

TLC2272M-MIL Advanced LinCMOS Rail-to-Rail Operational Amplifier

1 Features

- Output Swing Includes Both Supply Rails
- Low Noise: $9 \text{ nV}/\sqrt{\text{Hz}}$ Typical at $f = 1 \text{ kHz}$
- Low-Input Bias Current: 1-pA Typical
- Fully-Specified for Both Single-Supply and Split-Supply Operation
- Common-Mode Input Voltage Range Includes Negative Rail
- High-Gain Bandwidth: 2.2-MHz Typical
- High Slew Rate: $3.6\text{-V}/\mu\text{s}$ Typical
- Low Input Offset Voltage: 2.5 mV Maximum at $T_A = 25^\circ\text{C}$
- Macromodel Included
- Performance Upgrades for the TLC272 and TLC274
- Available in Q-Temp Automotive

2 Applications

- White Goods (Refrigerators, Washing Machines)
- Hand-held Monitoring Systems
- Configuration Control and Print Support
- Transducer Interfaces
- Battery-Powered Applications

3 Description

The TLC2272M-MIL device is a dual operational amplifier from Texas Instruments. The device exhibits rail-to-rail output performance for increased dynamic range in single- or split-supply applications. The TLC2272M-MIL device offers 2 MHz of bandwidth and $3 \text{ V}/\mu\text{s}$ of slew rate for higher-speed applications. The device offers comparable ac performance while having better noise, input offset voltage, and power dissipation than existing CMOS operational amplifiers. The TLC2272M-MIL device has a noise voltage of $9 \text{ nV}/\sqrt{\text{Hz}}$, two times lower than competitive solutions.

The TLC2272M-MIL device, exhibiting high input impedance and low noise, is excellent for small-signal conditioning for high-impedance sources such as piezoelectric transducers. Because of the micropower dissipation levels, the device works well in hand-held monitoring and remote-sensing applications. In addition, the rail-to-rail output feature, with single- or split-supplies, makes this device a great choice when interfacing with analog-to-digital converters (ADCs). For precision applications, the TLC2272AM-MIL device is available with a maximum input offset voltage of $950 \mu\text{V}$. This device is fully characterized at 5 V and $\pm 5 \text{ V}$.

The TLC2272M-MIL device also makes a great upgrade to the TLC272 in standard designs, offering increased output dynamic range, lower noise voltage, and lower input offset voltage. This enhanced feature set allows the device to be used in a wider range of applications. For applications that require higher output drive and wider input voltage range, see the TLV2432 and TLV2442 devices.

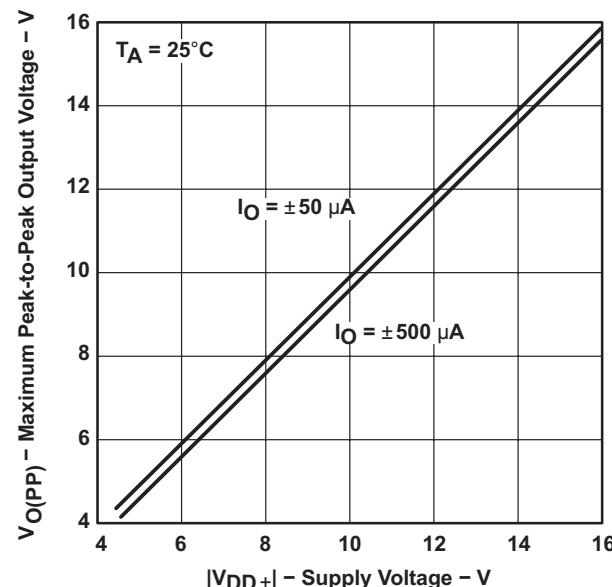
If the design requires single amplifiers, see the TLV2211, TLV2221 and TLV2231 family. These devices are single rail-to-rail operational amplifiers in the SOT-23 package. Their small size and low power consumption make them ideal for high density, battery-powered equipment.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLC2272M-MIL	SOIC (8)	$3,91 \text{ mm} \times 4,90 \text{ mm}$
	CDIP (8)	$6,67 \text{ mm} \times 9,60 \text{ mm}$
	LCCC (20)	$8,89 \text{ mm} \times 8,89 \text{ mm}$
	CFP (10)	$6,35 \text{ mm} \times 6,35 \text{ mm}$

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Maximum Peak-to-Peak Output Voltage vs Supply Voltage



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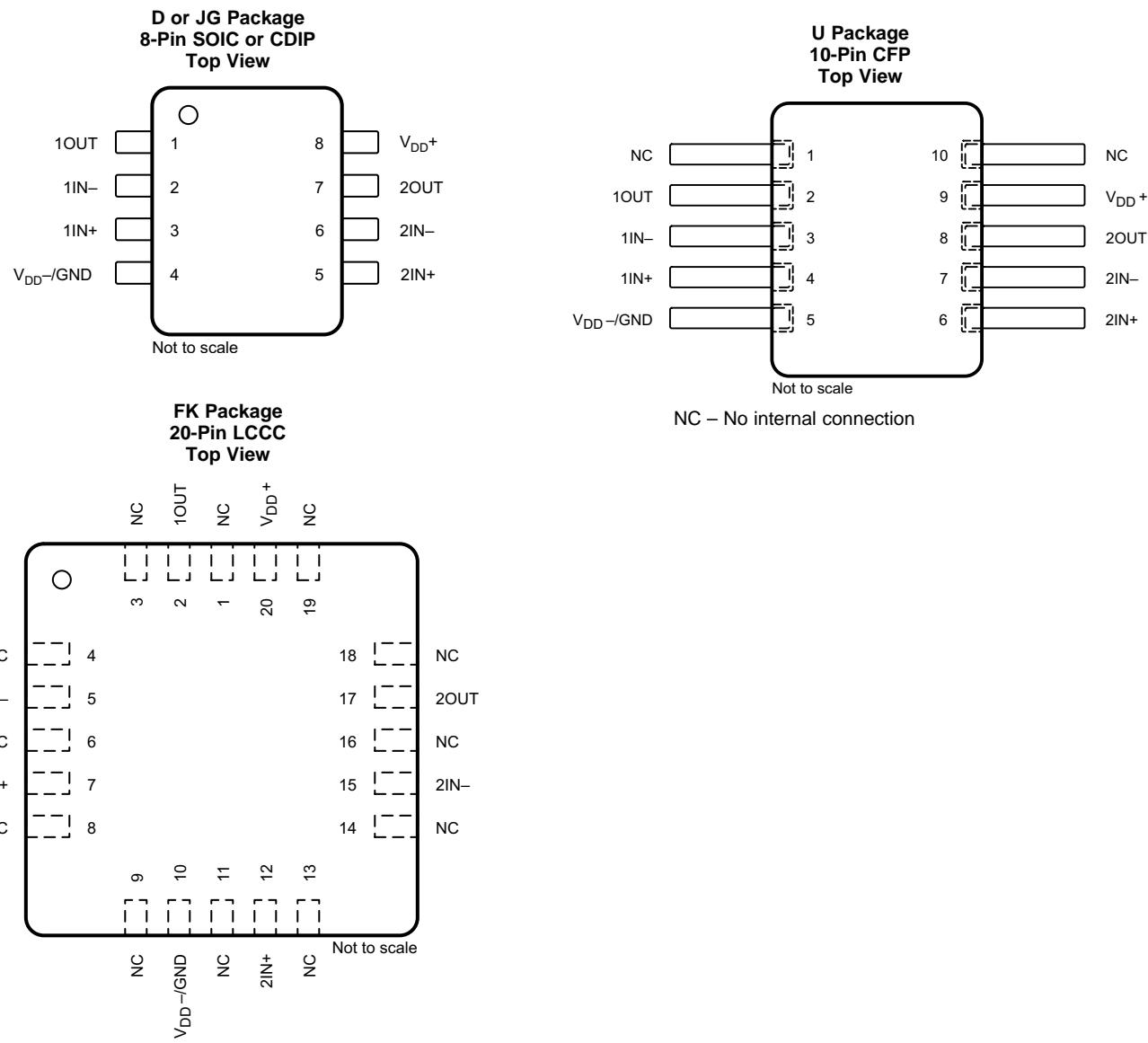
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4 Revision History

DATE	REVISION	NOTE
June 2017	*	Initial release

5 Pin Configuration and Functions



Pin Functions

NAME	PIN			I/O	DESCRIPTION
	D or JG	NO.	FK		
1IN+	3	7	4	I	Non-inverting input, Channel 1
1IN–	2	5	3	I	Inverting input, Channel 1
1OUT	1	2	2	O	Output, Channel 1
2IN+	5	12	6	I	Non-inverting input, Channel 2
2IN–	6	15	7	I	Inverting input, Channel 2
2OUT	7	17	8	O	Output, Channel 2
V _{DD} +	8	20	9	—	Positive (highest) supply
V _{DD} –	—	—	—	—	Negative (lowest) supply
V _{DD} –/GND	4	10	5	—	Negative (lowest) supply
NC	—	1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	1, 10	—	No connection

6 Specifications

6.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted)⁽¹⁾

	MIN	MAX	UNIT
Supply voltage, V_{DD+} ⁽²⁾		8	V
V_{DD-} ⁽²⁾		-8	V
Differential input voltage, V_{ID} ⁽³⁾		±16	V
Input voltage, V_I (any input) ⁽²⁾	$V_{DD-} - 0.3$	V_{DD+}	V
Input current, I_I (any input)		±5	mA
Output current, I_O		±50	mA
Total current into V_{DD+}		±50	mA
Total current out of V_{DD-}		±50	mA
Duration of short-circuit current at (or below) 25°C ⁽⁴⁾	Unlimited		
Operating ambient temperature range, T_A	-55	125	
Storage temperature, T_{stg}	-65	150	°C

- 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.
- All voltage values, except differential voltages, are with respect to the midpoint between V_{DD+} and V_{DD-} .
- Differential voltages are at IN+ with respect to IN-. Excessive current will flow if input is brought below $V_{DD-} - 0.3$ V.
- The output may be shorted to either supply. Temperature or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.

6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 ⁽¹⁾	Devices in D packages	±2000
	Charged-device model (CDM), per AEC Q100-011	Devices in D packages	±1000

- AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
$V_{DD\pm}$	Supply voltage	±2.2	±8	V
V_I	Input voltage	V_{DD-}	$V_{DD+} - 1.5$	V
V_{IC}	Common-mode input voltage	V_{DD-}	$V_{DD+} - 1.5$	V
T_A	Operating ambient temperature	-55	125	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾	TLC2272M-MIL				UNIT
	D (SOIC)	JG (CDIP)	FK (LCCC)	U (CFP)	
	8-PIN		20-PIN	10-PIN	
$R_{\theta,JA}$	Junction-to-ambient thermal resistance ⁽²⁾⁽³⁾	115.6		—	°C/W
$R_{\theta,JC(\text{top})}$	Junction-to-case (top) thermal resistance ⁽²⁾⁽³⁾	61.8		18	°C/W
$R_{\theta,JB}$	Junction-to-board thermal resistance	55.9		—	°C/W
ψ_{JT}	Junction-to-top characterization parameter	14.3		—	°C/W
ψ_{JB}	Junction-to-board characterization parameter	55.4		—	°C/W
$R_{\theta,JC(\text{bot})}$	Junction-to-case (bottom) thermal resistance	—		—	°C/W
				8.68	°C/W

- For more information about traditional and new thermal metrics, see [Semiconductor and IC Package Thermal Metrics](#).
- Maximum power dissipation is a function of $T_{J(\text{max})}$, $R_{\theta,JA}$, and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(\text{max})} - T_A) / R_{\theta,JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
- The package thermal impedance is calculated in accordance with JESD 51-7 (plastic) or MIL-STD-883 Method 1012 (ceramic).

