EE 230
Lecture 16

Nonideal Op Amp Characteristics

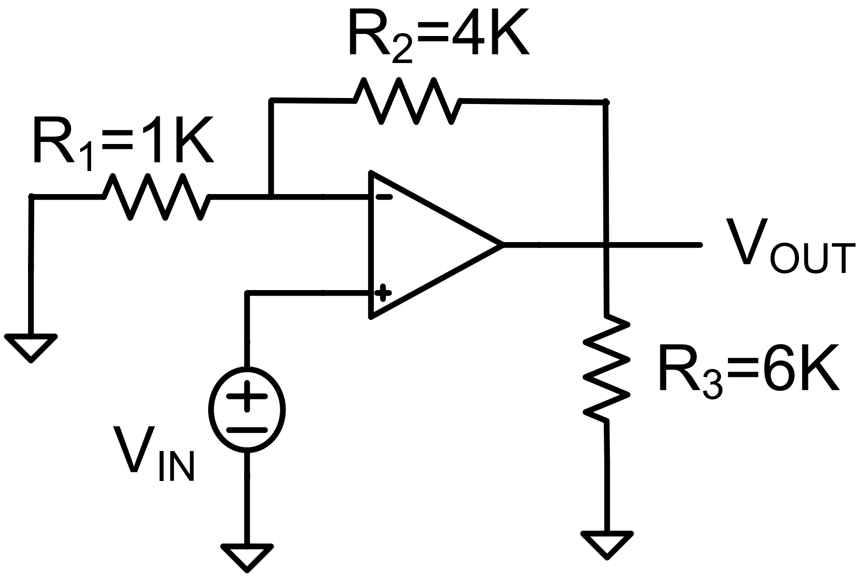
Quiz 11

The dc gain of this circuit was measured to be 5 and the 3dB bandwidth was measured to be 600KHz. Determine as many of the following as possible from this information if it is known that the op amp can be modeled as a single-pole lowpass amplifier.

Ao (dc gain of the Op Amp)

P (pole of the Op Amp)

GB (gain-bandwidth product of Op Amp)



And the number is ?

1 3 8

5 4

2 6

9 7

And the number is ?

1 3 8

5

5

4

2 6

9 7

Quiz 11 Solution:

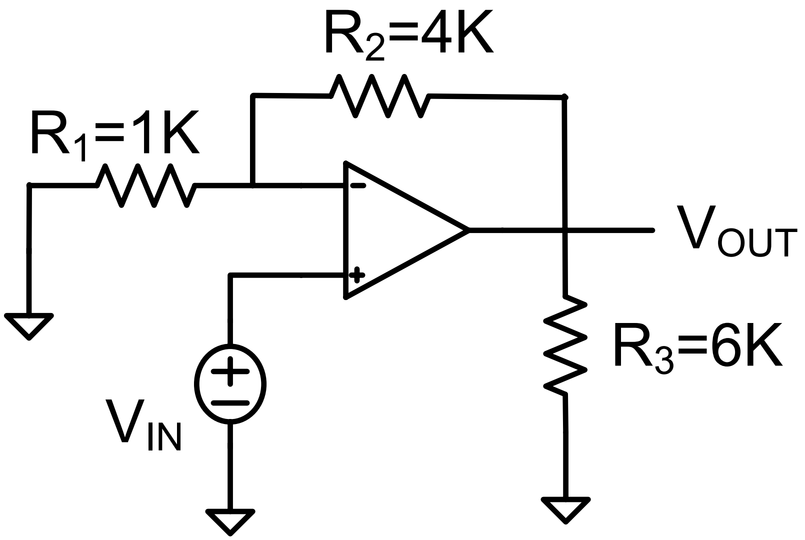
The dc gain of this circuit was measured to be 5 and the 3dB bandwidth was measured to be 600KHz. Determine as many of the following as possible from this information if it is known that the op amp can be modeled as a single-pole lowpass amplifier.

A_o (dc gain of the Op Amp)

p (pole of the Op Amp)

GB (gain-bandwidth product of Op Amp)

Insufficient information to determine A_o or p



$$GB = K_o BW = \left(1 + \frac{R_2}{R_1}\right) BW$$

Quiz 11 Solution:

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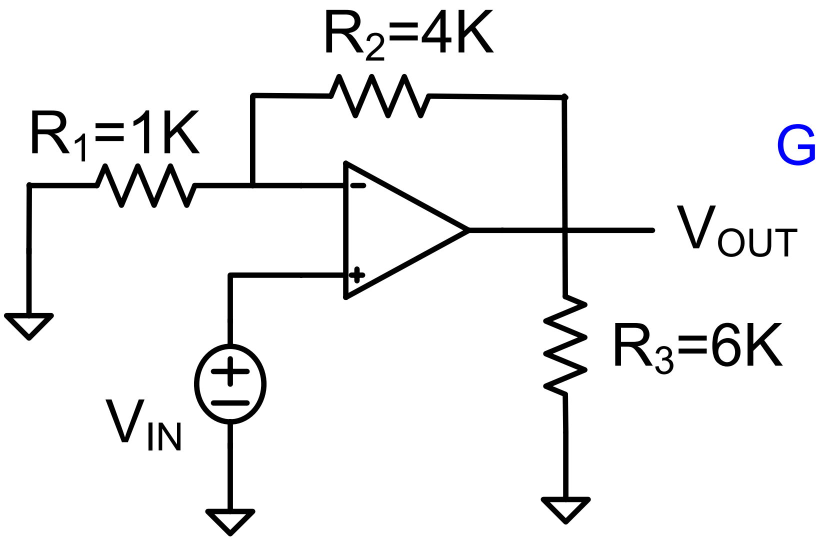


$$GB = K_o BW = \left(1+\frac{R_2}{R_1}\right) BW$$

$$GB = 5 \bullet 600KHz = 3MHz = (18.8M\,Rad/Sec)$$

Review from Last Time:

Nonideal op amp characteristics

- Finite Gain
- Finite BW

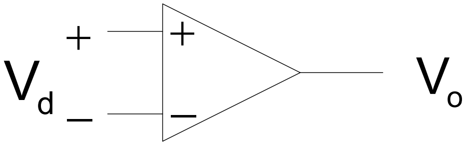
GB

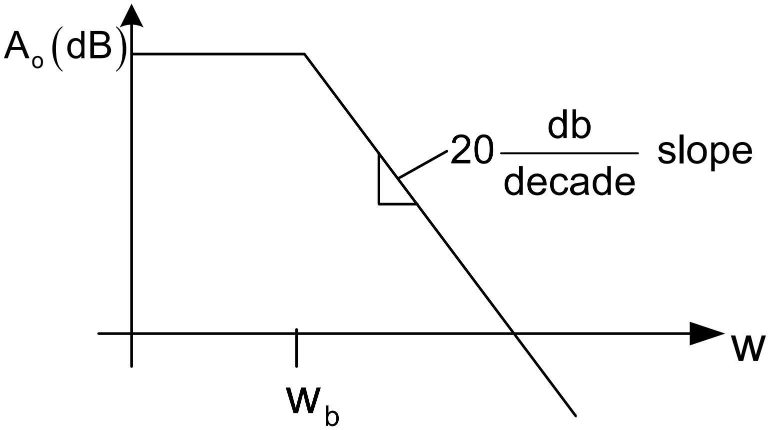
- Compensation
- Output Saturation
- Slew Rate
- R_{IN} & R_{OUT}
- Offset Voltage
- Bias Currents

- CMRR
- PSRR
- Offset Current
- Full Power Bandwidth

Review from Last Time:

Finite GB and BW





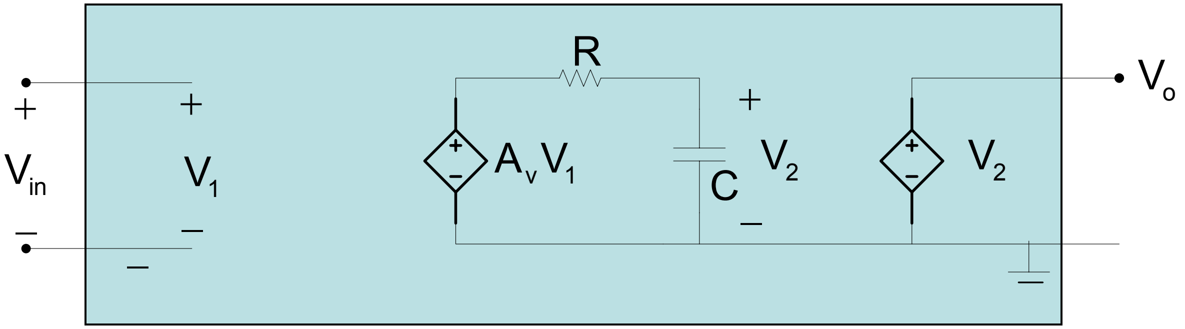
$$A_o\omega_b = GB$$

GB termed Gain-Bandwidth Product

$$A(s) = \frac{A_o}{\frac{s}{\omega_b}+1} \quad \Longleftrightarrow \quad A(s)=\frac{GB}{s}$$

Review from Last Time:

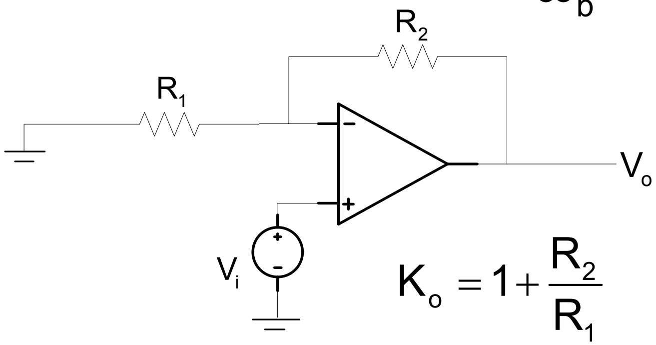
Macromodel of op amp



$$\frac{V_o}{V_i}=\frac{A_o}{1+\frac{s}{\omega_b}}$$

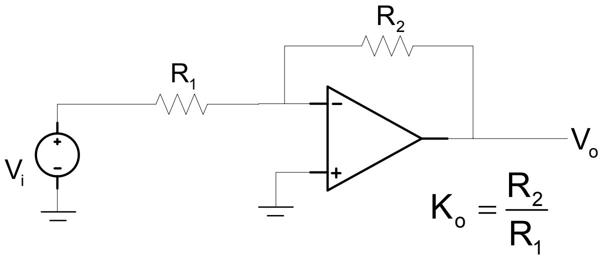
If C=1F

$$R=\frac{1}{\omega_b}$$



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

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

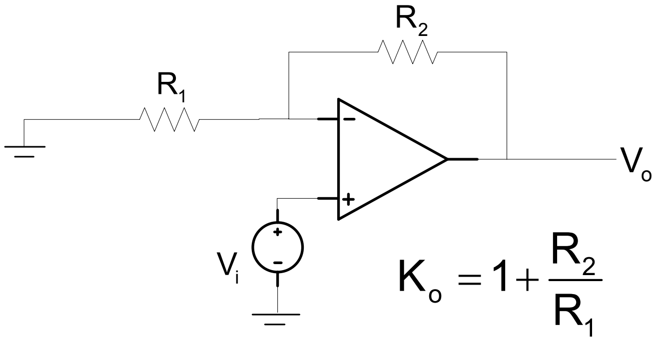


$$K_o=\frac{R_2}{R_1}$$

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

Basic inverting or noninverting amplifier useful for measuring GB

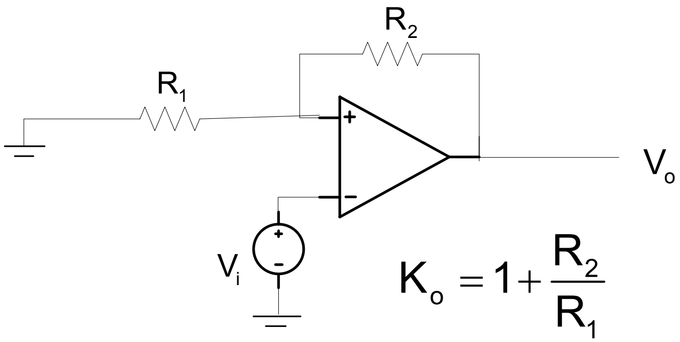
Review from Last Time:



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

$$p = -\frac{GB}{K_O}$$

Stable



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

$$p = \frac{GB}{K_O}$$

Unstable !

Essentially all op amp circuits designed to operate linearly will be unstable if the input terminals of the operational amplifier are interchanged !!

The ability to make this determination is <u>one</u> of the major reasons for studying stability in this course

Nonideal op amp characteristics

- Finite Gain
- Finite BW

GB

- Compensation
- → Output Saturation
- Slew Rate
- R_{IN} & R_{OUT}
- Offset Voltage
- Bias Currents

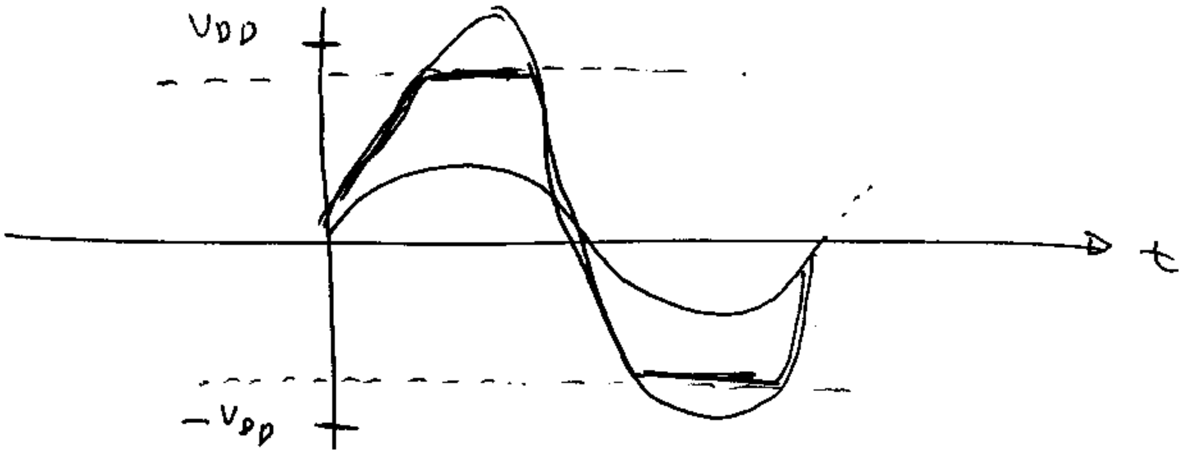
- CMRR
- PSRR
- Offset Current
- Full Power Bandwidth

Output Saturation

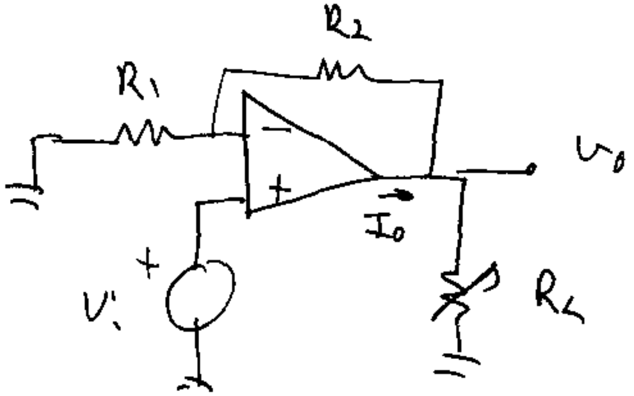
- Voltage Limit → Maximum or minimum output voltages an op amp can provide
- Current Limit → Maximum or minimum output currents an op amp can provide

Often $V_{OMAX} \simeq V_{DD} - 1.2V$

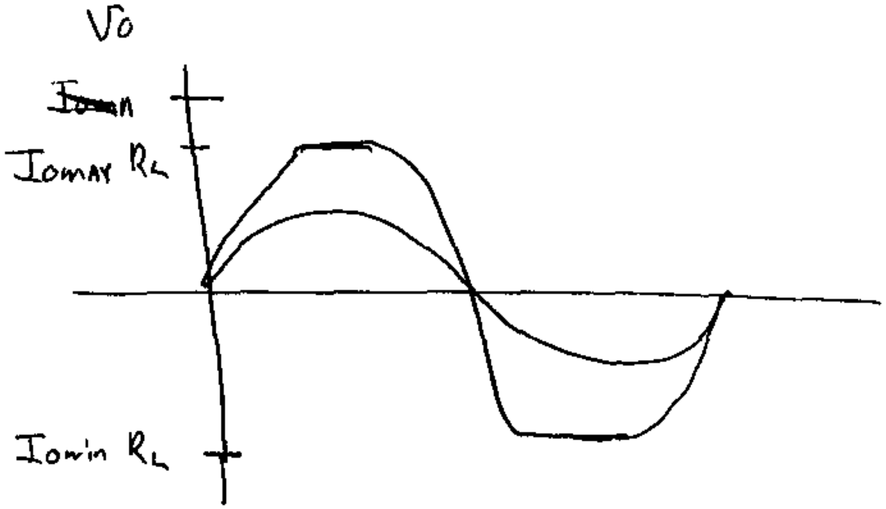
$V_{Omin} \simeq V_{SS} + 1,2V$



Nonlinear distortion is introduced



$$I_o = \frac{V_o - V_i}{R_2} + \frac{V_o}{R_L} \simeq \frac{V_o}{R_L}$$



Output current saturation provides similar limits to what was seen with output voltage saturation

Usually tell difference between voltage & current saturation by looking at saturation voltage

Nonideal op amp characteristics

- Finite Gain
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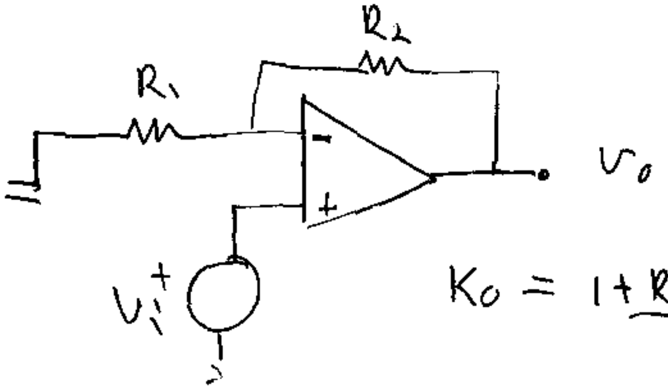
Slew Rate

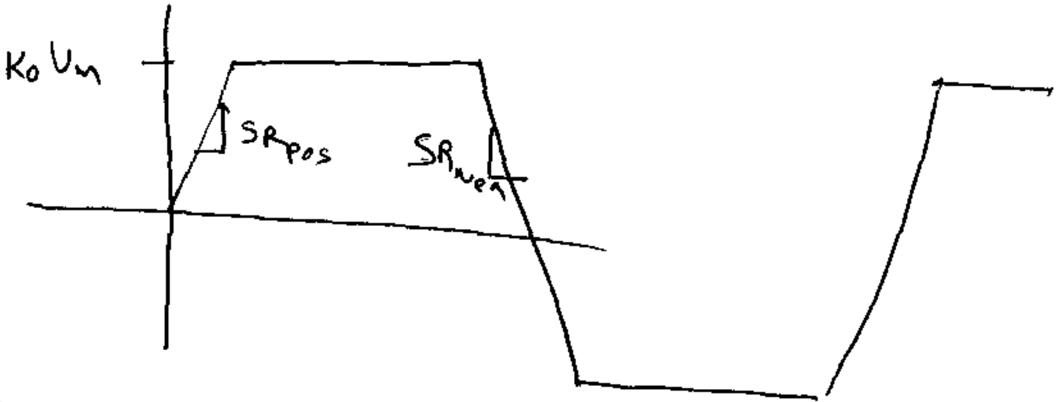
Maximum Rate of Change at Output of Op Amp.



