# LM358

## LOW POWER DUAL OPERATIONAL AMPLIFIERS

## Description

The LM358 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.
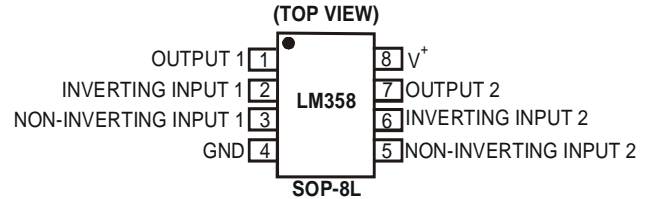
Application areas include transducer amplifiers, dc gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM358 series can be directly operated from the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring an additional ±15V power supply.

## Features

- Internally frequency compensated for unity gain
- Large dc voltage gain: 100 dB
- Very low supply current drain (500µA); essentially independent of supply voltage
- Wide bandwidth (unity gain): 1MHz (temperature compensated)
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low input offset voltage: 2mV
- Wide power supply range:
  - Single supply: 3V to 32V
  - Dual supplies: ±1.5V to ±16V
- Large output voltage swing: 0V to $V^+$ - 1.5V
- SOP-8L packaging
- "Green" Molding Compound (No Br, Sb)
- Lead Free Finish/ RoHS Compliant (Note 1)

Notes: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied. Please visit our website at http://www.diodes.com/products/lead_free.html.

## Pin Assignments

**(TOP VIEW)**

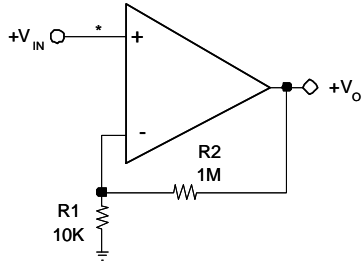| Pin | Name | Pin | Name |
|-----|------|-----|------|
| 1 | OUTPUT 1 | 8 | $V^+$ |
| 2 | INVERTING INPUT 1 | 7 | OUTPUT 2 |
| 3 | NON-INVERTING INPUT 1 | 6 | INVERTING INPUT 2 |
| 4 | GND | 5 | NON-INVERTING INPUT 2 |

LM358

SOP-8L

## Applications

- Eliminates the need for dual supplies
- Compatible with all forms of logic
- Two internally compensated op amps
- Low power drain ideal for battery operation
- Allows direct sensing near GND
- $V_{OUT}$ can swing to GND

## Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, whilst operating from only a single power supply voltage.
- The unity gain crossing frequency is temperature compensated.
- The input bias current is temperature compensated.

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



*R not needed due to temperature independent I$_{IN}$
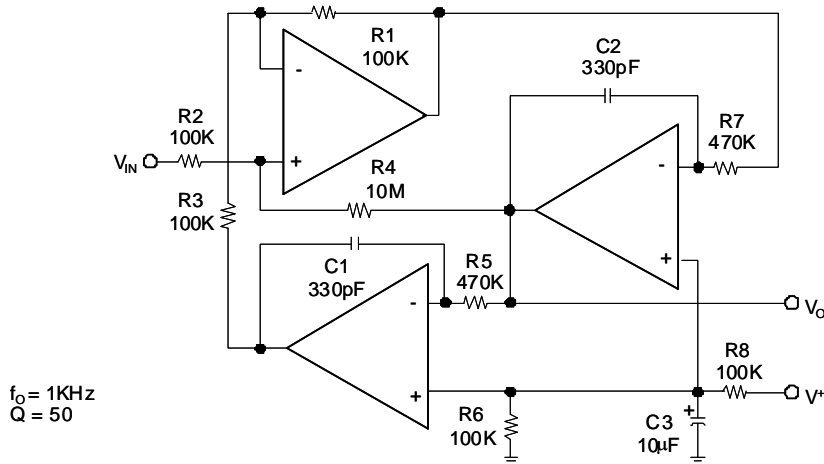
**Non-Inverting DC Gain (0V Output)**

$$GAIN = 1 + \frac{R2}{R1} = 101 \text{ (as shown)}$$
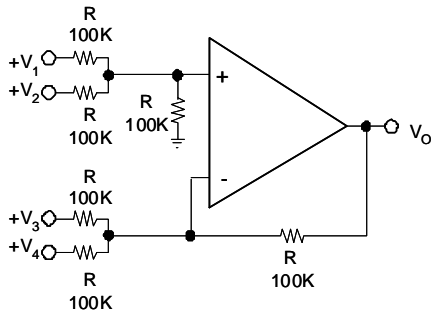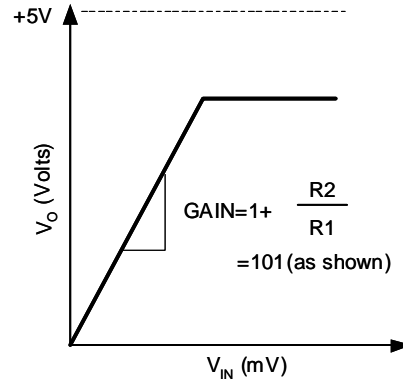