6.5 TLC2272M-MIL Electrical Characteristics $V_{DD} = 5$ V

at specified ambient temperature, $V_{DD} = 5$ V; $T_A = 25^\circ\text{C}$, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
V_{IO}	Input offset voltage	$V_{IC} = 0$ V, $V_{DD\pm} = \pm 2.5$ V, $V_O = 0$ V, $R_S = 50$ Ω		$T_A = 25^\circ\text{C}$	300	2500	μV	
				$T_A = -55^\circ\text{C}$ to 125°C	3000			
α_{VIO}	Temperature coefficient of input offset voltage	$V_{IC} = 0$ V, $V_{DD\pm} = \pm 2.5$ V, $V_O = 0$ V, $R_S = 50$ Ω		2			$\mu\text{V}/^\circ\text{C}$	
Input offset voltage long-term drift ⁽¹⁾		$V_{IC} = 0$ V, $V_{DD\pm} = \pm 2.5$ V, $V_O = 0$ V, $R_S = 50$ Ω		0.002			$\mu\text{V}/\text{mo}$	
I_{IO}	Input offset current	$V_{IC} = 0$ V, $V_{DD\pm} = \pm 2.5$ V, $V_O = 0$ V, $R_S = 50$ Ω		$T_A = 25^\circ\text{C}$	0.5	60	pA	
				$T_A = -55^\circ\text{C}$ to 125°C	800			
I_{IB}	Input bias current	$V_{IC} = 0$ V, $V_{DD\pm} = \pm 2.5$ V, $V_O = 0$ V, $R_S = 50$ Ω		$T_A = 25^\circ\text{C}$	1	60	pA	
				$T_A = -55^\circ\text{C}$ to 125°C	800			
V_{ICR}	Common-mode input voltage	$R_S = 50$ Ω ; $ V_{IO} \leq 5$ mV		$T_A = 25^\circ\text{C}$	-0.3	2.5	4	V
				$T_A = -55^\circ\text{C}$ to 125°C	0	2.5	3.5	
V_{OH}	High-level output voltage	$I_{OH} = -20$ μA		4.99			V	
		$I_{OH} = -200$ μA		$T_A = 25^\circ\text{C}$	4.85	4.93		
				$T_A = -55^\circ\text{C}$ to 125°C	4.85			
		$I_{OH} = -1$ mA		$T_A = 25^\circ\text{C}$	4.25	4.65		
				$T_A = -55^\circ\text{C}$ to 125°C	4.25			
V_{OL}	Low-level output voltage	$I_{OL} = 50$ μA		0.01			V	
		$V_{IC} = 2.5$ V		$I_{OL} = 500$ μA	$T_A = 25^\circ\text{C}$	0.09	0.15	
					$T_A = -55^\circ\text{C}$ to 125°C	0.15		
		$I_{OL} = 5$ mA			$T_A = 25^\circ\text{C}$	0.9	1.5	
					$T_A = -55^\circ\text{C}$ to 125°C	1.5		
A_{VD}	Large-signal differential voltage amplification	$V_{IC} = 2.5$ V, $V_O = 1$ V to 4 V, $R_L = 10$ k Ω ⁽²⁾		$T_A = 25^\circ\text{C}$	10	35	V/mV	
				$T_A = -55^\circ\text{C}$ to 125°C	10			
		$V_{IC} = 2.5$ V, $V_O = 1$ V to 4 V; $R_L = 1$ M Ω ⁽²⁾		175				
r_{id}	Differential input resistance			10 ¹²			Ω	
r_i	Common-mode input resistance			10 ¹²			Ω	
C_i	Common-mode input capacitance	$f = 10$ kHz, P package		8			pF	
Z_o	Closed-loop output impedance	$f = 1$ MHz, $A_V = 10$		140			Ω	
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ V to 2.7 V, $V_O = 2.5$ V, $R_S = 50$ Ω		$T_A = 25^\circ\text{C}$	70	75	dB	
				$T_A = -55^\circ\text{C}$ to 125°C	70			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$)	$V_{DD} = 4.4$ V to 16 V, $V_{IC} = V_{DD} / 2$, no load		$T_A = 25^\circ\text{C}$	80	95	dB	
				$T_A = -55^\circ\text{C}$ to 125°C	80			
I_{DD}	Supply current	$V_O = 2.5$ V, no load		$T_A = 25^\circ\text{C}$	2.2	3	mA	
				$T_A = -55^\circ\text{C}$ to 125°C	3			
SR	Slew rate at unity gain	$V_O = 0.5$ V to 2.5 V, $R_L = 10$ k Ω ⁽²⁾ , $C_L = 100$ pF ⁽²⁾		$T_A = 25^\circ\text{C}$	2.3	3.6	$\text{V}/\mu\text{s}$	
				$T_A = -55^\circ\text{C}$ to 125°C	1.7			
V_n	Equivalent input noise voltage	$f = 10$ Hz		50			$\text{nV}/\sqrt{\text{Hz}}$	
		$f = 1$ kHz		9				
V_{NPP}	Peak-to-peak equivalent input noise voltage	$f = 0.1$ Hz to 1 Hz		1			μV	
		$f = 0.1$ Hz to 10 Hz		1.4				
I_n	Equivalent input noise current			0.6			$\text{fA}/\sqrt{\text{Hz}}$	
THD+N	Total harmonic distortion + noise	$V_O = 0.5$ V to 2.5 V, $f = 20$ kHz, $R_L = 10$ k Ω ⁽²⁾		$A_V = 1$	0.0013%			
				$A_V = 10$	0.004%			
				$A_V = 100$	0.03%			
Gain-bandwidth product		$f = 10$ kHz, $R_L = 10$ k Ω ⁽²⁾ , $C_L = 100$ pF ⁽²⁾		2.18			MHz	
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 2$ V, $A_V = 1$, $R_L = 10$ k Ω ⁽²⁾ , $C_L = 100$ pF ⁽²⁾		1			MHz	
t_s	Settling time	$A_V = -1$, $R_L = 10$ k Ω ⁽²⁾ , Step = 0.5 V to 2.5 V, $C_L = 100$ pF ⁽²⁾		$To 0.1\%$	1.5		μs	
				$To 0.01\%$	2.6			

(1) Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

(2) Referenced to 0 V.

TLC2272M-MIL Electrical Characteristics $V_{DD} = 5$ V (continued)

at specified ambient temperature, $V_{DD} = 5$ V; $T_A = 25^\circ\text{C}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
φ_m Phase margin at unity gain	$R_L = 10 \text{ k}\Omega^{(2)}$, $C_L = 100 \text{ pF}^{(2)}$		50		$^\circ$
Gain margin	$R_L = 10 \text{ k}\Omega^{(2)}$, $C_L = 100 \text{ pF}^{(2)}$		10		dB

6.6 TLC2272M-MIL Electrical Characteristics $V_{DD\pm} = \pm 5$ V

at specified ambient temperature, $V_{DD\pm} = \pm 5$ V; $T_A = 25^\circ\text{C}$, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT		
V_{IO}	Input offset voltage	$V_{IC} = 0$ V, $V_O = 0$ V, $R_S = 50 \Omega$		$T_A = 25^\circ\text{C}$	300	2500	μV		
				$T_A = -55^\circ\text{C}$ to 125°C	3000				
α_{VIO}	Temperature coefficient of input offset voltage	$V_{IC} = 0$ V, $V_O = 0$ V, $R_S = 50 \Omega$		2			$\mu\text{V}/^\circ\text{C}$		
Input offset voltage long-term drift ⁽¹⁾		$V_{IC} = 0$ V, $V_O = 0$ V, $R_S = 50 \Omega$		0.002			$\mu\text{V}/\text{mo}$		
I_{IO}	Input offset current	$V_{IC} = 0$ V, $V_O = 0$ V, $R_S = 50 \Omega$		$T_A = 25^\circ\text{C}$	0.5	60	pA		
				$T_A = -55^\circ\text{C}$ to 125°C	800				
I_{IB}	Input bias current	$V_{IC} = 0$ V, $V_O = 0$ V, $R_S = 50 \Omega$		$T_A = 25^\circ\text{C}$	1	60	pA		
				$T_A = -55^\circ\text{C}$ to 125°C	800				
V_{ICR}	Common-mode input voltage	$R_S = 50 \Omega$; $ V_{IO} \leq 5$ mV		$T_A = 25^\circ\text{C}$	-5.3	0	V		
				$T_A = -55^\circ\text{C}$ to 125°C	-5	0			
V_{OM+}	Maximum positive peak output voltage	$I_O = -20 \mu\text{A}$		4.99			V		
		$I_O = -200 \mu\text{A}$		$T_A = 25^\circ\text{C}$	4.85	4.93			
				$T_A = -55^\circ\text{C}$ to 125°C	4.85				
		$I_O = -1 \text{ mA}$		$T_A = 25^\circ\text{C}$	4.25	4.65			
				$T_A = -55^\circ\text{C}$ to 125°C	4.25				
V_{OM-}	Maximum negative peak output voltage	$V_{IC} = 0$ V,	$I_O = 50 \mu\text{A}$	-4.99			V		
			$I_O = 500 \mu\text{A}$	$T_A = 25^\circ\text{C}$	-4.85	-4.91			
				$T_A = -55^\circ\text{C}$ to 125°C	-4.85				
			$I_O = 5 \text{ mA}$	$T_A = 25^\circ\text{C}$	-3.5	-4.1			
				$T_A = -55^\circ\text{C}$ to 125°C	-3.5				
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 4$ V; $R_L = 10 \text{ k}\Omega$		$T_A = 25^\circ\text{C}$	20	50	V/mV		
				$T_A = -55^\circ\text{C}$ to 125°C	20				
		$V_O = \pm 4$ V; $R_L = 1 \text{ M}\Omega$		300					
r_{id}	Differential input resistance			10 ¹²			Ω		
r_i	Common-mode input resistance			10 ¹²			Ω		
C_i	Common-mode input capacitance	$f = 10$ kHz, P package		8			pF		
Z_o	Closed-loop output impedance	$f = 1$ MHz, $A_V = 10$		130			Ω		
CMRR	Common-mode rejection ratio	$V_{IC} = -5$ V to 2.7 V, $V_O = 0$ V, $R_S = 50 \Omega$		$T_A = 25^\circ\text{C}$	75	80	dB		
				$T_A = -55^\circ\text{C}$ to 125°C	75				
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD} / \Delta V_{IO}$)	$V_{DD+} = 2.2$ V to ± 8 V, $V_{IC} = 0$ V, no load		$T_A = 25^\circ\text{C}$	80	95	dB		
				$T_A = -55^\circ\text{C}$ to 125°C	80				
I_{DD}	Supply current	$V_O = 0$ V, no load		$T_A = 25^\circ\text{C}$	2.4	3	mA		
				$T_A = -55^\circ\text{C}$ to 125°C	3				
SR	Slew rate at unity gain	$V_O = \pm 2.3$ V, $R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		$T_A = 25^\circ\text{C}$	2.3	3.6	$\text{V}/\mu\text{s}$		
				$T_A = -55^\circ\text{C}$ to 125°C	1.7				
V_n	Equivalent input noise voltage	$f = 10$ Hz		50			$\text{nV}/\sqrt{\text{Hz}}$		
				9					
V_{NPP}	Peak-to-peak equivalent input noise voltage	$f = 0.1$ Hz to 1 Hz		1			μV		
				1.4					
I_n	Equivalent input noise current			0.6			$\text{fA}/\sqrt{\text{Hz}}$		
THD+N	Total harmonic distortion + noise	$V_O = \pm 2.3$, $f = 20$ kHz, $R_L = 10 \text{ k}\Omega$		$A_V = 1$	0.0011%				
				$A_V = 10$	0.004%				
				$A_V = 100$	0.03%				
Gain-bandwidth product		$f = 10$ kHz, $R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		2.25			MHz		
B_{OM}	Maximum output-swing bandwidth	$V_{O(PP)} = 4.6$ V, $A_V = 1$, $R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		0.54			MHz		
t_s	Settling time	$A_V = -1$, $R_L = 10 \text{ k}\Omega$, Step = -2.3 V to 2.3 V, $C_L = 100 \text{ pF}$		To 0.1%	1.5		μs		
				To 0.01%	3.2				
ϕ_m	Phase margin at unity gain	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		52			$^\circ$		

(1) Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at $T_A = 150^\circ\text{C}$ extrapolated to $T_A = 25^\circ\text{C}$ using the Arrhenius equation and assuming an activation energy of 0.96 eV.

TLC2272M-MIL Electrical Characteristics $V_{DD\pm} = \pm 5$ V (continued)

at specified ambient temperature, $V_{DD\pm} = \pm 5$ V; $T_A = 25^\circ\text{C}$, unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Gain margin	$R_L = 10 \text{ k}\Omega$, $C_L = 100 \text{ pF}$		10		dB

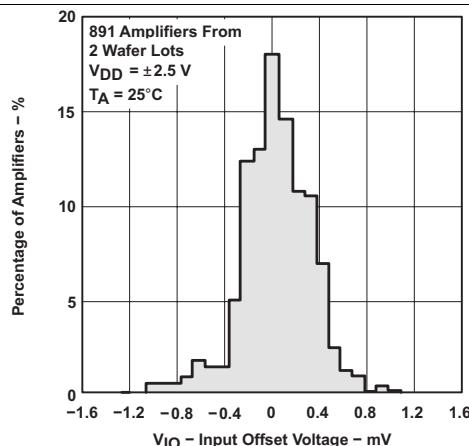
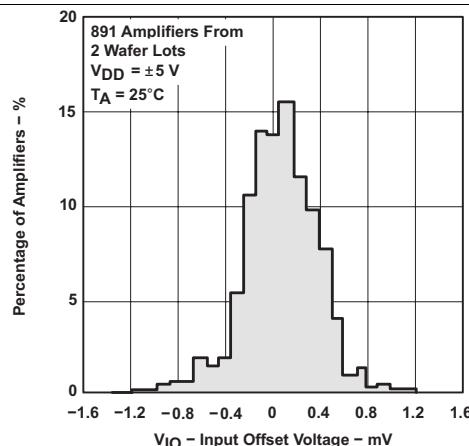
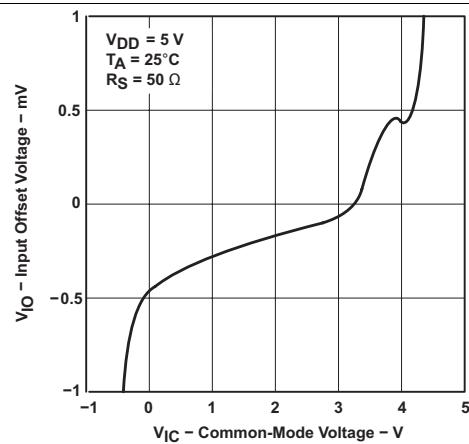
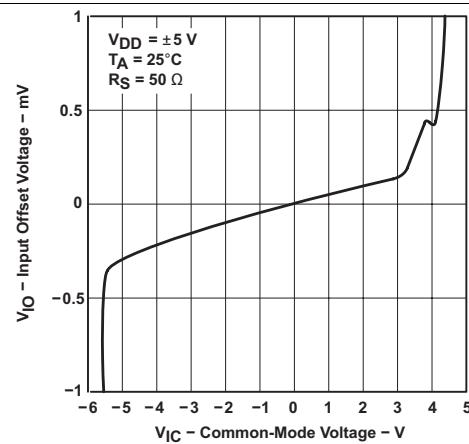
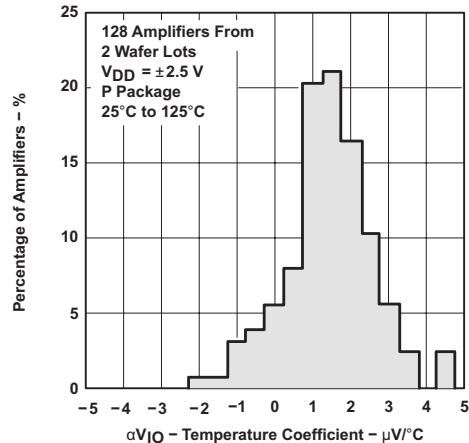
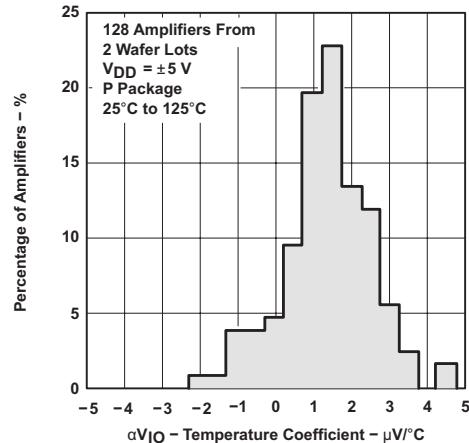
6.7 Typical Characteristics

