THE DATASHEET OF

OPA140AIDGKT

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OPAx140 High-precision, low-noise, rail-to-rail output, 11-MHz JFET op amp

1 Features

- Very-Low Offset Drift: 1 μV/°C maximum
- Very-Low Offset: 120 μV
- Low Input Bias Current: 10 pA maximum
- Very-Low 1/f Noise: 250 nV_{PP}, 0.1 Hz to 10 Hz
- Low Noise: 5.1 $nV/\sqrt{Hz}$
- Slew Rate: 20 V/μs
- Low Supply Current: 2 mA maximum
- Input Voltage Range Includes V– supply
- Single-Supply Operation: 4.5 V to 36 V
- Dual-Supply Operation: ±2.25 V to ±18 V
- No Phase Reversal
- Industry-Standard SOIC Packages
- VSSOP, TSSOP, and SOT-23 Packages

2 Applications

- Battery-Powered Instruments
- Industrial Controls
- Medical Instrumentation
- Photodiode Amplifiers
- Active Filters
- Data Acquisition Systems
- Automatic Test Systems

3 Description

The OPA140, OPA2140, and OPA4140 operational amplifier (op amp) family is a series of low-power JFET input amplifiers that features good drift and low input bias current. The rail-to-rail output swing and input range that includes V– allow designers to take advantage of the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).

The OPA140 achieves 11-MHz unity-gain bandwidth and 20-V/μs slew rate while consuming only 1.8 mA (typical) of quiescent current. It runs on a single 4.5-V to 36-V supply or dual ±2.25-V to ±18-V supplies.

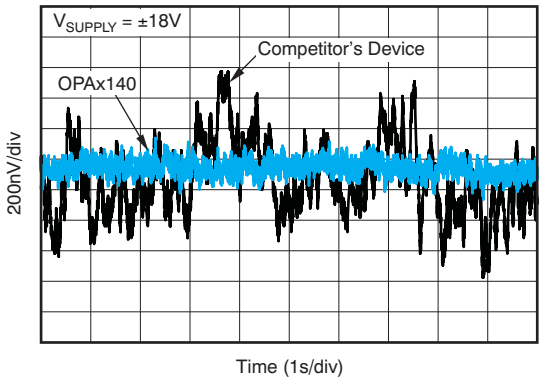
All versions are fully specified from –40°C to +125°C for use in the most challenging environments. The OPA140 (single) is available in the 5-pin SOT-23, 8-pin VSSOP, and 8-pin SOIC packages; the OPA2140 (dual) is available in both 8-pin VSSOP and 8-pin SOIC packages; and the OPA4140 (quad) is available in the 14-pin SOIC and 14-pin TSSOP packages.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA140	SOIC (8)	4.90 mm × 3.90 mm
	SOT23 (5)	2.90 mm × 1.60 mm
	VSSOP (8)	3.00 mm × 3.00 mm
OPA2140	SOIC (8)	4.90 mm × 3.90 mm
	VSSOP (8)	3.00 mm × 3.00 mm
OPA4140	SOIC (14)	8.65 mm × 3.90 mm
	TSSOP (14)	5.00 mm × 4.40 mm

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

0.1-Hz to 10-Hz Noise



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Revision History

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

Changes from Revision C (August 2016) to Revision D — **Page**

- Changed Figure 12 x-axis title From: Frequency (Hz) To: Output Amplitude (V_{RMS}) ... 10

Changes from Revision B (November 2015) to Revision C — **Page**

- Changed units for E_n Input voltage noise From: µV To: nV in *Electrical Characteristics: V_S = 4.5 V to 36 V; ±2.25 V to ±18 V* ... 7

Changes from Revision A (August 2010) to Revision B — **Page**

- Added *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1
- Changed title of Table 1 From: *Characteristic Performance Measurements* To: *Table of Graphs* ... 8
- Changed section 7.37 title From: *Power Dissipation and Thermal Protection* To: *Thermal Protection* ... 18

Changes from Original (July 2010) to Revision A — **Page**

- Changed device and data sheet status to production data status ... 1
- Added SOIC (8) (MSOP) packages ... 3

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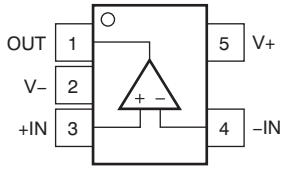
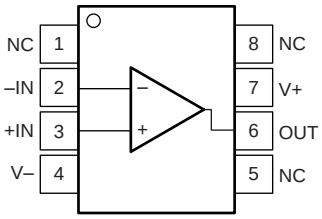
5 Pin Configuration and Functions

DBV Package: OPA140
5-Pin SOT-23
Top View



D and DGK Packages: OPA140
8-Pin SOIC and VSSOP
Top View



Pin Functions: OPA140

PIN			I/O	DESCRIPTION
NAME	OPA140			
	D (SOIC), DGK (VSSOP)	DBV (SOT)		
+IN	3	3	I	Noninverting input
–IN	2	4	I	Inverting input
NC	1, 5, 8	—	—	No internal connection (can be left floating)
OUT	6	1	O	Output
V+	7	5	—	Positive (highest) power supply
V–	4	2	—	Negative (lowest) power supply

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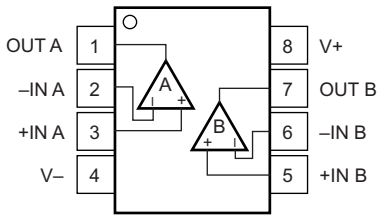
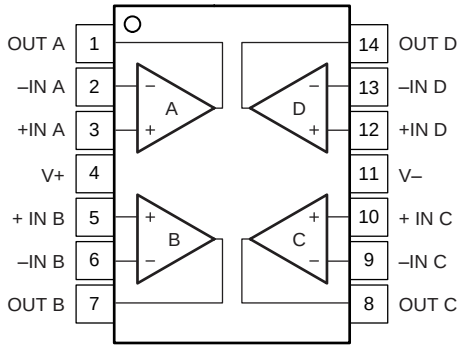
D and DGK Packages: OPA2140
8-Pin SOIC and VSSOP
Top View



D and PW Packages: OPA4140
14-Pin SOIC and TSSOP
Top View



Pin Functions: OPA2140 and OPA4140

PIN			I/O	DESCRIPTION
NAME	OPA2140	OPA4140		
	D (SOIC), DGK (VSSOP)	D (SOIC), PW (TSSOP)		
+IN A	3	3	I	Noninverting input, channel A
+IN B	5	5	I	Noninverting input, channel B
+IN C	—	10	I	Noninverting input, channel C
+IN D	—	12	I	Noninverting input, channel D
–IN A	2	2	I	Inverting input, channel A
–IN B	6	6	I	Inverting input, channel B
–IN C	—	9	I	Inverting input, channel C
–IN D	—	13	I	Inverting input, channel D
OUT A	1	1	O	Output, channel A
OUT B	7	7	O	Output, channel B
OUT C	—	8	O	Output, channel C
OUT D	—	14	O	Output, channel D
V+	8	4	—	Positive (highest) power supply
V–	4	11	—	Negative (lowest) power supply

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Supply voltage, V_S = (V+) – (V–)			40	V
Signal input pins	Voltage(2)	(V–) – 0.5	(V+) + 0.5	V
	Current(2)	–10	10	mA
Output short circuit(3)		Continuous		
Temperature	Operating	–55	150	°C
	Junction		150	
	Storage, T_{stg}	–65	150	

(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) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.5 V beyond the supply rails should be current-limited to 10 mA or less.
(3) Short-circuit to V_S/2 (ground in symmetrical dual-supply setups), one amplifier per package.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±500	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
Supply voltage	±2.25		±18	V
Specified temperature	–40		125	°C

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6.4 Thermal Information: OPA140

THERMAL METRIC(1)		OPA140			UNIT
		D (SOIC)	DBV (SOT)	DGK (VSSOP)	
		8 PINS	5 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	160	210	180	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	75	200	55	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	60	110	130	°C/W
ψ_{JT}	Junction-to-top characterization parameter	9	40	N/A	°C/W
ψ_{JB}	Junction-to-board characterization parameter	50	105	120	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Thermal Information: OPA2140

THERMAL METRIC(1)		OPA2140		UNIT
		D (SOIC)	DGK (VSSOP)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	160	180	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	75	55	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	60	130	°C/W
ψ_{JT}	Junction-to-top characterization parameter	9	N/A	°C/W
ψ_{JB}	Junction-to-board characterization parameter	50	120	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.6 Thermal Information: OPA4140

THERMAL METRIC(1)		OPA4140		UNIT
		D (SOIC)	PW (TSSOP)	
		14 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	97	135	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	56	45	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	53	66	°C/W
ψ_{JT}	Junction-to-top characterization parameter	19	N/A	°C/W
ψ_{JB}	Junction-to-board characterization parameter	46	60	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

