LM158/LM258/LM358/LM2904 Low Power Dual Operational Amplifiers

Check for Samples: LM158-N, LM258-N, LM2904-N, LM358-N

FEATURES

- **Available in 8-Bump DSBGA Chip-Sized Package, (See AN-1112 (SNVA009))**
- **Internally Frequency Compensated for Unity Gain**
- **Large DC Voltage Gain: 100 dB**
- **Wide Bandwidth (Unity Gain): 1 MHz (Temperature Compensated)**
- **Wide Power Supply Range:**
  - **Single Supply: 3V to 32V**
  - **Or Dual Supplies: ±1.5V to ±16V**
- **Very Low Supply Current Drain (500 μA)—Essentially Independent of Supply Voltage**
- **Low Input Offset Voltage: 2 mV**
- **Input Common-Mode Voltage Range Includes Ground**
- **Differential Input Voltage Range Equal to the Power Supply Voltage**
- **Large Output Voltage Swing**

UNIQUE CHARACTERISTICS

- **In the Llinear Mode the Input Common-Mode Voltage Range Includes Ground and the Output Voltage Can Also Swing to Ground, even though Operated from Only a Single Power Supply Voltage.**
- **The Unity Gain Cross Frequency is Temperature Compensated.**
- **The Input Bias Current is also Temperature Compensated.**

ADVANTAGES

- **Two Internally Compensated Op Amps**
- **Eliminates Need for Dual Supplies**
- **Allows Direct Sensing Near GND and V_{OUT} Also Goes to GND**
- **Compatible with All Forms of Logic**
- **Power Drain Suitable for Battery Operation**

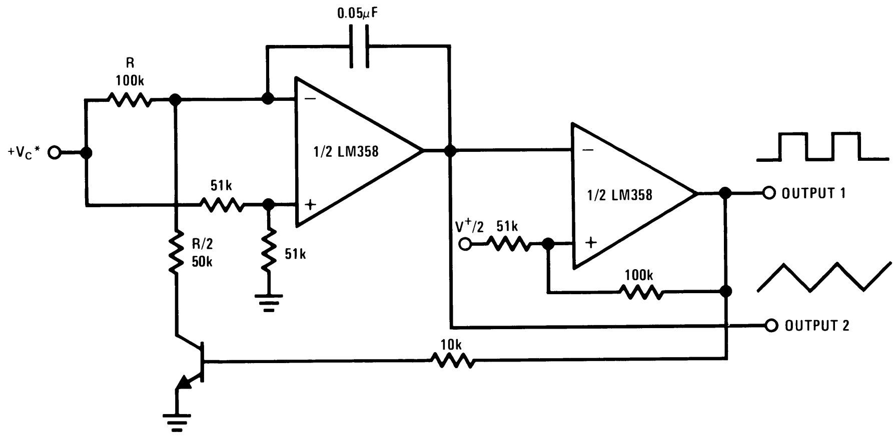
DESCRIPTION

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM158 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

The LM358 and LM2904 are available in a chip sized package (8-Bump DSBGA) using TI's DSBGA package technology.

Voltage Controlled Oscillator (VCO)



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS(1)(2)

		LM158/LM258/LM358 LM158A/LM258A/LM358A	LM2904
Supply Voltage, V^+		32V	26V
Differential Input Voltage		32V	26V
Input Voltage		−0.3V to +32V	−0.3V to +26V
Power Dissipation(3)			
PDIP (P)		830 mW	830 mW
TO-99 (LMC)		550 mW	
SOIC (D)		530 mW	530 mW
DSBGA (YPB)		435mW	
Output Short-Circuit to GND (One Amplifier)(4)	$V^+ \leq 15V$ and $T_A = 25°C$	Continuous	Continuous
Input Current ($V_{IN} < −0.3V$)(5)		50 mA	50 mA
Operating Temperature Range			
LM358		0°C to +70°C	−40°C to +85°C
LM258		−25°C to +85°C	
LM158		−55°C to +125°C	
Storage Temperature Range		−65°C to +150°C	−65°C to +150°C
Lead Temperature, PDIP (P)			
(Soldering, 10 seconds)		260°C	260°C
Lead Temperature, TO-99 (LMC)			
(Soldering, 10 seconds)		300°C	300°C
Soldering Information			
PDIP Package (P)			
Soldering (10 seconds)		260°C	260°C
SOIC Package (D)			
Vapor Phase (60 seconds)		215°C	215°C
Infrared (15 seconds)		220°C	220°C
ESD Tolerance(6)		250V	250V

(1) Refer to RETS158AX for LM158A military specifications and to RETS158X for LM158 military specifications.
(2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(3) For operating at high temperatures, the LM358/LM358A, LM2904 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 120°C/W for PDIP, 182°C/W for TO-99, 189°C/W for SOIC package, and 230°C/W for DSBGA, which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM258/LM258A and LM158/LM158A can be derated based on a +150°C maximum junction temperature. The dissipation is the total of both amplifiers—use external resistors, where possible, to allow the amplifier to saturate or to reduce the power which is dissipated in the integrated circuit.
(4) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
(5) This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the op amps to go to the V^+voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3V (at 25°C).
(6) Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

$V^+ = +5.0V$, unless otherwise stated

Parameter	Conditions	LM158A			LM358A			LM158/LM258			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(1), $T_A = 25°C$		1	2		2	3		2	5	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$,		20	50		45	100		45	150	nA
	$V_{CM} = 0V$, (2)										
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		2	10		5	30		3	30	nA
Input Common-Mode Voltage Range	$V^+ = 30V$, (3) (LM2904, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V
Supply Current	Over Full Temperature Range										
	$R_L = \infty$ on All Op Amps										
	$V^+ = 30V$ (LM2904 $V^+ = 26V$)		1	2		1	2		1	2	mA
	$V^+ = 5V$		0.5	1.2		0.5	1.2		0.5	1.2	mA

(1) $V_O \simeq 1.4V$, $R_S = 0\Omega$ with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ −1.5V) at 25°C. For LM2904, V^+ from 5V to 26V.
(2) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
(3) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2904), independent of the magnitude of V^+.

ELECTRICAL CHARACTERISTICS

$V^+ = +5.0V$, unless otherwise stated

Parameter	Conditions	LM358			LM2904			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	See (1), $T_A = 25°C$		2	7		2	7	mV
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$, $V_{CM} = 0V$, See (2)		45	250		45	250	nA
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		5	50		5	50	nA
Input Common-Mode Voltage Range	$V^+ = 30V$, See (3) (LM2904, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	V
Supply Current	Over Full Temperature Range							
	$R_L = \infty$ on All Op Amps							
	$V^+ = 30V$ (LM2904 $V^+ = 26V$)		1	2		1	2	mA
	$V^+ = 5V$		0.5	1.2		0.5	1.2	mA

(1) $V_O \simeq 1.4V$, $R_S = 0\Omega$ with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ −1.5V) at 25°C. For LM2904, V^+ from 5V to 26V.
(2) The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.
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ELECTRICAL CHARACTERISTICS

$V^+ = +5.0V$, See(1), unless otherwise stated

Parameter	Conditions	LM158A Min	LM158A Typ	LM158A Max	LM358A Min	LM358A Typ	LM358A Max	LM158/LM258 Min	LM158/LM258 Typ	LM158/LM258 Max	Units
Large Signal Voltage Gain	$V^+ = 15V$, $T_A = 25°C$, $R_L \geq 2\ k\Omega$, (For $V_O = 1V$ to $11V$)	50	100		25	100		50	100		V/mV
Common-Mode Rejection Ratio	$T_A = 25°C$, $V_{CM} = 0V$ to $V^+−1.5V$	70	85		65	85		70	85		dB
Power Supply Rejection Ratio	$V^+ = 5V$ to $30V$ (LM2904, $V^+ = 5V$ to $26V$), $T_A = 25°C$	65	100		65	100		65	100		dB
Amplifier-to-Amplifier Coupling	f = 1 kHz to 20 kHz, $T_A = 25°C$ (Input Referred), See(2)		−120			−120			−120		dB
Output Current — Source	$V_{IN}^+ = 1V$, $V_{IN}^- = 0V$, $V^+ = 15V$, $V_O = 2V$, $T_A = 25°C$	20	40		20	40		20	40		mA
Output Current — Sink	$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $V^+ = 15V$, $T_A = 25°C$, $V_O = 2V$	10	20		10	20		10	20		mA
	$V_{IN}^- = 1V$, $V_{IN}^+ = 0V$ $T_A = 25°C$, $V_O = 200\ mV$, $V^+ = 15V$	12	50		12	50		12	50		μA
Short Circuit to Ground	$T_A = 25°C$, See(3), $V^+ = 15V$		40	60		40	60		40	60	mA
Input Offset Voltage	See(4)			4			5			7	mV
Input Offset Voltage Drift	$R_S = 0\Omega$		7	15		7	20		7		μV/°C
Input Offset Current	$I_{IN(+)} − I_{IN(−)}$			30			75			100	nA
Input Offset Current Drift	$R_S = 0\Omega$		10	200		10	300		10		pA/°C
Input Bias Current	$I_{IN(+)}$ or $I_{IN(−)}$		40	100		40	200		40	300	nA
Input Common-Mode Voltage Range	$V^+ = 30\ V$, See(5) (LM2904, $V^+ = 26V$)	0		$V^+−2$	0		$V^+−2$	0		$V^+−2$	V
Large Signal Voltage Gain	$V^+ = +15V$ ($V_O = 1V$ to $11V$) $R_L \geq 2\ k\Omega$	25			15			25			V/mV
Output Voltage Swing — V_{OH}	$V^+ = +30V$, $R_L = 2\ k\Omega$	26			26			26			V
	(LM2904, $V^+ = 26V$), $R_L = 10\ k\Omega$	27	28		27	28		27	28		V
Output Voltage Swing — V_{OL}	$V^+ = 5V$, $R_L = 10\ k\Omega$		5	20		5	20		5	20	mV

(1) These specifications are limited to $−55°C \leq T_A \leq +125°C$ for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to $−25°C \leq T_A \leq +85°C$, the LM358/LM358A temperature specifications are limited to $0°C \leq T_A \leq +70°C$, and the LM2904 specifications are limited to $−40°C \leq T_A \leq +85°C$.