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

If $V_i(t)$ is a square wave of hight V_m, $V_o(t)$ will ideally be a square wave of height $K_o V_m$

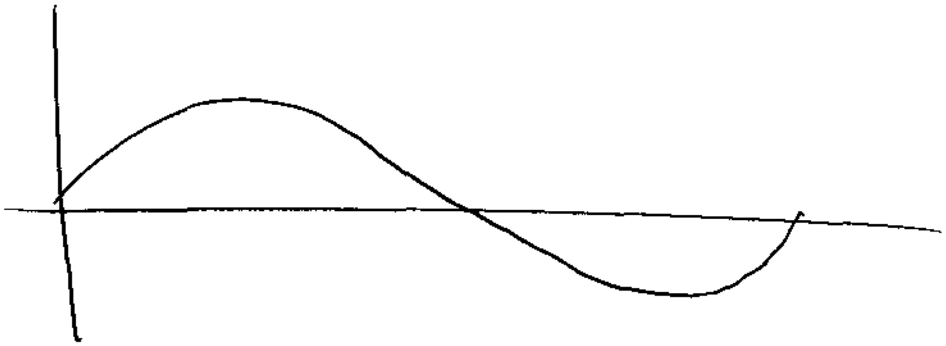
Actual Output.

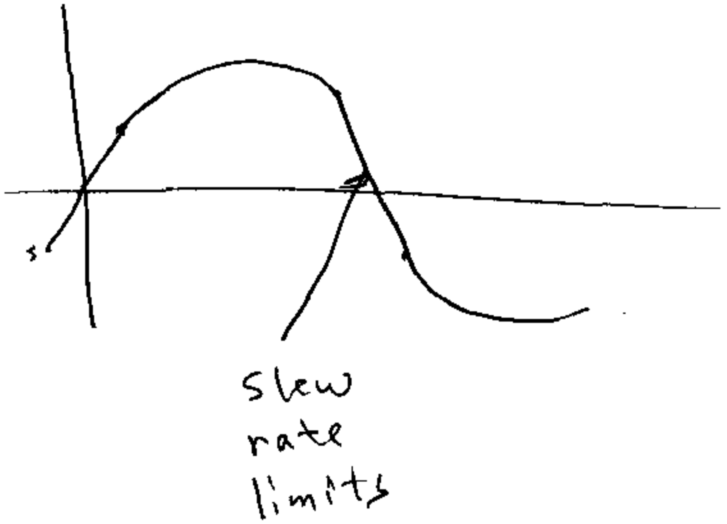


SR in V/μsec

1V/μsec to 100V/μsec

SR with sinusoidal signals





$$V_o = V_m \sin(\omega t + \theta)$$

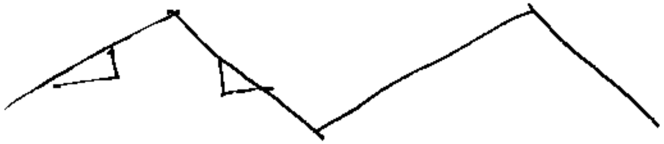
$$\frac{dV_o}{dt} = V_m \cos(\omega t + \theta)\, \omega < SR$$

To avoid slew distortion

$$V_m \omega < SR$$

If $V_m \omega$ significantly larger than SR

output will become a triangle wave



Nonideal op amp characteristics

- Finite Gain
- Finite BW

GB

- Compensation
- Output Saturation
- Slew Rate
- R_{IN} & R_{OUT}
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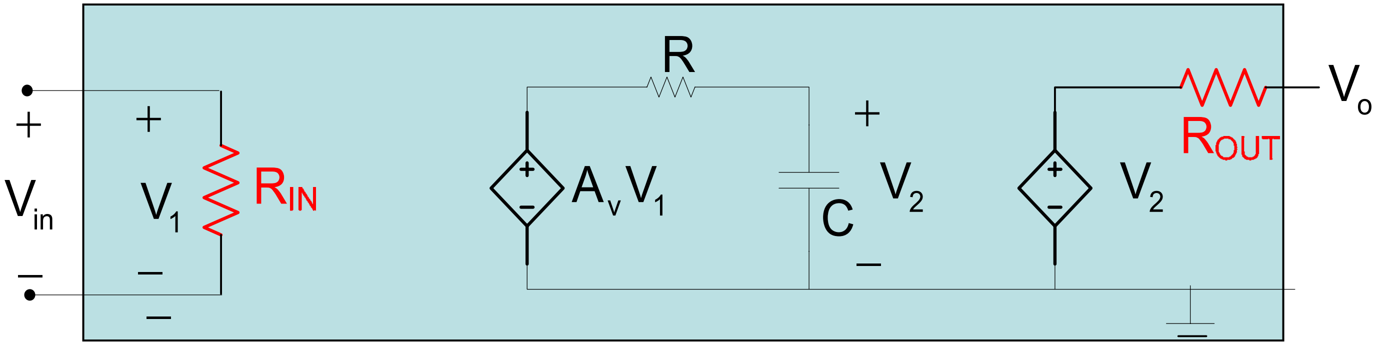
R_{IN} and R_{OUT}

R_{IN} is the input impedance to an op amp
(a few MΩ for bipolar inputs, many GΩ for FET input op amps)

R_{OUT} is the output impedance of an op amp
(in the 75Ω range)

Macromodel including R_{IN} and R_{OUT}



Several thousand commercially available op amps, specs can vary considerably!

Nonideal op amp characteristics

- Finite Gain
- Finite BW

GB

- Compensation
- Output Saturation
- Slew Rate
- R_{IN} & R_{OUT}
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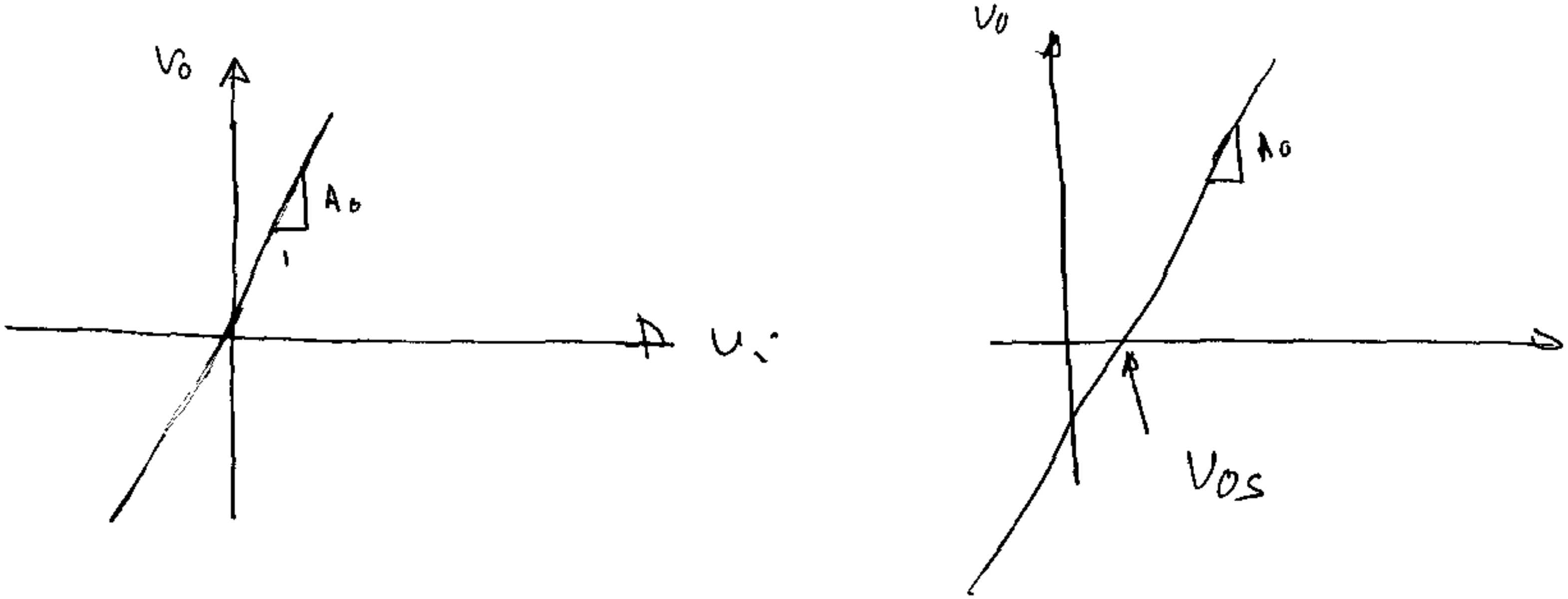
- PSRR
- Offset Current
- Full Power Bandwidth

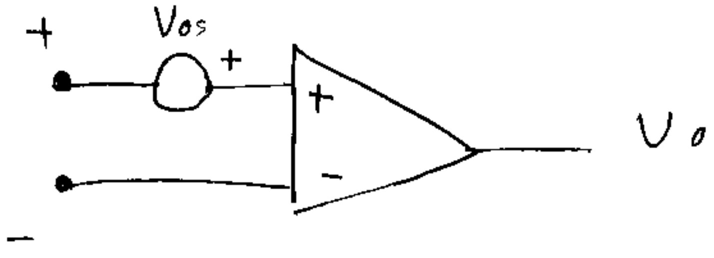
Offset Voltage (Input Referred Offset Voltage)



