



LM358

## Dual Operational Amplifier

### GENERAL DESCRIPTION

The LM358 is a dual operational amplifier with internal frequency compensation. It is optimized for high voltage operation from 3V to 32V single supply or  $\pm 1.5V$  to  $\pm 16V$  dual supplies, and consumes only  $440\mu A$  quiescent current.

The LM358 features low power, low offset voltage and low bias current. The device can offer high open-loop voltage gain. It is well suited for various applications.

The LM358 is available in Green SOIC-8 and MSOP-8 packages. It is specified over the  $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  temperature range.

### FEATURES

- Support Single or Dual Power Supplies:  
 $3V$  to  $32V$  or  $\pm 1.5V$  to  $\pm 16V$
- Low Quiescent Current:  $440\mu A$  (TYP)
- Low Input Offset Voltage:  $5.8\text{mV}$  (MAX)
- Low Input Offset Current:  $20\text{pA}$  (TYP)
- Low Input Bias Current:  $10\text{pA}$  (TYP)
- Minimum Input Common Mode Voltage:  $(-\text{V}_S) - 0.1V$
- Maximum Differential Input Voltage:  $+32V/-32V$
- Open-Loop Differential Voltage Gain:  $111\text{dB}$  (TYP)
- Gain-Bandwidth Product:  $1.1\text{MHz}$
- Frequency-Compensated Amplifier
- $0^{\circ}\text{C}$  to  $+70^{\circ}\text{C}$  Operating Temperature Range
- Available in Green SOIC-8 and MSOP-8 Packages

### APPLICATIONS

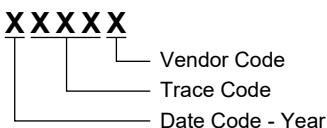
Wearable Products  
Temperature Measurements  
Battery-Powered Systems  
Sensors  
Audio  
Active Filters  
Communications  
Test Equipment

## PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
LM358	SOIC-8	0°C to +70°C	LM358ZS8G/TR	LM 358ZS8 XXXXX	Tape and Reel, 4000
	MSOP-8	0°C to +70°C	LM358ZMS8G/TR	LM358 ZMS8 XXXXX	Tape and Reel, 4000

## MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.



Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

## ABSOLUTE MAXIMUM RATINGS

Supply Voltage Range, $V_S^{(1)}$ .....	-0.3V to 32V
Differential Input Voltage Range, $V_{ID}^{(2)}$ .....	-32V to 32V
Input Voltage Range (Either Input).....	-0.3V to 32V
Junction Temperature.....	+150°C
Storage Temperature Range.....	-65°C to +150°C
Lead Temperature (Soldering, 10s).....	+260°C
ESD Susceptibility	
HBM.....	6000V
CDM .....	1000V

## RECOMMENDED OPERATING CONDITIONS

Input Common Mode Voltage Range.....	-0.1V to ( $+V_S$ ) - 1.5V
Operating Temperature Range.....	0°C to +70°C

### NOTES:

1. The network GND is the reference point for all voltage values, except for differential voltages and  $V_S$  when measuring  $I_{SC}$ .
2. Differential voltage is between +IN and -IN.

## OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

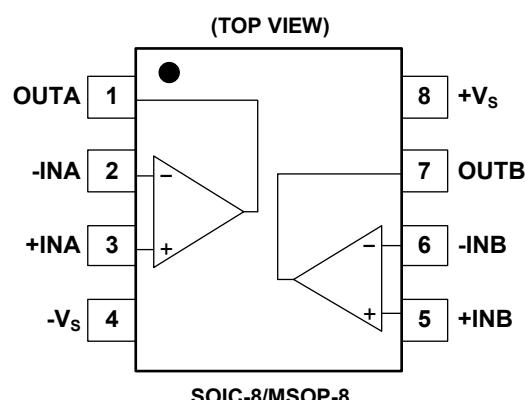
## ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

## DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

## PIN CONFIGURATION



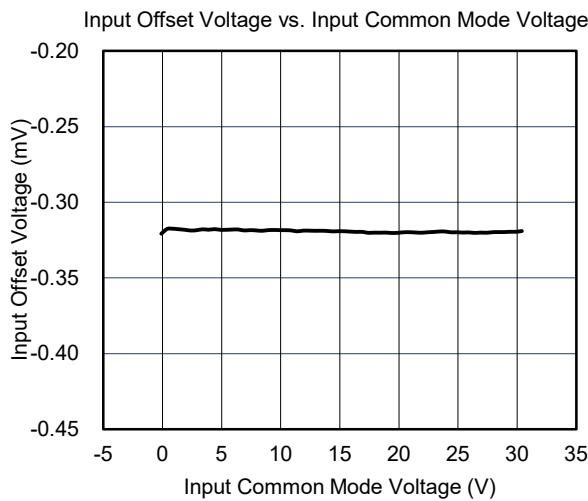
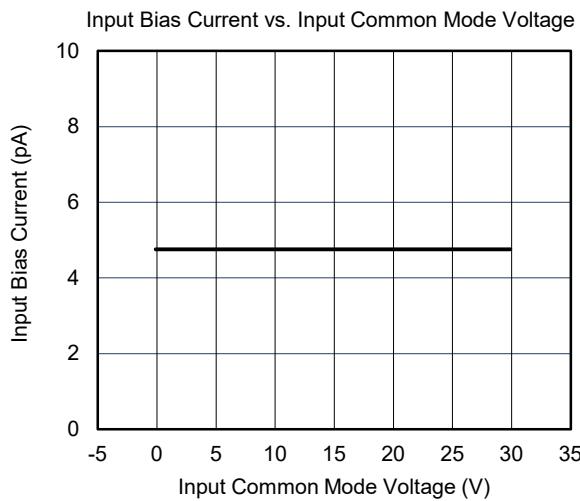
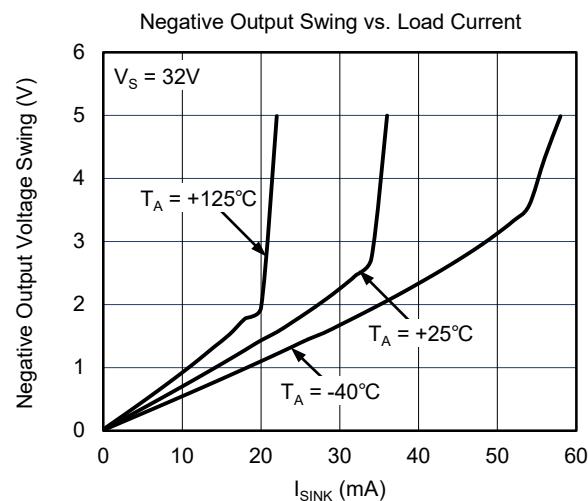
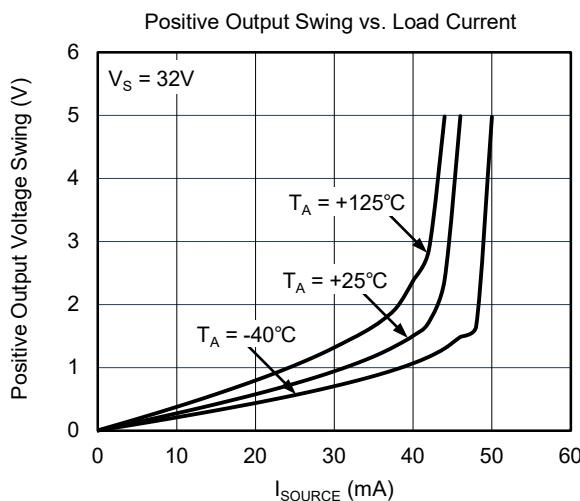
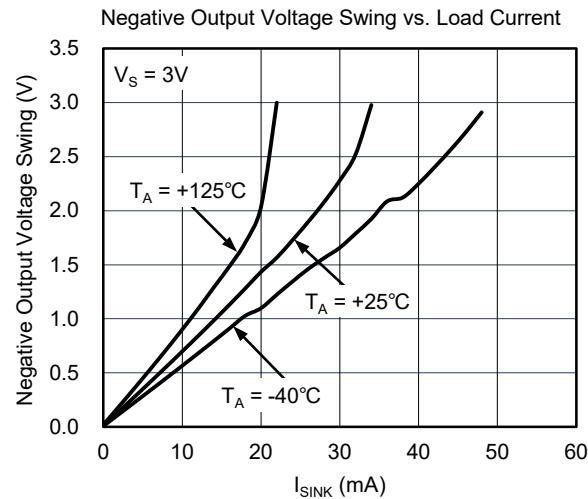
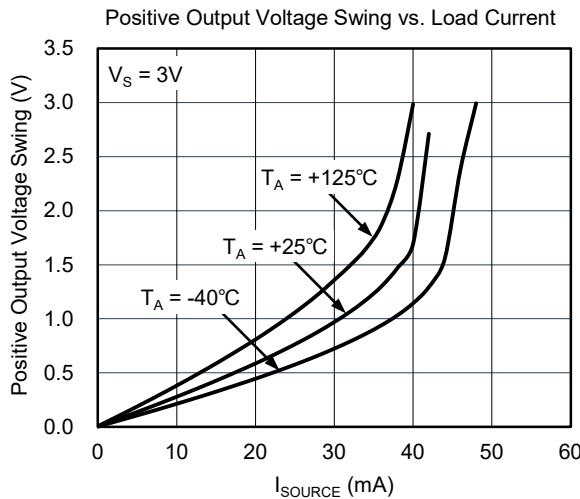
**ELECTRICAL CHARACTERISTICS**