(2) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.

(3) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

(4) $V_O \simeq 1.4V$, $R_S = 0\Omega$ with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ −1.5V) at 25°C. For LM2904, V^+ from 5V to 26V.

(5) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2904), independent of the magnitude of V^+.

ELECTRICAL CHARACTERISTICS (continued)

V^+ = +5.0V, See(1), unless otherwise stated

Parameter		Conditions	LM158A			LM358A			LM158/LM258			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Output Current	Source	V_{IN}^+ = +1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V	10	20		10	20		10	20		mA
	Sink	V_{IN}^- = +1V, V_{IN}^+ = 0V, V^+ = 15V, V_O = 2V	10	15		5	8		5	8		mA

ELECTRICAL CHARACTERISTICS

V^+ = +5.0V, See(1), unless otherwise stated

Parameter		Conditions	LM358			LM2904			Units
			Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain		V^+ = 15V, T_A = 25°C, R_L ≥ 2 kΩ, (For V_O = 1V to 11V)	25	100		25	100		V/mV
Common-Mode Rejection Ratio		T_A = 25°C, V_{CM} = 0V to V^+−1.5V	65	85		50	70		dB
Power Supply Rejection Ratio		V^+ = 5V to 30V (LM2904, V^+ = 5V to 26V), T_A = 25°C	65	100		50	100		dB
Amplifier-to-Amplifier Coupling		f = 1 kHz to 20 kHz, T_A = 25°C (Input Referred), See(2)		−120			−120		dB
Output Current	Source	V_{IN}^+ = 1V, V_{IN}^- = 0V, V^+ = 15V, V_O = 2V, T_A = 25°C	20	40		20	40		mA
	Sink	V_{IN}^- = 1V, V_{IN}^+ = 0V V^+ = 15V, T_A = 25°C, V_O = 2V	10	20		10	20		mA
		V_{IN}^- = 1V, V_{IN}^+ = 0V T_A = 25°C, V_O = 200 mV, V^+ = 15V	12	50		12	50		μA
Short Circuit to Ground		T_A = 25°C, See(3), V^+ = 15V		40	60		40	60	mA
Input Offset Voltage		See(4)			9			10	mV
Input Offset Voltage Drift		R_S = 0Ω		7			7		μV/°C
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$			150		45	200	nA
Input Offset Current Drift		R_S = 0Ω		10			10		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$		40	500		40	500	nA
Input Common-Mode Voltage Range		V^+ = 30 V, See(5) (LM2904, V^+ = 26V)	0		V^+−2	0		V^+ −2	V

(1) These specifications are limited to −55°C ≤ T_A ≤ +125°C for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to −25°C ≤ T_A ≤ +85°C, the LM358/LM358A temperature specifications are limited to 0°C ≤ T_A ≤ +70°C, and the LM2904 specifications are limited to −40°C ≤ T_A ≤ +85°C.
(2) Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitance increases at higher frequencies.
(3) Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 40 mA independent of the magnitude of V^+. At values of supply voltage in excess of +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
(4) V_O ≃ 1.4V, R_S = 0Ω with V^+ from 5V to 30V; and over the full input common-mode range (0V to V^+ −1.5V) at 25°C. For LM2904, V^+ from 5V to 26V.
(5) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5V (at 25°C), but either or both inputs can go to +32V without damage (+26V for LM2904), independent of the magnitude of V^+.

ELECTRICAL CHARACTERISTICS (continued)

$V^+ = +5.0V$, See(1), unless otherwise stated

Parameter		Conditions		LM358			LM2904			Units
				Min	Typ	Max	Min	Typ	Max	
Large Signal Voltage Gain		$V^+ = +15V$ (V_O = 1V to 11V) $R_L \geq 2\ k\Omega$		15			15			V/mV
Output Voltage	V_{OH}	$V^+ = +30V$	$R_L = 2\ k\Omega$	26			22			V
		(LM2904, $V^+ = 26V$)	$R_L = 10\ k\Omega$	27	28		23	24		V
Swing	V_{OL}	$V^+ = 5V$, $R_L = 10\ k\Omega$			5	20		5	100	mV
Output Current	Source	$V_{IN}^+ = +1V$, $V_{IN}^- = 0V$, $V^+ = 15V$, $V_O = 2V$		10	20		10	20		mA
	Sink	$V_{IN}^- = +1V$, $V_{IN}^+ = 0V$, $V^+ = 15V$, $V_O = 2V$		5	8		5	8		mA

TYPICAL PERFORMANCE CHARACTERISTICS

Input Voltage Range

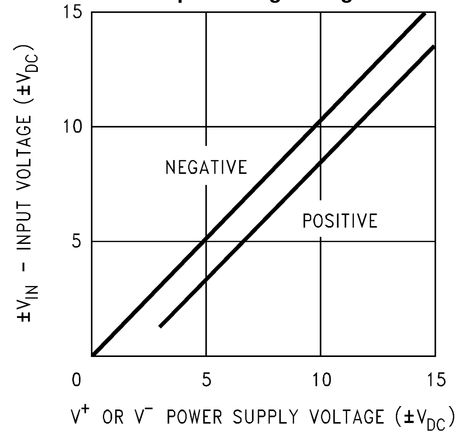


Figure 1.

Input Current

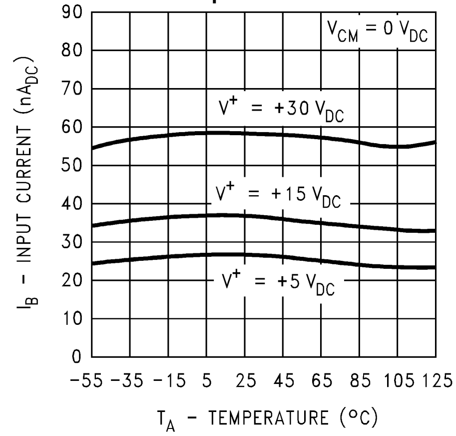


Figure 2.

Supply Current

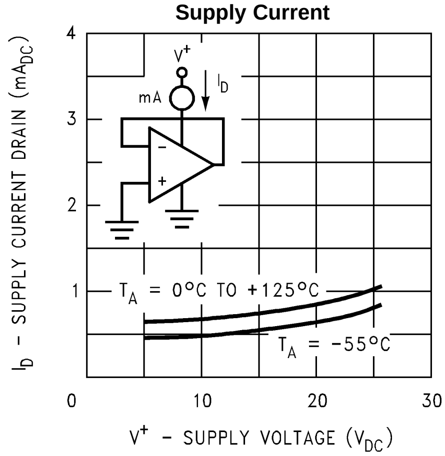


Figure 3.

Voltage Gain

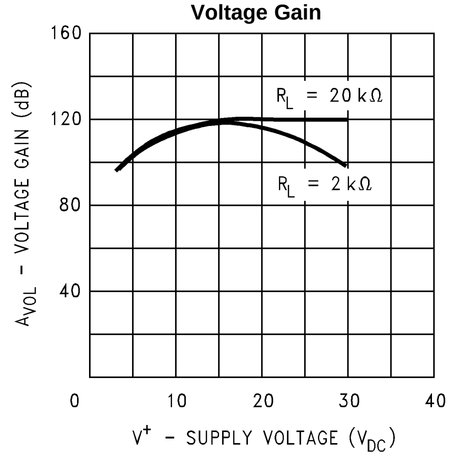


Figure 4.

Open Loop Frequency Response

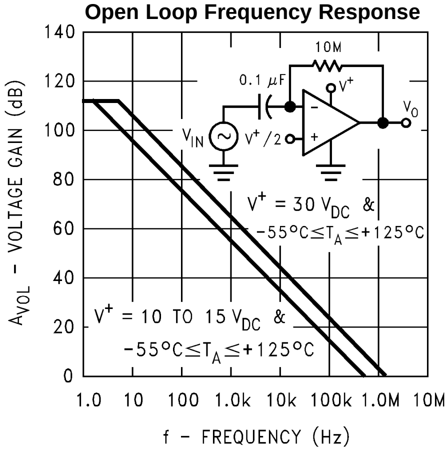


Figure 5.

