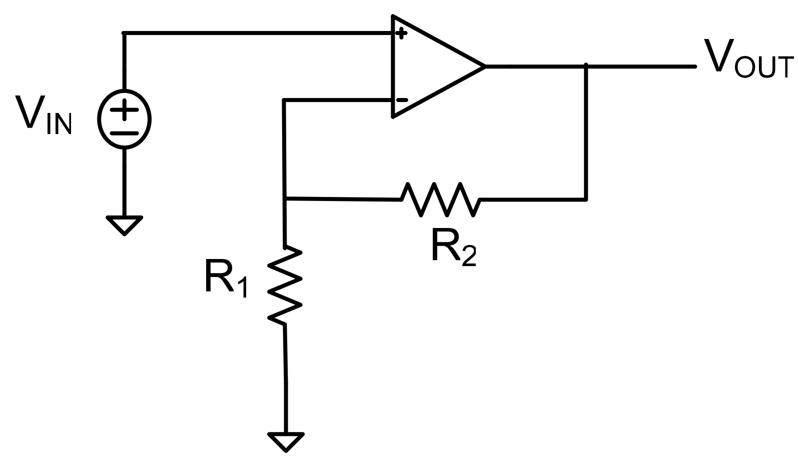
This circuit is often called a Gyrator

Nonideal Properties of Operational Amplifiers

In even the most basic applications, the laboratory performance of the circuit often differs dramatically from what is predicted for some op amps.

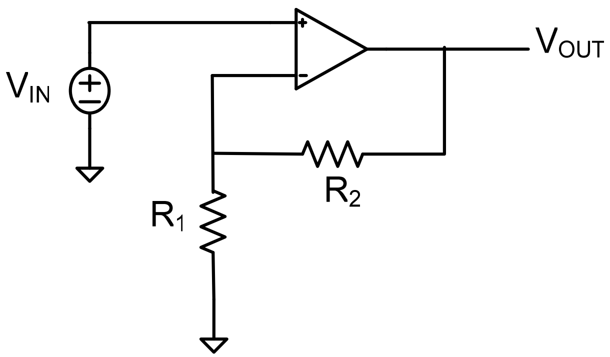
With proper knowledge of the characteristics of the op amp, designers can usually design circuits that behave almost like what is expected with ideal op amps

Essential to know nonideal properties of the op amp and how to manage them to be an effective design engineer

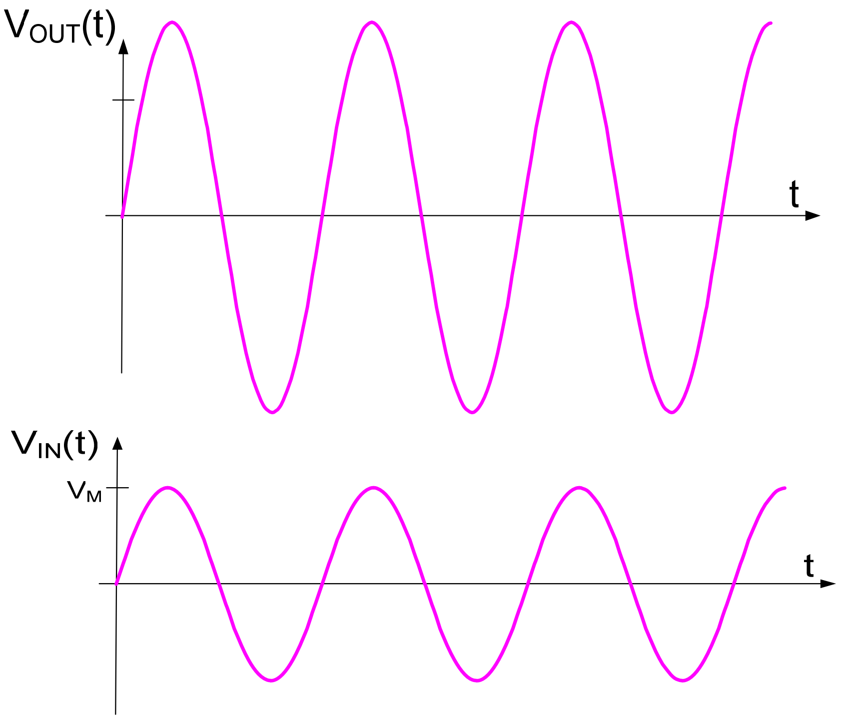


Nonideal Properties of Operational Amplifiers

Example:

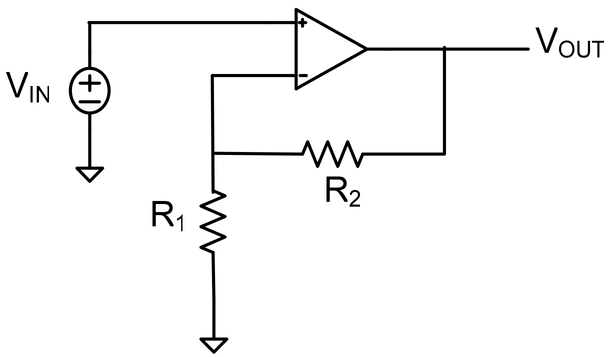


Desired input and output waveforms

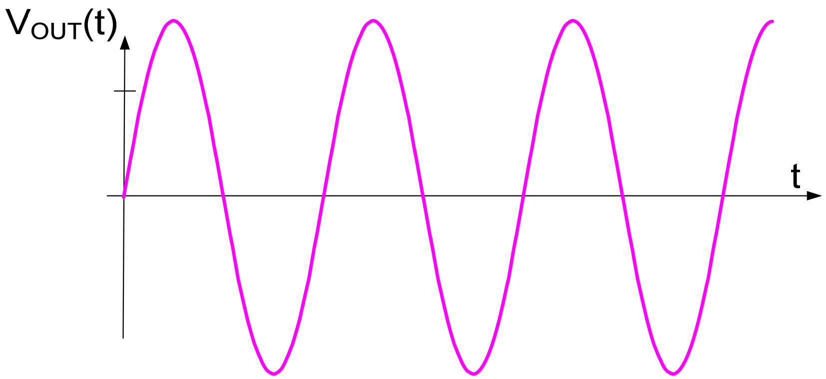


Nonideal Properties of Operational Amplifiers

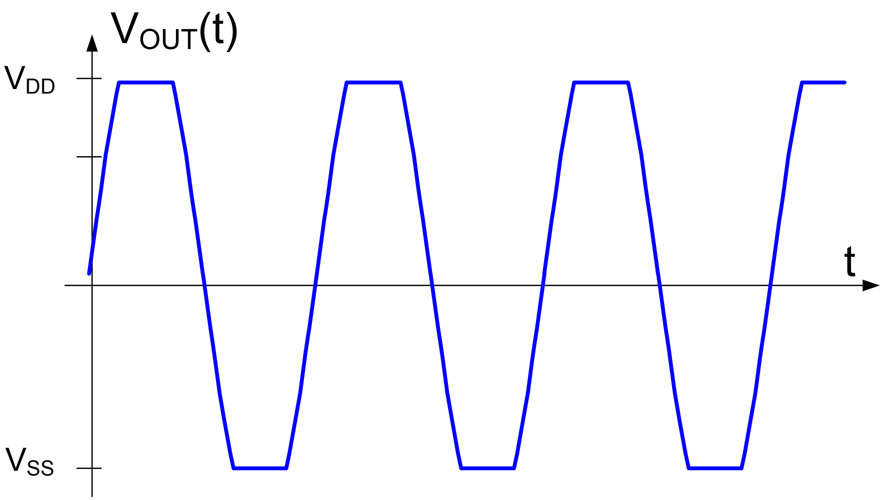
Example:

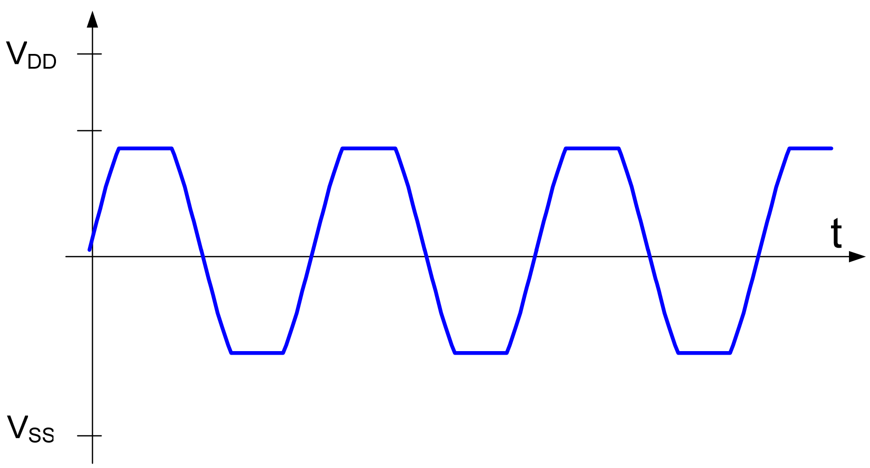


Desired output waveforms



What can happen:

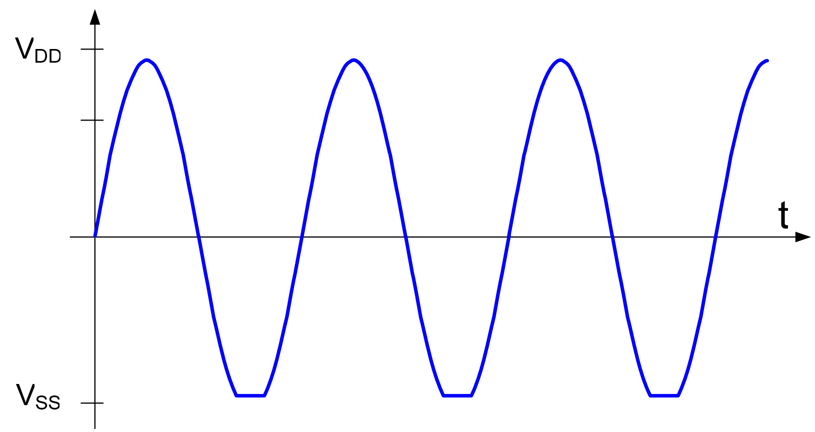


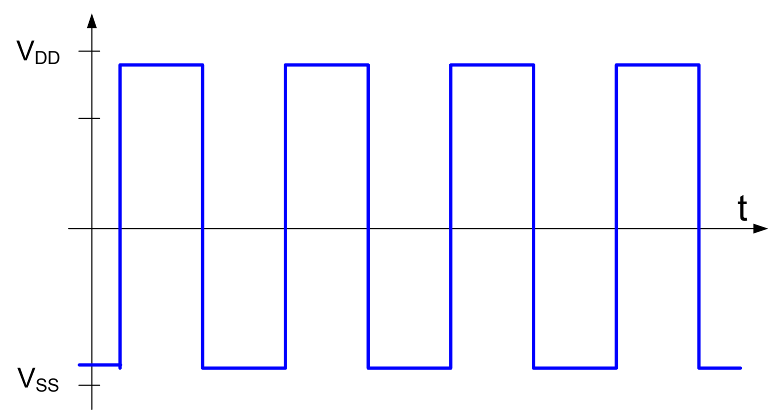


Nonideal Properties of Operational Amplifiers

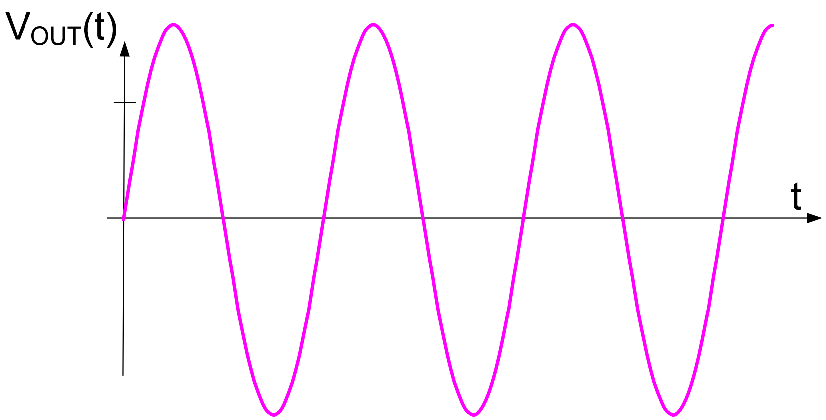
Example:

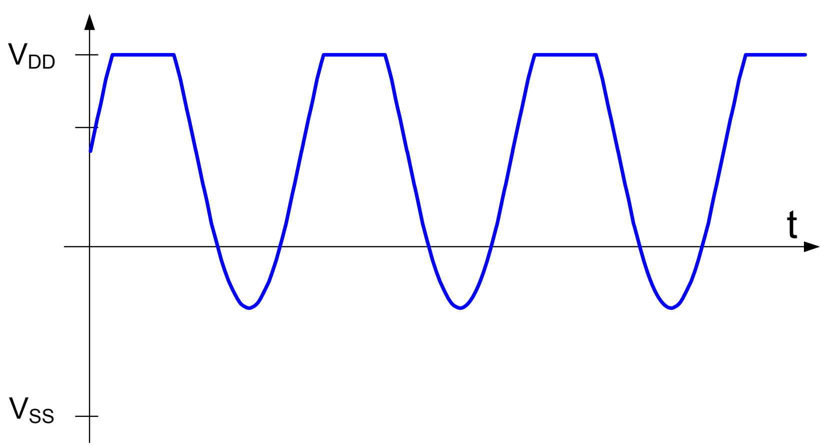
Desired output waveforms





What can happen:



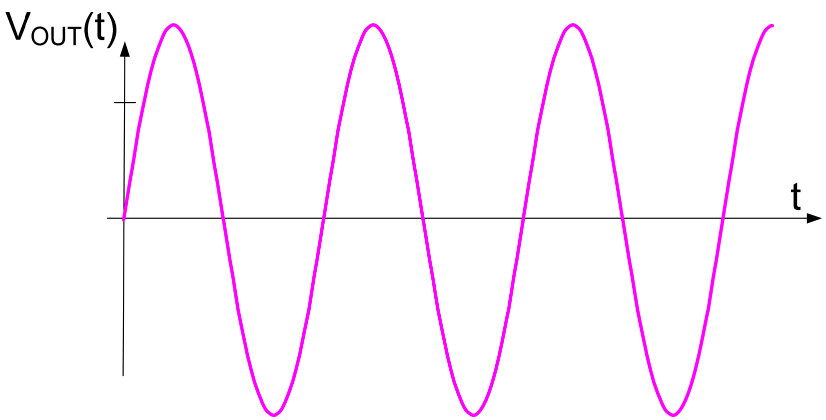


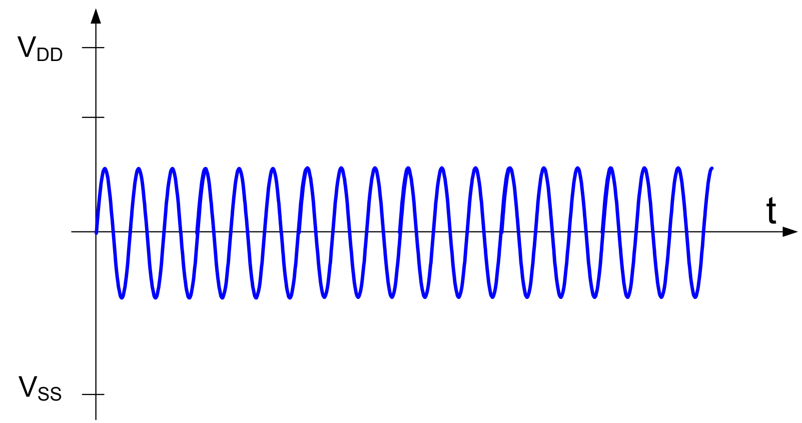
Nonideal Properties of Operational Amplifiers

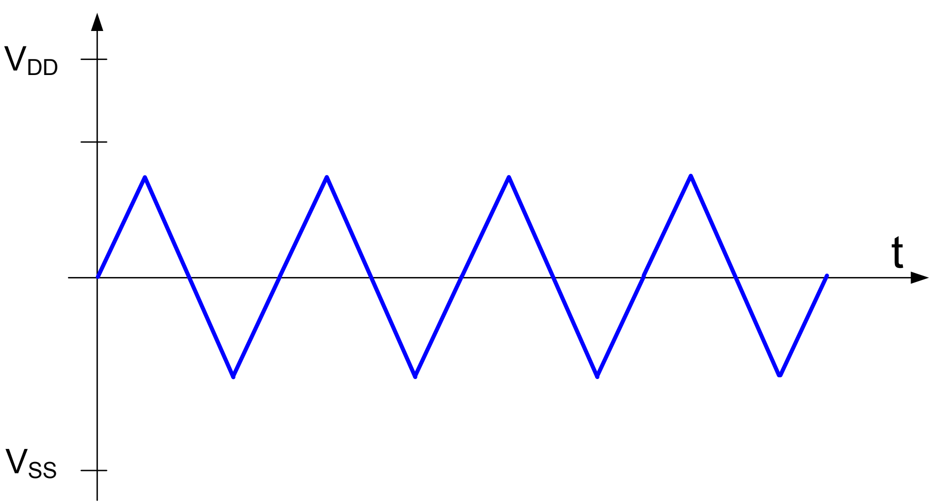
Example:

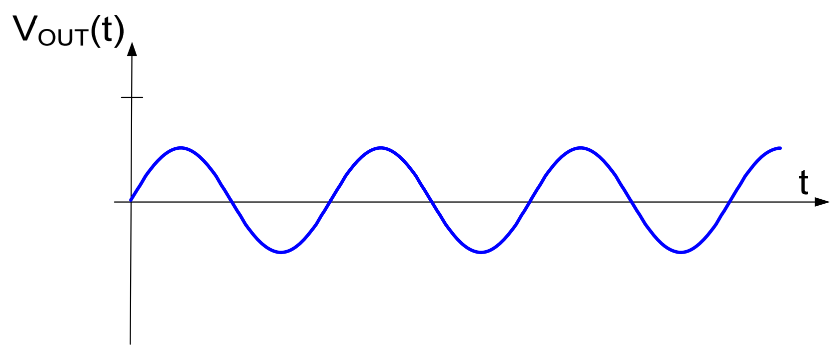
Desired output waveforms

What can happen:

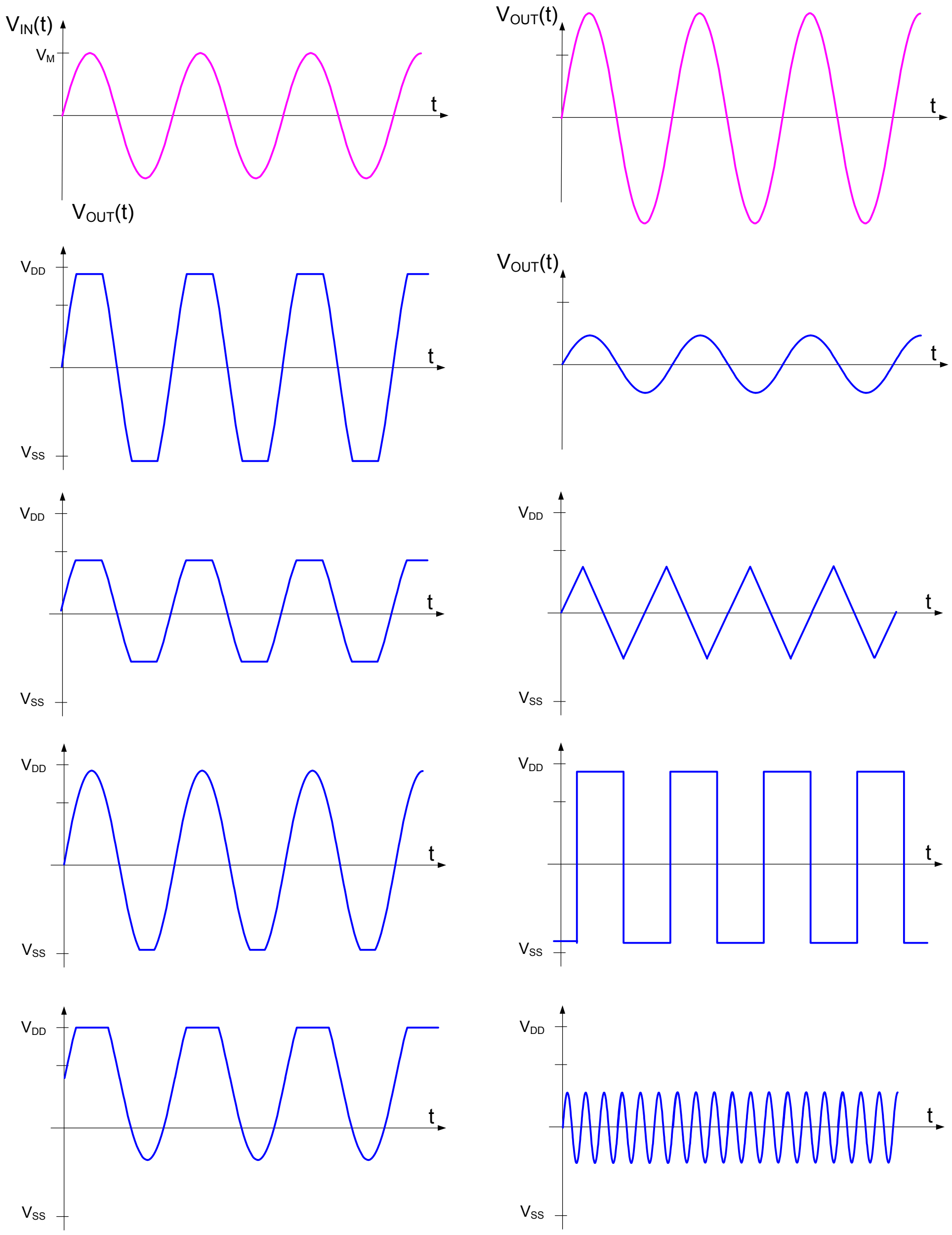


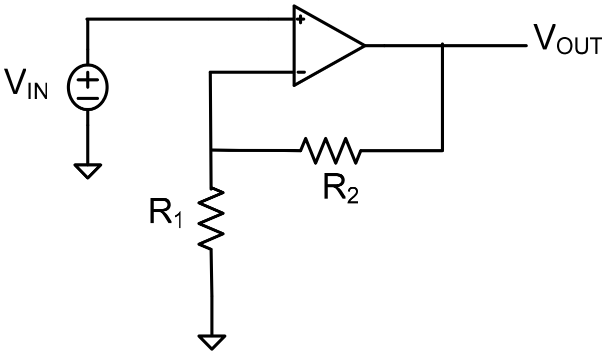






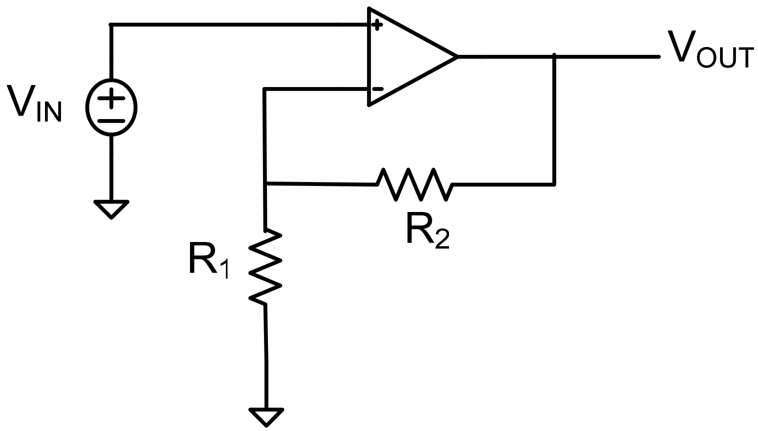
Some of the more common nonideal effects in Op Amp circuits

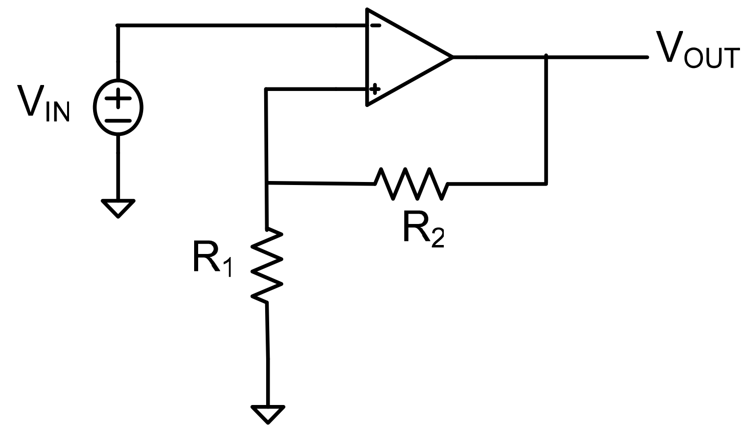




Will try to identify the source cause of all of these problems and how they can be resolved

Nonideal Properties of Operational Amplifiers





For ideal Op Amps, both circuits have gain

$$A_{FB} = 1+\frac{R_2}{R_1}$$

All op amp circuits that have been considered to date have a similar counterpart circuit but only one of the two circuits will perform as predicted

Must also observe what property of the nonideal op amp causes renders one to the two circuits ineffective and determine how to select the correct orientation

Inventor of two-stage Op Amp

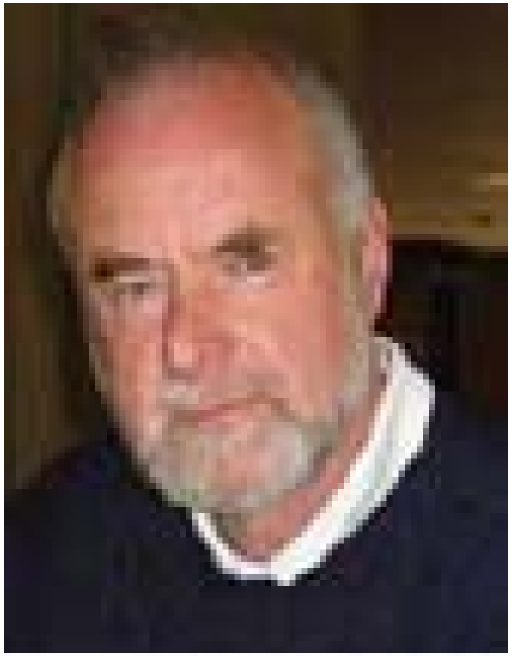
Robert Widlar

(considered by many as the most brilliant integrated circuit designer ever)

Widlar began his IC career at Fairchild semiconductor in Sept 63 at age of approx 26 where he designed several pioneering op amps. By 1966, the commercial success of his designs became apparent, and Widlar asked for a raise. He was turned down, and jumped ship to the fledgling National Semiconductor. At National he continued to turn out amazing designs, and was able to retire just before his 30th birthday in 1970.

Inventor of the internally-compensated Op Amp

Dave Fullagar



(from posted www site)

- Joined Fairchild in Jan 1966 and asked to design an op amp
- His design was the first internally-compensate op amp, the 741
- Fullagar was 26 years old when this was designed (introduced) in 1968
- Largest selling integrated circuit ever
- Still in high-volume production even though over 40 years old
- Fullagar later started the linear design activities at Intersil
- Cofounder (catalyst) of Maxim

Nonideal Op Amp Characteristics

- Absolute Maximum Ratings
- Electrical Characteristics
  - AC
  - DC

These are in the data sheets of the op amps along with connection information, occasionally application information, connection information, and sometimes even information about the design

Application notes, available from almost all manufacturers, often give more general information, definitions, more extensive application information, and other useful details.

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

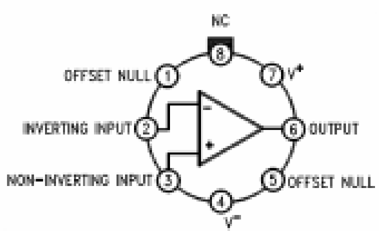
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Features

Connection Diagrams

Metal Can Package

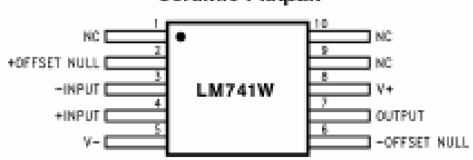


00934102

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1), LM741AH/883 or LM741CH
See NS Package Number H08C

Ceramic Flatpak



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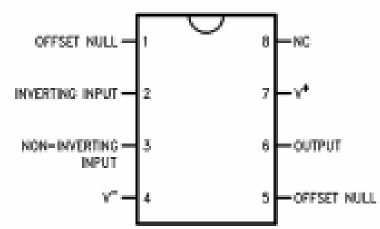
Order Number LM741W/883
See NS Package Number W10A

Dual-In-Line or S.O. Package



00934103

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Absolute Maximum Ratings (Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

(Note 7)

	LM741A	LM741	LM741C
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 3)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 4)	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Junction Temperature	150°C	150°C	100°C
Soldering Information			
N-Package (10 seconds)	260°C	260°C	260°C
J- or H-Package (10 seconds)	300°C	300°C	300°C
M-Package			
Vapor Phase (60 seconds)	215°C	215°C	215°C
Infrared (15 seconds)	215°C	215°C	215°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering
surface mount devices.