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6.7 Electrical Characteristics: V_S = 4.5 V to 36 V; ±2.25 V to ±18 V

at T_A = 25°C, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V_{OS}	Input offset voltage				30	120	µV
		V_S = ±18 V, T_A = –40°C to 125°C				220	
		V_S = ±2.25 V to ±18 V, T_A = –40°C to 125°C				±4	µV/V
dV_{OS}/dT	Input offset voltage drift	V_S = ±18 V, T_A = –40°C to 125°C			±0.35	1	µV/°C
PSRR	Power-supply rejection ratio	V_S = ±2.25 V to ±18 V, T_A = –40°C to 125°C			±0.1	±0.5	µV/V
INPUT BIAS CURRENT							
I_B	Input bias current				±0.5	±10	pA
		T_A = –40°C to 125°C				±3	nA
I_{OS}	Input offset current				±0.5	±10	pA
		T_A = –40°C to 125°C				±1	nA
NOISE							
E_n	Input voltage noise	f = 0.1 Hz to 10 Hz			250		nV_{PP}
		f = 0.1 Hz to 10 Hz			42		nV_{RMS}
e_n	Input voltage noise density	f = 10 Hz			8		$nV/\sqrt{Hz}$
		f = 100 Hz			5.8		
		f = 1 kHz			5.1		
i_n	Input current noise density	f = 1 kHz			0.8		$fA/\sqrt{Hz}$
INPUT VOLTAGE							
V_{CM}	Common-mode voltage	T_A = –40°C to 125°C		(V–) – 0.1		(V+) – 3.5	V
CMRR	Common-mode rejection ratio	V_S = ±18 V, V_{CM} = (V–) – 0.1 V to (V+) – 3.5 V		126	140		dB
			T_A = –40°C to 125°C	120			
INPUT IMPEDANCE							
Z_{ID}	Differential				10^{13} || 10		Ω || pF
Z_{IC}	Common-mode	V_{CM} = (V–) – 0.1 V to (V+) – 3.5 V			10^{13} || 7		Ω || pF
OPEN-LOOP GAIN							
A_{OL}	Open-loop voltage gain	V_O = (V–) + 0.35 V to (V+) – 0.35 V, R_L = 10 kΩ		120	126		dB
		V_O = (V–) + 0.35 V to (V+) – 0.35 V, R_L = 2 kΩ		114	126		
			T_A = –40°C to 125°C	108			
FREQUENCY RESPONSE							
BW	Gain bandwidth product				11		MHz
SR	Slew rate				20		V/µs
t_s	Settling time	12-bit			880		ns
		16-bit			1.6		µs
t_{OR}	Overload recovery time				600		ns
THD+N	Total harmonic distortion + noise	1 kHz, G = 1, V_O = 3.5 V_{RMS}			0.00005%		
OUTPUT							
V_O	Voltage output	R_{LOAD} = 10 kΩ, A_{OL} ≥ 108 dB		(V–) + 0.2		(V+) – 0.2	V
		R_{LOAD} = 2 kΩ, A_{OL} ≥ 108 dB		(V–) + 0.35		(V+) – 0.35	
I_{SC}	Short-circuit current	Source			36		mA
		Sink			–30		
C_{LOAD}	Capacitive load drive			See Figure 19 and Figure 20			
Z_O	Open-loop output impedance	f = 1 MHz, I_O = 0 A (See Figure 18)			16		Ω

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Electrical Characteristics: V_S = 4.5 V to 36 V; ±2.25 V to ±18 V (continued)

at T_A = 25°C, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY						
V_S	Power-supply voltage		4.5 (±2.25)		9 (±18)	V
I_Q	Quiescent current per amplifier	I_O = 0 A		1.8	2	mA
		T_A = –40°C to 125°C			2.7	
CHANNEL SEPARATION						
	Channel separation	At dc		0.02		µV/V
		At 100 kHz		10		

6.8 Typical Characteristics

Table 1. Table of Graphs

DESCRIPTION	FIGURE
Offset Voltage Production Distribution	Figure 1
Offset Voltage Drift Distribution	Figure 2
Offset Voltage vs Common-Mode Voltage (Maximum Supply)	Figure 3
I_B vs Common-Mode Voltage	Figure 5
Input Offset Voltage vs Temperature	Figure 4
Output Voltage Swing vs Output Current	Figure 6
CMRR and PSRR vs Frequency (RTI)	Figure 7
Common-Mode Rejection Ratio vs Temperature	Figure 8
0.1-Hz to 10-Hz Noise	Figure 9
Input Voltage Noise Density vs Frequency	Figure 10
THD+N Ratio vs Frequency (80-kHz AP Bandwidth)	Figure 11
THD+N Ratio vs Output Amplitude	Figure 12
Quiescent Current vs Temperature	Figure 13
Quiescent Current vs Supply Voltage	Figure 14
Gain and Phase vs Frequency	Figure 15
Closed-Loop Gain vs Frequency	Figure 16
Open-Loop Gain vs Temperature	Figure 17
Open-Loop Output Impedance vs Frequency	Figure 18
Small-Signal Overshoot vs Capacitive Load (G = 1)	Figure 19
Small-Signal Overshoot vs Capacitive Load (G = –1)	Figure 20
No Phase Reversal	Figure 21
Positive Overload Recovery	Figure 23
Negative Overload Recovery	Figure 24
Large-Signal Positive and Negative Settling Time	Figure 25, Figure 26
Small-Signal Step Response (G = 1)	Figure 27
Small-Signal Step Response (G = –1)	Figure 28
Large-Signal Step Response (G = 1)	Figure 29
Large-Signal Step Response (G = –1)	Figure 30
Short-Circuit Current vs Temperature	Figure 31
Maximum Output Voltage vs Frequency	Figure 22
Channel Separation vs Frequency	Figure 32

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at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

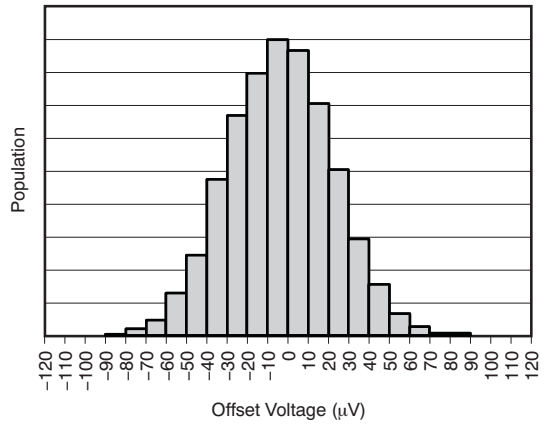

Figure 1. Offset Voltage Production Distribution

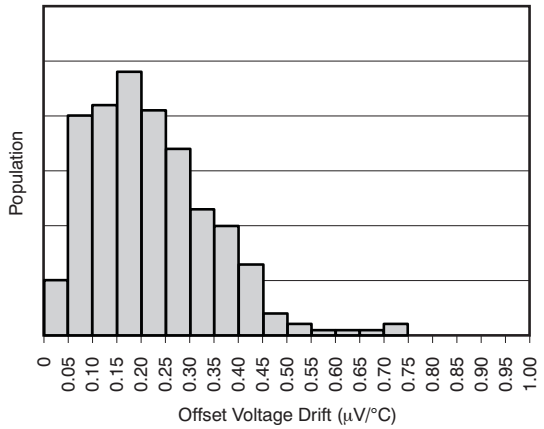

Figure 2. Offset Voltage Drift Distribution

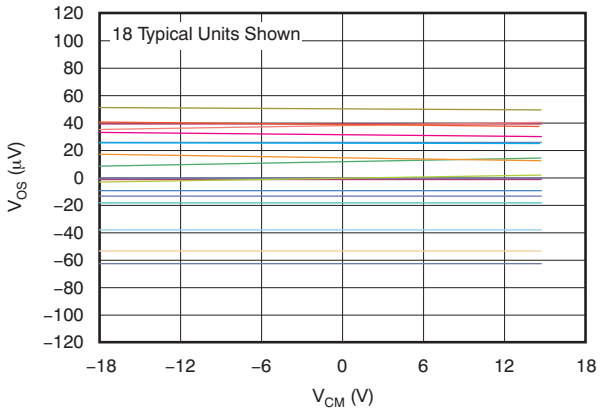

Figure 3. Offset Voltage vs Common-Mode Voltage

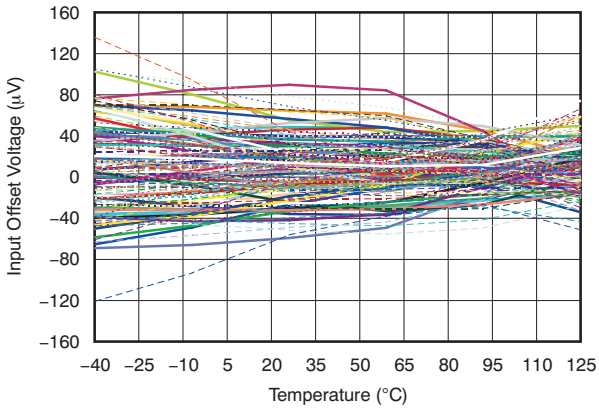

Figure 4. Input Offset Voltage vs Temperature (144 Amplifiers)

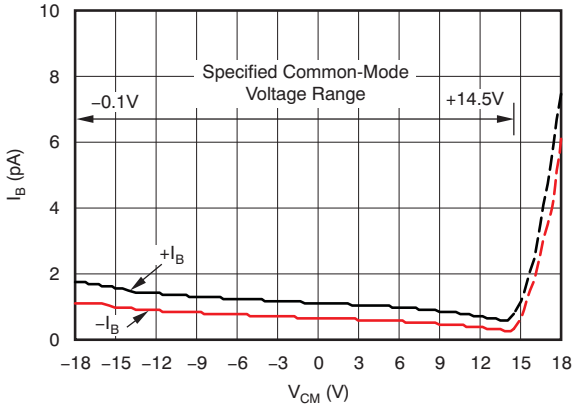

Figure 5. I_B vs Common-Mode Voltage

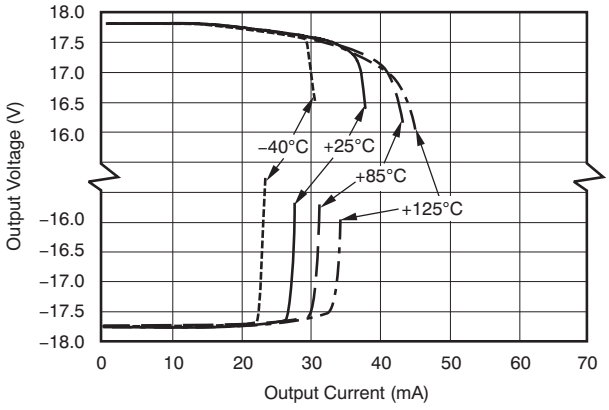

Figure 6. Output Voltage Swing vs Output Current (Maximum Supply)

at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

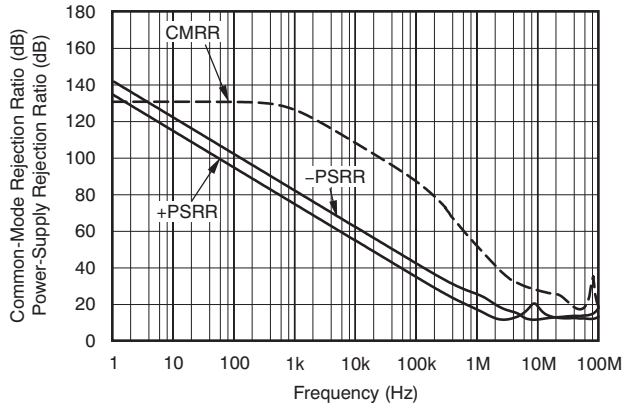

Figure 7. CMRR and PSRR vs Frequency (Referred to Input)