( $V_S = 3V$  to  $32V$ ,  $-0.1V < V_{CM} < (+V_S) - 1.5V$ ,  $R_L = 10k\Omega$  connected to  $V_S/2$ , Full =  $0^\circ C$  to  $+70^\circ C$ , typical values are at  $T_A = +25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TEMP	MIN	TYP	MAX	UNITS
<b>Input Characteristics</b>							
Input Offset Voltage	$V_{OS}$		+25°C		1.2	5.8	mV
			Full			6.6	
Input Bias Current	$I_B$	$V_{CM} = V_S/2$	+25°C		10		pA
Input Offset Current	$I_{OS}$	$V_{CM} = V_S/2$	+25°C		20		pA
Maximum Differential Input Voltage	$ V_{ID} $		Full			$V_S$	V
Input Common Mode Voltage Range	$V_{CM}$		Full	-0.1		$(+V_S) - 1.5V$	V
Common Mode Rejection Ratio	CMRR	$-0.1V < V_{CM} < (+V_S) - 1.5V$	+25°C	82	118		dB
			Full	80			
Open-Loop Voltage Gain	$A_{OL}$	$R_L = 10k\Omega$ to $V_S/2$	+25°C	92	111		dB
			Full	90			
<b>Output Characteristics</b>							
Output Voltage Swing from Rail	$V_{OH}$	$R_L = 10k\Omega$	+25°C		42	60	mV
			Full			70	
	$V_{OL}$	$R_L = 10k\Omega$	+25°C		110	190	mV
			Full			210	
Output Short-Circuit Current	$I_{SC}$		+25°C	12	18		mA
<b>Power Supply</b>							
Operating Voltage Range	$V_S$		Full	3		32	V
Quiescent Current	$I_Q$	$I_{OUT} = 0A$	+25°C		440	680	$\mu A$
			Full			800	
Power Supply Rejection Ratio	PSRR		+25°C	102	122		dB
			Full	100			
Turn-On Time		$G = +1$	+25°C		42		$\mu s$
<b>Dynamic Performance (<math>C_L = 100pF</math>)</b>							
Gain-Bandwidth Product	GBP		+25°C		1.1		MHz
Phase Margin	$\Phi_O$		+25°C		60		°
Slew Rate	SR	$G = +1$	+25°C		0.35		V/ $\mu s$
Overload Recovery Time	ORT	$V_{IN} \times G > V_S$	+25°C		2.3		$\mu s$
<b>Noise</b>							
Input Voltage Noise		$f = 0.1Hz$ to $10Hz$	+25°C		8.7		$\mu V_{P,P}$
Input Voltage Noise Density	$e_n$	$f = 1kHz$	+25°C		36		nV/ $\sqrt{Hz}$

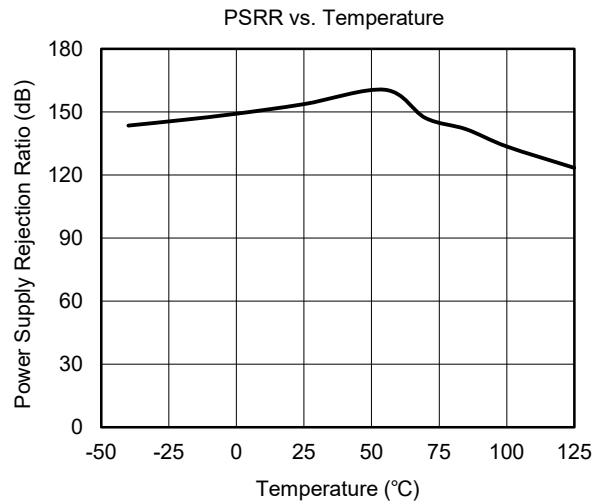
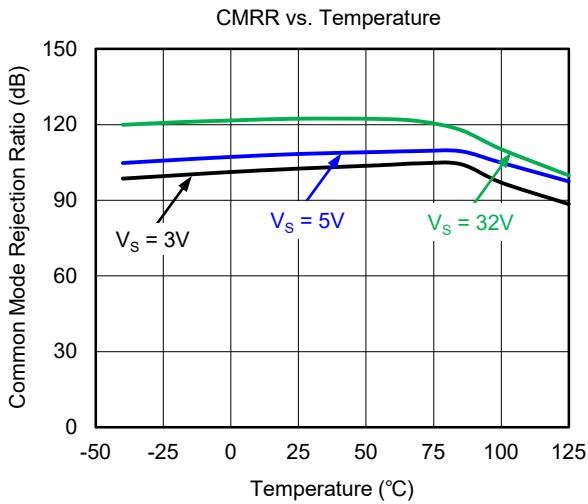
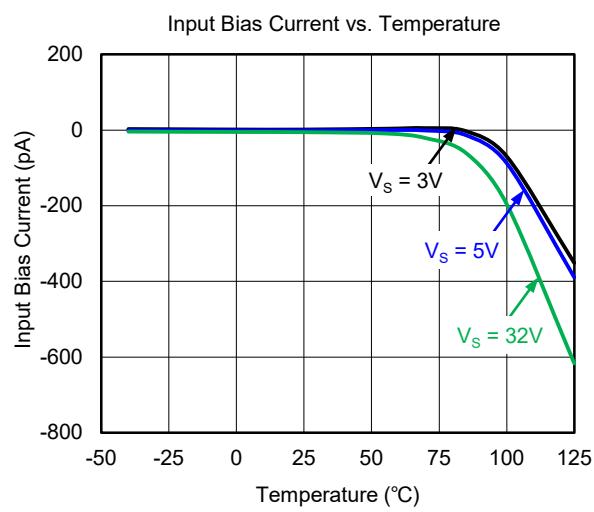
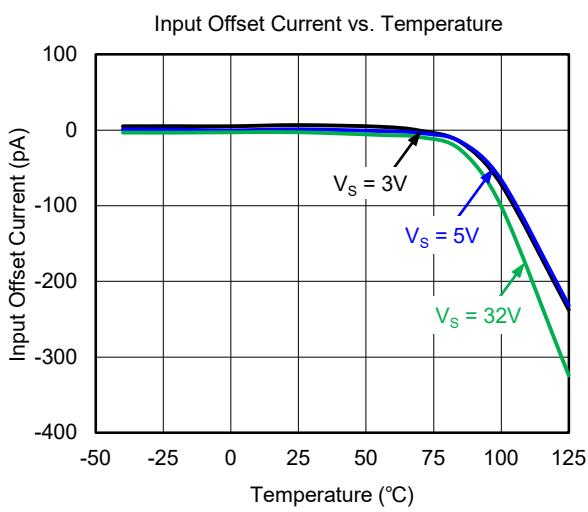
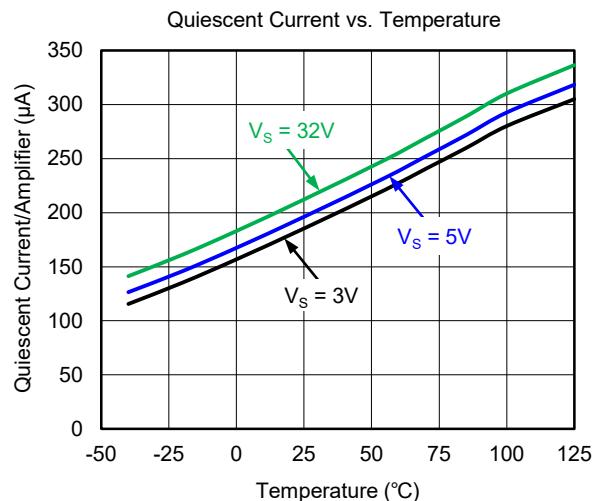
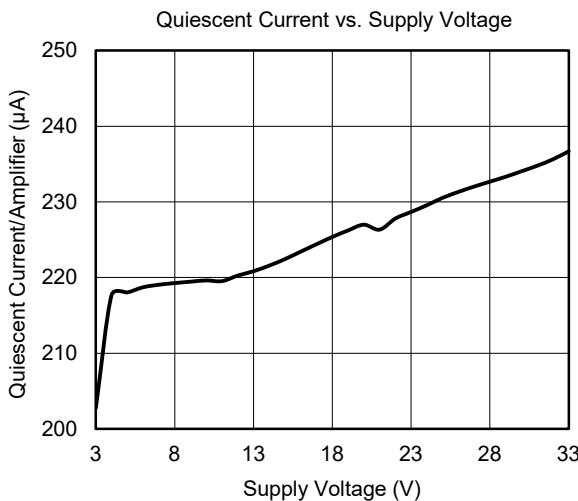
## TYPICAL PERFORMANCE CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $V_{CM} = V_S/2$ , unless otherwise noted.



