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

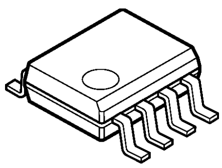
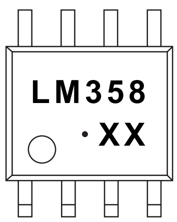


Figure 2-1. SOP8 Package



"**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: ±1.5 to ±16V
- Two independent operational amplifiers built-in:
  - Equivalent to one-half of an LM324
  - Quiescent current of 500μA / 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)

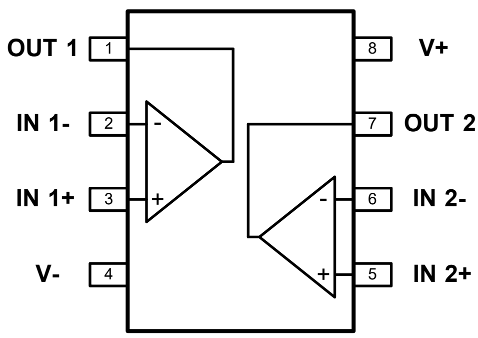


Figure 2-3. Pin Connections

5 Pin Configuration and Orderable Information

5.1 Pin Configuration and Function

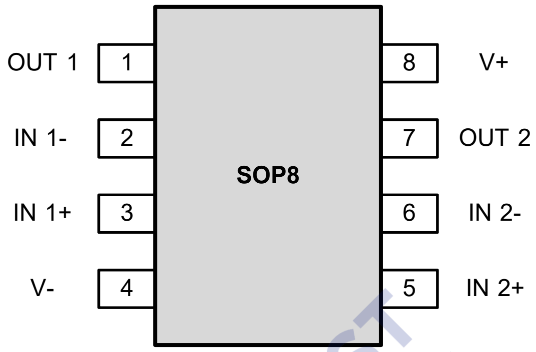


Figure 5-1. LM358 Pin Map

PIN NAME	LM358 SOP8	I / O	DESCRIPTION
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 reportprovided 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)(1)

CHARACTERISTIC		SYMBOL	VALUE	UNIT
Maximum power supply	Single supply	V_S	36	V
	Dual supplies		±18	
Maximum differential input range(2)		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°C, V_S ≤ 15V		t_{SC}	Continuous(3)	s
Maximum input pin current (V_{IN} < -0.3V)(4)		I_{IN}	50	mA
Maximum junction temperature		$T_{J\ MAX}$	150	°C
Storage temperature		T_{stg}	-65 ~ 150	°C
Soldering temperature & time		T_{solder}	260°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 -0.3V (at 25°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		±1.5	-	±16	
Common-mode voltage range		V_{CM}	V-	-	(V+) - 2.0	V
Operating ambient temperature		T_A	0	-	70	°C

6 Specifications

6.3 ESD Ratings

ESD RATINGS		SYMBOL	VALUE	UNIT
Electrostatic discharge(5)	Human body model	$V_{ESD\text{-}HBM}$	2000	V
	Machine model	$V_{ESD\text{-}MM}$	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(6)	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°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°C, unless otherwise specified)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS(7)		MIN.	TYP.(8)	MAX.	UNIT
Offset Voltage							
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 (ΔV_{IO} / ΔV_S)	PSRR	V_S = 5.0 to 30V		65	100	-	dB
Input Voltage Range							
Common-mode voltage range	V_{CM}	V_S = 5.0 to 30V	T_A = 25°C	V-	-	(V+) - 1.5	V
			T_A = 0 to 70°C	V-	-	(V+) - 2.0	V
Common-mode rejection ratio	CMRR	V_S = 5.0 to 30V; V_{CM} = 0V		65	90	-	dB
Power Supply							
Quiescent current per amplifier	I_Q	R_L = ∞	V_S = 5.0V	-	0.5	1.2	mA
			V_S = 30V	-	1.0	2.0	mA
Input Bias Current							
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
Frequency Response							
Gain bandwidth product	GBW	-		-	1.0	-	MHz
Slew rate	SR	G = +1		-	0.4	-	V / μs
Output							
Voltage output swing from rail	V_{OUT}	V_S = 30V, R_L = 2kΩ	Positive rail	-	-	4.0	V
		V_S = 30V, R_L ≥ 10kΩ	Positive rail	-	2.0	3.0	V
		V_S = 5.0V, R_L = 10kΩ	Negative rail	-	5.0	20	mV
Output current	I_{OUT}	V_S = 15V, V_{OUT} = 0V, V_{ID} = 1V	Source	20	40	-	mA
		V_S = 15V, V_{OUT} =2V, V_{ID} = -1V	Sink	10	15	-	mA
		V_S = 15V, V_{OUT} =0.2V, V_{ID} = -2V	Sink	12	50	-	μA
Short-circuit current	I_{SC}	V_S = 15V		-	40	60	mA
Open-loop Gain							
Open-loop voltage gain	A_{OL}	V_S = 15V, V_{OUT} = 1.0 to 11V, R_L ≥ 2kΩ		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°C.