Common-Mode Rejection Ratio

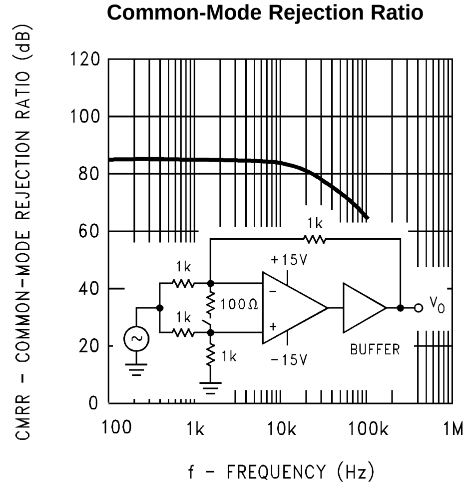


Figure 6.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Voltage Follower Pulse Response

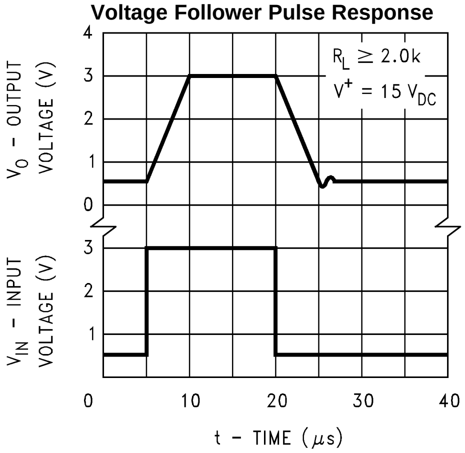


Figure 7.

Voltage Follower Pulse Response (Small Signal)

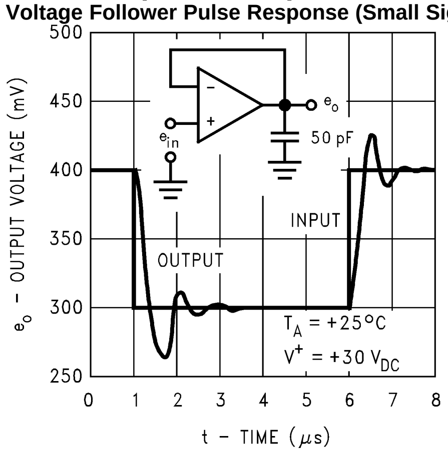


Figure 8.

Large Signal Frequency Response

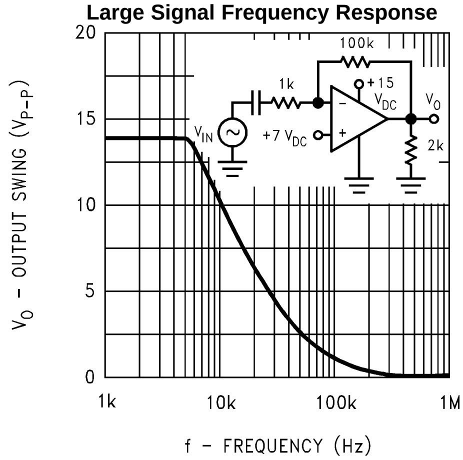


Figure 9.

Output Characteristics Current Sourcing

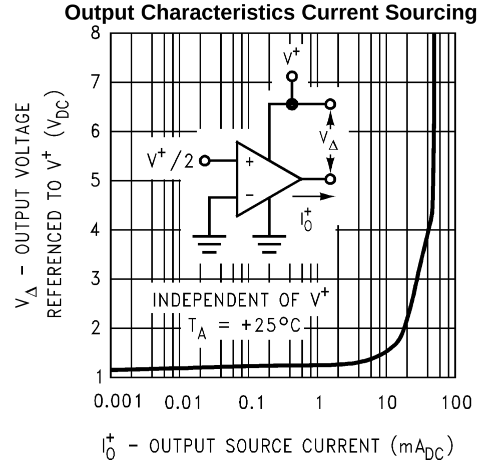


Figure 10.

Output Characteristics Current Sinking

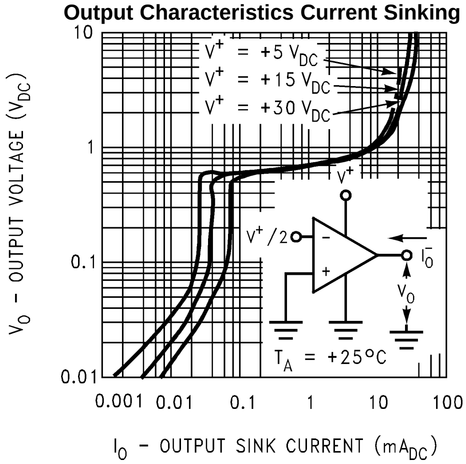


Figure 11.

Current Limiting

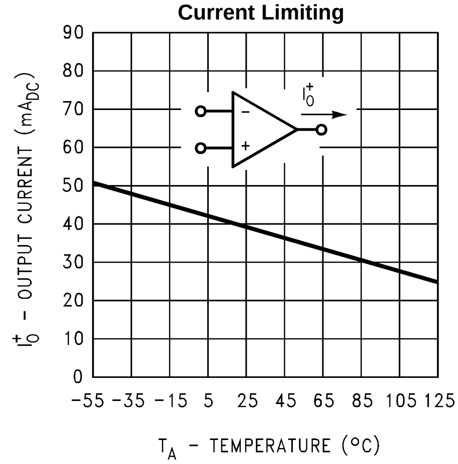


Figure 12.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Input Current (LM2902 only)

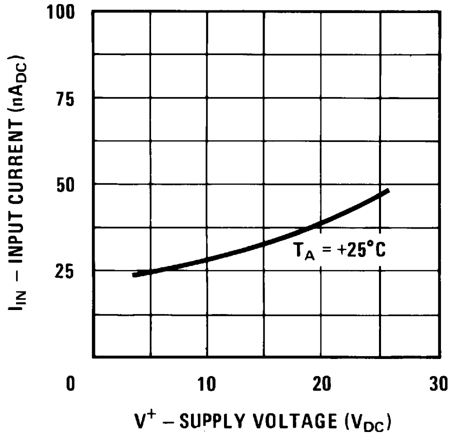


Figure 13.

Voltage Gain (LM2902 only)

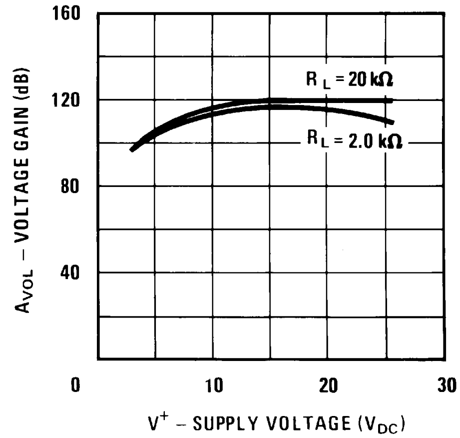


Figure 14.

APPLICATION HINTS

The LM158 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of 3 V_{DC} to 30 V_{DC}.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive function temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see TYPICAL PERFORMANCE CHARACTERISTICS) than a standard IC op amp.

The circuits presented in the TYPICAL SINGLE-SUPPLY APPLICATIONS emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

CONNECTION DIAGRAM

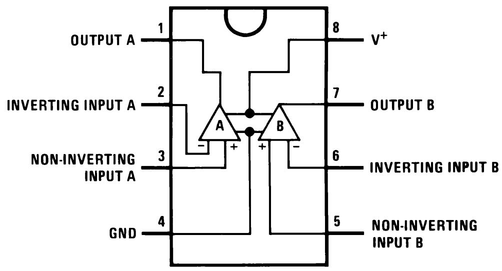


Figure 15. PDIP/CDIP/SOIC Package – Top View (See Package Number P, NAB0008A, or D)

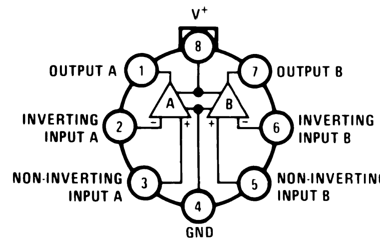


Figure 16. TO-99 Package – Top View (See Package Number LMC)

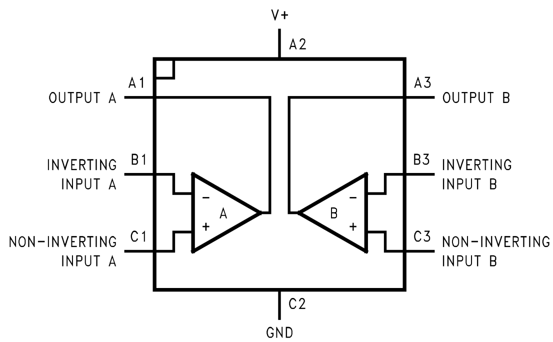
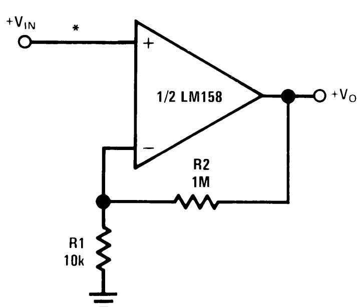


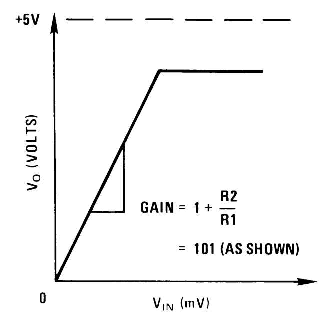
Figure 17. 8-Bump DSBGA - Top View, Bump Side Down (See Package Number YPB0008AAA)