ESD Tolerance (Note 8)	400V	400V	400V

Electrical Characteristics (Note 5)

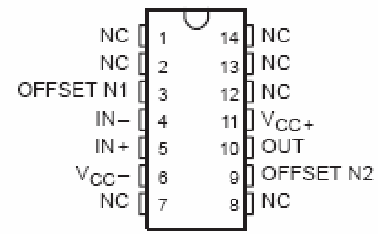
Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	$T_A = 25^\circ C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25^\circ C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25^\circ C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25^\circ C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25^\circ C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25^\circ C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V

Electrical Characteristics (Note 5) (Continued)

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain	$T_A = 25^\circ C$, $R_L \ge 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \le T_A \le T_{AMAX}$,										
	$R_L \ge 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \ge 10\ k\Omega$	±16									V
	$R_L \ge 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \ge 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \ge 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25^\circ C$	10	25	35		25			25		mA
	$T_{AMIN} \le T_A \le T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$										
	$R_S \le 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \le 50\Omega$, $V_{CM} = \pm 12V$	80	95								dB
Supply Voltage Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$,										
	$V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \le 50\Omega$	86	96								dB
	$R_S \le 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25^\circ C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		µs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	$T_A = 25^\circ C$	0.437	1.5								MHz
Slew Rate	$T_A = 25^\circ C$, Unity Gain	0.3	0.7			0.5			0.5		V/µs
Supply Current	$T_A = 25^\circ C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25^\circ C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

- Short-Circuit Protection
- Offset-Voltage Null Capability
- Large Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-Up
- Designed to Be Interchangeable With Fairchild μA741

μA741M . . . J PACKAGE
(TOP VIEW)



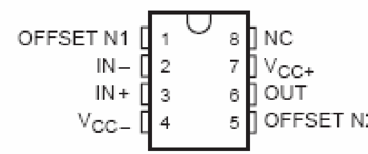
description

The μA741 is a general-purpose operational amplifier featuring offset-voltage null capability.

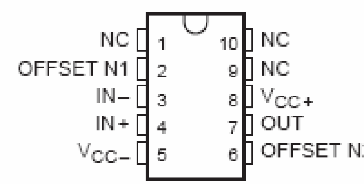
The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low value potentiometer may be connected between the offset null inputs to null out the offset voltage as shown in Figure 2.

The μA741C is characterized for operation from 0°C to 70°C. The μA741I is characterized for operation from −40°C to 85°C.The μA741M is characterized for operation over the full military temperature range of −55°C to 125°C.

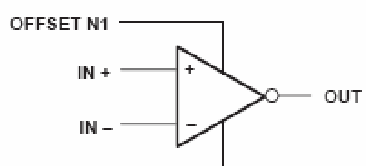
μA741M . . . JG PACKAGE
μA741C, μA741I . . . D, P, OR PW PACKAGE
(TOP VIEW)



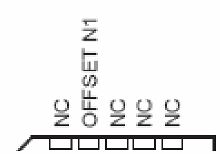
μA741M . . . U PACKAGE
(TOP VIEW)



symbol



μA741M . . . FK PACKAGE
(TOP VIEW)



electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	μA741C			μA741I, μA741M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 0	25°C		1	6		1	5	mV
			Full range			7.5			6	
$\Delta V_{IO(adj)}$	Offset voltage adjust range	V_O = 0	25°C		±15			±15		mV
I_{IO}	Input offset current	V_O = 0	25°C		20	200		20	200	nA
			Full range			300			500	
I_{IB}	Input bias current	V_O = 0	25°C		80	500		80	500	nA
			Full range			800			1500	
V_{ICR}	Common-mode input voltage range		25°C	±12	±13		±12	±13		V
			Full range	±12			±12			
V_{OM}	Maximum peak output voltage swing	R_L = 10 kΩ	25°C	±12	±14		±12	±14		V
		R_L ≥ 10 kΩ	Full range	±12			±12			
		R_L = 2 kΩ	25°C	±10	±13		±10	±13		
		R_L ≥ 2 kΩ	Full range	±10			±10			
A_{VD}	Large-signal differential voltage amplification	R_L ≥ 2 kΩ	25°C	20	200		50	200		V/mV
		V_O = ±10 V	Full range	15			25			
r_i	Input resistance		25°C	0.3	2		0.3	2		MΩ
r_o	Output resistance	V_O = 0, See Note 5	25°C		75			75		Ω
C_i	Input capacitance		25°C		1.4			1.4		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$	25°C	70	90		70	90		dB
			Full range	70			70			
k_{SVS}	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	V_{CC} = ±9 V to ±15 V	25°C		30	150		30	150	μV/V
			Full range			150			150	
I_{OS}	Short-circuit output current		25°C		±25	±40		±25	±40	mA
I_{CC}	Supply current	V_O = 0, No load	25°C		1.7	2.8		1.7	2.8	mA
			Full range			3.3			3.3	
P_D	Total power dissipation	V_O = 0, No load	25°C		50	85		50	85	mW
			Full range			100			100	

† All characteristics are measured under open-loop conditions with zero common-mode input voltage unless otherwise specified. Full range for the μA741C is 0°C to 70°C, the μA741I is –40°C to 85°C, and the μA741M is –55°C to 125°C.

NOTE 5: This typical value applies only at frequencies above a few hundred hertz because of the effects of drift and thermal feedback.

operating characteristics, $V_{CC\pm}$ = ±15 V, T_A = 25°C

PARAMETER		TEST CONDITIONS		μA741C			μA741I, μA741M			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
t_r	Rise time	V_I = 20 mV, C_L = 100 pF,	R_L = 2 kΩ, See Figure 1		0.3			0.3		μs
	Overshoot factor				5%			5%		
SR	Slew rate at unity gain	V_I = 10 V, C_L = 100 pF,	R_L = 2 kΩ, See Figure 1		0.5			0.5		V/μs

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE
vs
FREQUENCY

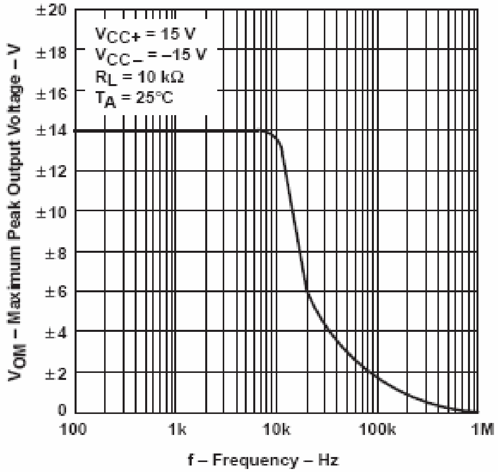


Figure 6

OPEN-LOOP SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
SUPPLY VOLTAGE

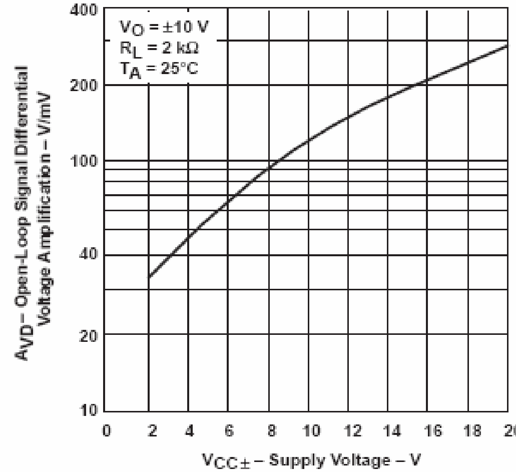
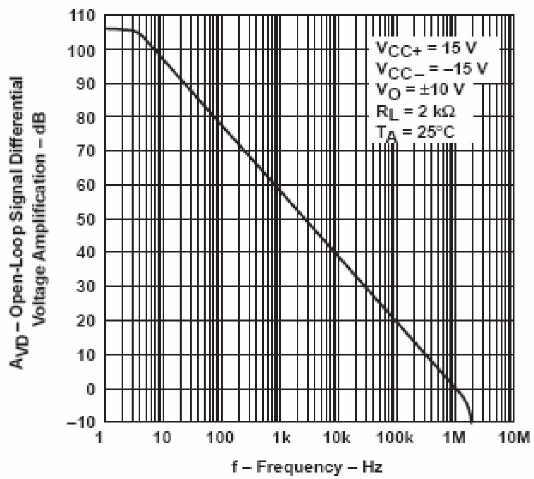


Figure 7

OPEN-LOOP LARGE-SIGNAL DIFFERENTIAL
VOLTAGE AMPLIFICATION
vs
FREQUENCY



Sometimes need to get GB from frequency response

National Semiconductor

December 18, 2008

LMP2231 Single Micropower, 1.6V, Precision Operational Amplifier with CMOS Inputs

General Description

The LMP2231 is a single micropower precision amplifier designed for battery powered applications. The 1.6V to 5.5V operating supply voltage range and quiescent power consumption of only 16 μW extend the battery life in portable battery operated systems. The LMP2231 is part of the LMP® precision amplifier family. The high impedance CMOS input makes it ideal for instrumentation and other sensor interface applications.

The LMP2231 has a maximum offset of 150 μV and maximum offset voltage drift of only 0.4 μV/°C along with low bias current of only ±20 fA. These precise specifications make the LMP2231 a great choice for maintaining system accuracy and long term stability.

The LMP2231 has a rail-to-rail output that swings 15 mV from the supply voltage, which increases system dynamic range.

Features

(For V_S = 5V, Typical unless otherwise noted)

- Supply current 10 μA
- Operating voltage range 1.6V to 5.5V
- Low TCV_{OS} ±0.4 μV/°C (max)
- V_{OS} ±150 μV (max)
- Input bias current 20 fA
- PSRR 120 dB
- CMRR 97 dB
- Open loop gain 120 dB
- Gain bandwidth product 130 kHz
- Slew rate 58 V/ms
- Input voltage noise, f = 1 kHz 60 nV/√Hz
- Temperature range –40°C to 125°C

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

ESD Tolerance (Note 2)	
Human Body Model	2000V
Machine Model	100V
Differential Input Voltage	±300 mV
Supply Voltage ($V_S = V^+ - V^-$)	6V
Voltage on Input/Output Pins	$V^+ + 0.3V$, $V^- - 0.3V$
Storage Temperature Range	−65°C to 150°C
Junction Temperature (Note 3)	150°C
Mounting Temperature	
Infrared or Convection (20 sec.)	+235°C

Operating Ratings (Note 1)

Operating Temperature Range (Note 3)	−40°C to 125°C
Supply Voltage ($V_S = V^+ - V^-$)	1.6V to 5.5V
Package Thermal Resistance (θ_{JA}) (Note 3)	
5-Pin SOT23	160.6 °C/W
8-Pin SOIC	116.2 °C/W

5V DC Electrical Characteristics (Note 4) Unless otherwise specified, all limits guaranteed for $T_A = 25°C$, V+ = 5V, V− = 0V, $V_{CM} = V_O = V+/2$, and $R_L > 1\ M\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			±10	±150 **±230**	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2231A		±0.3	±0.4	μV/°C
		LMP2231B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			0.02	±1 **±50**	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	$0V \le V_{CM} \le 4V$	81 **80**	97		dB
PSRR	Power Supply Rejection Ratio	$1.6V \le V+ \le 5.5V$ $V- = 0V$, $V_{CM} = 0V$	83 **83**	120		dB
CMVR	Common Mode Voltage Range	CMRR ≥ 80 dB CMRR ≥ 79 dB	−0.2 **−0.2**		4.2 **4.2**	V
A_{VOL}	Large Signal Voltage Gain	$V_O = 0.3V$ to $4.7V$ $R_L = 10\ k\Omega$ to V+/2	110 **108**	120		dB
V_O	Output Swing High	$R_L = 10\ k\Omega$ to V+/2 $V_{IN}(diff) = 100\ mV$		17	50 **50**	mV from either rail
	Output Swing Low	$R_L = 10\ k\Omega$ to V+/2 $V_{IN}(diff) = -100\ mV$		17	50 **50**	
I_O	Output Current (Note 7)	Sourcing, V_O to V− $V_{IN}(diff) = 100\ mV$	27 **19**	30		mA
		Sinking, V_O to V+ $V_{IN}(diff) = -100\ mV$	17 **12**	22		
I_S	Supply Current			10	16 **18**	μA

5V AC Electrical Characteristics (Note 4) Unless otherwise specified, all limits guaranteed for $T_A = 25°C$, $V^+ = 5V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$, and $R_L > 1\ M\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions		Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
GBW	Gain-Bandwidth Product	$C_L = 20$ pF, $R_L = 10$ kΩ			130		kHz
SR	Slew Rate	$A_V = +1$	Falling Edge	33 **32**	58		V/ms
			Rising Edge	33 **32**	48		
θ_m	Phase Margin	$C_L = 20$ pF, $R_L = 10$ kΩ			78		deg
G_m	Gain Margin	$C_L = 20$ pF, $R_L = 10$ kΩ			27		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		$nV/\sqrt{Hz}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.3		μV_{PP}
i_n	Input-Referred Current Noise	f = 1 kHz			10		$fA/\sqrt{Hz}$
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, $R_L = 10$ kΩ			0.002		%

1.8V DC Electrical Characteristics

(Note 4) Unless otherwise specified, all limits guaranteed for $T_A = 25°C$, V+ = 1.8V, V− = 0V, $V_{CM} = V_O$ = V+/2, and R_L > 1 MΩ. **Boldface** limits apply at the temperature extremes.

