

## LM358 Operational Amplifier

### 1 Introduction

LM358 is an industry-standard operational amplifier. It consists of two independent operational amplifiers, each with high gain and low power consumption characteristics. LM358 is equivalent to half of LM324. The LM358 can operate at power voltages as low as 3.0 V or as high as 32 V, and supports the use of single or dual power sources for power supply. Therefore, LM358 is widely used in various application circuits, such as audio amplifiers, DC gain components, and conventional operational amplifier circuits.

### 2 Available Package

PART NUMBER	PACKAGE
LM358	SOP8

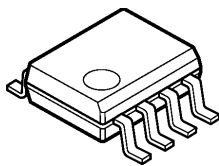
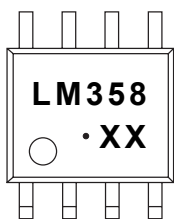


Figure 2-1. SOP8 Package



"LM358": Device number.  
 "." Solid Dot: Green molding compound device.  
 "XX": Code, indicates weekly record information.

Figure 2-2. Marking Information

### 3 Features

- Power supply range:
  - Single supply: 3.0 to 32V
  - Dual supplies:  $\pm 1.5$  to  $\pm 16$ V
- Two independent operational amplifiers built-in:
  - Equivalent to one-half of an LM324
  - Quiescent current of 500 $\mu$ A / channel
- Input offset voltage of 5mV max. at 25°C
- Low bias current of 45nA typ. at 25°C
- Unity-gain bandwidth of 1.0MHz typical
- Internally frequency compensated for unity gain
- Common-mode input voltage range includes ground

### 4 Applications

- Computer and motherboard
- Household electric appliances
- Inverter circuit
- Motor control
- Multi-functional printer
- Power supply and portable charger
- Uninterruptible power supply (UPS)

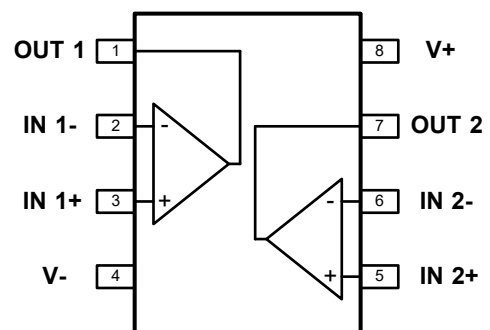


Figure 2-3. Pin Connections

## 5 Pin Configuration and Orderable Information

### 5.1 Pin Configuration and Function

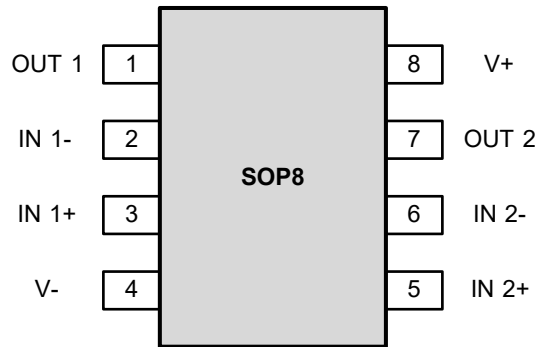


Figure 5-1. LM358 Pin Map

PIN NAME	LM358	I / O	DESCRIPTION
	SOP8		
OUT 1	1	O	Output of the operational amplifier 1.
IN 1-	2	I	Negative input of the operational amplifier 1.
IN 1+	3	I	Positive input of the operational amplifier 1.
V-	4	-	Negative (lowest) supply or ground for single supply.
IN 2+	5	I	Positive input of the operational amplifier 2.
IN 2-	6	I	Negative input of the operational amplifier 2.
OUT 2	7	O	Output of the operational amplifier 2.
V+	8	-	Positive (highest) supply.

### 5.2 Orderable Information

MODEL	DEVICE	PACKAGE	OP TEMP	ECO PLAN	MSL	PACKING OPTION	SORT
-	LM358	SOP8	0 ~ 70°C	RoHS & Green	Level 3 168 HR	Tape and Reel 4000 Units / Reel	Active
Others	-	-	-	-	-	-	Customized

**Note:**

**ECO PLAN:** For the RoHS and Green certification standards of this product, please refer to the official report provided by JSCJ.

**MSL:** Moisture Sensitivity Level. Determined according to JEDEC industry standard classification.

**SORT:** Specifically defined as follows:

Active: Recommended for new products;

Customized: Products manufactured to meet the specific needs of customers.

## 6 Specifications

### 6.1 Absolute Maximum Ratings

(over operating ambient temperature range, unless otherwise specified)<sup>(1)</sup>

CHARACTERISTIC		SYMBOL	VALUE	UNIT
Maximum power supply	Single supply	$V_S$	36	V
	Dual supplies		$\pm 18$	
Maximum differential input range <sup>(2)</sup>		$V_{ID}$	-36 ~ 36	V
Maximum input range (either input)		$V_{IN}$	-0.3 ~ 36	V
Duration of output short circuit (one amplifier) to ground (or below) at $T_A = 25^\circ\text{C}$ , $V_S \leq 15\text{V}$		$t_{SC}$	Continuous <sup>(3)</sup>	s
Maximum input pin current ( $V_{IN} < -0.3\text{V}$ ) <sup>(4)</sup>		$I_{IN}$	50	mA
Maximum junction temperature		$T_{J\text{MAX}}$	150	$^\circ\text{C}$
Storage temperature		$T_{stg}$	-65 ~ 150	$^\circ\text{C}$
Soldering temperature & time		$T_{solder}$	260 $^\circ\text{C}$ , 10s	-

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum rated conditions for extended periods may affect device reliability.

(2) Differential voltages are at  $IN+$ , with respect to  $IN-$ .

(3) Short circuits from outputs to  $V_S$  can cause excessive heating and eventual destruction. A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

(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  $-0.3\text{V}$  (at  $25^\circ\text{C}$ ).