TYPICAL SINGLE-SUPPLY APPLICATIONS

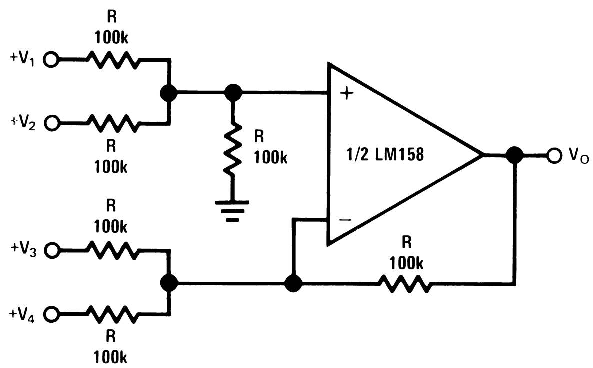
($V^+ = 5.0\ V_{DC}$)

Figure 18. Non-Inverting DC Gain (0V Output)



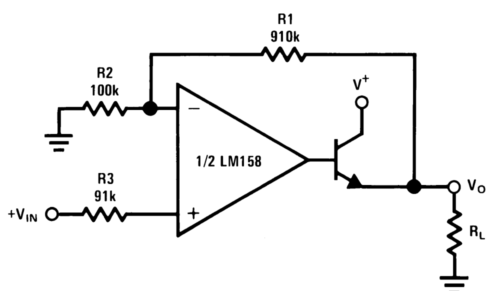


*R not needed due to temperature independent I_{IN}



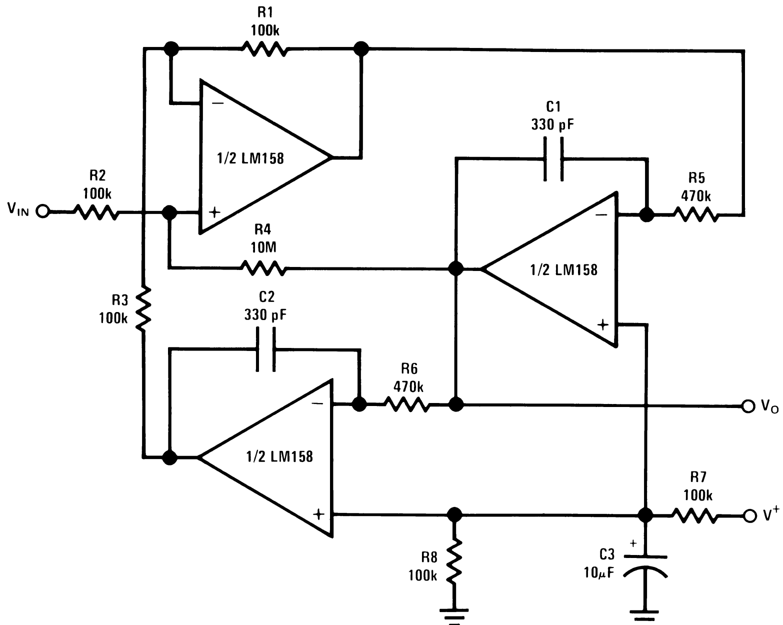
Where: $V_O = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

Figure 19. DC Summing Amplifier ($V_{IN'S} \geq 0\ V_{DC}$ and $V_O \geq 0\ V_{DC}$)



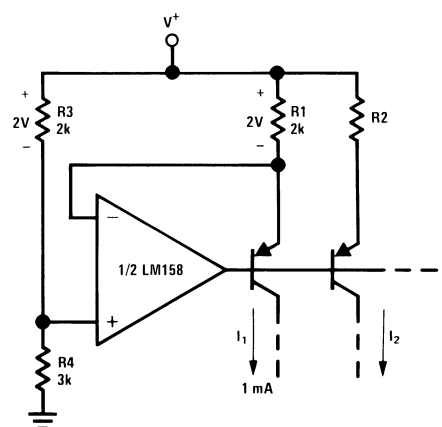
$V_O = 0\ V_{DC}$ for $V_{IN} = 0\ V_{DC}$
$A_V = 10$

Figure 20. Power Amplifier



f_o = 1 kHz
Q = 50
A_v = 100 (40 dB)

Figure 21. "BI-QUAD" RC Active Bandpass Filter



$$I_2 = \left(\frac{R1}{R2}\right) I_1$$

Figure 22. Fixed Current Sources

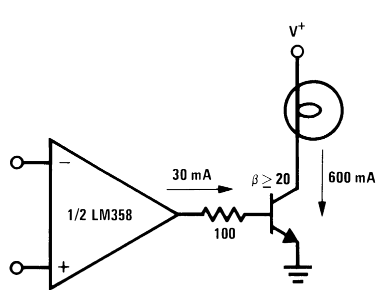


Figure 23. Lamp Driver

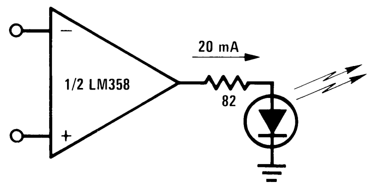
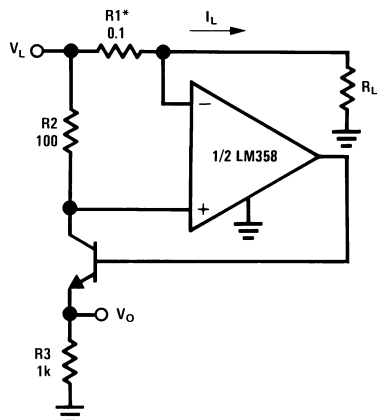


Figure 24. LED Driver



$$V_O = \frac{1V\,(I_L)}{1A}$$

*(Increase R1 for I_L small)
$V_L \le V^+ - 2V$

Figure 25. Current Monitor

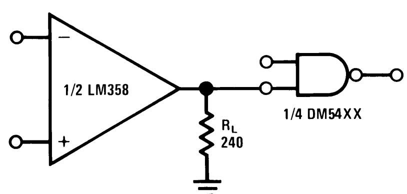
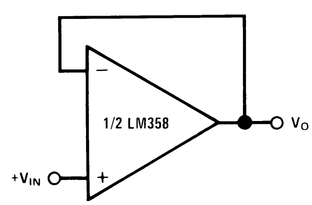


Figure 26. Driving TTL



$V_O = V_{IN}$

Figure 27. Voltage Follower

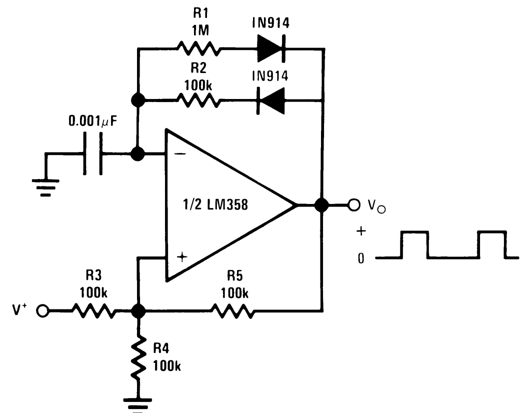


Figure 28. Pulse Generator

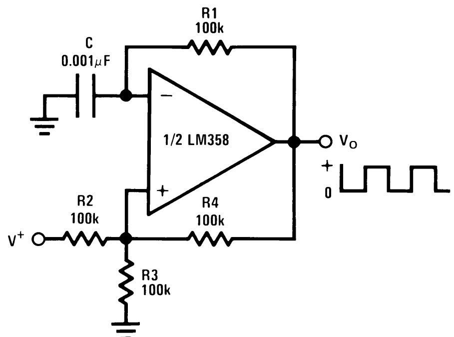


Figure 29. Squarewave Oscillator

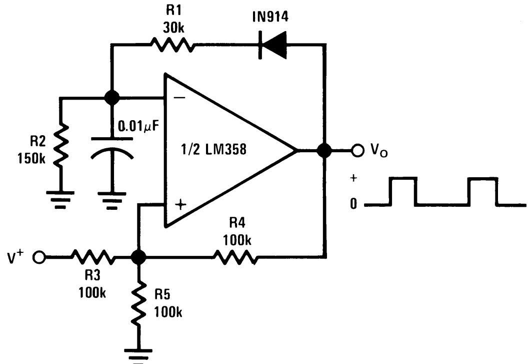
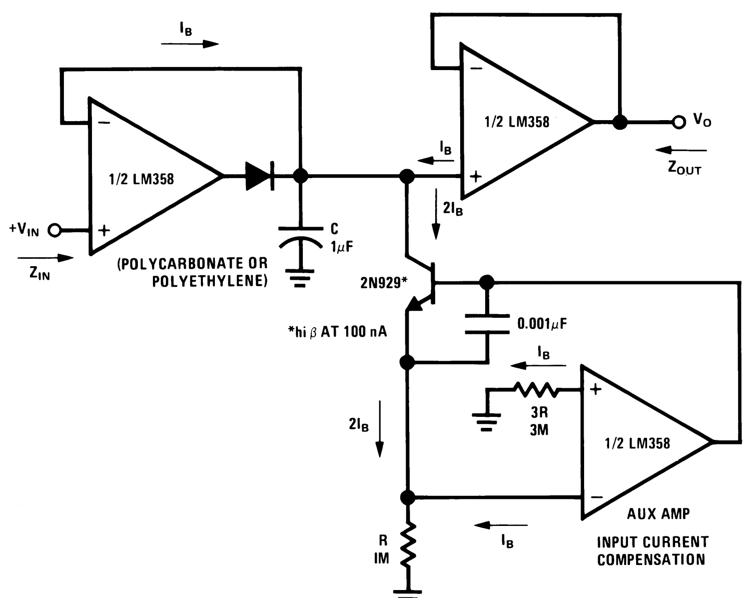
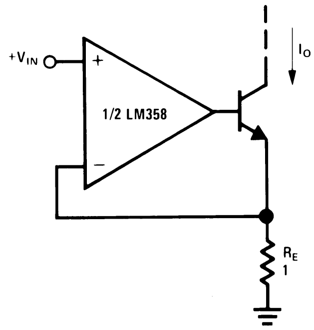


