TEXAS INSTRUMENTS

LMx58-N Low-Power, Dual-Operational Amplifiers

1 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 Linear 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

2 Applications

- Active Filters
- General Signal Conditioning and Amplification
- 4- to 20-mA Current Loop Transmitters

3 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 3.3-V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

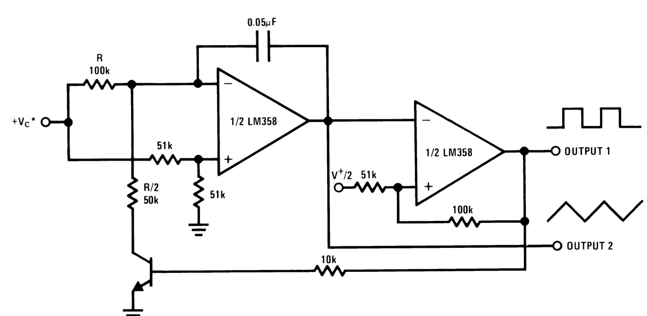
The LM358 and LM2904 are available in a chip sized package (8-Bump DSBGA) using TI's DSBGA package technology.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM158-N	TO-CAN (8)	9.08 mm x 9.09 mm
	CDIP (8)	10.16 mm x 6.502 mm
LM258-N	TO-CAN (8)	9.08 mm x 9.09 mm
LM2904-N	DSBGA (8)	1.31 mm x 1.31 mm
	SOIC (8)	4.90 mm x 3.91 mm
	PDIP (8)	9.81 mm x 6.35 mm
LM358-N	TO-CAN (8)	9.08 mm x 9.09 mm
	DSBGA (8)	1.31 mm x 1.31 mm
	SOIC (8)	4.90 mm x 3.91 mm
	PDIP (8)	9.81 mm x 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Voltage Controlled Oscillator (VCO)



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4 Revision History

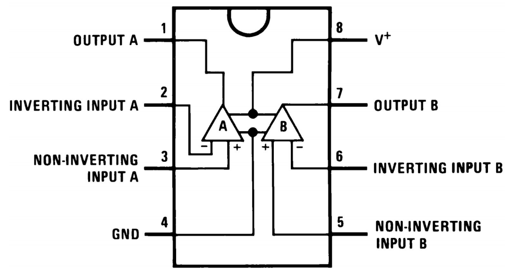
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision H (March 2013) to Revision I	Page
• Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section	1

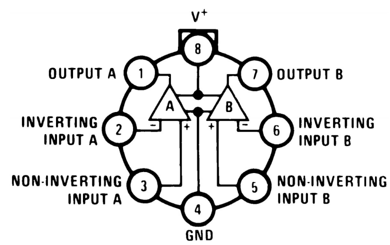
Changes from Revision G (March 2013) to Revision H	Page
• Changed layout of National Data Sheet to TI format	25

5 Pin Configuration and Functions

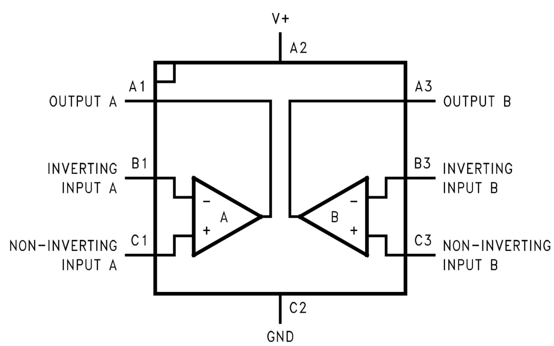
D, P, and NAB Package
8-Pin SOIC, PDIP, and CDIP
Top View



LMC Package
8-Pin TO-99
Top View



YPB Package
8-Pin DSBGA
Top View



Pin Functions

PIN			TYPE	DESCRIPTION
D/P/LMC NO.	DSBGA NO.	NAME		
1	A1	OUTA	O	Output , Channel A
2	B1	-INA	I	Inverting Input, Channel A
3	C1	+INA	I	Non-Inverting Input, Channel A
4	C2	GND / V-	P	Ground for Single supply configurations. negative supply for dual supply configurations
5	C3	+INB	I	Output, Channel B
6	B3	-INB	I	Inverting Input, Channel B
7	A3	OUTB	O	Non-Inverting Input, Channel B
8	A2	V+	P	Positive Supply

6 Specifications

6.1 Absolute Maximum Ratings

See [1][2][3].

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

(1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not ensured. For ensured specifications and the test conditions, see the Electrical Characteristics.
(2) Refer to RETS158AX for LM158A military specifications and to RETS158X for LM158 military specifications.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(4) 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.
(5) 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 +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.
(6) 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 −0.3 V (at 25°C).

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±250	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	MAX	UNIT
Supply Voltage (V+ - V-):LM158. LM258, LM358	3 (±1.5)	32 (±16)	V
Supply Voltage (V+ - V-):LM2904	3 (±1.5)	26 (±13)	V
Operating Temperature: LM158	-55	125	°C
Operating Temperature: LM258	-25	85	°C
Operating Temperature: LM358	0	70	°C
Operating Temperature: LM2904	-40	85	°C

6.4 Thermal Information

THERMAL METRIC[1]		LM158-N, LM258-N, LM358-N	LM158-N	LM2904-N, LM358-N			UNIT
		LMC	NAB	YPB	D	P	
		8 PINS					
$R_{\theta JA}$	Junction-to-ambient thermal resistance	155	132	230	189	120	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics: LM158A, LM358A, LM158, LM258

V^+ = +5.0 V, See[1], unless otherwise stated

PARAMETER	TEST CONDITIONS	LM158A			LM358A			LM158, LM258			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	See[2], 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} = 0 V,[3]										
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, V_{CM} = 0V, T_A = 25°C		2	10		5	30		3	30	nA
Input Common-Mode	V^+ = 30 V,[4]	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	V
Voltage Range	(LM2904, V^+ = 26V), T_A = 25°C										
Supply Current	Over Full Temperature Range										
	R_L = ∞ 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
Large Signal Voltage Gain	V^+ = 15 V, T_A = 25°C, R_L ≥ 2 kΩ, (For V_O = 1 V to 11 V)	50	100		25	100		50	100		V/mV
Common-Mode	T_A = 25°C,	70	85		65	85		70	85		dB
Rejection Ratio	V_{CM} = 0 V to V^+−1.5 V										
Power Supply	V^+ = 5 V to 30 V	65	100		65	100		65	100		dB
Rejection Ratio	(LM2904, V^+ = 5 V to 26 V), T_A = 25°C										

(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) V_O ≃ 1.4 V, R_S = 0 Ω with V^+ from 5 V to 30 V; and over the full input common-mode range (0 V to V^+ −1.5 V) at 25°C. For LM2904, V^+ from 5 V to 26 V.
(3) 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.
(4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2904), independent of the magnitude of V^+.