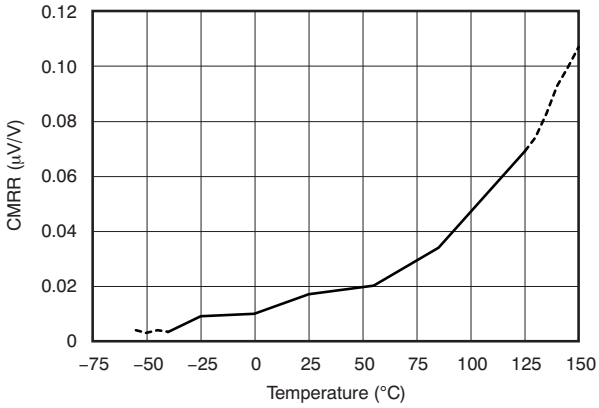

Figure 8. Common-Mode Rejection Ratio vs Temperature

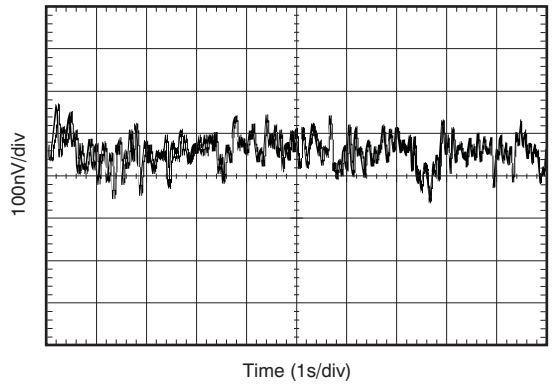

Figure 9. 0.1-Hz to 10-Hz Noise

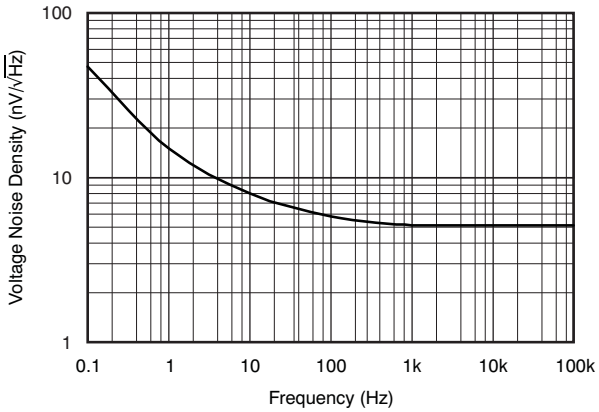

Figure 10. Input Voltage Noise Density vs Frequency

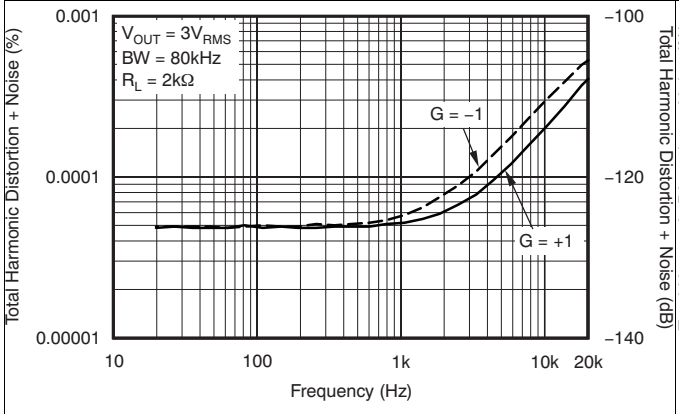

Figure 11. THD+N Ratio vs Frequency

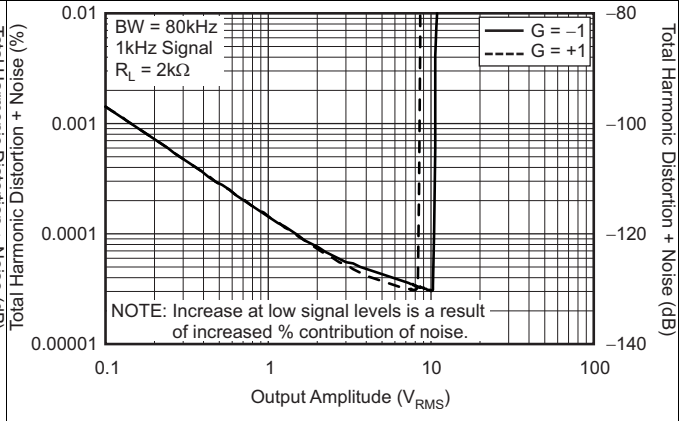

Figure 12. THD+N Ratio vs Output Amplitude

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at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