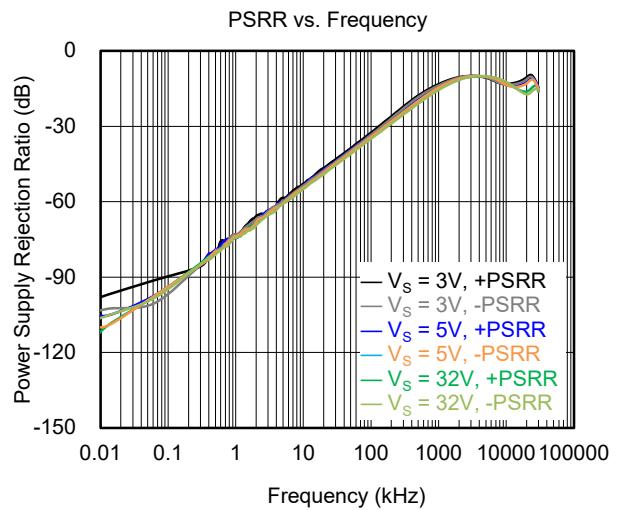
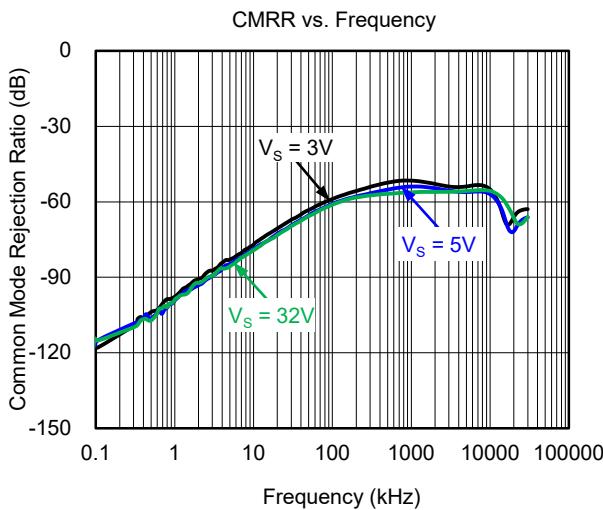
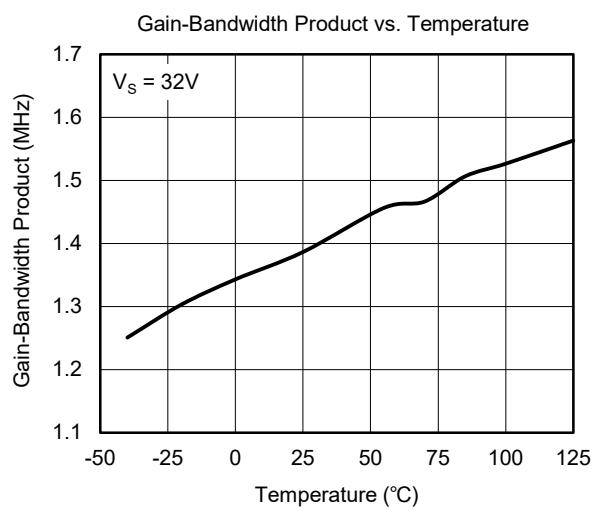
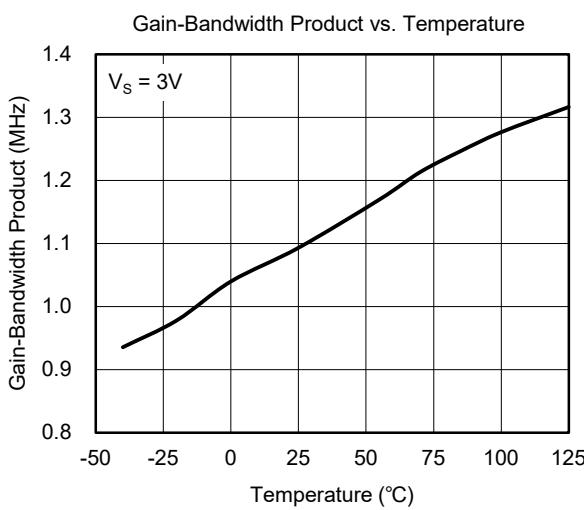
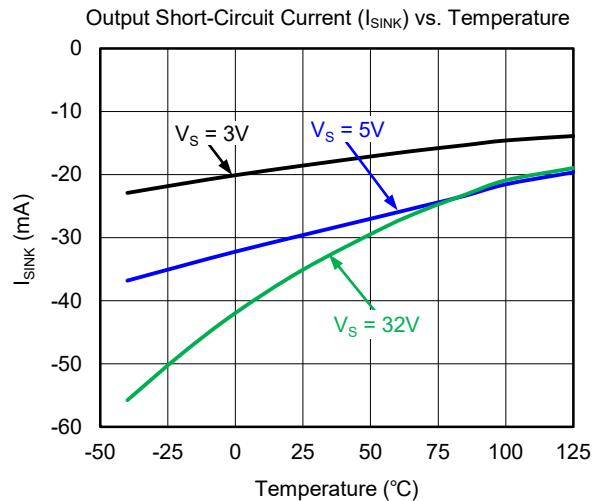
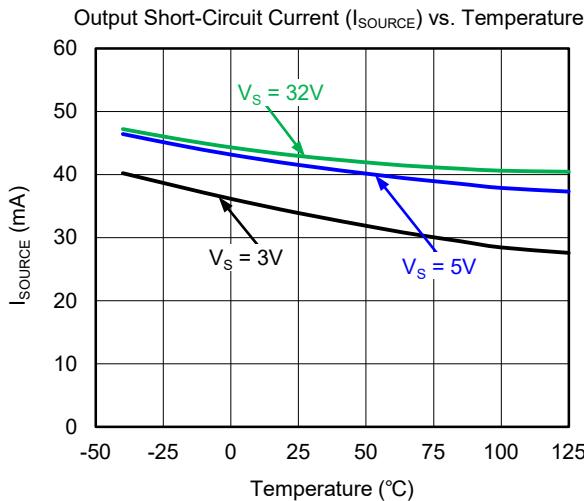
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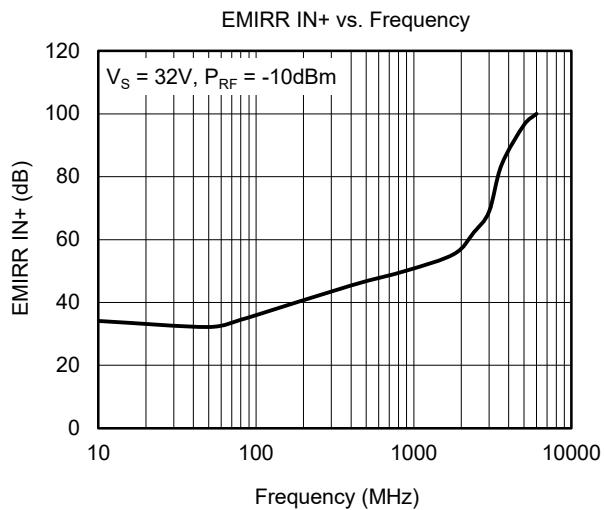
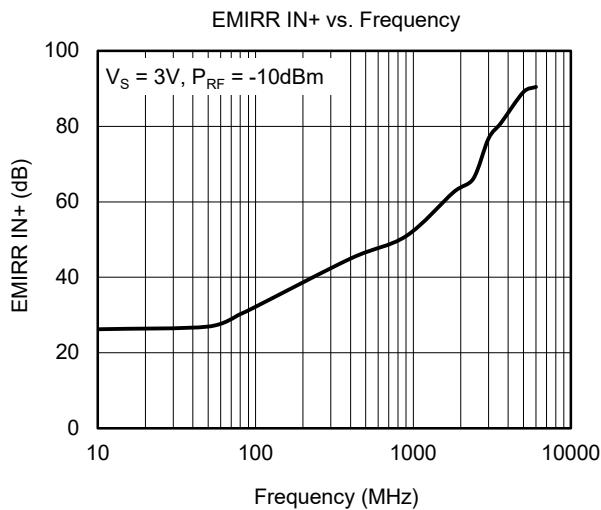
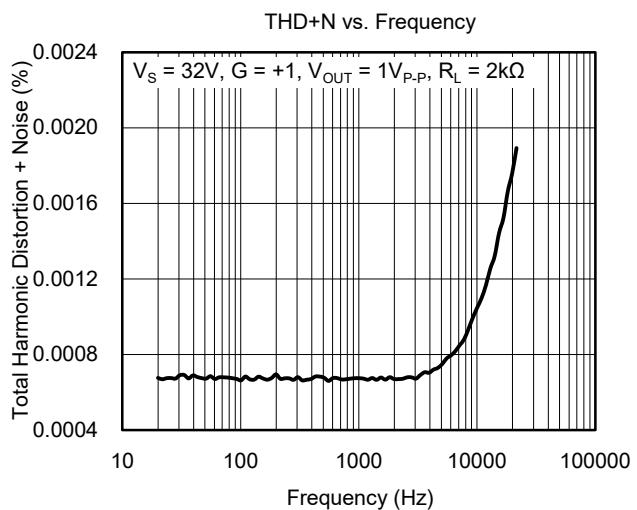
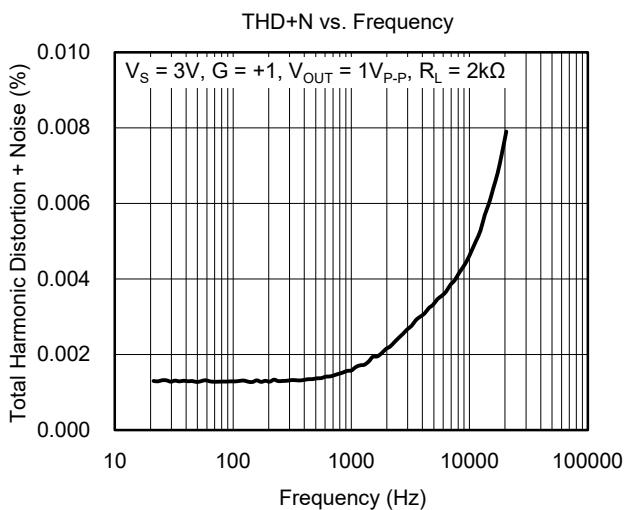
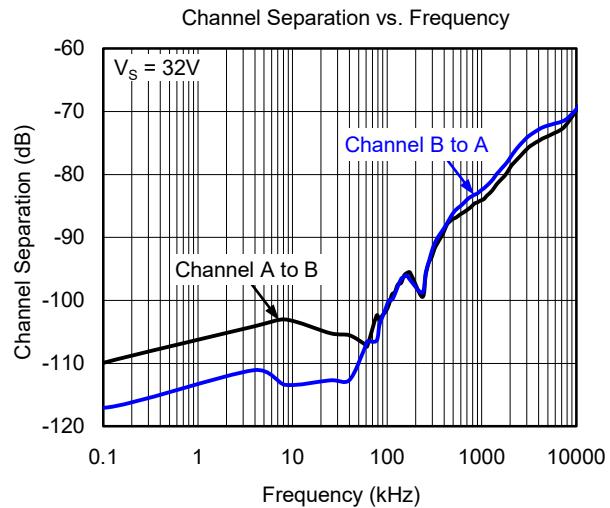
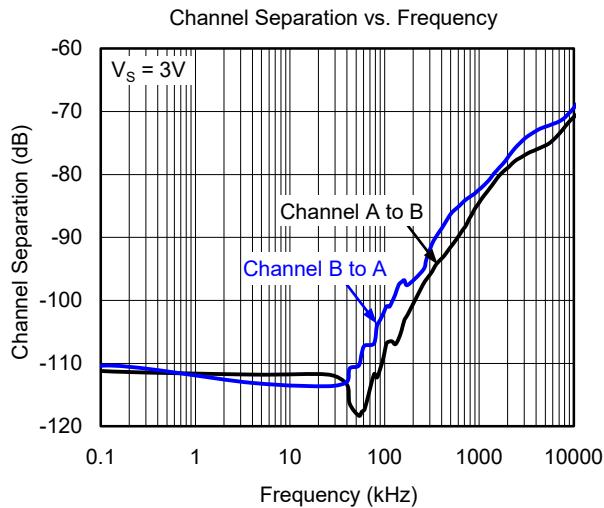