Electrical Characteristics: LM158A, LM358A, LM158, LM258 (continued)

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

PARAMETER		TEST CONDITIONS	LM158A MIN	LM158A TYP	LM158A MAX	LM358A MIN	LM358A TYP	LM358A MAX	LM158, LM258 MIN	LM158, LM258 TYP	LM158, LM258 MAX	UNIT
Power Supply Rejection Ratio		V^+ = 5 V to 30 V (LM2904, V^+ = 5 V to 26 V), 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(5)		−120			−120			−120		dB
Output Current	Source	V_{IN}^+ = 1 V, V_{IN}^- = 0 V, V^+ = 15 V, V_O = 2 V, T_A = 25°C	20	40		20	40		20	40		mA
	Sink	V_{IN}^- = 1 V, V_{IN}^+ = 0 V V^+ = 15 V, T_A = 25°C, V_O = 2 V	10	20		10	20		10	20		mA
		V_{IN}^- = 1 V, V_{IN}^+ = 0 V T_A = 25°C, V_O = 200 mV, V^+ = 15 V	12	50		12	50		12	50		µA
Short Circuit to Ground		T_A = 25°C, See(6), V^+ = 15 V		40	60		40	60		40	60	mA
Input Offset Voltage		See(2)			4			5			7	mV
Input Offset Voltage Drift		R_S = 0Ω		7	15		7	20		7		µV/°C
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$			30			75			100	nA
Input Offset Current Drift		R_S = 0Ω		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(4) (LM2904, V^+ = 26 V)	0		V^+−2	0		V^+−2	0		V^+−2	V
Large Signal Voltage Gain		V^+ = +15 V (V_O = 1 V to 11 V) R_L ≥ 2 kΩ	25			15			25			V/mV
Output Voltage Swing	V_{OH}	V^+ = +30 V, R_L = 2 kΩ	26			26			26			V
		(LM2904, V^+ = 26 V), R_L = 10 kΩ	27	28		27	28		27	28		V
	V_{OL}	V^+ = 5V, R_L = 10 kΩ		5	20		5	20		5	20	mV
Output Current	Source	V_{IN}^+ = +1 V, V_{IN}^- = 0 V, V^+ = 15 V, V_O = 2 V	10	20		10	20		10	20		mA
	Sink	V_{IN}^- = +1 V, V_{IN}^+ = 0 V, V^+ = 15 V, V_O = 2 V	10	15		5	8		5	8		mA

(5) 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.
(6) 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 +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

6.6 Electrical Characteristics: LM358, LM2904

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

PARAMETER		TEST CONDITIONS	LM358			LM2904			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage		See(2) , T_A = 25°C		2	7		2	7	mV
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$, T_A = 25°C, V_{CM} = 0 V, See(3)		45	250		45	250	nA
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$, V_{CM} = 0 V, T_A = 25°C		5	50		5	50	nA
Input Common-Mode Voltage Range		V^+ = 30 V, See(4) (LM2904, V^+ = 26 V), 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^+ = 30 V (LM2904 V^+ = 26 V)		1	2		1	2	mA
		V^+ = 5 V		0.5	1.2		0.5	1.2	mA
Large Signal Voltage		V^+ = 15V, T_A = 25°C,							
Gain		$R_L \geq 2$ kΩ, (For V_O = 1 V to 11 V)	25	100		25	100		V/mV
Common-Mode Rejection Ratio		T_A = 25°C, V_{CM} = 0 V to $V^+-1.5$ V	65	85		50	70		dB
Power Supply Rejection Ratio		V^+ = 5 V to 30 V (LM2904, V^+ = 5 V to 26 V), 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(5)		−120			−120		dB
Output Current	Source	V_{IN}^+ = 1 V, V_{IN}^- = 0 V, V^+ = 15 V, V_O = 2 V, T_A = 25°C	20	40		20	40		mA
	Sink	V_{IN}^- = 1 V, V_{IN}^+ = 0 V V^+ = 15V, T_A = 25°C, V_O = 2 V	10	20		10	20		mA
		V_{IN}^- = 1 V, V_{IN}^+ = 0 V T_A = 25°C, V_O = 200 mV, V^+ = 15 V	12	50		12	50		μA
Short Circuit to Ground		T_A = 25°C, See(6), V^+ = 15 V		40	60		40	60	mA
Input Offset Voltage		See(2)			9			10	mV
Input Offset Voltage Drift		R_S = 0 Ω		7			7		μV/°C
Input Offset Current		$I_{IN(+)} - I_{IN(-)}$			150		45	200	nA
Input Offset Current Drift		R_S = 0 Ω		10			10		pA/°C
Input Bias Current		$I_{IN(+)}$ or $I_{IN(-)}$		40	500		40	500	nA

(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) $V_O \simeq 1.4$ V, R_S = 0 Ω with V^+ from 5 V to 30 V; and over the full input common-mode range (0 V to V^+ −1.5 V) at 25°C. For LM2904, V^+ from 5 V to 26 V.
(3) 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.
(4) The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3 V (at 25°C). The upper end of the common-mode voltage range is V^+ −1.5 V (at 25°C), but either or both inputs can go to 32 V without damage (26 V for LM2904), independent of the magnitude of V^+.
(5) 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.
(6) 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 +15 V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Electrical Characteristics: LM358, LM2904 (continued)

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

PARAMETER		TEST CONDITIONS		LM358 MIN	LM358 TYP	LM358 MAX	LM2904 MIN	LM2904 TYP	LM2904 MAX	UNIT
Input Common-Mode Voltage Range		$V^+ = 30$ V, See(4) (LM2904, $V^+ = 26$ V)		0		V^+-2	0		V^+-2	V
Large Signal Voltage Gain		$V^+ = +15$ V ($V_O = 1$ V to 11 V) $R_L \geq 2$ kΩ		15			15			V/mV
Output Voltage	V_{OH}	$V^+ = 30$ V	$R_L = 2$ kΩ	26			22			V
		(LM2904, $V^+ = 26$ V)	$R_L = 10$ kΩ	27	28		23	24		V
Swing	V_{OL}	$V^+ = 5$ V, $R_L = 10$ kΩ			5	20		5	100	mV
Output Current	Source	$V_{IN}^+ = 1$ V, $V_{IN}^- = 0$ V, $V^+ = 15$ V, $V_O = 2$ V		10	20		10	20		mA
	Sink	$V_{IN}^- = 1$ V, $V_{IN}^+ = 0$ V, $V^+ = 15$ V, $V_O = 2$ V		5	8		5	8		mA

