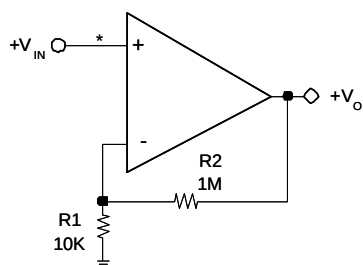
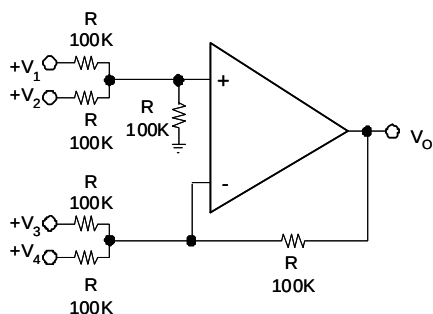
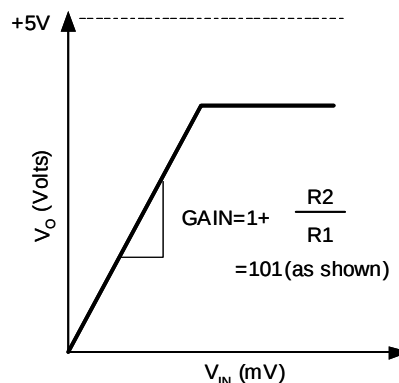


Typical Single-Supply Circuit ($V^+=5.0V_{DC}$)



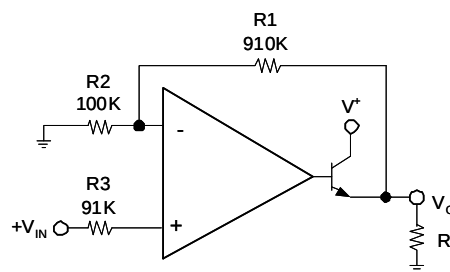
*R not needed due to temperature independent I_{IN}

Non-Inverting DC Gain (0V Output)



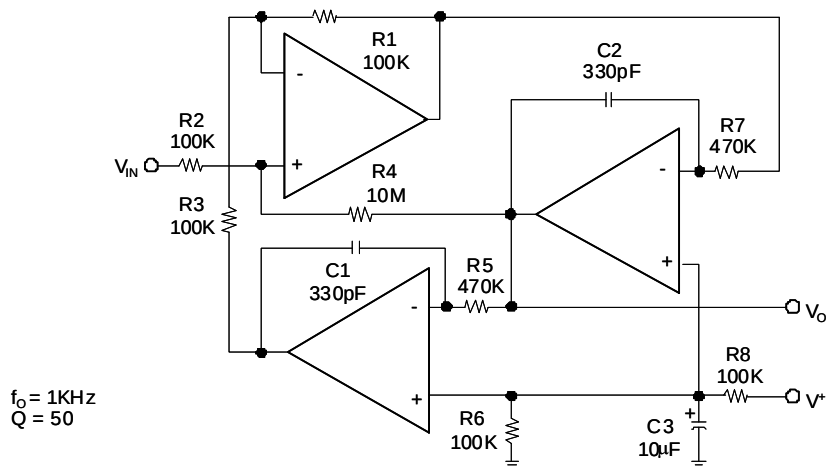
Where: $V_O = V_1 + V_2 - V_3 - V_4$
($V_1 + V_2 > (V_3 + V_4)$ to keep $V_O > 0 V_{DC}$)

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



$V_O = 0 V_{DC}$ for $V_{IN} = 0 V_{DC}$
 $A_v = 10$

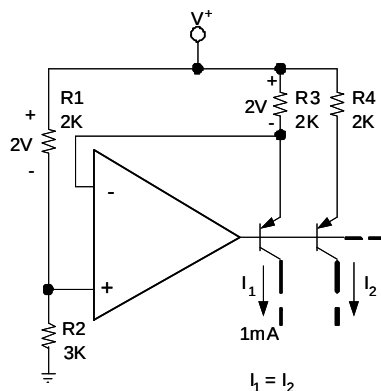
Power Amplifier



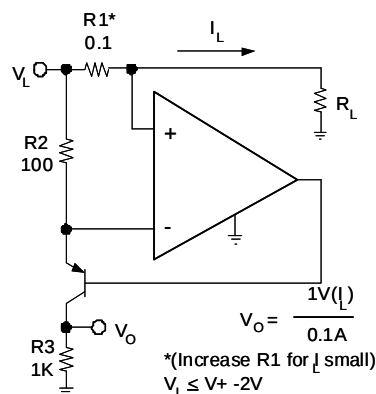
$f_o = 1KHz$
 $Q = 50$

"BI-QUAD" RC Active Bandpass Filter

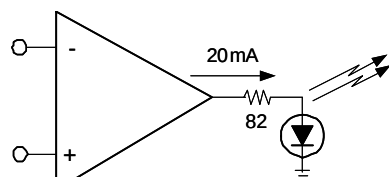
Typical Single-Supply Circuit (Continued) ($V^+ = 5.0V_{DC}$)