Figure 30. Pulse Generator



HIGH Z_{IN}
LOW Z_{OUT}

Figure 31. Low Drift Peak Detector



I_O = 1 amp/volt V_{IN}
(Increase R_E for I_O small)

Figure 32. High Compliance Current Sink

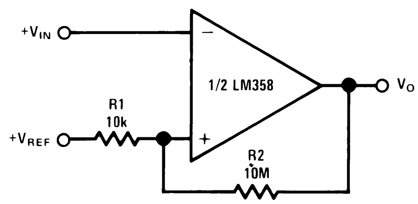
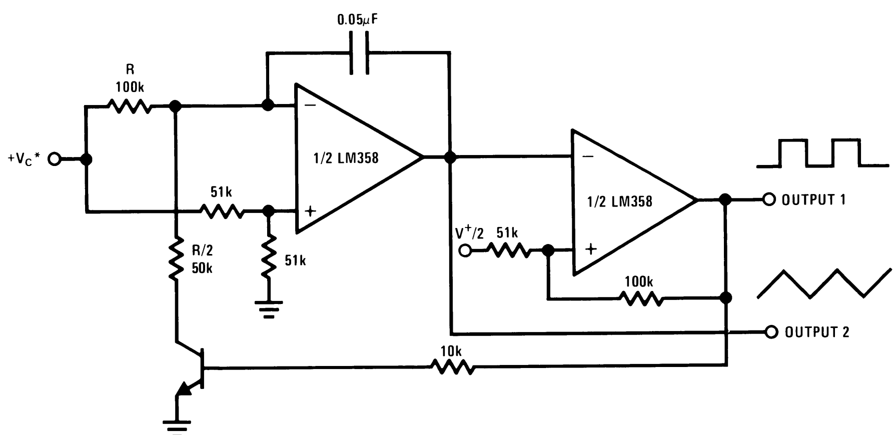
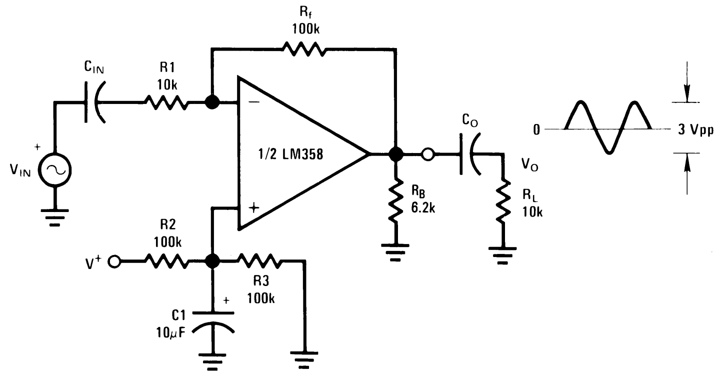


Figure 33. Comparator with Hysteresis



*WIDE CONTROL VOLTAGE RANGE: 0 $V_{DC} \leq V_C \leq 2$ (V^+ −1.5V $_{DC}$)

Figure 34. Voltage Controlled Oscillator (VCO)



$$A_V = \frac{R_f}{R1} \quad \text{(As shown, } A_V = 10\text{)}$$

Figure 35. AC Coupled Inverting Amplifier

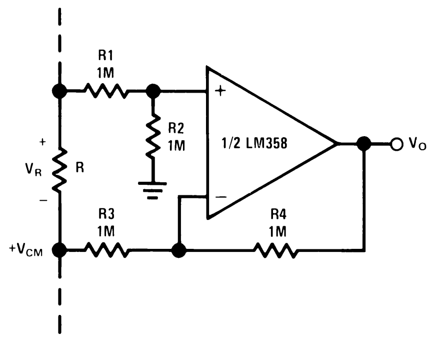
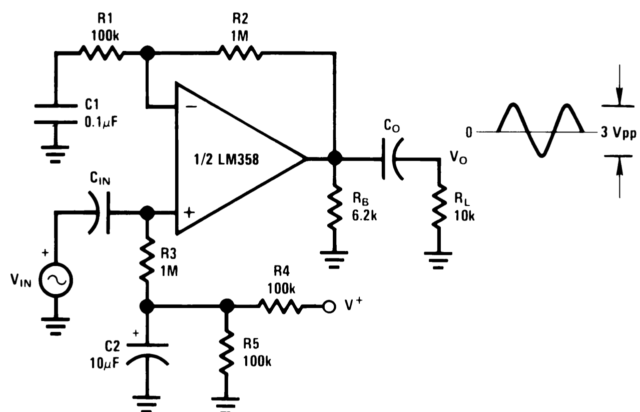


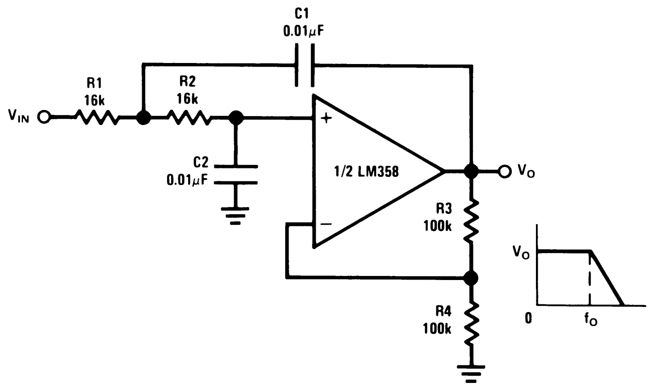
Figure 36. Ground Referencing a Differential Input Signal



$$A_V = 1 + \frac{R2}{R1}$$

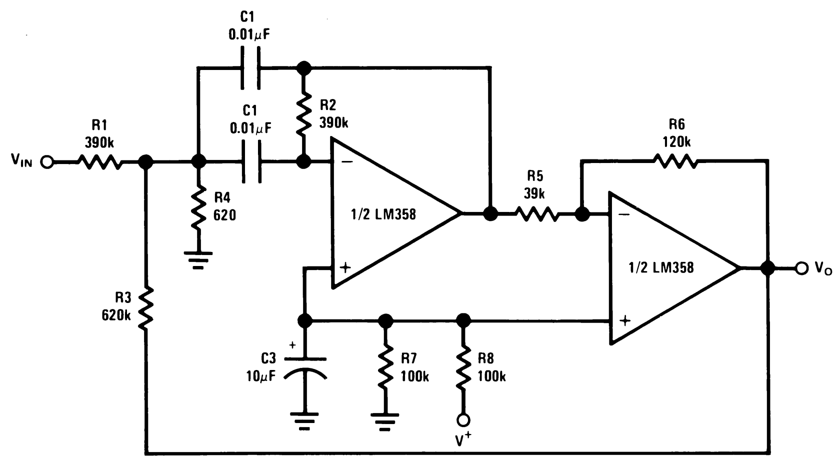
A_v = 11 (As Shown)

Figure 37. AC Coupled Non-Inverting Amplifier



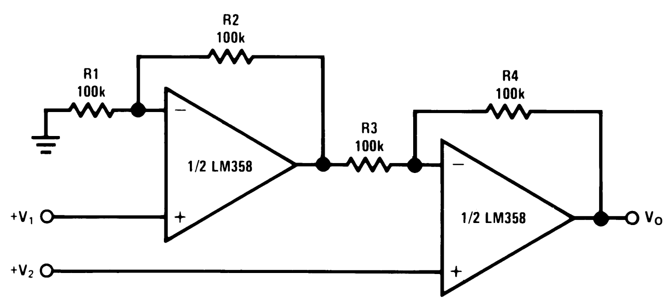
f_o = 1 kHz
Q = 1
A_V = 2

Figure 38. DC Coupled Low-Pass RC Active Filter



f_o = 1 kHz
Q = 25

Figure 39. Bandpass Active Filter



For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$$V_O = 1 + \frac{R4}{R3}\,(V_2 - V_1)$$

As Shown: $V_O = 2\,(V_2 - V_1)$

Figure 40. High Input Z, DC Differential Amplifier

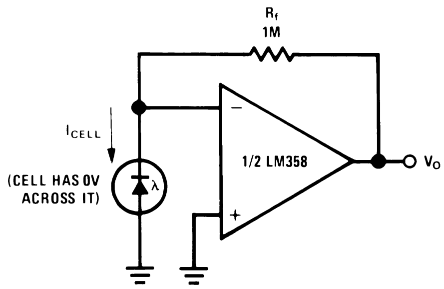
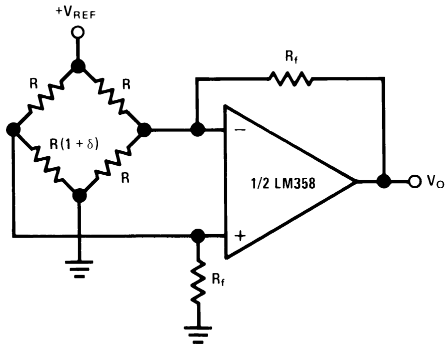