6.7 Typical Characteristics

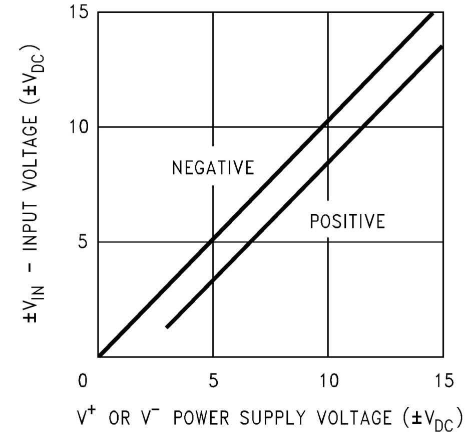


Figure 1. Input Voltage Range

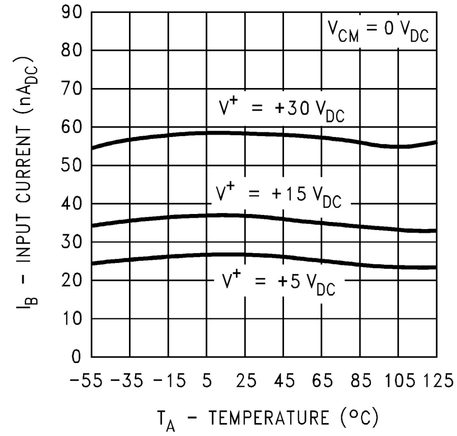


Figure 2. Input Current

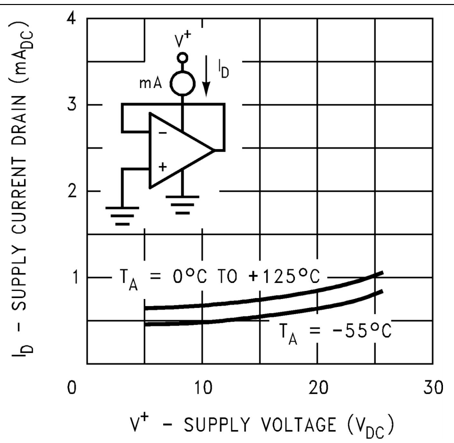


Figure 3. Supply Current

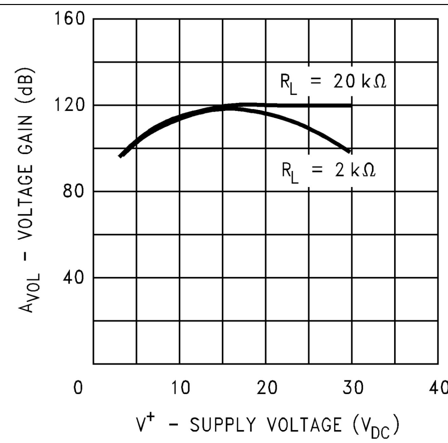


Figure 4. Voltage Gain

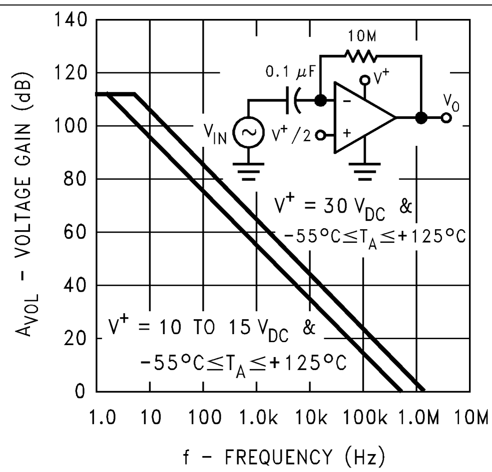


Figure 5. Open Loop Frequency Response

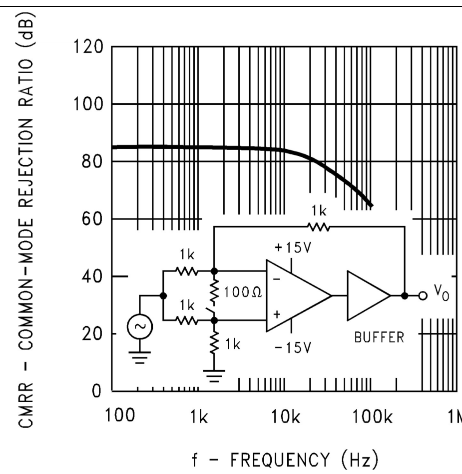


Figure 6. Common-Mode Rejection Ratio

Typical Characteristics (continued)

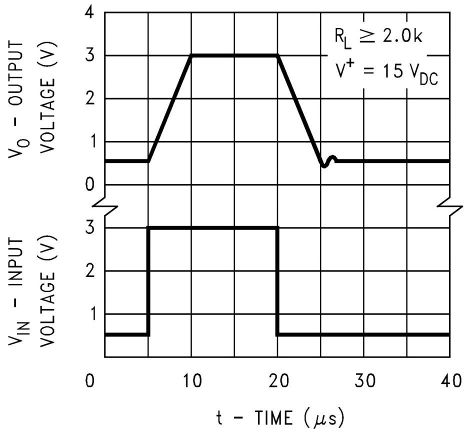


Figure 7. Voltage Follower Pulse Response

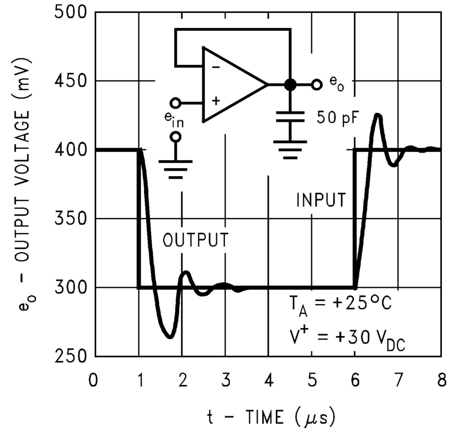


Figure 8. Voltage Follower Pulse Response (Small Signal)

