Dual, 9 MHz Precision Operational Amplifier

OP-285*

FEATURES

Low Offset Voltage: 250 μV
Low Noise: 6 nV/√Hz
Low Distortion: 0.0006%
High Slew Rate: 22 V/μs
Wide Bandwidth: 9 MHz
Low Supply Current: 5 mA
Low Offset Current: 2 nA
Unity-Gain Stable
SO-8 Package

APPLICATIONS

High Performance Audio
Active Filters
Fast Amplifiers
Integrators

GENERAL DESCRIPTION

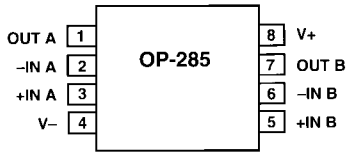
The OP-285 is a precision high speed amplifier featuring the Butler Amplifier front-end. This new front-end design combines the accuracy and low noise performance of bipolar transistors with the speed of JFETs. This yields an amplifier with high slew rates, low offset and good noise performance at low supply currents. Bias currents are also low compared to bipolar designs.

The OP-285 offers the slew rate and low power of a JFET amplifier combined with the precision, low noise and low drift of a bipolar amplifier. Input offset voltage is laser-trimmed and guaranteed less than 250 μV. This makes the OP-285 useful in dc coupled or summing applications without the need for special selections or the added noise of additional offset adjustment circuitry. Slew rates of 22 V/μs and a bandwidth of 9 MHz make the OP-285 one of the most accurate medium speed amplifiers available.

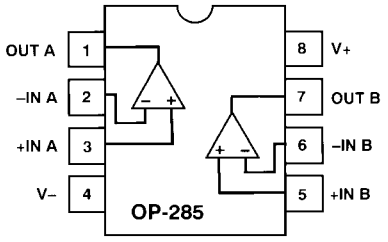
*Patents pending.

PIN CONNECTIONS

8-Lead Narrow-Body SO
(S Suffix)



8-Lead Epoxy DIP
(P Suffix)



The combination of low noise, speed and accuracy can be used to build high speed instrumentation systems. Circuits such as instrumentation amplifiers, ramp generators, bi-quad filters and dc coupled audio systems are all practical with the OP-285.

For applications that require long term stability, the OP-285 has a guaranteed maximum long term drift specification.

The OP-285 is specified over the XIND—extended industrial—(−40°C to +85°C) temperature range. OP-285s are available in 8-pin plastic DIP and SOIC-8 surface mount packages.

REV. 0

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Tel: 617/329-4700 **Fax: 617/326-8703**

OP-285—SPECIFICATIONS

ELECTRICAL CHARACTERISTICS (@ V_S = ±15.0 V, T_A = +25°C unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
INPUT CHARACTERISTICS						
Offset Voltage	V_{OS}			35	250	μV
Offset Voltage	V_{OS}	$-40°C \le T_A \le +85°C$			600	μV
Input Bias Current	I_B	V_{CM} = 0 V		100	350	nA
Input Bias Current	I_B	V_{CM} = 0 V, $-40°C \le T_A \le +85°C$			400	nA
Input Offset Current	I_{OS}	V_{CM} = 0 V		2	±50	nA
Input Offset Current	I_{OS}	V_{CM} = 0 V, $-40°C \le T_A \le +85°C$		2	±100	nA
Input Voltage Range	V_{CM}		−10.5		+10.5	V
Common-Mode Rejection	CMRR	V_{CM} = ±10.5 V, $-40°C \le T_A \le +85°C$	80	106		dB
Large Signal Voltage Gain	A_{VO}	R_L = 2 kΩ	250			V/mV
Large Signal Voltage Gain	A_{VO}	R_L = 2 kΩ, $-40°C \le T_A \le +85°C$	175			V/mV
Large Signal Voltage Gain	A_{VO}	R_L = 600 Ω		200		V/mV
Common-Mode Input Capacitance				7.5		pF
Differential Input Capacitance				3.7		pF
Long Term Offset Voltage	ΔV_{OS}	Note 1			300	μV
Offset Voltage Drift	$\Delta V_{OS}/\Delta T$			1		μV/°C
OUTPUT CHARACTERISTICS						
Output Voltage Swing	V_O	R_L = 2 kΩ	−13.5	±13.9	+13.5	V
Output Voltage Swing	V_O	R_L = 2 kΩ, $-40°C \le T_A \le +85°C$	−13	±13.9	+13	V
		R_L = 600 Ω, V_S = ±18 V		−16/+14		V
POWER SUPPLY						
Power Supply Rejection Ratio	PSRR	V_S = ±4.5 V to ±18 V	85	111		dB
Power Supply Rejection Ratio	PSRR	V_S = ±4.5 V to ±18 V, $-40°C \le T_A \le +85°C$	80			dB
Supply Current	I_{SY}	V_S = ±4.5 V to ±18 V, V_O = 0 V, R_L = ∞, $-40°C \le T_A \le +85°C$		4	5	mA
Supply Current	I_{SY}	V_S = ±22 V, V_O = 0 V, R_L = ∞, $-40°C \le T_A \le +85°C$			5.5	mA
Supply Voltage Range	VS		±4.5		±22	V
DYNAMIC PERFORMANCE						
Slew Rate	SR	R_L = 2 kΩ	15	22		V/μs
Gain Bandwidth Product	GBP			9		MHz
Phase Margin	θo			62		Degrees
Settling Time	t_S	To 0.1%, 10 V Step		625		ns
Settling Time	t_S	To 0.01%, 10 V Step		750		ns
Distortion		A_V = +1, V_{OUT} = 8.5 V p-p, f = 1 kHz, R_L = 2 kΩ		−104		dB
Voltage Noise Density	e_n	f = 30 Hz		7		$nV/\sqrt{Hz}$
Voltage Noise Density	e_n	f = 1 kHz		6		$nV/\sqrt{Hz}$
Current Noise Density	i_n	f = 1 kHz		0.9		$pA/\sqrt{Hz}$
Headroom		THD + Noise ≤ 0.01%, R_L = 2 kΩ, V_S = ±18 V		>12.9		dBu

NOTE

[1]Long term offset voltage is guaranteed by a 1000 hour life test performed on three independent wafer lots at +125°C, with an LTPD of 1.3.

Specifications subject to change without notice.

WAFER TEST LIMITS (@ V_S = ±15.0 V, T_A = +25°C unless otherwise noted)

Parameter	Symbol	Conditions	Limit	Units
Offset Voltage	V_{OS}		250	μV max
Input Bias Current	I_B	V_{CM} = 0 V	350	nA max
Input Offset Current	I_{OS}	V_{CM} = 0 V	±50	nA max
Input Voltage Range[1]	V_{CM}		±10.5	V min
Common-Mode Rejection	CMRR	V_{CM} = ±10.5 V	80	dB min
Power Supply Rejection Ratio	PSRR	V = ±4.5 V to ±18 V	85	dB
Large Signal Voltage Gain	A_{V_O}	R_L = 2 kΩ	250	V/mV min
Output Voltage Range	V_O	R_L = 2 kΩ	13	V min
Supply Current	I_{SY}	V_O = 0 V, R_L = ∞	5	mA max

NOTES
Electrical tests and wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualifications through sample lot assembly and testing.
[1]Guaranteed by CMR test.