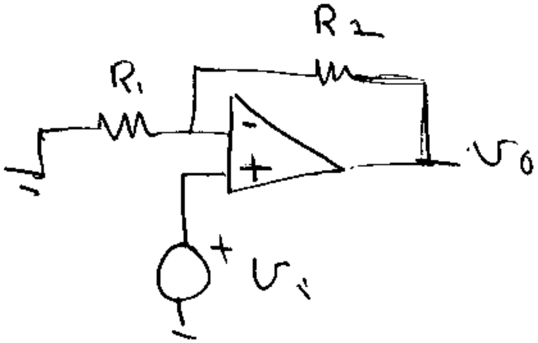
Vos can be positive or negative

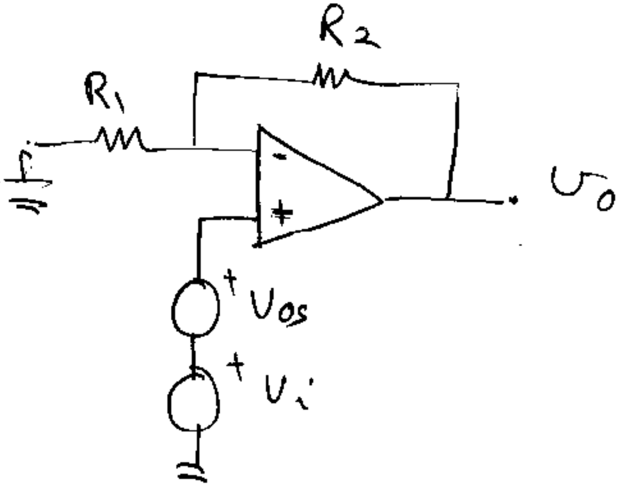
Vos is a random variable

Vos can be modeled with a dc voltage source in series with input terminal



Effects of Vos on basic noninverting amplifier





$$V_o = V_i\left(1+\frac{R_2}{R_1}\right) + V_{os}\left(1+\frac{R_2}{R_1}\right)$$

If $V_i >> V_{os}$, V_{os} does not adversely affect performance

$V_i \sim V_{os}$, V_{os} presents a major problem

$V_i << V_{os}$, V_{os} is very difficult to manage

$$V_o = V_i\left(1 + \frac{R_2}{R_1}\right) + V_{os}\left(1 + \frac{R_2}{R_1}\right)$$

If $V_{os} = 3\,mV$

$V_i = 3\,mV$

$1 + \frac{R_2}{R_1} = 1000$

$V_{o\,desired} = (3\,mV)(1000) = 3\,V$

$V_{o\,actual} = (3\,mv)(1000) + (3\,mv)1000 = 6\,V$

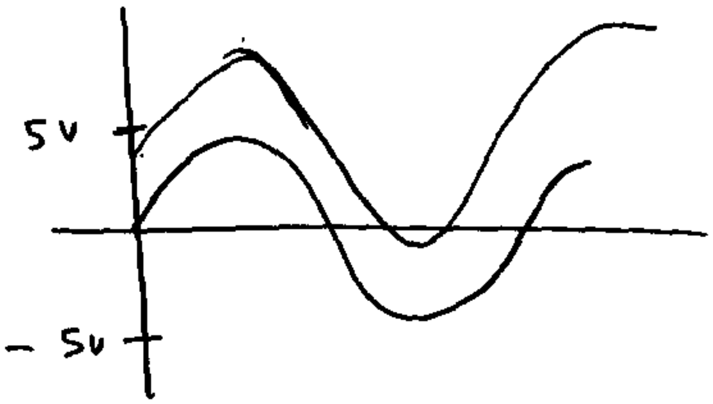
Methods of managing Vos

1) Cap. Coupling

2) trimming Vos

3) use the premium OA

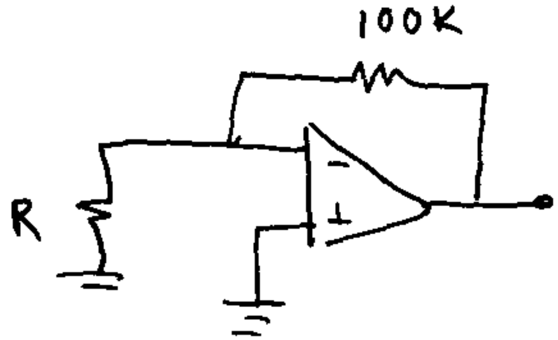
If $V_i = V_m \sin \omega t$



$V_{os} = 3\,mV$

$A_v = 1000$

Measurement of V_{os} (must be on every device if of concern)



$$v_o = V_{os}(1+100)$$

$$V_{os} = \frac{v_o}{101}$$

End of lecture

Nonideal op amp characteristics

- Finite Gain
- Finite BW

GB

- Compensation
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- Offset Current
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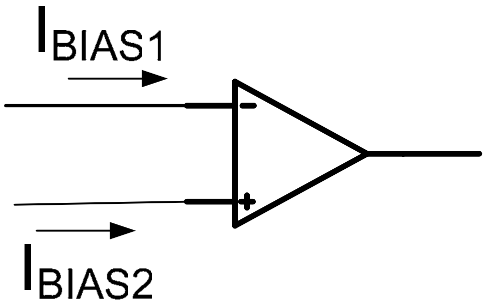
Bias and Offset Currents



I_{BIAS} is small for bipolar input op amps, extremely small for FET input op amps

Can be neglected in most designs regardless of whether FET or Bipolar input

Typical question on many interviews

$$I_{OFSET} = I_{BIAS1} - I_{BIAS2}$$

I_{OFFSET} is a random variable with zero mean for most designs

I_{BIAS} around 50 nA for 741, I_{OFFSET} around 3nA for 741

µA741, µA741Y
GENERAL-PURPOSE OPERATIONAL AMPLIFIERS

SLOS094B – NOVEMBER 1970 – REVISED SEPTEMBER 2000

- **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**

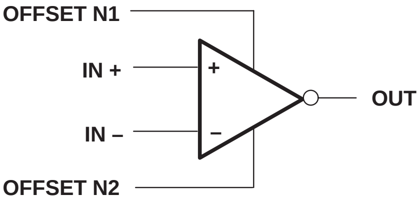
description

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

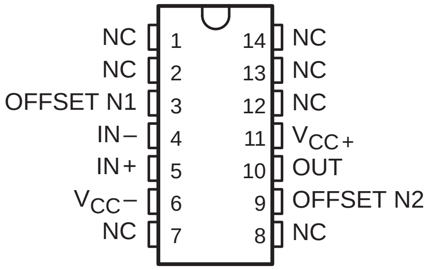
The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low value potentiometer may be connected between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

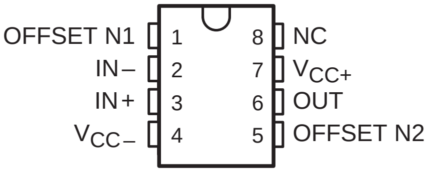
symbol



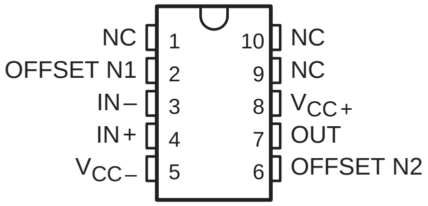
µA741M . . . J PACKAGE
(TOP VIEW)



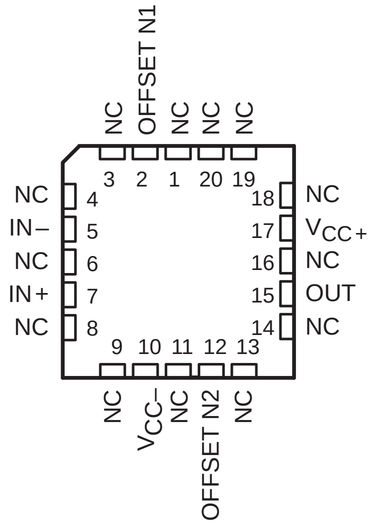
µA741M . . . JG PACKAGE
µA741C, µA741I . . . D, P, OR PW PACKAGE
(TOP VIEW)



µA741M . . . U PACKAGE
(TOP VIEW)



µA741M . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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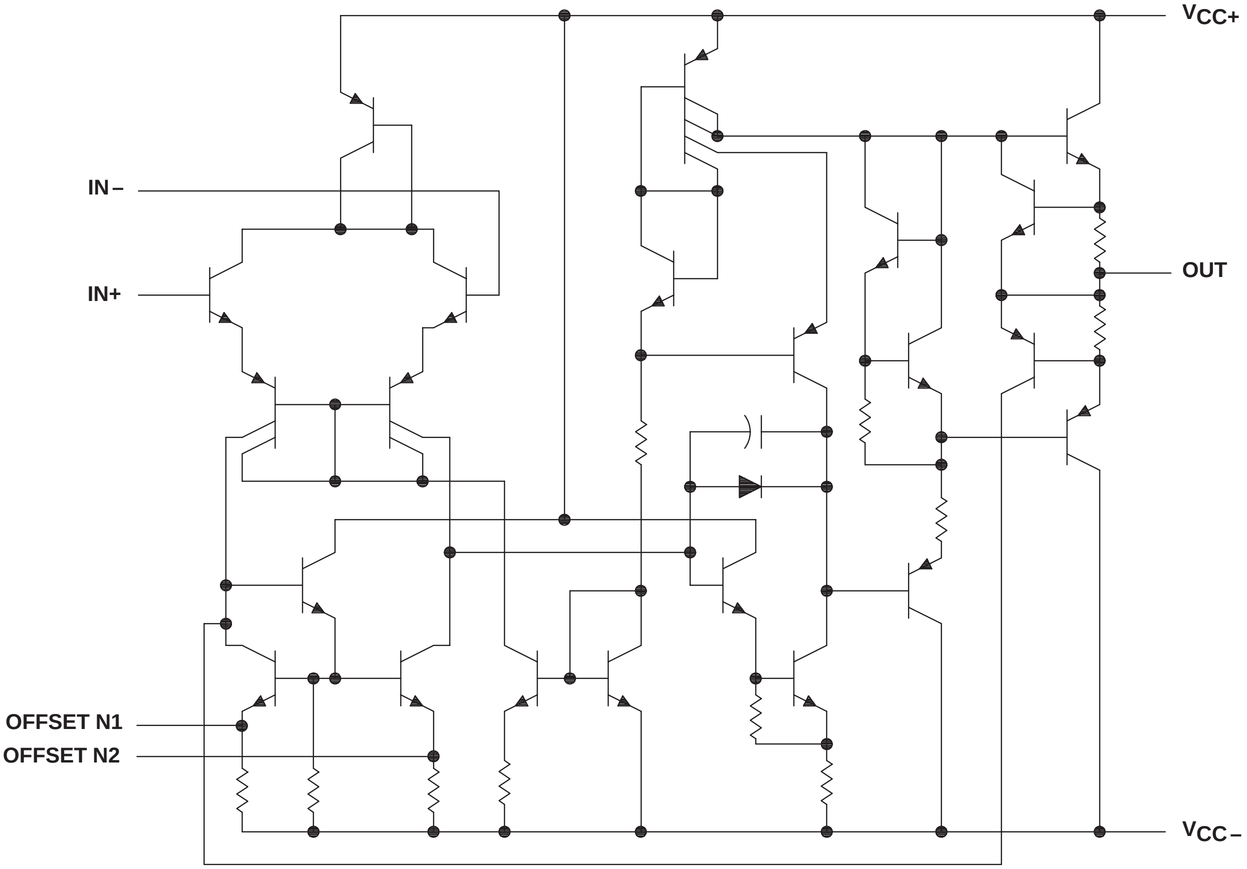
AVAILABLE OPTIONS