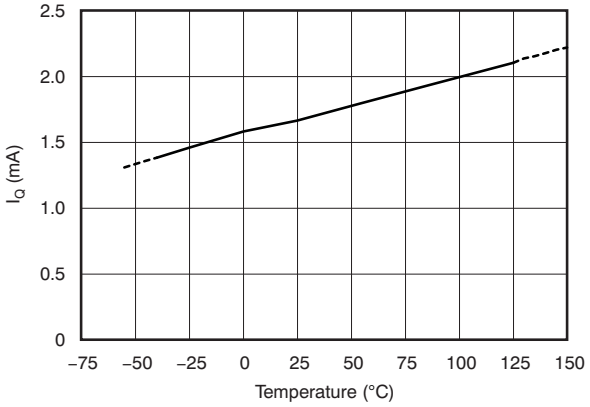

Figure 13. Quiescent Current vs Temperature

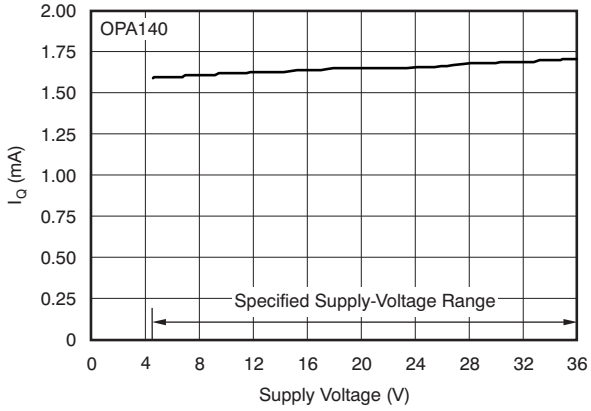

Figure 14. Quiescent Current vs Supply Voltage

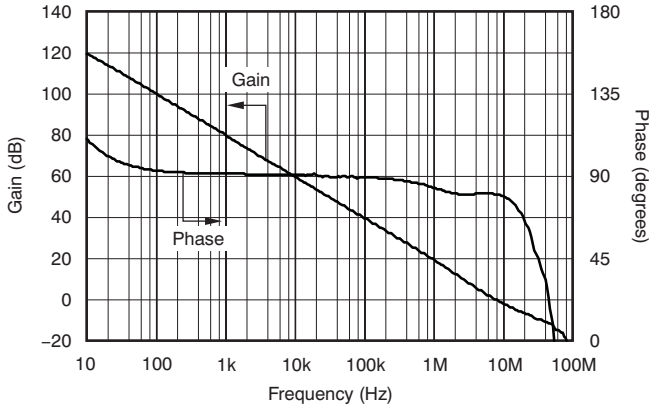

Figure 15. Gain and Phase vs Frequency

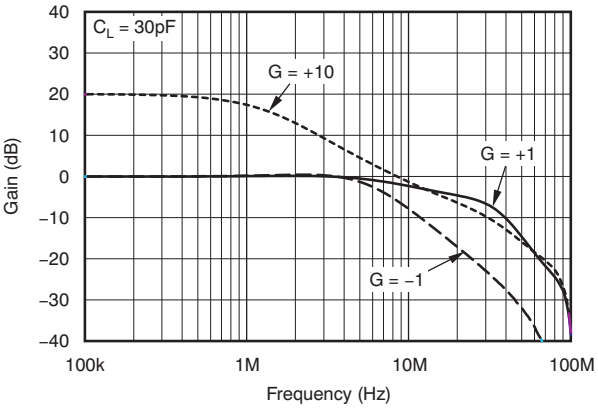

Figure 16. Closed-Loop Gain vs Frequency

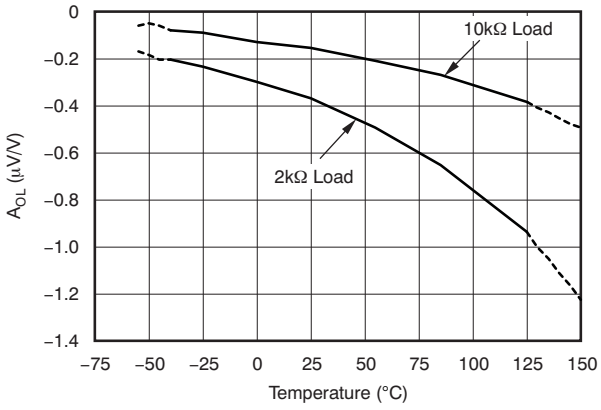

Figure 17. Open-Loop Gain vs Temperature

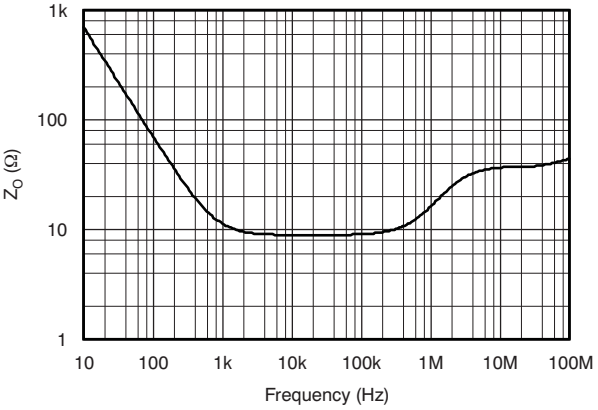

Figure 18. Open-Loop Output Impedance vs Frequency

at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

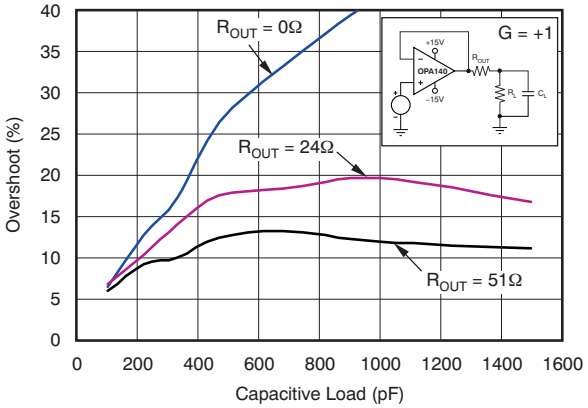

Figure 19. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)

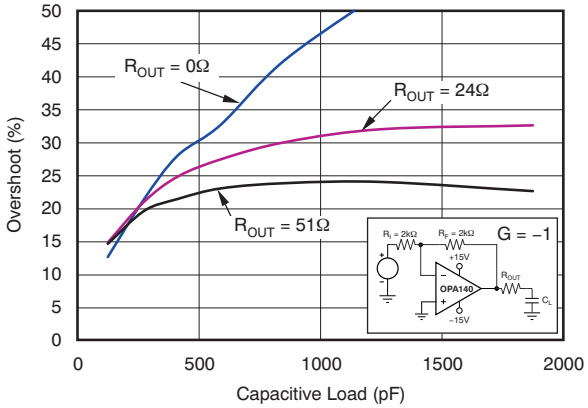

Figure 20. Small-Signal Overshoot vs Capacitive Load (100-mV Output Step)

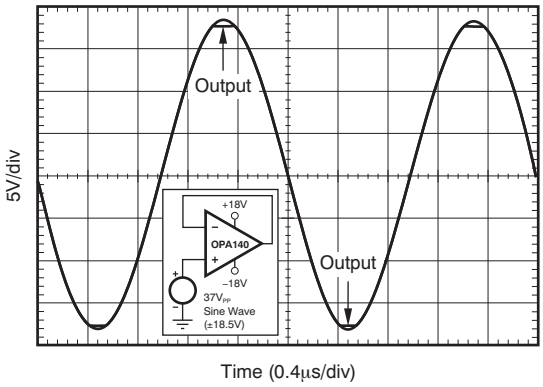

Figure 21. No Phase Reversal

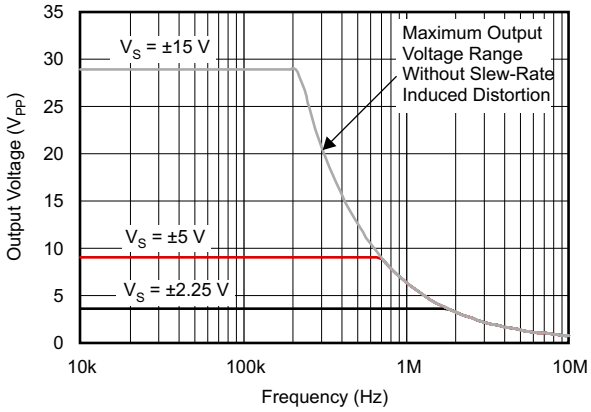

Figure 22. Maximum Output Voltage vs Frequency

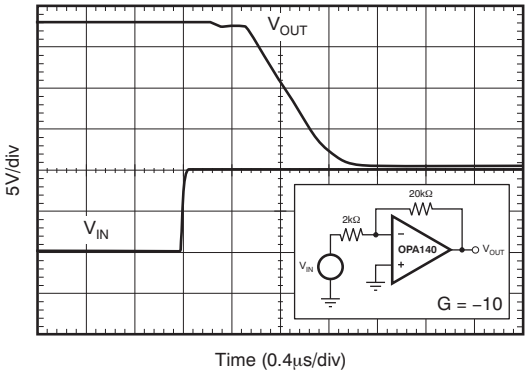

Figure 23. Positive Overload Recovery

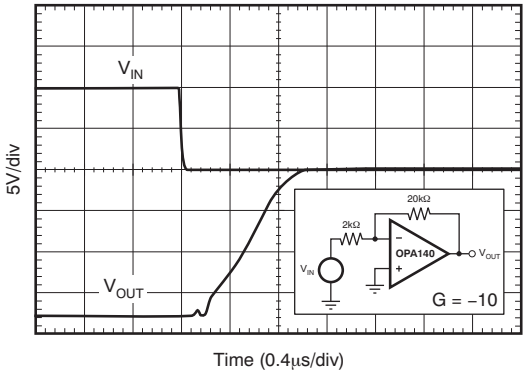

Figure 24. Negative Overload Recovery

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at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

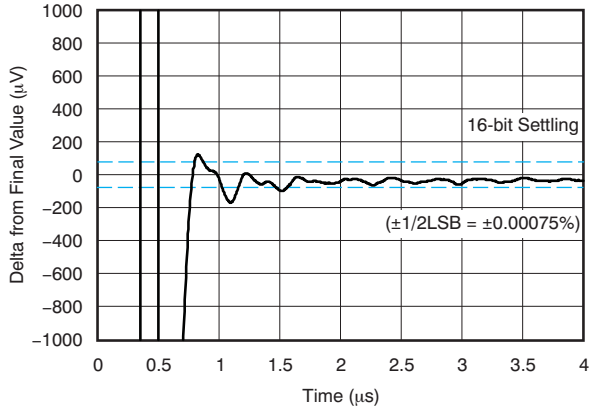

Figure 25. Large-Signal Positive Settling Time (10-V Step)

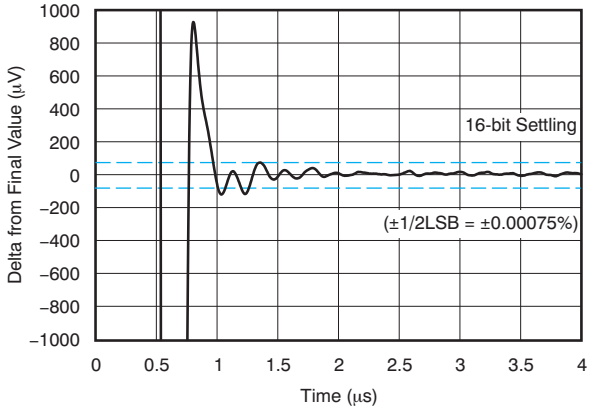

Figure 26. Large-Signal Negative Settling Time (10-V Step)

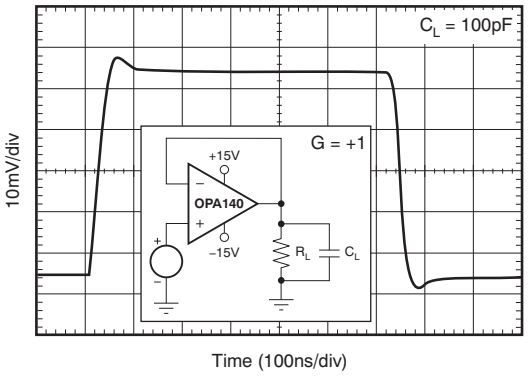

Figure 27. Small-Signal Step Response (100 mV)

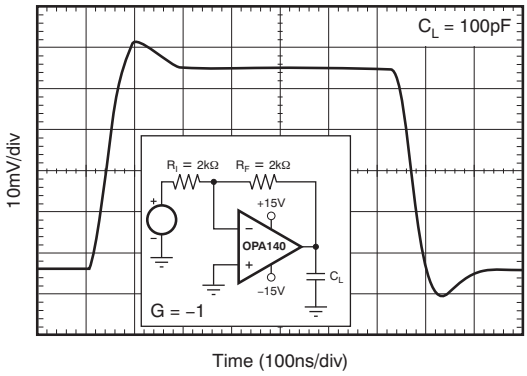

Figure 28. Small-Signal Step Response (100 mV)

