

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: $\pm 1.5V$ to $\pm 16V$
- 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

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 $\pm 15V$ power supplies.

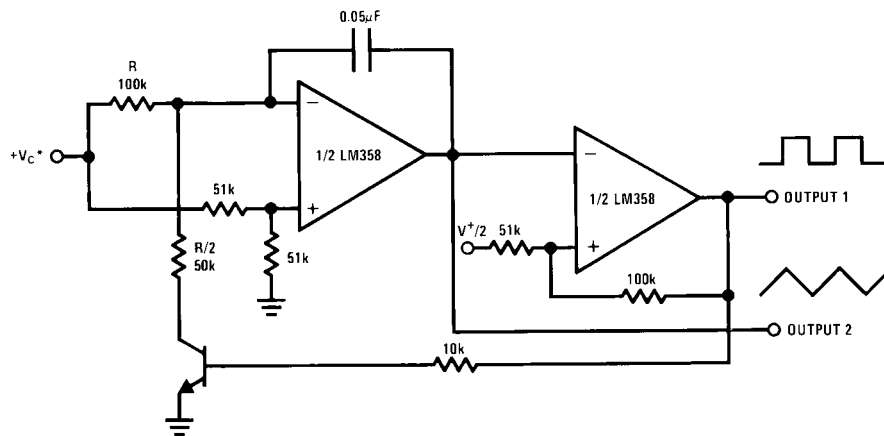
The LM358 and LM2904 are available in a chip sized package (8-Bump DSBGA) using TI's DSBGA package technology.



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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 ⁺ ≤ 15V and T _A = 25°C	
Continuous	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, V _{CM} = 0V, ⁽²⁾		20	50		45	100		45	150	nA
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⁾	0		V ⁺ -1.5	0		V ⁺ -1.5	0		V ⁺ -1.5	V
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

- (1) 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.
- (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 = ∞ 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 ≈ 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.
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ELECTRICAL CHARACTERISTICS
 $V^+ = +5.0V$, See⁽¹⁾, unless otherwise stated

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

- (1) These specifications are limited to $-55^\circ C \leq T_A \leq +125^\circ C$ for the LM158/LM158A. With the LM258/LM258A, all temperature specifications are limited to $-25^\circ C \leq T_A \leq +85^\circ C$, the LM358/LM358A temperature specifications are limited to $0^\circ C \leq T_A \leq +70^\circ C$, and the LM2904 specifications are limited to $-40^\circ C \leq T_A \leq +85^\circ C$.
- (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) $V_O = 1.4V$, $R_S = 0\Omega$ with V^+ from 5V to 30V; and over the full input common-mode range (0V to $V^+ - 1.5V$) at $25^\circ C$. 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 $25^\circ C$). The upper end of the common-mode voltage range is $V^+ - 1.5V$ (at $25^\circ C$), 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	V ⁺ = 15V, T _A = 25°C,							
Gain	R _L ≥ 2 kΩ, (For V _O = 1V to 11V)	25	100		25	100		V/mV
Common-Mode Rejection Ratio	T _A = 25°C,	65	85		50	70		dB
	V _{CM} = 0V to V ⁺ - 1.5V							
Power Supply Rejection Ratio	V ⁺ = 5V to 30V	65	100		50	100		dB
	(LM2904, V ⁺ = 5V to 26V), T _A = 25°C							
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,	20	40		20	40	mA
		V _{IN⁻} = 0V,						
		V ⁺ = 15V,						
		V _O = 2V, T _A = 25°C						
	Sink	V _{IN⁻} = 1V, V _{IN⁺} = 0V	10	20		10	20	mA
		V ⁺ = 15V, T _A = 25°C,						
V _O = 2V								
	V _{IN⁻} = 1V, V _{IN⁺} = 0V	12	50		12	50	μA	
	T _A = 25°C, V _O = 200 mV,							
	V ⁺ = 15V							
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	$V^+ = +15V$		15			15			V/mV	
	$(V_O = 1V \text{ to } 11V)$									
	$R_L \geq 2 \text{ k}\Omega$									
Output	V_{OH}	$V^+ = +30V$	26			22			V	
Voltage		$(LM2904, V^+ = 26V)$								$R_L = 10 \text{ k}\Omega$
Swing	V_{OL}	$V^+ = 5V, R_L = 10 \text{ k}\Omega$			5	20		5	100	mV
Output Current	Source	$V_{IN}^+ = +1V, V_{IN}^- = 0V,$		10	20		10	20		mA
		$V^+ = 15V, V_O = 2V$								
	Sink	$V_{IN}^- = +1V, V_{IN}^+ = 0V,$		5	8		5	8		mA
		$V^+ = 15V, V_O = 2V$								

TYPICAL PERFORMANCE CHARACTERISTICS

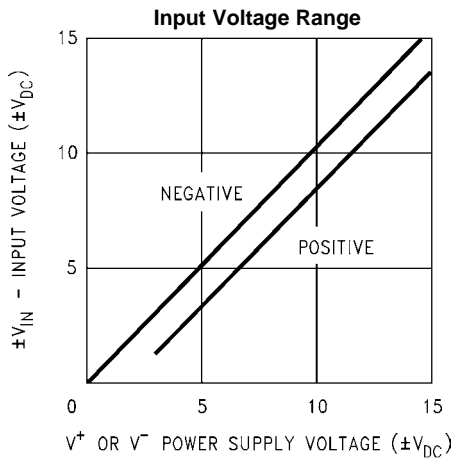


Figure 1.