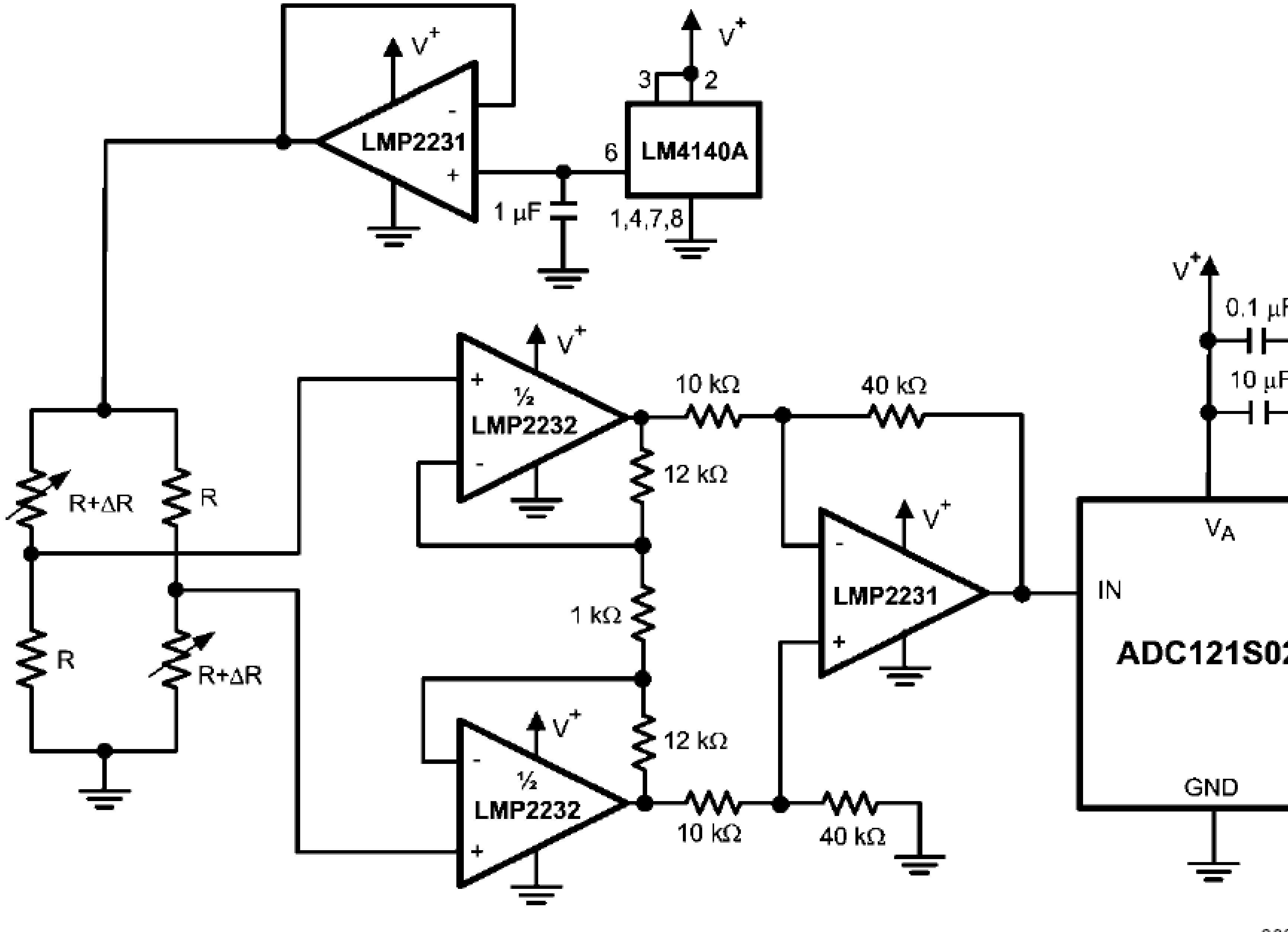
Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage			±10	±230 **±325**	μV
TCV_{OS}	Input Offset Voltage Drift	LMP2231A		±0.3	±0.4	μV/°C
		LMP2231B		±0.3	±2.5	
I_{BIAS}	Input Bias Current			0.02	±1.0 **±50**	pA
I_{OS}	Input Offset Current			5		fA
CMRR	Common Mode Rejection Ratio	0V ≤ V_{CM} ≤ 0.8V	76 **75**	92		dB
PSRR	Power Supply Rejection Ratio	1.6V ≤ V+ ≤ 5.5V V− = 0V, V_{CM} = 0V	83 **83**	120		dB
CMVR	Common Mode Voltage Rang	CMRR ≥ 76 dB CMRR ≥ 75 dB	−0.2 **0**		1.0 **1.0**	V
A_{VOL}	Large Signal Voltage Gain	V_O = 0.3V to 1.5V R_L = 10 kΩ to V+/2	103 **103**	120		dB
V_O	Output Swing High	R_L = 10 kΩ to V+/2 V_{IN}(diff) = 100 mV		12	50 **50**	mV from either rail
	Output Swing Low	R_L = 10 kΩ to V+/2 V_{IN}(diff) = −100 mV		13	50 **50**	
I_O	Output Current (Note 7)	Sourcing, V_O to V− V_{IN}(diff) = 100 mV	2.5 **2**	5		mA
		Sinking, V_O to V+ V_{IN}(diff) = −100 mV	2 **1.5**	5		
I_S	Supply Current			10	14 **15**	μA

1.8V AC Electrical Characteristics

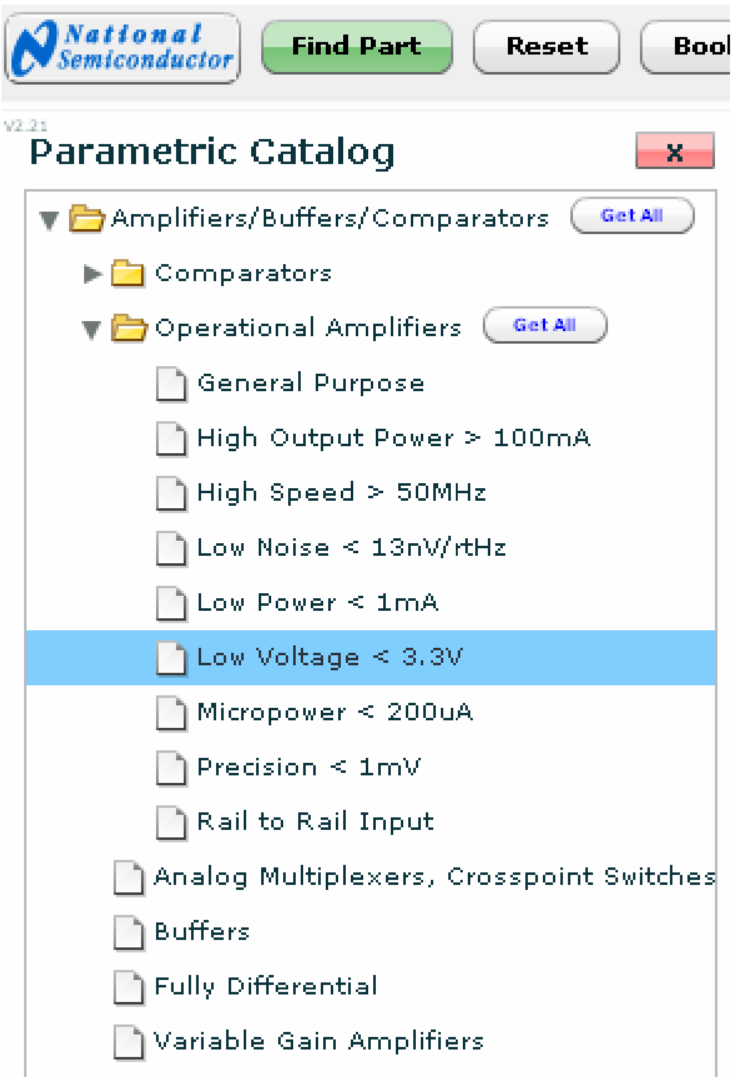
(Note 4) Unless otherwise is specified, all limits guaranteed for $T_A = 25°C$, $V^+ = 1.8V$, $V^- = 0V$, $V_{CM} = V_O = V^+/2$, and $R_L > 1\ M\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions		Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
GBW	Gain-Bandwidth Product	$C_L = 20$ pF, $R_L = 10$ kΩ			127		kHz
SR	Slew Rate	$A_V = +1$, $C_L = 20$ pF $R_L = 10$ kΩ	Falling Edge		58		V/ms
			Rising Edge		48		V/ms
θ_m	Phase Margin	$C_L = 20$ pF, $R_L = 10$ kΩ			70		deg
G_m	Gain Margin	$C_L = 20$ pF, $R_L = 10$ kΩ			25		dB
e_n	Input-Referred Voltage Noise Density	f = 1 kHz			60		$nV/\sqrt{Hz}$
	Input-Referred Voltage Noise	0.1 Hz to 10 Hz			2.4		μV_{PP}
i_n	Input-Referred Current Noise	f = 1 kHz			10		$fA/\sqrt{Hz}$
THD+N	Total Harmonic Distortion + Noise	f = 100 Hz, $R_L = 10$ kΩ			0.005		%

cal Application



Strain Gauge Bridge Amplifier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High Speed > 50MHz
Low Noise < 13nV/rtHz
Low Power < 1mA
Low Voltage < 3.3V
Micropower < 200uA
Precision < 1mV
Rail to Rail Input
Analog Multiplexers, Crosspoint Switches
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Fully Differential
Variable Gain Amplifiers

Low Voltage < 3.3V (111/111)

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annels) | Supply Current Per Channel (mA): 9.6, 0.00095; <= 9.6, >= 0.000, Go | PowerWise Rating 2 (uA/MHz): 5400, 1.8; <= 5400, >= 1.8, Go | Slew Rate (Volts/usec): 940, 0.0041; <= 940, >= 0.004, Go | Offset Voltage max, 25C (mV): 10, 0.005; <= 10, Go | Max Input Bias Current (nA): 30000, 0.00002; <= 3000C, Go | Input OutputType: Not Rail to Rail, R-R In and Out, Vcm to V-, No..., Vcm to V-, R-... | Price(1K US$)*: 55, 0.246; <= 55, >= 0.246, Go | Packaging: CERDIP, DIE, LLP, MDIP

Part	Supply Min (Volt)	Supply Max (Volt)	Gain Bandwidth (MHz)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Offset Voltage max, 25C (mV)	Max Input Bias Current (nA) ▲	Input OutputType	Price(1K US$)*	Packaging
LMP7721	1.8	5.5	17	1	1.3	76.5	10.5	0.15	0.00002	Vcm to V-, Not R	4.9500	SOIC NARROW
LMP2231	1.6	5.5	0.13	1	0.016	123	0.042	0.15	0.001	Vcm to V-, R-R (	1.4000|0.9500	SOIC NARROW|SOT·
LMP2016	2.7	5	3	2	0.93	310	4	0.005	0.003	Vcm to V-, R-R (	1.5000	MINI SOIC|SOIC NAI
LMP2015	2.7	5	3	1	0.93	310	4	0.005	0.003	Vcm to V-, R-R (	1.1000	SOIC NARROW|SOT·
LMC6442	1.8	11	0.01	2	0.00095	95	0.0041	3|7	0.004	Vcm to V-, R-R (	1.0200	MDIP|SOIC NARROW
LMV2011	2.7	5	3	1	0.93	310	4	0.025	0.005	Vcm to V-, R-R (	0.9500	SOIC NARROW|SOT·
LMP2011	2.7	5	3	1	0.93	310	4	0.025	0.005	Vcm to V-, R-R (	1.0500	SOIC NARROW|SOT·
LMP2014MT	2.7	5	3	4	0.93	310	4	0.025	0.005	Vcm to V-, R-R (	2.1000	TSSOP
LMP2012	2.7	5	3	2	0.93	310	4	0.025	0.005	Vcm to V-, R-R (	1.3500	MINI SOIC|SOIC NAI
LPV531	2.7	5	4.6	1	0.425	92.4	2.5	4.5	0.01	Vcm to V-, R-R (	0.4500	TSOT
LMV832	2.7	5.5	3.3	2	0.24	72	2	1	0.01	Vcm to V-, R-R (	0.7900	MINI SOIC
LMV831	2.7	5.5	3.3	1	0.25	72	2	1	0.01	Vcm to V-, R-R (	0.5500	SC-70
LMC6572	2.7	10	0.22	2	0.038	172.7	0.09	3|7	0.01	Vcm to V-, R-R (	0.5910|0.7780	SOIC NARROW
LMC6574	2.7	10	0.22	4	0.038	172.7	0.09	3|7	0.01	Vcm to V-, R-R (	1.9400|1.2000	SOIC NARROW
LMC7111	2.7	11	0.05	1	0.025	500	0.027	7	0.02	R-R In and Out	0.4450	SOT-23
LMV791	1.8	5	17	1	1.15	67.6	9.5	1.35	0.025	Vcm to V-, R-R (	0.5000	TSOT
LMV301	1.8	5	1	1	0.163	163	0.66	8	0.05	Vcm to V-, R-R (	0.2900	SC-70
LMP7701	2.7	12	2.5	1	0.715	286	1	0.2	0.05	R-R In and Out	1.0500	SOT-23
LMP7709	2.7	12	14	4	0.75	53.6	5.6	0.15	0.05	R-R In and Out	2.4500	TSSOP
LMP7707	2.7	12	14	1	0.75	53.6	5.6	0.15	0.05	R-R In and Out	1.1500	SOT-23
LMC8101	2.7	10	1	1	0.7	700	1	5	0.064	R-R In and Out	0.4560	MINI SOIC|MICRO S
LMC7101	2.7	15.5	1.1	1	0.5	454.5	1.1	3|7	0.064	R-R In and Out	0.3900|0.3290	SOT-23