### 6.2 Recommend Operating Conditions

(over operating ambient temperature range, unless otherwise specified)

PARAMETER		SYMBOL	MIN.	NOM.	MAX.	UNIT
Power supply range	Single supply	$V_S$	3.0	-	32	V
	Dual supplies		$\pm 1.5$	-	$\pm 16$	
Common-mode voltage range		$V_{CM}$	$V-$	-	$(V+) - 2.0$	V
Operating ambient temperature		$T_A$	0	-	70	$^\circ\text{C}$

## 6 Specifications

### 6.3 ESD Ratings

ESD RATINGS		SYMBOL	VALUE	UNIT
Electrostatic discharge <sup>(5)</sup>	Human body model	$V_{ESD-HBM}$	2000	V
	Machine model	$V_{ESD-MM}$	200	

(5) ESD testing is conducted in accordance with the relevant specifications formulated by the Joint Electronic Equipment Engineering Commission (JEDEC). The human body model (HBM) electrostatic discharge test is based on the JESD22-114D test standard, using a 100pF capacitor and discharging to each pin of the device through a resistance of 1.5kΩ. The electrostatic discharge test in mechanical model (MM) is based on the JESD22-115-A test standard and uses a 200pF capacitor to discharge directly to each pin of the device.

### 6.4 Thermal Information

THERMAL METRIC <sup>(6)</sup>	SYMBOL	LM358	UNIT
		SOP8	
Junction-to-ambient thermal resistance	$R_{\theta JA}$	164.9	°C/W
Junction-to-case thermal resistance	$R_{\theta JC}$	44.8	°C/W
Reference maximum power dissipation (continuous)	$P_{D Ref}$	0.61	W

(6)  $T_A = 25^\circ\text{C}$ , measured on evaluation board with 1oz. copper traces of minimum pad size, all device outputs were active.

## 6 Specifications

### 6.5 Electrical Characteristics

LM358 (for  $V_S = (V+) - (V-) = 5.0V$ ,  $T_A = 25^\circ C$ , unless otherwise specified)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS <sup>(7)</sup>	MIN.	TYP. <sup>(8)</sup>	MAX.	UNIT		
<b>Offset Voltage</b>								
Input offset voltage	$V_{OS}$	$V_S = 5.0V, V_{CM} = 0V, V_{OUT} = 1.4V$	-	±2.0	±5.0	mV		
Input offset voltage vs power supply ( $\Delta V_{IO} / \Delta V_S$ )	PSRR	$V_S = 5.0$ to 30V	65	100	-	dB		
<b>Input Voltage Range</b>								
Common-mode voltage range	$V_{CM}$	$V_S = 5.0$ to 30V	$T_A = 25^\circ C$	V-	-	(V+) - 1.5	V	
			$T_A = 0$ to 70°C	V-	-	(V+) - 2.0		
Common-mode rejection ratio	CMRR	$V_S = 5.0$ to 30V; $V_{CM} = 0V$	65	90	-	dB		
<b>Power Supply</b>								
Quiescent current per amplifier	$I_Q$	$R_L = \infty$	$V_S = 5.0V$	-	0.5	1.2	mA	
			$V_S = 30V$	-	1.0	2.0	mA	
<b>Input Bias Current</b>								
Input bias current	$I_{IB}$	$V_{CM} = 0V, V_{OUT} = 1.4V$	-	±45	±250	nA		
Input offset current	$I_{OS}$	$V_{CM} = 0V, V_{OUT} = 1.4V$	-	±3.0	±50	nA		
<b>Frequency Response</b>								
Gain bandwidth product	GBW	-	-	1.0	-	MHz		
Slew rate	SR	$G = +1$	-	0.4	-	V / $\mu s$		
<b>Output</b>								
Voltage output swing from rail	$V_{OUT}$	$V_S = 30V, R_L = 2k\Omega$	Positive rail	-	-	4.0	V	
		$V_S = 30V, R_L \geq 10k\Omega$		-	2.0	3.0		
		$V_S = 5.0V, R_L = 10k\Omega$	Negative rail	-	5.0	20	mV	
Output current	$I_{OUT}$	$V_S = 15V$	Source	$V_{OUT} = 0V, V_{ID} = 1V$	20	40	-	mA
			Sink	$V_{OUT} = 2V, V_{ID} = -1V$	10	15	-	mA
				$V_{OUT} = 0.2V, V_{ID} = -2V$	12	50	-	$\mu A$
Short-circuit current	$I_{SC}$	$V_S = 15V$	-	40	60	mA		
<b>Open-loop Gain</b>								
Open-loop voltage gain	$A_{OL}$	$V_S = 15V, V_{OUT} = 1.0$ to 11V, $R_L \geq 2k\Omega$	25	100	-	V / mV		

**Note:**

(7) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. Maximum  $V_S$  for testing purposes is 30V.

(8) All typical values are  $T_A = 25^\circ C$ .

## 6 Specifications

### 6.6 Typical Characteristics

LM358 ( $T_A = 25^\circ\text{C}$ , unless otherwise specified)