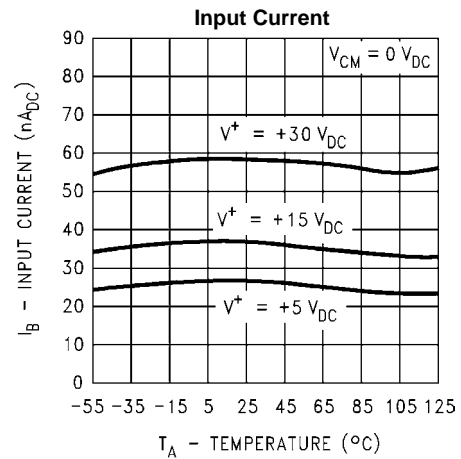


Figure 2.

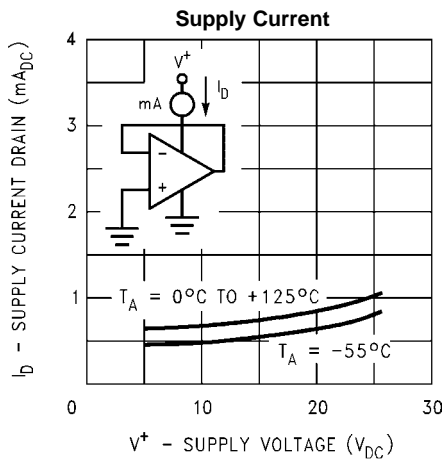


Figure 3.

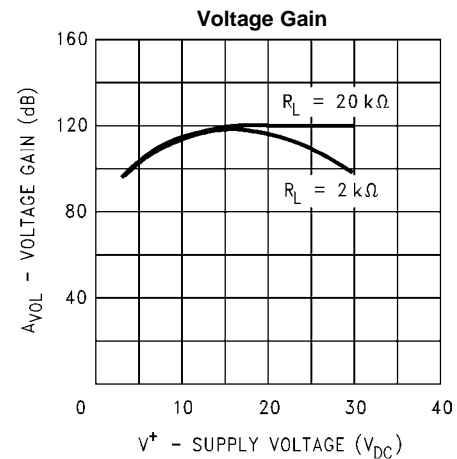


Figure 4.

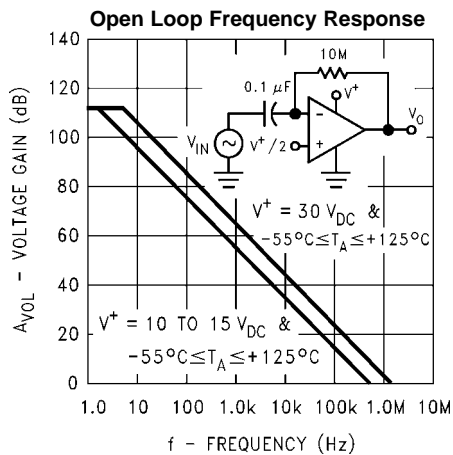


Figure 5.