6 Specifications

6.6 Typical Characteristics

LM358 (T_A = 25°C, unless otherwise specified)

Figure 6-1. Input Voltage Range

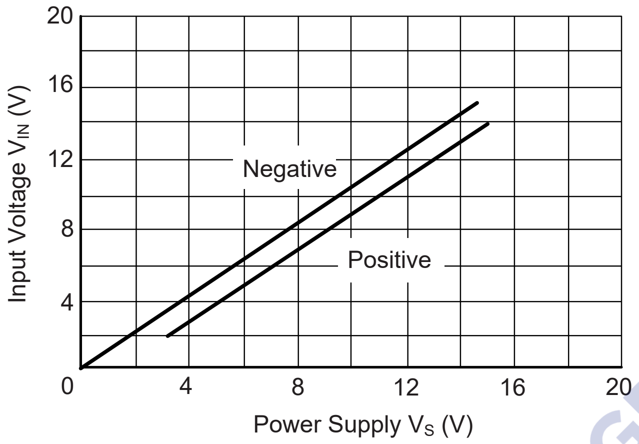


Figure 6-2. Large-Signal Open Loop Voltage Gain

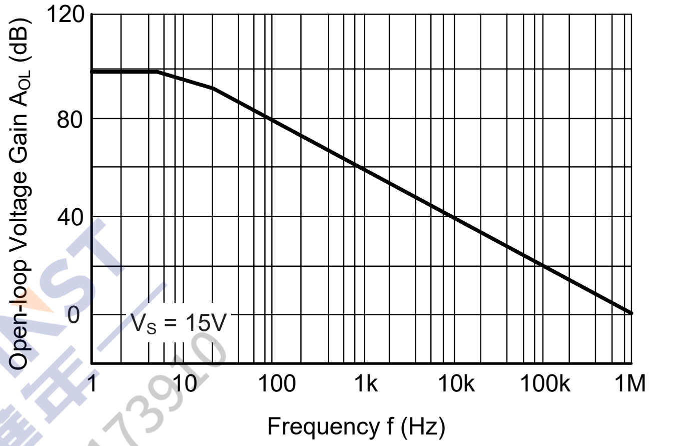


Figure 6-3. Large-Signal Frequency Response

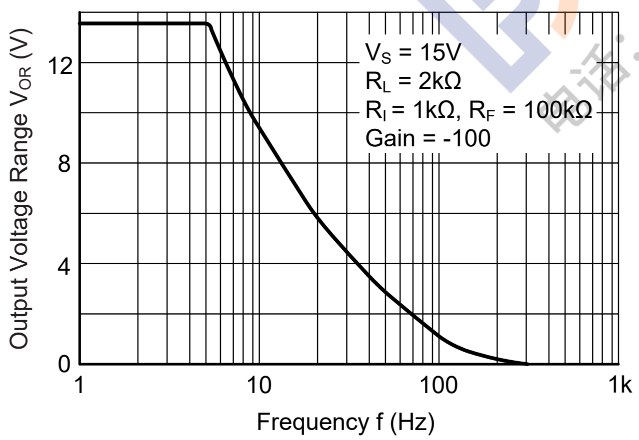


Figure 6-4. Small Signal Voltage Follower Pulse Response (Noninverting)