ABSOLUTE MAXIMUM RATINGS[1]

Supply Voltage . . . . . ±22 V
Input Voltage[2] . . . . . ±18 V
Differential Input Voltage[2] . . . . . ±7.5 V
Output Short-Circuit Duration to Gnd[3] . . . . . Indefinite
Storage Temperature Range
P, S Package . . . . . −65°C to +150°C
Operating Temperature Range
OP-285G . . . . . −40°C to +85°C
Junction Temperature Range
P, S Package . . . . . −65°C to +150°C
Lead Temperature Range (Soldering, 60 Sec) . . . . . +300°C

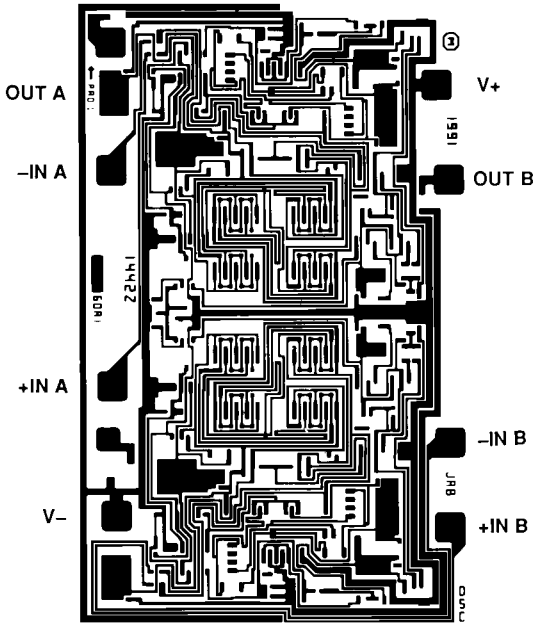
Package Type	θ_{JA}[4]	θ_{JC}	Units
8-Pin Plastic DIP (P)	103	43	°C/W
8-Pin SOIC (S)	158	43	°C/W

NOTES
[1]Absolute maximum ratings apply to both DICE and packaged parts, unless otherwise noted.
[2]For supply voltages less than ±7.5 V, the absolute maximum input voltage is equal to the supply voltage.
[3]Shorts to either supply may destroy the device. See data sheet for full details.
[4]θ_{JA} is specified for the worst case conditions, i.e., θ_{JA} is specified for device in socket for cerdip, P-DIP, and LCC packages; θ_{JA} is specified for device soldered in circuit board for SOIC package.

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
OP285GP	−40°C to +85°C	8-Pin Plastic DIP	N-8
OP285GS	−40°C to +85°C	8-Pin SOIC	SO-8
OP285GSR	−40°C to +85°C	SO-8 Reel, 2500 pcs.	
OP285GBC	+25°C	DICE	

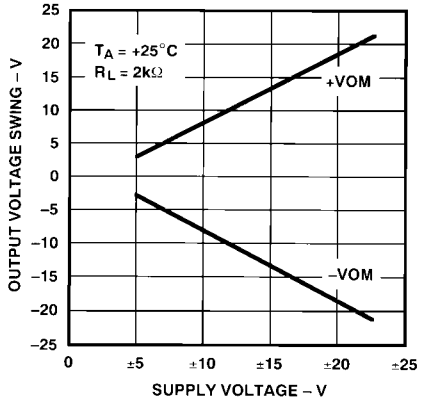
DICE CHARACTERISTICS



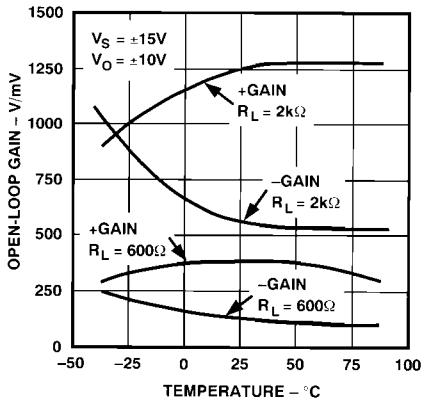
OP-285 Die Size 0.070 × 0.108 inch, 7,560 sq. mils

Substrate (Die Backside) Is Connected to V–
Transistor Count, 45

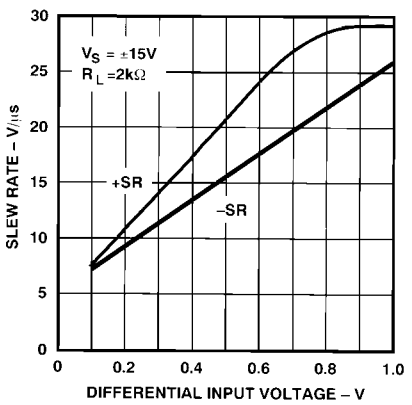
OP-285—Typical Performance Characteristics



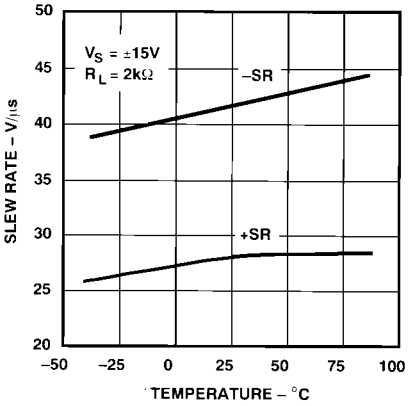
Output Voltage Swing vs. Supply Voltage



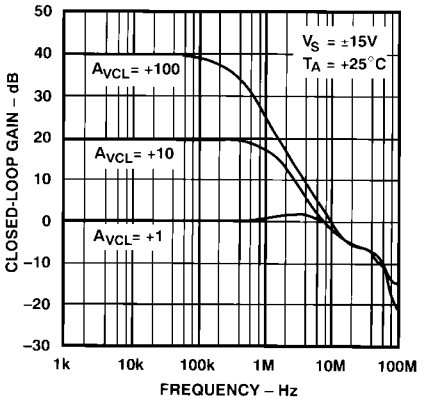
Open-Loop Gain vs. Temperature



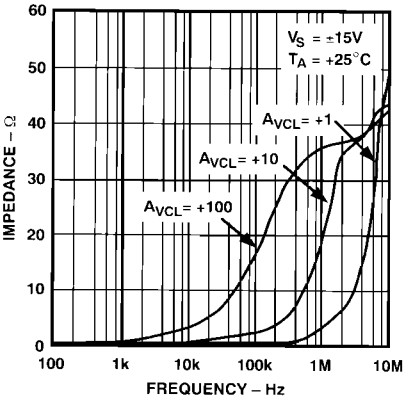
Slew Rate vs. Differential Input Voltage



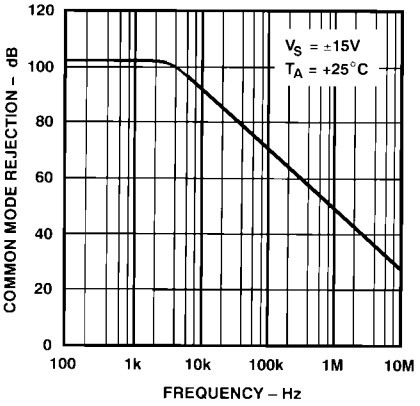
Slew Rate vs. Temperature



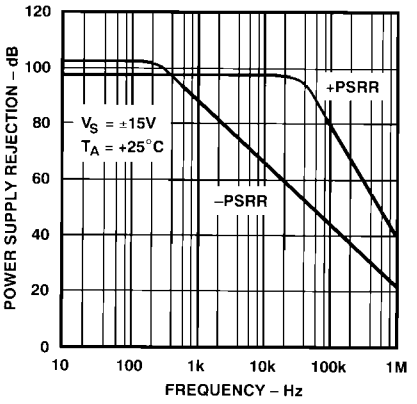
Closed-Loop Gain vs. Frequency



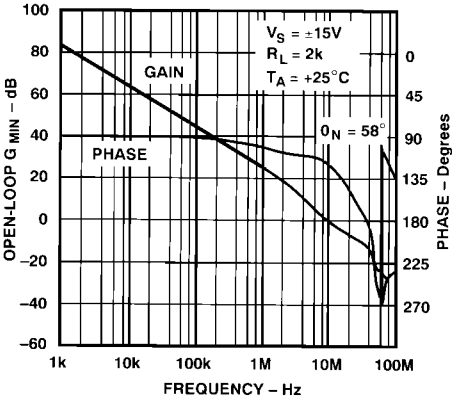
Closed-Loop Output Impedance vs. Frequency