Table 1. Table of Graphs

		FIGURE ⁽¹⁾
V _{IO}	Input offset voltage	Distribution vs Common-mode voltage
		1, 2 3, 4
α _{VIO}	Input offset voltage temperature coefficient	Distribution
I _{IB} / I _{IO}	Input bias and input offset current	vs ambient temperature
		7 ⁽²⁾
	Input voltage	vs Supply voltage vs ambient temperature
V _{OH}	High-level output voltage	vs High-level output current
V _{OL}	Low-level output voltage	vs Low-level output current
V _{OM+}	Maximum positive peak output voltage	vs Output current
V _{OM-}	Maximum negative peak output voltage	vs Output current
V _{O(PP)}	Maximum peak-to-peak output voltage	vs Frequency
I _{OS}	Short-circuit output current	vs Supply voltage
		vs ambient temperature
V _O	Output voltage	vs Differential input voltage
A _{VD}	Large-signal differential voltage amplification	vs Load resistance
	Large-signal differential voltage amplification and phase margin	vs Frequency
	Large-signal differential voltage amplification	vs ambient temperature
z ₀	Output impedance	vs Frequency
CMRR	Common-mode rejection ratio	vs Frequency
		vs ambient temperature
k _{SVR}	Supply-voltage rejection ratio	vs Frequency
		vs ambient temperature
I _{DD}	Supply current	vs Supply voltage
		vs ambient temperature
SR	Slew rate	vs Load Capacitance
		vs ambient temperature
V _O	Inverting large-signal pulse response	36, 37
	Voltage-follower large-signal pulse response	38, 39
	Inverting small-signal pulse response	40, 41
	Voltage-follower small-signal pulse response	42, 43
V _n	Equivalent input noise voltage	44, 45
	Noise voltage over a 10-second period	46
	Integrated noise voltage	47
THD+N	Total harmonic distortion + noise	vs Frequency
	Gain-bandwidth product	vs Supply voltage
		vs ambient temperature
φ _m	Phase margin	vs Load capacitance
	Gain margin	vs Load capacitance

(1) For all graphs where V_{DD} = 5 V, all loads are referenced to 2.5 V.

(2) Data at high and low temperatures are applicable only within the rated operating ambient temperature range of the device.


Figure 1. Distribution of Input Offset Voltage

Figure 2. Distribution of Input Offset Voltage

Figure 3. Input Offset Voltage vs Common-Mode Voltage

Figure 4. Input Offset Voltage vs Common-Mode Voltage

Figure 5. Distribution of Amplifiers vs Input Offset Voltage Temperature Coefficient

Figure 6. Distribution of Amplifiers vs Input Offset Voltage Temperature Coefficient

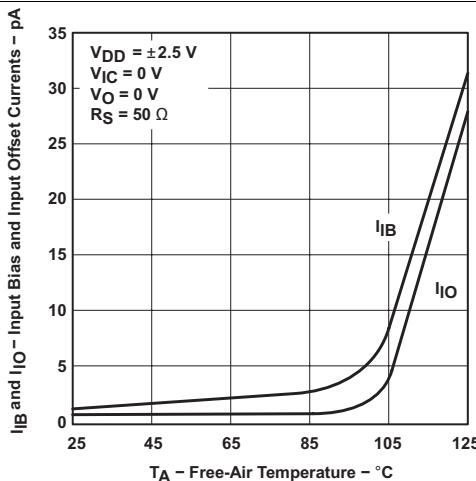


Figure 7. Input Bias and Input Offset Current vs Ambient Temperature

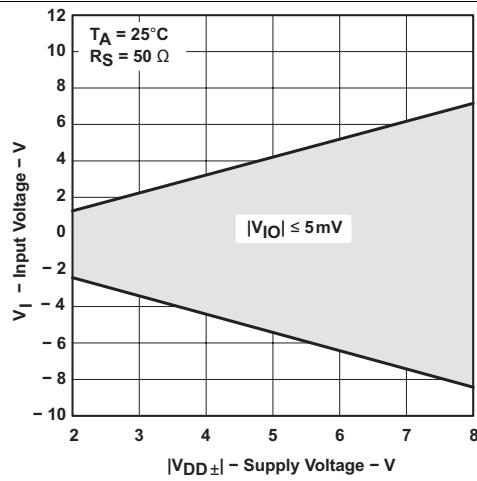


Figure 8. Input Voltage vs Supply Voltage

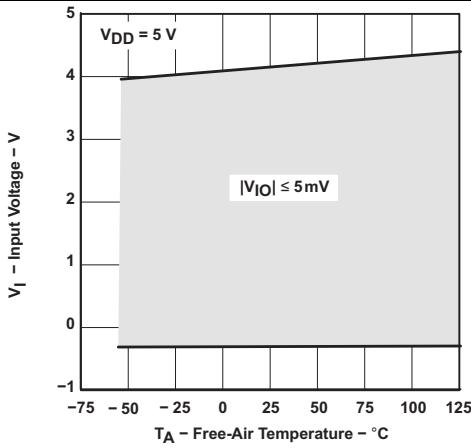


Figure 9. Input Voltage vs Ambient Temperature

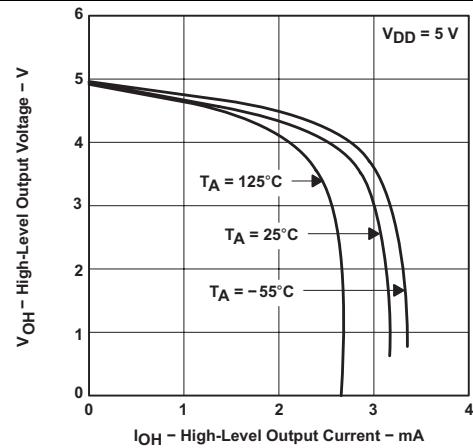


Figure 10. High-Level Output Voltage vs High-Level Output Current

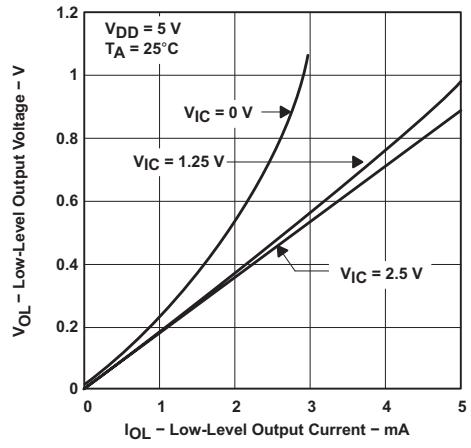


Figure 11. Low-Level Output Voltage vs Low-Level Output Current

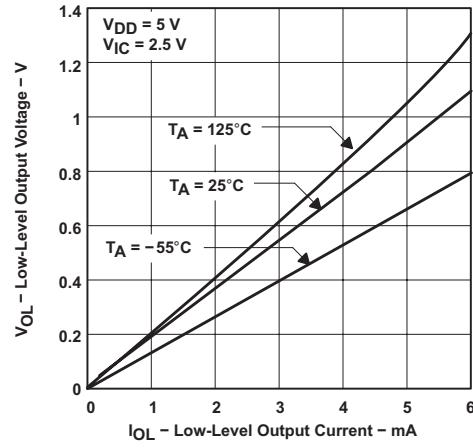


Figure 12. Low-Level Output Voltage vs Low-Level Output Current

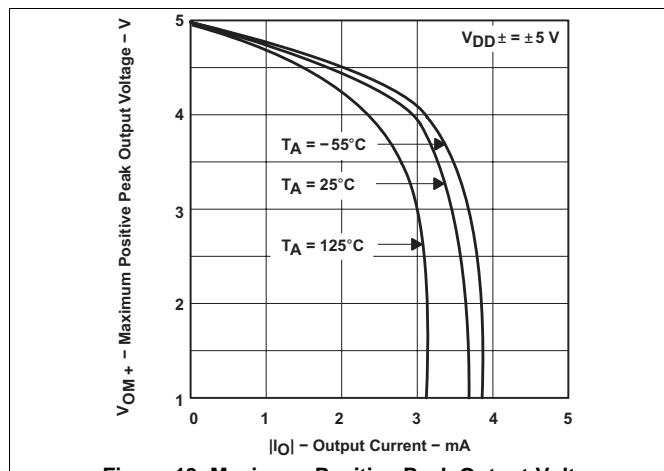


Figure 13. Maximum Positive Peak Output Voltage vs Output Current

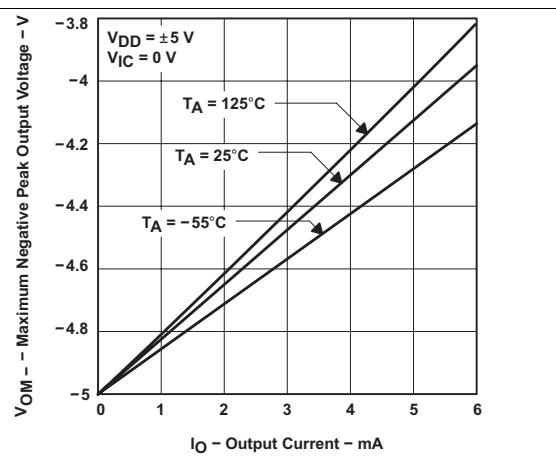


Figure 14. Maximum Negative Peak Output Voltage vs Output Current

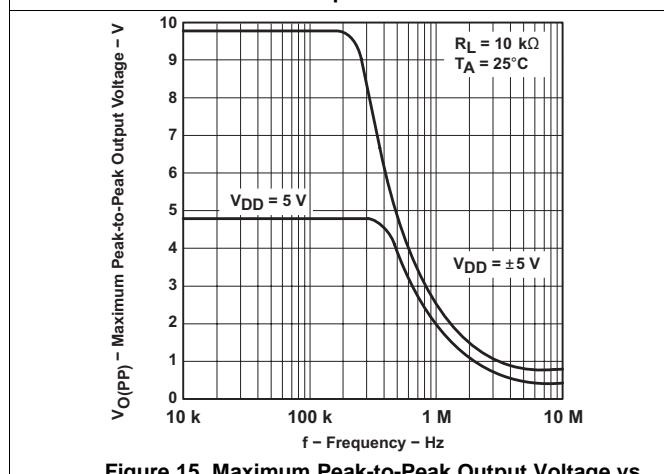


Figure 15. Maximum Peak-to-Peak Output Voltage vs Frequency

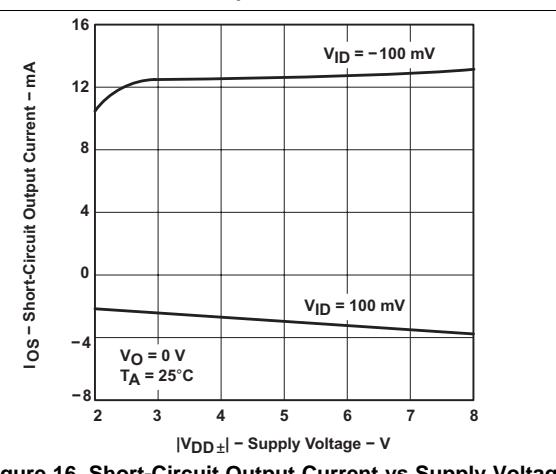
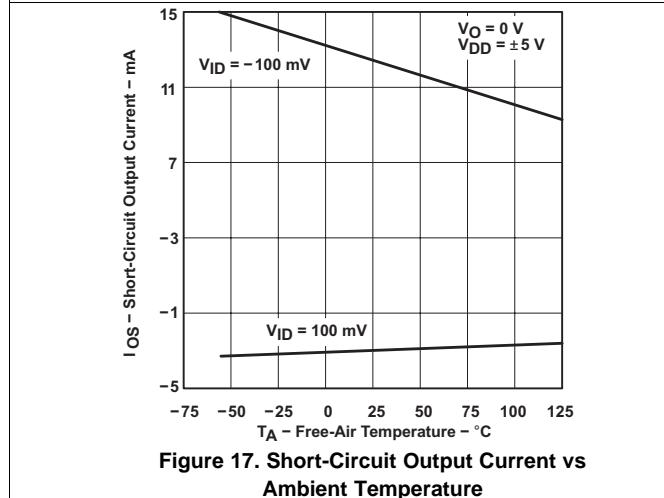