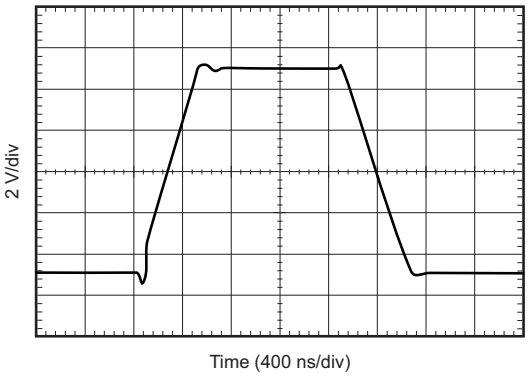

Figure 29. Large-Signal Step Response

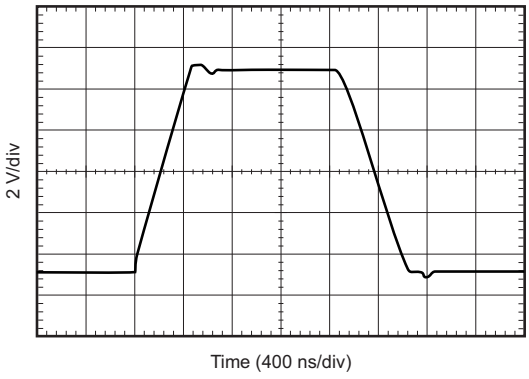

Figure 30. Large-Signal Step Response

at T_A = 25°C, V_S = ±18 V, R_L = 2 kΩ connected to midsupply, and V_{CM} = V_{OUT} = midsupply (unless otherwise noted)

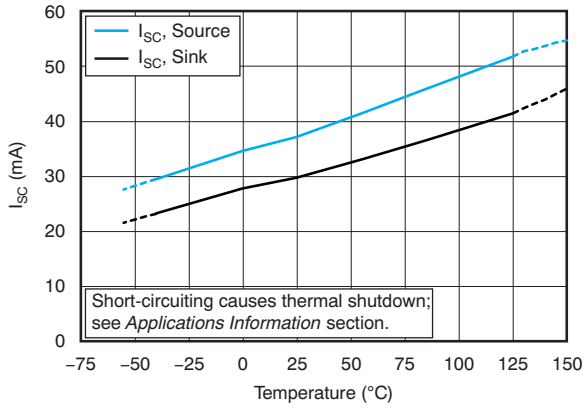

Figure 31. Short Circuit Current vs Temperature

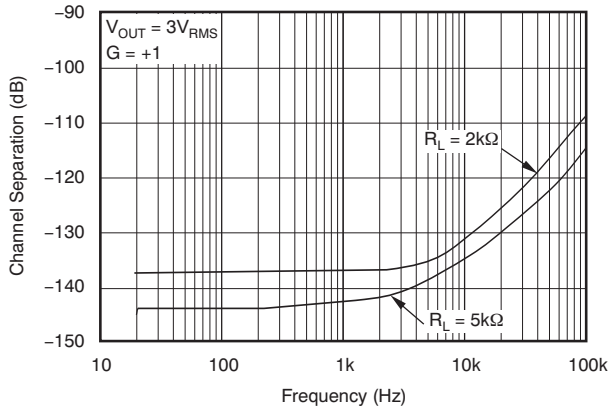

Figure 32. Channel Separation vs Frequency

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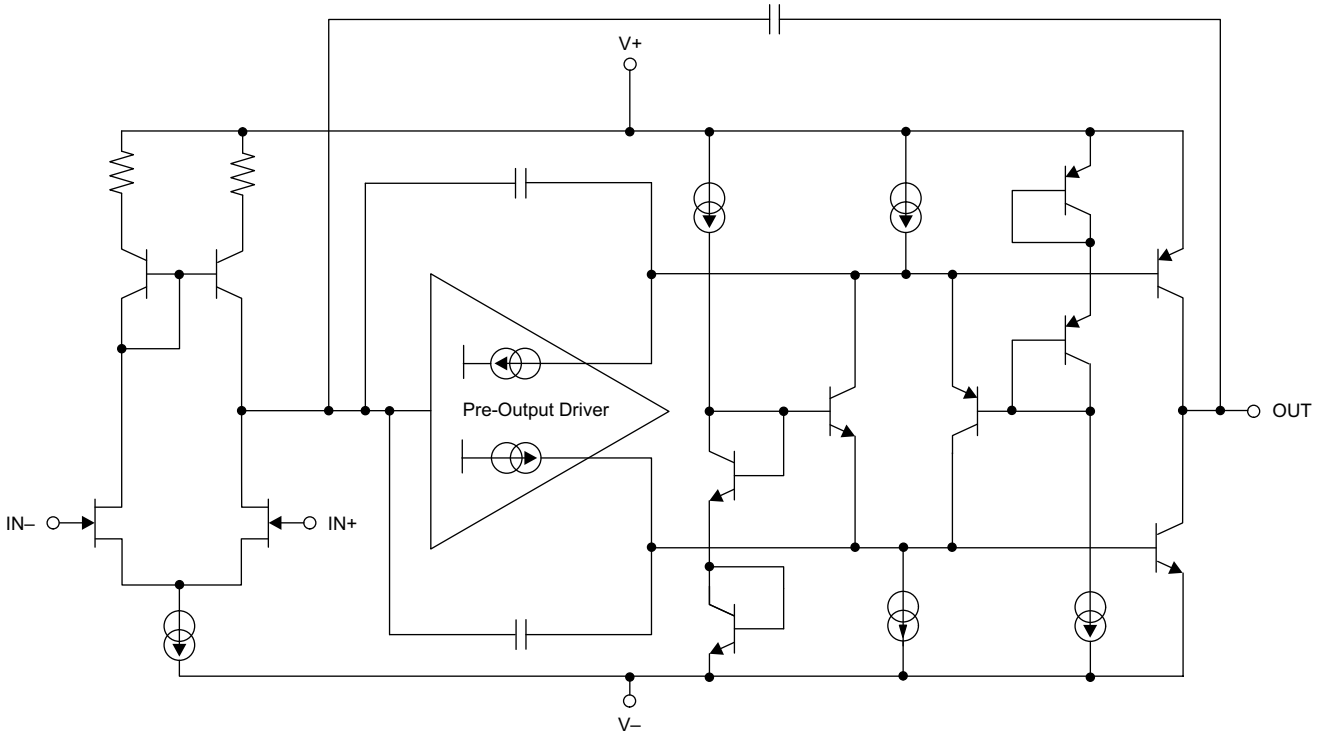
7 Detailed Description

7.1 Overview

The OPAx140 family of operational amplifiers is a series of low-power JFET input amplifiers that feature superior drift performance and low input bias current. The rail-to-rail output swing and input range that includes V– allow designers to use the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision analog-to-digital converters (ADCs) and digital-to-analog converters (DACs). The OPAx140 series achieves 11-MHz unity-gain bandwidth and 20-V/μs slew rate, and consumes only 1.8 mA (typical) of quiescent current. These devices operate on a single 4.5-V to 36-V supply or dual ±2.25-V to ±18-V supplies.

The *Functional Block Diagram* section shows the simplified diagram of the OPAx140.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Operating Voltage

The OPA140, OPA2140, and OPA4140 series of op amps can be used with single or dual supplies from an operating range of V_S = 4.5 V (±2.25 V) and up to V_S = 36 V (±18 V). These devices do not require symmetrical supplies; they only require a minimum supply voltage of 4.5 V (±2.25 V). For V_S less than ±3.5 V, the common-mode input range does not include midsupply. Supply voltages higher than 40 V can permanently damage the device; see the *Absolute Maximum Ratings* table. Key parameters are specified over the operating temperature range, T_A = –40°C to 125°C. Key parameters that vary over the supply voltage or temperature range are shown in the *Typical Characteristics* section of this data sheet.

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Feature Description (continued)

7.3.2 Capacitive Load and Stability

The dynamic characteristics of the OPAx140 have been optimized for commonly encountered gains, loads, and operating conditions. The combination of low closed-loop gain and high capacitive loads decreases the phase margin of the amplifier and can lead to gain peaking or oscillations. As a result, heavier capacitive loads must be isolated from the output. The simplest way to achieve this isolation is to add a small resistor (R_{OUT} equal to 50 Ω, for example) in series with the output.

Figure 19 and Figure 20 illustrate graphs of *Small-Signal Overshoot vs Capacitive Load* for several values of R_{OUT}. Also, see the *Feedback Plots Define Op Amp AC Performance Application Bulletin*, available for download from www.ti.com, for details of analysis techniques and application circuits.

7.3.3 Output Current Limit

The output current of the OPAx140 series is limited by internal circuitry to 36 mA/–30 mA (sourcing/sinking), to protect the device if the output is accidentally shorted. This short circuit current depends on temperature, as shown in Figure 31.

7.3.4 Noise Performance

Figure 33 shows the total circuit noise for varying source impedances with the operational amplifier in a unity-gain configuration (with no feedback resistor network and therefore no additional noise contributions). The OPA140 and OPA211 are shown with total circuit noise calculated. The op amp itself contributes both a voltage noise component and a current noise component. The voltage noise is commonly modeled as a time-varying component of the offset voltage. The current noise is modeled as the time-varying component of the input bias current and reacts with the source resistance to create a voltage component of noise. Therefore, the lowest noise op amp for a given application depends on the source impedance. For low source impedance, current noise is negligible, and voltage noise generally dominates. The OPA140, OPA2140, and OPA4140 family has both low voltage noise and extremely low current noise because of the FET input of the op amp. As a result, the current noise contribution of the OPAx140 series is negligible for any practical source impedance, which makes it the better choice for applications with high source impedance.

The equation in Figure 33 shows the calculation of the total circuit noise, with these parameters:

- e_n = voltage noise
- I_n = current noise
- R_S = source impedance
- k = Boltzmann's constant = 1.38×10^{-23} J/K
- T = temperature in degrees Kelvin (K)

For more details on calculating noise, see *Basic Noise Calculations*.