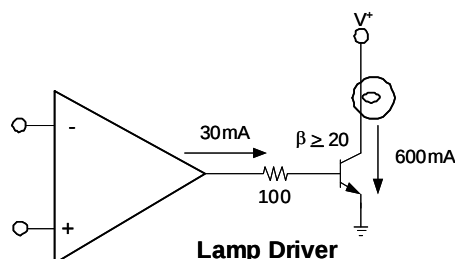
Fixed Current Sources



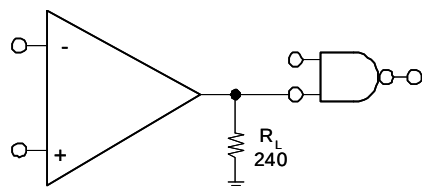
Current Monitor



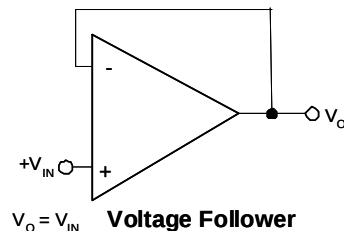
LED Driver



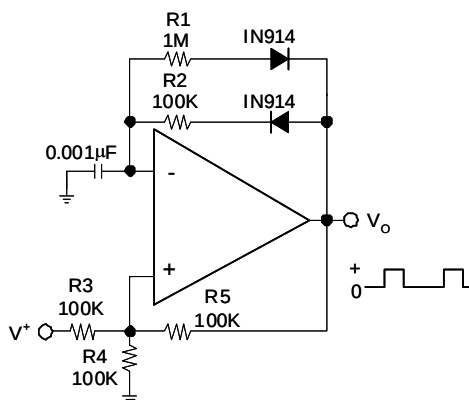
Lamp Driver



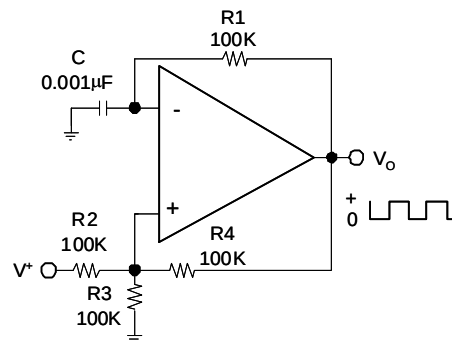
Driving TTL



Voltage Follower

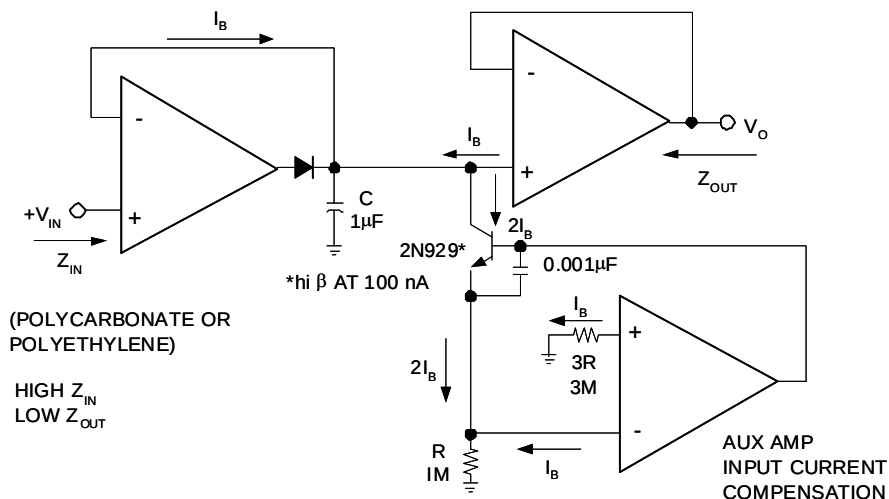


Pulse Generator

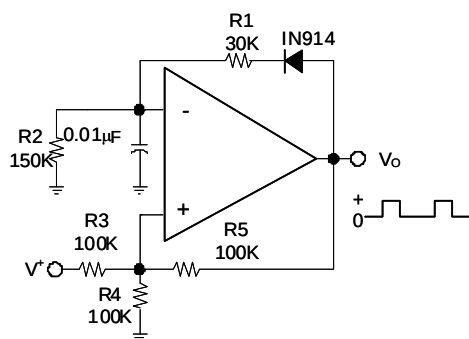


Square wave Oscillator

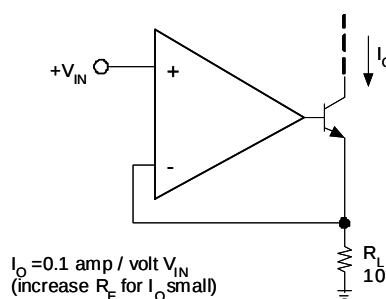
Typical Single-Supply Circuit (Continued) ($V^+ = 5.0V_{DC}$)