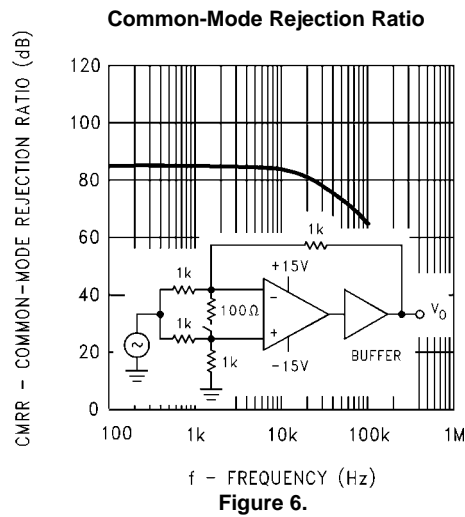


Figure 6.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

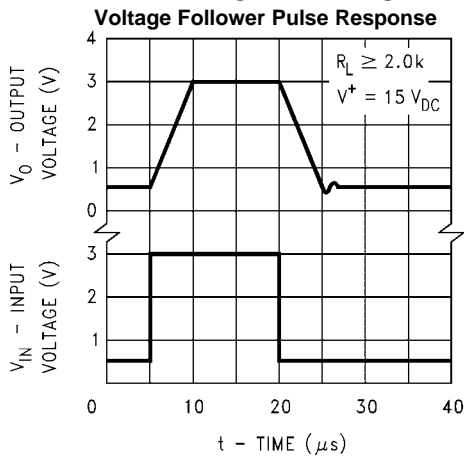


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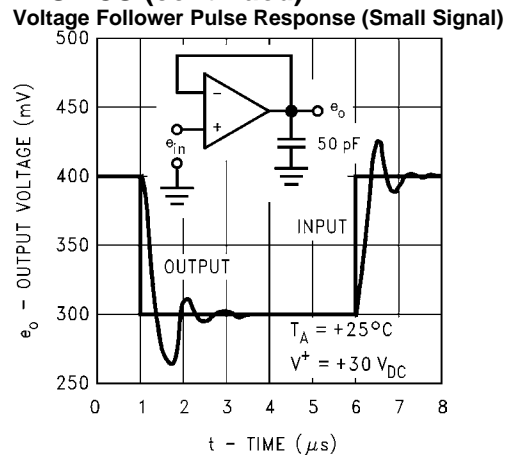


Figure 8.

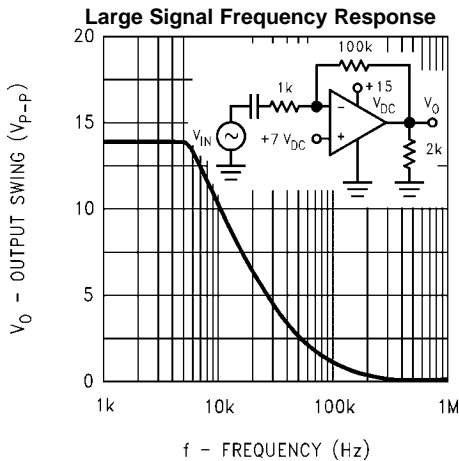


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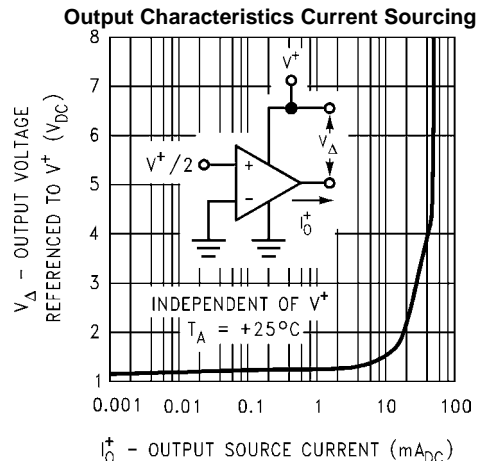


Figure 10.

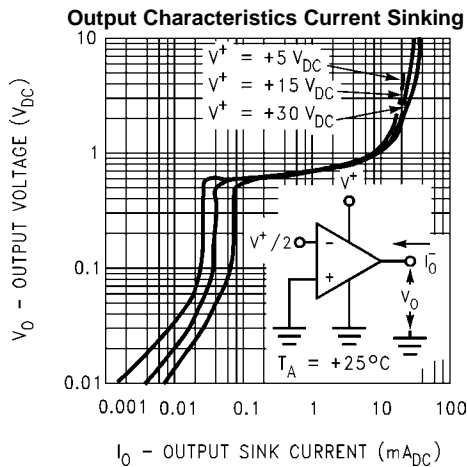


Figure 11.

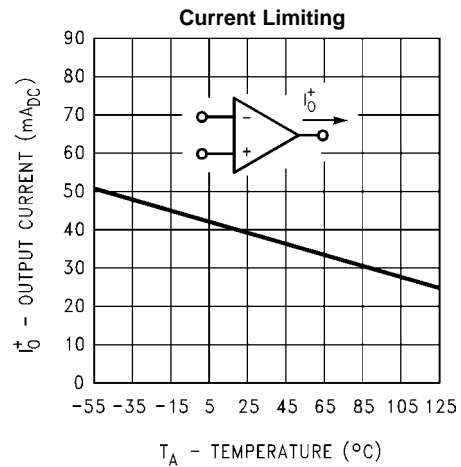


Figure 12.

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

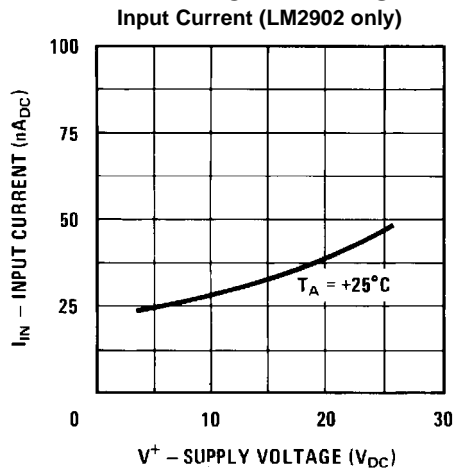


Figure 13.