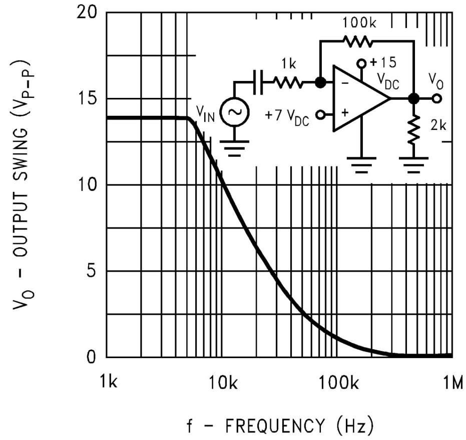


Figure 9. Large Signal Frequency Response

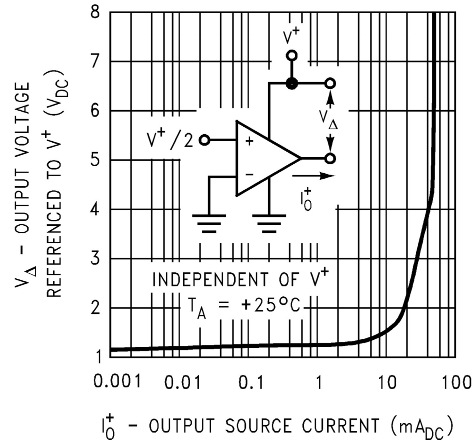


Figure 10. Output Characteristics Current Sourcing

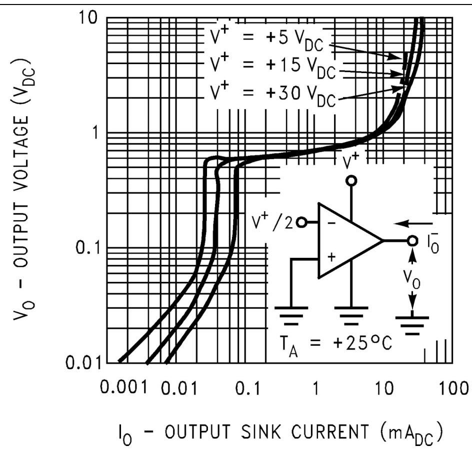


Figure 11. Output Characteristics Current Sinking

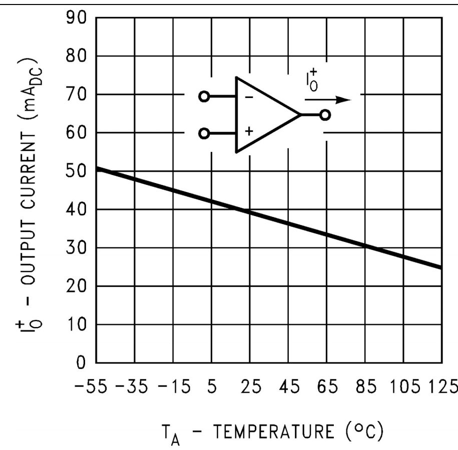


Figure 12. Current Limiting

Typical Characteristics (continued)

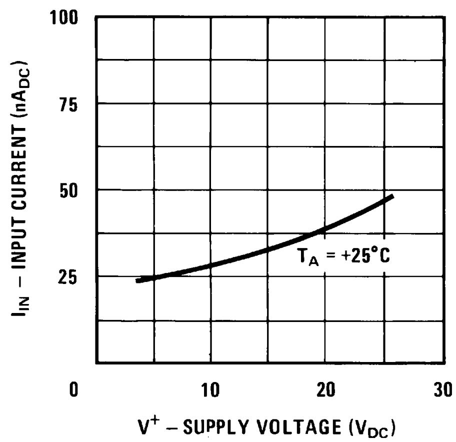


Figure 13. Input Current (LM2902 Only)

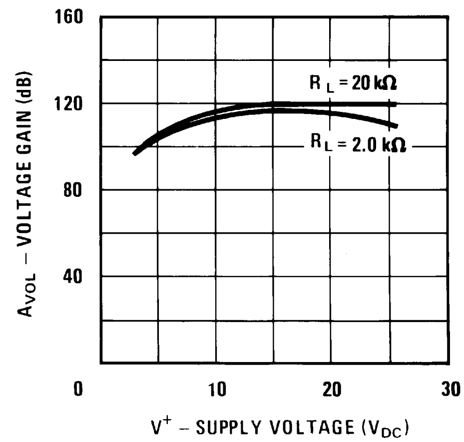


Figure 14. Voltage Gain (LM2902 Only)

7 Detailed Description

7.1 Overview

The LM158 series are operational amplifiers which can 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}.

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.

7.2 Functional Block Diagram

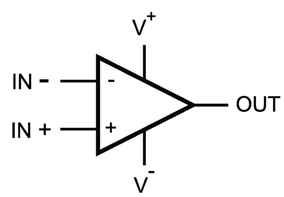


Figure 15. (Each Amplifier)

7.3 Feature Description

The amplifier's differential inputs consist of a non-inverting input (+IN) and an inverting input (–IN). The amplifer amplifies only the difference in voltage between the two inpus, which is called the differential input voltage. The output voltage of the op-amp Vout is given by Equation 1:

VOUT = AOL (IN+ - IN-)

where

- AOL is the open-loop gain of the amplifier, typically around 100dB (100,000x, or 10uV per Volt). (1)

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 power dissipation which will cause eventual failure due to excessive junction 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 Characteristics*) than a standard IC op amp.

7.4 Device Functional Modes

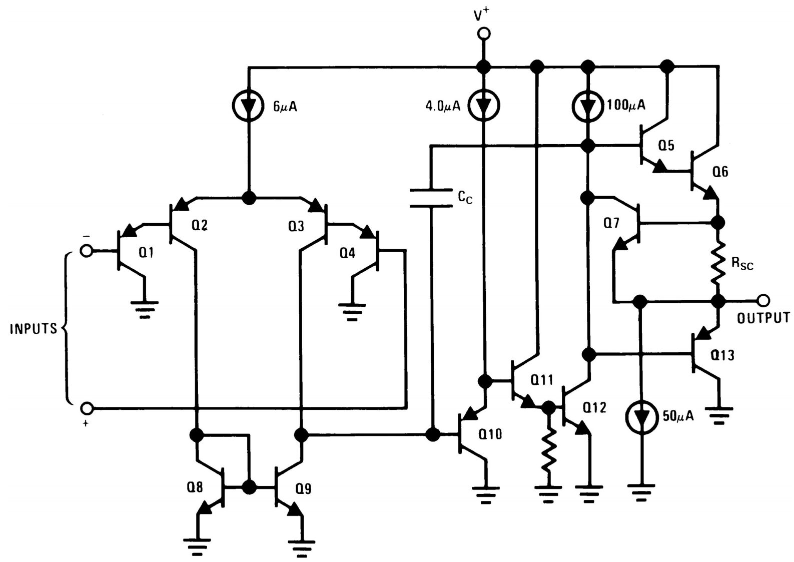


Figure 16. Schematic Diagram

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.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

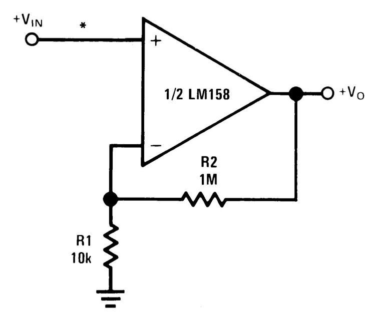
8.1 Application Information

The LM158 family bring performance, economy, and ease-of-use to a wide variety of op-amp applications.

8.2 Typical Applications

8.2.1 Noninverting DC Gain

Figure 17 shows a high input impedance non-inverting circuit. This circuit gives a closed-loop gain equal to the ratio of the sum of R1 and R2 to R1 and a closed-loop 3 dB bandwidth equal to the amplifier unity-gain frequency divided by the closed-loop gain. This design has the benefit of a very high input impedance, which is equal to the differential input impedance multiplied by loop gain. (Open loop gain/Closed loop gain.) In DC coupled applications, input impedance is not as important as input current and its voltage drop across the source resistance. Note that the amplifier output will go into saturation if the input is allowed to float. This may be important if the amplifier must be switched from source to source.



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

Figure 17. Non-Inverting DC Gain (0-V Output)

8.2.1.1 Design Requirements

For this example application, the supply voltage is +5V, and 100x±5% of noninverting gain is necessary. Signal input impedance is approx 10kΩ.