Figure 6-1. Input Voltage Range

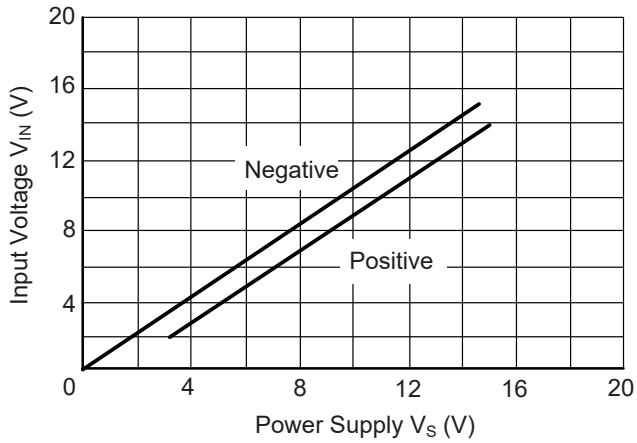


Figure 6-2. Large-Signal Open Loop Voltage Gain

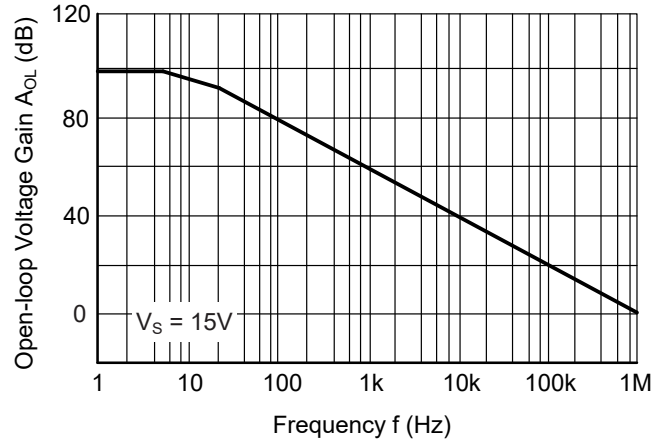


Figure 6-3. Large-Signal Frequency Response

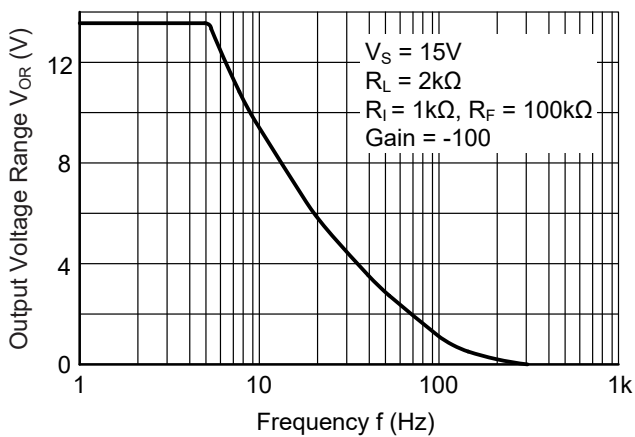


Figure 6-4. Small Signal Voltage Follower Pulse Response (Noninverting)

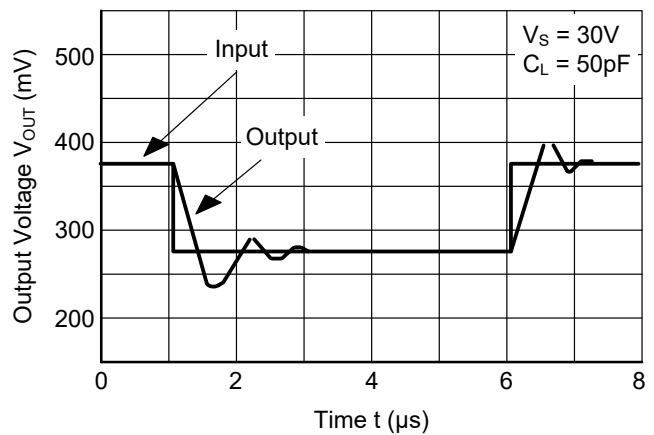


Figure 6-5. Power Supply Current

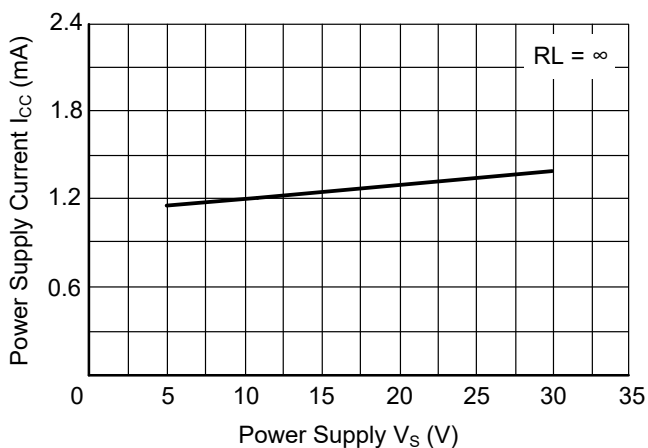
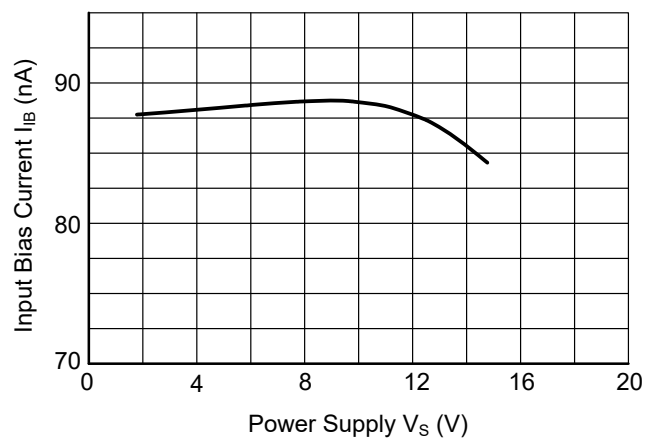