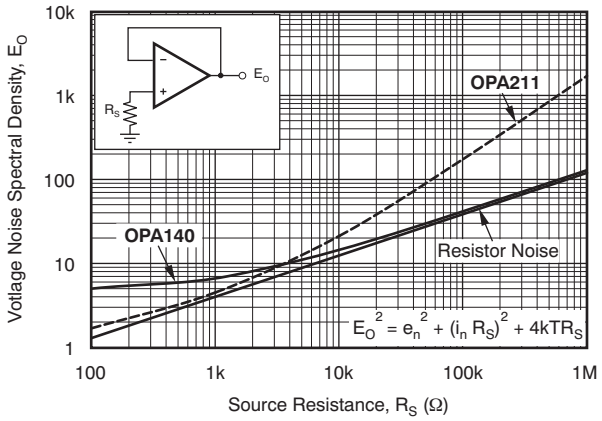

Figure 33. Noise Performance of the OPA140 and OPA211 in Unity-Gain Buffer Configuration

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Feature Description (continued)

7.3.5 Basic Noise Calculations

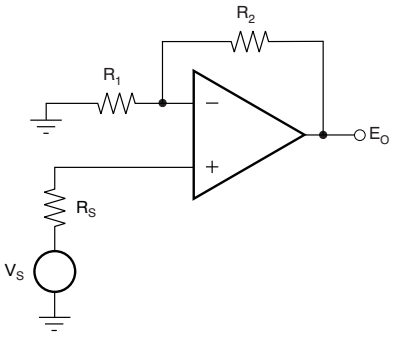
Low-noise circuit design requires careful analysis of all noise sources. External noise sources can dominate in many cases; consider the effect of source resistance on overall op amp noise performance. Total noise of the circuit is the root-sum-square combination of all noise components.

The resistive portion of the source impedance produces thermal noise proportional to the square root of the resistance. This function is plotted in Figure 33. The source impedance is usually fixed; consequently, select the op amp and the feedback resistors to minimize the respective contributions to the total noise.

Figure 34 illustrates both noninverting **(A)** and inverting **(B)** op amp circuit configurations with gain. In circuit configurations with gain, the feedback network resistors also contribute noise. In general, the current noise of the op amp reacts with the feedback resistors to create additional noise components. However, the extremely low current noise of the OPAx140 means that its current noise contribution can be neglected.

The feedback resistor values can generally be chosen to make these noise sources negligible. Low impedance feedback resistors load the output of the amplifier. The equations for total noise are shown for both configurations.

A) Noise in Noninverting Gain Configuration



Noise at the output:

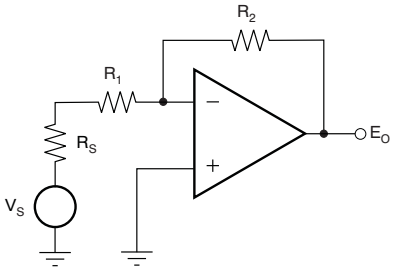
$$E_O^2 = \left(1 + \frac{R_2}{R_1}\right)^2 e_n^2 + \left(\frac{R_2}{R_1}\right)^2 e_1^2 + e_2^2 + \left(1 + \frac{R_2}{R_1}\right)^2 e_s^2$$

Where $e_S = \sqrt{4kTR_S}$ = thermal noise of R_S

$e_1 = \sqrt{4kTR_1}$ = thermal noise of R_1

$e_2 = \sqrt{4kTR_2}$ = thermal noise of R_2

B) Noise in Inverting Gain Configuration



Noise at the output:

$$E_O^2 = \left(1 + \frac{R_2}{R_1 + R_S}\right)^2 e_n^2 + \left(\frac{R_2}{R_1 + R_S}\right)^2 e_1^2 + e_2^2 + \left(\frac{R_2}{R_1 + R_S}\right)^2 e_s^2$$

Where $e_S = \sqrt{4kTR_S}$ = thermal noise of R_S

$e_1 = \sqrt{4kTR_1}$ = thermal noise of R_1

$e_2 = \sqrt{4kTR_2}$ = thermal noise of R_2

For the OPAx140 series of operational amplifiers at 1 kHz, $e_n = 5.1\ nV/\sqrt{Hz}$.

Figure 34. Noise Calculation in Gain Configurations

7.3.6 Phase-Reversal Protection

The OPA140, OPA2140, and OPA4140 family has internal phase-reversal protection. Many FET- and bipolar-input op amps exhibit a phase reversal when the input is driven beyond its linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The input circuitry of the OPA140, OPA2140, and OPA4140 prevents phase reversal with excessive common-mode voltage; instead, the output limits into the appropriate rail (see Figure 21).

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Feature Description (continued)

7.3.7 Thermal Protection

The OPAx140 series of op amps are capable of driving 2-kΩ loads with power-supply voltages of up to ±18 V over the specified temperature range. In a single-supply configuration, where the load is connected to the negative supply voltage, the minimum load resistance is 2.8 kΩ at a supply voltage of 36 V. For lower supply voltages (either single-supply or symmetrical supplies), a lower load resistance may be used, as long as the output current does not exceed 13 mA; otherwise, the device short circuit current protection circuit may activate.

Internal power dissipation increases when operating at high supply voltages. Copper leadframe construction used in the OPA140, OPA2140, and OPA4140 series devices improves heat dissipation compared to conventional materials. Printed-circuit-board (PCB) layout can also help reduce a possible increase in junction temperature. Wide copper traces help dissipate the heat by acting as an additional heatsink. Temperature rise can be further minimized by soldering the devices directly to the PCB rather than using a socket.

Although the output current is limited by internal protection circuitry, accidental shorting of one or more output channels of a device can result in excessive heating. For instance, when an output is shorted to mid-supply, the typical short-circuit current of 36 mA leads to an internal power dissipation of over 600 mW at a supply of ±18 V.

In the case of a dual OPA2140 in an 8-pin VSSOP package (thermal resistance θ_{JA} = 180°C/W), such power dissipation would lead the die temperature to be 220°C above ambient temperature, when both channels are shorted. This temperature increase significantly decreases the operating life of the device.

To prevent excessive heating, the OPAx140 series has an internal thermal shutdown circuit that shuts down the device if the die temperature exceeds approximately 180°C. When this thermal shutdown circuit activates, a built-in hysteresis of 15°C makes sure that the die temperature must drop to approximately 165°C before the device switches on again.

Additional consideration should be given to the combination of maximum operating voltage, maximum operating temperature, load, and package type. Figure 35 and Figure 36 show several practical considerations when evaluating the OPA2140 (dual version) and the OPA4140 (quad version).

As an example, the OPA4140 has a maximum total quiescent current of 10.8 mA (2.7 mA/channel) over temperature. The 14-pin TSSOP package has a typical thermal resistance of 135°C/W. This parameter means that because the junction temperature should not exceed 150°C to provide reliable operation, either the supply voltage must be reduced, or the ambient temperature should remain low enough so that the junction temperature does not exceed 150°C. This condition is illustrated in Figure 35 for various package types. Moreover, resistive loading of the output causes additional power dissipation and thus self-heating, which also must be considered when establishing the maximum supply voltage or operating temperature. To this end, Figure 36 shows the maximum supply voltage versus temperature for a worst-case dc load resistance of 2 kΩ.

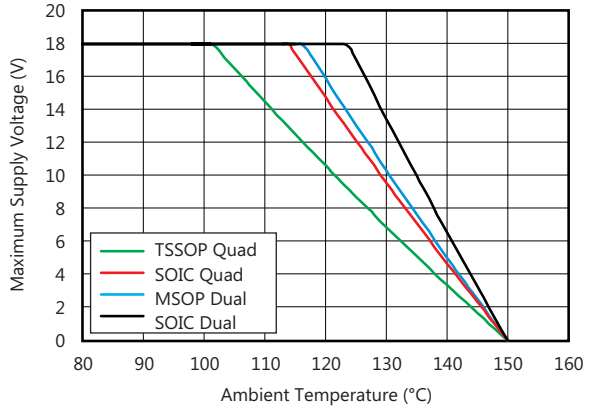

Figure 35. Maximum Supply Voltage vs Temperature (OPA2140 and OPA4140), Quiescent Condition

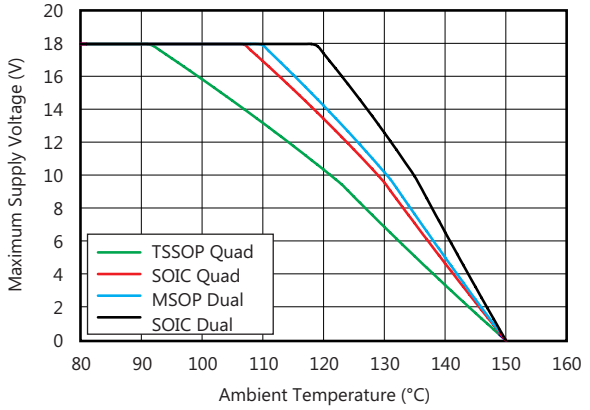

Figure 36. Maximum Supply Voltage vs Temperature (OPA2140 and OPA4140), Maximum DC Load

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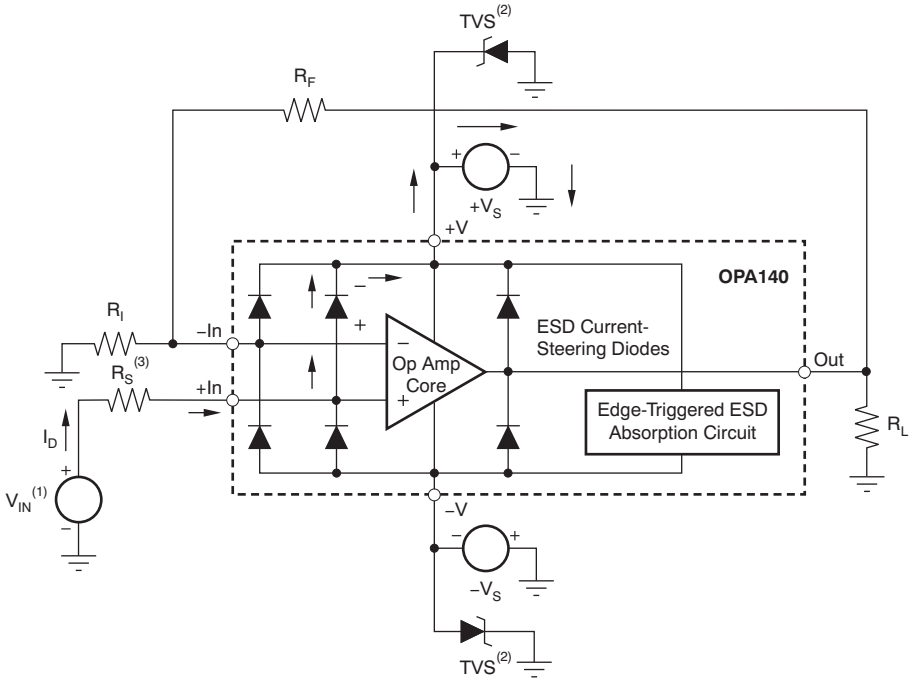
Feature Description (continued)

7.3.8 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but may involve the supply voltage pins or even the output pin. Each of these different pin functions have electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect them from accidental ESD events both before and during product assembly.