8.2.1.2 Detailed Design Procedure

Using the equation for a non-inverting amplifier configuration ; G = 1+ R2/R1, set R1 to 10kΩ, and R2 to 99x the value of R1, which would be 990kΩ. Replacing the 990kΩ with a 1MΩ will result in a gain of 101, which is within the desired gain tolerance.

The gain-frequency characteristic of the amplifier and its feedback network must be such that oscillation does not occur. To meet this condition, the phase shift through amplifier and feedback network must never exceed 180° for any frequency where the gain of the amplifier and its feedback network is greater than unity. In practical applications, the phase shift should not approach 180° since this is the situation of conditional stability. Obviously the most critical case occurs when the attenuation of the feedback network is zero.

Typical Applications (continued)

8.2.1.3 Application Curve

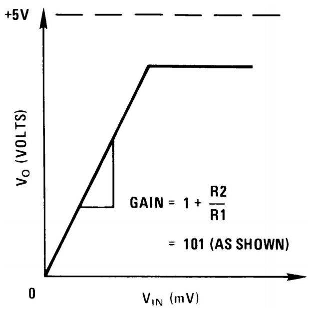
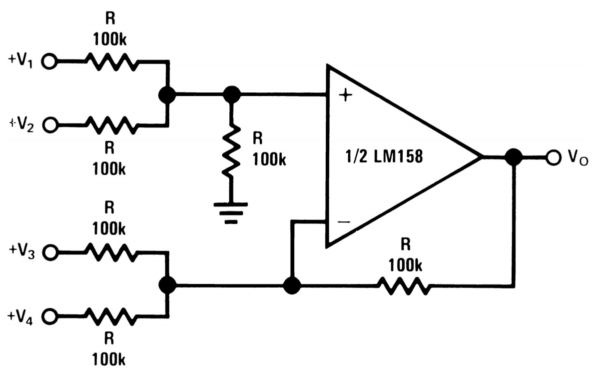


Figure 18. Transfer Curve for Non-Inverting Configuration

8.2.2 System Examples

8.2.2.1 Typical Single-Supply Applications

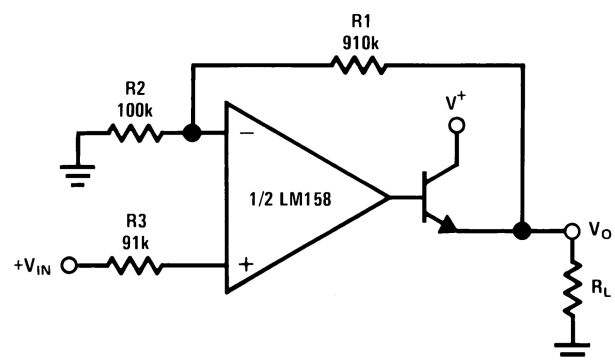
($V^+ = 5.0\ V_{DC}$)



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 $V_O \geq 0\ V_{DC}$)



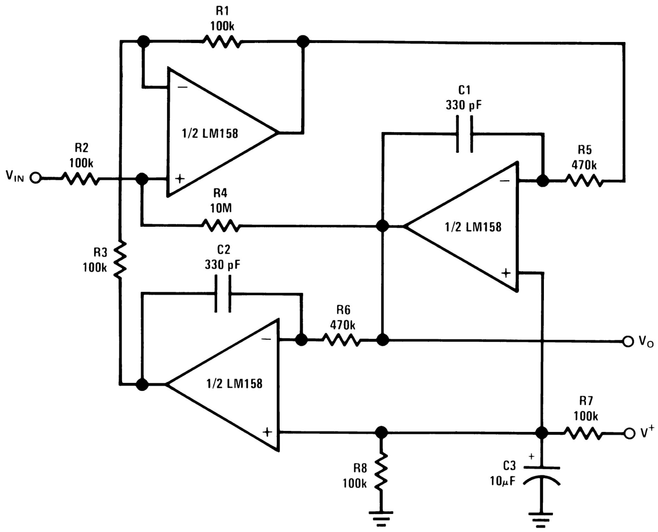
$V_O = 0\ V_{DC}$ for $V_{IN} = 0\ V_{DC}$

$A_V = 10$

Figure 20. Power Amplifier

Typical Applications (continued)

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



f_o = 1 kHz

Q = 50

A_v = 100 (40 dB)

Figure 21. “BI-QUAD” RC Active Bandpass Filter

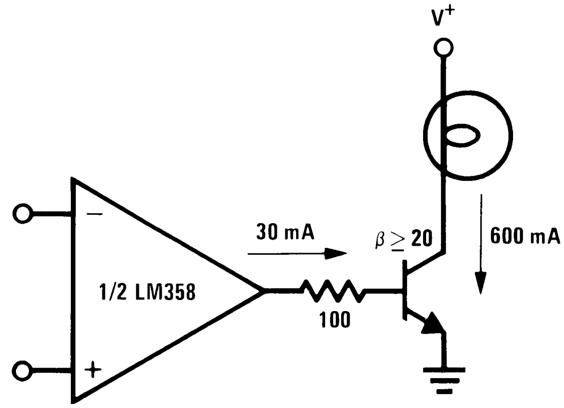


Figure 22. Lamp Driver

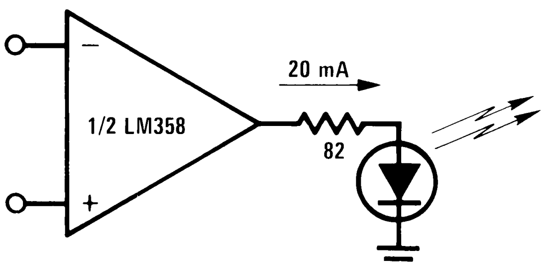


Figure 23. LED Driver

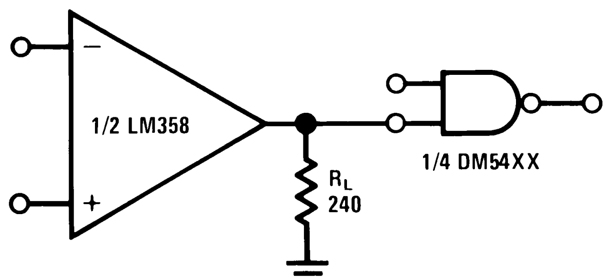


Figure 24. Driving TTL

Typical Applications (continued)

(V^+ = 5.0 V_{DC})