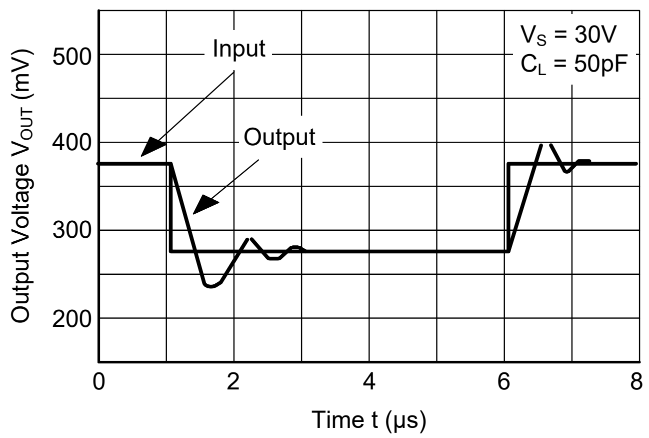


Figure 6-5. Power Supply Current

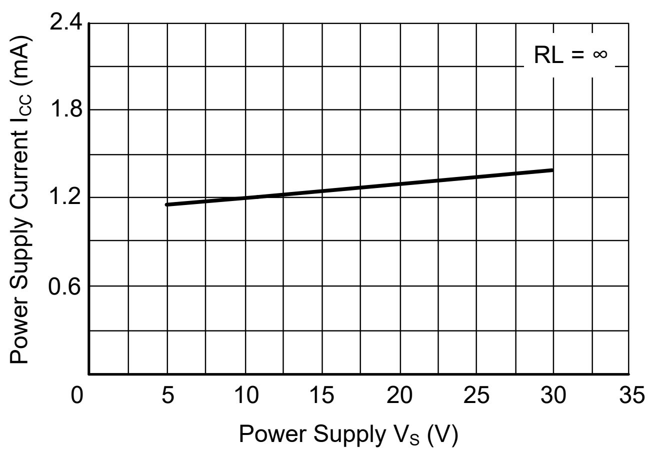
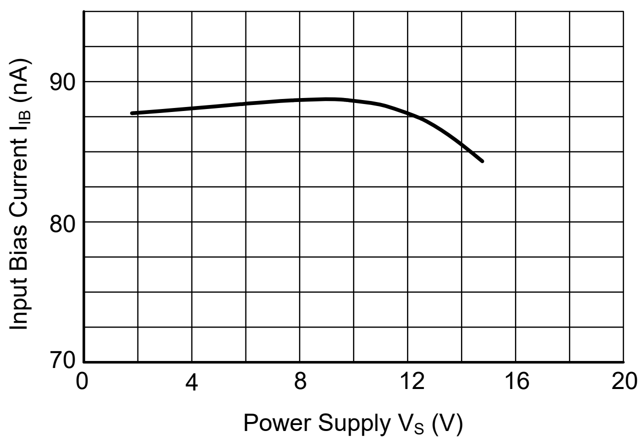