It is helpful to have a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event. Figure 37 shows an illustration of the ESD circuits contained in the OPAx140 series (indicated by the dashed line area). The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power-supply lines, where they meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.



(1) V_{IN} = $+V_S$ + 500 mV.

(2) TVS: $+V_{S(max)} > V_{TVSBR\ (Min)} > +V_S$

(3) Suggested value approximately 1 kΩ.

Figure 37. Equivalent Internal ESD Circuitry and Its Relation to a Typical Circuit Application

An ESD event produces a short duration, high-voltage pulse that is transformed into a short duration, high-current pulse as it discharges through a semiconductor device. The ESD protection circuits are designed to provide a current path around the operational amplifier core to prevent it from being damaged. The energy absorbed by the protection circuitry is then dissipated as heat.

When an ESD voltage develops across two or more of the amplifier device pins, current flows through one or more of the steering diodes. Depending on the path that the current takes, the absorption device may activate. The absorption device has a trigger, or threshold voltage, that is above the normal operating voltage of the OPAx140 but below the device breakdown voltage level. Once this threshold is exceeded, the absorption device quickly activates and clamps the voltage across the supply rails to a safe level.

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Feature Description (continued)

When the operational amplifier connects into a circuit such as the one Figure 37 shows, the ESD protection components are intended to remain inactive and not become involved in the application circuit operation. However, circumstances may arise where an applied voltage exceeds the operating voltage range of a given pin. Should this condition occur, there is a risk that some of the internal ESD protection circuits may be biased on, and conduct current. Any such current flow occurs through steering diode paths and rarely involves the absorption device.

Figure 37 depicts a specific example where the input voltage, V_{IN}, exceeds the positive supply voltage ($+V_S$) by 500 mV or more. Much of what happens in the circuit depends on the supply characteristics. If $+V_S$ can sink the current, one of the upper input steering diodes conducts and directs current to $+V_S$. Excessively high current levels can flow with increasingly higher V_{IN}. As a result, the data sheet specifications recommend that applications limit the input current to 10 mA.

If the supply is not capable of sinking the current, V_{IN} may begin sourcing current to the operational amplifier, and then take over as the source of positive supply voltage. The danger in this case is that the voltage can rise to levels that exceed the operational amplifier absolute maximum ratings.

Another common question involves what happens to the amplifier if an input signal is applied to the input while the power supplies $+V_S$ or $–V_S$ are at 0 V.

Again, it depends on the supply characteristic while at 0 V, or at a level below the input signal amplitude. If the supplies appear as high impedance, then the operational amplifier supply current may be supplied by the input source through the current steering diodes. This state is not a normal bias condition; the amplifier most likely will not operate normally. If the supplies are low impedance, then the current through the steering diodes can become quite high. The current level depends on the ability of the input source to deliver current, and any resistance in the input path.

If there is an uncertainty about the ability of the supply to absorb this current, external Zener diodes may be added to the supply pins as shown in Figure 37. The Zener voltage must be selected such that the diode does not turn on during normal operation.

However, its Zener voltage should be low enough so that the Zener diode conducts if the supply pin begins to rise above the safe operating supply voltage level.

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Feature Description (continued)

7.3.9 EMI Rejection

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many op amps is a change in the offset voltage as a result of RF signal rectification. An op amp that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this section provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the op amp. In general, only the noninverting input is tested for EMIRR for the following three reasons:

- Op amp input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
- The noninverting and inverting op amp inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance
- EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input terminal can be isolated on a PCB. This isolation allows the RF signal to be applied directly to the noninverting input terminal with no complex interactions from other components or connecting PCB traces. Figure 38

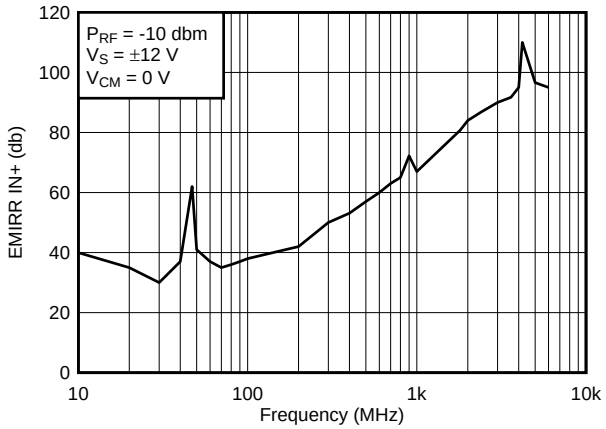

Figure 38. OPA2140 EMIRR

The EMIRR IN+ of the OPA2140 is plotted versus frequency as shown in .If available, any dual and quad op amp device versions have nearly similar EMIRR IN+ performance. The OPA2140 unity-gain bandwidth is
11 MHz. EMIRR performance below this frequency denotes interfering signals that fall within the op amp bandwidth.

For more information, see the *EMI Rejection Ratio of Operational Amplifiers Application Report*, available for download from www.ti.com.

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Feature Description (continued)

Table 2 lists the EMIRR IN+ values for the OPA2140 at particular frequencies commonly encountered in real-world applications. Applications listed in Table 2 may be centered on or operated near the particular frequency shown. This information may be of special interest to designers working with these types of applications, or working in other fields likely to encounter RF interference from broad sources, such as the industrial, scientific, and medical (ISM) radio band.

Table 2. OPA2140 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION OR ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	53.1 dB
900 MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications	72.2 dB
1.8 GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)	80.7 dB
2.4 GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz)	86.8 dB
3.6 GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	91.7 dB
5 GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)	96.6 dB

7.3.10 EMIRR +IN Test Configuration

Figure 39 shows the circuit configuration for testing the EMIRR IN+. An RF source is connected to the op amp noninverting input terminal using a transmission line. The op amp is configured in a unity gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM). A large impedance mismatch at the op amp input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. The resulting DC offset voltage is sampled and measured by the multimeter. The LPF isolates the multimeter from residual RF signals that may interfere with multimeter accuracy.

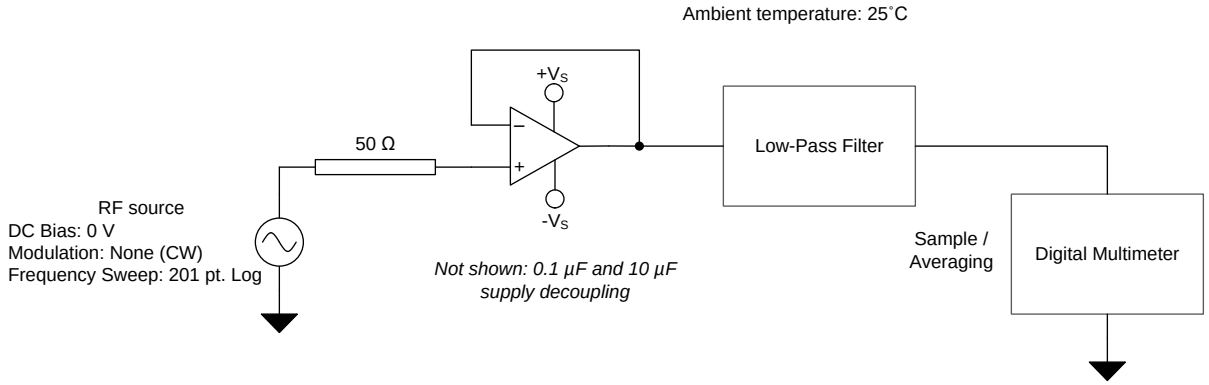

Figure 39. EMIRR +IN Test Configuration

7.4 Device Functional Modes

The OPAx140 has a single functional mode and is operational when the power-supply voltage is greater than 4.5 V (±2.25 V). The maximum power supply voltage for the OPAx140 is 36 V (±18 V).

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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

The OPA140, OPA2140, and OPA4140 are unity-gain stable, operational amplifiers with very low noise, input bias current, and input offset voltage. Applications with noisy or high-impedance power supplies require decoupling capacitors placed close to the device pins. In most cases, 0.1-μF capacitors are adequate. Designers can easily use the rail-to-rail output swing and input range that includes V– to take advantage of the low-noise characteristics of JFET amplifiers while also interfacing to modern, single-supply, precision data converters.

8.2 Typical Application

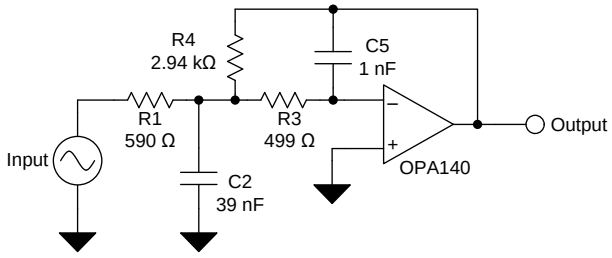

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Figure 40. 25-kHz Low-pass Filter

8.2.1 Design Requirements

Lowpass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The OPAx140 are an excellent choice to construct high-speed, high-precision active filters. Figure 40 shows a second-order, low-pass filter commonly encountered in signal processing applications.