Figure 6-6. Input Bias Current

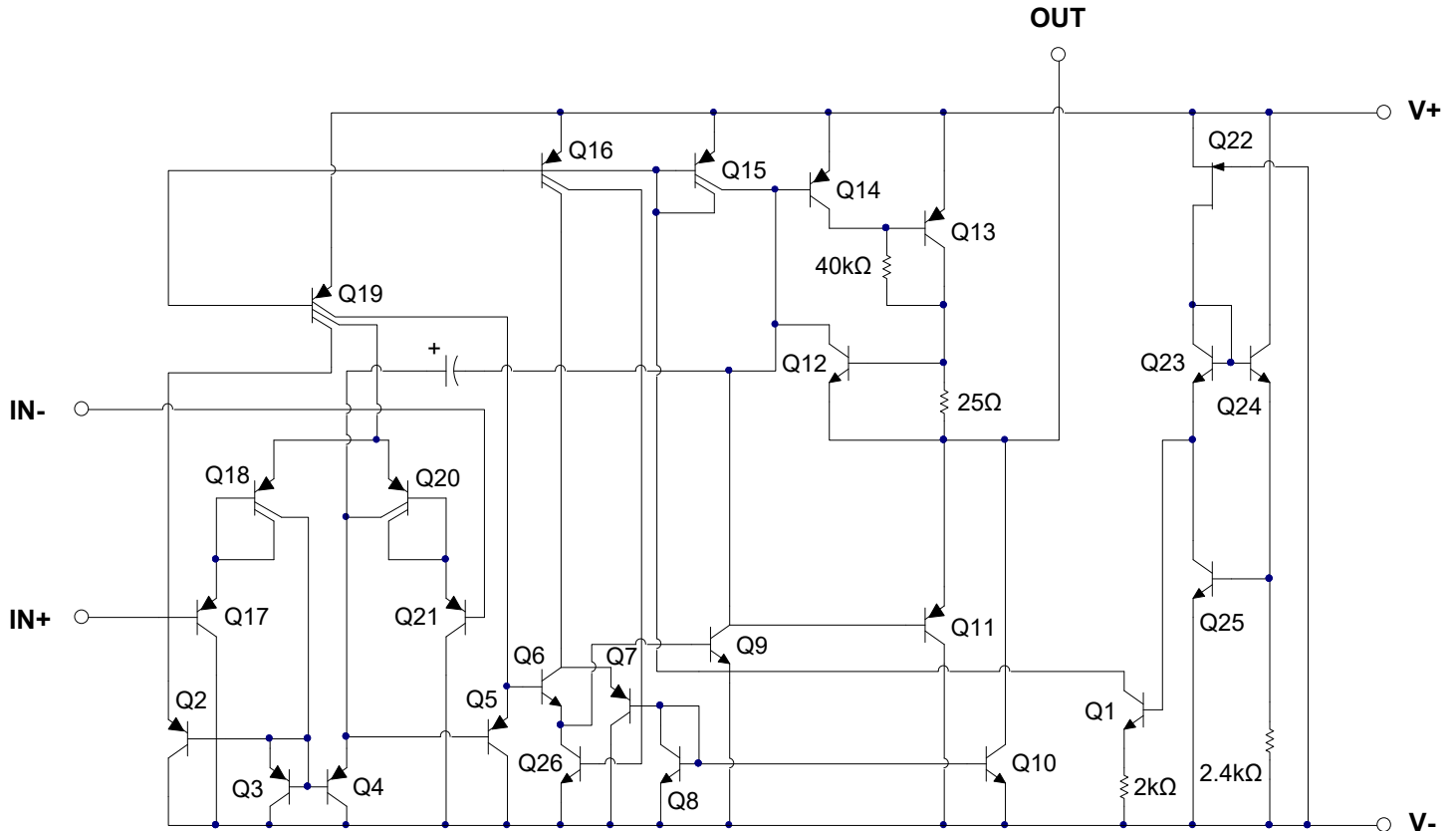


## 7 Detail Description

### 7.1 Description

The LM358 consists of two high gain, low-power consumption operational amplifiers, which can be powered by either a single power supply or a dual power supply. The  $V_S$  should be at least 1.5V higher than the input common mode voltage. The low power supply current is independent of the power supply voltage. The LM358 can be directly powered from a standard 5V power supply used in digital systems without the need for an additional  $\pm 5V$  power supply.

### 7.2 Representative Schematic Diagram



(One-half of Circuit Shown)

## 8 Application and Implementation

### 8.1 Typical Application Circuits

The LM358 is composed of two independent high gain operational amplifiers and supports the use of single or dual power supplies. The maximum supply voltage  $V_S$  can reach 32V and it has low power consumption current. Therefore, the LM358 is widely used in various operational amplifier circuits.

#### Basic Circuit

Figure 8-1 shows a typical application of LM358, where a positive voltage  $V_{IN}$  is input from IN and then output from OUT after passing through the circuit. The output voltage  $V_{OUT}$  of OUT has the opposite polarity to  $V_{IN}$ . At this point, the ratio of output voltage to input voltage is the gain  $A_V$ . Their relationship is shown by the following equation:

$$\frac{V_{IN}}{R_I} = \frac{-V_{OUT}}{R_F}$$

$$A_V = \frac{V_{OUT}}{V_{IN}} = -\frac{R_F}{R_I}$$

Once the required gain for circuit design is determined, a value can be selected for  $R_I$  and  $R_F$  based on the above formula. It is recommended to use a kilo-ohm level resistor to reduce the current consumed by the device in circuit use.

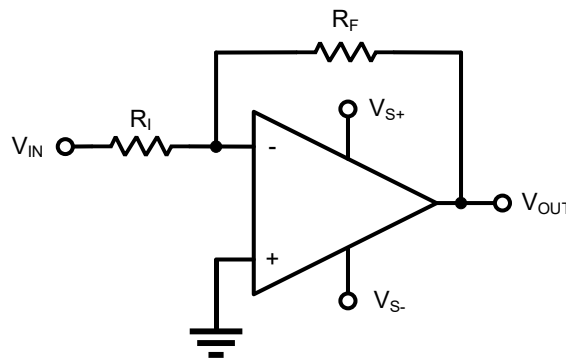


Figure 8-1. Basic Circuit

#### Power Supply

The LM358 can be powered by either a single power supply or a dual power supply, as shown in Figures 8-2 and 8-3. It is recommended to use a 0.1 $\mu$ F bypass capacitor and place it near the power pin to reduce noise or errors in high impedance power coupling. For more information, please refer to *Layout Guidelines*.