Figure 6-6. Input Bias Current

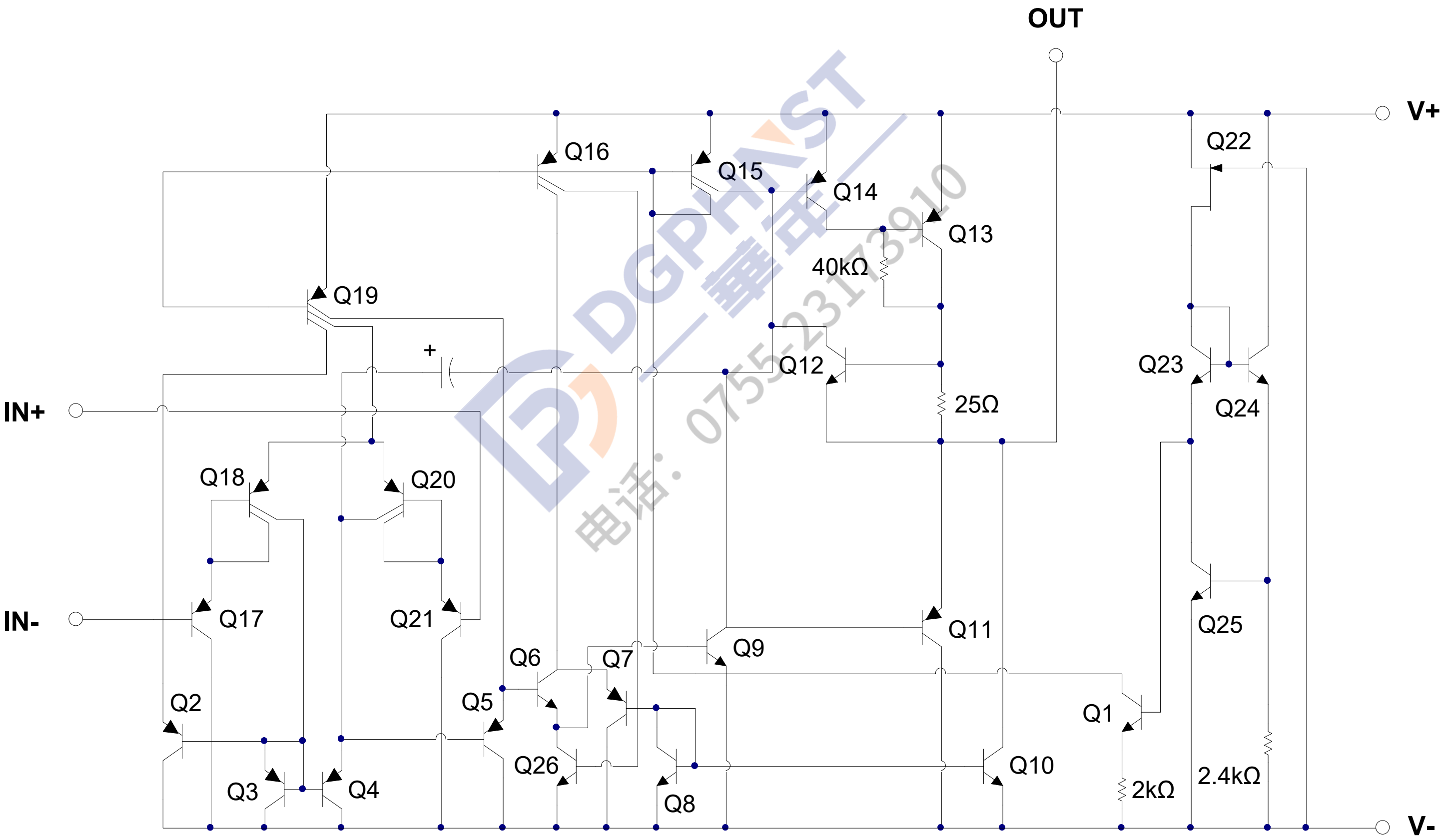


7 Detail Description

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 ± 5V power supply.

7.2 Representative Schematic Diagram



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 9-1 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.

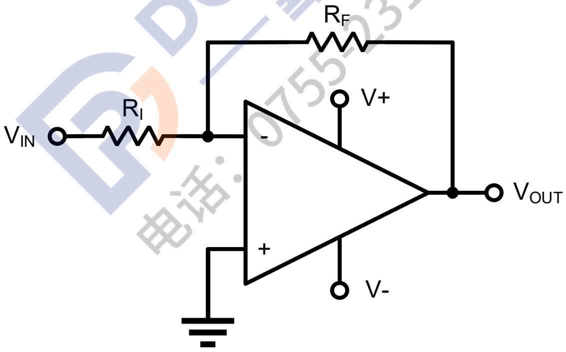


Figure 8-1. Basic Circuit

Power Supply

The LM358 can be powered by either a single power supply or a dual power supply, as shown in Figures 9-2 and 9-3. It is recommended to use a 0.1μF 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*.

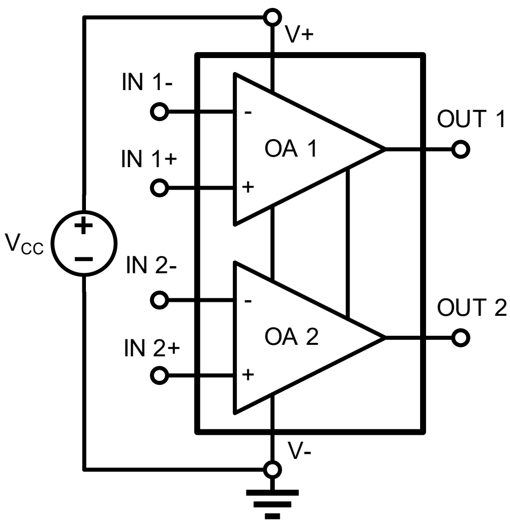


Figure 8-2. Single Power Supply

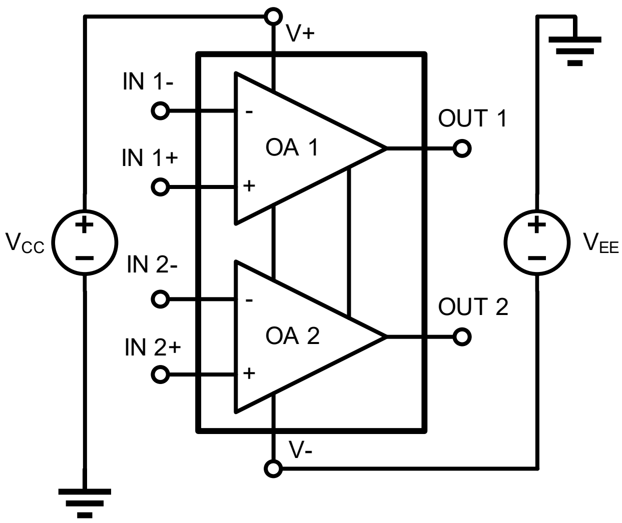
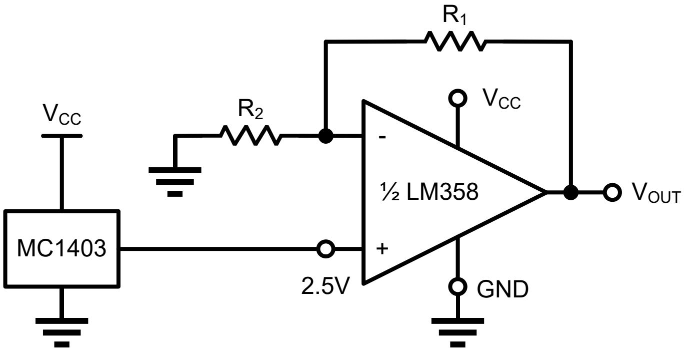