Part	Supply Min (Volt)	Supply Max (Volt)	Gain Bandwidth (MHz)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Offset Voltage max, 25C (mV)	Max Input Bias Current ▲ (nA)	Input OutputType	Price(1K US$)*	Packaging
LMH6601	2.4	5.5	125	1	9.6	38.4	275	2.4	0.1	Vcm to V-, R-R (	0.8500|0.6500	SC-70
LMP7715	1.8	5.5	17	1	1.15	67.6	9.5	0.15	0.1	Vcm to V-, R-R (	0.8000	SOT-23
LMV751	2.7	5.5	5	1	0.6	120	2.3	1	0.1	Vcm to V-, R-R (	0.7900	SOT-23
LMV797	1.8	5	17	2	1.3	76.5	9.5	1.35	0.1	Vcm to V-, R-R (	0.6300	MINI SOIC
LMV796	1.8	5	17	1	1.15		9.5	1.35	0.1	Vcm to V-, R-R (	0.4500	SOT-23
LMV794	1.8	5	88	2	1.3	13.1	28	1.35	0.1	Vcm to V-, R-R (	0.9000|	MINI SOIC|SOIC NA
LMV793	1.8	5	88	1	1.15	13.1	28	1.35	0.1	Vcm to V-, R-R (	0.6500	SOIC NARROW|SOT
LMV792	1.8	5	17	2	1.3	76.5	9.5	1.35	0.1	Vcm to V-, R-R (	0.6700	MINI SOIC
LMV774	2.7	5	3.5	4	0.6	171.4	1.4	1	0.1	Vcm to V-, R-R (	0.9000	TSSOP
LMV772	2.7	5	3.5	2	0.6	171.4	1.4	1	0.1	Vcm to V-, R-R (	0.7100	MINI SOIC|SOIC NA
LMV771	2.7	5	3.5	1	0.6	171.4	1.4	0.85	0.1	Vcm to V-, R-R (	0.5100	SC-70
LMP7711	1.8	5.5	17	1	1.15	67.6	9.5	0.15	0.1	Vcm to V-, R-R (	0.8000	TSOT
LMP7718	1.8	5.5	88	2	1.3	14.8	28	0.15	0.1	Vcm to V-, R-R (	1.2500	MINI SOIC|SOIC NA
LMV710	2.7	5	5	1	1.17	234	5	3	0.1	R-R In and Out	0.4490	SOT-23
LMP7712	1.8	5.5	17	2	1.3	76.5	9.5	0.15	0.1	Vcm to V-, R-R (	1.2500	MINI SOIC
LMP7717	1.8	5.5	88	1	1.15	13	28	0.15	0.1	Vcm to V-, R-R (	0.8500	SOIC NARROW|SOT
LMP7716	1.8	5.5	17	2	1.3	76.5	9.5	0.15	0.1	Vcm to V-, R-R (	1.1500|1.4500	MINI SOIC
LMV712	2.7	5.5	5	2	1.17	234	5	3	0.13	R-R In and Out	0.6200|0.7500|(	LLP|MINI SOIC|MIC
LMV716	2.7	5	5	2	1.6	320	5.8	5	0.13	Vcm to V-, R-R (	0.4500	MINI SOIC
LMC6494	2.5	15.5	1.5	4	0.5	333.3	1.3	3|6	0.2	R-R In and Out	1.8600|2.8600	SOIC NARROW
LMC6492	2.5	15.5	1.5	2	0.5	333.3	1.3	3|6	0.2	R-R In and Out	1.0000|1.2500	SOIC NARROW
LMV842	2.7	12	4.5	2	1.02	226.7	2.5	0.5	0.3	R-R In and Out	1.1500	MINI SOIC
LMV841	2.7	12	4.5	1	1.02	226.7	2.5	0.5	0.3	R-R In and Out	0.7000	SC-70
LMV844	2.7	12	4.5	4	1.02	226.7	2.5	0.5	0.3	R-R In and Out	1.9000	TSSOP|SOIC NARR(

Part	Supply Min (Volt)	Supply Max (Volt)	Gain Bandwidth (MHz)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Offset Voltage max, 25C (mV)	Max Input Bias Current ▲ (nA)	Input OutputType	Price(1K US$)*	Packaging
LMV344	2.7	5.5	1	4	0.107	107	1	5	0.375	Vcm to V-, R-R (	0.4880|0.4400	TSSOP|SOIC NARRO
LMV341	2.7	5.5	1	1	0.107	107	1	4	0.375	Vcm to V-, R-R (	0.3130	SC-70
LMV342	2.7	5.5	1	2	0.107	107	1	5	0.375	Vcm to V-, R-R (	0.4090|0.3930	MINI SOIC|SOIC NA
LMP7702	2.7	12	2.5	2	0.75	300	1	0.22	0.4	R-R In and Out	1.4000	MINI SOIC
LMP7704	2.7	12	2.5	4	0.725	290	1	0.22	0.4	R-R In and Out	1.9000	TSSOP
LMV854	2.7	5.5	8	4	0.41	51.3	4.5	1	0.5	Vcm to V-, R-R (	1.2000	TSSOP
LMV852	2.7	5.5	8	2	0.41	51.3	4.5	1	0.5	Vcm to V-, R-R (	0.9000	MINI SOIC
LMV862	2.7	5.5	30	2	2.25	75	18	1	0.5	Vcm to V-, R-R (	0.9500	MINI SOIC
LMV861	2.7	5.5	30	1	2.25	75	18	1	0.5	Vcm to V-, R-R (	0.6700	SC-70
LMV851	2.7	5.5	8	1	0.41	51.3	4.5	1	0.5	Vcm to V-, R-R (	0.6300	SC-70
LPV511	2.7	12	0.027	1	0.00097	18.7	0.0077	3	1.9	R-R In and Out	0.4500	SC-70
LM4250	2	36	0.25	1	0.01	40	0.2	6	20	Not Rail to Rail	0.4380|0.4660	MDIP|SOIC NARROW
LP324	3	32	0.1	4	0.02125	212.5	0.05	9	20	Vcm to V-, Not R	0.3790|0.4850	MDIP|TSSOP|SOIC
LM10	1.1	7|45	0.09|0.05	1	0.28|0.27|0.3	3111.1|5400|33	0.2	2|4	30|40	Vcm to V-, R-R (	1.3200|55.0000	TO-5|MDIP|SOIC W
LMV551	2.7	5.5	3	1	0.037	12.3	1	3	38	Vcm to V-, R-R (	0.4500	SC-70|SOT-23
LMV554	2.7	5.0	3	4	0.037	12.3	1	3	38	Vcm to V-, R-R (	0.7900	TSSOP
LMV552	2.7	5.5	3	2	0.037	12.3	1	3	38	Vcm to V-, R-R (	0.5900	MINI SOIC
LP2902	3	26	0.1	4	0.02125	212.5	0.05	10	40	Vcm to V-, Not R	0.5380|0.5690	MDIP|SOIC NARROW
LMV934	1.8	5.5	1.5	4	0.116	77.3	0.42	5.5	50	R-R In and Out	0.6490|0.6310	TSSOP|SOIC NARRO
LMV931	1.8	5.5	1.5	1	0.116	77.3	0.42	4	50	R-R In and Out	0.4200	SC-70|SOT-23
LMV982	1.8	5	1.5	2	0.116	77.3	0.42	5.5	50	R-R In and Out	0.5890	MINI SOIC
LMV932	1.8	5.5	1.5	2	0.116	77.3	0.42	5.5	50	R-R In and Out	0.5200	MINI SOIC|SOIC NA
LM432	2.5	16	1	2	0.075	75	0.5	4	50	Vcm to V-, Not R	0.4700	SOIC NARROW
LMV981	1.8	5	1.5	1	0.116	77.3	0.42	4	50	R-R In and Out	0.5800|0.3900	SC-70|SOT-23|MICR

Part	Supply Min (Volt)	Supply Max (Volt)	Gain Bandwidth (MHz)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Offset Voltage max, 25C (mV)	Max Input Bias Current (nA)	Input OutputType	Price(1K US$)*	Packaging
LPV321	2.7	5	0.152	1	0.009	59.2	0.1	7	60	Vcm to V-, R-R (	0.3100	SC-70|SOT-23
LPV358	2.7	5	0.152	2	0.007	46.1	0.1	7	60	Vcm to V-, R-R (	0.3960	MINI SOIC|SOIC NAI
LPV324	2.7	5	0.152	4	0.0075	49.3	0.1	7	60	Vcm to V-, R-R (	0.4860	TSSOP|SOIC NARRO
LMV951	0.9	3	2.8	1	0.37	132.1	1.4	2.8	85	R-R In and Out	0.5200	TSOT
LMV651	2.7	5.5	12	1	0.11	9.2	2.8	1.5	100	Vcm to V-, R-R (	0.4500	SC-70
LMV652	2.7	5.5	12	2	0.11	9.2	2.8	1.5	100	Vcm to V-, R-R (	0.5900	MINI SOIC
LMV641	2.7	12	10	1	0.158	15.8	1.6	0.5	105	Vcm to V-, R-R (	0.6200	SOIC NARROW|SC-7
LMV821	2.5	5.5	5.6	1	0.3	53.6	2	3.5	150	Vcm to V-, R-R (	0.4100	SC-70|SOT-23
LMV824	2.5	5.5	5.6	4	0.25	38.5	2	3.5	150	Vcm to V-, R-R (	0.5800	TSSOP|SOIC NARRO
LMV822	2.5	5.5	5.6	2	0.25	44.6	2	3.5	150	Vcm to V-, R-R (	0.5000	MINI SOIC|SOIC NAI
LM7301	2.2	30	4	1	0.6	150	1.25	6	250	R-R In and Out	0.8480	SOIC NARROW|SOT-
LMV654	2.7	5.5	12	4	0.119	9.2	3.2	1.8	300	Vcm to V-, R-R (	0.9500	TSSOP
LM6132	2.7	24	10	2	0.36	36	14	2|6	350|300	R-R In and Out	1.6000|1.2500	MDIP|SOIC NARROW
LM6134	2.7	24	10	4	0.36	36	14	2|6	350|300	R-R In and Out	1.8300|1.7100|:	MDIP|SOIC NARROW
LMV721	2.2	5.5	10	1	1.03	103	5.25	3	400	Vcm to V-, R-R (	0.4820	SC-70|SOT-23
LMV722	2.2	5.5	10	2	0.9	90	5.25	3	400	Vcm to V-, R-R (	0.6100	MINI SOIC|SOIC NAI
LMV358	2.7	5.5	1	2	0.105	105	1	7	500	Vcm to V-, R-R (	0.3000	MINI SOIC|SOIC NAI
LMV321	2.7	5.5	1	1	0.13	130	1	7	500	Vcm to V-, R-R (	0.2460|0.2570	SC-70|SOT-23
LMV324	2.7	5.5	1	4	0.1025	102.5	1	7	500	Vcm to V-, R-R (	0.4330|0.3520	TSSOP|SOIC NARRO
LM6144	1.8	24	17	4	0.65	38.2	25	2.5|1	526	R-R In and Out	2.9400|3.8300	MDIP|SOIC NARROW
LM6142	1.8	24	17	2	0.65	38.2	25	2.5|1	526	R-R In and Out	2.2100|12.6000	MDIP|CERDIP|SOIC
LM6154	2.7	24	75	4	1.4	1.8	30	5	1500	R-R In and Out	2.8600	SOIC NARROW
LM6152	2.7	24	75	2	1.4	1.8	30	5|2	1500	R-R In and Out	1.4900|1.8500	SOIC NARROW
LMV116	2.7	12	45	1	0.6	13.3	40	5	2200	Vcm to V-, R-R (	0.5600	SOT-23
LMV118	2.7	12	45	1	0.6	13.3	40	5	2200	Vcm to V-, R-R (	0.5800	SOT-23
LM8261	2.5	30	21	1	0.97	46.2	12	5	2700	R-R In and Out	0.9540	SOT-23
LM8272	2.5	24	13	2	0.9	69.2	12	5	2700	R-R In and Out	1.3000	MINI SOIC
LM8262	2.5	22	21	2	1.05	50	12	7	2700	R-R In and Out	1.0500	MINI SOIC
LMH6644	2.7	12.8	130	4	2.7	20.8	135	5	3250	Vcm to V-, R-R (	1.3000|	TSSOP|SOIC NARRO
LMH6639	3	12	190	1	3.6	15.8	172	5	3250	Vcm to V-, R-R (	0.7000|	SOIC NARROW|SOT-
LMH6643	2.7	12.8	130	2	2.7	20.8	135	5	3250	Vcm to V-, R-R (	0.7900	MINI SOIC|SOIC NAI
LMH6642	2.7	12.8	130	1	2.7	20.8	135	5	3250	Vcm to V-, R-R (	0.6600	SOIC NARROW|SOT-
LMH6647	2.5	12	55	1	0.725	13.2	22	3	4000	R-R In and Out	0.7100	SOIC NARROW|SOT-
LMH6646	2.5	12	55	2	0.725	13.2	22	3	4000	R-R In and Out	1.0500|	MINI SOIC|SOIC NAI
LMH6645	2.5	12	55	1	0.725	13.2	22	3	4000	R-R In and Out	0.7100	SOIC NARROW|SOT-
LMH6682	3	12	190	2	6.5	18.1	940	5	30000	Vcm to V-, Not R	0.8900	MINI SOIC|SOIC NAI
LMH6658	3	12	270	2	6	22.2	700	5	30000	Vcm to V-, Not R	0.9500	MINI SOIC|SOIC NAI
LMH6657	3	12	270	1	6	22.2	700	5	30000	Vcm to V-, Not R	0.7500	SC-70|SOT-23
LMH6683	3	12	190	3	6.5	18.1	940	5	30000	Vcm to V-, Not R	1.2400	TSSOP|SOIC NARRO

High Output Power > 100mA (25/25)

Search Panel

(MHz)	Supply Max (Volt)	Supply Min (Volt)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Input OutputType	Max Input Bias Current (nA)	Price(1K US$)*	Packaging
	84 / 5; >= 5 Go	20 / 2.4; <= 20 Go	70 / 0.78; <= 70, >= 0.78 Go	16666.7 / 14.4; <= 16666, >= 14.4 Go	3600 / 2; <= 3600, >= 2 Go	☑ Not Rail to Rail ☑ R-R In and Out ☑ Vcm to V-, No... ☑ Vcm to V-, R-...	14000 / 0.1; <= 14000 Go	78.7 / 0.449; <= 78.7, >= 0.449 Go	☑ CERDIP ☑ CERPAC ☑ DIE ☑ ISOLATE