Where: $V_O = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2) > (V_3 + V_4)$ to keep $V_O > 0 \text{ V}_{DC}$

**DC Summing Amplifier**
**(V$_{IN'S}$ ≥ 0 V$_{DC}$ and V$_O$ ≥ 0 V$_{DC}$)**
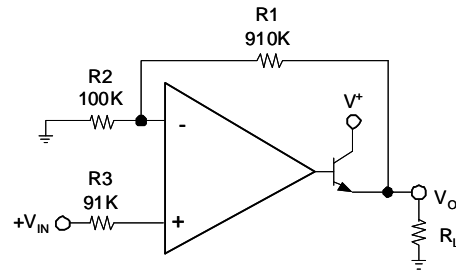


$V_O = 0 \text{ V}_{DC}$ for $V_{IN} = 0 \text{ V}_{DC}$
$A_V = 10$

**Power Amplifier**



$f_O = 1KHz$
$Q = 50$

**"BI-QUAD" RC Active Bandpass Filter**

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## LOW POWER DUAL OPERATIONAL AMPLIFIERS

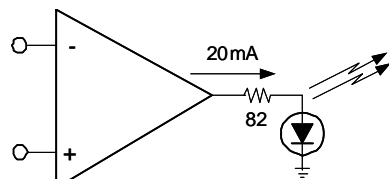## Typical Single-Supply Circuit (Continued) ($V^+$=5.0$V_{DC}$)

**Fixed Current Sources**

$I_1 = I_2$

**Current Monitor**

$$V_O = \frac{1V(I_L)}{0.1A}$$

*(Increase R1 for $I_L$ small)

$V_L \leq V+ -2V$
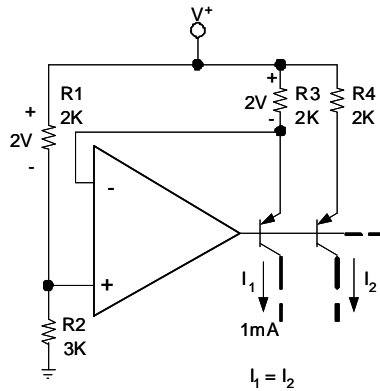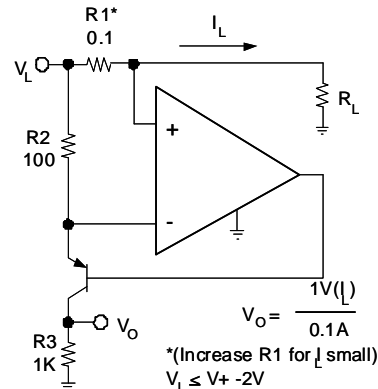
**LED Driver**
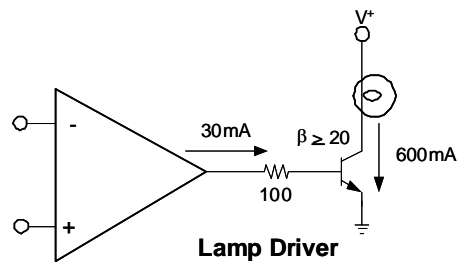
**Lamp Driver**
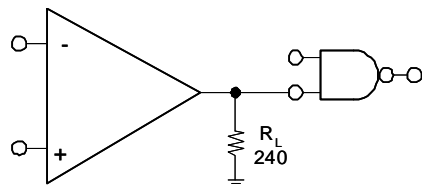
**Driving TTL**

**Voltage Follower**

$V_O = V_{IN}$
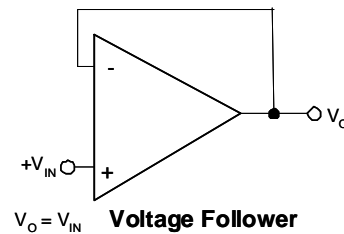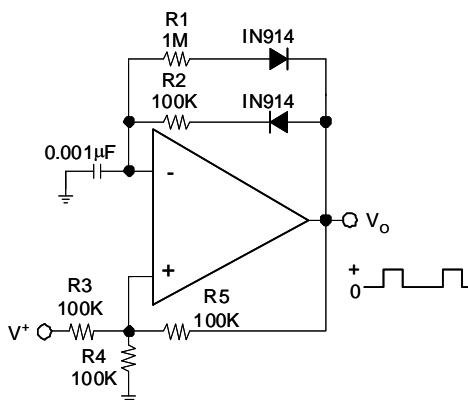
**Pulse Generator**

**Square wave Oscillator**

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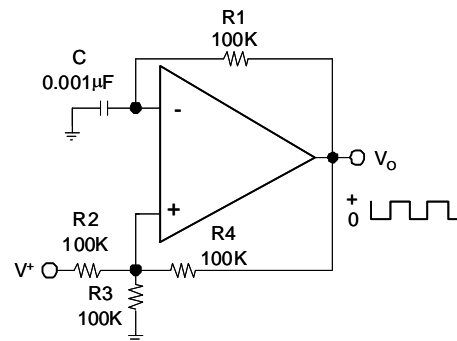
## Typical Single-Supply Circuit (Continued) ($V^+$=5.0$V_{DC}$)