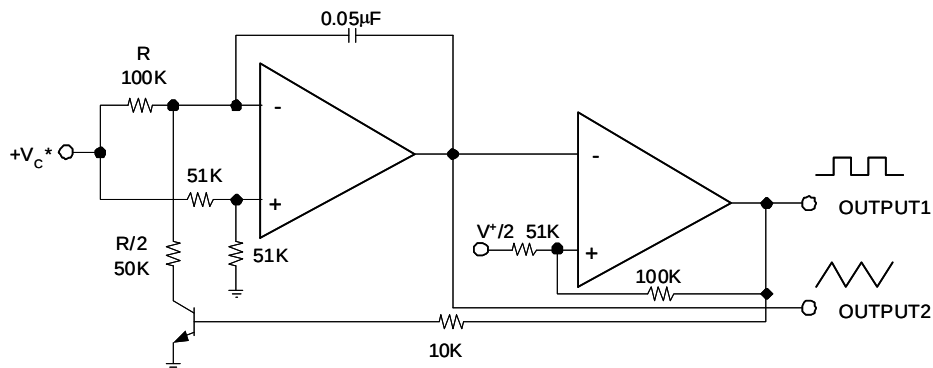
Low Drift Peak Detector



Pulse Generator



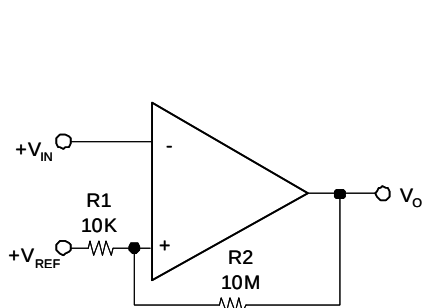
High Compliance Current Sink



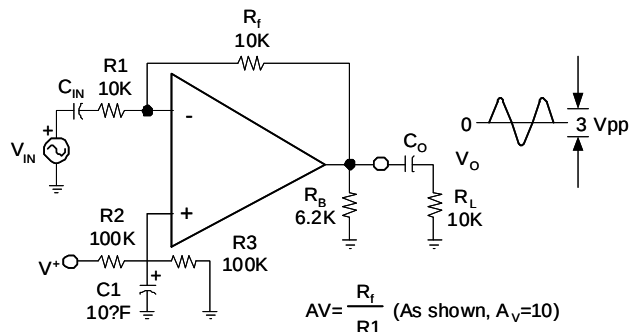
*WIDE CONTROL VOLTAGE RANGE: $0 V_{DC} \leq V_C \leq 2 (V^+ - 1.5V_{DC})$

Voltage Controlled Oscillator (VCO)

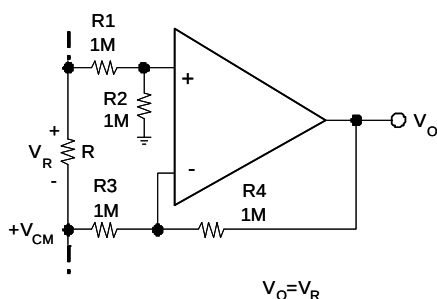
Typical Single-Supply Circuit (Continued) ($V^+ = 5.0V_{DC}$)