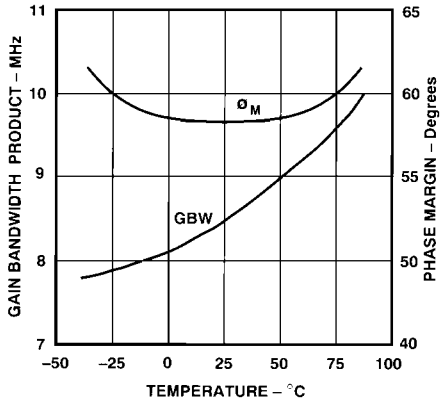
Common-Mode Rejection vs. Frequency



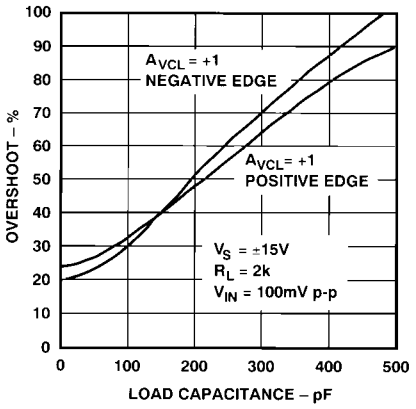
Power Supply Rejection vs. Frequency



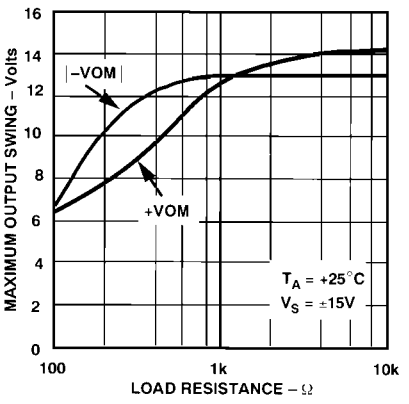
Open-Loop Gain, Phase vs. Frequency



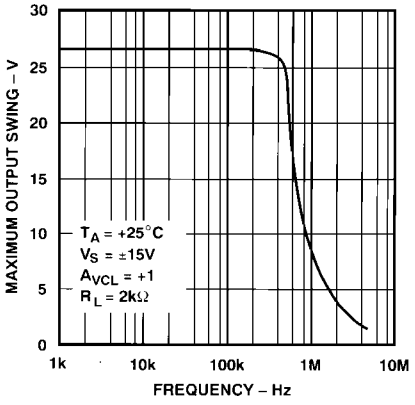
Gain Bandwidth Product, Phase Margin vs. Temperature



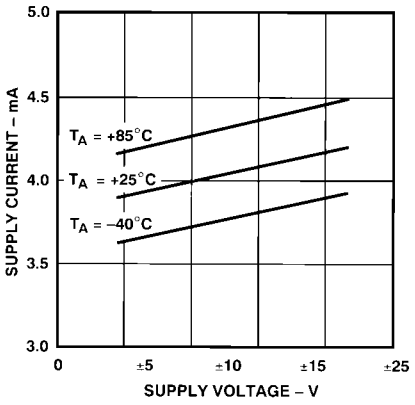
Small-Signal Overshoot vs. Load Capacitance



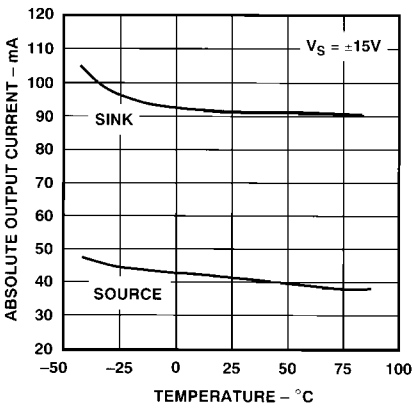
Maximum Output Voltage vs. Load Resistance