**Low Drift Peak Detector**

$I_B$

$+V_{IN}$

$Z_{IN}$

C
1µF

(POLYCARBONATE OR
POLYETHYLENE)

HIGH $Z_{IN}$
LOW $Z_{OUT}$

*hi β AT 100 nA

$V_O$

$Z_{OUT}$

$I_B$

2N929*

$2I_B$

0.001µF

$I_B$

3R
3M

$2I_B$

R
IM

$I_B$

AUX AMP
INPUT CURRENT
COMPENSATION



**Pulse Generator**

R1
30K
IN914

R2
150K
0.01µF

R3
100K

$V^+$

R4
100K

R5
100K

$V_O$
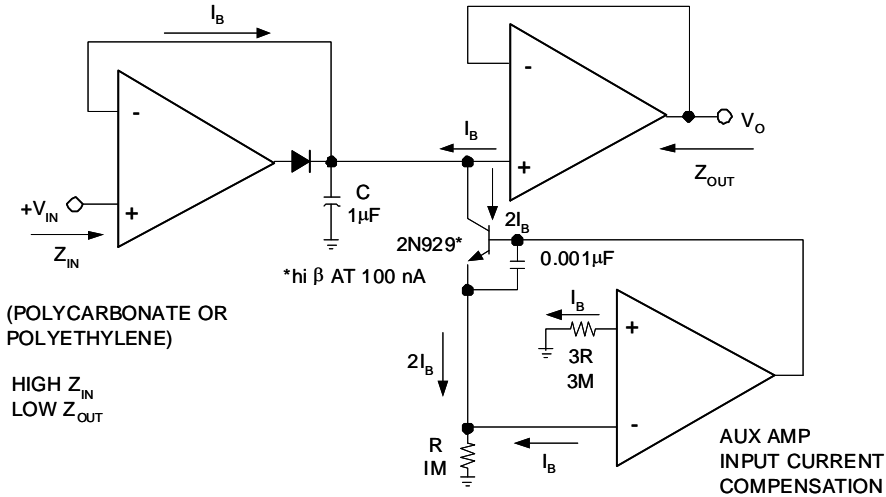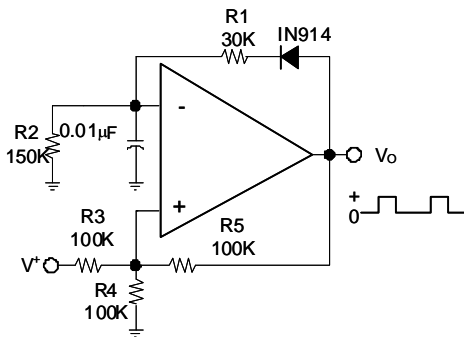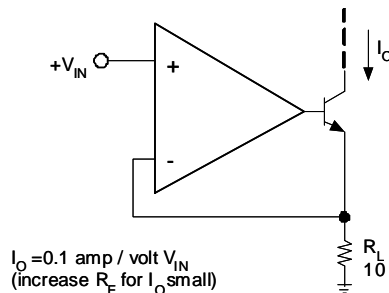


**High Compliance Current Sink**

$+V_{IN}$

$I_O$

$I_O$ =0.1 amp / volt $V_{IN}$
(increase $R_E$ for $I_O$ small)

$R_L$
10



**Voltage Controlled Oscillator (VCO)**

0.05µF

R
100K

$+V_C$*

51K

R/2
50K

51K

V$^+$/2  51K

100K

10K

OUTPUT1

OUTPUT2
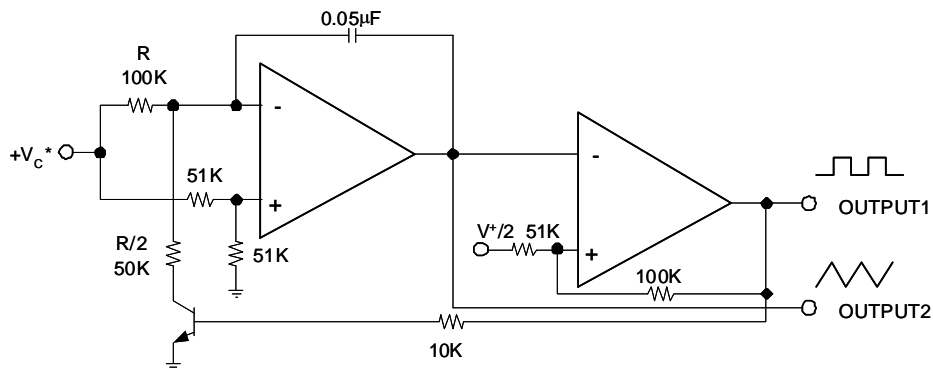
*WIDE CONTROL VOLTAGE RANGE: 0 $V_{DC}$ ≤ $V_C$ ≤ 2 ($V^+$ -1.5$V_{DC}$)