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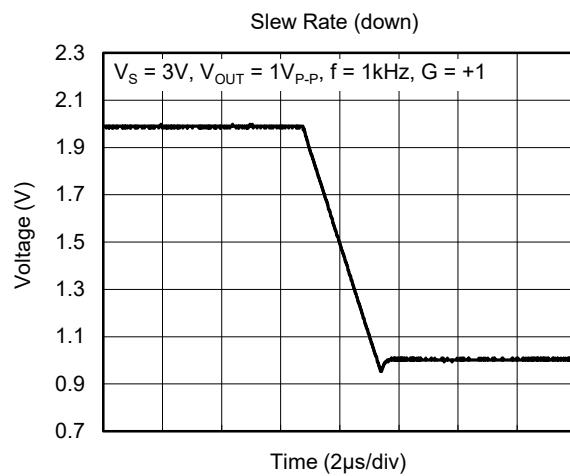
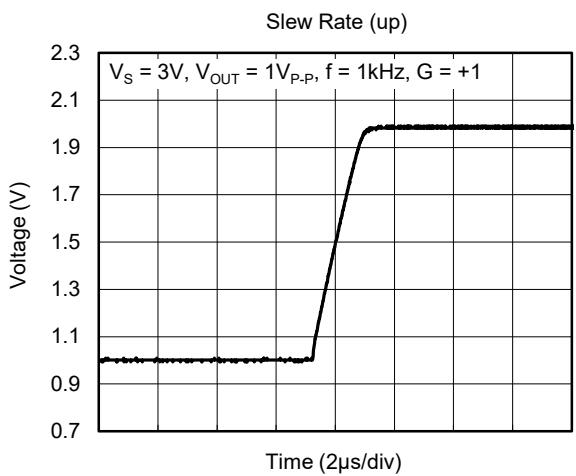
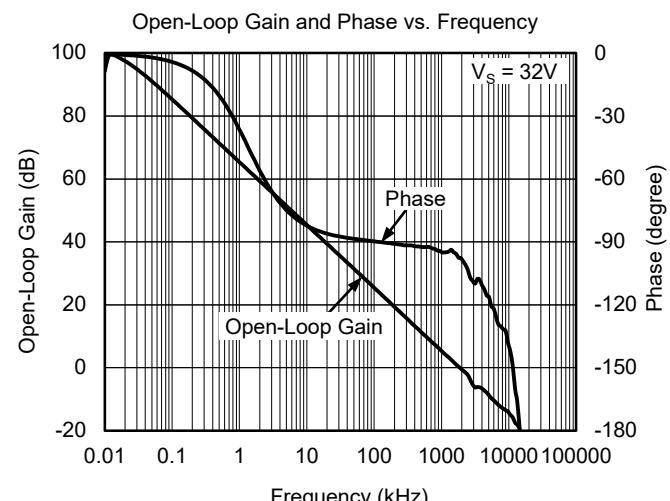
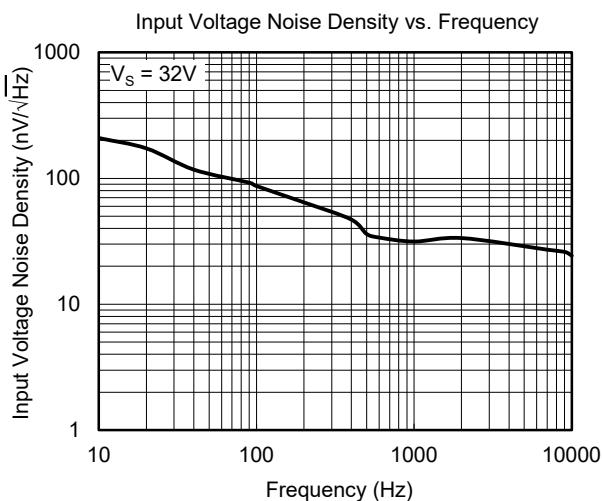
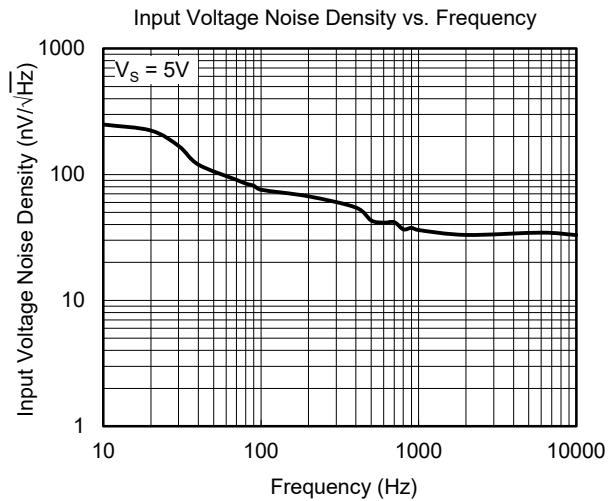
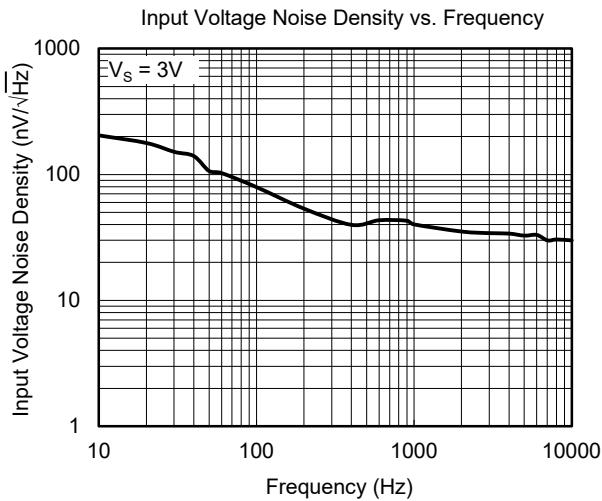
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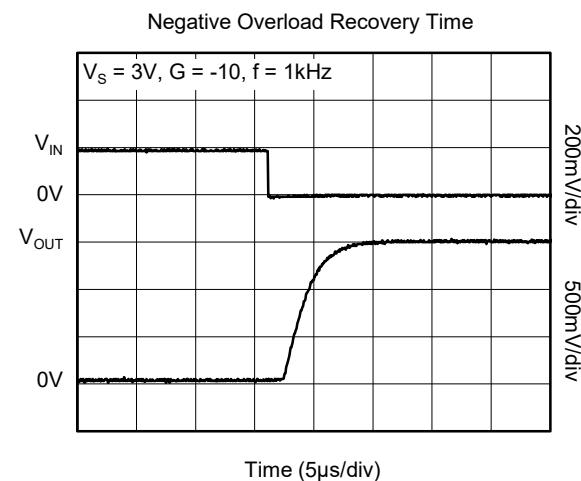
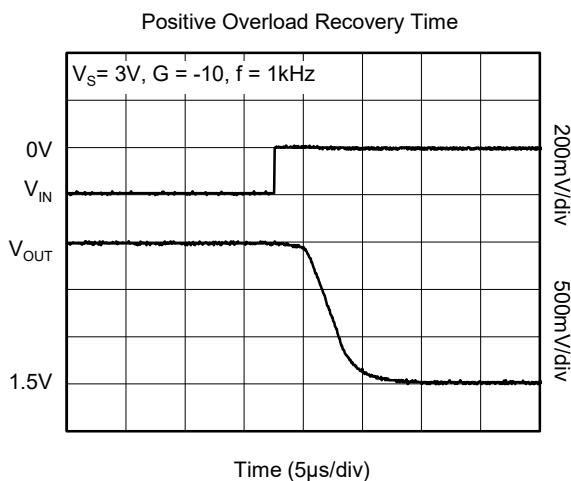
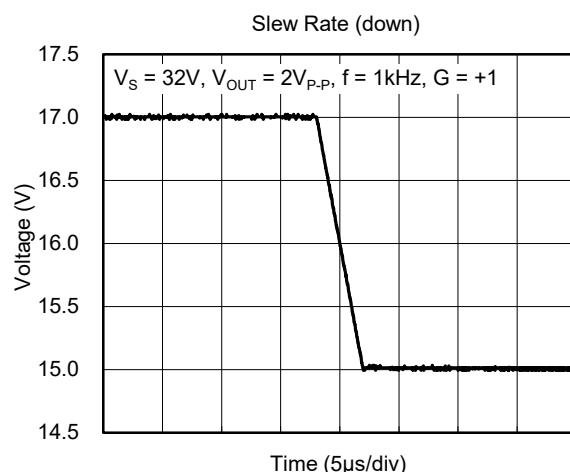
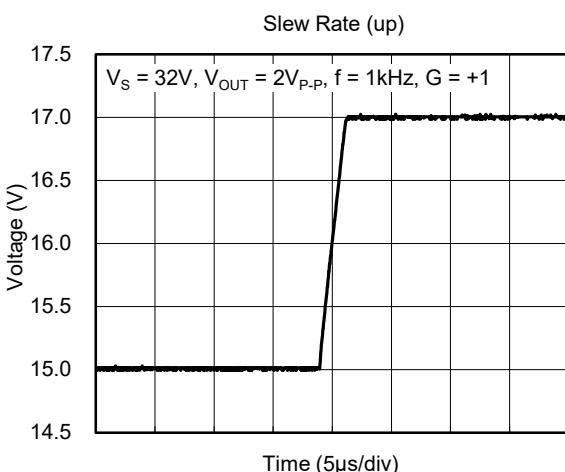
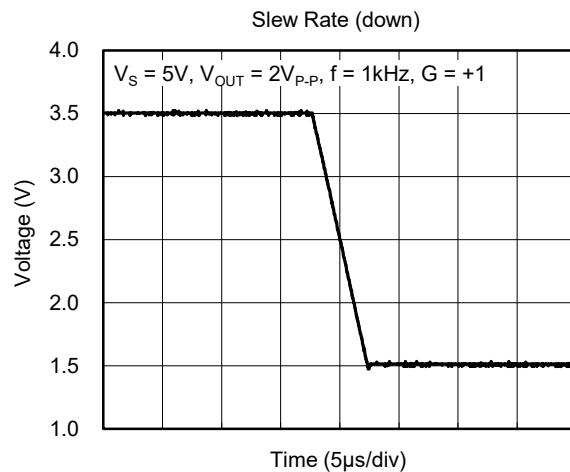