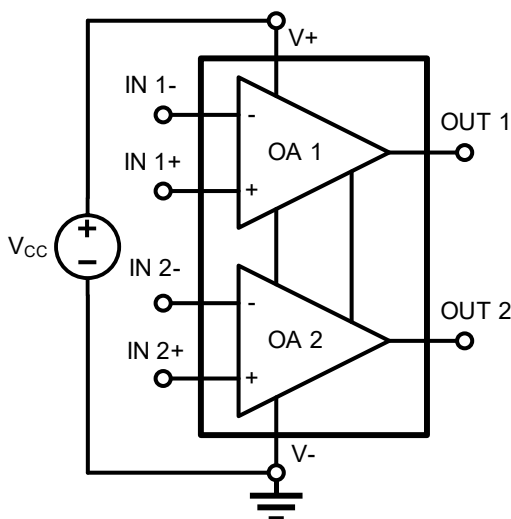


Figure 8-2. Single Power Supply

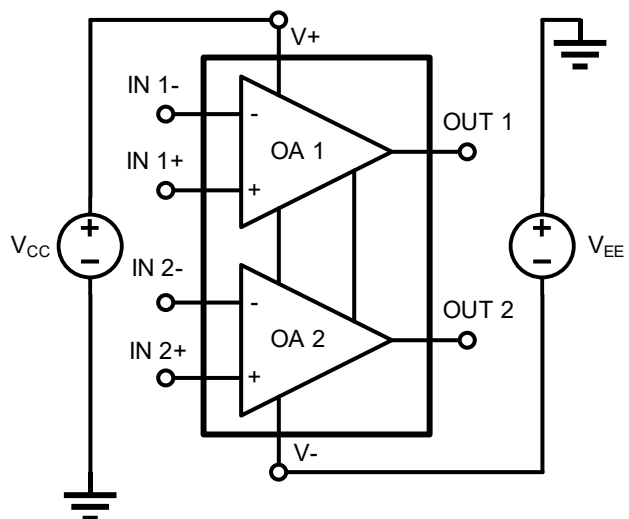


Figure 8-3. Dual Power Supply



## 8 Application and Implementation

### 8.1 Typical Application Circuits (continued)

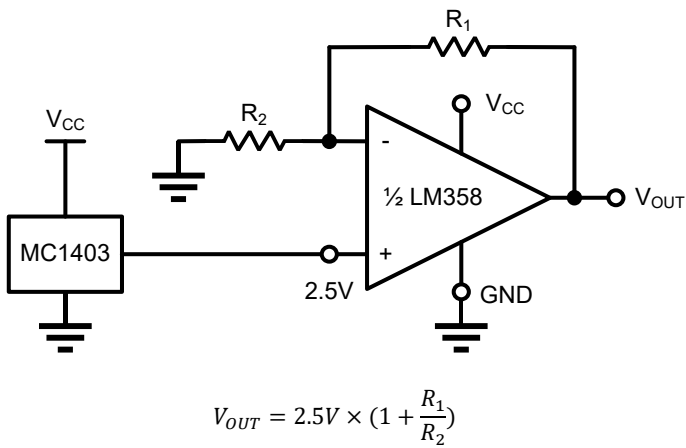


Figure 8-4. Voltage Reference

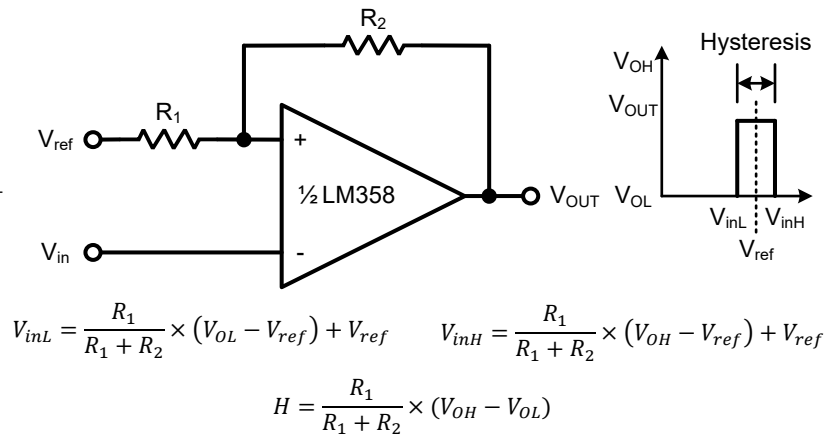


Figure 8-5. Comparator with Hysteresis

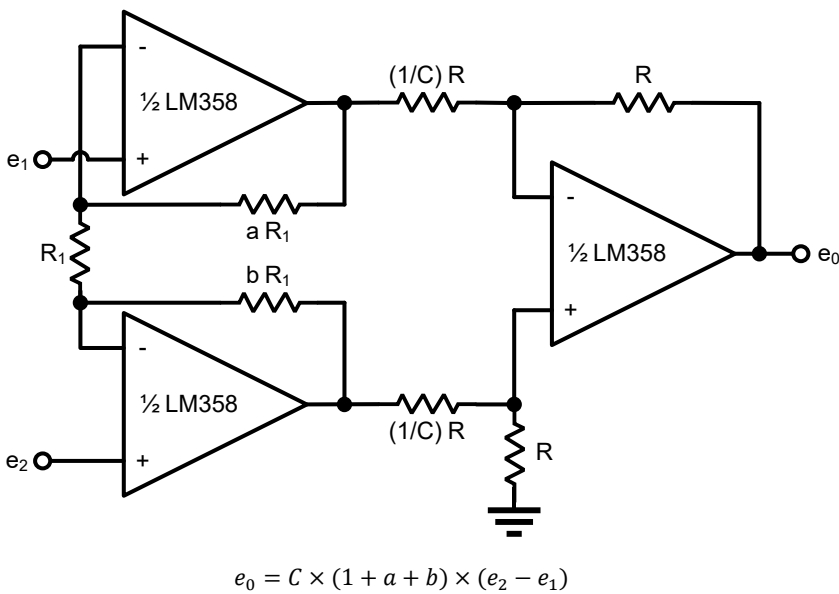
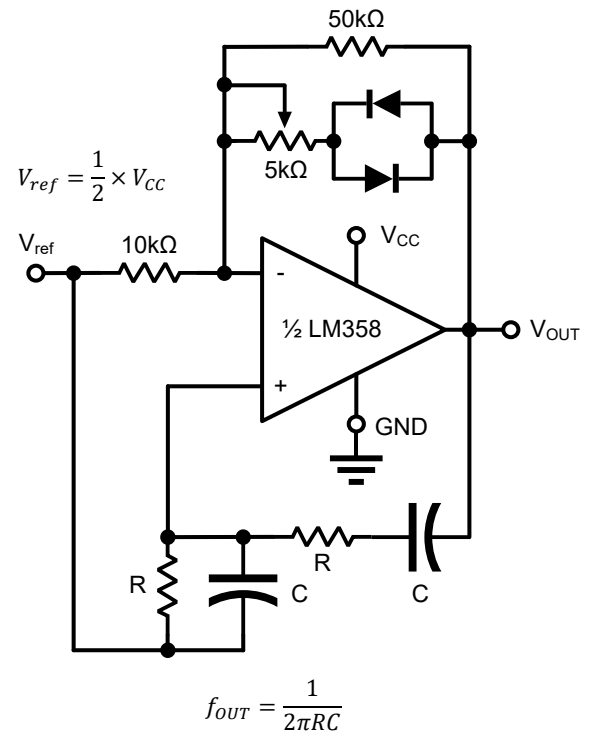