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## Typical Single-Supply Circuit (Continued) (V⁺=5.0V_DC)
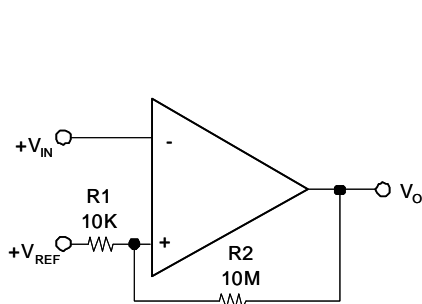


**Comparator with Hysteresis**



$$AV = \frac{R_f}{R_1} \text{ (As shown, } A_V = 10)$$
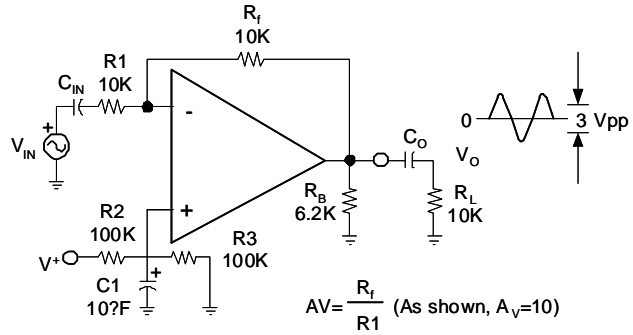
**AC Coupled Inverting Amplifier**
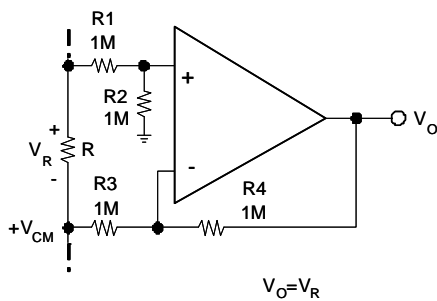


$$V_O = V_R$$

**Ground Referencing a Differential Input Signal**



$$A_V = 11 \text{(As Shown)}$$
$$A_V = 1 + \frac{R2}{R1}$$
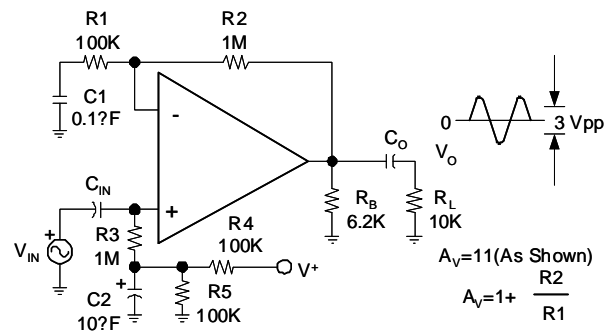
**AC Coupled Non-Inverting Amplifier**
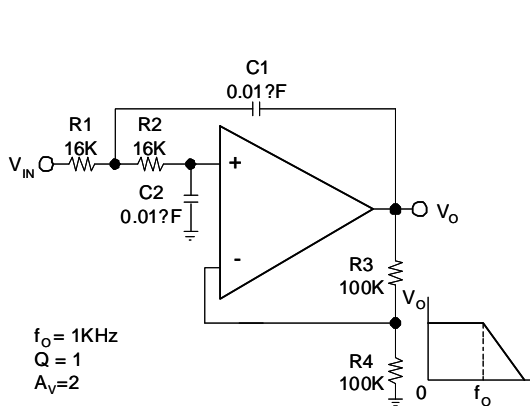


$$f_O = 1KHz$$
$$Q = 1$$
$$A_V = 2$$

**DC Coupled Low-Pass RC Active Filter**



$$\text{For } \frac{R1}{R2} = \frac{R4}{R3} \text{ (CMRR depends on this resistor ratio match)}$$
$$V_O = (1 + \frac{R4}{R3})(V_2 - V_1)$$
As Shown: $V_O = 2(V_2 - V_1)$
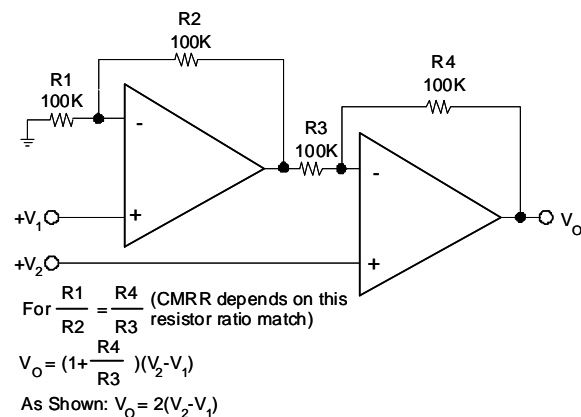
**High Input Z, DC Differential Amplifier**