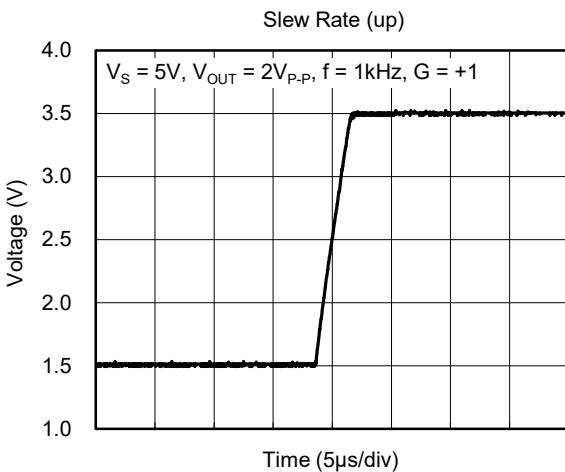
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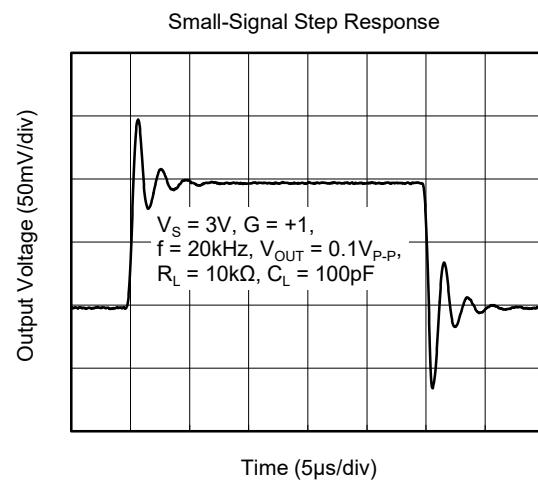
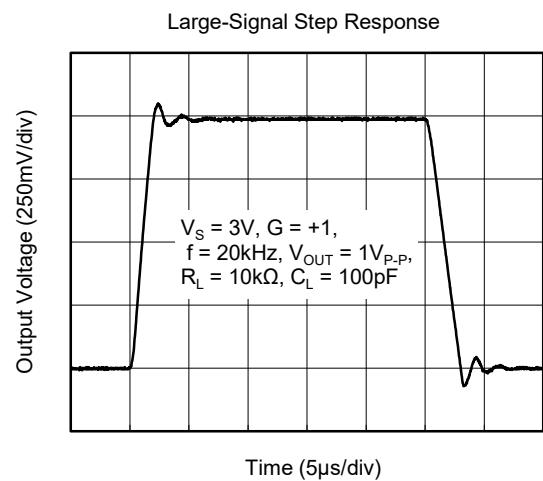
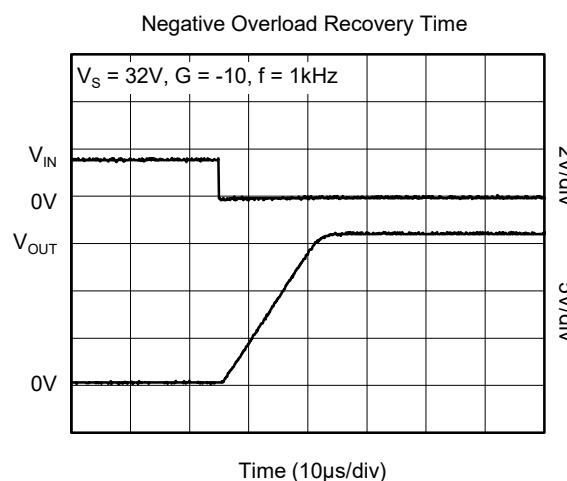
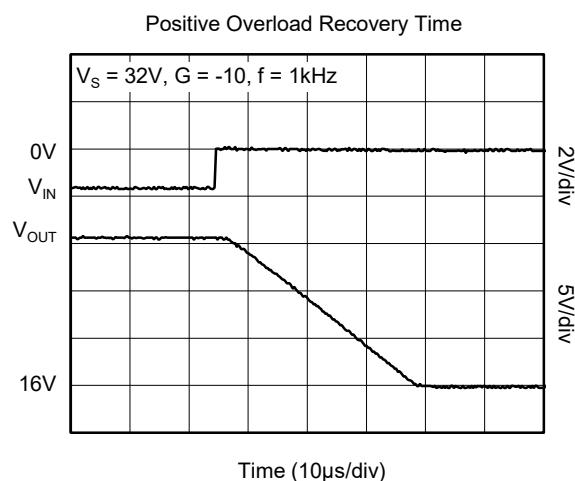
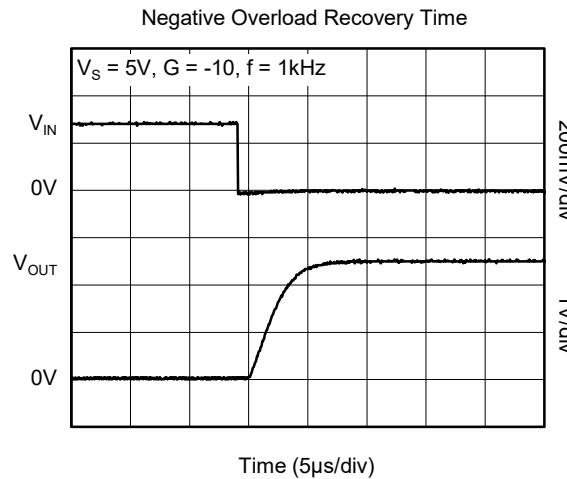
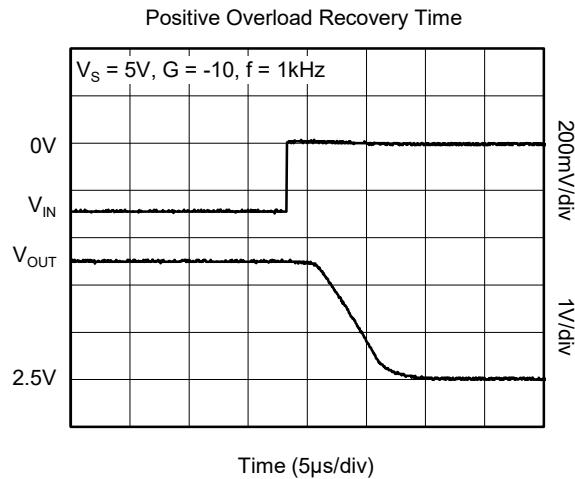
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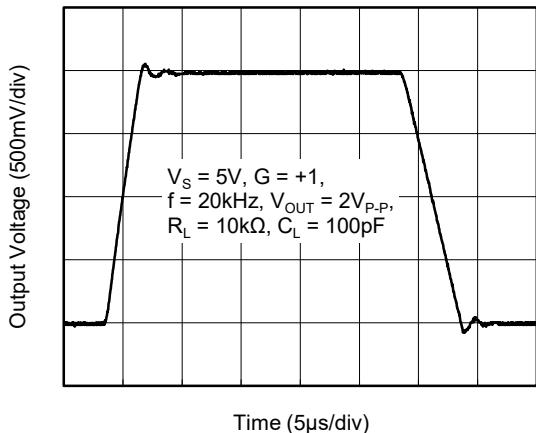
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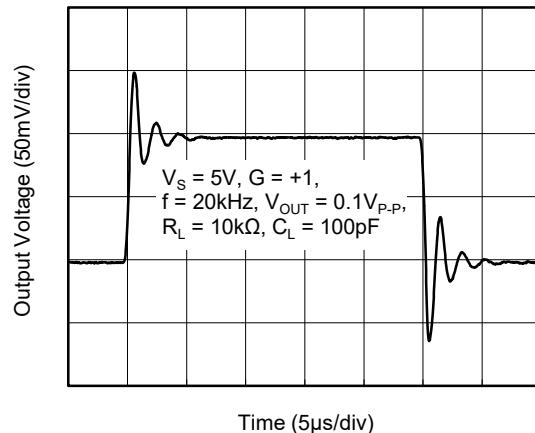