Part	Output Current (mA) ▼	Offset Voltage max, 25C (mV)	Gain Bandwidth (MHz)	Supply Max (Volt)	Supply Min (Volt)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Slew Rate (Volts/usec)	Input OutputType	Max Input Bias Current (nA)	Price(1K US$)*	Packaging
LM7372	150	8	120	36	9	6.5	14.8	3000	Not Rail to Rail	12000	1.9800	PSOP|SOIC NARROV
LM1877	1000	15	5	26	6	12.5	2500	2	Not Rail to Rail	50	0.6150	SOIC WIDE
LM3875	6000	10	8	84	20	30	3750	11	Not Rail to Rail	1000	3.4300	ISOLATED TO220
LM3886	11500	10	3	84	18	50	16666.7	19	Not Rail to Rail	1000	3.4300	TO-220|ISOLATED T
LM4765	3500	15	7.5	64	18	25	3333.3	18	Not Rail to Rail	500	3.5000	TO-220
LM6171	135	3|6	100	34	5.5	2.5	15.6	3600	Not Rail to Rail	4000	1.4500|1.1900	MDIP|SOIC NARROW
LM6172	85	1.5|3	100	36	5.5	2.3	14.4	3000	Not Rail to Rail	4000	78.7000|1.7000	MDIP|CERDIP|SOIC
LM6181	130	5	100	32	7	7.5	62.5	1400	Not Rail to Rail	5000	1.2400	MDIP|SOIC NARROW
LM6584	75	4	15.4	13	5	0.78	50.6	15	R-R In and Out	7000	1.2400	TSSOP|SOIC NARRO
LM6588	230	4	15.4	16	5	0.8	51.9	15	R-R In and Out	7000	1.1500	TSSOP|SOIC NARRO
LM675	4000	10	5.5	60	10	18	3272.7	8	Not Rail to Rail	2000	2.7500	TO-220
LM7332	100	4	20	32	2.5	1.2	60	13.2	R-R In and Out	1000	1.3000	MINI SOIC|SOIC NAI
LM1875	4000	15	5.5	60	16	70	12727.3	8	Not Rail to Rail	2000	1.6600	TO-220
LM8261	53	5	21	30	2.5	0.97	46.2	12	R-R In and Out	2700	0.9540	SOT-23
LM8262	60	7	21	22	2.5	1.05	50	12	R-R In and Out	2700	1.0500	MINI SOIC
LM8272	100	5	13	24	2.5	0.9	69.2	12	R-R In and Out	2700	1.3000	MINI SOIC
LMH6601	150	2.4	125	5.5	2.4	9.6	38.4	275	Vcm to V-, R-R (	0.1	0.8500|0.6500	SC-70
LMH6639	160	5	190	12	3	3.6	15.8	172	Vcm to V-, R-R (	3250	0.7000|	SOIC NARROW|SOT-
LMH6640	110	1	62	16	4.5	4	21.1	170	Vcm to V-, R-R (	3500	1.1500	SOT-23
LMH6642	115	5	130	12.8	2.7	2.7	20.8	135	Vcm to V-, R-R (	3250	0.6600	SOIC NARROW|SOT-
LMH6643	115	5	130	12.8	2.7	2.7	20.8	135	Vcm to V-, R-R (	3250	0.7900	MINI SOIC|SOIC NAI
LMH6644	115	5	130	12.8	2.7	2.7	20.8	135	Vcm to V-, R-R (	3250	1.3000|	TSSOP|SOIC NARRO
LMH6672	200	5.5	130	12	5	6.2	34.4	170	Vcm to V-, Not R	14000	1.6000	PSOP|SOIC NARROV
LMV710	40	3	5	5	2.7	1.17	234	5	R-R In and Out	0.1	0.4490	SOT-23
LMV715	32	3	5	5.5	2.7	1.17	234	5	R-R In and Out	0.13	0.6500|0.7500|(	LLP|MINI SOIC|MICR

General Purpose (55/55)

Search Panel

w Rate (Volts/usec)	Supply Min (Volt)	Supply Max (Volt)	Offset Voltage max, 25C (mV)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Max Input Bias Current (nA)	Price(1K US$)*	Packaging
70 – 0.05; <= 70, >= 0.05	12 – 1.1; <= 12	45 – 5.5; >= 5.5	15 – 0.4; <= 15	18.5 – 0.01; <= 18.5, >= 0.01	5400 – 29.2; <= 5400, >= 29.2	30000 – 0.01; <= 3000(	55 – 0.212; <= 55, >= 0.212	☑ CERDIP ☑ CERPACK ☑ DIE ☑ LCC

Part	Gain Bandwidth (MHz)	Channels (Channels)	Input OutputType	Slew Rate (Volts/usec)	Supply Min (Volt)	Supply Max (Volt)	Offset Voltage max, 25C (mV)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Max Input Bias Current (nA)	Price(1K US$)*	Packaging
LM348	1	4	Not Rail to Rail	0.5	10	36	6	0.6	600	400	0.4320	MDIP|SOIC NARROW
LF156	5	1	Vcm to V+, Not F	12	10	44	5	5	1000	50	4.0300|14.4000	TO-99
LF256	5	1	Vcm to V+, Not F	12	10	44	5	5	1000	5	4.0300	TO-99
LF347	4	4	Vcm to V+, Not F	13	8	36	10|5	1.8	450	8	0.9220|0.8320|(	MDIP|SOIC NARROW
LF353	4	2	Vcm to V+, Not F	13	10	36	10	1.8	450	8	0.3860|0.4100	MDIP|SOIC NARROW
LF356	5	1	Vcm to V+, Not F	12	10	36	10	5	1000	8	0.3490|0.3630|(	MDIP|SOIC NARROW
LF411	4	1	Not Rail to Rail	15	10	44|36	0.4|5|1	1.8	450	3|4	2.8500|29.9000	MDIP|CERDIP|CERPA
LF412	4	2	Not Rail to Rail	15	10	36|45	3|1	1.8	450	50	14.7000|5.4000	TO-5|MDIP|CERDIP|
LM10	0.09|0.05	1	Vcm to V-, R-R (	0.2	1.1	7|45	2|4	0.28|0.27|0.3	3111.1|5400|33	30|40	1.3200|55.0000	TO-5|MDIP|SOIC W
LM101A	1	1	Vcm to V+, Not F	0.5	10	44	2	1.8	1800	100	4.4000|13.7000	CERDIP|CERPACK|T(
LM118	15	1	Not Rail to Rail	70	10	40	4	4.5	300	500	27.1000|5.1500	CERDIP|WAFER|TO-
LM124	1	4	Vcm to V-, Not R	0.5	3	32	|5|2	0.18	180	|100|300	19.5000|4.0000	CERDIP|CERPACK|L(
LM13700	2	2	Not Rail to Rail	50	10	36	4	1.3	650	7000	0.4390|0.8690	MDIP|SOIC NARROW
LM1458	1	2	Not Rail to Rail	0.5	6	36	6	1.5	1500	800	0.3790|0.3330	MDIP|SOIC NARROW
LM148	0.9	4	Not Rail to Rail	0.5	10	|44	5	0.6	666.7	325	4.6000|6.3100|	CERDIP|WAFER|DIE
LM1558	1	2	Not Rail to Rail	0.5	6	44	5	1.5	1500	1500	11.9000|4.0100	CERDIP|TO-99
LM158	1	2	Vcm to V-, Not R	0.5	3	32	|5|2	0.25	250	|100|300	17.7000|4.4000	CERDIP|CERPACK|W
LM201A	1	1	Vcm to V+, Not F	0.5	10	44	2	1.8	1800	100	3.9300	TO-99
LM224	1	4	Vcm to V-, Not R	0.5	3	32	5	0.18	180	300	4.0000	CERDIP
LM258	1	2	Vcm to V-, Not R	0.5	3	32	5	0.25	250	300	3.6000	TO-99
LM2902	1	4	Vcm to V-, Not R	0.5	3	26	7	0.18	180	500	0.3790|0.4390|(	MDIP|TSSOP|SOIC N
LM2904	1	2	Vcm to V-, Not R	0.1	3	26	7	0.25	250	500	0.2960|0.3360|	MDIP|SOIC NARROW
LM301A	1	1	Vcm to V+, Not F	0.5	10	36	7.5	1.8	1800	300	3.9300|0.3030	MDIP|TO-99
LM318	15	1	Not Rail to Rail	70	10	40	10	4.5	300	750	0.4090|0.4250	MDIP|SOIC NARROW

Part	Gain Bandwidth ▼ (MHz)	Channels (Channels)	Input OutputType	Slew Rate (Volts/usec)	Supply Min (Volt)	Supply Max (Volt)	Offset Voltage max, 25C (mV)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Max Input Bias Current (nA)	Price(1K US$)*	Packaging
LM321	1	1	Vcm to V-, Not R	0.5	3	32	7	0.45	450	500	0.2120	SOT-23
LM324	1	4	Vcm to V-, Not R	0.5	3	32	|3|7	0.18	180	200||500	3.9000|0.4090|(	TSSOP|MDIP|CERDII
LM346	1.2	4	Not Rail to Rail	0.4	3	36	6	0.035	29.2	250	0.6120	SOIC NARROW
LF147	4	4	Vcm to V+, Not F	13	5	44	5	1.8	450	10	10.3000|5.2400	CERDIP
LM358	1	2	Vcm to V-, Not R	0.1	3	32	3|7	0.25	250	200|500	0.2800|0.2960|:	MDIP|SOIC NARROW
LM359	400	2	Not Rail to Rail	60	5	22		18.5	46.3	30000	1.3500	SOIC NARROW
LM392	1	2	Vcm to V-, Not R	0.1	3	32	5	0.5	500	400	0.4580|0.5830	MDIP|SOIC NARROW
LM4250	0.25	1	Not Rail to Rail	0.2	2	36	6	0.01	40	20	0.4380|0.4660	MDIP|SOIC NARROW
LM432	1	2	Vcm to V-, Not R	0.5	2.5	16	4	0.075	75	50	0.4700	SOIC NARROW
LM611	0.8	1	Vcm to V-, Not R	0.7	4	36	5	0.21	262.6	40	0.9500|0.8400	SOIC NARROW
LM613	0.8	2	Vcm to V-, Not R	0.7	4	36	5	0.112	140	40	1.5000	SOIC WIDE
LM614	0.8	4	Vcm to V-, Not R	0.7	4	36	5	0.112	140	40	1.4300|	SOIC WIDE|DIE
LM741	1	1	Not Rail to Rail	0.5	10	|44|36	|5|6	1.7	1700	|800|1500	0.2500|11.4000	MDIP|CERDIP|TO-9
LM747	1.5	2	Not Rail to Rail	0.5	10	44	5	1.7	1133.3	1500	9.3000|13.7000	CERDIP|WAFER|TO-:
LM748	1	1	Not Rail to Rail	0.5	10	44	5	1.9	1900	1500	13.1000	TO-99
LM833	15	2	Not Rail to Rail	7	10	36	5	2.5	166.7	1050	0.3330|0.3130|(	MDIP|MINI SOIC|SO
LM837	25	4	Not Rail to Rail	10	10	36	5	2.5	100	1050	0.5720	SOIC NARROW
LME49710	55	1	Not Rail to Rail	20	5	34	0.7	4.8	87.3	72	0.9000|5.5000	MDIP|SOIC NARROW
LME49720	55	2	Not Rail to Rail	20	5	34	0.7	5	90.9	72	10.5000|1.9000	MDIP|SOIC NARROW
LME49740	55	4	Not Rail to Rail	20	5	34	0.7	4.62	84	72	4.0000	MDIP|SOIC NARROW
LMV831	3.3	1	Vcm to V-, R-R (	2	2.7	5.5	1	0.25	72	0.01	0.5500	SC-70
LMV832	3.3	2	Vcm to V-, R-R (	2	2.7	5.5	1	0.24	72	0.01	0.7900	MINI SOIC
LMV834	3.3	4	Vcm to V-, R-R (	2	2.7	5.5	1	0.24	73	0.5	1.1000	TSSOP
LMV851	8	1	Vcm to V-, R-R (	4.5	2.7	5.5	1	0.41	51.3	0.5	0.6300	SC-70
LMV852	8	2	Vcm to V-, R-R (	4.5	2.7	5.5	1	0.41	51.3	0.5	0.9000	MINI SOIC
LMV854	8	4	Vcm to V-, R-R (	4.5	2.7	5.5	1	0.41	51.3	0.5	1.2000	TSSOP
LMV861	30	1	Vcm to V-, R-R (	18	2.7	5.5	1	2.25	75	0.5	0.6700	SC-70
LMV862	30	2	Vcm to V-, R-R (	18	2.7	5.5	1	2.25	75	0.5	0.9500	MINI SOIC
LP2902	0.1	4	Vcm to V-, Not R	0.05	3	26	10	0.02125	212.5	40	0.5380|0.5690	MDIP|SOIC NARROW
LP324	0.1	4	Vcm to V-, Not R	0.05	3	32	9	0.02125	212.5	20	0.3790|0.4850	MDIP|TSSOP|SOIC N
TL082	4	2	Vcm to V+, Not F	13	10|12	36	15	1.75	437.5	8	0.4250|0.5550	MDIP|SOIC NARROW

Micropower < 200uA (36/36)

Search Panel

Voltage max, 25C (mV)	Max Input Bias Current (nA)	CMRR (dB)	PSRR (dB)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Price(1K US$)*	Packaging
<= 10 Go	300 0.001 <= 300 Go	120 85 <= 120 >= 85 Go	120 85 <= 120 >= 85 Go	4 1 <= 4 >= 1 Go	0.425 0.0004 <= 0.425 >= 0.000 Go	500 9.2 <= 500 >= 9.2 Go	2.55 0.31 <= 2.55 >= 0.31 Go	☑ DIE ☑ MDIP ☑ MINI SOIC ☑ SC-70