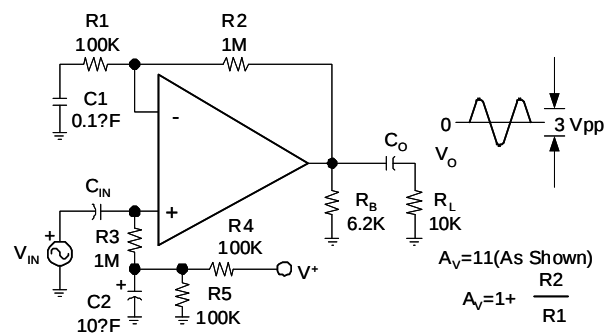
Comparator with Hysteresis



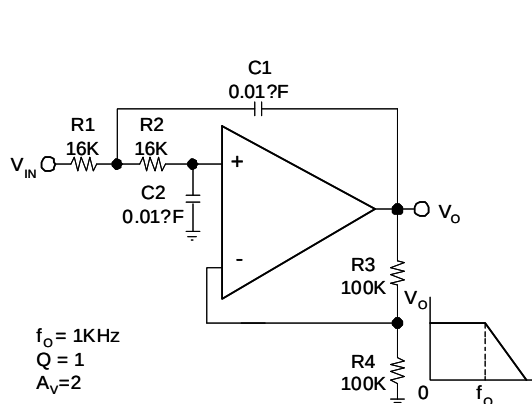
AC Coupled Inverting Amplifier



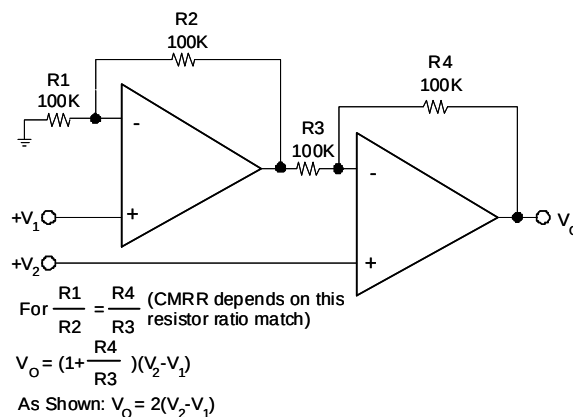
Ground Referencing a Differential Input Signal



AC Coupled Non-Inverting Amplifier

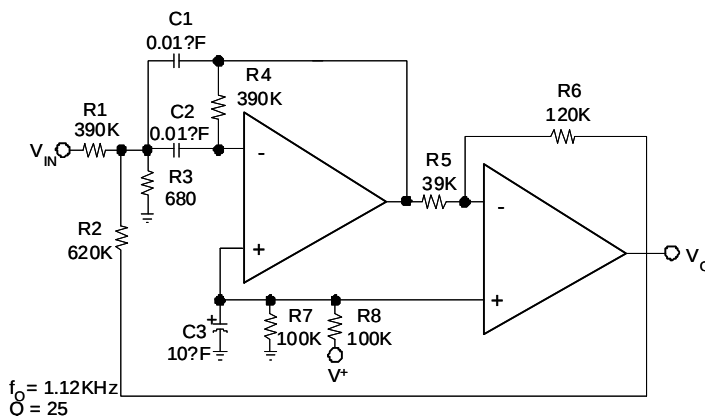


DC Coupled Low-Pass RC Active Filter

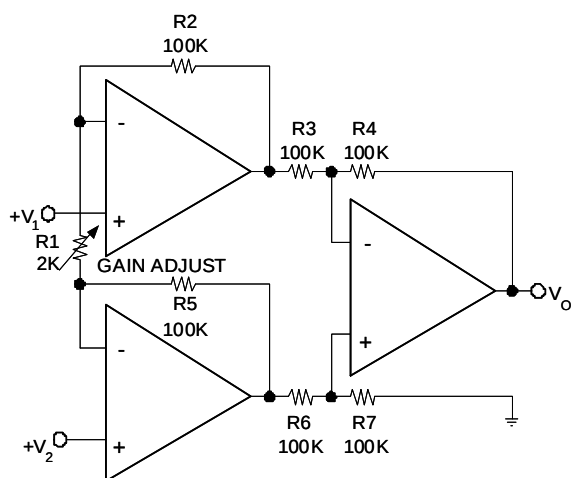


High Input Z, DC Differential Amplifier

Typical Single-Supply Circuit (Continued) ($V^+ = 5.0V_{DC}$)



Bandpass Active Filter

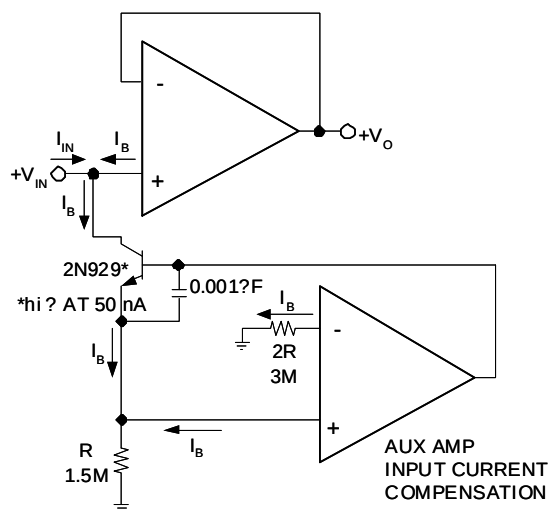


If $R1 = R5$ & $R3 = R4 = R6 = R7$ (CMRR depends on match)