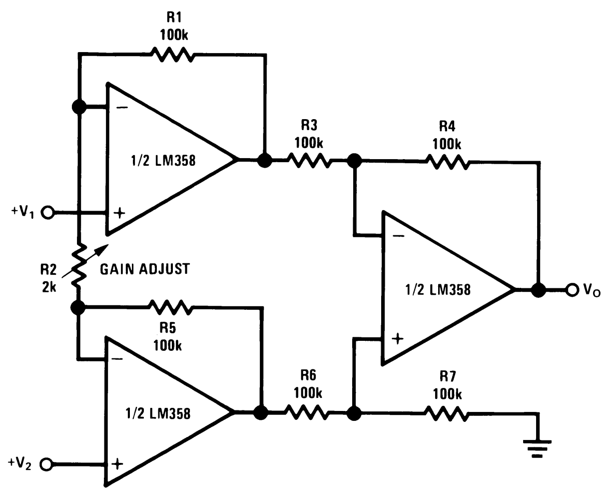
Figure 41. Photo Voltaic-Cell Amplifier



For $\delta << 1$ and $R_f >> R$

$$V_O \cong V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$$

Figure 42. Bridge Current Amplifier



If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

$$V_O = 1 + \frac{2R1}{R2}(V_2 - V_1)$$

As shown $V_O = 101\ (V_2 - V_1)$

Figure 43. High Input Z Adjustable-Gain DC Instrumentation Amplifier

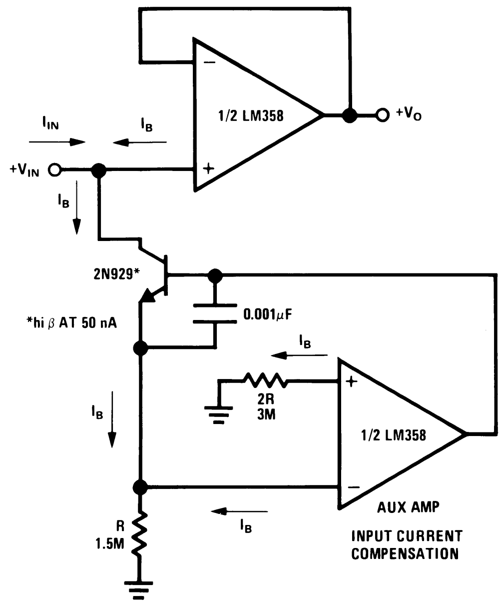
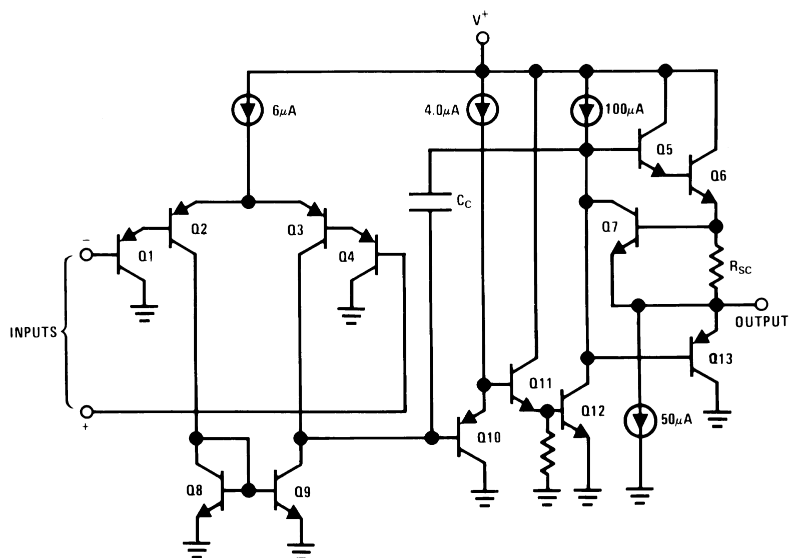


Figure 44. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)

SCHEMATIC DIAGRAM

(Each Amplifier)



REVISION HISTORY

Changes from Revision G (March 2013) to Revision H	Page
• Changed layout of National Data Sheet to TI format	21

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM158AH	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	LM158AH	Samples
LM158AH/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LM158AH	Samples
LM158H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	LM158H	Samples
LM158H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LM158H	Samples
LM158J	ACTIVE	CDIP	NAB	8	40	TBD	Call TI	Call TI	-55 to 125	LM158J	Samples
LM258H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-25 to 85	LM258H	Samples
LM258H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-25 to 85	LM258H	Samples
LM2904ITP/NOPB	ACTIVE	DSBGA	YPB	8	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	A 09	Samples
LM2904ITPX/NOPB	ACTIVE	DSBGA	YPB	8	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	A 09	Samples
LM2904M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	-40 to 85	LM 2904M	
LM2904M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	-40 to 85	LM 2904M	Samples
LM2904MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	-40 to 85	LM 2904M	
LM2904MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	-40 to 85	LM 2904M	Samples
LM2904N	NRND	PDIP	P	8	40	TBD	Call TI	Call TI	-40 to 85	LM 2904N	
LM2904N/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-NA-UNLIM	-40 to 85	LM 2904N	Samples
LM358AM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 70	LM 358AM	
LM358AM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	0 to 70	LM 358AM	Samples
LM358AMX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 70	LM 358AM	

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM358AMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	0 to 70	LM 358AM	Samples
LM358AN	NRND	PDIP	P	8	40	TBD	Call TI	Call TI	0 to 70	LM 358AN	
LM358AN/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 70	LM 358AN	Samples
LM358H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	0 to 70	LM358H	Samples
LM358M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 70	LM 358M	
LM358M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	0 to 70	LM 358M	Samples
LM358MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 70	LM 358M	
LM358MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-260C-UNLIM	0 to 70	LM 358M	Samples
LM358N	NRND	PDIP	P	8	40	TBD	Call TI	Call TI	0 to 70	LM 358N	
LM358N/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	SN | CU SN	Level-1-NA-UNLIM	0 to 70	LM 358N	Samples
LM358TP/NOPB	ACTIVE	DSBGA	YPB	8	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	0 to 70	A 07	Samples
LM358TPX/NOPB	ACTIVE	DSBGA	YPB	8	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	0 to 70	A 07	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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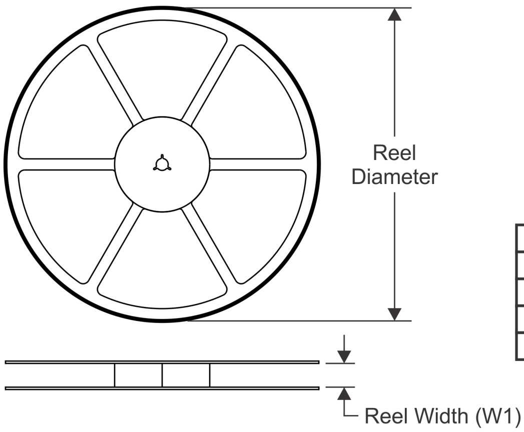
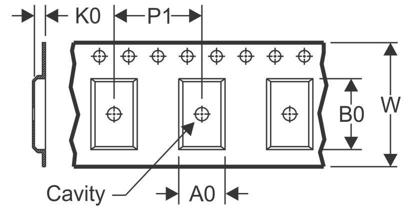
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

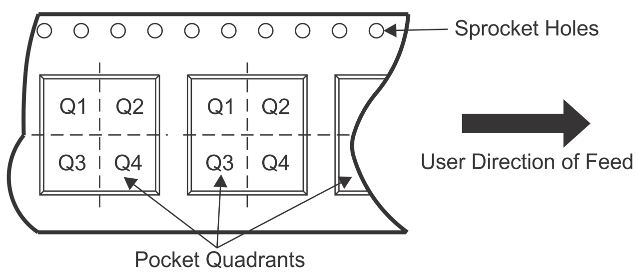


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

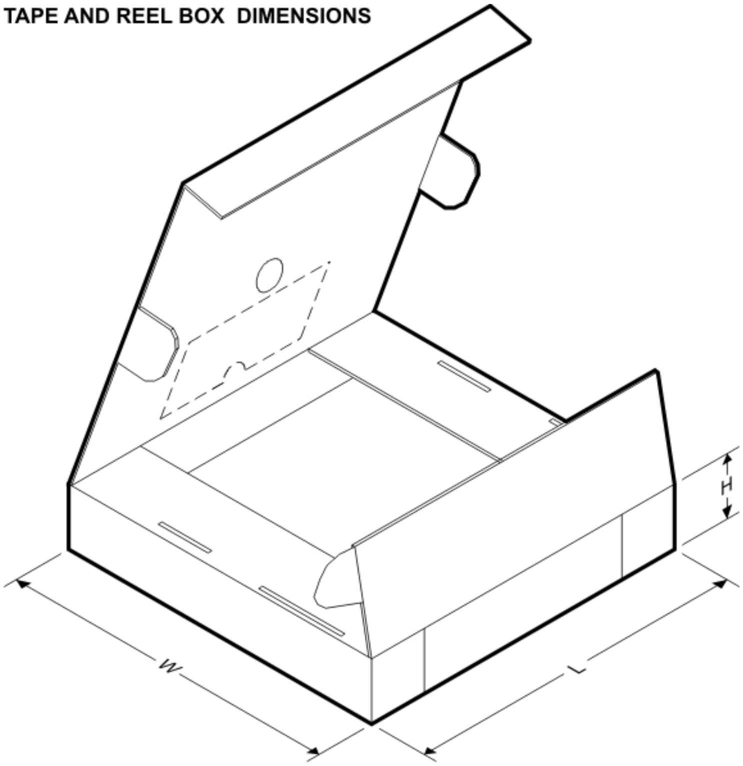
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM2904ITP/NOPB	DSBGA	YPB	8	250	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM2904ITPX/NOPB	DSBGA	YPB	8	3000	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM2904MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM2904MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358AMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358AMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM358TP/NOPB	DSBGA	YPB	8	250	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1
LM358TPX/NOPB	DSBGA	YPB	8	3000	178.0	8.4	1.5	1.5	0.66	4.0	8.0	Q1