T_A	PACKAGED DEVICES							CHIP FORM (Y)
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	CERAMIC DIP (JG)	PLASTIC DIP (P)	TSSOP (PW)	FLAT PACK (U)	
0°C to 70°C	µA741CD				µA741CP	µA741CPW		µA741Y
–40°C to 85°C	µA741ID				µA741IP			
–55°C to 125°C		µA741MFK	µA741MJ	µA741MJG			µA741MU	

The D package is available taped and reeled. Add the suffix R (e.g., µA741CDR).

schematic

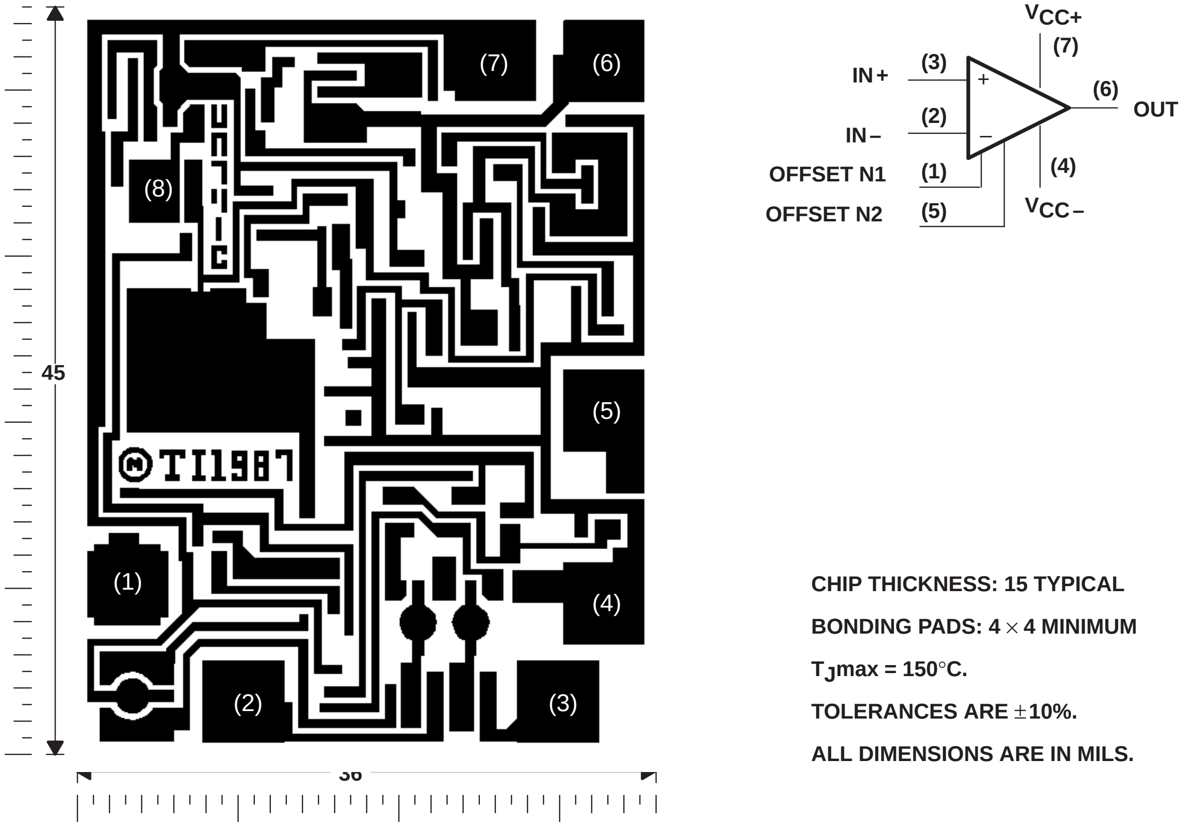


Component Count	
Transistors	22
Resistors	11
Diode	1
Capacitor	1

μA741Y chip information

This chip, when properly assembled, displays characteristics similar to the μA741C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

BONDING PAD ASSIGNMENTS



CHIP THICKNESS: 15 TYPICAL

BONDING PADS: 4 × 4 MINIMUM

$T_J$max = 150°C.

TOLERANCES ARE ±10%.

ALL DIMENSIONS ARE IN MILS.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

		μA741C	μA741I	μA741M	UNIT
Supply voltage, V_{CC+} (see Note 1)		18	22	22	V
Supply voltage, V_{CC-} (see Note 1)		–18	–22	–22	V
Differential input voltage, V_{ID} (see Note 2)		±15	±30	±30	V
Input voltage, V_I any input (see Notes 1 and 3)		±15	±15	±15	V
Voltage between offset null (either OFFSET N1 or OFFSET N2) and V_{CC-}		±15	±0.5	±0.5	V
Duration of output short circuit (see Note 4)		unlimited	unlimited	unlimited	
Continuous total power dissipation		See Dissipation Rating Table			
Operating free-air temperature range, T_A		0 to 70	–40 to 85	–55 to 125	°C
Storage temperature range		–65 to 150	–65 to 150	–65 to 150	°C
Case temperature for 60 seconds	FK package			260	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	J, JG, or U package			300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	D, P, or PW package	260	260		°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at IN+ with respect to IN–.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
4. The output may be shorted to ground or either power supply. For the μA741M only, the unlimited duration of the short circuit applies at (or below) 125°C case temperature or 75°C free-air temperature.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	5.8 mW/°C	64°C	464 mW	377 mW	N/A
FK	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
J	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
JG	500 mW	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
P	500 mW	N/A	N/A	500 mW	500 mW	N/A
PW	525 mW	4.2 mW/°C	25°C	336 mW	N/A	N/A
U	500 mW	5.4 mW/°C	57°C	432 mW	351 mW	135 mW

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm15$ 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	$R_L = 10\ k\Omega$	25°C	±12	±14		±12	±14		V
		$R_L \geq 10\ k\Omega$	Full range	±12			±12			
		$R_L = 2\ k\Omega$	25°C	±10	±13		±10	±13		
		$R_L \geq 2\ k\Omega$	Full range	±10			±10			
A_{VD}	Large-signal differential voltage amplification	$R_L \geq 2\ k\Omega$	25°C	20	200		50	200		V/mV
		$V_O = \pm10$ 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 ($\Delta V_{IO}/\Delta V_{CC}$)	$V_{CC} = \pm9$ 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, $V_{CC\pm} = \pm15$ 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, $R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figure 1		0.3			0.3		μs
	Overshoot factor			5%			5%		
SR	Slew rate at unity gain	$V_I = 10$ V, $R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figure 1		0.5			0.5		V/μs

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm15$ V, $T_A = 25°C$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	µA741Y			UNIT
			MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$		1	6	mV
$\Delta V_{IO(adj)}$	Offset voltage adjust range	$V_O = 0$		±15		mV
I_{IO}	Input offset current	$V_O = 0$		20	200	nA
I_{IB}	Input bias current	$V_O = 0$		80	500	nA
V_{ICR}	Common-mode input voltage range		±12	±13		V
V_{OM}	Maximum peak output voltage swing	$R_L = 10$ kΩ	±12	±14		V
		$R_L = 2$ kΩ	±10	±13		
A_{VD}	Large-signal differential voltage amplification	$R_L \geq 2$ kΩ	20	200		V/mV
r_i	Input resistance		0.3	2		MΩ
r_o	Output resistance	$V_O = 0$, See Note 5		75		Ω
C_i	Input capacitance			1.4		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}\text{min}$	70	90		dB
k_{SVS}	Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$)	$V_{CC} = \pm9$ V to ±15 V		30	150	µV/V
I_{OS}	Short-circuit output current			±25	±40	mA
I_{CC}	Supply current	$V_O = 0$, No load		1.7	2.8	mA
P_D	Total power dissipation	$V_O = 0$, No load		50	85	mW

† All characteristics are measured under open-loop conditions with zero common-mode voltage unless otherwise specified.

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, $V_{CC\pm} = \pm15$ V, $T_A = 25°C$

PARAMETER		TEST CONDITIONS	µA741Y			UNIT
			MIN	TYP	MAX	
t_r	Rise time	$V_I = 20$ mV, $R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1		0.3		µs
	Overshoot factor			5%		
SR	Slew rate at unity gain	$V_I = 10$ V, $R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1		0.5		V/µs

PARAMETER MEASUREMENT INFORMATION

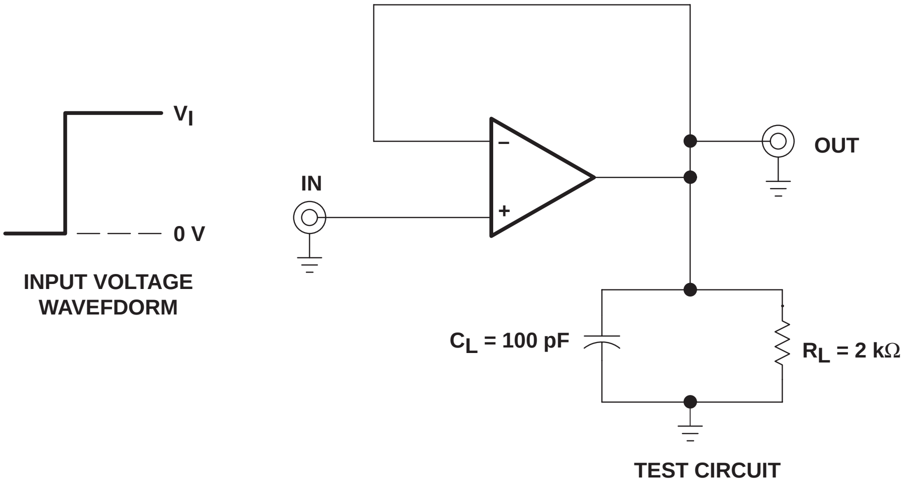


Figure 1. Rise Time, Overshoot, and Slew Rate

APPLICATION INFORMATION

Figure 2 shows a diagram for an input offset voltage null circuit.