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



$f_O$ = 1.12KHz
Q = 25
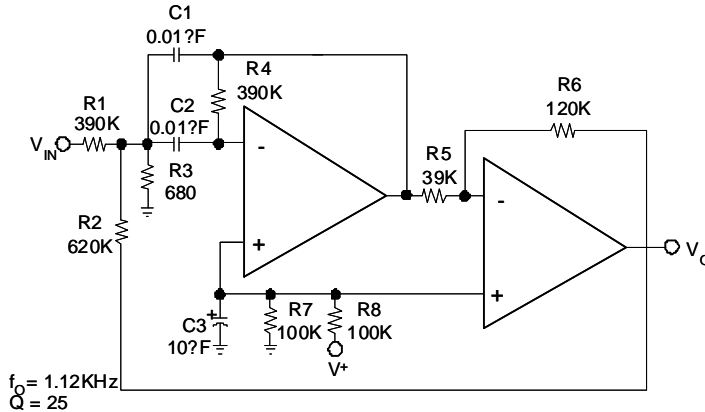
**Bandpass Active Filter**
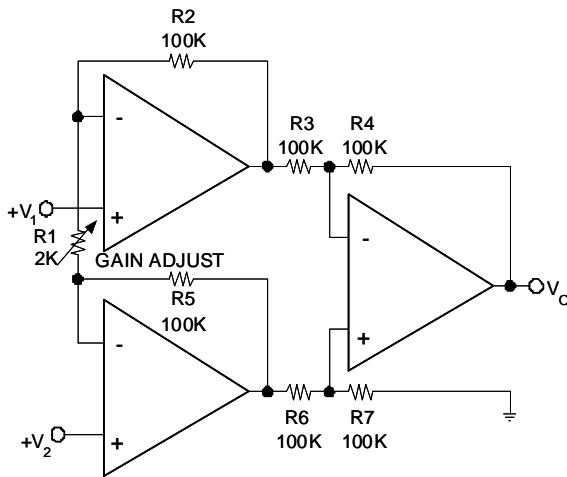


If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

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

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

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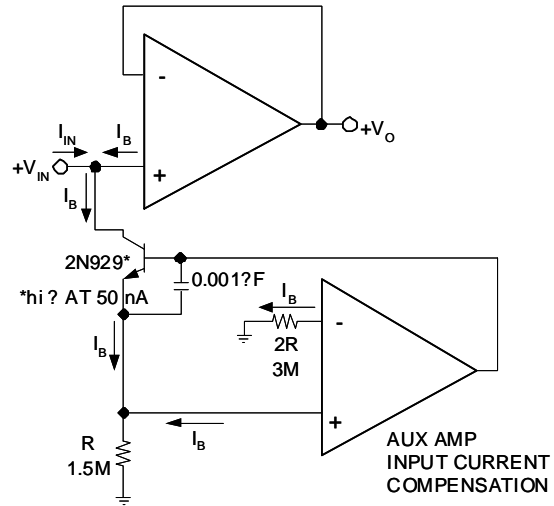


**Using Symmetrical Amplifiers to Reduce
Input Current (General Concept)**

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## Functional Block Diagram
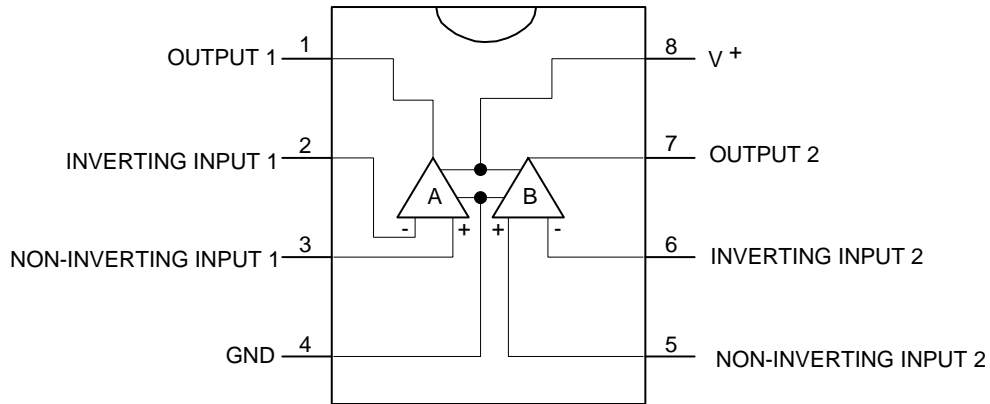


## Pin Descriptions

| 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 |

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## 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)** | $V^+ \leq 15V$ and $T_A=25^oC$ | Continuous | |
| | Input Current ($V_{IN} < -0.3V$) **(Note 4)** | | 40 | mA |
| $T_{OP}$ | Operating Temperature Range | | 0 to +70 | $^oC$ |
| $T_{ST}$ | Storage Temperature Range | | -65 to +150 | $^oC$ |

Notes:    2. 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.

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 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.