$$V_O = \left(1 + \frac{2R_2}{R_1}\right)(V_2 - V_1)$$

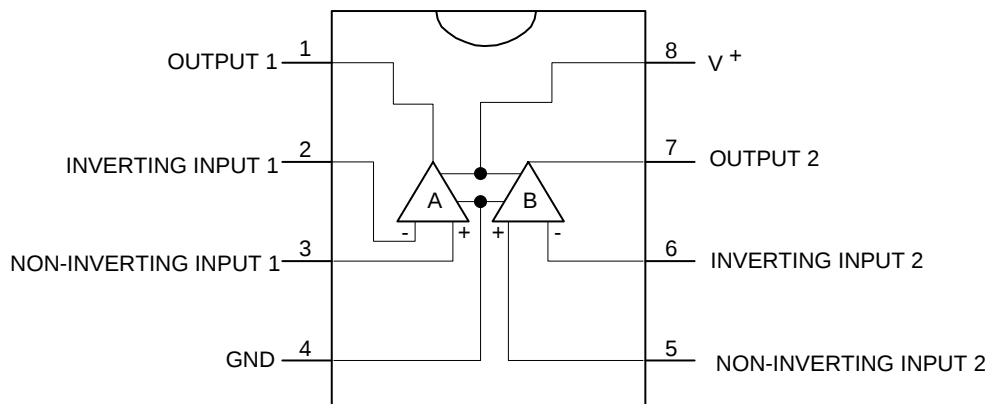
As Shown: $V_O = 101(V_2 - V_1)$

**High Input Z Adjustable-Gain
DC Instrumentation Amplifier**



**Using Symmetrical Amplifiers to Reduce
Input Current (General Concept)**

Functional Block Diagram



Pin Descriptions

Pin Name	Pin #	Description
OUTPUT 1	1	Channel 1 Output
INVERTING INPUT 1	2	Channel 1 Inverting Input
NON-INVERTING INPUT 1	3	Channel 1 Non-inverting Input
GND	4	Ground
NON-INVERTING INPUT 2	5	Channel 2 Non-inverting Input
INVERTING INPUT 2	6	Channel 2 Inverting Input
OUTPUT 2	7	Channel 2 Output
V ⁺	8	Chip Supply Voltage

Absolute Maximum Ratings

Symbol	Parameter	Rating	Unit
V_{CC}	Supply voltage	32	V
	Differential Input Voltage	32	V
V_{IN}	Input Voltage	-0.3 to +32	V
P_D	Power Dissipation (Note 2)	600	mW
	Output Short-Circuit to GND (One Amplifier) (Note 3)	Continuous	
	Input Current ($V_{IN} < -0.3V$) (Note 4)		
T_{OP}	Operating Temperature Range	0 to +70	°C
T_{ST}	Storage Temperature Range	-65 to +150	°C

- Notes:
- For operating at high temperatures, the LM358 must be derated based on a +125°C maximum junction temperature and a thermal resistance of 189°C/W, which applies for the device soldered in a printed circuit board, operating in a still air ambient. 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.
 - 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 40mA 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.
 - 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).

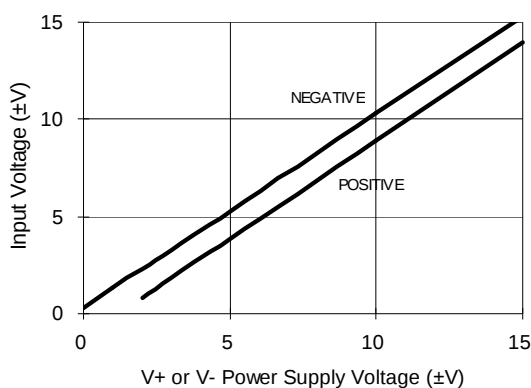
Electrical Characteristics ($T_A = 25^\circ\text{C}$, $V^+ = +5.0\text{V}$, unless otherwise stated) (Note 5)