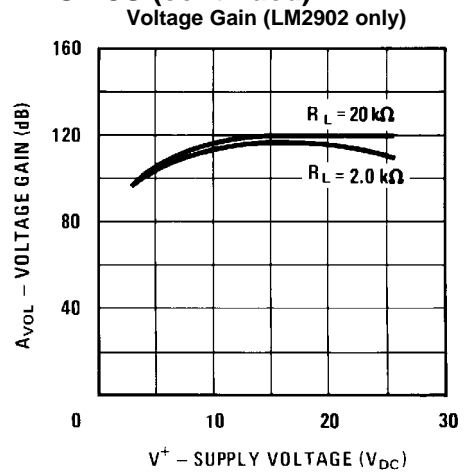


Figure 14.

CONNECTION DIAGRAM

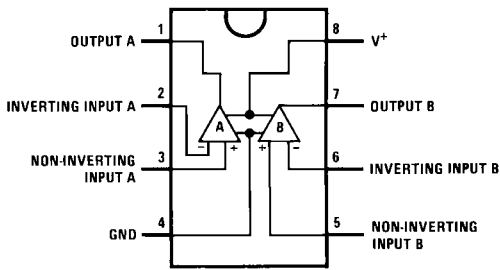


Figure 15. PDIP/CDIP/SOIC Package – Top View
(See Package Number P, NAB0008A, or D)

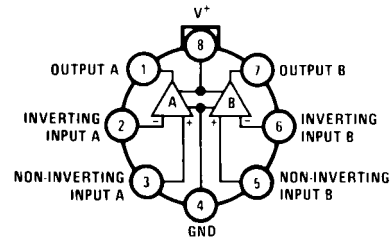


Figure 16. TO-99 Package – Top View
(See Package Number LMC)

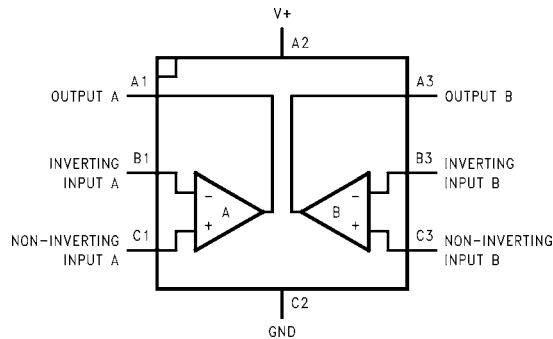
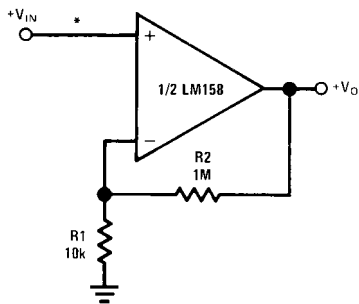


Figure 17. 8-Bump DSBGA - Top View, Bump Side Down
(See Package Number YPB0008AAA)

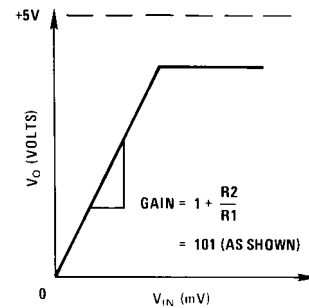
TYPICAL SINGLE-SUPPLY APPLICATIONS

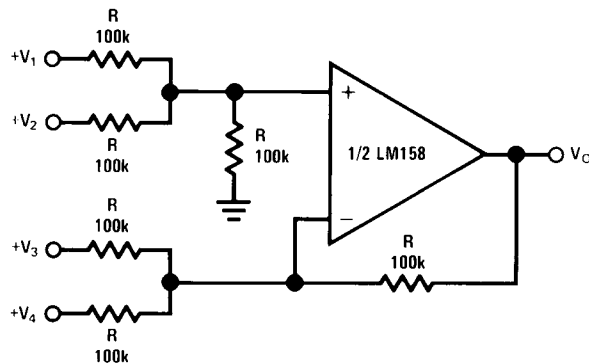
($V^+ = 5.0 V_{DC}$)

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



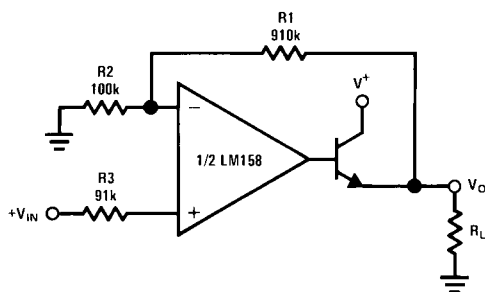
*R not needed due to temperature independent I_{IN}