Figure 16. Short-Circuit Output Current vs Supply Voltage



**Figure 17. Short-Circuit Output Current vs
Ambient Temperature**

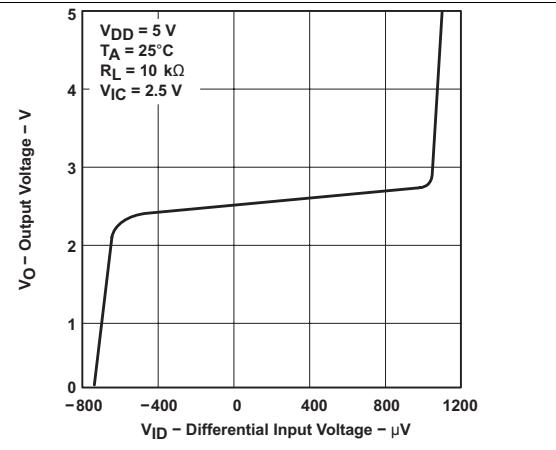


Figure 18. Output Voltage vs Differential Input Voltage

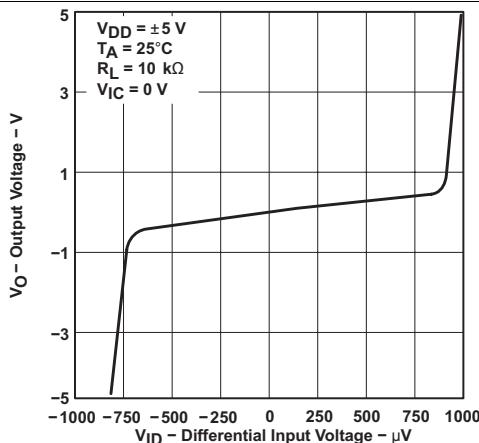


Figure 19. Output Voltage vs Differential Input Voltage

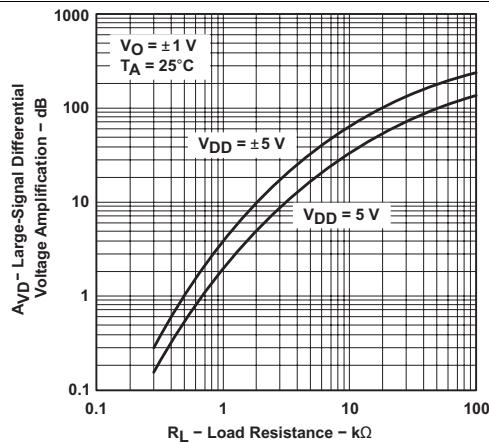


Figure 20. Large-Signal Differential Voltage Amplification vs Load Resistance

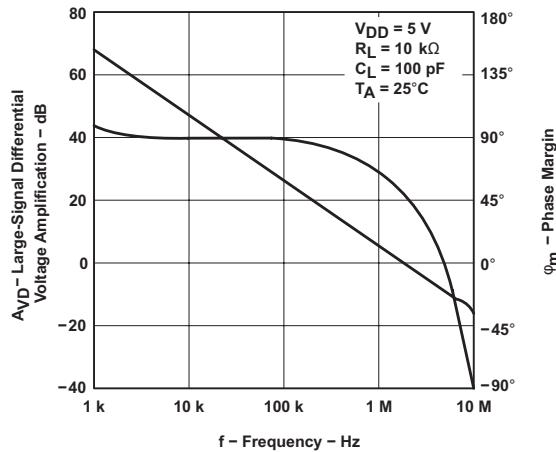


Figure 21. Large-Signal Differential Voltage Amplification and Phase Margin vs Frequency

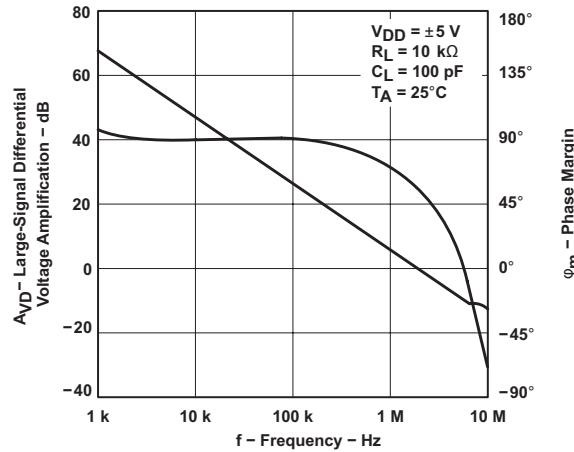


Figure 22. Large-Signal Differential Voltage Amplification and Phase Margin vs Frequency

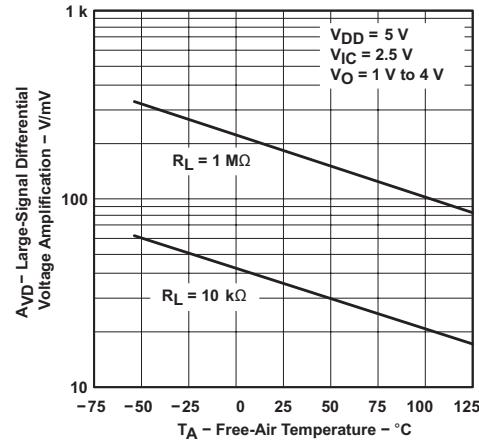


Figure 23. Large-Signal Differential Voltage Amplification vs Ambient Temperature

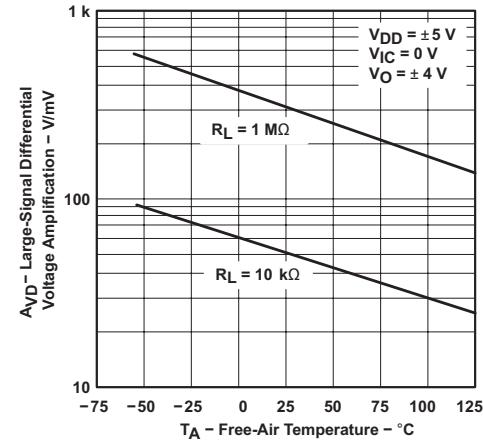
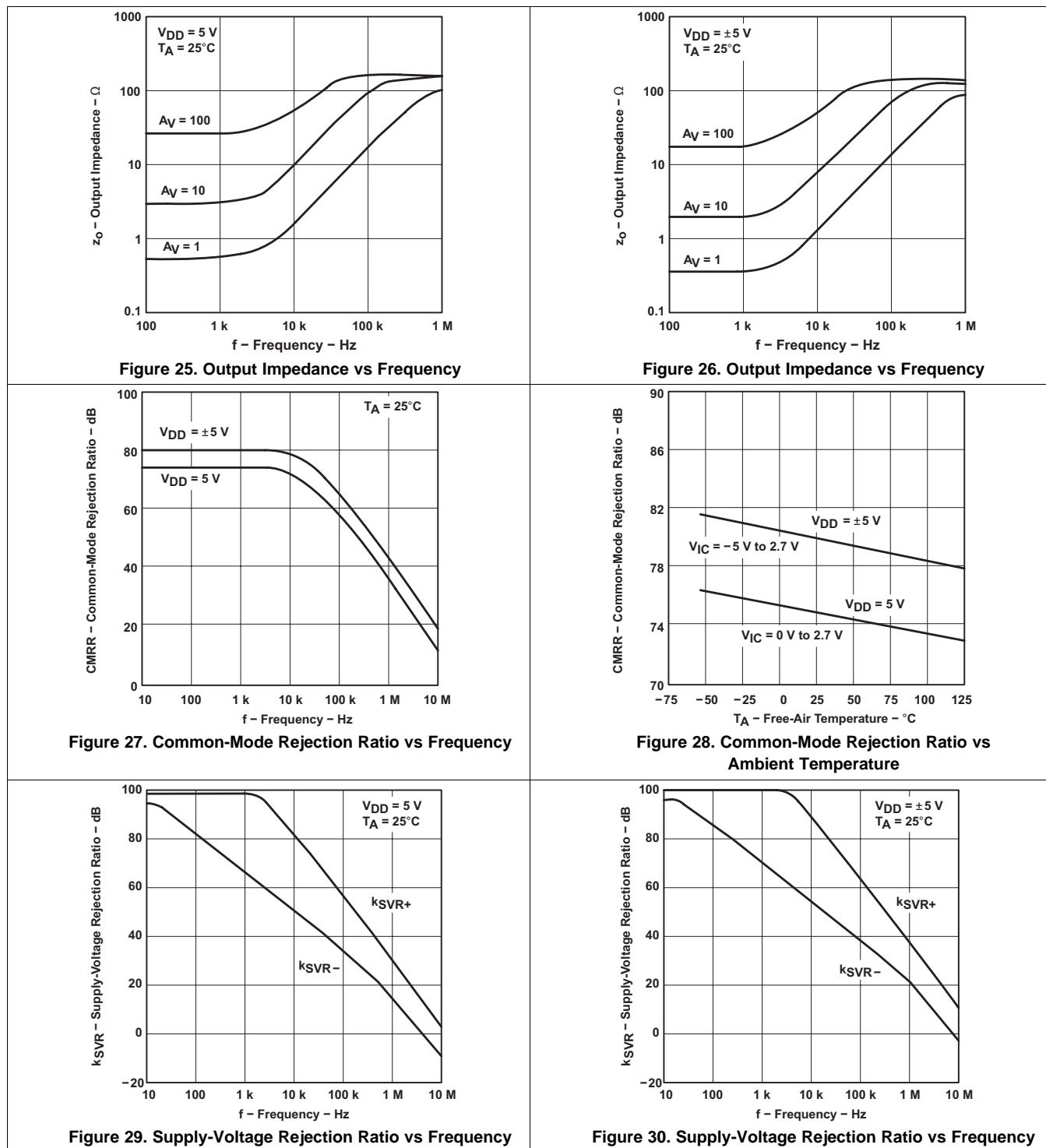


Figure 24. Large-Signal Differential Voltage Amplification vs Ambient Temperature