4. 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).
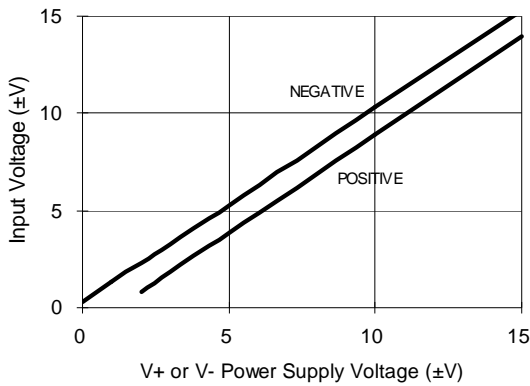
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## Electrical Characteristics (T$_A$ = 25$^o$C, V$^+$ = +5.0V, unless otherwise stated) (Note 5)

| Symbol | Parameter | Conditions | | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|---|
| V$_{IO}$ | Input Offset Voltage | T$_A$ = 25$^o$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 Over Full Temperature Range | R$_L$ = ∞ on All Op Amps | V$^+$ = 30V | - | 1 | 2 | mA |
| | | | 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$^o$C | 26 | - | - | V |
| | | | R$_L$ = 10kΩ, T$_A$ = 25$^o$C | 27 | 28 | - | V |
| V$_{OL}$ | | (V$^+$=5V) | R$_L$ = 10kΩ, T$_A$ = 25$^o$C | - | 5 | 20 | mV |

Notes:  5. The LM358 temperature specifications are limited to 0°C ≤ T$_A$ ≤ +70°C.
6. 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.
7. 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.
8. The input common-mode voltage of either input signal voltage should not be allowed to go negative by more than 0.3V (at25°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, independent of the magnitude of V$^+$.
9. 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.
10. 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 +15V, continuous short-circuits can exceed the power dissipation ratings and cause eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

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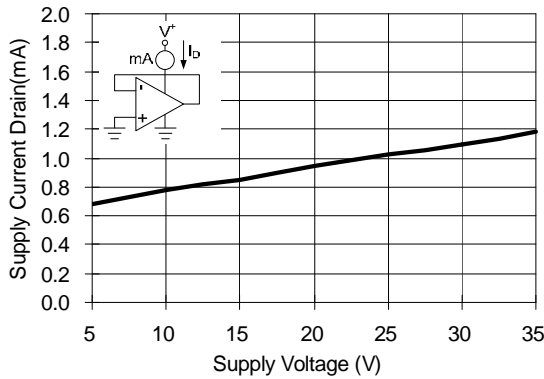## Typical Performance Characteristics
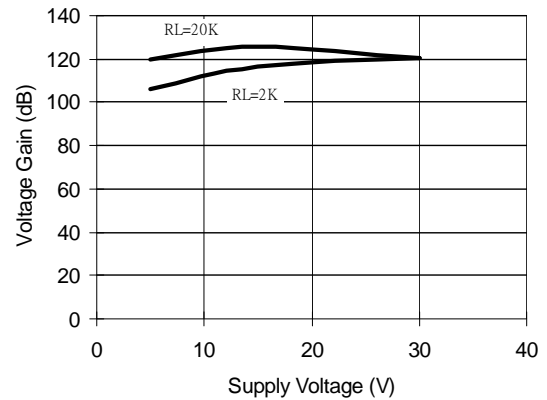
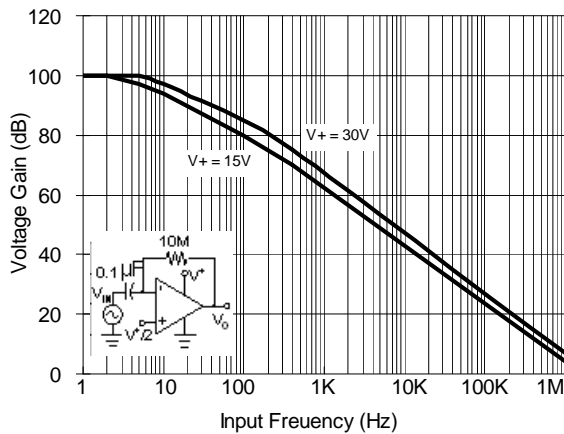**Input Voltage Range**