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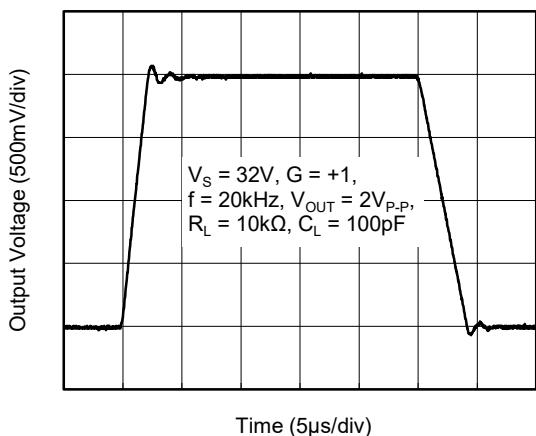
Large-Signal Step Response



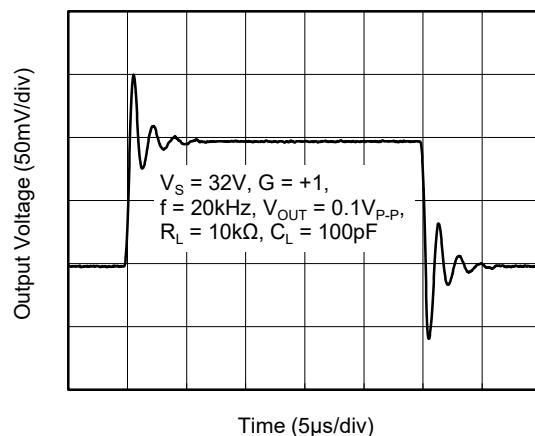
Small-Signal Step Response



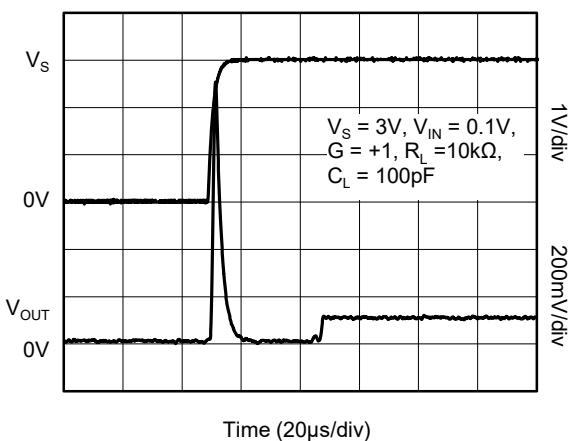
Large-Signal Step Response



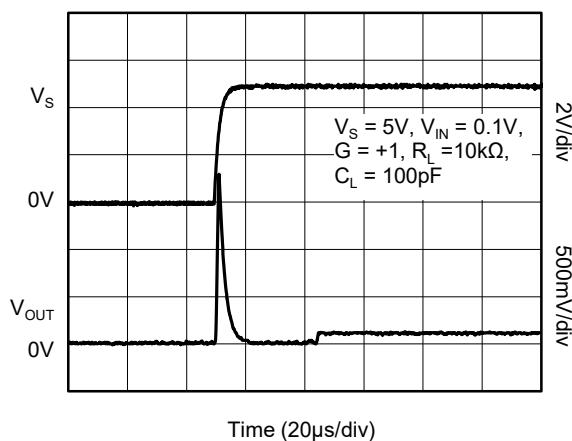
Small-Signal Step Response



Turn-On Time



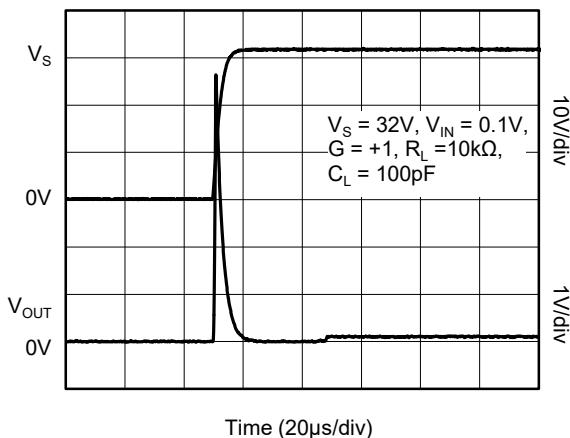
Turn-On Time



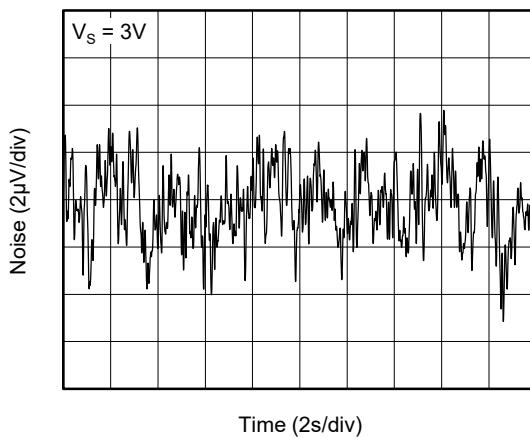
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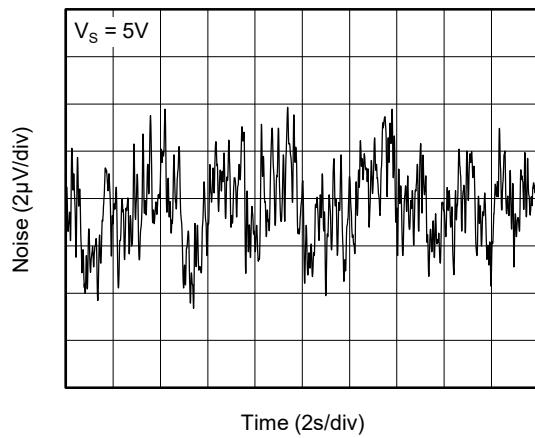
Turn-On Time