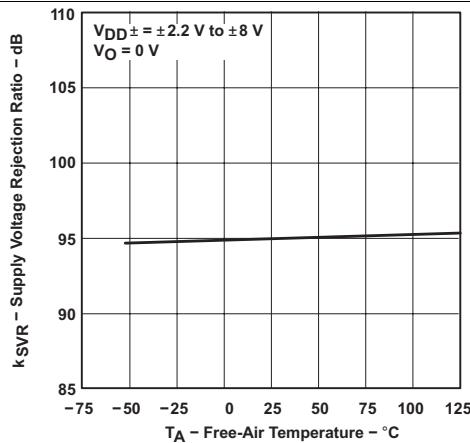


Figure 31. Supply-Voltage Rejection Ratio vs Ambient Temperature

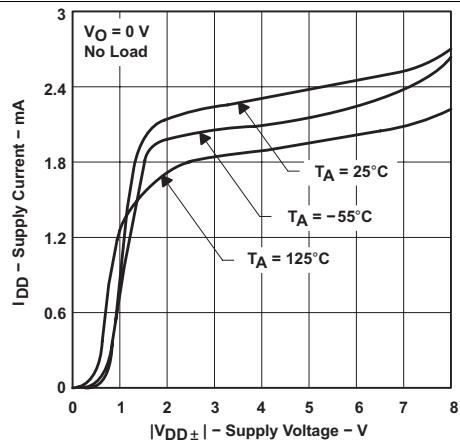


Figure 32. Supply Current vs Supply Voltage

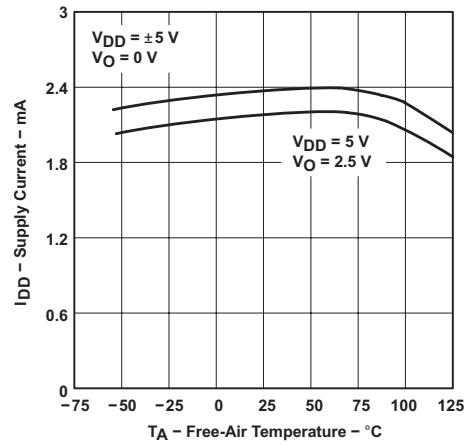


Figure 33. Supply Current vs Ambient Temperature

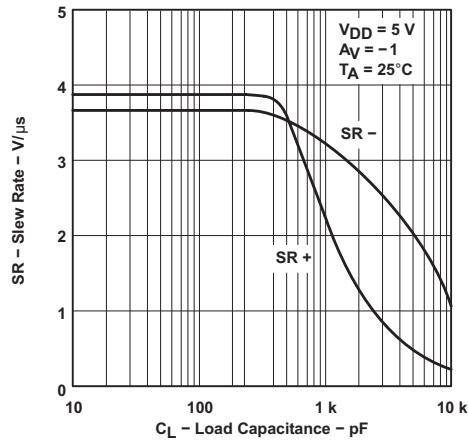


Figure 34. Slew Rate vs Load Capacitance

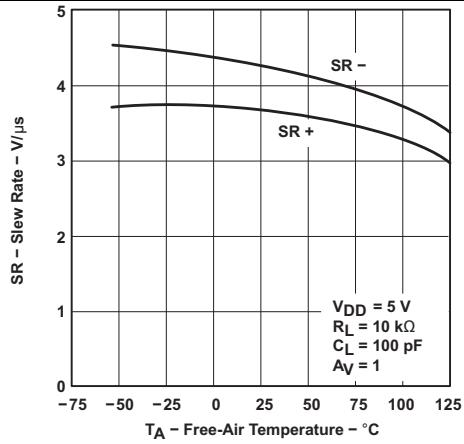


Figure 35. Slew Rate vs Ambient Temperature

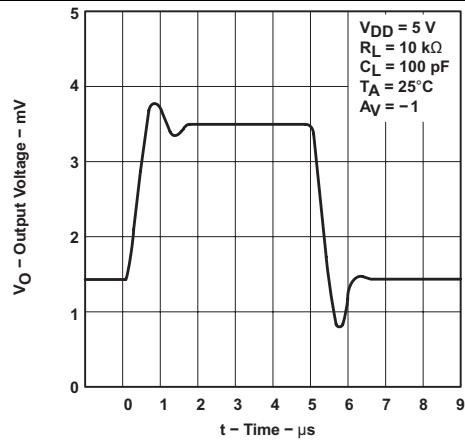
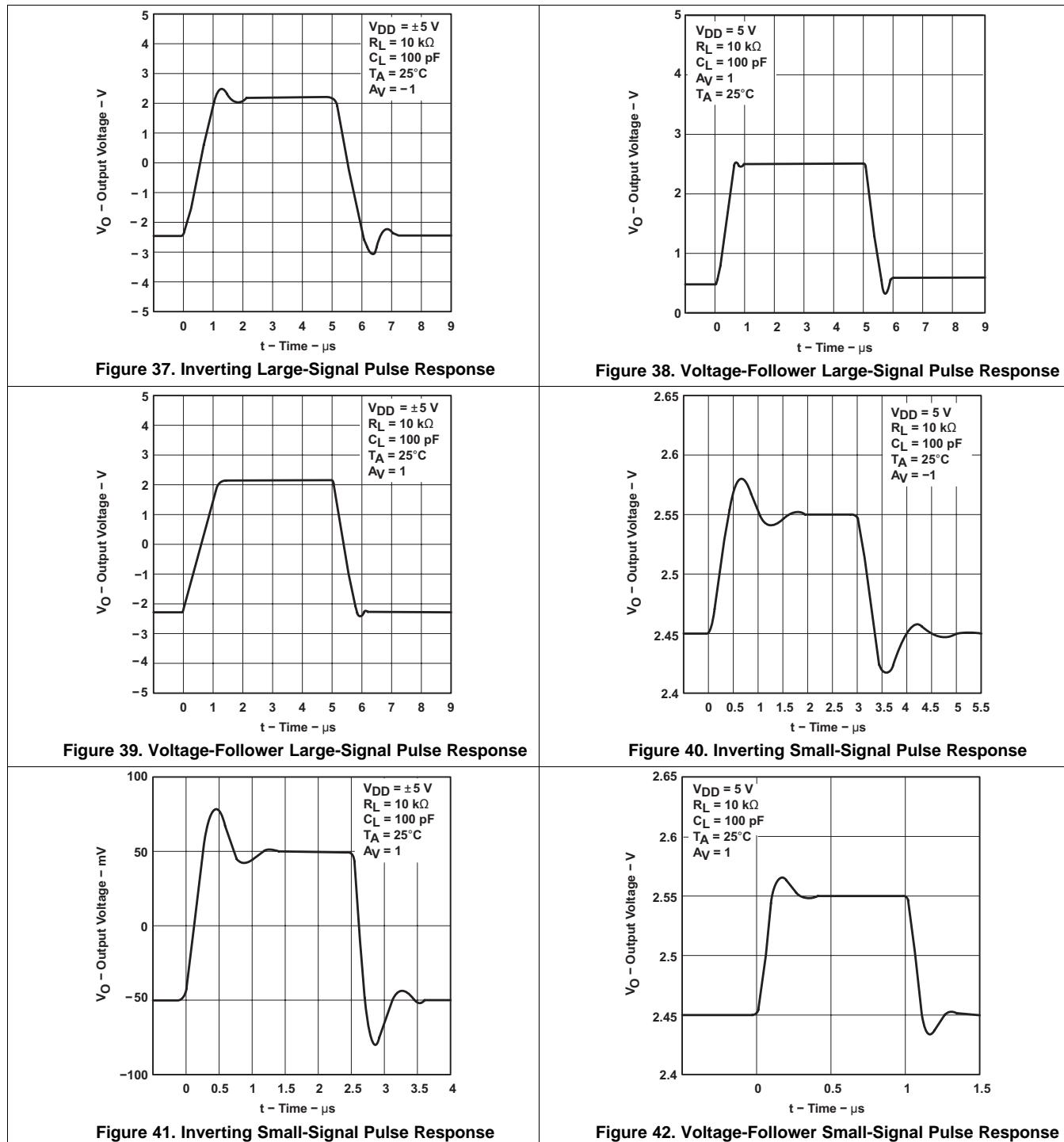
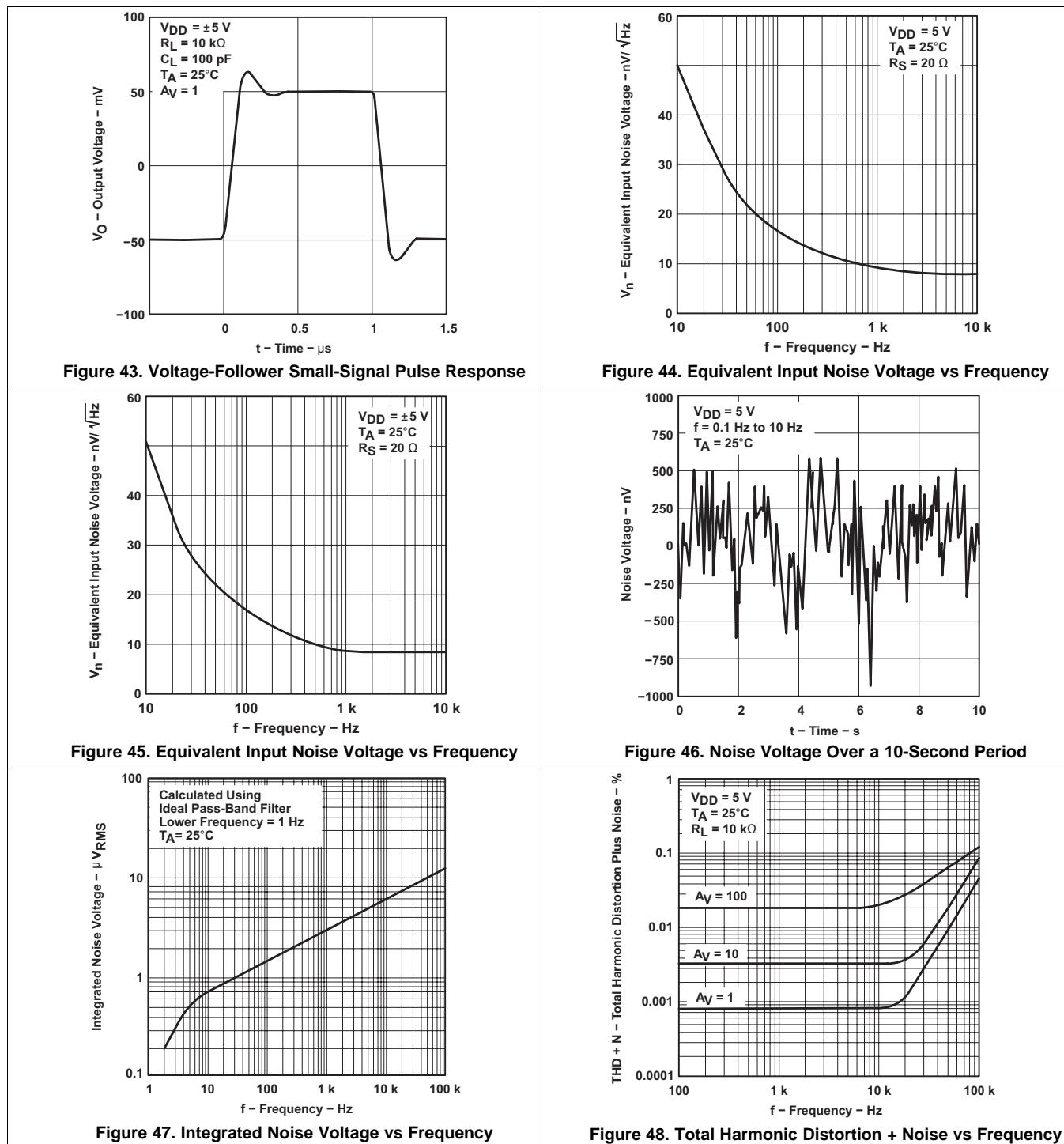
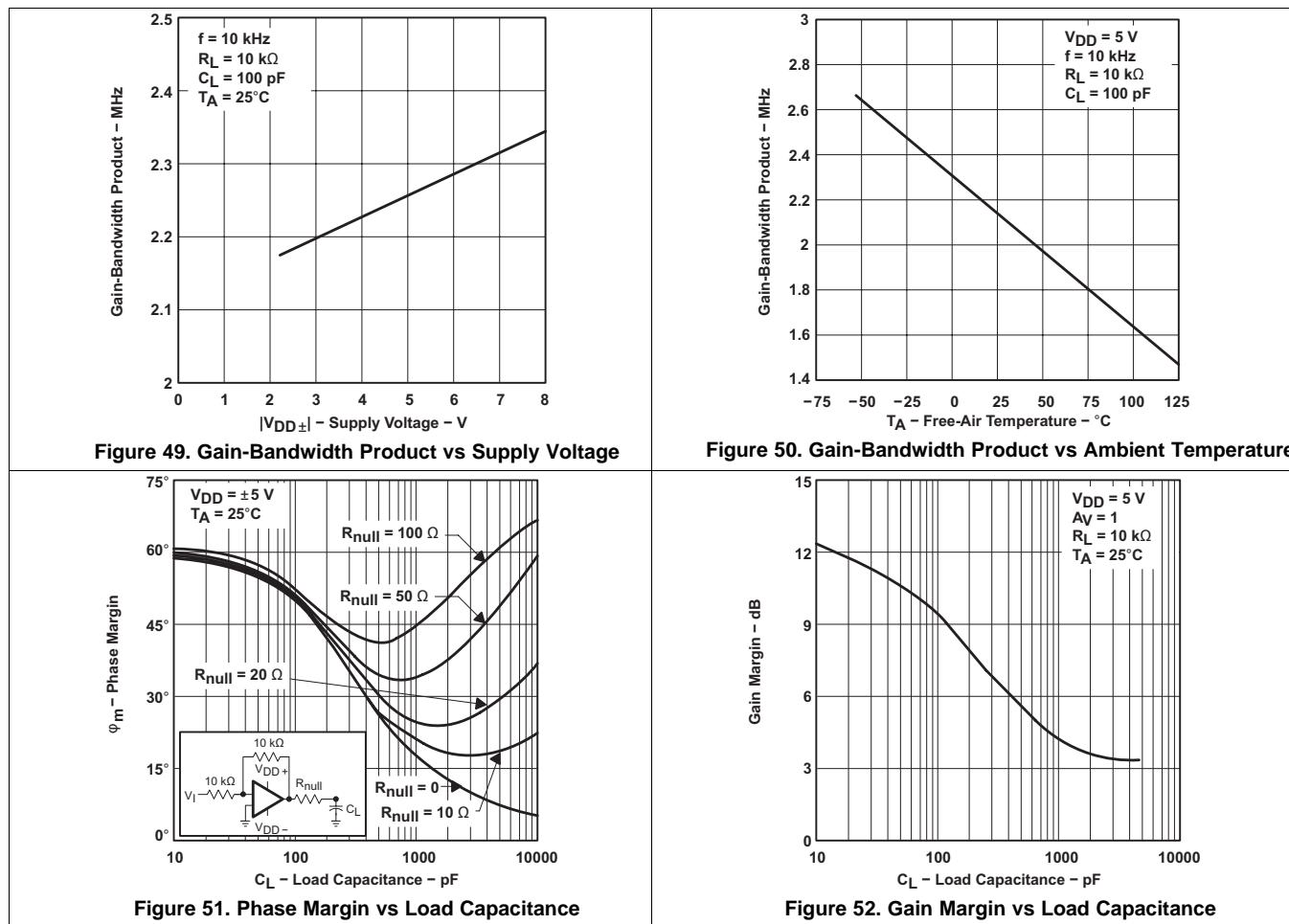


Figure 36. Inverting Large-Signal Pulse Response







7 Detailed Description

7.1 Overview

The TLC2272M-MIL device is a rail-to-rail output operational amplifier. The device operates from a 4.4-V to 16-V single supply or $\pm 2.2\text{-V}$ to $\pm 8\text{-V}$ dual supply, is unity-gain stable, and is suitable for a wide range of general-purpose applications.