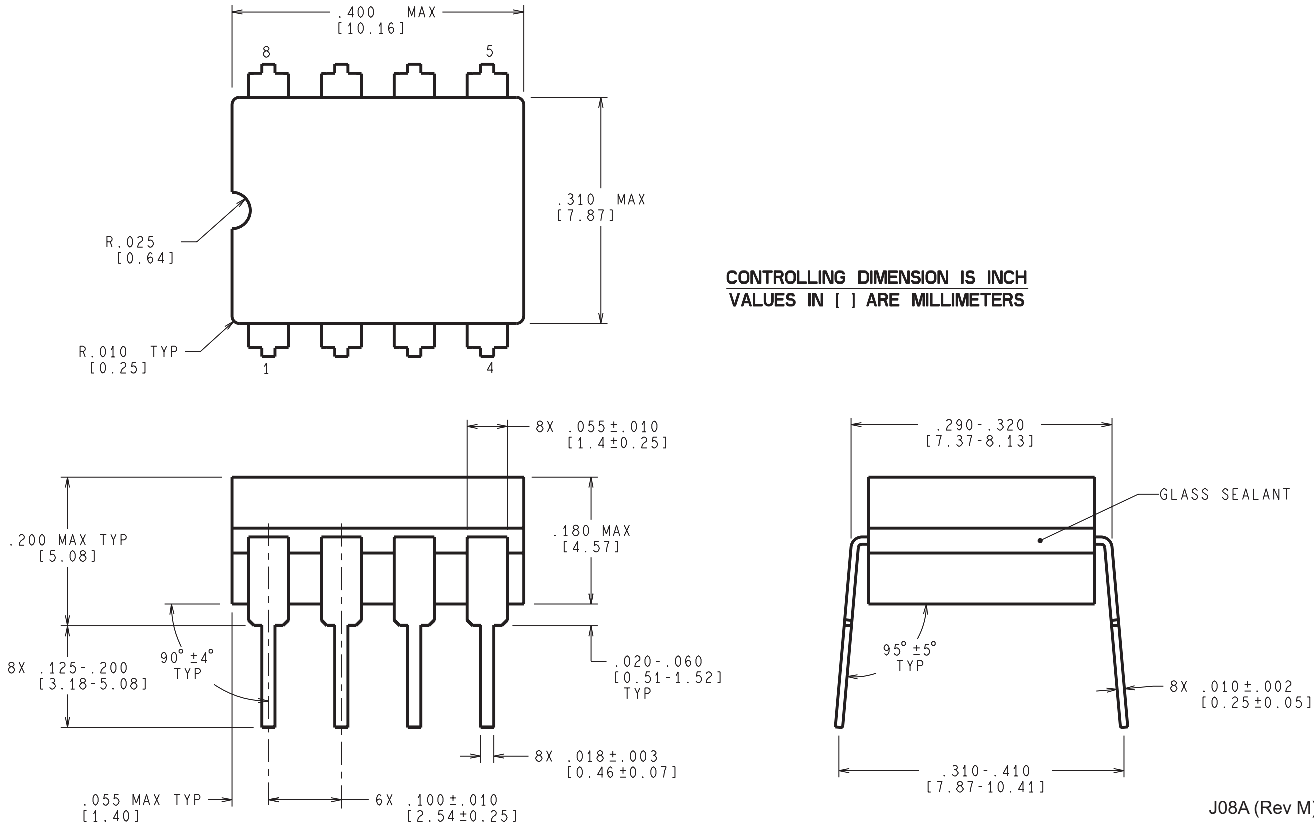
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

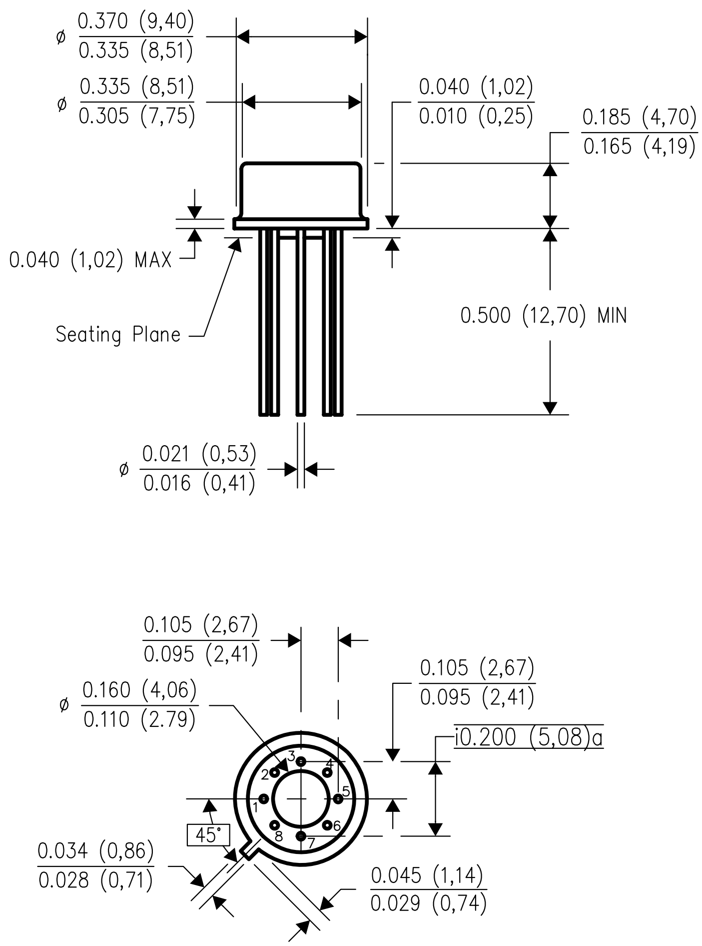
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2904ITP/NOPB	DSBGA	YPB	8	250	210.0	185.0	35.0
LM2904ITPX/NOPB	DSBGA	YPB	8	3000	210.0	185.0	35.0
LM2904MX	SOIC	D	8	2500	367.0	367.0	35.0
LM2904MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358AMX	SOIC	D	8	2500	367.0	367.0	35.0
LM358AMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358MX	SOIC	D	8	2500	367.0	367.0	35.0
LM358MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0
LM358TP/NOPB	DSBGA	YPB	8	250	210.0	185.0	35.0
LM358TPX/NOPB	DSBGA	YPB	8	3000	210.0	185.0	35.0

NAB0008A



J08A (Rev M)