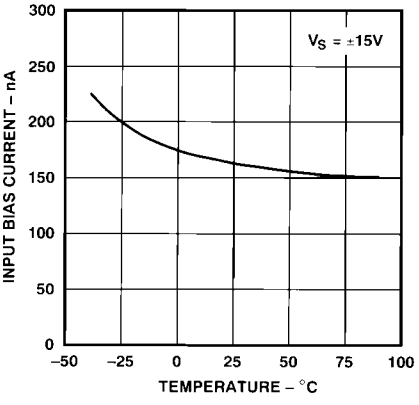
Maximum Output Swing vs. Frequency



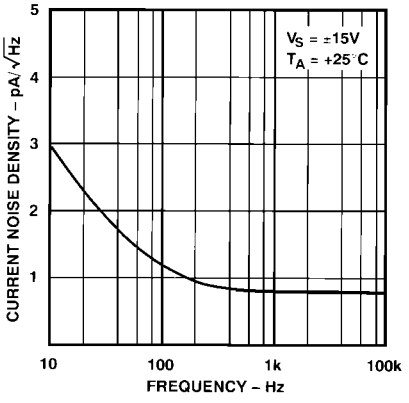
Supply Current vs. Supply Voltage



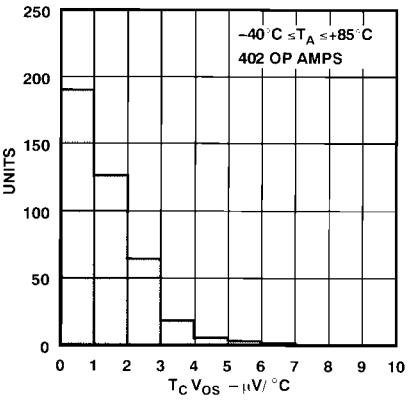
Short Circuit Current vs. Temperature



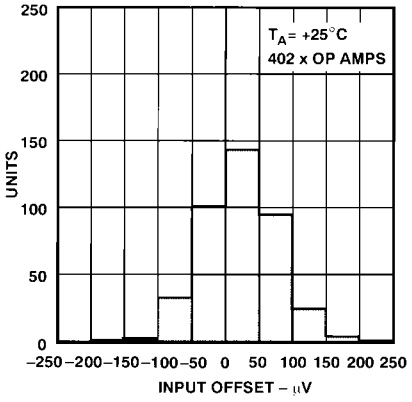
Input Bias Current vs. Temperature



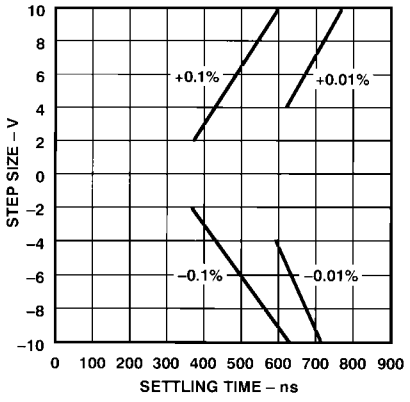
Current Noise Density vs. Frequency



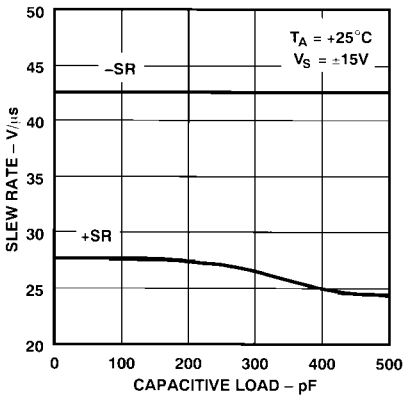
t_C V_{OS} Distribution



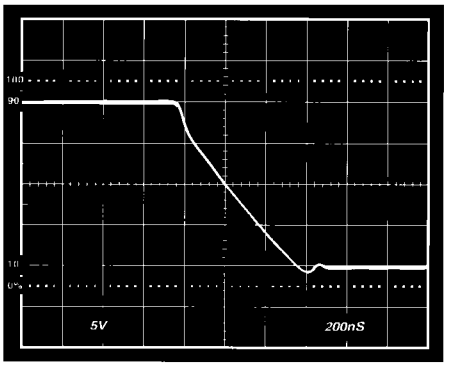
Input Offset (V_{OS}) Distribution



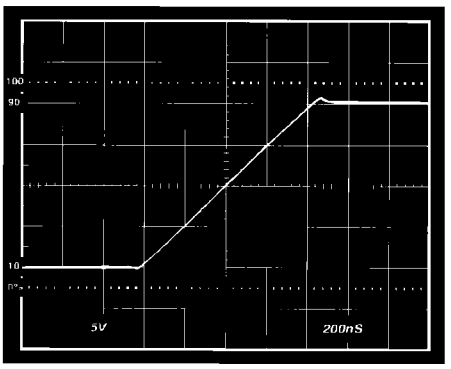
Settling Time vs. Step Size



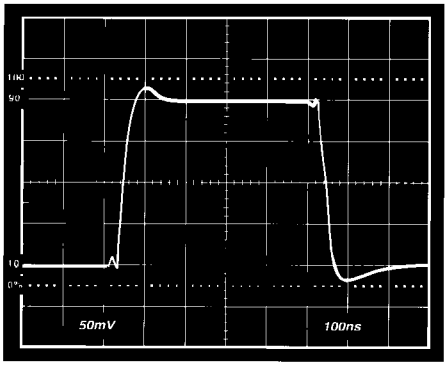
Slew Rate vs. Capacitive Load



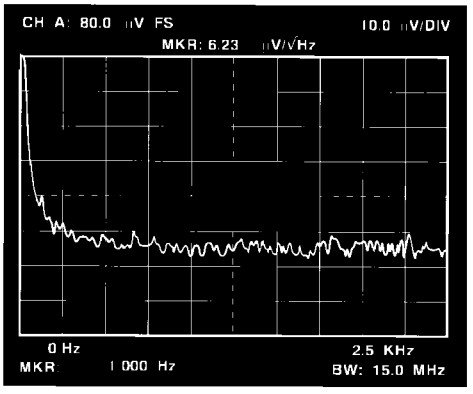
Negative Slew Rate
R_L = 2 kΩ, V_S = ±15 V, A_V = +1



Positive Slew Rate
R_L = 2 kΩ, V_S = ±15 V, A_V = +1



Small Signal Response
R_L = 2 kΩ, V_S = ±15 V, A_V = +1



OP-285 Voltage Noise Density vs. Frequency V_S = ±15 V, A_V = 1000

APPLICATIONS

Short Circuit Protection

The OP-285 has been designed with inherent short circuit protection to ground. An internal 30 Ω resistor, in series with the output, limits the output current at room temperature to $I_{SC}+$ = 40 mA and $I_{SC}-$ = −90 mA, typically, with ±15 V supplies.

However, shorts to either supply may destroy the device when excessive voltages or current are applied. If it is possible for a user to short an output to a supply, for safe operation, the output current of the OP-285 should be design-limited to ±30 mA, as shown in Figure 1.

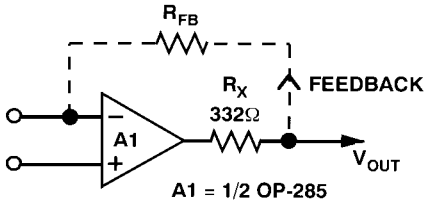


Figure 1. Recommended Output Short Circuit Protection

Input Over Current Protection

The maximum input differential voltage that can be applied to the OP-285 is determined by a pair of internal Zener diodes connected across the inputs. They limit the maximum differential input voltage to ±7.5 V. This is to prevent emitter-base junction breakdown from occurring in the input stage of the OP-285 when very large differential voltages are applied. However, in order to preserve the OP-285's low input noise voltage, internal resistance in series with the inputs were not used to limit the current in the clamp diodes. In small-signal applications, this is not an issue; however, in industrial applications, where large differential voltages can be inadvertently applied to the device, large transient currents can be made to flow through these diodes. The diodes have been designed to carry a current of ±8 mA; and, in applications where the OP-285's differential voltage were to exceed ±7.5 V, the resistor values shown in Figure 2 safely limit the diode current to ±8 mA.

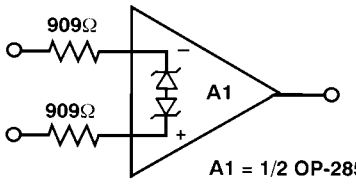


Figure 2. OP-285 Input Over Current Protection

Output Voltage Phase Reversal

Since the OP-285's input stage combines bipolar transistors for low noise and p-channel JFETs for high speed performance, the output voltage of the OP-285 may exhibit phase reversal if either of its inputs exceed its negative common-mode input voltage. This might occur in very severe industrial applications where a sensor, or system, fault might apply very large voltages on the inputs of the OP-285. Even though the input voltage range of the OP-285 is ±10.5 V, an input voltage of approximately −13.5 V will cause output voltage phase reversal. In inverting amplifier configurations, the OP-285's internal 7.5 V input clamping diodes will prevent phase reversal; however, they will not prevent this effect from occurring in noninverting applications. For these applications, the fix is a simple one and is illustrated in Figure 3. A 3.92 kΩ resistor in series with the noninverting input of the OP-285 cures the problem.

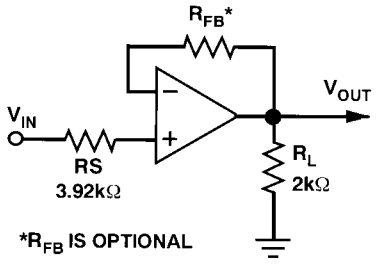


Figure 3. Output Voltage Phase Reversal Fix

Overload, or Overdrive, Recovery

Overload, or overdrive, recovery time of an operational amplifier is the time required for the output voltage to recover to a rated output voltage from a saturated condition. This recovery time is important in applications where the amplifier must recover quickly after a large abnormal transient event. The circuit shown in Figure 4 was used to evaluate the OP-285's overload recovery time. The OP-285 takes approximately 1.2 μs to recover to V_{OUT} = +10 V and approximately 1.5 μs to recover to V_{OUT} = −10 V.

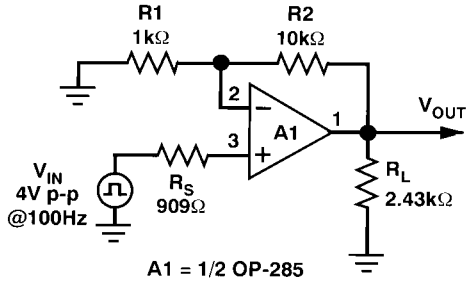


Figure 4. Overload Recovery Time Test Circuit

Driving the Analog Input of an A/D Converter

Settling characteristics of operational amplifiers also include the amplifier's ability to recover, i.e., settle, from a transient output current load condition. When driving the input of an A/D converter, especially successive-approximation converters, the amplifier must maintain a constant output voltage under dynamically changing load current conditions. In these types of converters, the comparison point is usually diode clamped, but it may deviate several hundred millivolts resulting in high frequency modulation of the A/D input current. Amplifiers that exhibit high closed-loop output impedances and/or low unity-gain crossover frequencies recover very slowly from output load current transients. This slow recovery leads to linearity errors or missing codes because of errors in the instantaneous input voltage. Therefore, the amplifier chosen for this type of application should exhibit low output impedance and high unity-gain bandwidth so that its output has had a chance to settle to its nominal value before the converter makes its comparison.