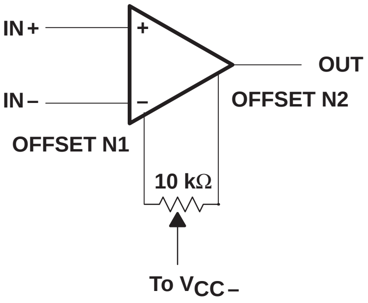


Figure 2. Input Offset Voltage Null Circuit

TYPICAL CHARACTERISTICS†

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

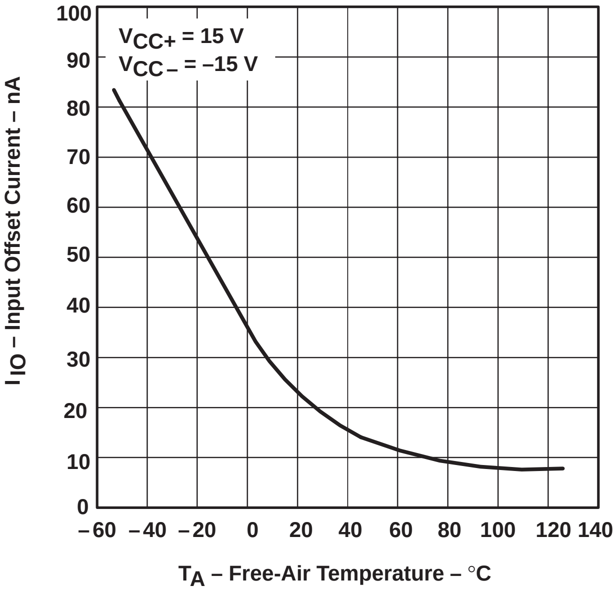


Figure 3

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

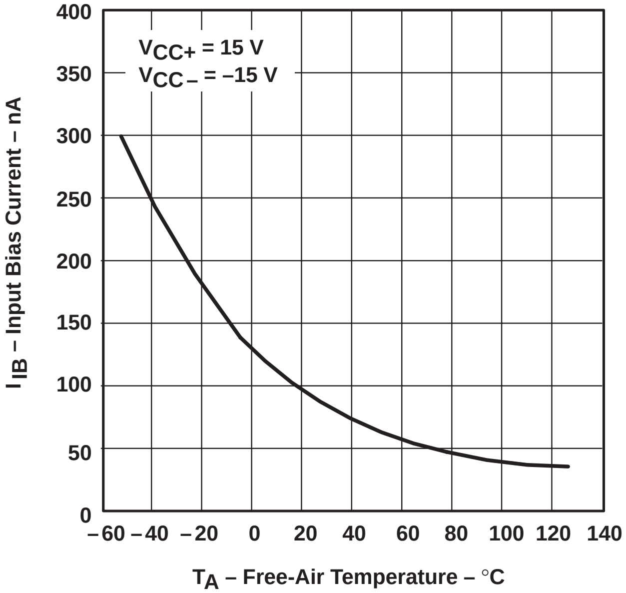


Figure 4

MAXIMUM PEAK OUTPUT VOLTAGE
vs
LOAD RESISTANCE

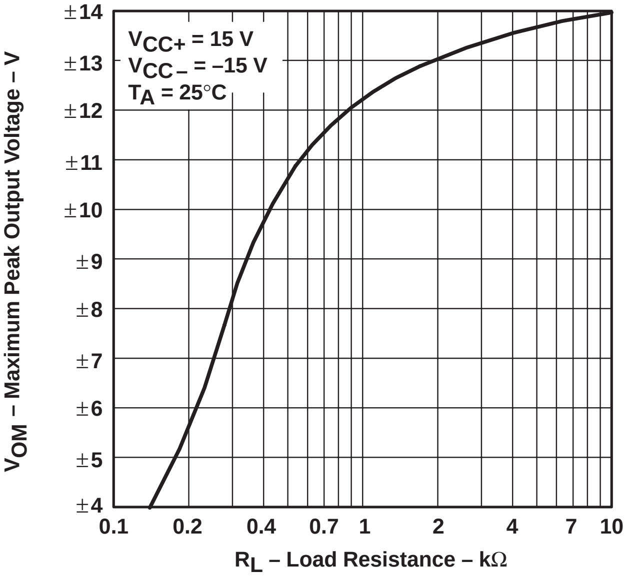


Figure 5

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† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE vs FREQUENCY

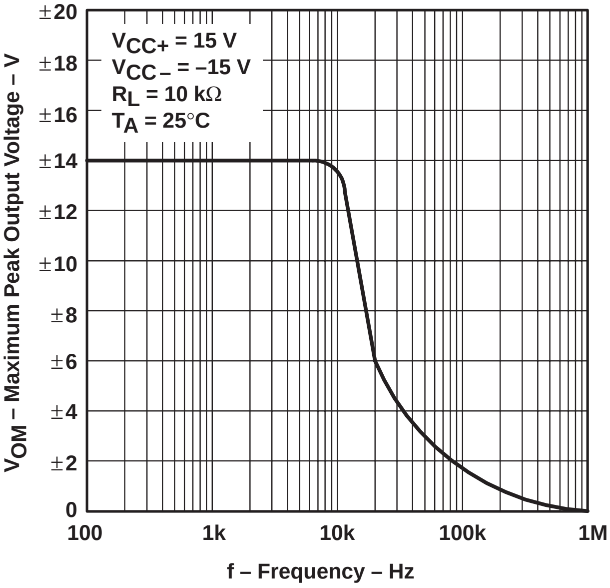


Figure 6

OPEN-LOOP SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs SUPPLY VOLTAGE

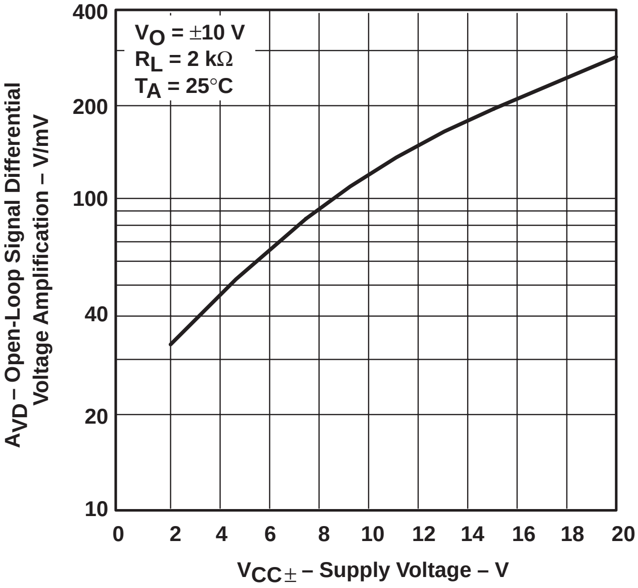
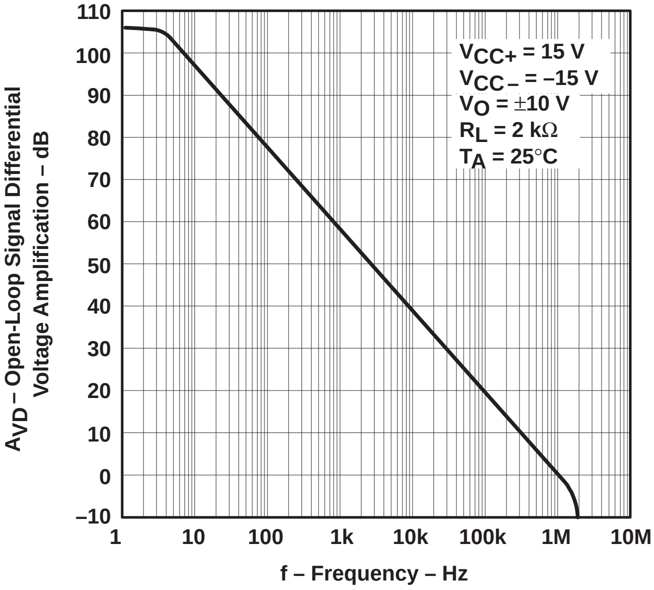