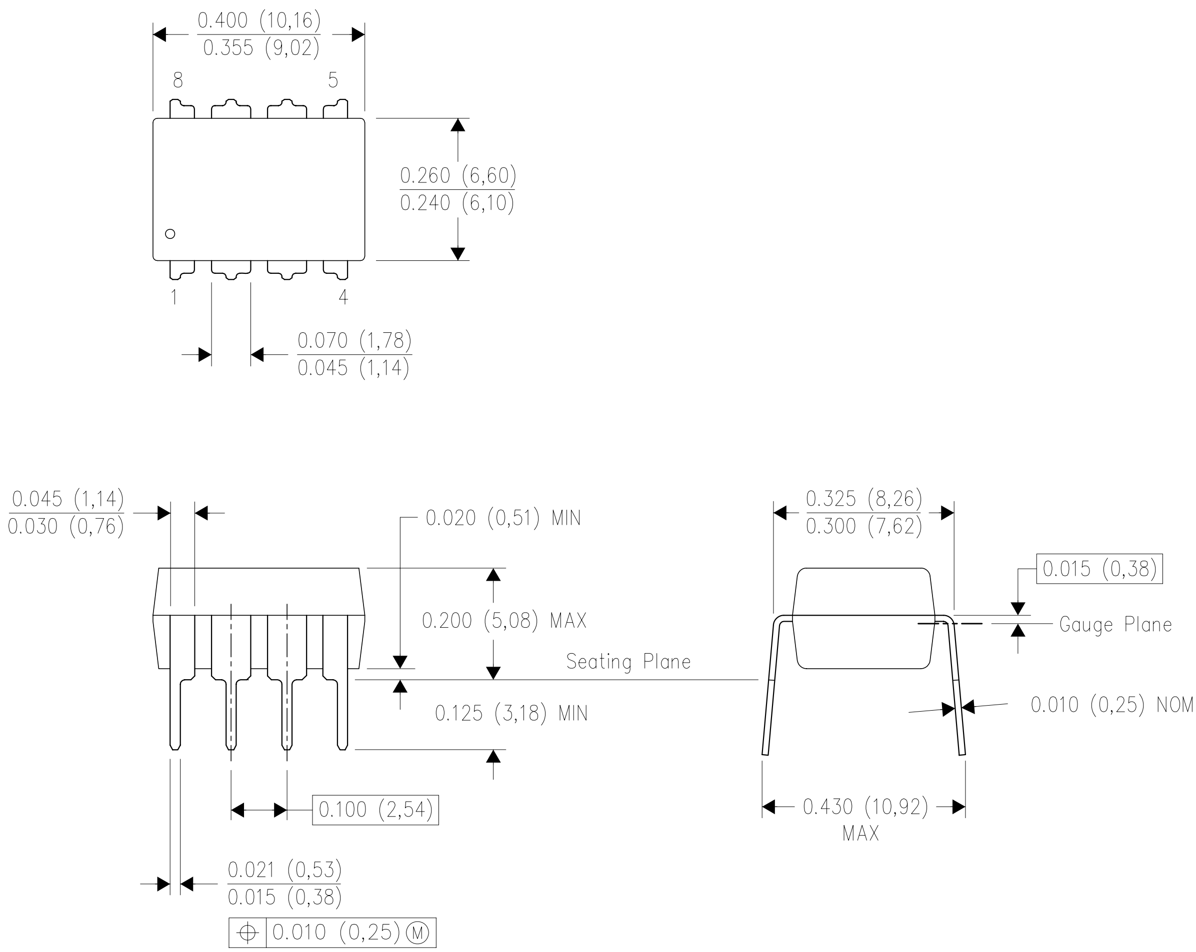
LMC (O-MBCY-W8) METAL CYLINDRICAL PACKAGE



4202483/B 09/07

NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
- D. Pin numbers shown for reference only. Numbers may not be marked on package.
- E. Falls within JEDEC MO-002/TO-99.

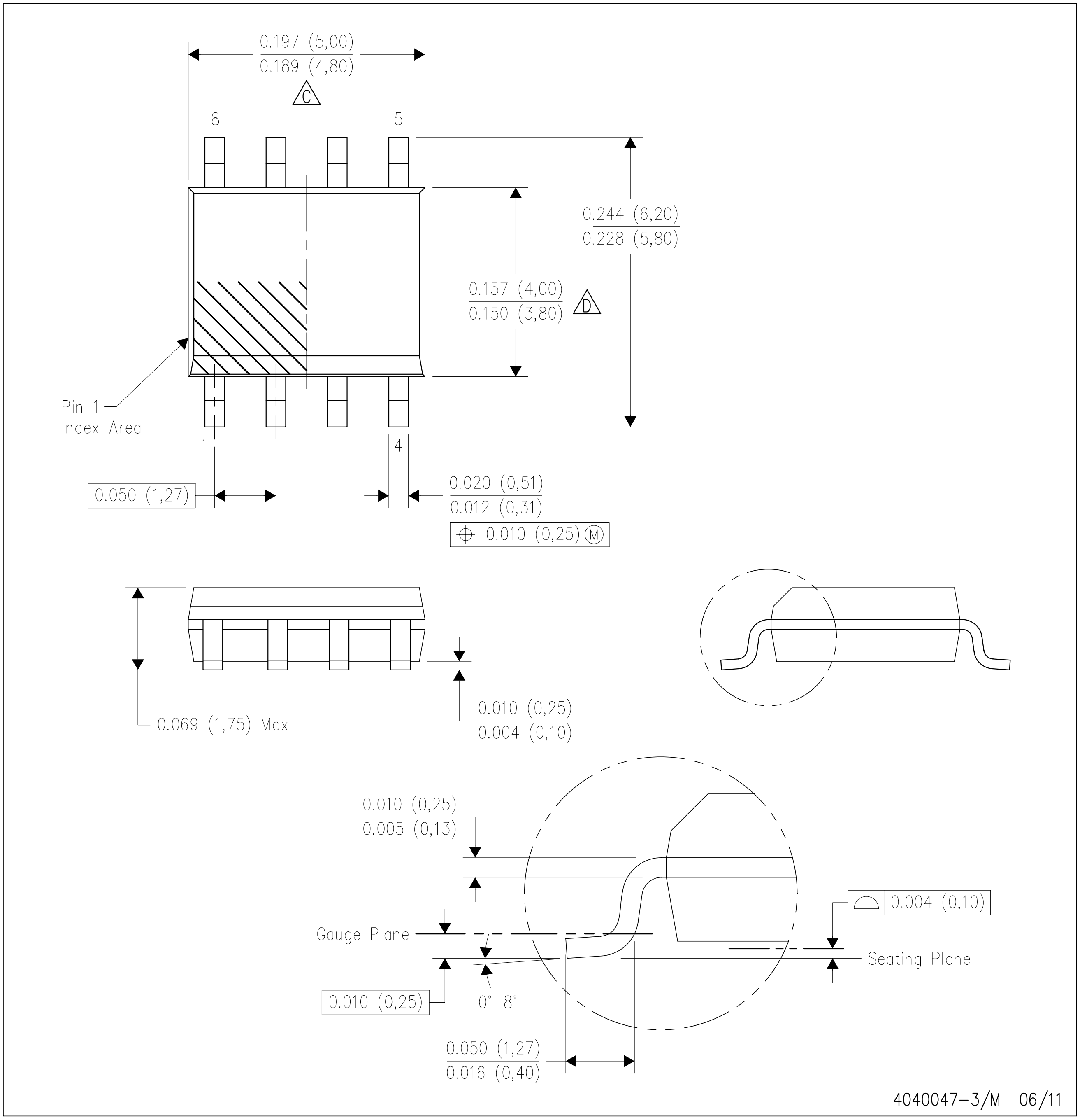
P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



4040082/E 04/2010

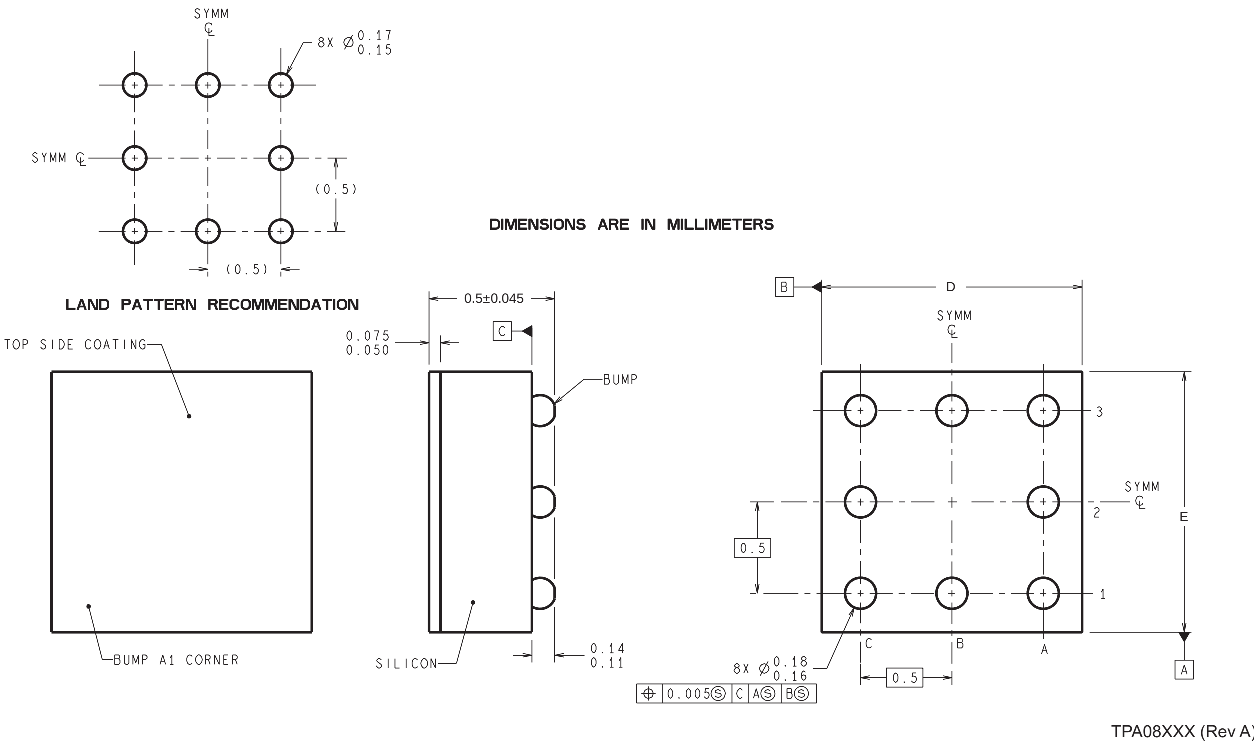
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AA.

YPB0008



D: Max = 1.337 mm, Min =1.276 mm

E: Max = 1.337 mm, Min =1.276 mm

4215100/A 12/12

NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.

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