Figure 8-3. Dual Power Supply

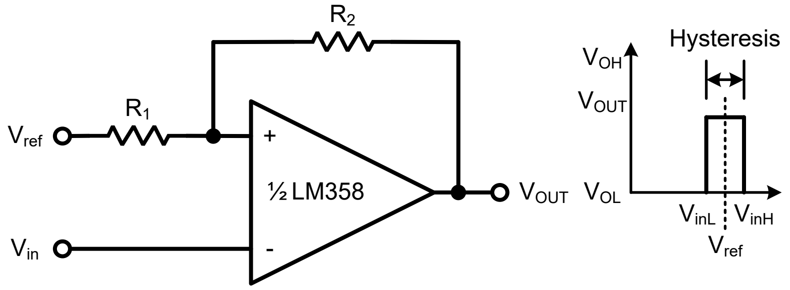
8 Application and Implementation

8.1 Typical Application Circuits (continued)



$$V_{OUT} = 2.5V \times (1 + \frac{R_1}{R_2})$$

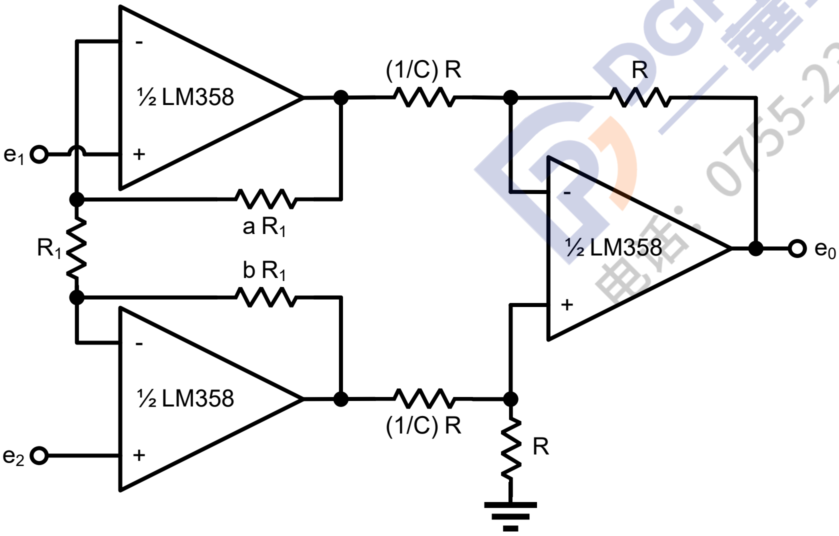
Figure 8-4. Voltage Reference



$$V_{inL} = \frac{R_1}{R_1 + R_2} \times (V_{OL} - V_{ref}) + V_{ref} \qquad V_{inH} = \frac{R_1}{R_1 + R_2} \times (V_{OH} - V_{ref}) + V_{ref}$$

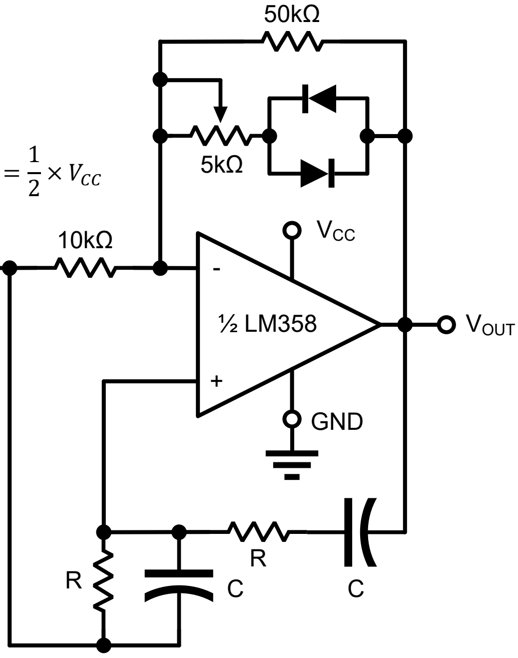
$$H = \frac{R_1}{R_1 + R_2} \times (V_{OH} - V_{OL})$$