Symbol	Parameter		Conditions		Min	Typ.	Max	Unit
V _{IO}	Input Offset Voltage		T _A = 25°C, (Note 6)		-	2	7	mV
I _B	Input Bias Current		I _{IN(+)} or I _{IN(-)} , T _A = 25°C, V _{CM} = 0V, (Note 7)		-	45	250	nA
I _{IO}	Input Offset Current		I _{IN(+)} - I _{IN(-)} , V _{CM} = 0V, T _A = 25°C		-	5	50	nA
V _{ICM}	Input Common-Mode Voltage Range		V ⁺ = 30V, (Note 8) T _A = 25°C		0	-	V ⁺ -1.5	V
I _S	Supply Current		R _L = ∞ on All Op Amps	V ⁺ = 30V	-	1	2	mA
	Over Full Temperature Range			V ⁺ = 5V	-	0.5	1.2	
A _V	Large Signal Voltage Gain		V ⁺ = 15V, T _A = 25°C, R _L > 2kΩ, (For V _O = 1V to 11V)		25	100	-	V/mV
CMRR	Common-Mode Rejection Ratio		T _A = 25°C, V _{CM} = 0V to V ⁺ -1.5V		65	85	-	dB
PSRR	Power Supply Rejection Ratio		V ⁺ = 5V to 30V, T _A = 25°C		65	100	-	dB
	Amplifier-to-Amplifier Coupling		f = 1KHz to 20 KHz, T _A = 25°C (Input Referred) (Note 9)		-	-120	-	dB
I _{SINK}	Output Current		Sink	V _{IN(-)} = 1V, V _{IN(+)} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C	10	20	-	mA
				V _{IN(-)} = 1V, V _{IN(+)} = 0V, V ⁺ = 15V, V _O = 200mV, T _A = 25°C	20	70	-	μA
I _{SOURCE}			Source	V _{IN(+)} = 1V, V _{IN(-)} = 0V, V ⁺ = 15V, V _O = 2V, T _A = 25°C	20	40	-	mA
I _{SC}	Short Circuit to Ground		T _A = 25°C, (Note 10) V ⁺ = 15V		-	40	60	mA
V _{OH}	Output Voltage Swing		(V ⁺ =30V)	R _L = 2kΩ, T _A = 25°C	26	-	-	V
				R _L = 10kΩ, T _A = 25°C	27	28	-	V
V _{OL}			(V ⁺ =5V)	R _L = 10kΩ, T _A = 25°C	-	5	20	mV

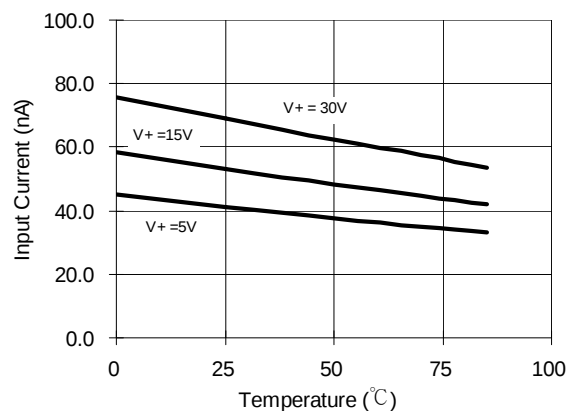
- Notes:
- The LM358 temperature specifications are limited to $0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$.
 - $V_O \cong 1.4\text{V}$, $R_S = 0\Omega$ with V^+ from 5V to 30V ; and over the full input common-mode range (0V to $V^+ - 1.5\text{V}$) at 25°C .
 - The direction of the input current 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.
 - 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 $V^+ - 1.5\text{V}$ (at 25°C), but either or both inputs can go to $+32\text{V}$ without damage, independent of the magnitude of V^+ .
 - 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.
 - Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the output maximum current is approximately 40mA independent of the magnitude of V^+ . At values of supply voltage in excess of $+15\text{V}$, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Typical Performance Characteristics