The circuit in Figure 5 illustrates a settling measurement circuit for evaluating the recovery time of an amplifier from an output load current transient. The amplifier is configured as a follower with a very high speed current generator connected to its output. In this test, a 1 mA transient current was used. As shown in Figure 6, the OP-285 exhibits an extremely fast recovery time of 139 ns to 0.01%. Because of its high gain-bandwidth product,

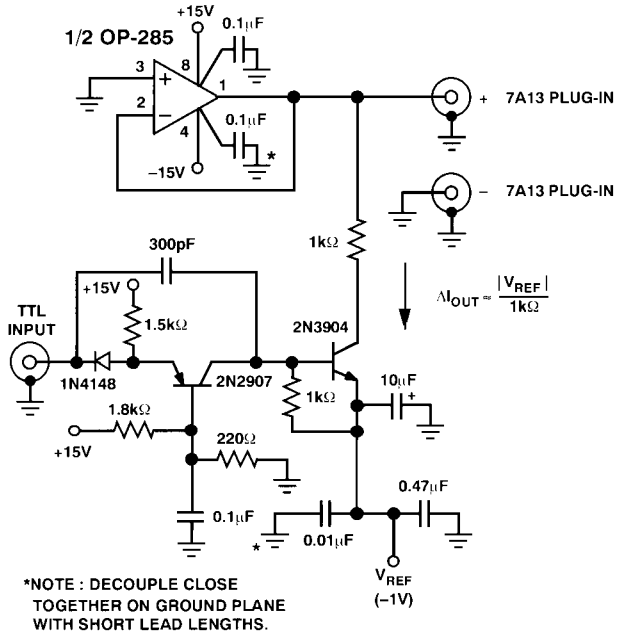


Figure 5. Transient Output Load Current Test Fixture

high open-loop gain, and low output impedance, the OP-285 is ideally suited to drive high speed A/D converters.

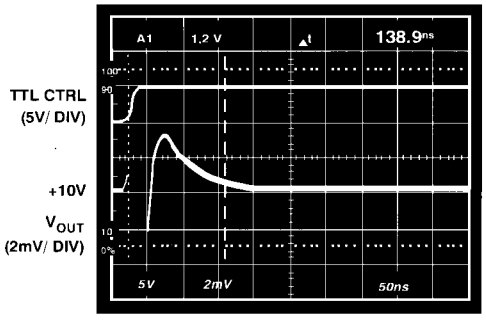


Figure 6. OP-285's Output Load Current Recovery Time

Measuring Settling Time

The design of OP-285 combines high slew rate and wide gain-bandwidth product to produce a fast-settling ($t_S < 1$ μs) amplifier for 8- and 12-bit applications. The test circuit designed to measure the settling time of the OP-285 is shown in Figure 7. This test method has advantages over false-sum node techniques in that the actual output of the amplifier is measured, instead of an error voltage at the sum node. Common-mode settling effects are exercised in this circuit in addition to the slew rate and bandwidth effects measured by the false-sum-node method. Of course, a reasonably flat-top pulse is required as the stimulus.

The output waveform of the OP-285 under test is clamped by Schottky diodes and buffered the JFET source follower. The signal is amplified by a factor of ten by the OP-260 and then Schottky-clamped at the output to prevent overloading the oscilloscope's input amplifier. The OP-41 is configured as a fast integrator which provides overall dc offset nulling.

High Speed Operation

As with most high speed amplifiers, care should be taken with supply decoupling, lead dress, and component placement. Recommended circuit configurations for inverting and noninverting applications are shown in Figures 8 and Figure 9.

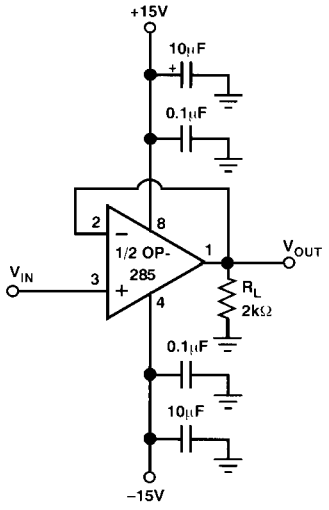


Figure 8. Unity Gain Follower

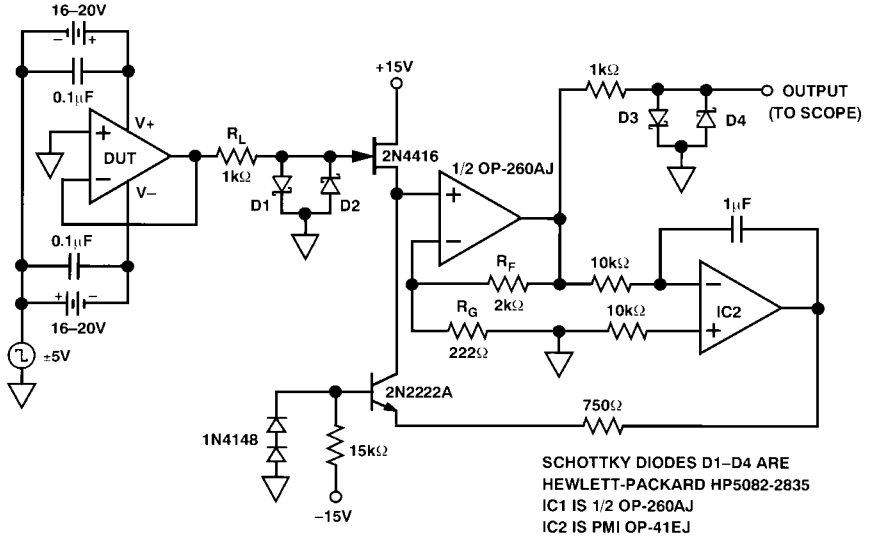


Figure 7. OP-285's Settling Time Test Fixture

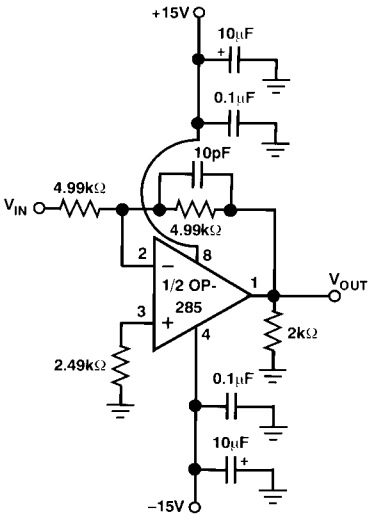


Figure 9. Unity Gain Inverter

In inverting and noninverting applications, the feedback resistance forms a pole with the source resistance and capacitance (R_S and C_S) and the OP-285's input capacitance (C_{IN}), as shown in Figure 10. With R_S and R_F in the kilohm range, this pole can create excess phase shift and even oscillation. A small capacitor, C_{FB}, in parallel with R_{FB} eliminates this problem. By setting R_S (C_S + C_{IN}) = $R_{FB}C_{FB}$, the effect of the feedback pole is completely removed.

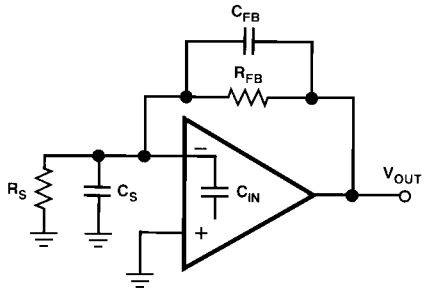


Figure 10. Compensating the Feedback Pole

High Speed, Low Noise Differential Line Driver

The circuit of Figure 11 is a unique line driver widely used in industrial applications. With ±18 V supplies, the line driver can deliver a differential signal of 30 V p-p into a 2.5 kΩ load. The high slew rate and wide bandwidth of the OP-285 combine to yield a full power bandwidth of 130 kHz while the low noise front end produces a referred-to-input noise voltage spectral density of 10 nV/$\sqrt{\text{Hz}}$. The design is a transformerless, balanced transmission system where output common-mode rejection of noise is of paramount importance. Like the transformer-based design, either output can be shorted to ground for unbalanced line driver applications without changing the circuit gain of 1. Other circuit gains can be set according to the equation in the diagram. This allows the design to be easily set to noninverting, inverting, or differential operation.