Figure 8-6. High Impedance Differential Amplifier



For  $f_{OUT} = 1\text{kHz}$ ,  $R = 16\text{k}\Omega$ ,  $C = 0.01\mu\text{F}$

Figure 8-8. Wien Bridge Oscillator

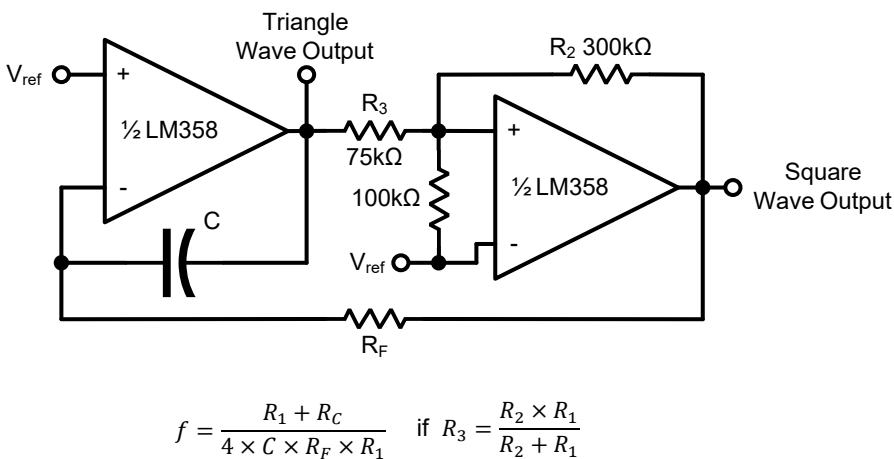


Figure 8-7. Function Generator

8 Application and Implementation

8.1 Typical Application Circuits (continued)

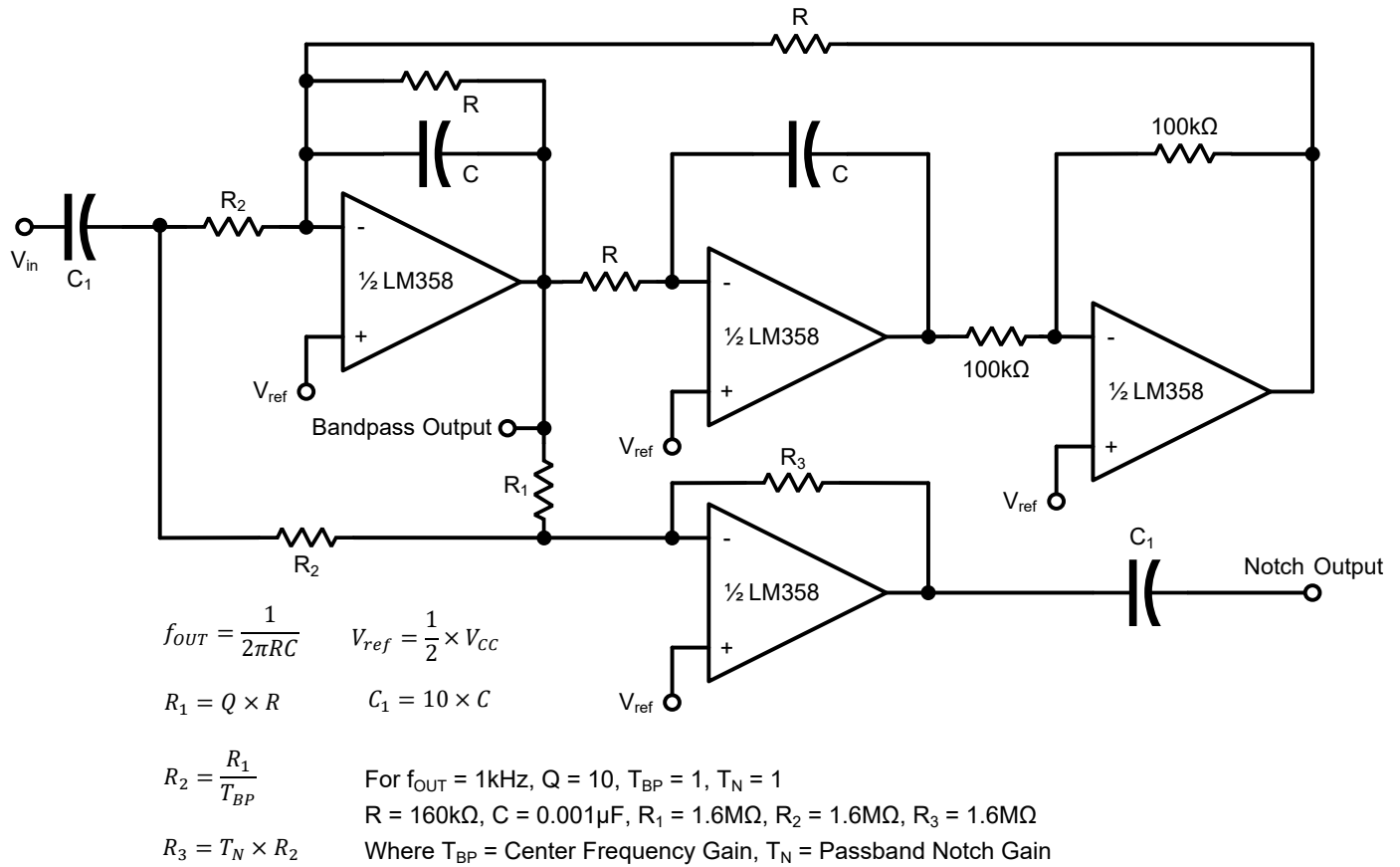
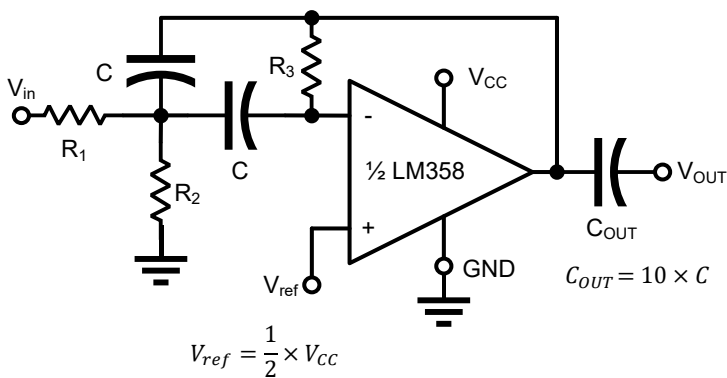