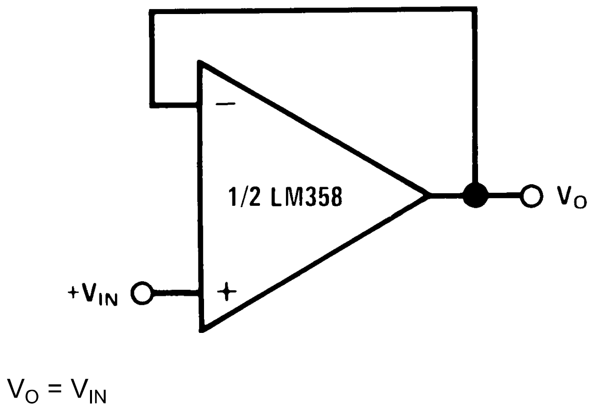


Figure 25. Voltage Follower

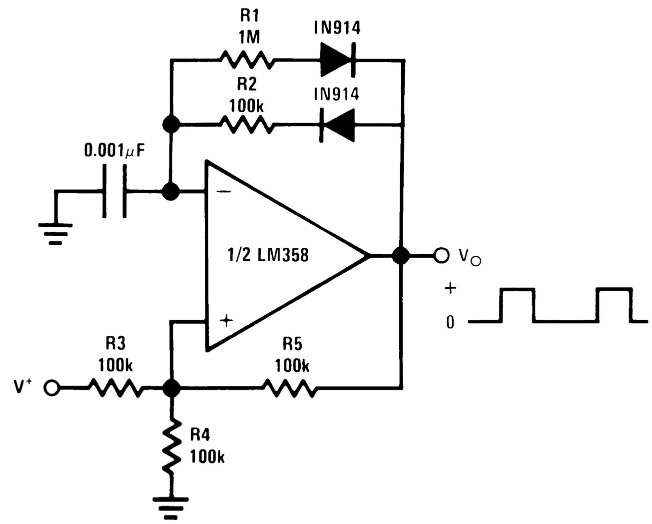


Figure 26. Pulse Generator

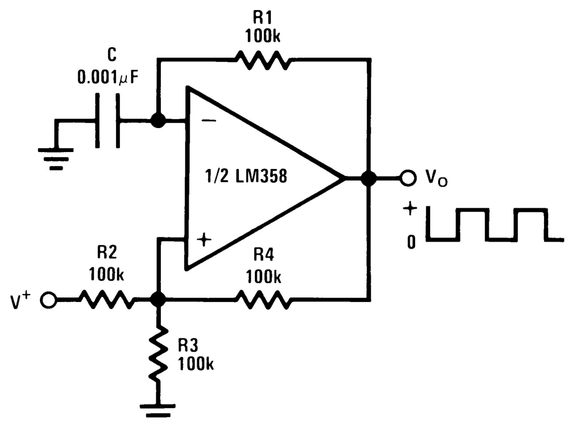


Figure 27. Squarewave Oscillator

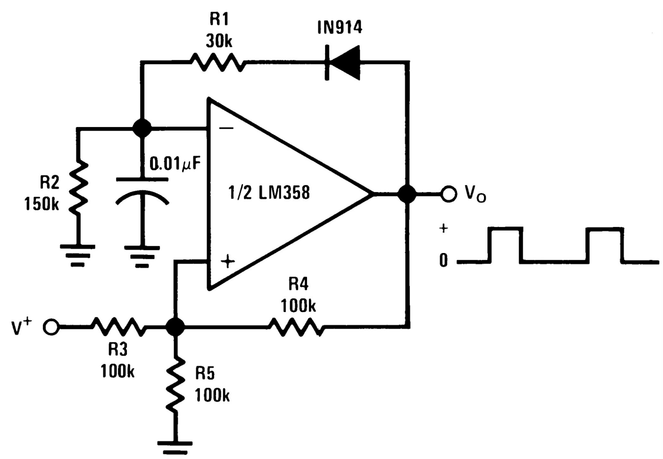
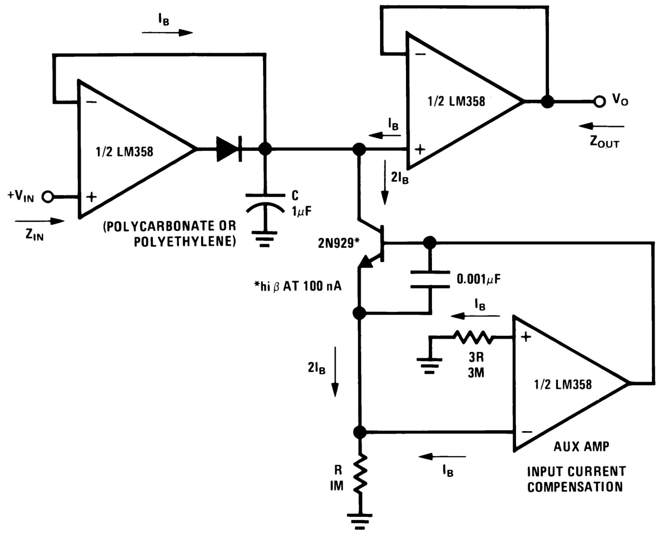


Figure 28. Pulse Generator

Typical Applications (continued)

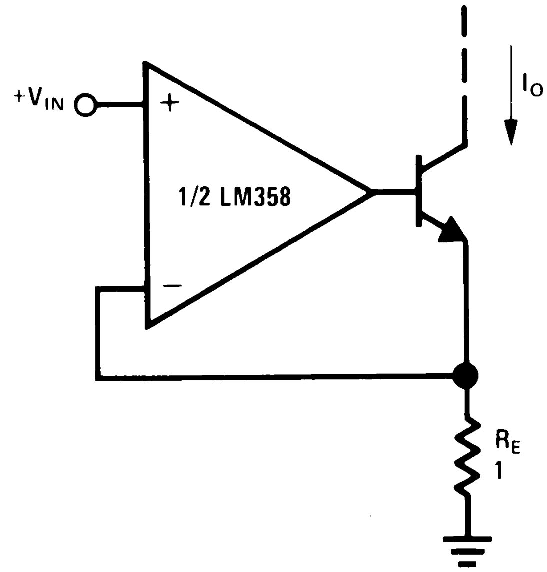
($V^+ = 5.0\ V_{DC}$)



HIGH Z_{IN}

LOW Z_{OUT}

Figure 29. Low Drift Peak Detector



I_O = 1 amp/volt V_{IN}

(Increase R_E for I_O small)

Figure 30. High Compliance Current Sink

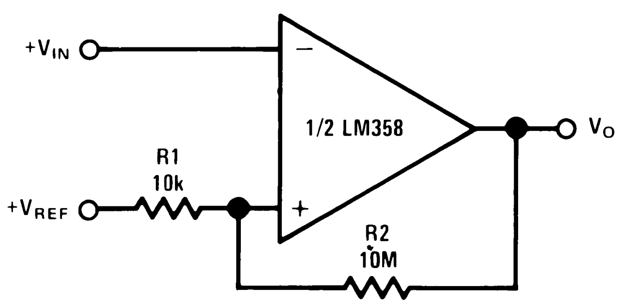
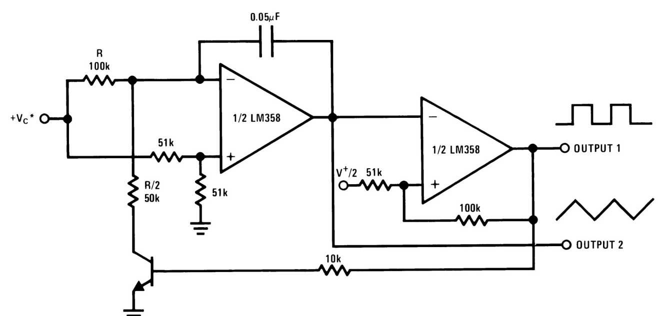