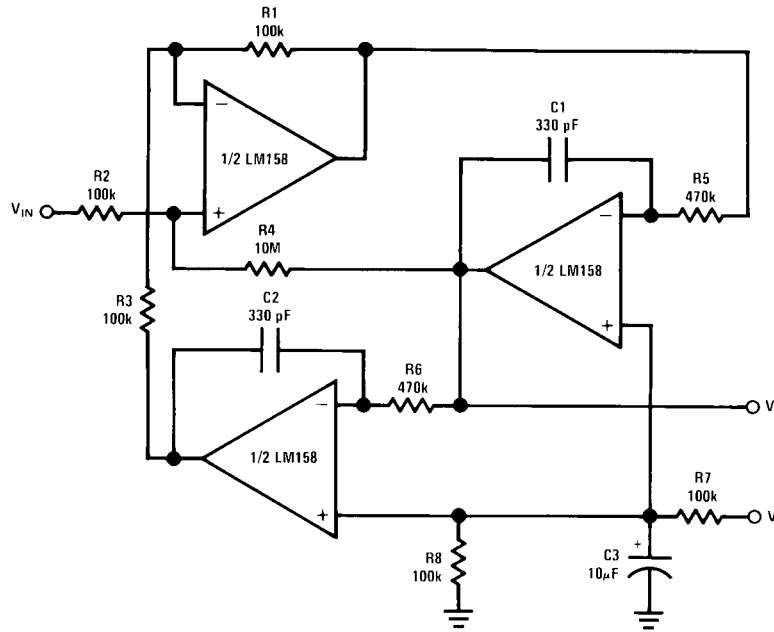
Where: $V_O = V_1 + V_2 - V_3 - V_4$
 $(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0 V_{DC}$

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



$f_o = 1 \text{ kHz}$
 $Q = 50$
 $A_v = 100 \text{ (40 dB)}$

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

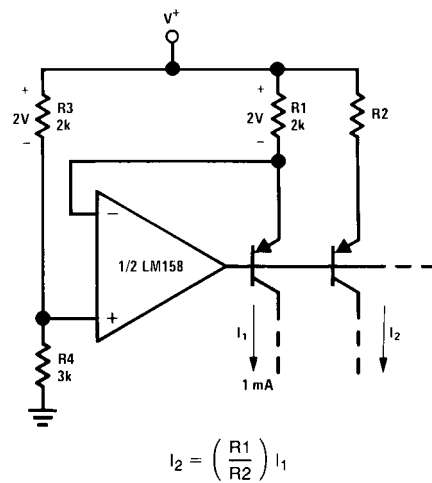


Figure 22. Fixed Current Sources

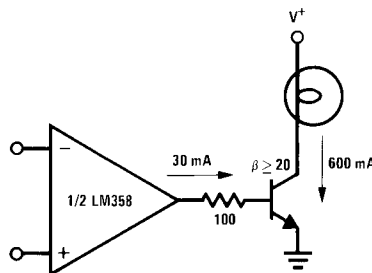


Figure 23. Lamp Driver

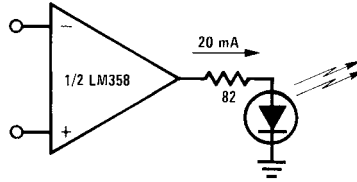
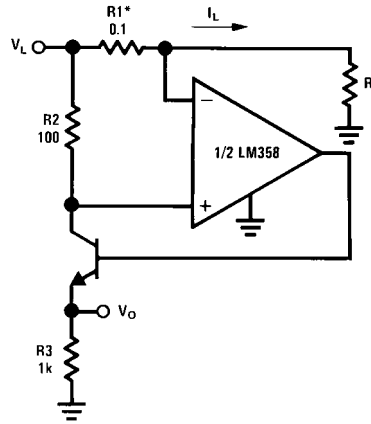


Figure 24. LED Driver



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

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

Figure 25. Current Monitor

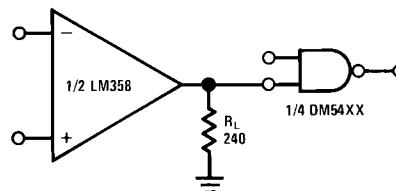
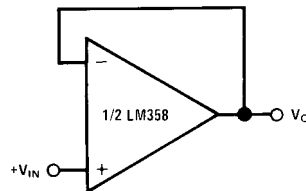