**Input Current vs Temperature**
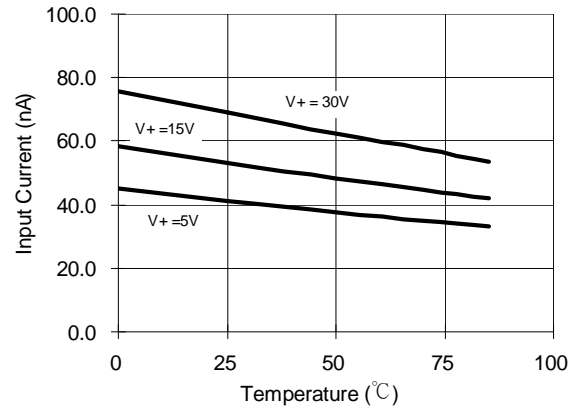
**Supply Current**

**Voltage Gain**

**Open Loop Frequency Response**

**Common-Mode Rejection Ratio**

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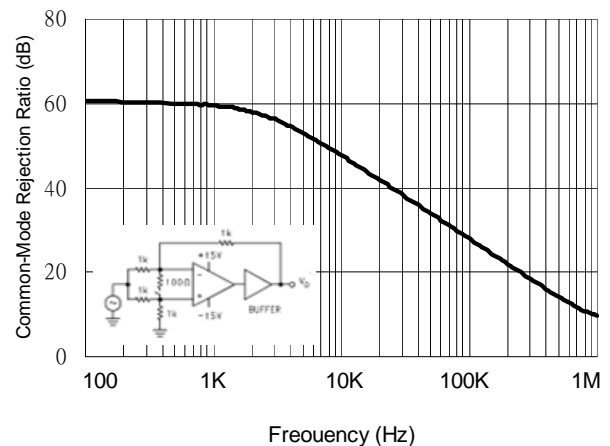
## Typical Performance Characteristics (Continued)

### Large Signal Frequency Response

Output Voltage(Vp-p) vs Input Freuency(HZ)

100K
1K
+15
$V_{DC}$
$V_O$
+7$V_{DC}$
2K
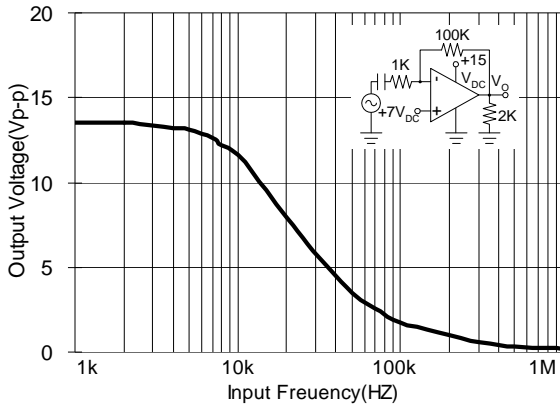
### Output Characteristics Current Sourcing

Output Voltage (V) vs Output Source Current (mA)

V⁺/2
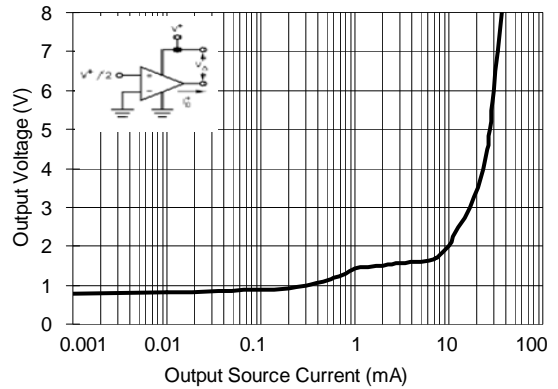
### Output Characteristics Current Sinking

Output Voltage (V) vs Output Sink Current (mA)

V+ = 5V
V+ = 30V
V+ =15V
V⁺/2
$T_A = +25°C$

### Current Limiting

Output Current (mA) vs Temperature (°C)

$I_O^+$

### Voltage Follower Pulse Response

Tek Stop

Δ: 2.52 V
@: 580mV
Δ: 4.80µs
@: −200ns

Ch1 Pk−Pk
2.60 V

Ch2 Pk−Pk
2.66 V

Ch1 1.00 V  Ch2 1.00 V  M 10.0µs  A  Ch1 ∫ 1.44 V

10.00 %

11 Jan 2011
14:17:20
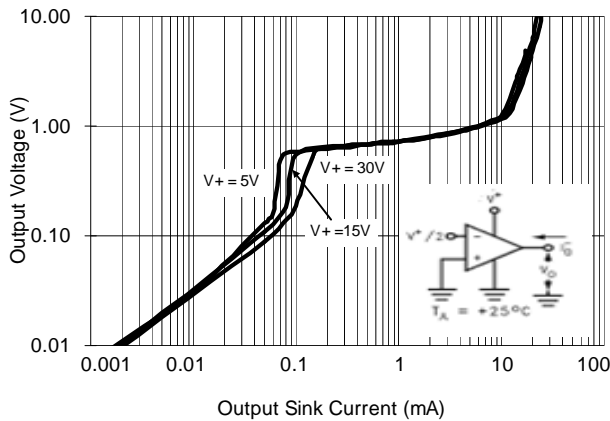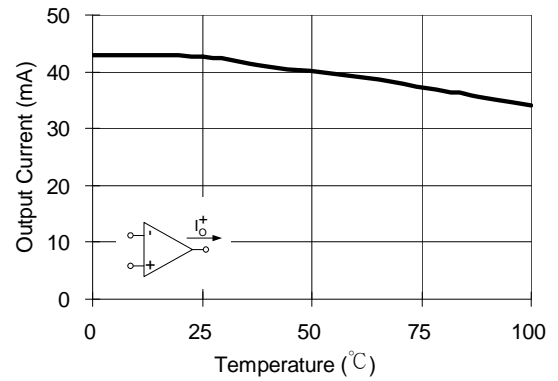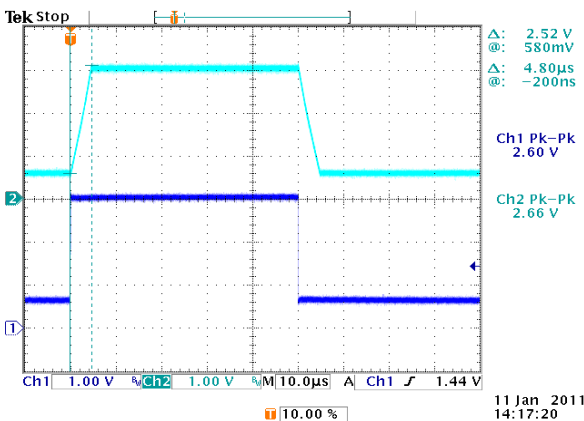
### Voltage Follower Pulse Response (Small Signal)