7.2 Functional Block Diagram

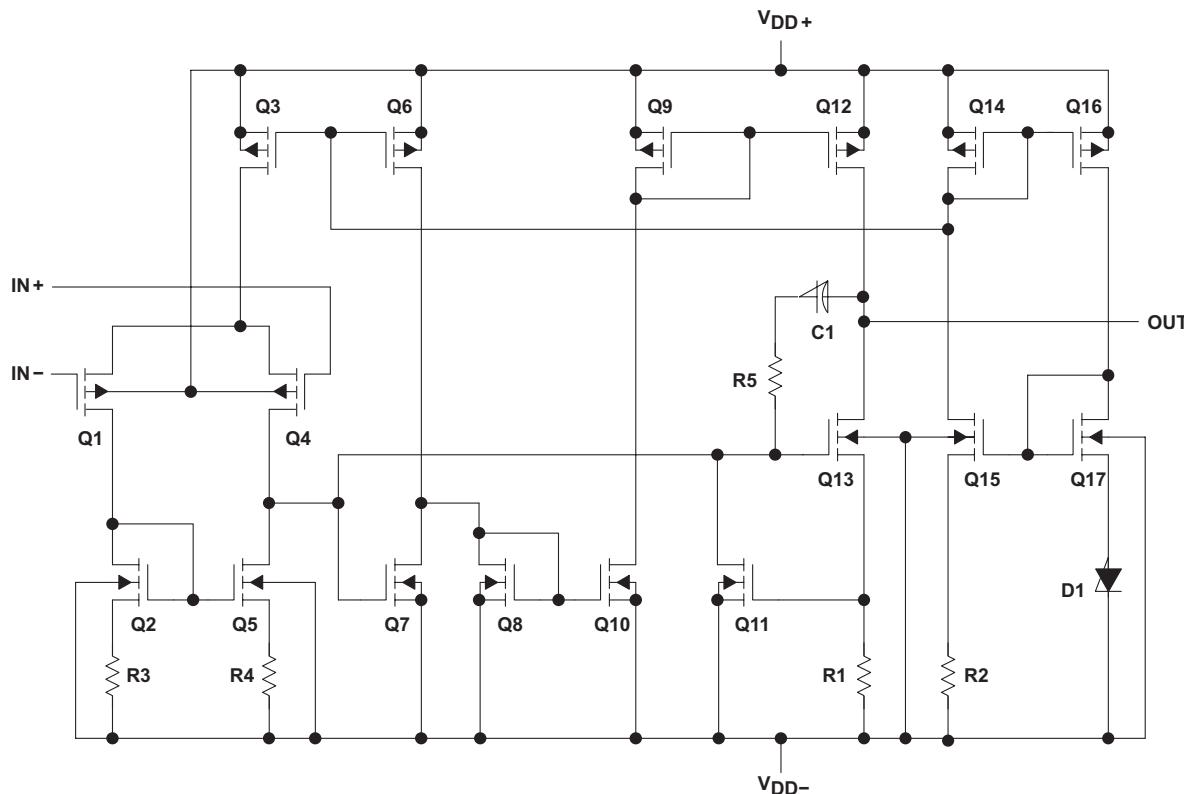


Table 2. Device Component Count⁽¹⁾

COMPONENT	COUNT
Transistors	38
Resistors	26
Diodes	9
Capacitors	3

(1) Includes both amplifiers and all ESD, bias, and trim circuitry.

7.3 Feature Description

The TLC2272M-MIL device features 2-MHz bandwidth and voltage noise of $9\text{ nV}/\sqrt{\text{Hz}}$ with performance rated from 4.4 V to 16 V across a temperature range of -55°C to 125°C . LinMOS suits a wide range of audio, automotive, industrial, and instrumentation applications.

7.4 Device Functional Modes

The TLC2272M-MIL device is powered on when the supply is connected. The device may operate with single or dual supply, depending on the application. The device is in its full-performance mode once the supply is above the recommended value.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Macromodel Information

Macromodel information provided was derived using MicroSim Parts™, the model generation software used with MicroSim PSpice™. The Boyle macromodel⁽¹⁾ and subcircuit in Figure 53 were generated using the TLC2272M-MIL typical electrical and operating characteristics at $T_A = 25^\circ\text{C}$. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

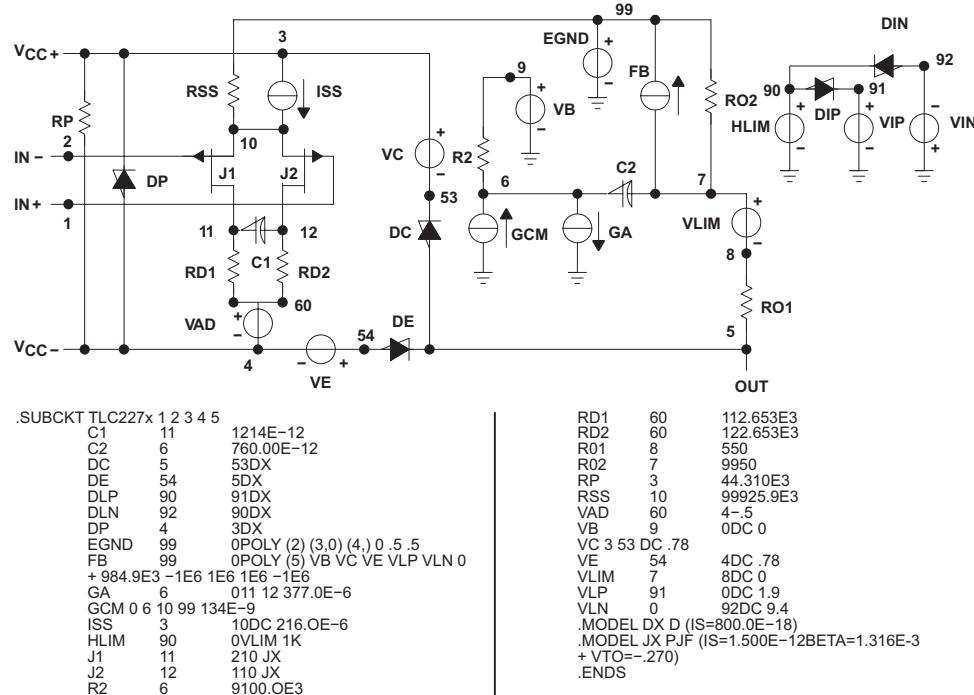


Figure 53. Boyle Macromodel and Subcircuit

(1) *Macromodeling of Integrated Circuit Operational Amplifiers*, IEEE Journal of Solid-State Circuits, SC-9, 353 (1974).

8.2 Typical Application

8.2.1 High-Side Current Monitor

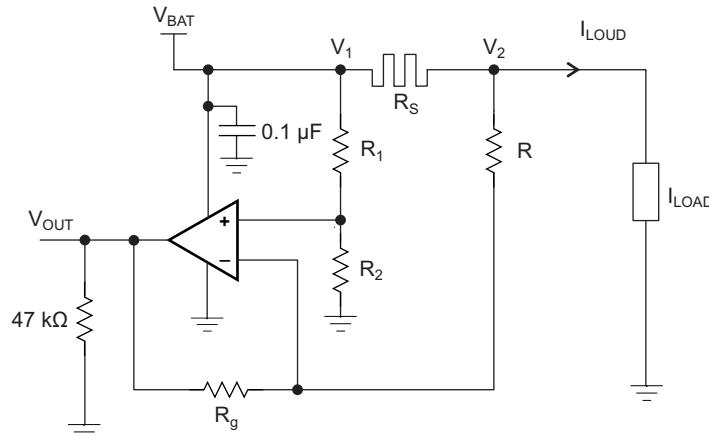


Figure 54. Equivalent Schematic (Each Amplifier)

8.2.1.1 Design Requirements

For this design example, use the parameters listed in [Table 3](#) as the input parameters.

Table 3. Design Parameters

PARAMETER	VALUE
V _{BAT}	12 V
R _{SENSE}	0.1 Ω
I _{LOAD}	0 A to 10 A
Operational amplifier	Set in differential configuration with gain = 10

8.2.1.2 Detailed Design Procedure

This circuit is designed for measuring the high-side current in automotive body control modules with a 12-V battery or similar applications. The operational amplifier is set as differential with an external resistor network.

8.2.1.2.1 Differential Amplifier Equations

[Equation 1](#) and [Equation 2](#) are used to calculate V_{OUT}.

$$V_{OUT} = \frac{R_g}{R} \left(\frac{\frac{R}{R_g} - \frac{R_1}{R_2}}{1 + \frac{R_1}{R_2}} \times \frac{V_1 + V_2}{2} + \frac{1 + \frac{1}{2} \left(\frac{R_1}{R_2} + \frac{R}{R_g} \right)}{1 + \frac{R_1}{R_2}} (V_1 - V_2) \right) \quad (1)$$

$$V_{OUT} = \frac{R_g}{R} \left(\frac{\frac{R}{R_g} - \frac{R_1}{R_2}}{1 + \frac{R_1}{R_2}} \times V_{BAT} + \frac{1 + \frac{1}{2} \left(\frac{R_1}{R_2} + \frac{R}{R_g} \right)}{1 + \frac{R_1}{R_2}} \times R_S \times I_{Load} \right) \quad (2)$$

In an ideal case R₁ = R and R₂ = R_g, and V_{OUT} can then be calculated using [Equation 3](#):

$$V_{OUT} = \frac{R_g}{R} \times R_S \times I_{Load} \quad (3)$$

However, as the resistors have tolerances, they cannot be perfectly matched.

$$\begin{aligned}
R_1 &= R \pm \Delta R_1 \\
R_2 &= R_2 \pm \Delta R_2 \\
R &= R \pm \Delta R \\
R_g &= R_g \pm \Delta R_g \\
Tol &= \frac{\Delta R}{R}
\end{aligned} \tag{4}$$

By developing the equations and neglecting the second order, the worst case is when the tolerances add up. This is shown by [Equation 5](#).

$$V_{OUT} = \pm (4 \text{ Tol}) \frac{R_g}{R + R_g} \times V_{BAT} + \left(1 \pm 2 \text{ Tol} \left(1 + \frac{2R}{R + R_g} \right) \right) \frac{R_g}{R} \times R_s \times I_{LOAD}$$

where

- Tol = 0.01 for 1%
- Tol = 0.001 for 0.1%

5

If the resistors are perfectly matched, then Tol = 0 and V_{OUT} is calculated using [Equation 6](#).

$$V_{OUT} = \frac{R_g}{R} \times R_s \times I_{LOAD} \tag{6}$$

The highest error is from the common mode, as shown in [Equation 7](#).

$$4 (\text{Tol}) \frac{R_g}{R + R_g} \times V_{BAT} \tag{7}$$

Gain of 10, $R_g / R = 10$, and Tol = 1%:

$$\text{Common mode error} = ((4 \times 0.01) / 1.1) \times 12 \text{ V} = 0.436 \text{ V}$$

Gain of 10 and Tol = 0.1%:

$$\text{Common mode error} = 43.6 \text{ mV}$$

The resistors were chosen from 2% batches.

$$R_1 \text{ and } R \text{ } 12 \text{ k}\Omega$$

$$R_2 \text{ and } R_g \text{ } 120 \text{ k}\Omega$$

$$\text{Ideal Gain} = 120 / 12 = 10$$

The measured value of the resistors:

$$R_1 = 11.835 \text{ k}\Omega$$

$$R = 11.85 \text{ k}\Omega$$

$$R_2 = 117.92 \text{ k}\Omega$$

$$R_g = 118.07 \text{ k}\Omega$$

8.2.1.3 Application Curves

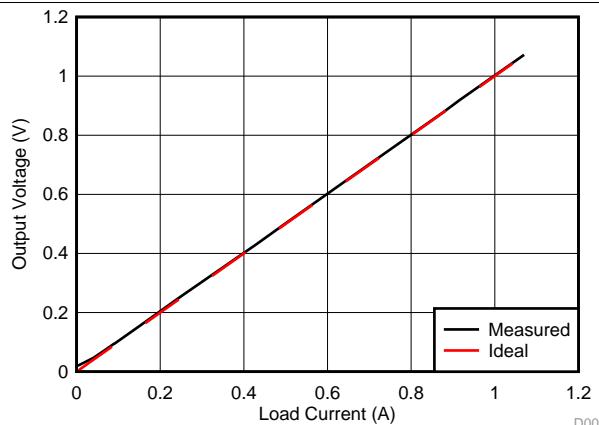


Figure 55. Output Voltage Measured vs Ideal
(0 to 1 A)

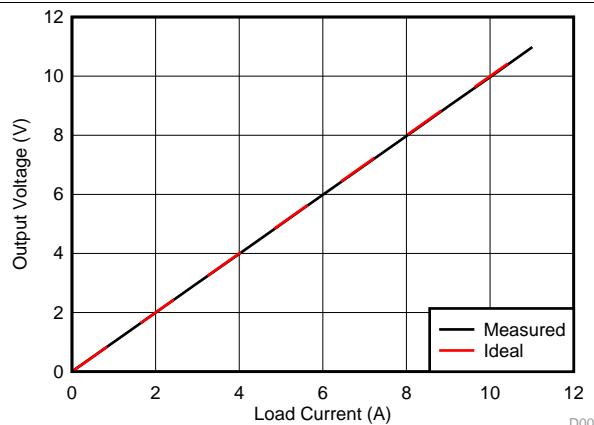


Figure 56. Output Voltage Measured vs Ideal
(0 to 10 A)

9 Power Supply Recommendations

Supply voltage for a single supply is from 4.4 V to 16 V, and from ± 2.2 V to ± 8 V for a dual supply. In the high-side sensing application, the supply is connected to a 12-V battery.