Figure 7

OPEN-LOOP LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREQUENCY



TYPICAL CHARACTERISTICS

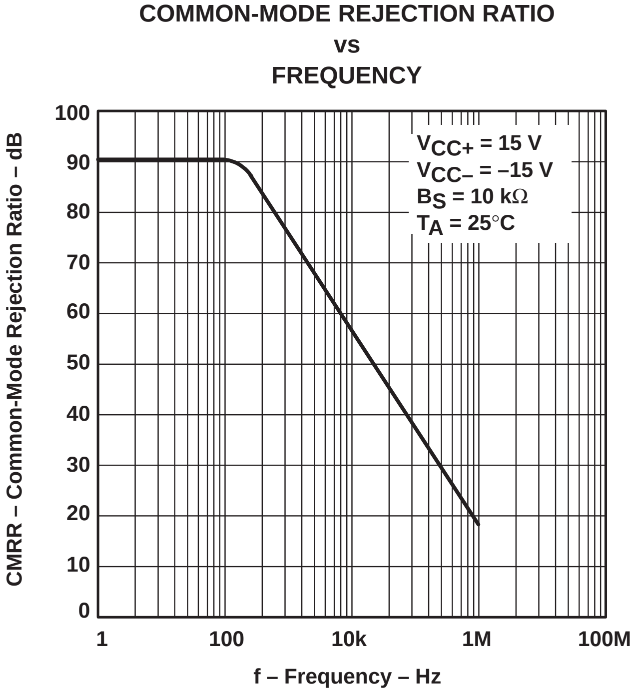


Figure 8

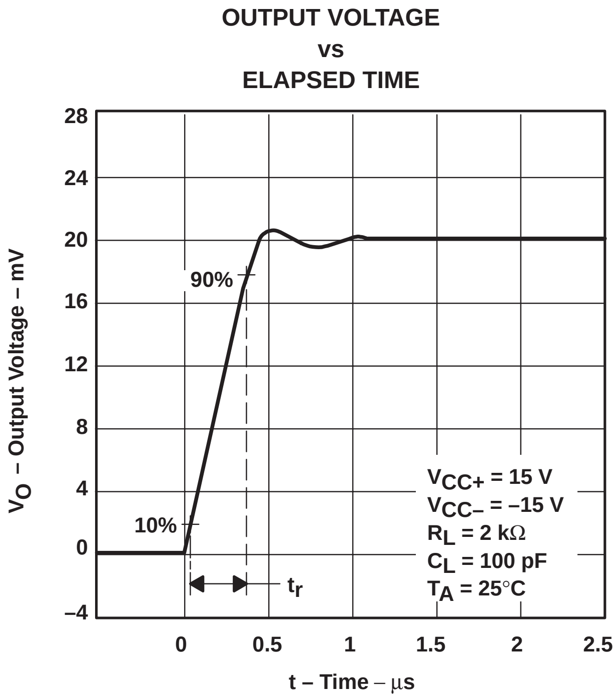


Figure 9

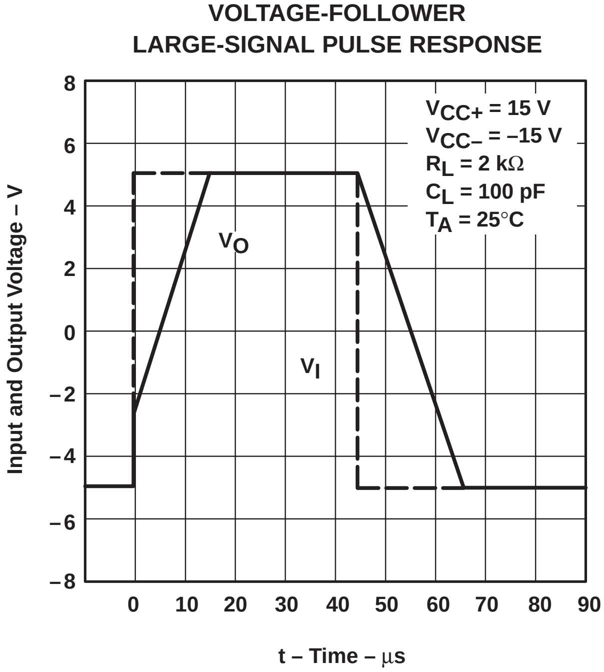


Figure 10

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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.

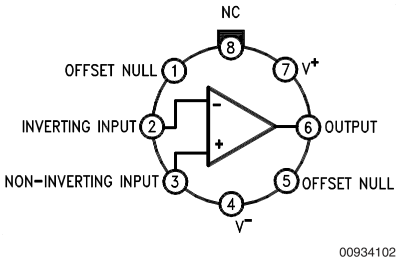
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

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

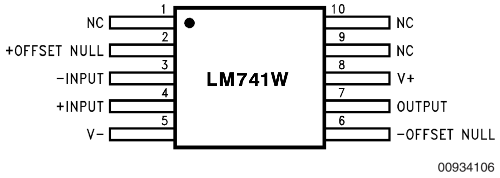
Metal Can Package



Note 1: LM741H is available per JM38510/10101

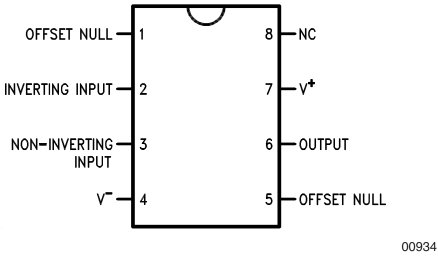
Order Number LM741H, LM741H/883 (Note 1), **LM741AH/883 or LM741CH**
See NS Package Number H08C

Ceramic Flatpak



Order Number LM741W/883
See NS Package Number W10A

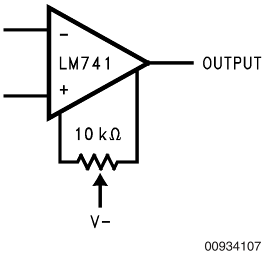
Dual-In-Line or S.O. Package



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

Typical Application

Offset Nulling Circuit



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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˚C										
	$R_S \leq 10$ kΩ					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
	$R_S \leq 10$ kΩ						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/˚C
Input Offset Voltage Adjustment Range	T_A = 25˚C, V_S = ±20V	±10				±15			±15		mV
Input Offset Current	T_A = 25˚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˚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˚C, V_S = ±20V	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, V_S = ±20V	0.5									MΩ
Input Voltage Range	T_A = 25˚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˚C, R_L ≥ 2 kΩ										
	V_S = ±20V, V_O = ±15V	50									V/mV
	V_S = ±15V, V_O = ±10V				50	200		20	200		V/mV
	T_{AMIN} ≤ T_A ≤ T_{AMAX},										
	R_L ≥ 2 kΩ,										
	V_S = ±20V, V_O = ±15V	32									V/mV
	V_S = ±15V, V_O = ±10V				25			15			V/mV
	V_S = ±5V, V_O = ±2V	10									V/mV
Output Voltage Swing	V_S = ±20V										
	R_L ≥ 10 kΩ	±16									V
	R_L ≥ 2 kΩ	±15									V
	V_S = ±15V										
	R_L ≥ 10 kΩ				±12	±14		±12	±14		V
	R_L ≥ 2 kΩ				±10	±13		±10	±13		V
Output Short Circuit	T_A = 25˚C	10	25	35		25			25		mA
Current	T_{AMIN} ≤ T_A ≤ T_{AMAX}	10		40							mA
Common-Mode	T_{AMIN} ≤ T_A ≤ T_{AMAX}										
Rejection Ratio	R_S ≤ 10 kΩ, V_{CM} = ±12V				70	90		70	90		dB
	R_S ≤ 50Ω, V_{CM} = ±12V	80	95								dB
Supply Voltage Rejection	T_{AMIN} ≤ T_A ≤ T_{AMAX},										
Ratio	V_S = ±20V to V_S = ±5V										
	R_S ≤ 50Ω	86	96								dB
	R_S ≤ 10 kΩ				77	96		77	96		dB
Transient Response	T_A = 25˚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˚C	0.437	1.5								MHz
Slew Rate	T_A = 25˚C, Unity Gain	0.3	0.7			0.5			0.5		V/µs
Supply Current	T_A = 25˚C					1.7	2.8		1.7	2.8	mA
Power Consumption	T_A = 25˚C										
	V_S = ±20V		80	150							mW
	V_S = ±15V					50	85		50	85	mW
LM741A	V_S = ±20V										
	T_A = T_{AMIN}			165							mW
	T_A = T_{AMAX}			135							mW
LM741	V_S = ±15V										
	T_A = T_{AMIN}					60	100				mW
	T_A = T_{AMAX}					45	75				mW

Note 2: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

Electrical Characteristics (Note 5) (Continued)

Note 3: For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under "Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.

Thermal Resistance	Cerdip (J)	DIP (N)	HO8 (H)	SO-8 (M)
θ_{jA} (Junction to Ambient)	100˚C/W	100˚C/W	170˚C/W	195˚C/W
θ_{jC} (Junction to Case)	N/A	N/A	25˚C/W	N/A

Note 4: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

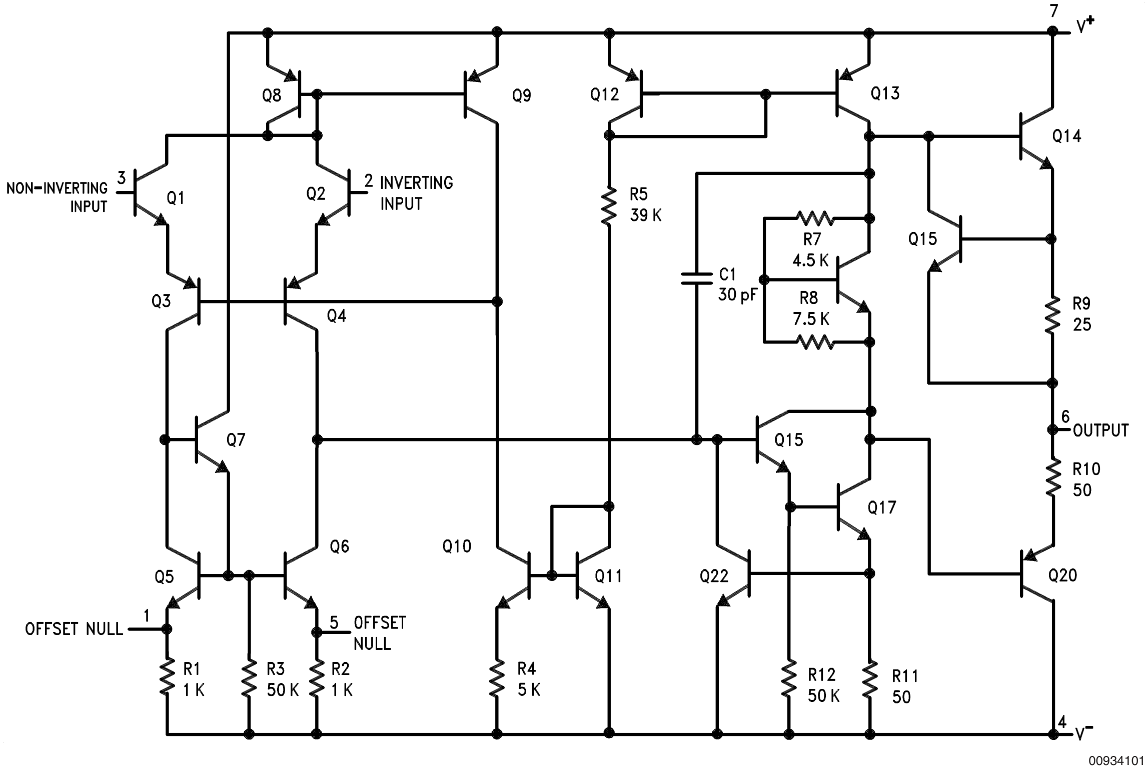
Note 5: Unless otherwise specified, these specifications apply for V_S = ±15V, −55˚C ≤ T_A ≤ +125˚C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0˚C ≤ T_A ≤ +70˚C.