Tek Stop

50 pF

Ch1 Pk−Pk
108mV

Ch1 50.0mV  Ch2 50.0mV  M 1.00µs  A  Ch1 ∫ 337mV

70.60 %

11 Jan 2011
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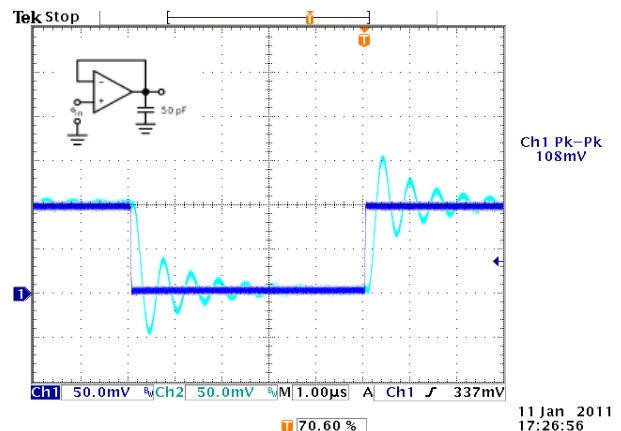
## Application Information

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.
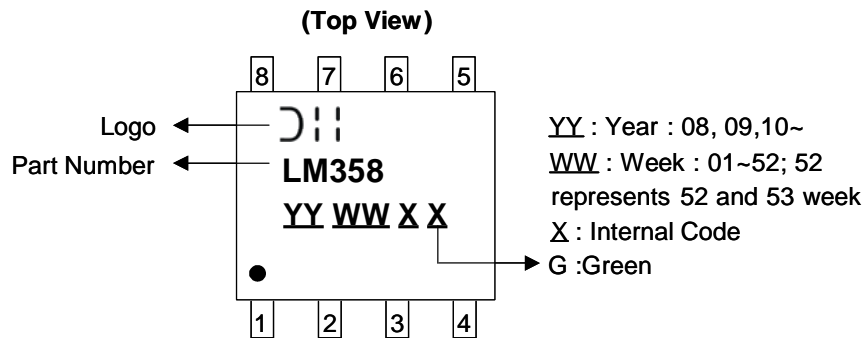
## LOW POWER DUAL OPERATIONAL AMPLIFIERS

## 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

**(Top View)**



Logo
Part Number

**LM358**
YY WW X X

YY : Year : 08, 09,10~
WW : Week : 01~52; 52 represents 52 and 53 week
X : Internal Code
G :Green

## Package Outline Dimensions (All Dimensions in mm)

**Package type: SOP-8L**



Land Pattern Recommendation
(Unit: mm)

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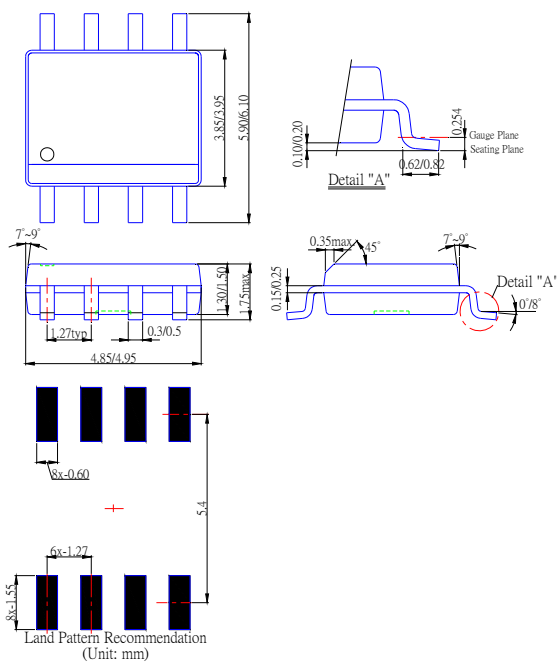
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