Figure 8-9. Bi-Quad Filter



Given:  $f_{OUT}$  = Center Frequency  
 $A(f_{OUT})$  = Gain at Center Frequency  
 Choose value  $f_{OUT}$ ,  $C$ , then:

$$R_3 = \frac{Q}{\pi \times f_{OUT} \times C} \quad R_1 = \frac{R_3}{2 \times A(f_{OUT})} \quad R_2 = \frac{R_1 \times R_3}{4 \times Q^2 \times R_1 + R_3}$$

For less than 10% error from operational amplifier.

$$\frac{Q_{OUT} \times f_{OUT}}{BW} < 0.1$$

Where  $f_{OUT}$  and  $BW$  are expressed in HZ.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

Figure 8-10. Multiple Feedback Bandpass Filter

## 8 Application and Implementation

### 8.2 Layout Guidelines

LM358 is widely used in various operational amplifier circuits. The following points should be taken in circuit design and PCB layout to help devices obtain the best operating performance:

1. Signal transmission traces should be as far away as possible from power supply traces to reduce parasitic coupling. It is recommended that signal traces be kept at least 5mm away from power supply lines. If the layout of the circuit does not allow this, it is better to lay out these traces vertically to avoid being parallel to each other as much as possible;
2. The length of the power supply traces should be as short as possible and bypass the power supply appropriately so as to reduce the power disturbance caused by current changes, such as when driving an AC signal to a heavy load;
3. It is recommended to use a bypass capacitor between each power supply pin (single power supply is V+, dual power supply is V+ and V-) and ground to reduce coupling noise transmitted through the power supply pins and operational amplifiers to the entire circuit. It is recommended to use ceramic bypass capacitors with low ESR and 0.1 $\mu$ F, and ensure that they are placed as close as possible to the corresponding pins of the device;
4. External components should be placed as close as possible to the device, and keeping RI and RF close to the input can minimize parasitic capacitance.
5. Analog grounding and digital grounding should be physically separated. Grounding the analog and digital parts of the circuit separately is a very simple but effective method for suppressing noise. When designing and laying out a multi-layer PCB circuit, one or more layers can be dedicated to a grounding layer, which can reduce EMI noise and help distribute appropriate heat on the circuit board;
6. Make sure the surface of the printed circuit board is clean and moisture-free. Use a surface coating to prevent moisture accumulation and help reduce parasitic resistance on the printed circuit board. Consider setting a low impedance guard ring (as shown in Figure 8-11) for the driver around the critical trace. The guard ring can significantly reduce the leakage current of nearby traces at different potentials.

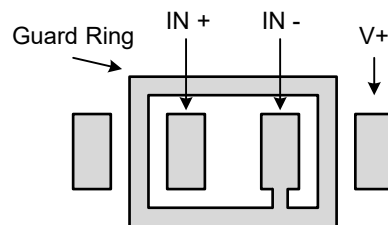


Figure 8-11. Guard Ring

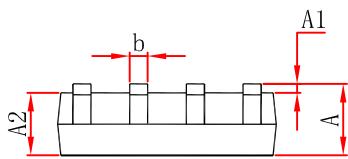
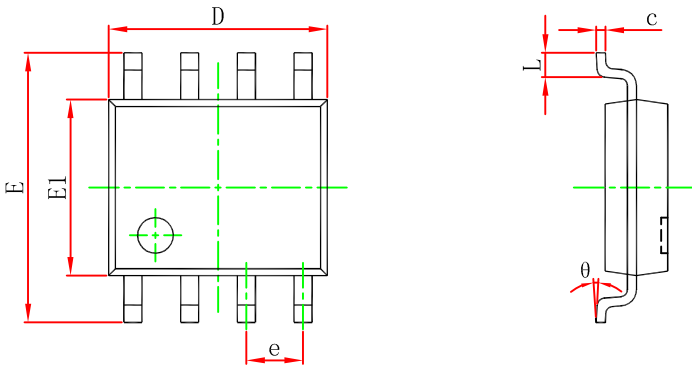
#### NOTE

The application information in this section is not part of the data sheet component specification, and JSCJ makes no commitment or statement to guarantee its accuracy or completeness. Customers are responsible for determining the rationality of corresponding components in their circuit design and making tests and verifications to ensure the normal realization of their circuit design.

9 Mechanical Information

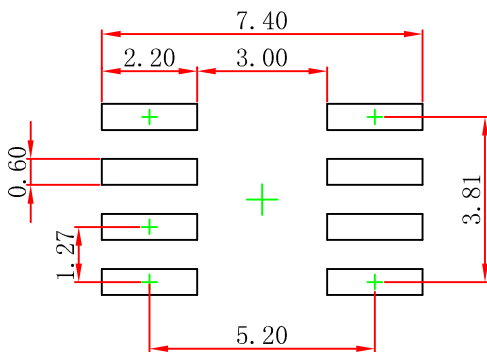
SOP8 Mechanical Information

Outline Dimensions



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.450	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
e	1.270 (BSC)		0.050 (BSC)	
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
L	0.400	1.270	0.016	0.050
theta	0°	8°	0°	8°

SOP8 Suggest Pad Layout



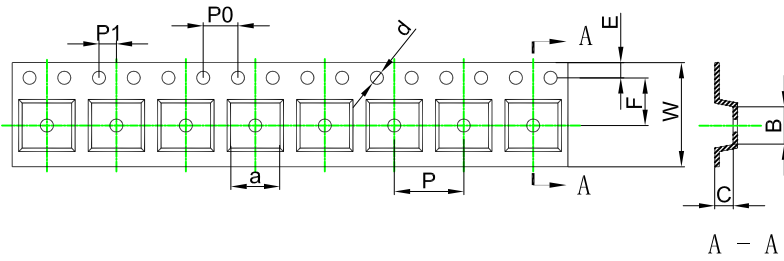
NOTE:

1. Controlling dimension: in millimeters.
2. General tolerance: ±0.05mm.
3. The pad layout is for reference purposes only.