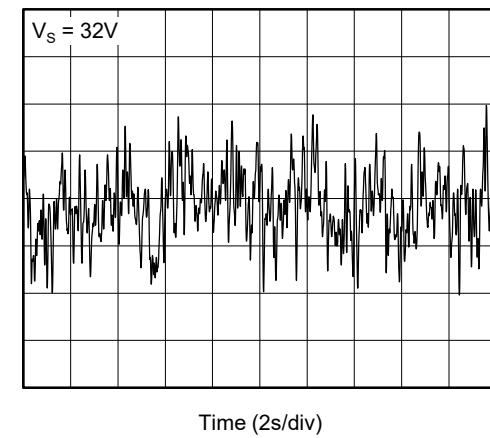
0.1Hz to 10Hz Input Voltage Noise



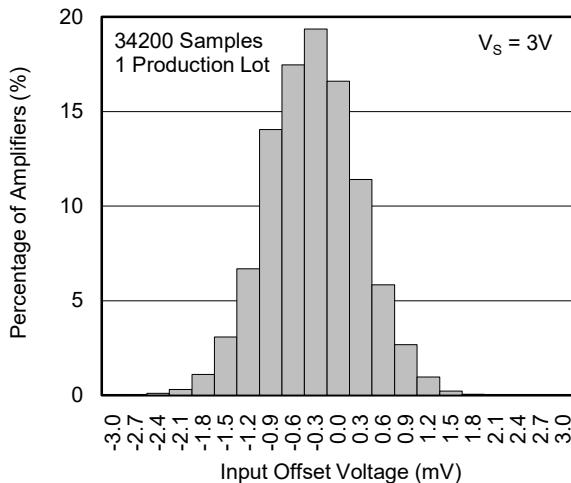
0.1Hz to 10Hz Input Voltage Noise



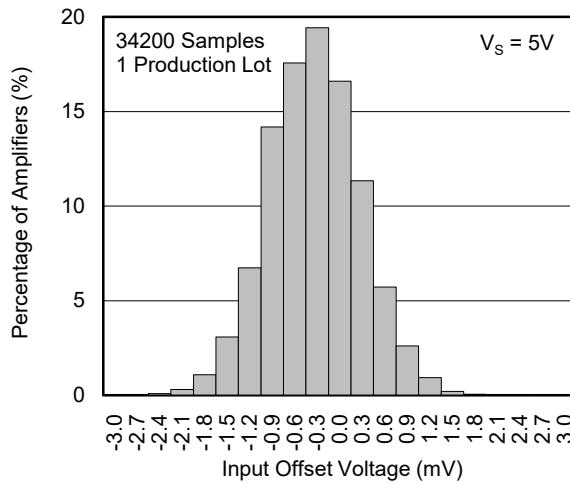
0.1Hz to 10Hz Input Voltage Noise



Input Offset Voltage Production Distribution

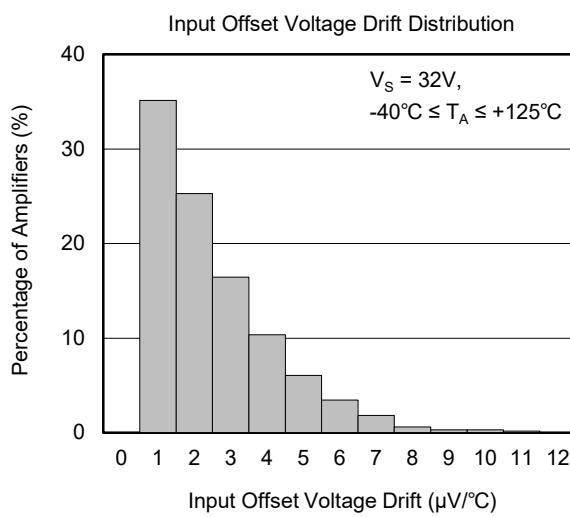
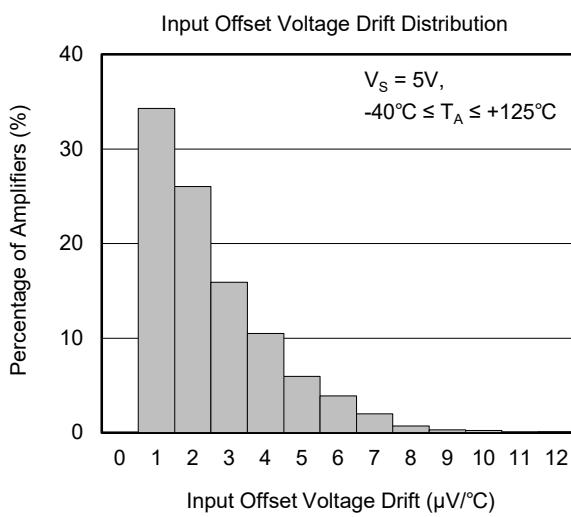
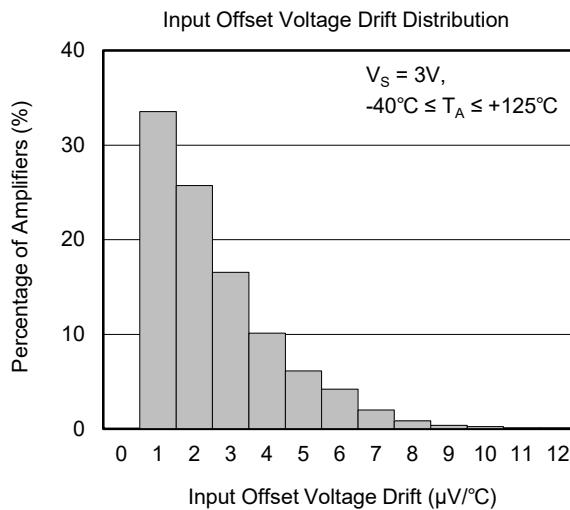
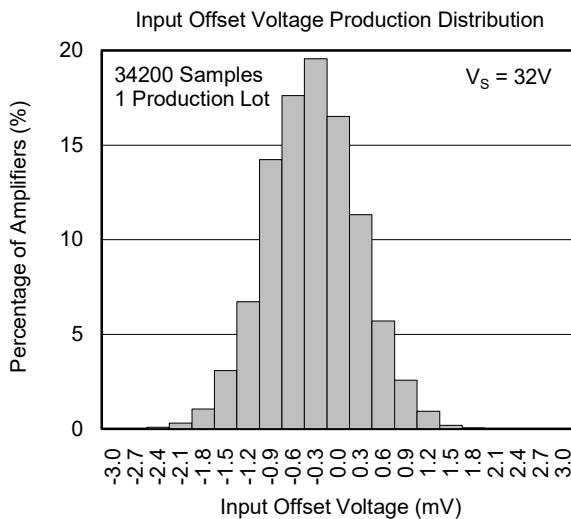


Input Offset Voltage Production Distribution



## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

At  $T_A = +25^\circ\text{C}$ ,  $V_{CM} = V_S/2$ , unless otherwise noted.



## DETAILED DESCRIPTION

The LM358 is a dual, high open-loop gain operational amplifier with internal frequency compensation. It is optimized for high voltage operation from 3V to 32V single supply or  $\pm 1.5V$  to  $\pm 16V$  dual supplies. The input common mode voltage range is from  $-0.1V$  to  $(+V_S) - 1.5V$ .

This LM358 makes it easier to implement all conventional operational amplifier circuits in a single-supply system, such as DC amplifier modules and transducer amplifiers. For instance, the device does not need extra  $\pm 5V$  supplies to work with the interface electronics, as it can be easily operated on the 5V source that is common for digital systems.

### Unity-Gain Bandwidth

The unity-gain bandwidth is the maximum supported frequency which can be amplified by an amplifier without distortion. The unity-gain bandwidth of LM358 is 1.1MHz.

### Slew Rate

The slew rate is the time period for the output change when input signal is changed. The slew rate of LM358 is  $0.35V/\mu s$ .

### Input Common Mode Voltage Range

The input common mode voltage range is from the device ground to  $(+V_S) - 1.5V$ . Also, the voltage level at the inputs can reach  $V_S$  without damaging the device. If the users desire the correct phase at the output of the operational amplifier, they need to make sure that at least one of the inputs is within the input common mode voltage range. If both of them are outside the input common mode voltage range, the state of the output will be undefined. However, if either input is below  $-0.3V$ , the input current should be limited and the output state will also be undefined.

### Device Functional Modes

The LM358 can be operated as it is powered by a DC power supply. The amplifier can be operated in single-supply or dual-supply mode.

## APPLICATION INFORMATION

The LM358 can be widely used for various signal processing purposes. The inputs have the option to get power before  $V_S$ , which allows for more versatility in circuits with multiple supplies.

### Typical Application

The following circuit is an application of an inverting amplifier. To explain, the input is positive while the output is negative. However, if the input signal is negative, the output will be positive as well.

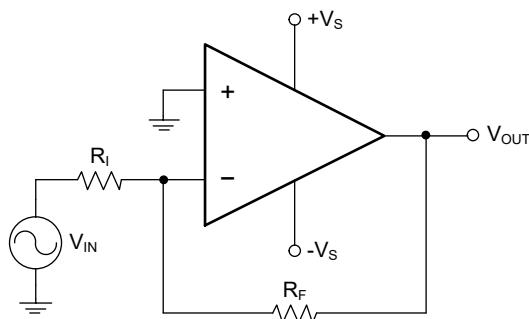


Figure 1. Application Schematic

The supply voltage range should always be larger than the input and the output range. The following example scales a signal with  $\pm 0.5V$  to  $\pm 1.8V$ , which means that the  $\pm 12V$  of the supply voltage is sufficient.