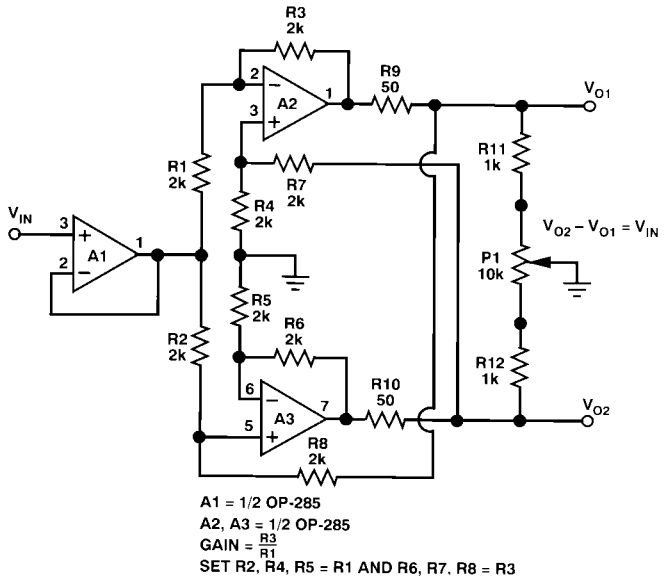


Figure 11. High Speed, Low Noise Differential Line Driver

Low Phase Error Amplifier

The simple amplifier configuration of Figure 12 utilizes the OP-285 and a few resistors to reduce phase error substantially over a wide frequency range when compared to conventional amplifier designs. This technique relies on the matched frequency characteristics of the two amplifiers in the OP-285. Each amplifier in the circuit has the same feedback network which produces a circuit gain of 10. Since the two amplifiers are set to the same gain and are matched due to the monolithic construction of the OP-285, they will exhibit identical frequency response. Recall from feedback theory that a pole of a feedback network becomes a zero in the loop gain response. By using this technique, the dominant pole of the amplifier in the feedback loop compensates for the dominant pole of the main amplifier,

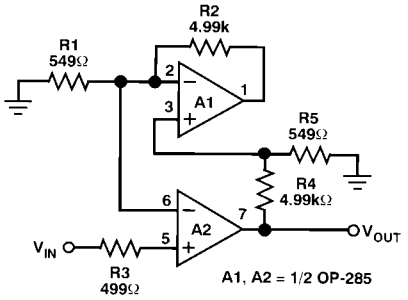


Figure 12. Active Feedback Allows Cancellation of A2's Dominant Pole by A1 Which Reduces the Phase Shift Significantly.

thereby reducing phase error dramatically. This is shown in Figure 13 where the 10× composite amplifier's phase response exhibits less than 1.5° phase shift through 500 kHz. On the other hand, the single gain stage amplifier exhibits 25 degrees of phase shift over the same frequency range. An additional benefit of the low phase error configuration is constant group delay, by virtue of constant phase shift at all frequencies below 500 kHz. Although this technique is valid for minimum circuit gains of 10, actual closed-loop magnitude response must be optimized for the amplifier chosen.

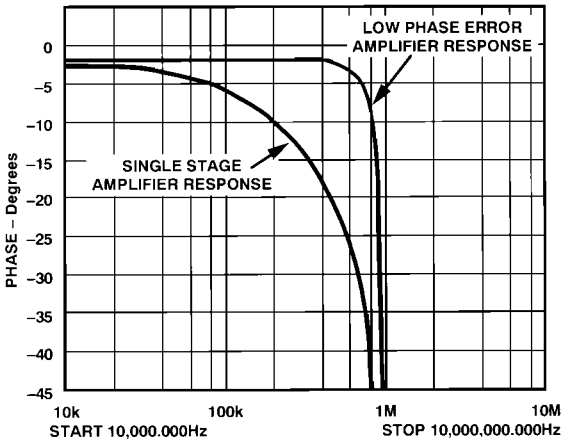


Figure 13. Phase Error Comparison

For a more detailed treatment on the design of low phase error amplifiers, please see Application Note AN-107.

Fast Current Pump

A fast, ±30 mA current source, illustrated in Figure 14, takes advantage of the OP-285's speed and high output current drive. This is a variation of the Howland current source where a second amplifier, A2, is used to increase load current accuracy and output voltage compliance. With supply voltages of ±15 V, the output voltage compliance of the current pump is ±8 V. To keep the output resistance in the MΩ range requires that 0.1% or better resistors be used in the circuit. The gain of the current pump can be easily changed according to the equations shown in the diagram.

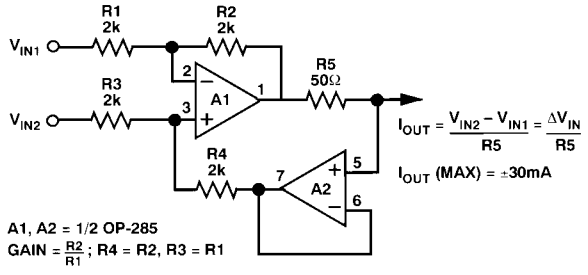


Figure 14. A Fast Current Pump

A Low Noise, High Speed Instrumentation Amplifier

A high speed, low noise instrumentation amplifier, constructed with a single OP-285, is illustrated in Figure 15. The circuit exhibits less than 1.2 μV p-p noise (RTI) in the 0.1 Hz to 10 Hz band and an input noise voltage spectral density of 9 nV/$\sqrt{Hz}$ (1 kHz) at a gain of 1000. The gain of the amplifier is easily set by R_G according to the formula:

$$\frac{V_{OUT}}{V_{IN}} = \frac{9.98\ k\Omega}{R_G} + 2$$

The advantages of a two op amp instrumentation amplifier based on a dual op amp is that the errors in the individual amplifiers tend to cancel one another. For example, the circuit's input offset voltage is determined by the input offset voltage matching of the OP-285, which is typically less than 250 μV.

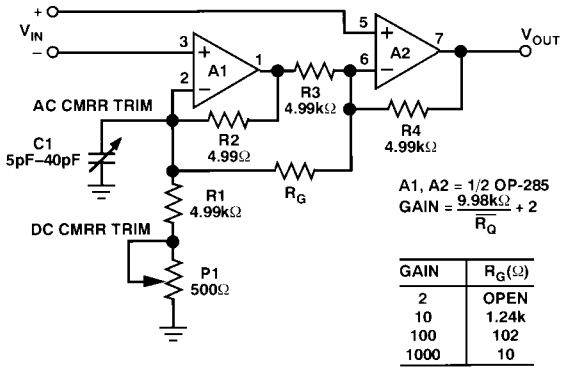


Figure 15. A High Speed Instrumentation Amplifier

Common-mode rejection of the circuit is limited by the matching of resistors R1 to R4. For good common-mode rejection, these resistors ought to be matched to better than 1%. The circuit was constructed with 1% resistors and included potentiometer P1 for trimming the DC CMRR and a capacitor C1 for trimming the AC CMRR. With these two trims, the circuit's common-mode rejection was better than 95 dB at 60 Hz and better than 65 dB at 10 kHz. For the best common-mode rejection performance, use a matched (better than 0.1%) thin-film resistor network for R1 through R4 and use the variable capacitor to optimize the circuit's AC CMR.