Figure 8-5. Comparator with Hysteresis



$$e_0 = C \times (1 + a + b) \times (e_2 - e_1)$$

Figure 8-6. High Impedance Differential Amplifier

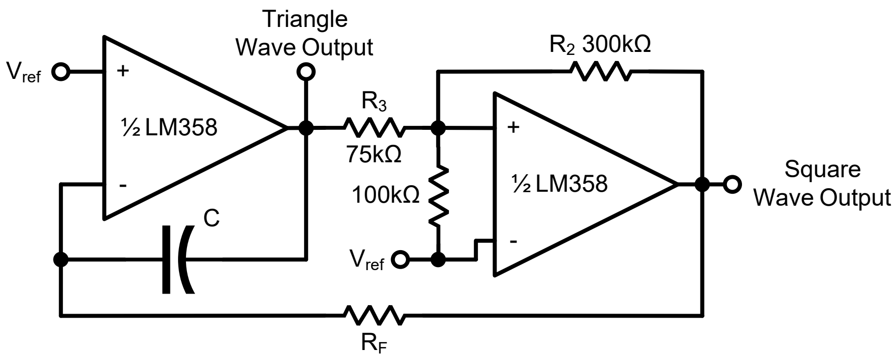


$$V_{ref} = \frac{1}{2} \times V_{CC}$$

$$f_{OUT} = \frac{1}{2\pi RC}$$

For f_{OUT} = 1kHz, R = 16kΩ, C = 0.01μF

Figure 8-8. Wien Bridge Oscillator

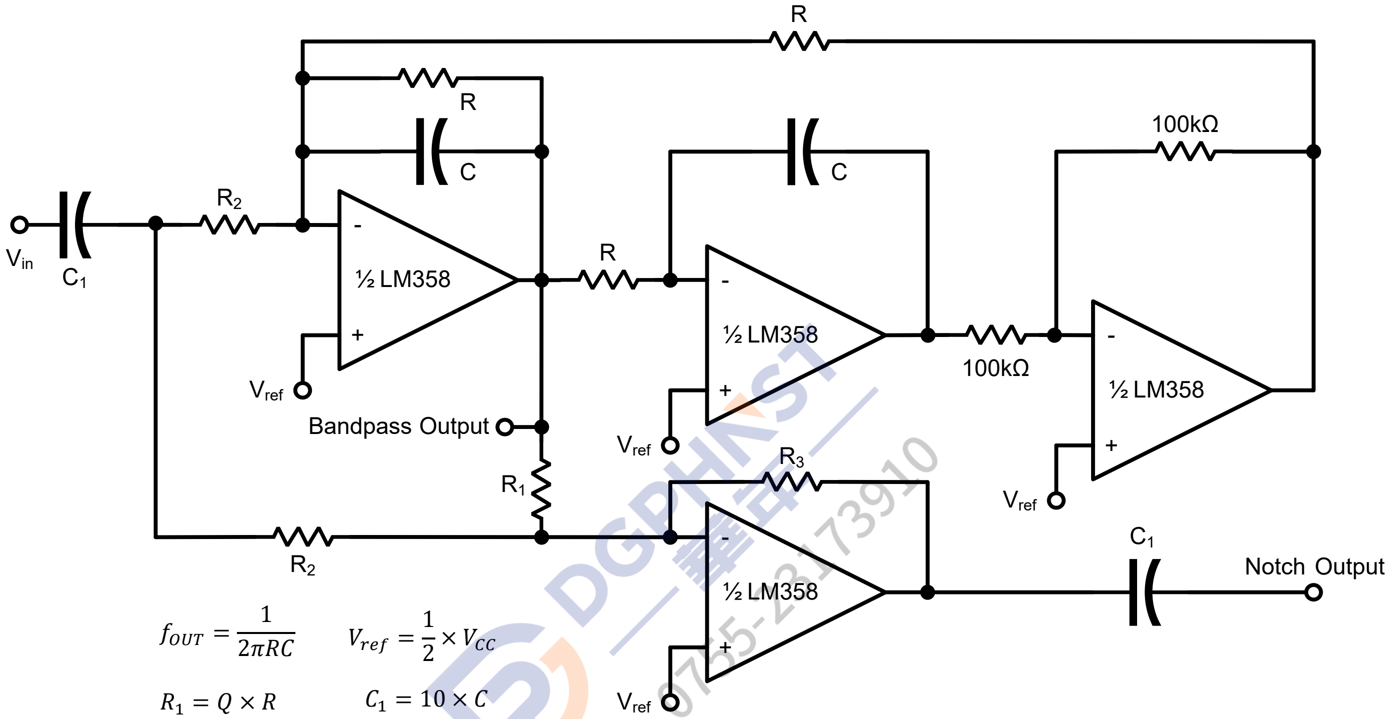


$$f = \frac{R_1 + R_C}{4 \times C \times R_F \times R_1} \quad \text{if } R_3 = \frac{R_2 \times R_1}{R_2 + R_1}$$