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(µs).

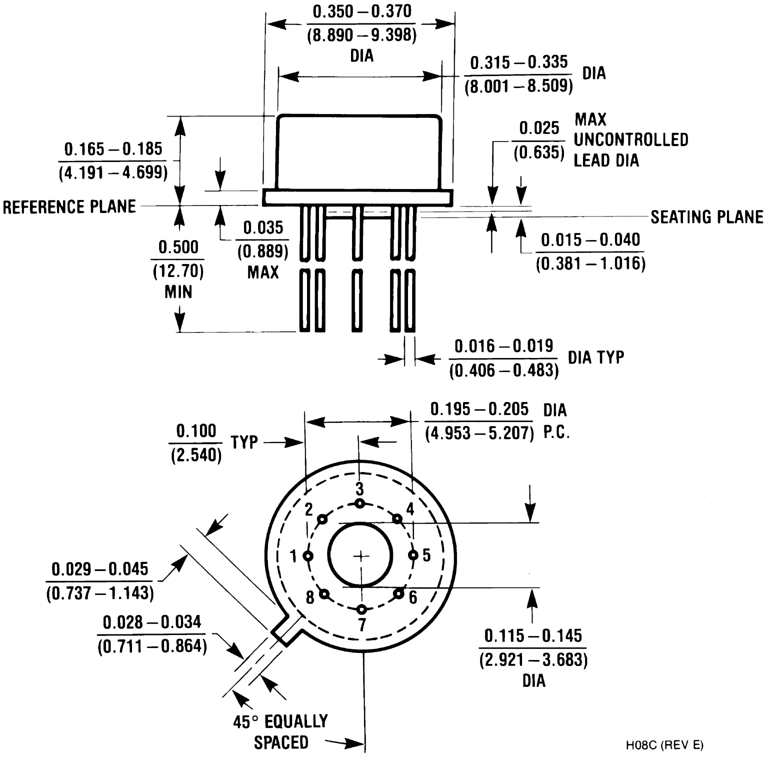
Note 7: For military specifications see RETS741X for LM741 and RETS741AX for LM741A.

Note 8: Human body model, 1.5 kΩ in series with 100 pF.

Schematic Diagram

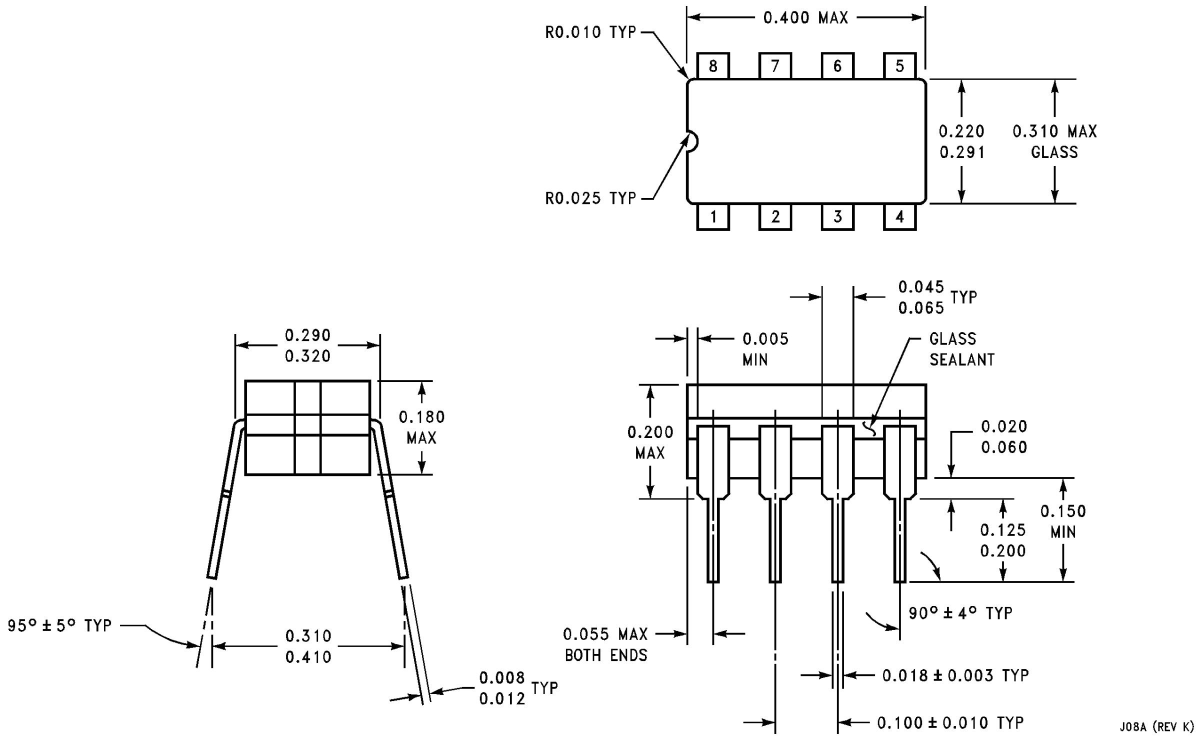


Physical Dimensions inches (millimeters) unless otherwise noted

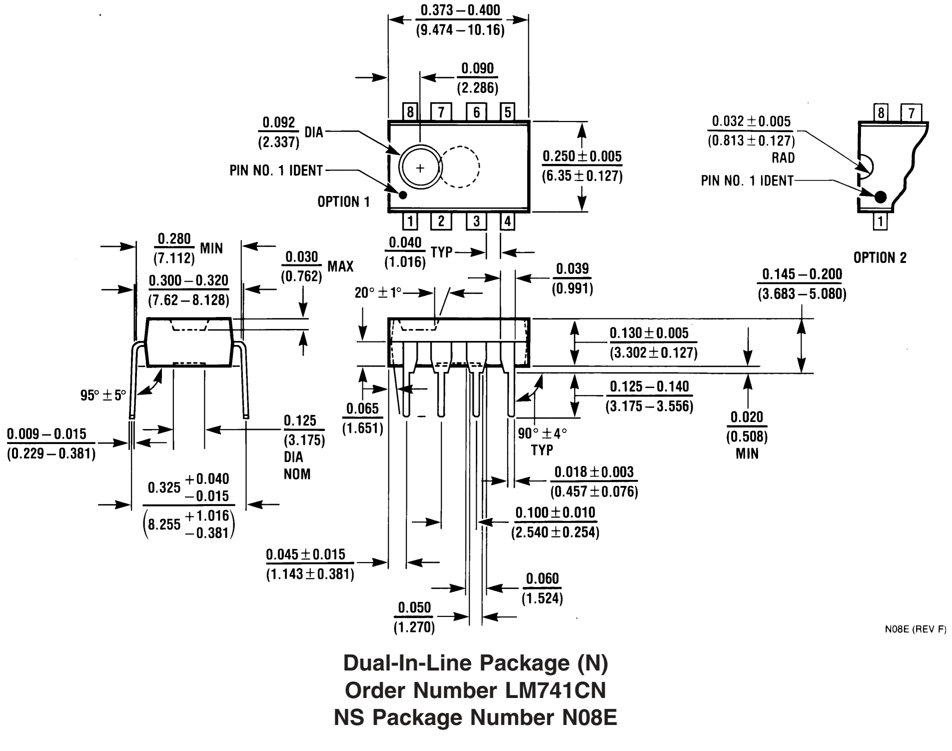


Metal Can Package (H)
Order Number LM741H, LM741H/883, LM741AH/883, LM741AH-MIL or LM741CH
NS Package Number H08C

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

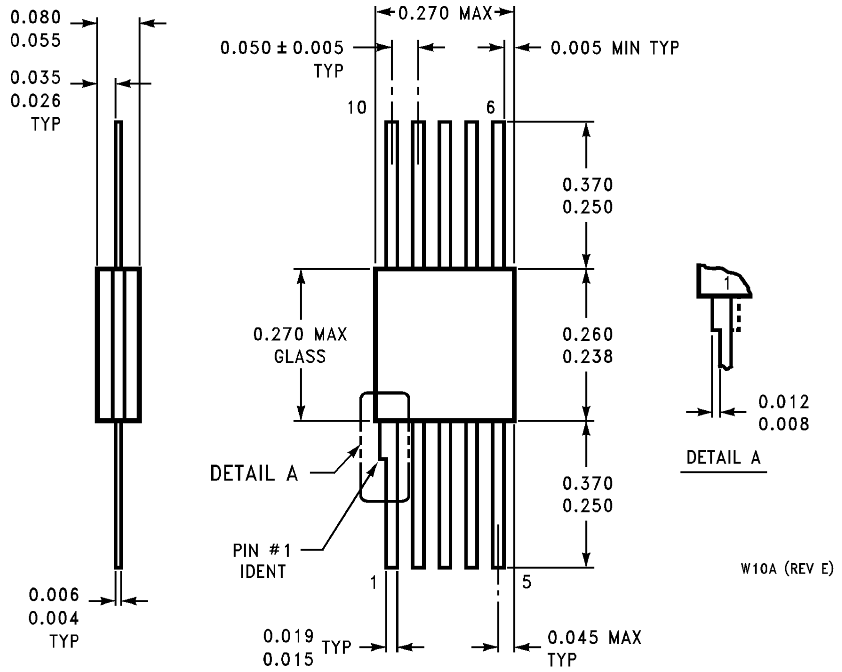


Ceramic Dual-In-Line Package (J)
Order Number LM741J/883
NS Package Number J08A



Dual-In-Line Package (N)
Order Number LM741CN
NS Package Number N08E

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



10-Lead Ceramic Flatpak (W)
Order Number LM741W/883, LM741WG-MPR or LM741WG/883
NS Package Number W10A

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