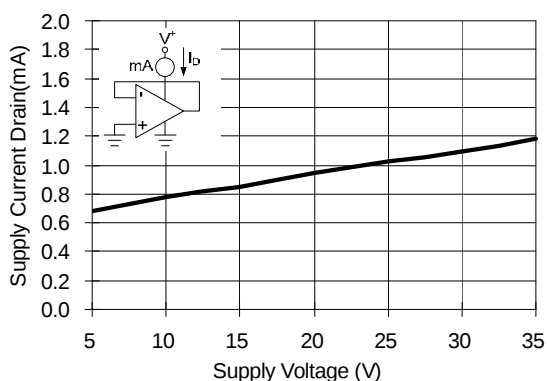
Input Voltage Range



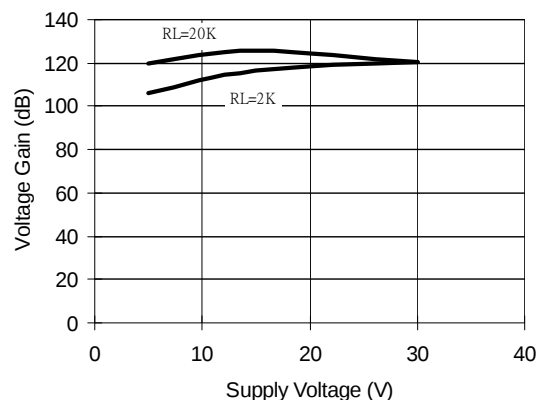
Input Current vs Temperature



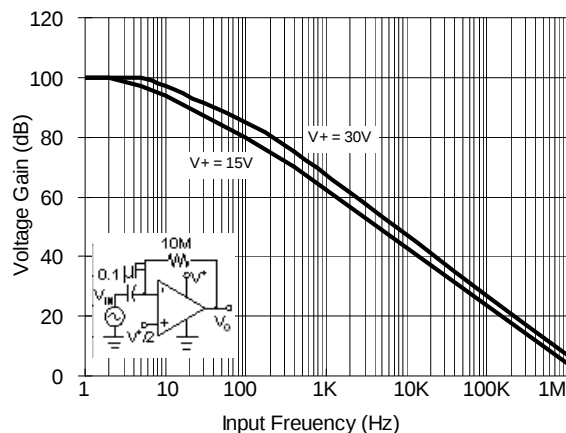
Supply Current



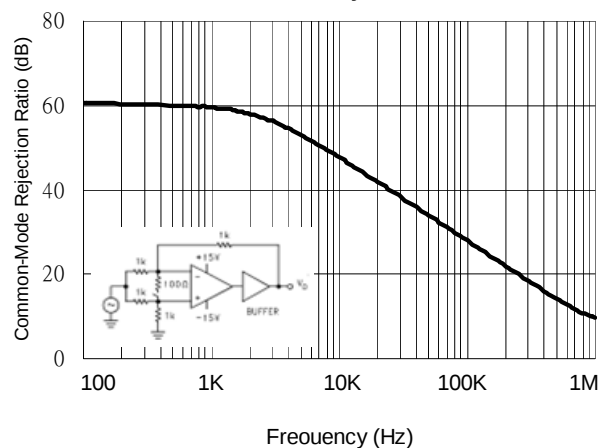
Voltage Gain



Open Loop Frequency Response

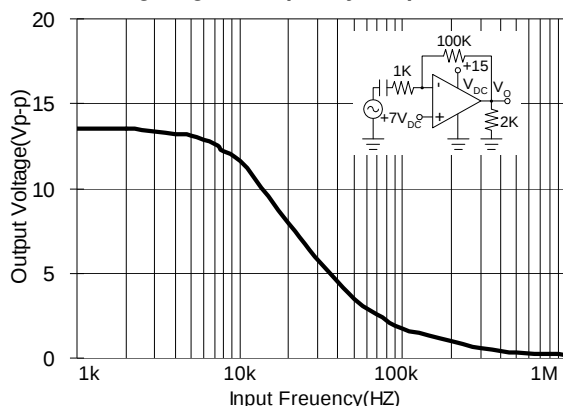


Common-Mode Rejection Ratio

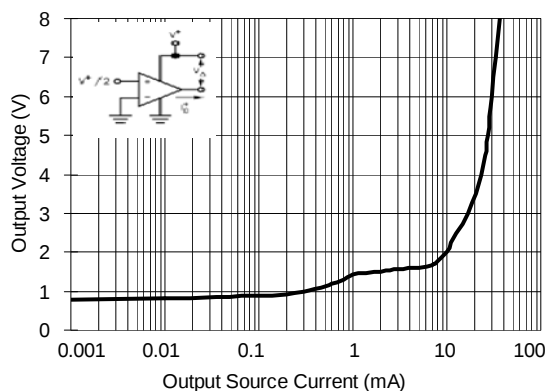


Typical Performance Characteristics (Continued)