Figure 26. Driving TTL



$$V_O = V_{IN}$$

Figure 27. Voltage Follower

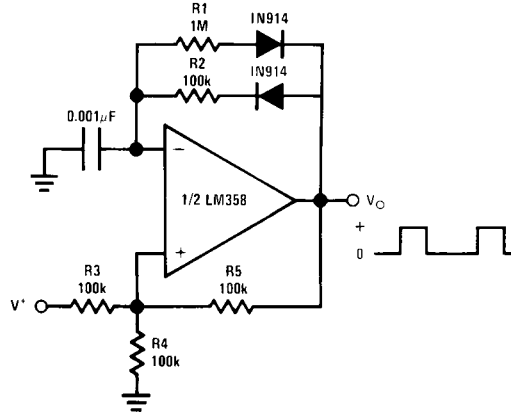


Figure 28. Pulse Generator

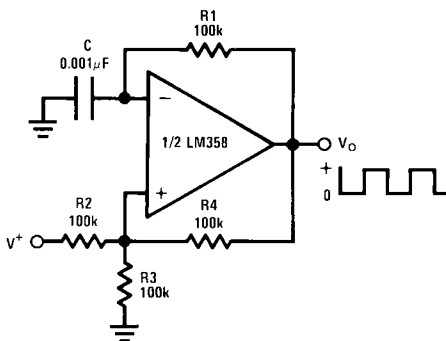


Figure 29. Squarewave Oscillator

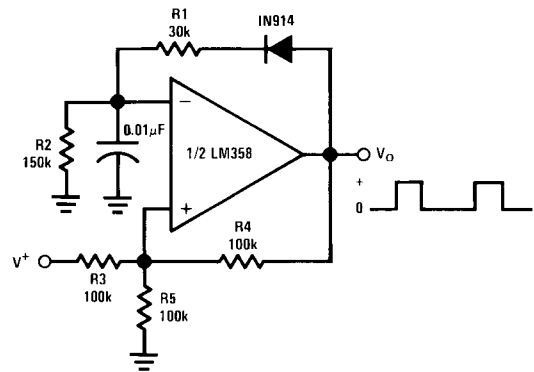
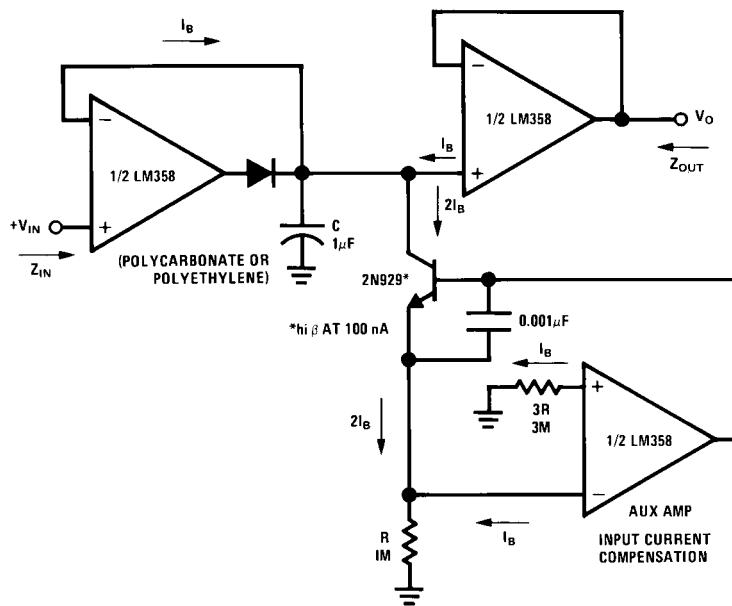
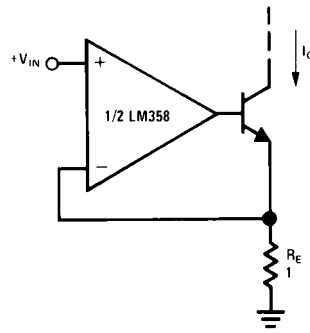


Figure 30. Pulse Generator



HIGH Z_{IN}
LOW Z_{OUT}

Figure 31. Low Drift Peak Detector



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

Figure 32. High Compliance Current Sink

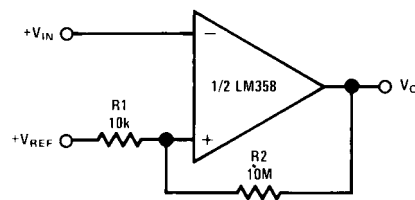
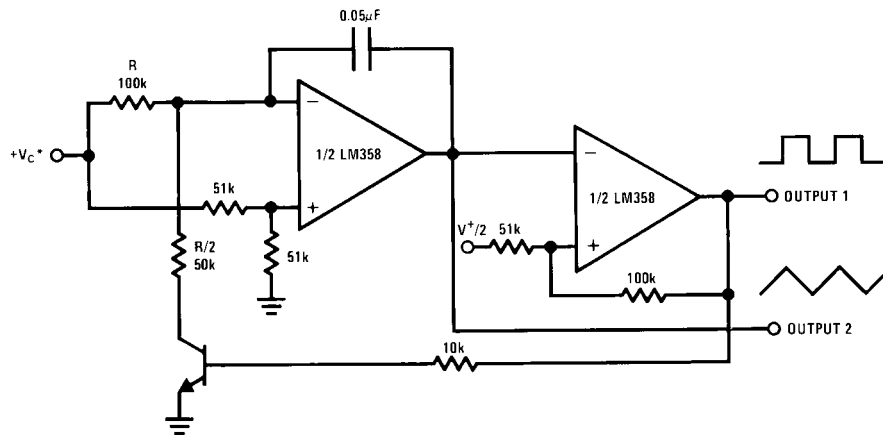