Part	Supply Min (Volt) ▲	Supply Max (Volt)	Gain Bandwidth (MHz)	Offset Voltage max, 25C (mV)	Max Input Bias Current (nA)	CMRR (dB)	PSRR (dB)	Channels (Channels)	Supply Current Per Channel (mA)	PowerWise Rating 2 (uA/MHz)	Price(1K US$)*	Packaging
LMP2234	1.6	5	0.13	0.15	0.001	97	120	4	0.009	69.2	1.9300|2.4000|	TSSOP|SOIC NARRO
LM4250	2	36	0.25	6	20			1	0.01	40	0.4380|0.4660	MDIP|SOIC NARROW
LMC6022	4.75	15.5	0.35	9	0.2			2	0.043	122.9	0.5720	SOIC NARROW
LMC6024	4.75	15.5	0.35	9	0.2			4	0.04	114.3	0.6720	SOIC NARROW
LMC6041	4.5	15.5	0.075	3|6	0.004			1	0.014	186.7	1.0700|0.7580	MDIP|SOIC NARROW
LMC6042	4.5	15.5	0.1	3|6	0.004			2	0.01	100	1.1800|0.9150|	MDIP|SOIC NARROW
LMC6044	4.5	15.5	0.1	3|6	0.004			4	0.01	100	1.1300|1.1100|	MDIP|SOIC NARROW
LMC6061	4.5	15.5	0.1	0.35|0.8	0.004|0.1	85	85	1	0.02	200	0.5510|0.7200	SOIC NARROW
LMC6062	4.5	|15.5	0.1	|0.35|0.8	|0.004|0.1	85	85	2	0.016	160	1.2100|1.1300|	MDIP|SOIC NARROW
LMC6064	4.5	15.5	0.1	0.35|0.8	0.004|0.1	85	85	4	0.016|0.02	200|160	1.9600|1.8800|	MDIP|SOIC NARROW
LMC6442	1.8	11	0.01	3|7	0.004			2	0.00095	95	1.0200	MDIP|SOIC NARROW
LMC6462	3	15.5	0.05	3|0.5	0.005	85	85	2	0.02	400	1.0100|1.3000|	MDIP|SOIC NARROW
LMC6464	3	15.5	0.05	3|0.5	0.005	85	85	4	0.02	400	1.8300|2.0200|	MDIP|SOIC NARROW
LMC6572	2.7	10	0.22	3|7	0.01			2	0.038	172.7	0.5910|0.7780	SOIC NARROW
LMC6574	2.7	10	0.22	3|7	0.01			4	0.038	172.7	1.9400|1.2000	SOIC NARROW
LMC7111	2.7	11	0.05	7	0.02			1	0.025	500	0.4450	SOT-23
LMP2231	1.6	5.5	0.13	0.15	0.001	97	120	1	0.016	123	1.4000|0.9500	SOIC NARROW|SOT-
LMP2232	1.6	5.5	0.13	0.15	0.003	97	120	2	0.014	107.7	1.4000|1.9000	MINI SOIC|SOIC NA
LM346	3	36	1.2	6	250			4	0.035	29.2	0.6120	SOIC NARROW
LMV551	2.7	5.5	3	3	38	93	90	1	0.037	12.3	0.4500	SC-70|SOT-23
LMV552	2.7	5.5	3	3	38	93	90	2	0.037	12.3	0.5900	MINI SOIC
LMV554	2.7	5.0	3	3	38	93	90	4	0.037	12.3	0.7900	TSSOP
LMV641	2.7	12	10	0.5	105	120	100	1	0.158	15.8	0.6200	SOIC NARROW|SC-7
LMV651	2.7	5.5	12	1.5	100			1	0.11	9.2	0.4500	SC-70
LMV652	2.7	5.5	12	1.5	100			2	0.11	9.2	0.5900	MINI SOIC
LMV654	2.7	5.5	12	1.8	300			4	0.119	9.2	0.9500	TSSOP
LP2902	3	26	0.1	10	40			4	0.02125	212.5	0.5380|0.5690	MDIP|SOIC NARROW
LP324	3	32	0.1	9	20			4	0.02125	212.5	0.3790|0.4850	MDIP|TSSOP|SOIC
LPC660	5	15	0.35	3|6	0.004			4	0.04	114.3	1.1200|1.4400	SOIC NARROW
LPC662	5	15	0.35	3|6	0.004			2	0.043	122.9	1.2000|0.9300	SOIC NARROW
LPV321	2.7	5	0.152	7	60			1	0.009	59.2	0.3100	SC-70|SOT-23
LPV324	2.7	5	0.152	7	60			4	0.0075	49.3	0.4860	TSSOP|SOIC NARRO
LPV358	2.7	5	0.152	7	60			2	0.007	46.1	0.3960	MINI SOIC|SOIC NA
LPV511	2.7	12	0.027	3	1.9			1	0.00097	18.7	0.4500	SC-70
LPV521	1.6	5.5	0.0062	1	0.001	102	109	1	0.0004	64.5	0.6500	SC-70
LPV531	2.7	5	4.6	4.5	0.01			1	0.425	92.4	0.4500	TSOT

Widely Varying Performance Characteristics (selected comparison)

Model	Type	Supply Min (V)	Supply Max (V)	Output Current (mA)	Supply Current/Channel (mA)	GB (MHz)	Power (mW)	Min Price $	Max Price $
LMP2234 (quad)	Micro-power	1.6	5	5	.009	0.13	.056[1]	1.93	2.40
LM741	General Purpose	10	36	25	1.7	1.0	60[2]	0.25	11.40
LM3886	Power	18	84	11,500	50	3.0	125000[2]	3.30	
LMP 2231	Low Voltage	1.6	5.1	5	.01	0.13	.018[1]	0.95	1.40
LMH 6624	High Speed	5	12	100	11.4	1500	72	1.86	

[1] Minimum [2] Maximum

Nonideal Op Amp Characteristics

Critical Parameters

- Gain-Bandwidth Product (GB)
- Offset Voltage
- Input Voltage Range
- Output Voltage Range
- Output Saturation Current
- Slew Rate

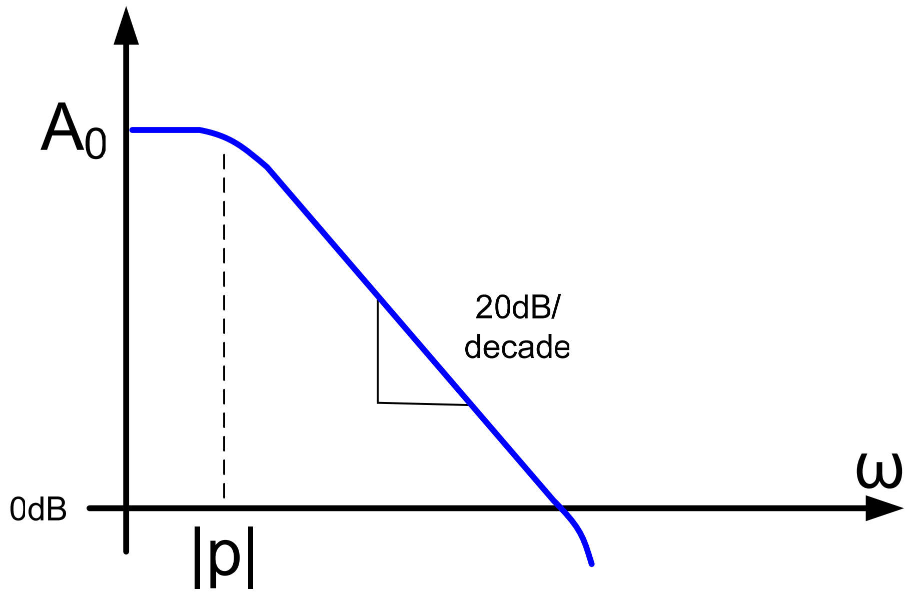
Usually Less Critical Parameters

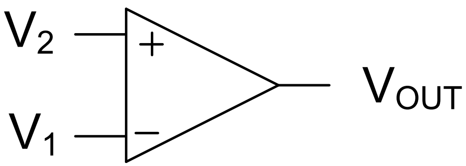
- DC voltage gain , A_0
- 3dB Bandwidth, BW

$GB = A_0 BW$

- Common Mode Rejection Ratio (CMRR)
- Power Supply Rejection Ratio (PSRR)
- R_{IN} and R_{OUT}
- Bias Currents
- Full Power Bandwidth
- Compensation

Gain, Bandwidth and GB





$$A(s)=\frac{V_{OUT}}{V_2-V_1}$$

BW = -p

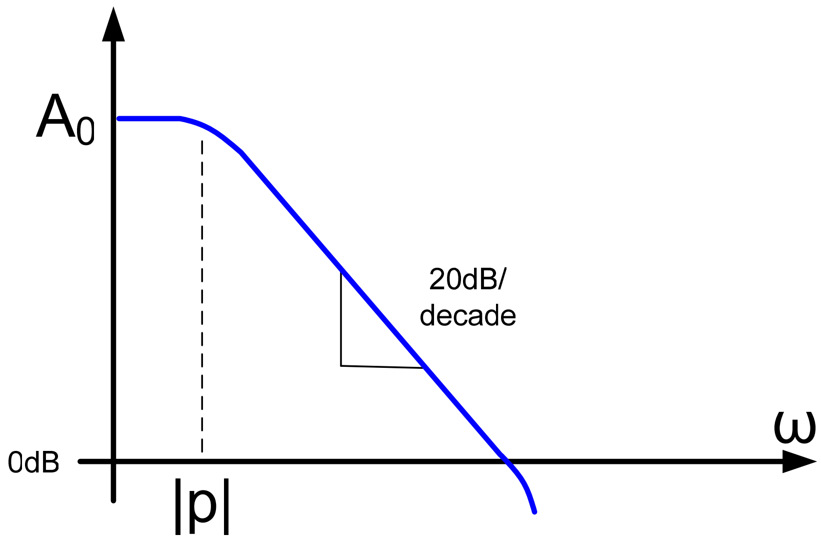
Since $GB=A_0(-p)$

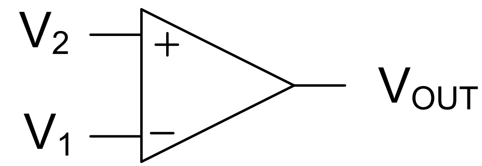
$$A(s)=\frac{A_0(-p)}{s-p}$$

Alternatively $A(s)=\frac{GB}{s-p}$

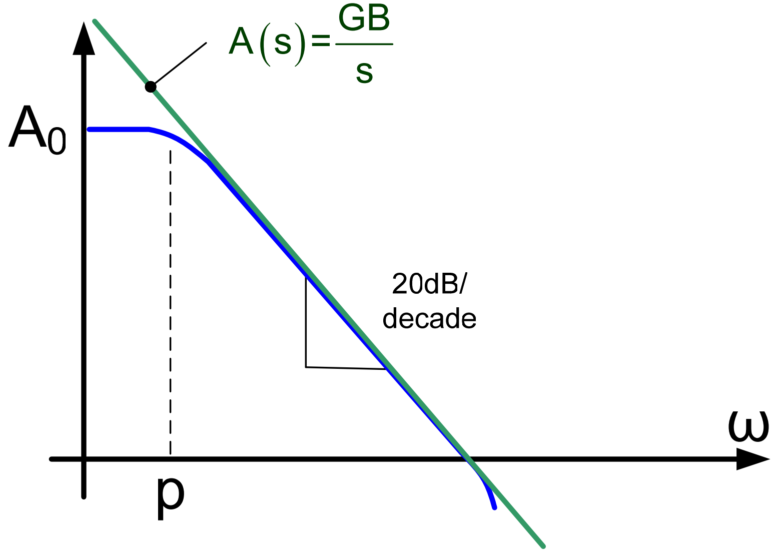
Almost all op amps are designed to have a first-order response down to unity gain

Gain, Bandwidth and GB





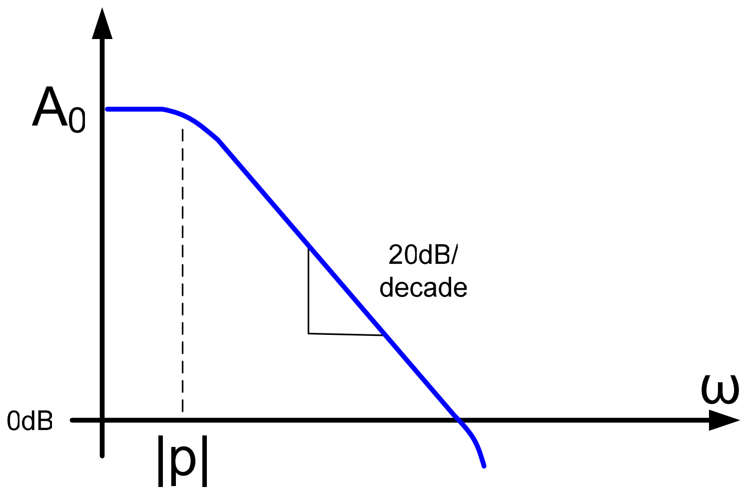
$$A(s)=\frac{GB}{s-p}$$

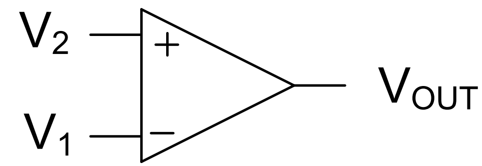


Simpler expression adequate for most applications

$$A(s)=\frac{GB}{s}$$

Gain, Bandwidth and GB





$$A(s)=\frac{GB}{s-p}$$

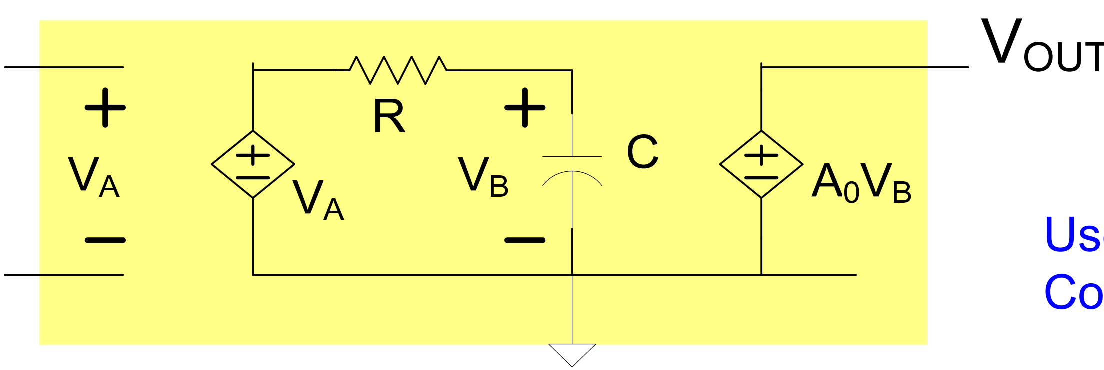
Macromodel of OA with Gain and BW effects