The following equations determine the voltage gain of the inverting amplifier circuit.

$$G = \frac{V_{OUT}}{V_{IN}} \quad (1)$$

$$G = \frac{1.8}{-0.5} = -3.6 \quad (2)$$

After setting the voltage gain, the value of the gain and feedback resistors should be determined as well. Since the operating current inside the circuit is in the mA range, the  $R_I$  and  $R_F$  should be at the level of k $\Omega$ . In this example, the  $R_I$  is 10k $\Omega$  and the  $R_F$  is 36k $\Omega$ .

$$G = -\frac{R_F}{R_I} \quad (3)$$

**REVISION HISTORY**

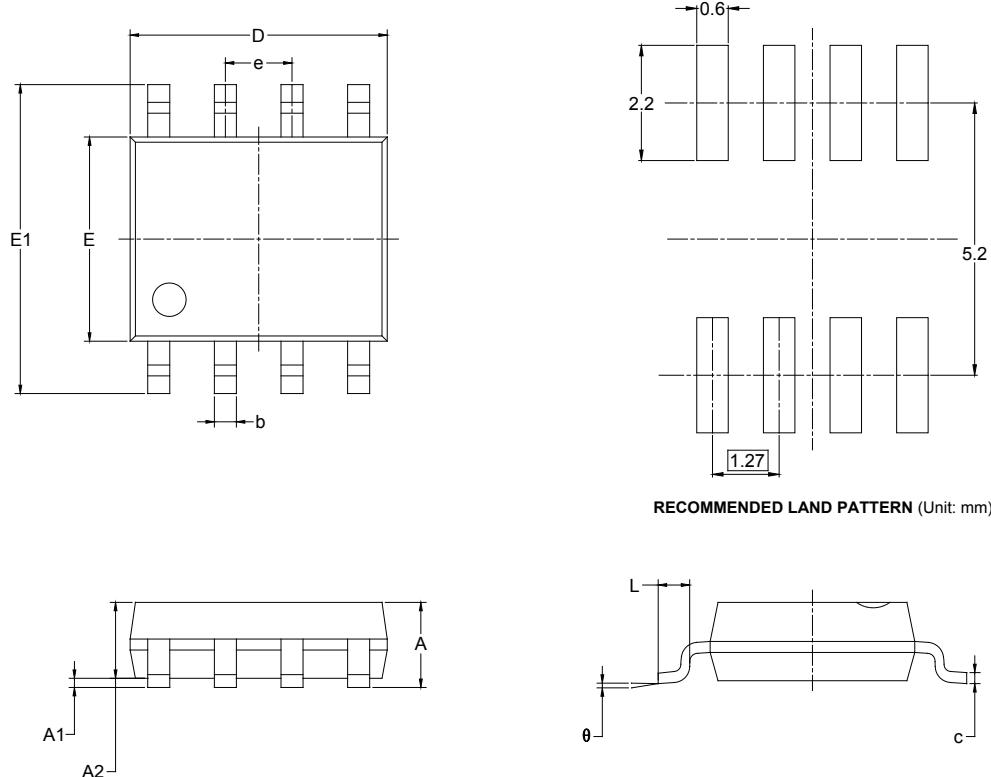
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Original (JUNE 2019) to REV.A</b>	<b>Page</b>
Changed from product preview to production data.....	All

# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### SOIC-8

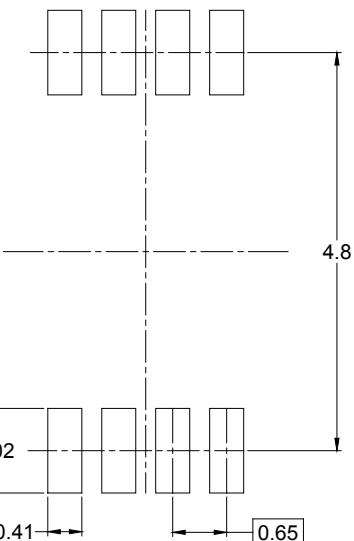
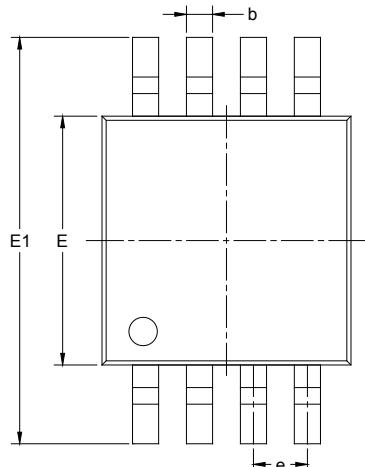


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

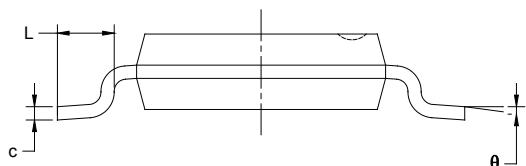
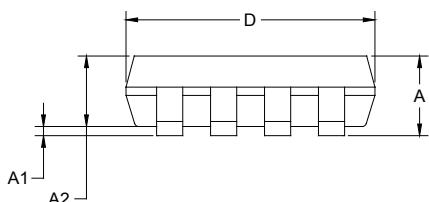
# PACKAGE INFORMATION

## PACKAGE OUTLINE DIMENSIONS

### MSOP-8



**RECOMMENDED LAND PATTERN** (Unit: mm)

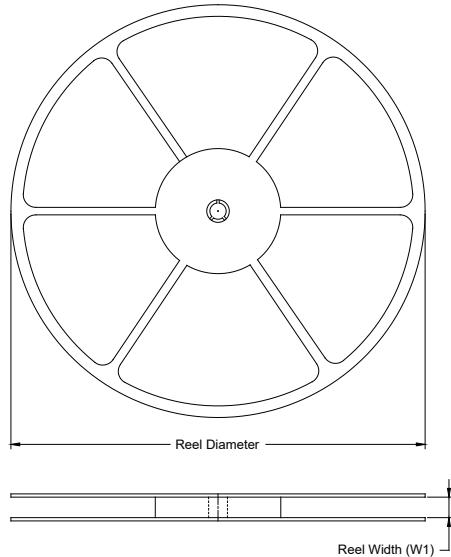


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

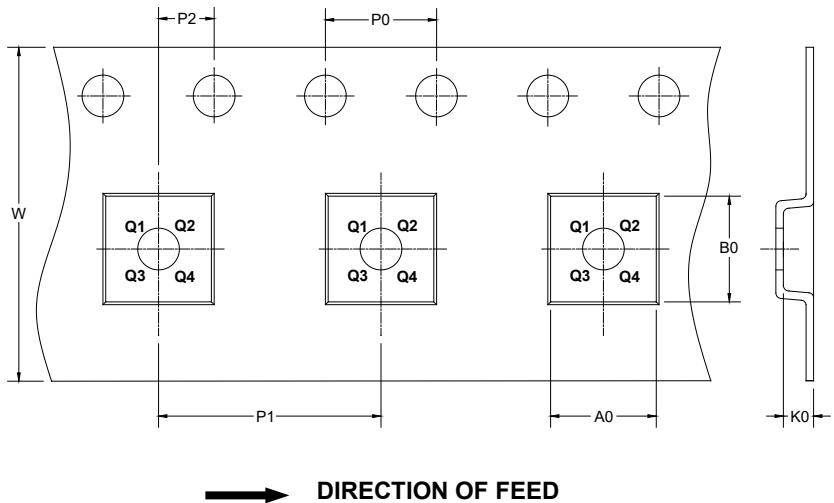
# PACKAGE INFORMATION

## TAPE AND REEL INFORMATION

### REEL DIMENSIONS



### TAPE DIMENSIONS



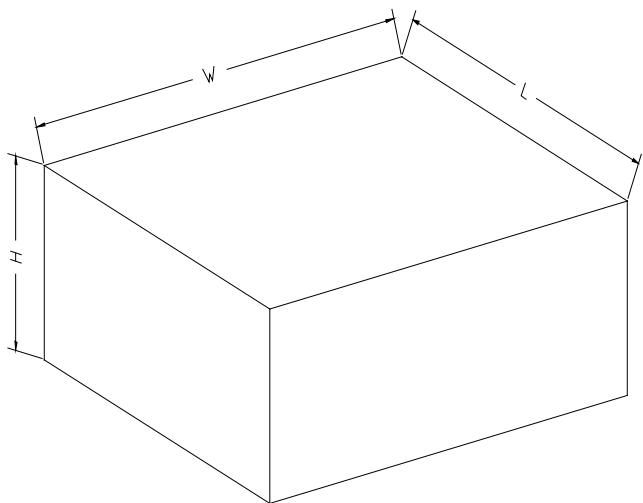
NOTE: The picture is only for reference. Please make the object as the standard.

### KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOIC-8	13"	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1
MSOP-8	13"	12.4	5.20	3.30	1.50	4.0	8.0	2.0	12.0	Q1

## PACKAGE INFORMATION

### CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

### KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13"	386	280	370	5

00002