10 Layout

10.1 Layout Guidelines

The TLC2272M-MIL device is a wideband amplifier. To realize the full operational performance of the device, good high-frequency printed-circuit-board (PCB) layout practices are required. Low-loss $0.1\text{-}\mu\text{F}$ bypass capacitors must be connected between each supply pin and ground as close to the device as possible. The bypass capacitor traces should be designed for minimum inductance.

10.2 Layout Example

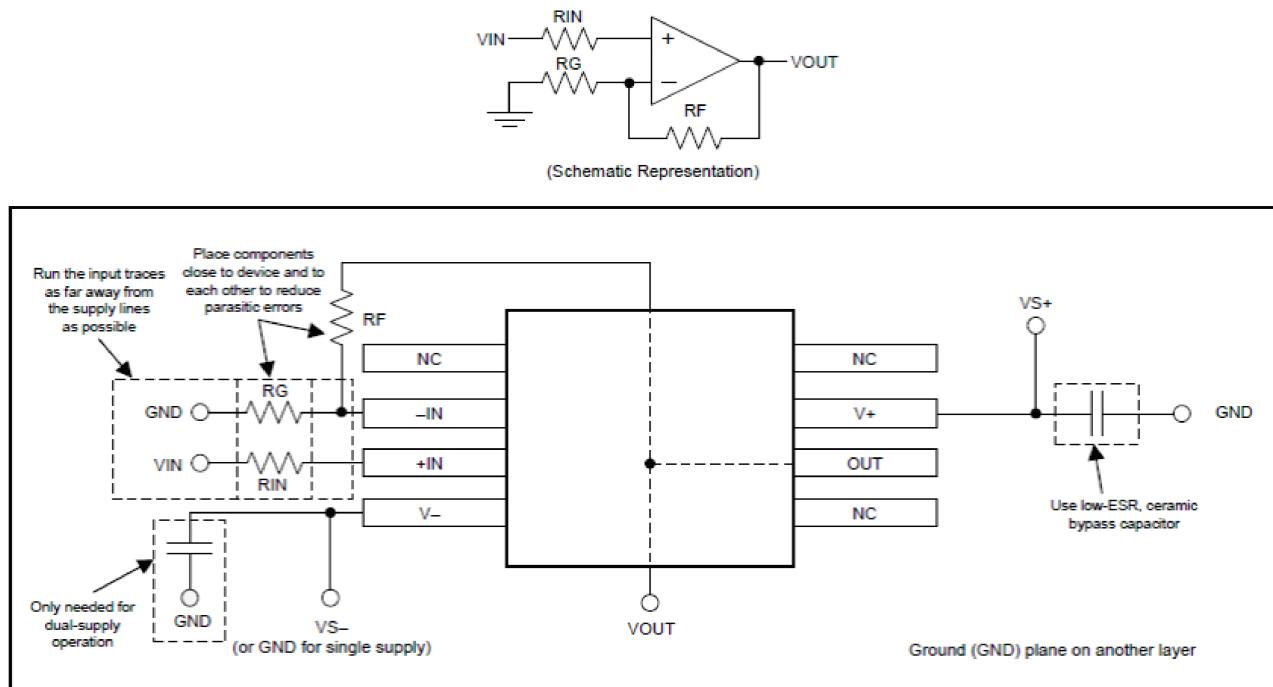


Figure 57. Layout Example

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

E2E is a trademark of Texas Instruments.

MicroSim Parts, PSpice are trademarks of MicroSim.

All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
5962-9555201NXD	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	Q2272M
5962-9555201NXDR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	Q2272M
5962-9555201NXDR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-55 to 125	Q2272M
5962-9555201Q2A	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9555201Q2A TLC2272 MFKB
5962-9555201QHA	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QHA TLC2272M
5962-9555201QPA	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QPA TLC2272M
TLC2272MFKB	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9555201Q2A TLC2272 MFKB
TLC2272MFKB.A	Active	Production	LCCC (FK) 20	55 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	5962- 9555201Q2A TLC2272 MFKB
TLC2272MJG	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	TLC2272MJG
TLC2272MJG.A	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	TLC2272MJG
TLC2272MJGB	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QPA TLC2272M
TLC2272MJGB.A	Active	Production	CDIP (JG) 8	50 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QPA TLC2272M
TLC2272MUB	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QHA TLC2272M
TLC2272MUB.A	Active	Production	CFP (U) 10	25 TUBE	No	SNPB	N/A for Pkg Type	-55 to 125	9555201QHA TLC2272M

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

(2) Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) RoHS values: Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

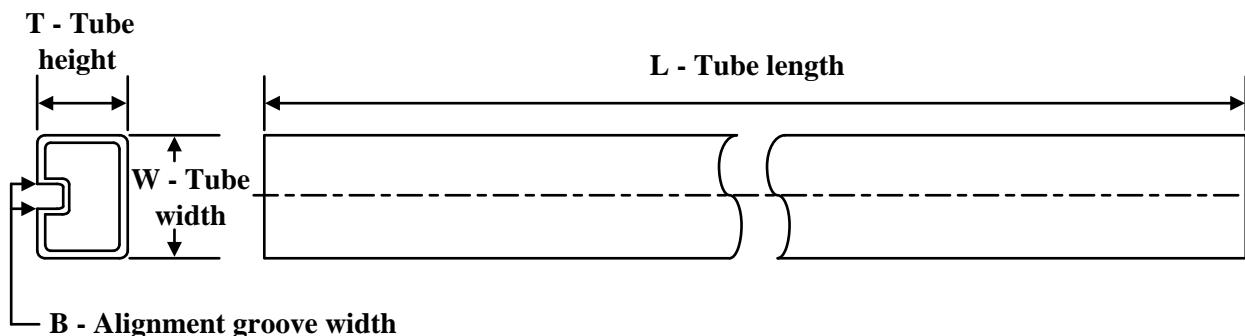
(5) MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TUBE


*All dimensions are nominal

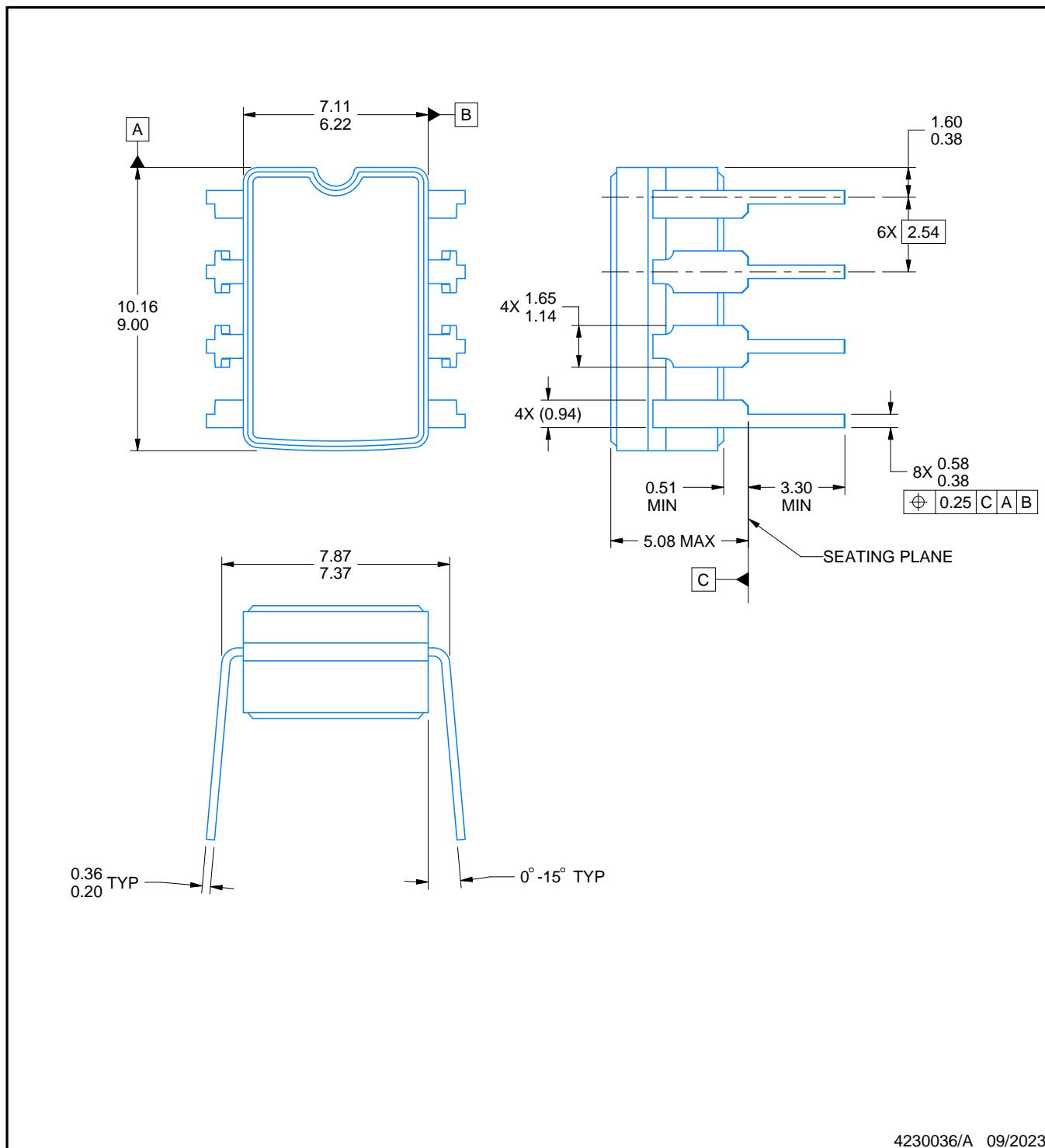
Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
5962-9555201Q2A	FK	LCCC	20	55	506.98	12.06	2030	NA
5962-9555201QHA	U	CFP	10	25	506.98	26.16	6220	NA
TLC2272MFKB	FK	LCCC	20	55	506.98	12.06	2030	NA
TLC2272MFKB.A	FK	LCCC	20	55	506.98	12.06	2030	NA
TLC2272MUB	U	CFP	10	25	506.98	26.16	6220	NA
TLC2272MUB.A	U	CFP	10	25	506.98	26.16	6220	NA

PACKAGE OUTLINE

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



4230036/A 09/2023

NOTES:

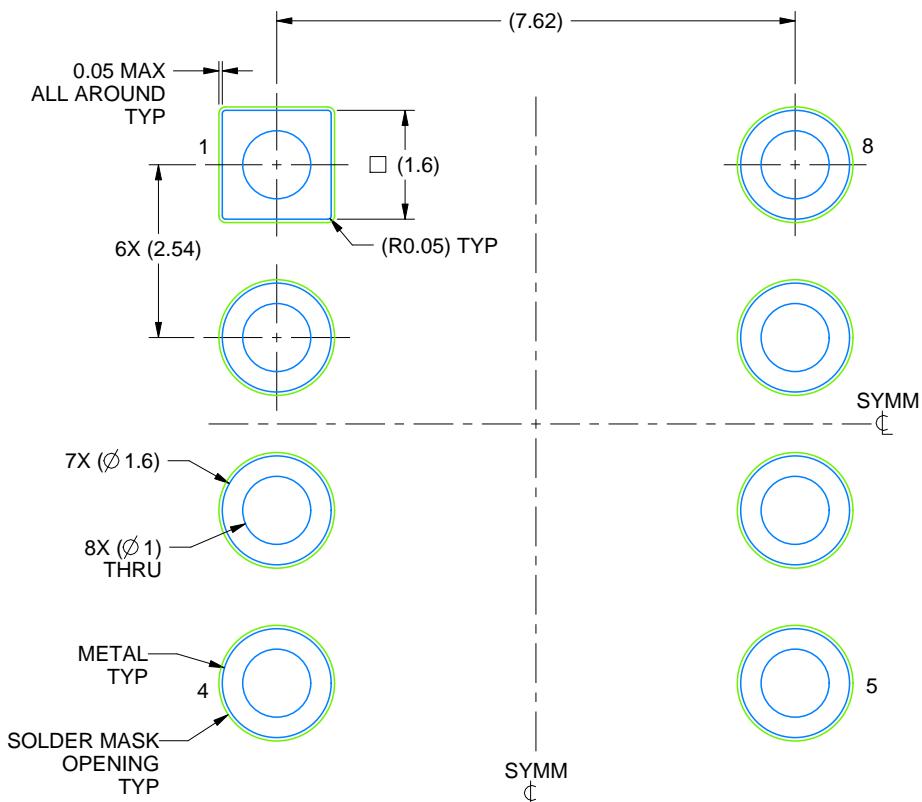
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package can be hermetically sealed with a ceramic lid using glass frit.
4. Index point is provided on cap for terminal identification.
5. Falls within MIL STD 1835 GDIP1-T8