Figure 31. Comparator with Hysteresis



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

Figure 32. Voltage Controlled Oscillator (VCO)

Typical Applications (continued)

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

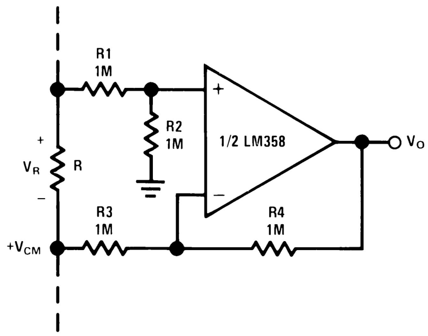
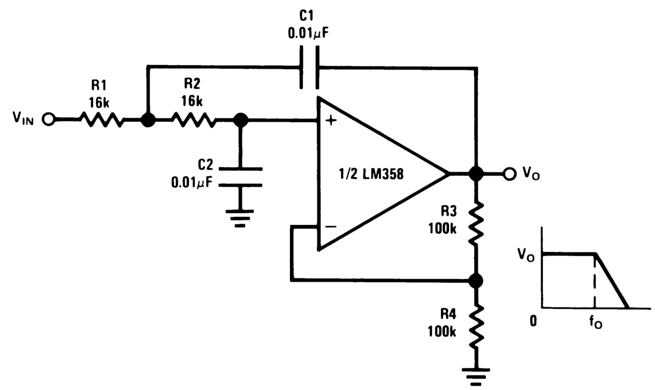


Figure 33. Ground Referencing a Differential Input Signal

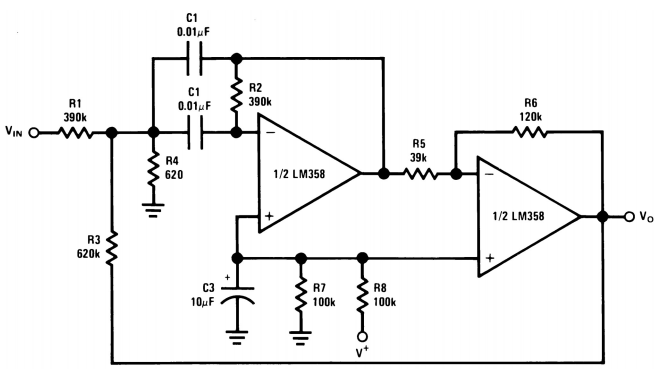


f_o = 1 kHz

Q = 1

A_V = 2

Figure 34. DC Coupled Low-Pass RC Active Filter



f_o = 1 kHz

Q = 25

Figure 35. Bandpass Active Filter

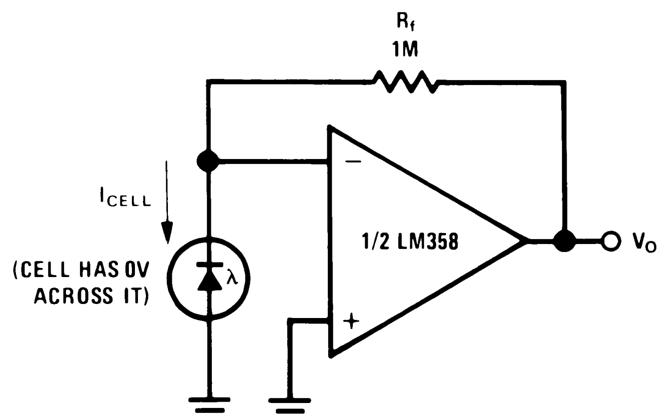


Figure 36. Photo Voltaic-Cell Amplifier

Typical Applications (continued)

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

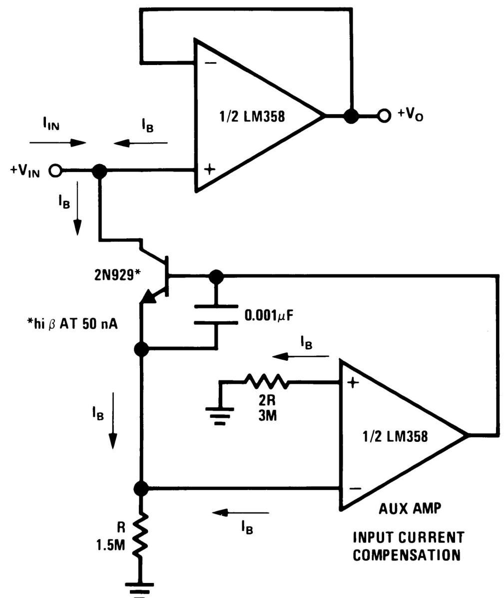
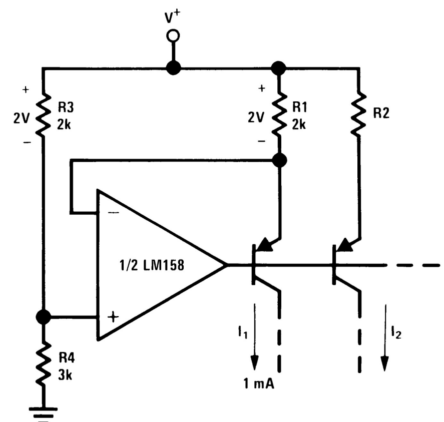


Figure 37. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)

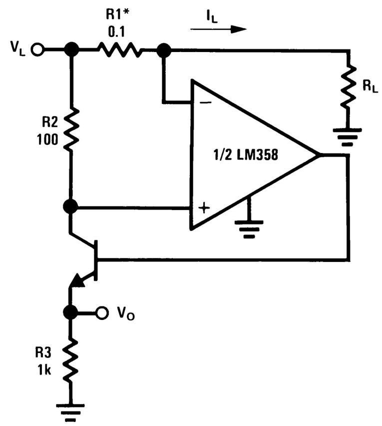


$$I_2 = \left(\frac{R1}{R2}\right) I_1$$

Figure 38. Fixed Current Sources

Typical Applications (continued)

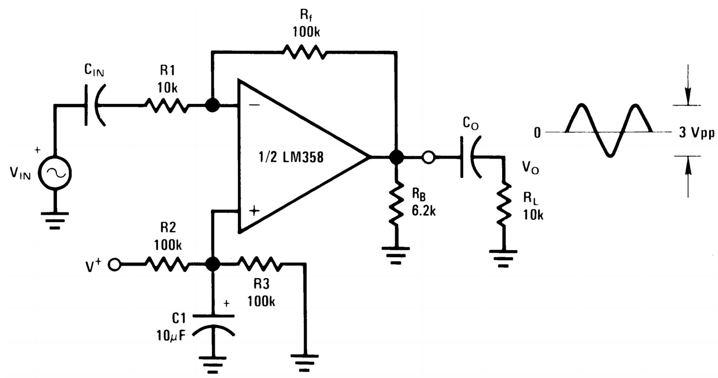
($V^+ = 5.0\ V_{DC}$)