An equivalent circuit that <u>performs</u> same as actual device

$$A(s)=\frac{A_0(-p)}{s-p}$$

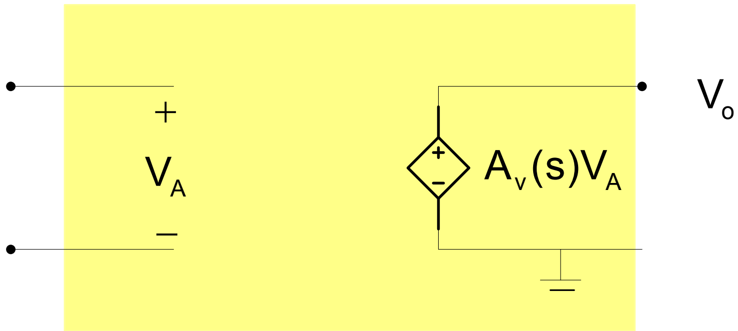
C=1

$R=A_0GB^{-1}$



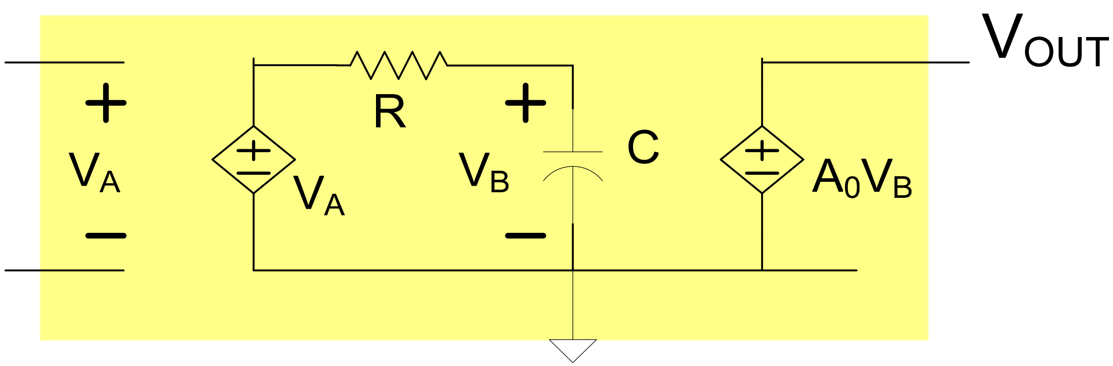
Useful for simulation
Component values not of concern

Macromodels of op amp that includes effects of frequency dependent gain



$$A_v(s)=\frac{A_o}{\frac{s}{\omega_b}+1}$$

Suitable for hand analysis or Matlab/Excel/C++ simulations



Suitable for use in circuit simulators

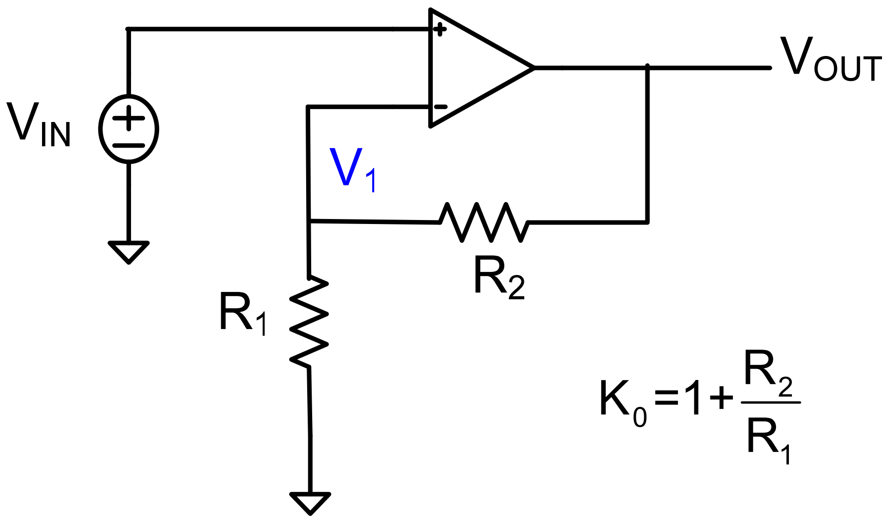
$$V_o=V_A\left[\frac{A_o}{1+RCs}\right]$$

C=1F $\quad R=\frac{1}{\omega_b}$

$$A_V(s)=\frac{A_o}{1+\frac{s}{\omega_b}}$$

Gain, Bandwidth and GB

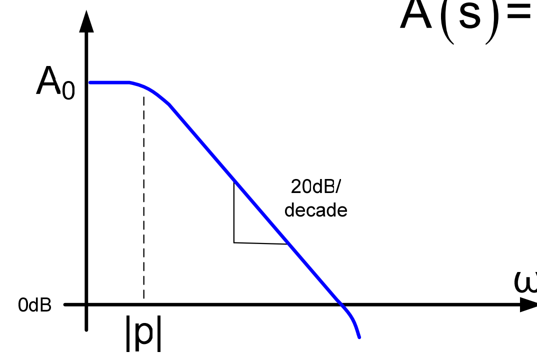
Effects of GB on basic circuits



$$K_0 = 1 + \frac{R_2}{R_1}$$

Basic Noninverting Amplifier

$$A(s) = \frac{GB}{s}$$



$$V_1(G_1 + G_2) = V_{OUT} G_2$$

$$V_{OUT} = \frac{GB}{s}(V_{IN} - V_1)$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{K_0}{1 + s\frac{K_0}{GB}}$$

$$BW = \frac{GB}{K_0}$$

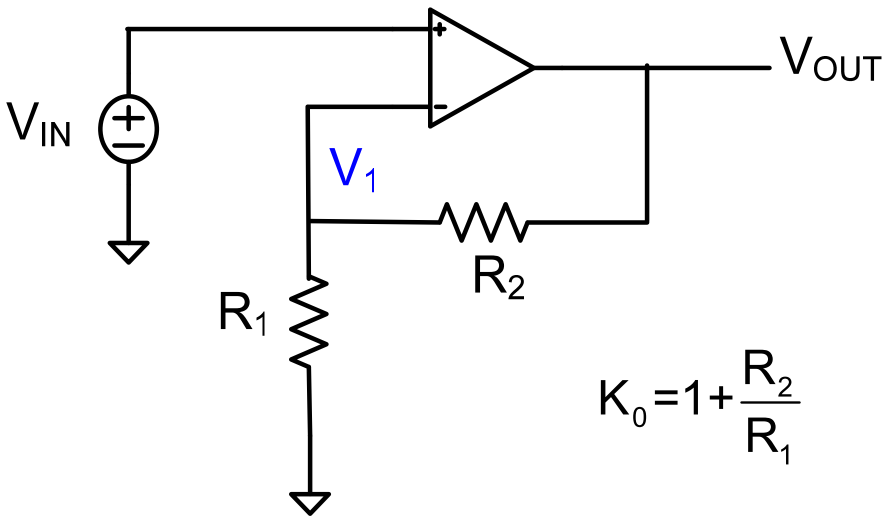
Closed loop GB is given by

$$GB_{CL} = K_0 \bullet \left(\frac{GB}{K_0}\right) = GB$$

Closed loop GB for basic noninverting amplifier is equal to the open-loop GB independent of K_0

Gain, Bandwidth and GB

Effects of GB on basic circuits



$$K_0 = 1 + \frac{R_2}{R_1}$$

Basic Noninverting Amplifier

Example: If an op amp with a GB of 5MHz is use to design a basic noninverting amplifier with a dc gain of 10, what is the closed-loop bandwidth?

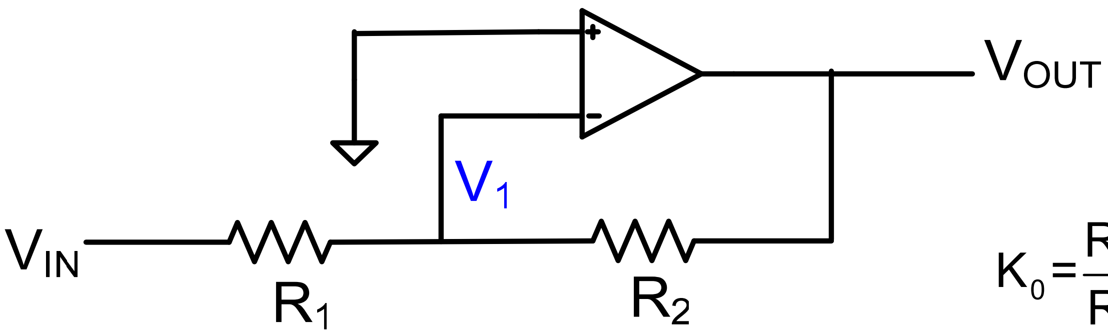
$$GB_{CL} = K_0 \bullet BW = K_0 \bullet \left(\frac{GB}{K_0}\right) = GB \quad \longrightarrow \quad BW = \frac{GB}{K_0} = \frac{5MHz}{10} = 500KHz$$

Example: If the closed-loop gain is increased, what happens to the BW?

BW decreases to GB/K_0

Gain, Bandwidth and GB

Effects of GB on basic circuits



$$K_0 = \frac{R_2}{R_1}$$

Basic Inverting Amplifier

$$V_1(G_1+G_2) = V_{OUT}G_2 + V_{IN}G_1$$

$$V_{OUT} = \frac{GB}{s}(-V_1)$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{K_0}{1+s\frac{(1+K_0)}{GB}}$$

$$BW = \frac{GB}{1+K_0}$$

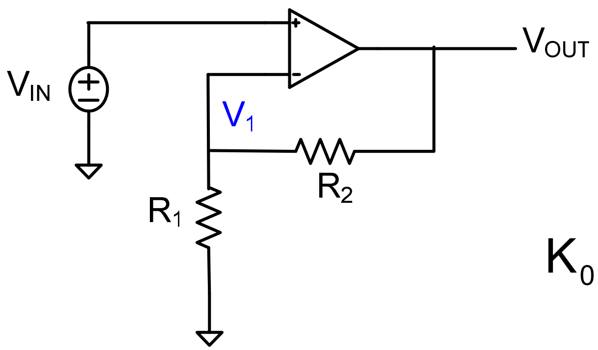
Closed loop GB is given by

$$GB_{CL} = K_0 \bullet \left(\frac{GB}{1+K_0}\right) = \left(\frac{K_0}{1+K_0}\right)GB$$

Closed loop gain +1 times closed loop bandwidth is equal to the open-loop GB

Gain, Bandwidth and GB

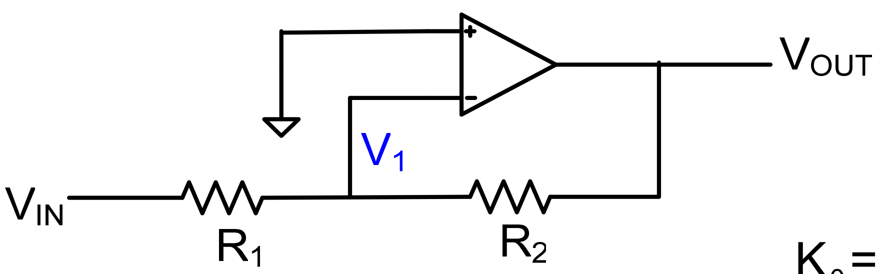
Effects of GB on basic circuits



Basic Noninverting Amplifier

$$K_0 = 1 + \frac{R_2}{R_1}$$

$$BW = \frac{GB}{K_0}$$



Basic Inverting Amplifier

$$K_0 = \frac{R_2}{R_1}$$

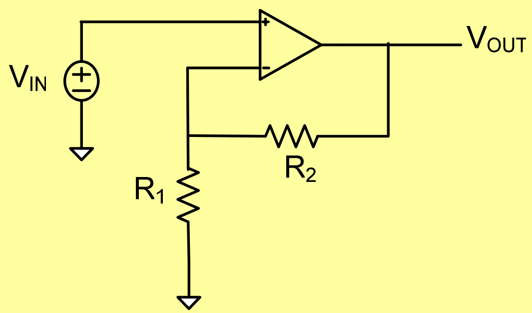
$$BW = \frac{GB}{1 + K_0}$$

$$BW = \frac{GB}{1 + R_2/R_1}$$

- For a given gain, the BW of the BNA is larger than that of the BIA
- Difference becomes significant when gain is small
- In terms of resistor values, expressions are identical
- In both cases, BW decreases rapidly with gain and is a serious concern about amplifiers
- Only way to improve BW with these structures is to get better Op Amp

Gain, Bandwidth and GB

Summary of Effects of GB on Basic Inverting and Noninverting Amplifiers

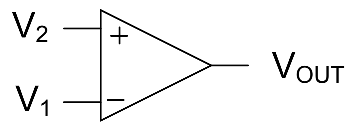


Basic Noninverting Amplifier

$$K_0 = 1 + \frac{R_2}{R_1}$$

$$BW = \frac{GB}{K_0}$$

$$A_{FB}(s) = \frac{K_0}{1 + s\frac{K_0}{GB}}$$

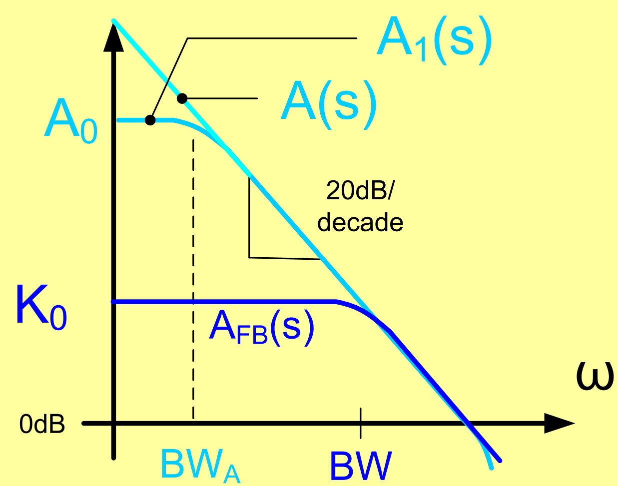


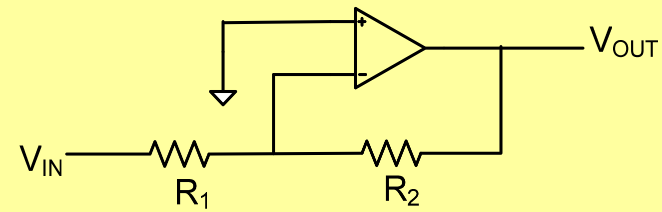
$$A_1(s) = \frac{GB}{s + BW_A}$$

$$GB = A_0 \bullet BW_A$$

$$A(s) = \frac{GB}{s}$$

Adequate model for most applications





Basic Inverting Amplifier

$$K_0 = \frac{R_2}{R_1}$$

$$BW = \frac{GB}{1 + K_0}$$

$$A_{FB}(s) = -\frac{K_0}{1 + s\frac{(1+K_0)}{GB}}$$

End of Lecture 16