Figure 33. Comparator with Hysteresis



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

Figure 34. Voltage Controlled Oscillator (VCO)

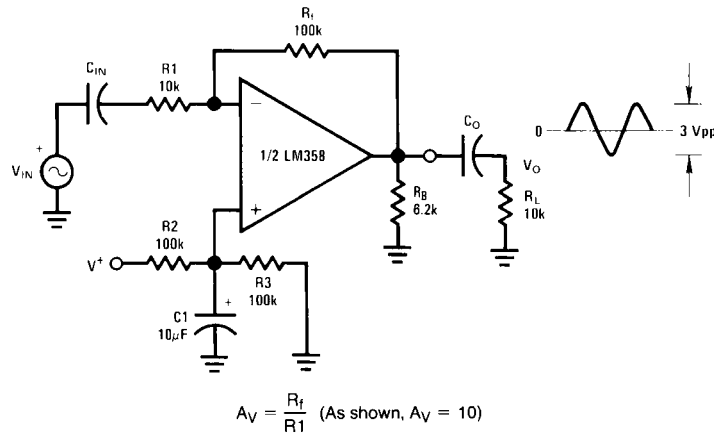


Figure 35. AC Coupled Inverting Amplifier

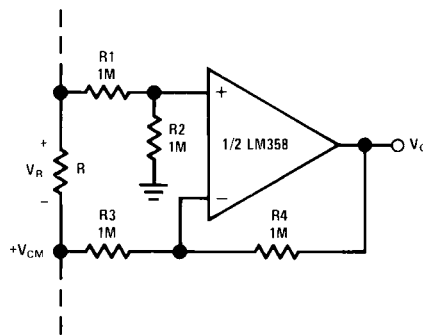
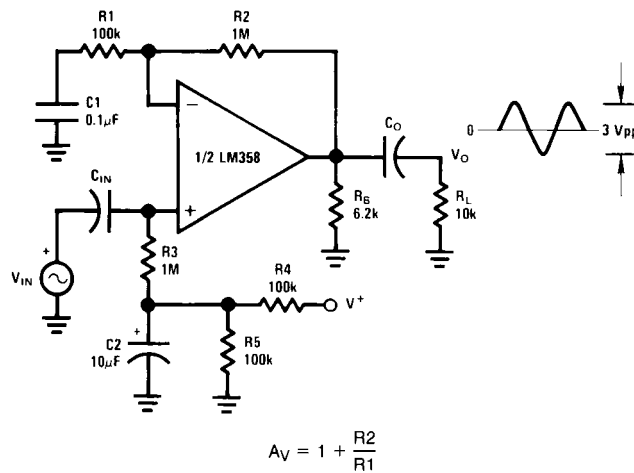
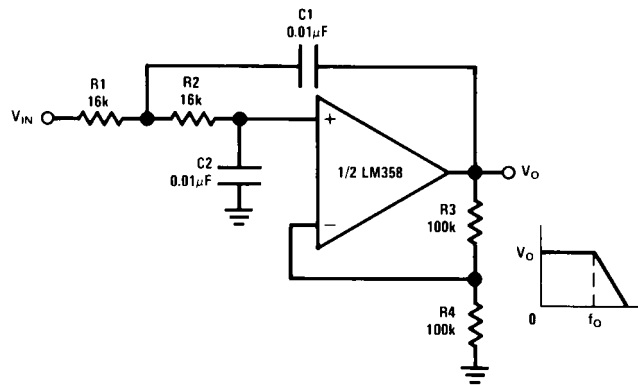


Figure 36. Ground Referencing a Differential Input Signal



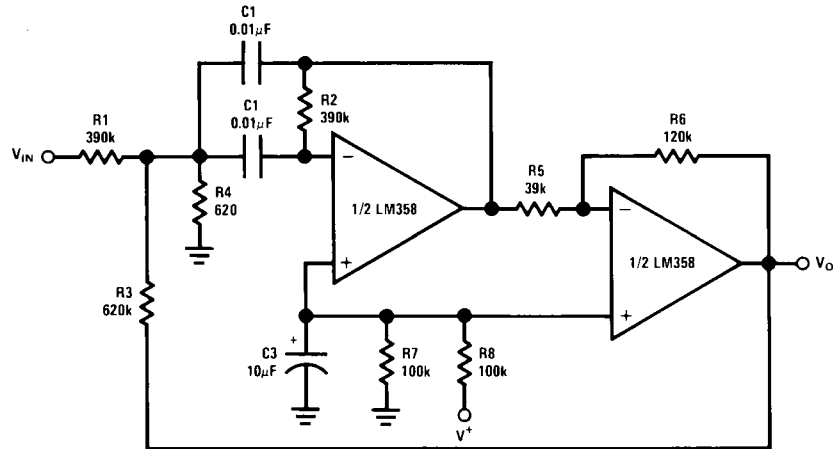
$A_v = 11$ (As Shown)