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

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

Figure 39. Current Monitor

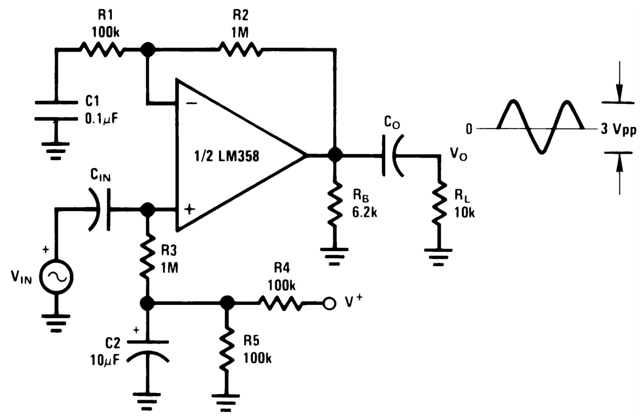


$$A_V = \frac{R_f}{R1}\quad \text{(As shown, } A_V = 10\text{)}$$

Figure 40. AC Coupled Inverting Amplifier

Typical Applications (continued)

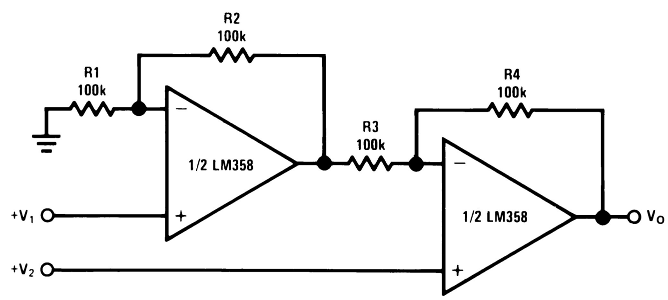
(V^{+} = 5.0 V_{DC})



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

A_v = 11 (As Shown)

Figure 41. AC Coupled Non-Inverting Amplifier

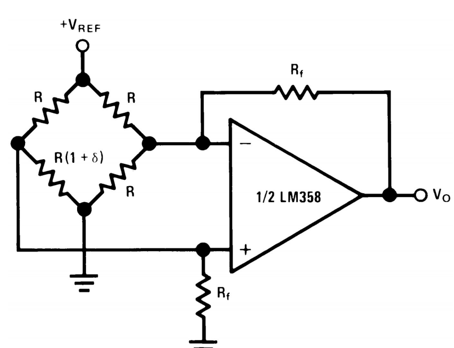


For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

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

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

Figure 42. High Input Z, DC Differential Amplifier



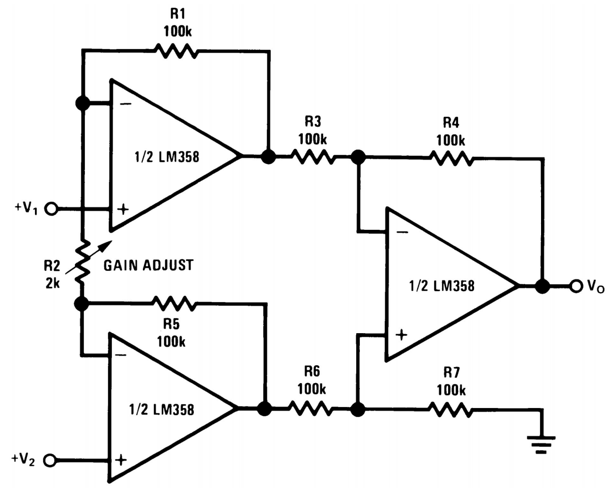
For $\delta << 1$ and $R_f >> R$

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

Figure 43. Bridge Current Amplifier

Typical Applications (continued)

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



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 44. High Input Z Adjustable-Gain DC Instrumentation Amplifier

9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply pins it is suggested that 10 nF capacitors be placed as close as possible to the op-amp power supply pins. For single supply, place a capacitor between V+ and V−supply leads. For dual supplies, place one capacitor between V+ and ground, and one capacitor between V- and ground.

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.

10 Layout

10.1 Layout Guidelines

For single-ended supply configurations, the V+ pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the V+ pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ and ground. The ground pin should be connected to the PCB ground plane at the pin of the device. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For dual supply configurations, both the V+ pin and V- pin should be bypassed to ground with a low ESR capacitor. The optimum placement is closest to the corresponding supply pin. Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ or V- and ground. The feedback components should be placed as close to the device as possible to minimize stray parasitics.

For both configurations, as ground plane underneath the device is recommended.

10.2 Layout Example

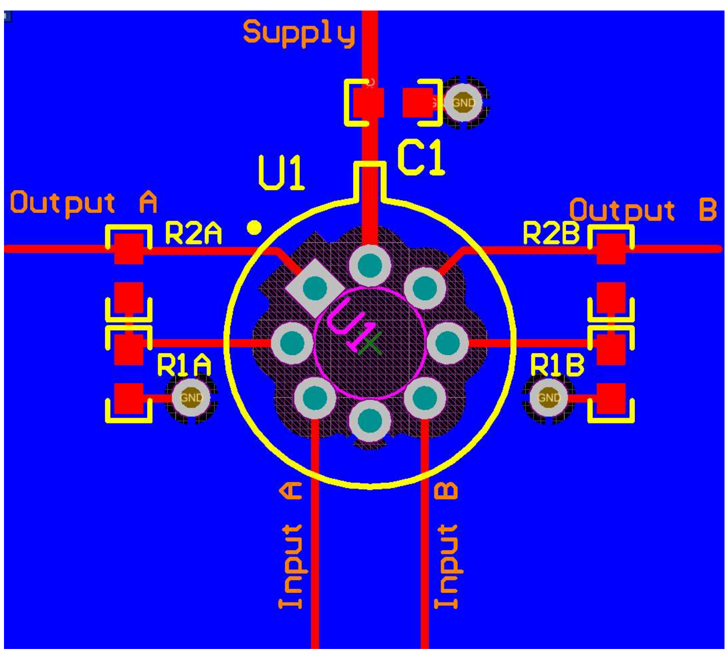


Figure 45. Layout Example

11 Device and Documentation Support

11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM158-N	Click here	Click here	Click here	Click here	Click here
LM258-N	Click here	Click here	Click here	Click here	Click here
LM2904-N	Click here	Click here	Click here	Click here	Click here
LM358-N	Click here	Click here	Click here	Click here	Click here

11.2 Trademarks

All trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution

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.

11.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.