The instrumentation amplifier exhibits very wide small- and large-signal bandwidths regardless of the gain setting, as shown in the table. Because of its low noise, wide gain-bandwidth product, and high slew rate, the OP-285 is ideally suited for high speed signal conditioning applications.

Circuit Gain	R_G (Ω)	Circuit Bandwidth V_{OUT} = 100 mV p-p	Circuit Bandwidth V_{OUT} = 20 V p-p
2	Open	5 MHz	780 kHz
10	1.24 k	1 MHz	460 kHz
100	102	90 kHz	85 kHz
1000	10	10 kHz	10 kHz

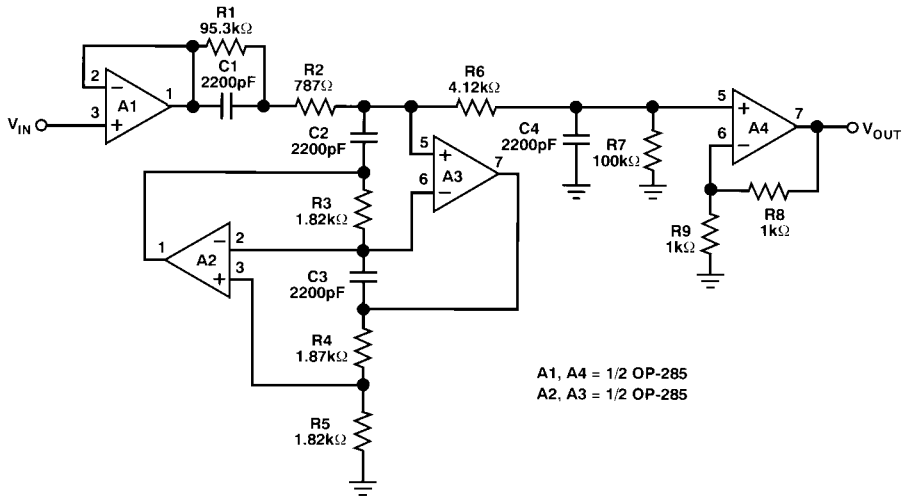


Figure 16. A 3-Pole, 40 kHz Low-Pass Filter

A 3-Pole, 40 kHz Low-Pass Filter

The closely matched and uniform ac characteristics of the OP-285 make it ideal for use in GIC (Generalized Impedance Converter) and FDNR (Frequency-Dependent Negative Resistor) filter applications. The circuit in Figure 16 illustrates a linear-phase, 3-pole, 40 kHz low-pass filter using an OP-285 as an inductance simulator (gyrator). The circuit uses one OP-285 (A2 and A3) for the FDNR and one OP-285 (A1 and A4) as an input buffer and bias current source for A3. Amplifier A4 is configured in a gain of 2 to set the pass band magnitude response to 0 dB. The benefits of this filter topology over classical approaches are that the op amp used in the FDNR is not in the signal path and that the filter's performance is relatively insensitive to component variations. Also, the configuration is such that large signal levels can be handled without overloading any of the filter's internal nodes. As shown in Figure 17, the OP-285's symmetric slew rate and low distortion produce a clean, well-behaved transient response.

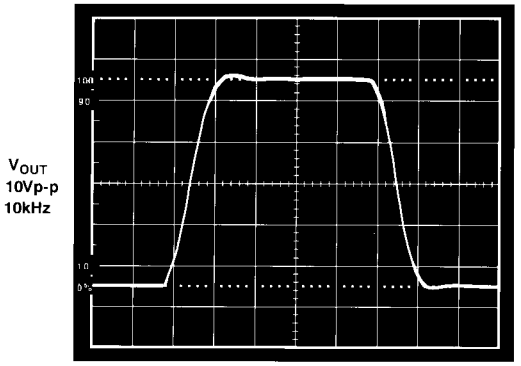


Figure 17. Low-Pass Filter Transient Response

Driving Capacitive Loads

The OP-285 was designed to drive both resistive loads to 600 Ω and capacitive loads of over 1000 pF and maintain stability. While there is a degradation in bandwidth when driving capacitive loads, the designer need not worry about device stability. The graph in Figure 18 shows the 0 dB bandwidth of the OP-285 with capacitive loads from 10 pF to 1000 pF.

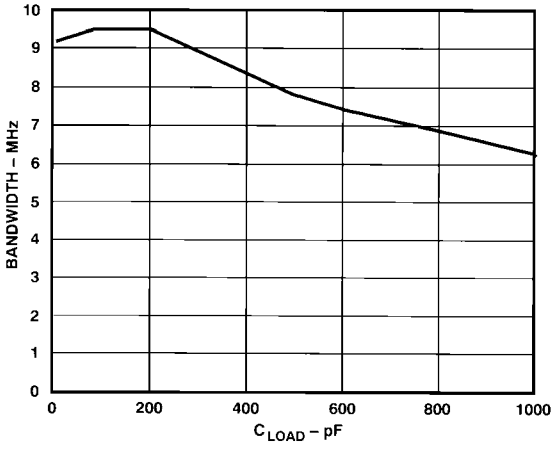
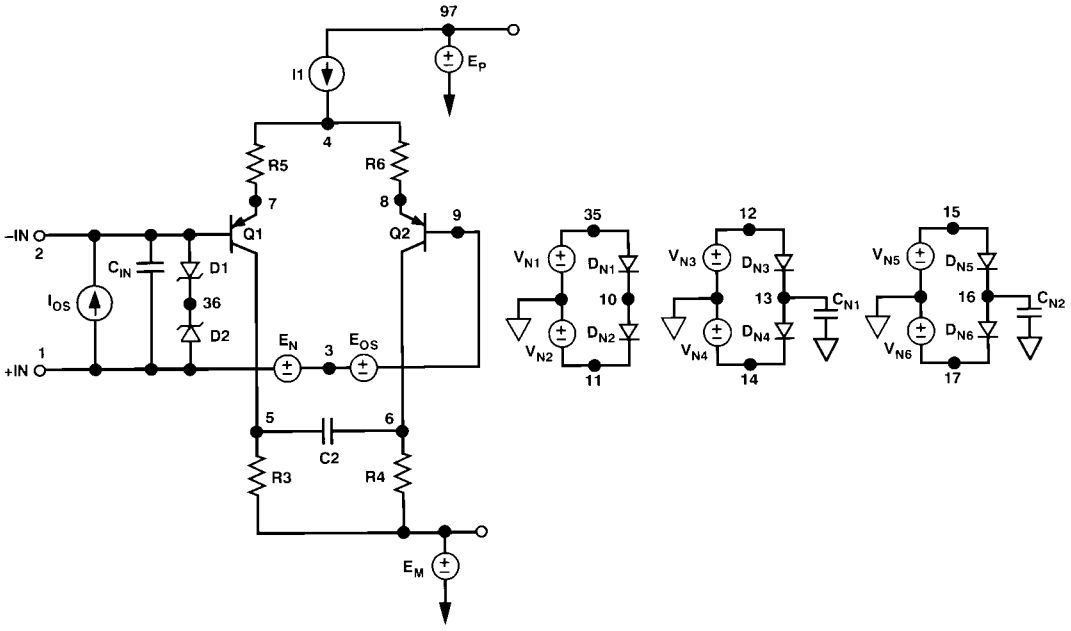