## 10 Packaging Information

### SOP8 Tape and Reel Information

#### Embossed Carrier Tape



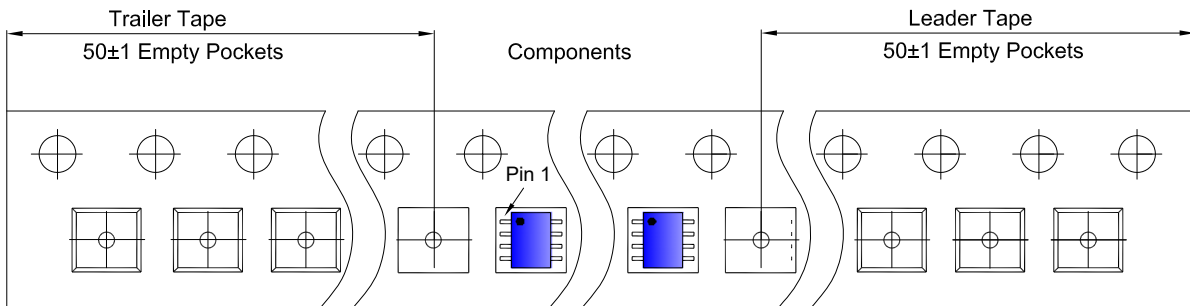
**Packaging Description:**

SOP8 parts are shipped in tape. The carrier tape is made from a dissipative (carbon filled) polycarbonate resin. The cover tape is a multilayer film (Heat Activated Adhesive in nature) primarily composed of polyester film, adhesive layer, sealant, and anti-static sprayed agent. These reeled parts in standard option are shipped with 2,500 units per 13" or 33cm diameter reel. The reels are clear in color and is made of polystyrene plastic (anti-static coated).

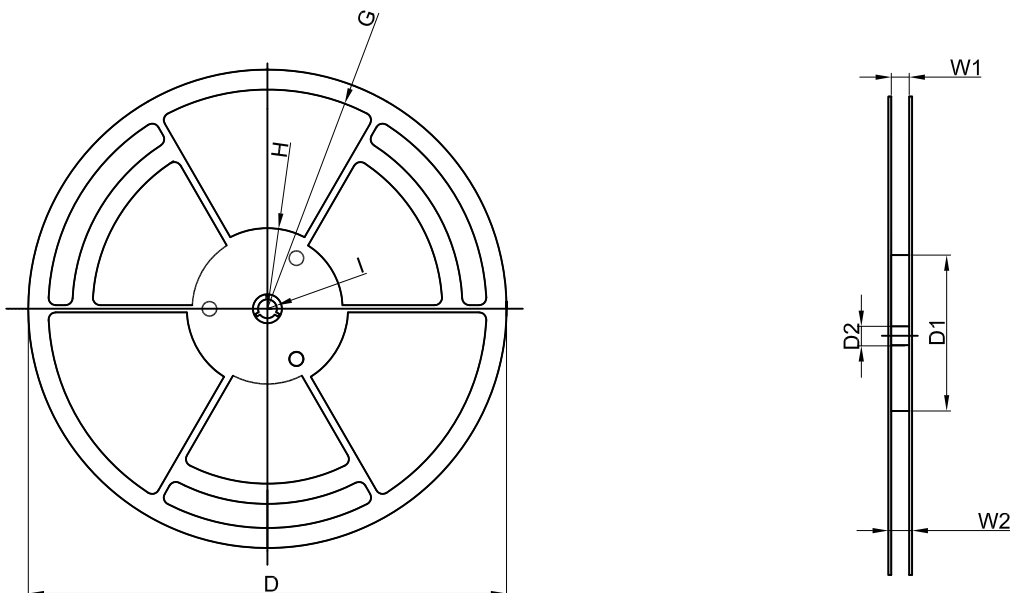
ALL DIM IN mm

Dimensions are in millimeter										
Pkg type	a	B	C	d	E	F	P0	P	P1	W
SOP8	6.40	5.40	2.10	Ø1.50	1.75	5.50	4.00	8.00	2.00	12.00

#### Tape Leader and Trailer



#### Reel



Dimensions are in millimeter								
Reel Option	D	D1	D2	G	H	I	W1	W2
13" Dia	Ø330.00	100.00	13.00	R151.00	R56.00	R6.50	12.40	17.60

REEL	Reel Size	Box	Box Size(mm)	Carton	Carton Size(mm)	G.W.(kg)
4,000 pcs	13 inch	8,000 pcs	360×360×65	64,000 pcs	565×380×390	

## 11 Notes and Revision History

### 11.1 Associated Product Family and Others

To view other products of the same type or IC products of other types, click the official website of JSCJ -- <https://www.jscj-elec.com> for more details.

### 11.2 Notes

#### Electrostatic Discharge Caution



This IC may be damaged by ESD. Relevant personnel shall comply with correct installation and use specifications to avoid ESD damage to the IC. If appropriate measures are not taken to prevent ESD damage, the hazards caused by ESD include but are not limited to degradation of integrated circuit performance or complete damage of integrated circuit. For some precision integrated circuits, a very small parameter change may cause the whole device to be inconsistent with its published specifications.

### 11.3 Revision History

May, 2023: released LM358 rev -1.0.

# DISCLAIMER

## **IMPORTANT NOTICE, PLEASE READ CAREFULLY**

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