Figure 37. AC Coupled Non-Inverting Amplifier



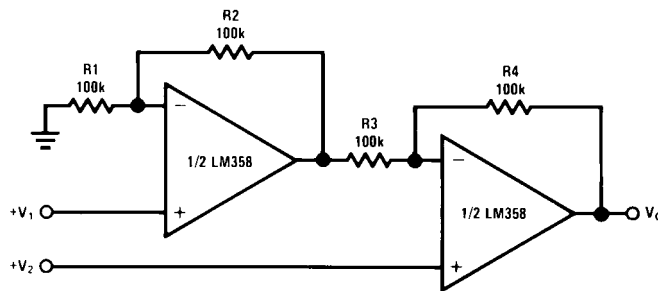
$f_o = 1 \text{ kHz}$
 $Q = 1$
 $A_V = 2$

Figure 38. DC Coupled Low-Pass RC Active Filter



$f_o = 1 \text{ kHz}$
 $Q = 25$

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

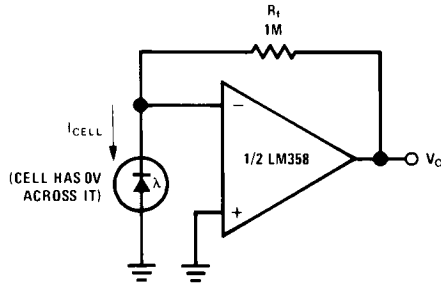
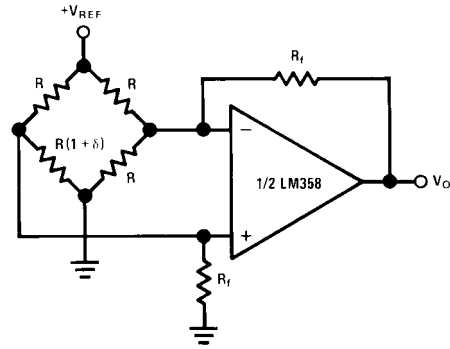


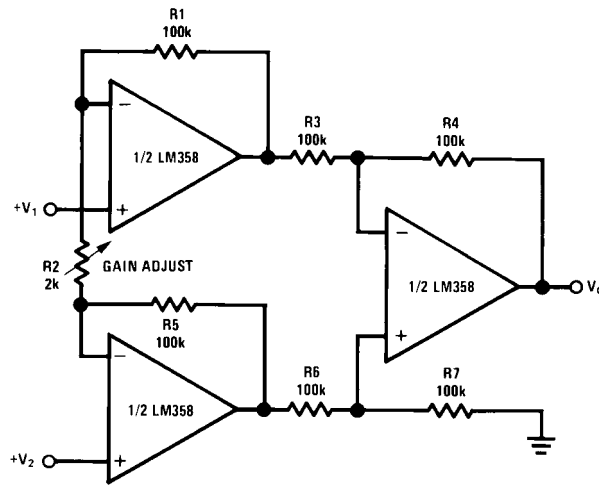
Figure 41. Photo Voltaic-Cell Amplifier



For $\delta \ll 1$ and $R_f \gg R$

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

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

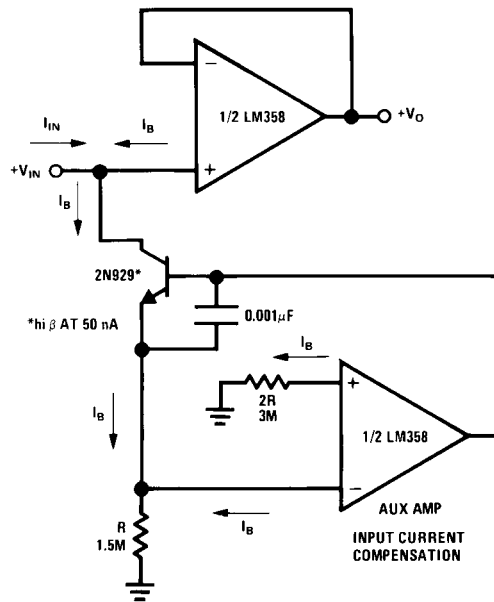


Figure 44. Using Symmetrical Amplifiers to Reduce Input Current (General Concept)

SCHEMATIC DIAGRAM

(Each Amplifier)