EXAMPLE BOARD LAYOUT

JG0008A

CDIP - 5.08 mm max height

CERAMIC DUAL IN-LINE PACKAGE



LAND PATTERN EXAMPLE
NON SOLDER MASK DEFINED
SCALE: 9X

4230036/A 09/2023

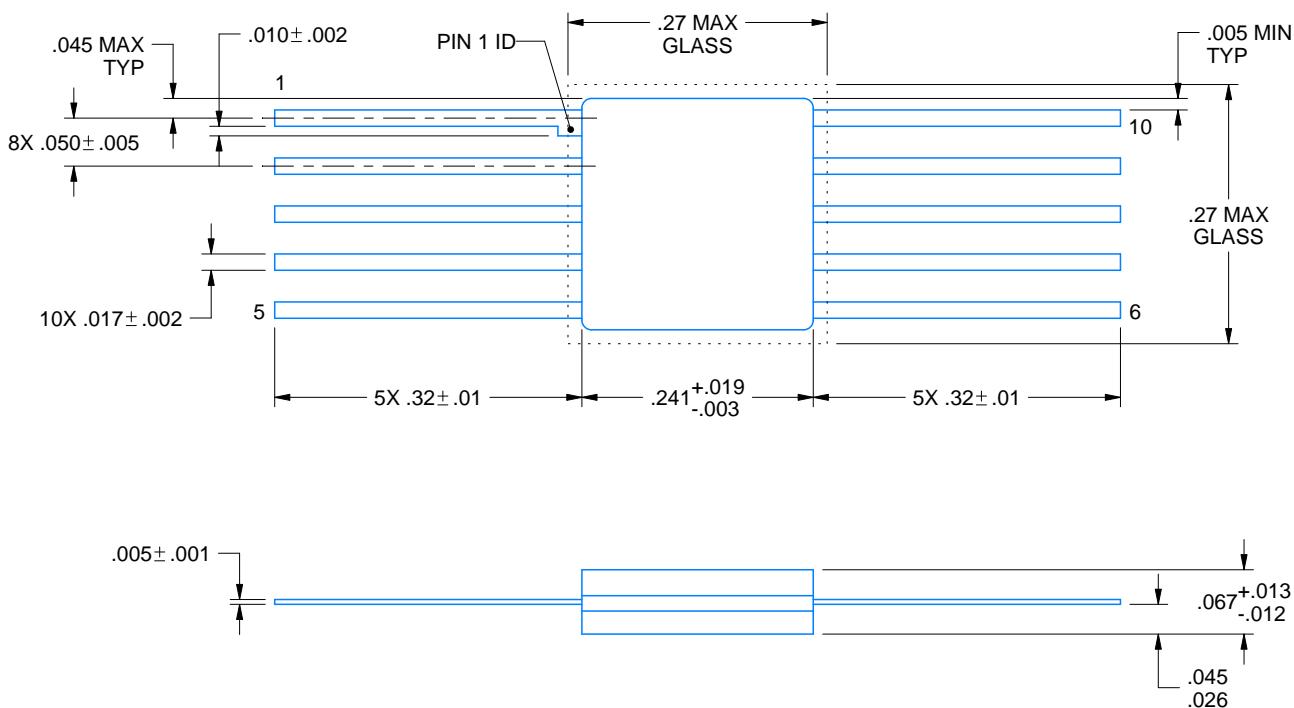
U0010A



PACKAGE OUTLINE

CFP - 2.03 mm max height

CERAMIC FLATPACK



4225582/A 01/2020

NOTES:

1. All linear dimensions are in inches. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

GENERIC PACKAGE VIEW

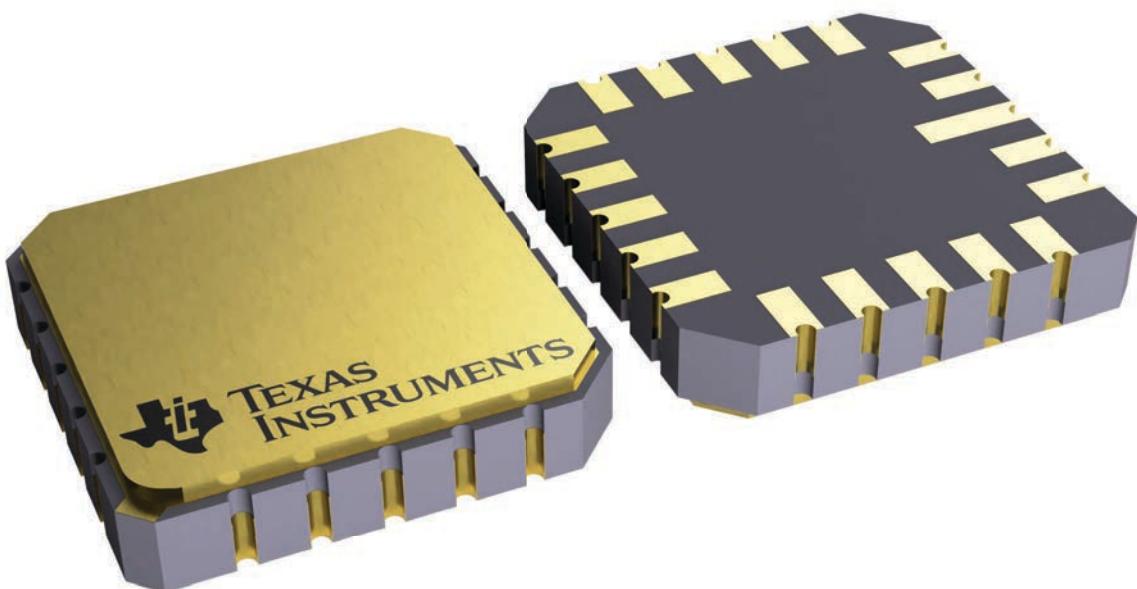
FK 20

LCCC - 2.03 mm max height

8.89 x 8.89, 1.27 mm pitch

LEADLESS CERAMIC CHIP CARRIER

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



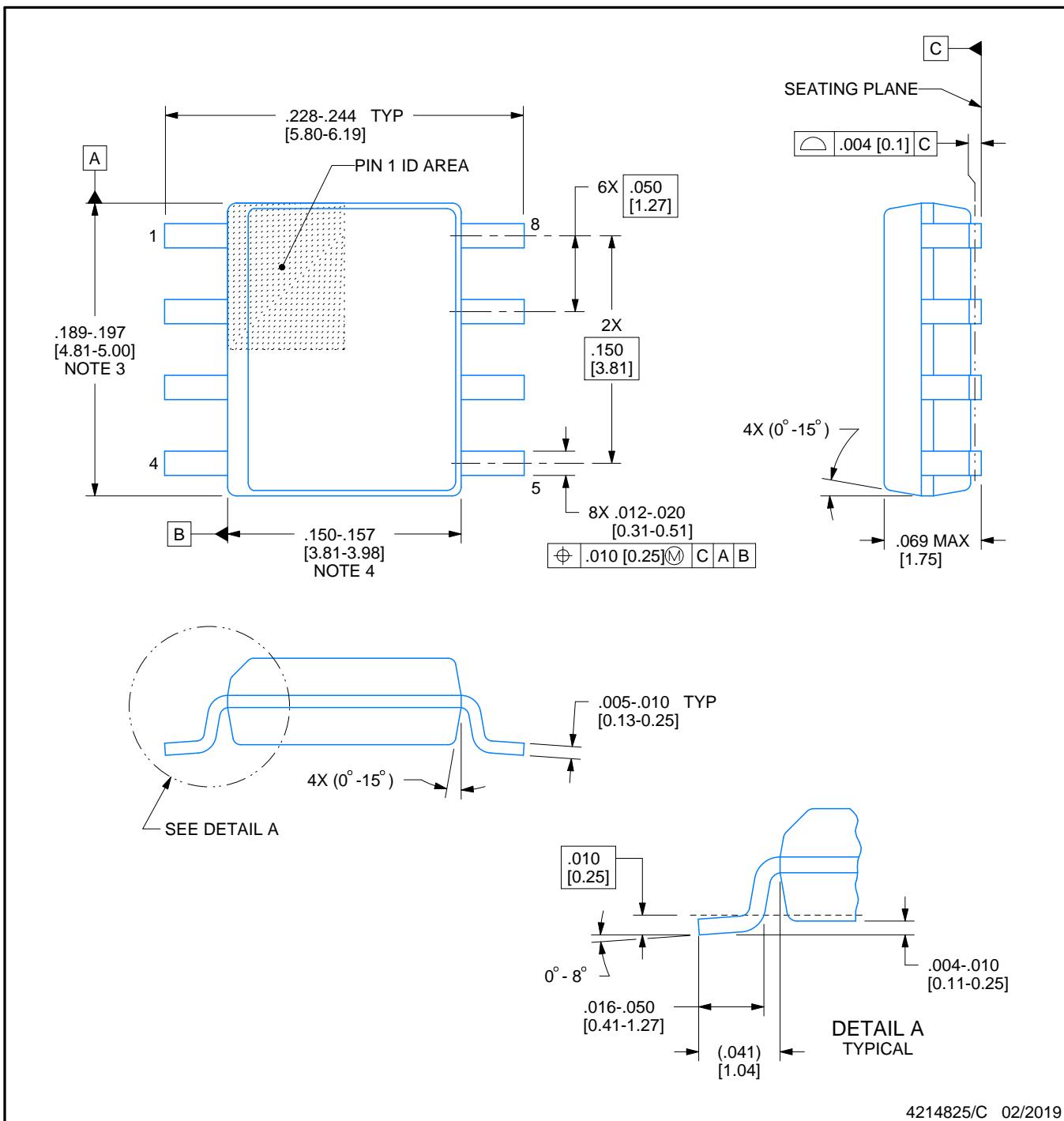
4229370VA\



PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES:

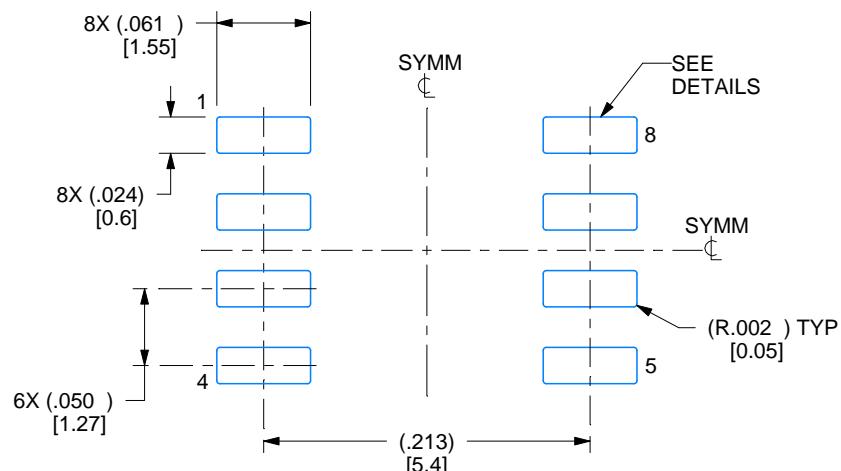
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

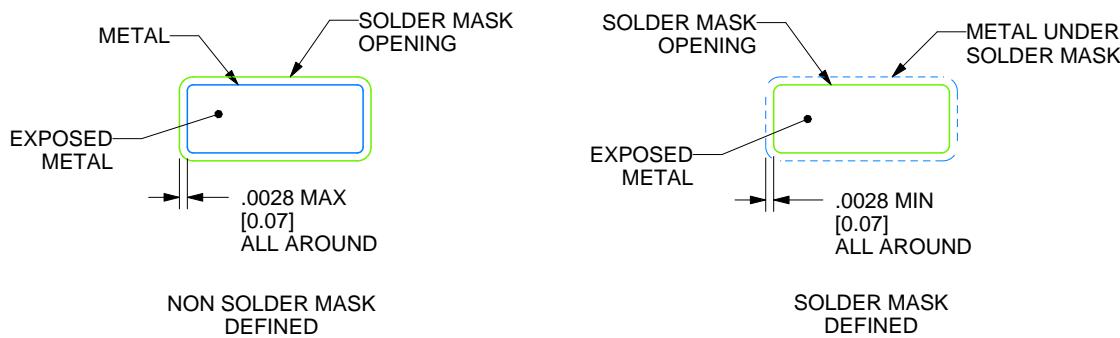
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

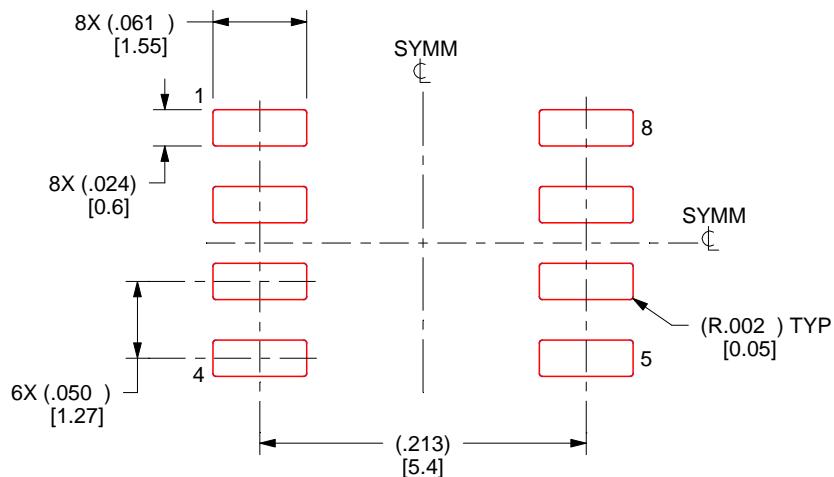
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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