Figure 8-7. Function Generator

8 Application and Implementation

8.1 Typical Application Circuits (continued)



$$f_{OUT} = \frac{1}{2\pi RC} \qquad V_{ref} = \frac{1}{2} \times V_{CC}$$

$$R_1 = Q \times R \qquad C_1 = 10 \times C$$

$$R_2 = \frac{R_1}{T_{BP}}$$

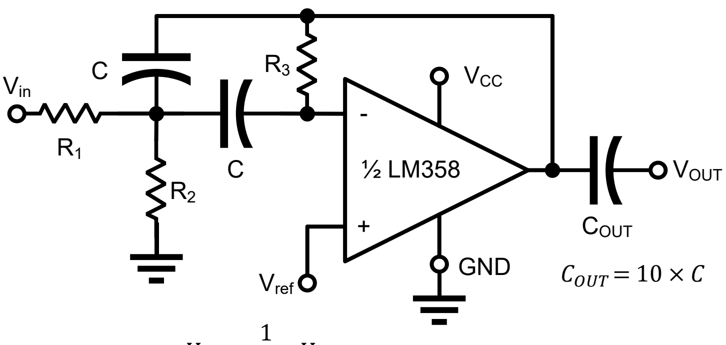
$$R_3 = T_N \times R_2$$

For f_{OUT} = 1kHz, Q = 10, T_{BP} = 1, T_N = 1

R = 160kΩ, C = 0.001µF, R_1 = 1.6MΩ, R_2 = 1.6MΩ, R_3 = 1.6MΩ

Where T_{BP} = Center Frequency Gain, T_N = Passband Notch Gain

Figure 8-9. Bi-Quad Filter



$$C_{OUT} = 10 \times C$$

$$V_{ref} = \frac{1}{2} \times V_{CC}$$

Given: f_{OUT} = Center Frequency

$A(f_{OUT})$ = Gain at Center Frequency

Choose value f_{OUT}, C, then:

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

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 0.1μF, 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.

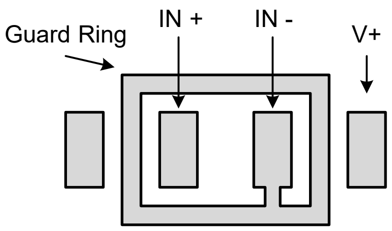


Figure 8-11. Guard Ring

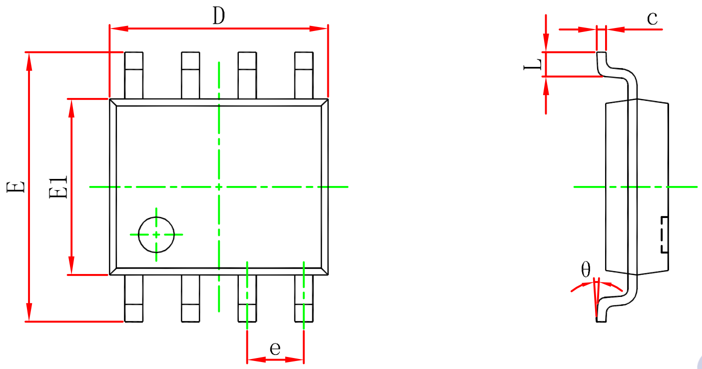
NOTE

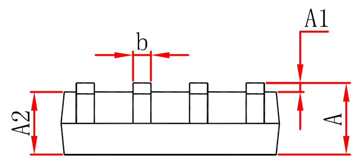
The application information in this section is not part of the data sheet component specification, and JSCJ makes no commitment or statement to guarantee its accuracy or completeness. Customers are responsible for determining the rationality of corresponding components in their circuit design and making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

9 Mechanical Information

SOP8 Mechanical Information

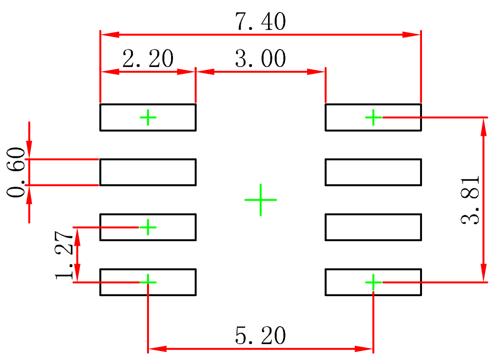
Outline Dimensions





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
θ	0°	8°	0°	8°

SOP8 Suggest Pad Layout



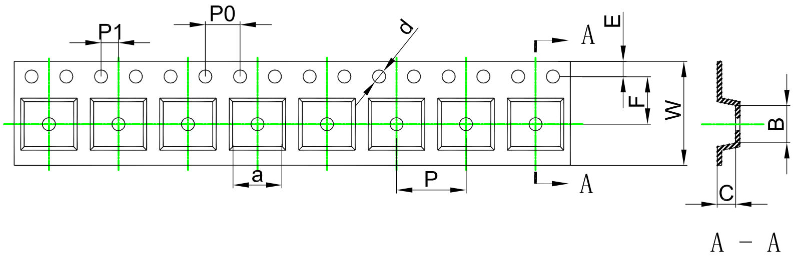
NOTE:

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

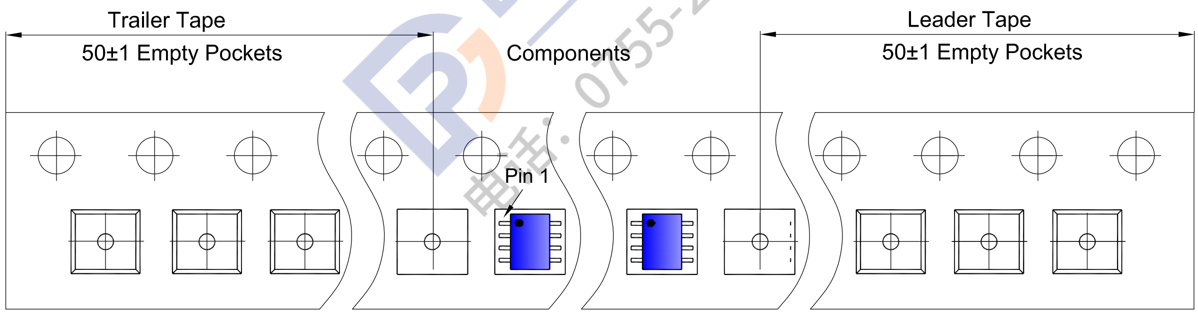
Embossed Carrier Tape



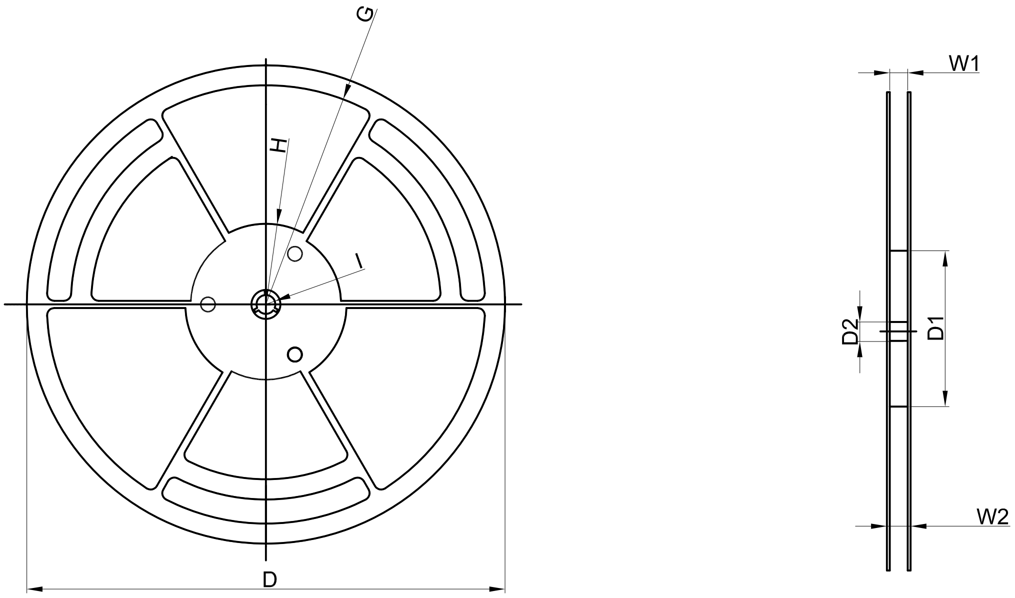
Packaging Description:
SOP8 parts are shipped in tape. The carrier tape is made from a dissipative (carbon filled) polycarbonate resin. The cover tape is a multilayer film (Heat Activated Adhesive in nature) primarily composed of polyester film, adhesive layer, sealant, and anti-static sprayed agent. 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

The information in this data sheet is intended to describe the operation and characteristics of our products. JSCJ has the right to make any modification, enhancement, improvement, correction or other changes to any content in this data sheet, including but not limited to specification parameters, circuit design and application information, without prior notice.

Any person who purchases or uses JSCJ products for design shall: 1. Select products suitable for circuit application and design; 2. Design, verify and test the rationality of circuit design; 3. Procedures to ensure that the design complies with relevant laws and regulations and the requirements of such laws and regulations. JSCJ makes no warranty or representation as to the accuracy or completeness of the information contained in this data sheet and assumes no responsibility for the application or use of any of the products described in this data sheet.

Without the written consent of JSCJ, this product shall not be used in occasions requiring high quality or high reliability, including but not limited to the following occasions: medical equipment, military facilities and aerospace. JSCJ shall not be responsible for casualties or property losses caused by abnormal use or application of this product.

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