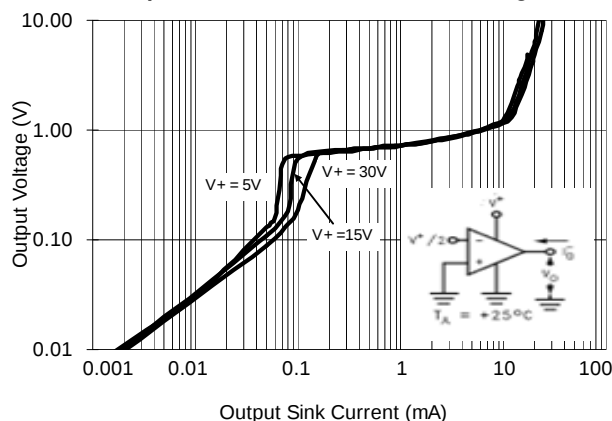
Large Signal Frequency Response



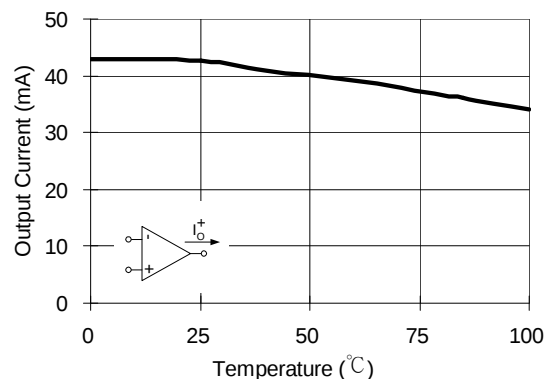
Output Characteristics Current Sourcing



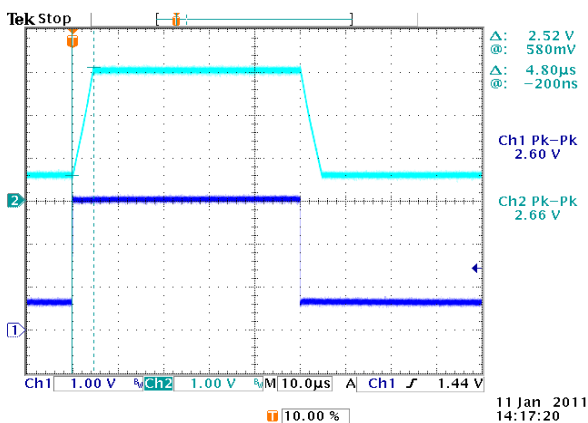
Output Characteristics Current Sinking



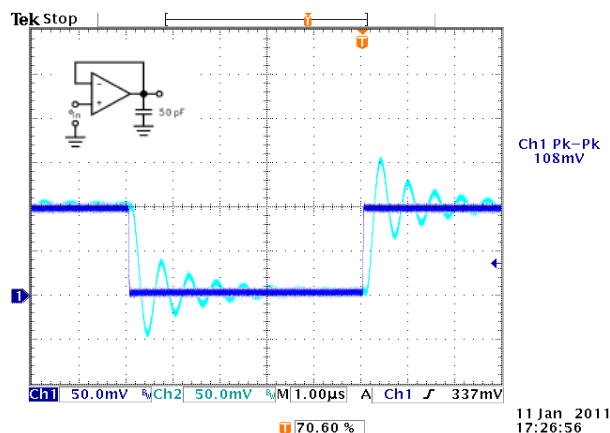
Current Limiting



Voltage Follower Pulse Response



Voltage Follower Pulse Response (Small Signal)



Application Information

The LM358 series are op amps 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. 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 50pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if a larger load capacitance must be driven by the amplifier.

The bias network of the LM358 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.

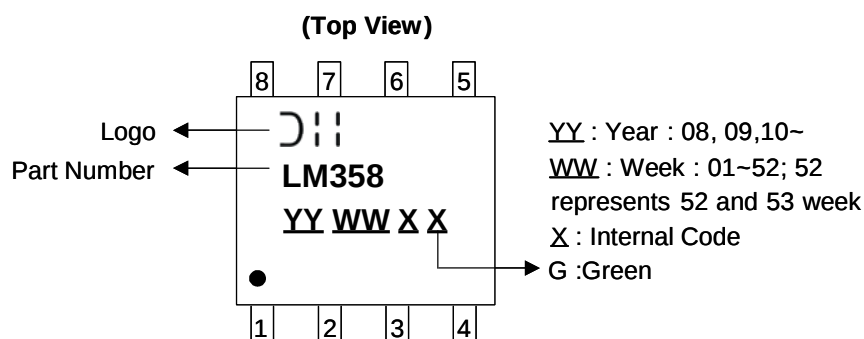
The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow 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.

Ordering Information

Device	Package Code	Packaging (Note 10)	Tube		13" Tape and Reel	
			Quantity	Part Number Suffix	Quantity	Part Number Suffix
LM358S-13	S	SOP-8L	NA	NA	2500/Tape & Reel	-13

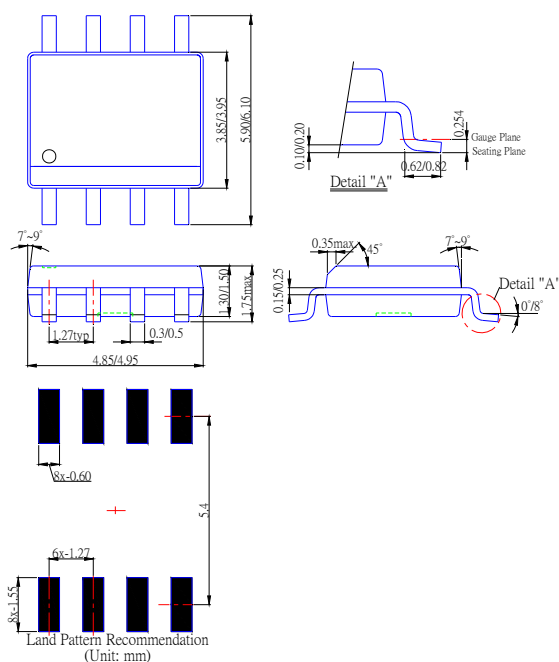
Notes: 10. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at <http://www.diodes.com/datasheets/ap02001.pdf>.

Marking Information



Package Outline Dimensions (All Dimensions in mm)

Package type: SOP-8L



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