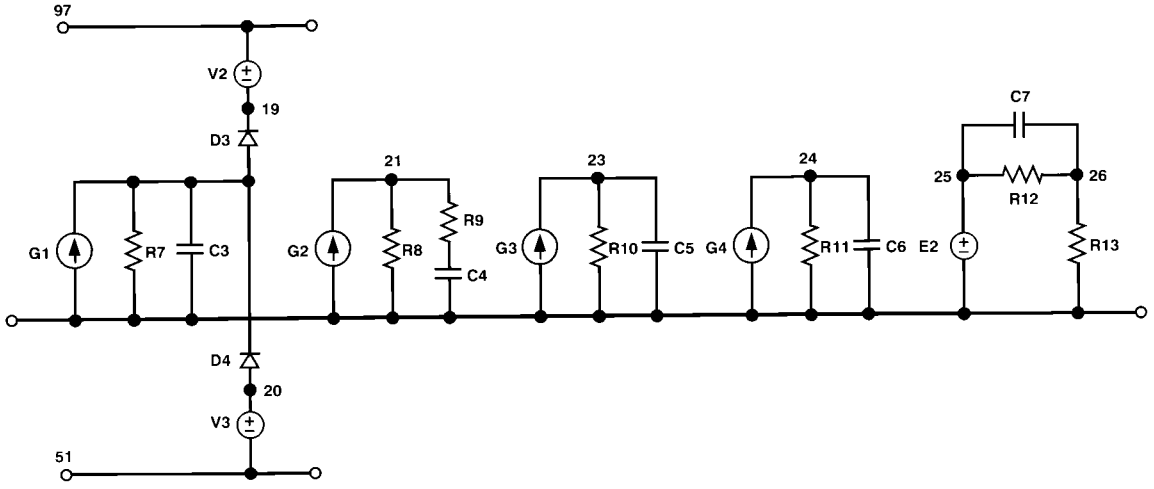
Figure 18. Bandwidth vs. C_{LOAD}

OP-285 SPICE Model

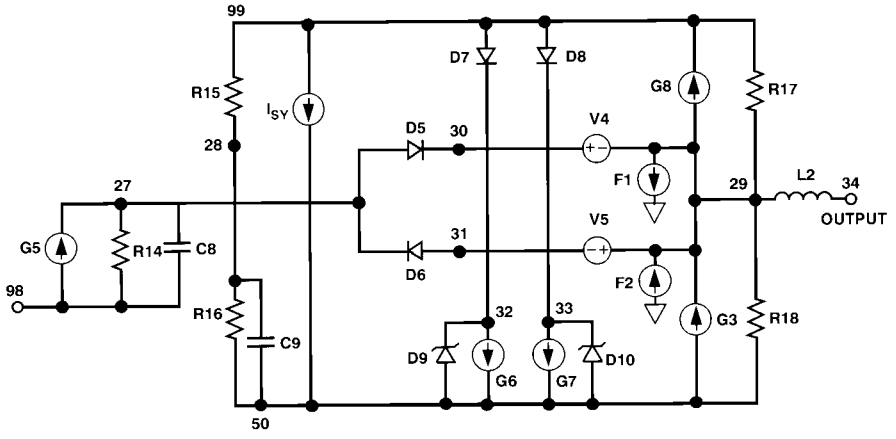
```
* Node assignments
*                        noninverting input
*                        |  inverting input
*                        |  |  positive supply
*                        |  |  |  negative supply
*                        |  |  |  |  output
*                        |  |  |  |  |
*                        |  |  |  |  |
.SUBCKT OP-285           1  2  99 50 34
*
* INPUT STAGE & POLE AT 100 MHZ
*
R3          5 51         2.188
R4          6 51         2.188
CIN 1 2     1.5E-12
C2          5 6          364E-12
I1          97 4         100E-3
IOS 1 2     1E-9
EOS 9 3     POLY(1) 26 28 35E-6 1
Q1          5 2 7 QX
Q2          6 9 8 QX
R5          7 4          1.672
R6          8 4          1.672
D1          2 36         DZ
D2          1 36         DZ
EN          3 1          10 0 1
GN1 0 2     13 0 1
GN2 0 1     16 0 1
*
EREF 98 0   28 0 1
EP          97 0         99 0 1
EM          51 0         50 0 1
*
* VOLTAGE NOISE SOURCE
*
DN1 35 10   DEN
DN2 10 11   DEN
VN1 35 0    DC 2
VN2 0 11    DC 2
*
* CURRENT NOISE SOURCE
*
DN3 12 13   DIN
DN4 13 14   DIN
VN3 12 0    DC 2
VN4 0 14    DC 2
CN1 13 0    7.53E-3
*
* CURRENT NOISE SOURCE
*
DN5 15 16   DIN
DN6 16 17   DIN
VN5 15 0    DC 2
VN6 0 17    DC 2
CN2 16 0    7.53E-3
*
* GAIN STAGE & DOMINANT POLE AT 32 HZ *
R7 18 98    1.09E6
C3 18 98    4.55E-9
G1 98 18    5 6 4.57E-1
V2 97 19    1.4
V3 20 51    1.4
D3 18 19    DX
D4 20 18    DX
*
* POLE/ZERO PAIR AT 1.5MHz/2.7MHz
*
R8 21 98    1E3
R9 21 22    1.25E3
C4 22 98    47.2E-12
G2 98 21    18 28 1E-3
*
* POLE AT 100 MHZ
*
R10 23 98   1
C5 23 98    1.59E-9
G3 98 23    21 28 1
*
* POLE AT 100 MHZ
*
R11 24 98   1
C6 24 98    1.59E-9
G4 98 24    23 28 1
*
* COMMON-MODE GAIN NETWORK WITH ZERO AT
  1 kHZ *
R12 25 26   1E6
C7 25 26    1.59E-12
R13 26 98   1
E2 25 98    POLY(2) 1 98 2 98 0 2.506 2.506
*
* POLE AT 100 MHZ
*
R14 27 98   1
C8 27 98    1.59E-9
G5 98 27    24 28 1
*
* OUTPUT STAGE
*
R15 28 99           100E3
R16 28 50           100E3
C9 28 50            1E-6
ISY 99 50           1.85E-3
R17 29 99           100
R18 29 50           100
L2 29 34            1E-9
G6 32 50            27 29 10E-3
G7 33 50            29 27 10E-3
G8 29 99            99 27 10E-3
G9 50 29            27 50 10E-3
V4 30 29            1.3
V5 29 31            3.8
F1 29 0             V4 1
F2 0 29             V5 1
D5 27 30            DX
D6 31 27            DX
D7 99 32            DX
D8 99 33            DX
D9 50 32            DY
D10 50 33           DY
*
* MODELS USED
*
.MODEL QX PNP(BF = 5E5)
.MODEL DX           D(IS = 1E-12)
.MODEL DY           D(IS = 1E-15 BV = 50)
.MODEL DZ           D(IS = 1E-15 BV = 7.0)
.MODEL DEN D(IS = 1E-12 RS = 4.35K KF = 1.95E-15
AF = 1) .MODEL DIN D(IS = 1E-12 RS = 77.3E-6
KF = 3.38E-15 AF = 1) .ENDS OP-285
```



Spice Diagram (A)



Spice Diagram (B)

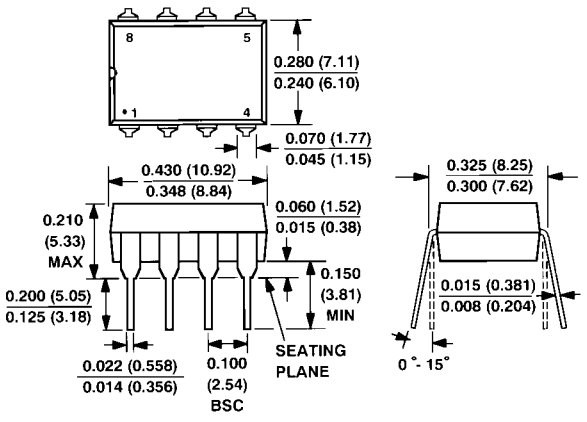


Spice Diagram (C)

OUTLINE DIMENSIONS

Dimension shown in inches and (mm).

N-8



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