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order Chebyshev filter response with 3-dB gain peaking in the passband

8.2.2 Detailed Design Procedure

The infinite-gain multiple-feedback circuit for a low-pass network function is shown in. Use Equation 1 to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1R_3C_2C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3R_4C_2C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, the gain at DC and the lowpass cutoff frequency are calculated by Equation 2:

$$\text{Gain} = \frac{R_4}{R_1}$$

$$f_C = \frac{1}{2\pi}\sqrt{(1/R_3R_4C_2C_5)} \quad (2)$$

Typical Application (continued)

Software tools are readily available to simplify filter design. WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The WEBENCH® Filter Designer lets you create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

Available as a web based tool from the WEBENCH Design Center, WEBENCH Filter Designer allows you to design, optimize, and simulate complete multistage active filter solutions within minutes.

8.2.3 Application Curve

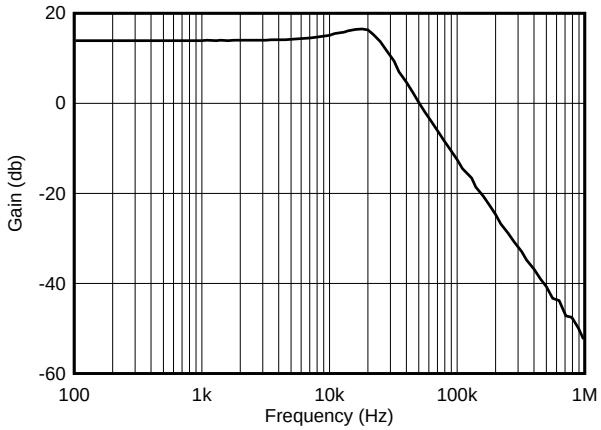

Figure 41. OPAx140 Second-Order, 25-kHz, Chebyshev, Low-Pass Filter

9 Power Supply Recommendations

The OPAx140 is specified for operation from 4.5 V to 36 V (±2.25 V to ±18 V); many specifications apply from –40°C to 125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the *Typical Characteristics*.

CAUTION

Supply voltages larger than 40 V can permanently damage the device; see the *Absolute Maximum Ratings*.

Place 0.1-μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see the *Layout* section.

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10 Layout

10.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-µF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current. For more detailed information, see *Circuit Board Layout Techniques* (SLOA089).
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. As illustrated in Figure 42, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- For best performance, TI recommends cleaning the PCB following board assembly.
- Any precision integrated circuit may experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, TI recommends baking the PCB assembly to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

10.2 Layout Example

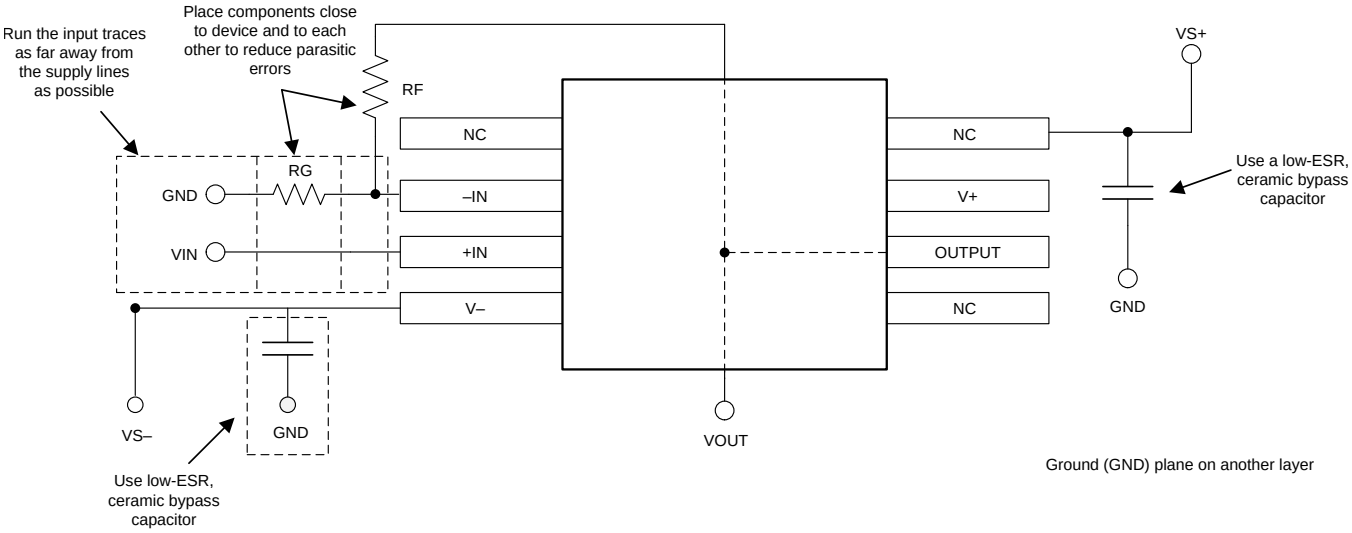

Figure 42. Operational Amplifier Board Layout for Noninverting Configuration

11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

11.1.1.1 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI is a free, fully-functional version of the TINA software, preloaded with a library of macro models in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a free download from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

NOTE

These files require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.

11.1.1.2 WEBENCH Filter Designer Tool

WEBENCH® Filter Designer is a simple, powerful, and easy-to-use active filter design program. The WEBENCH Filter Designer lets you create optimized filter designs using a selection of TI operational amplifiers and passive components from TI's vendor partners.

11.1.1.3 TI Precision Designs

TI Precision Designs are available online at http://www.ti.com/ww/en/analog/precision-designs/. TI Precision Designs are analog solutions created by TI's precision analog applications experts and offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits.

11.2 Documentation Support

11.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *Circuit Board Layout Techniques*
- Texas Instruments, *Op Amps for Everyone Design Reference*
- Texas Instruments, *OPA140, OPA2140, OPA4140 EMI Immunity Performance Technical Brief*
- Texas Instruments, *Compensate Transimpedance Amplifiers Intuitively Application Report*
- Texas Instruments, *Operational amplifier gain stability, Part 3: AC gain-error analysis*
- Texas Instruments, *Operational amplifier gain stability, Part 2: DC gain-error analysis*
- Texas Instruments, *Using infinite-gain, MFB filter topology in fully differential active filters*
- Texas Instruments, *Op Amp Performance Analysis Application Bulletin*
- Texas Instruments, *Single-Supply Operation of Operational Amplifiers Application Bulletin*
- Texas Instruments, *Tuning in Amplifiers Application Bulletin*
- Texas Instruments, *Shelf-Life Evaluation of Lead-Free Component Finishes Application Report*
- Texas Instruments, *Feedback Plots Define Op Amp AC Performance Application Bulletin*
- Texas Instruments, *EMI Rejection Ratio of Operational Amplifiers Application Report*

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11.3 Related Links

Table 3 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 3. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
OPA140	Click here	Click here	Click here	Click here	Click here
OPA2140	Click here	Click here	Click here	Click here	Click here
OPA4140	Click here	Click here	Click here	Click here	Click here

11.4 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.

11.5 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.

11.6 Trademarks

E2E is a trademark of Texas Instruments.
TINA-TI is a trademark of Texas Instruments, Inc and DesignSoft, Inc.
WEBENCH is a registered trademark of Texas Instruments.
Bluetooth is a registered trademark of Bluetooth SIG, Inc.
TINA, DesignSoft are trademarks of DesignSoft, Inc.
All other trademarks are the property of their respective owners.

11.7 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.

11.8 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.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA140AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA140	Samples
OPA140AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O140	Samples
OPA140AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O140	Samples
OPA140AIDGKR	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU | Call TI	Level-2-260C-1 YEAR	-40 to 125	(140, O140)	Samples
OPA140AIDGKT	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU | Call TI	Level-2-260C-1 YEAR	-40 to 125	140	Samples
OPA140AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	OPA140	Samples
OPA2140AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O2140A	Samples
OPA2140AIDGKR	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2140	Samples
OPA2140AIDGKT	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	2140	Samples
OPA2140AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O2140A	Samples
OPA4140AID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	O4140A	Samples
OPA4140AIDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 125	O4140A	Samples
OPA4140AIPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O4140A	Samples
OPA4140AIPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	O4140A	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) RoHS: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

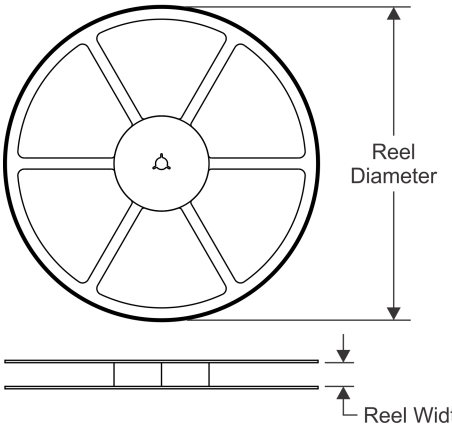
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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.

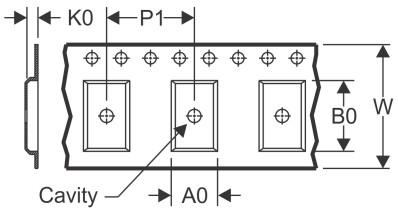
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

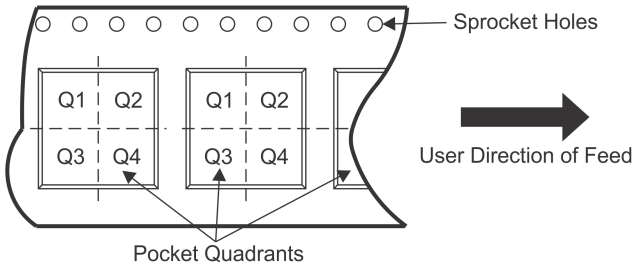


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

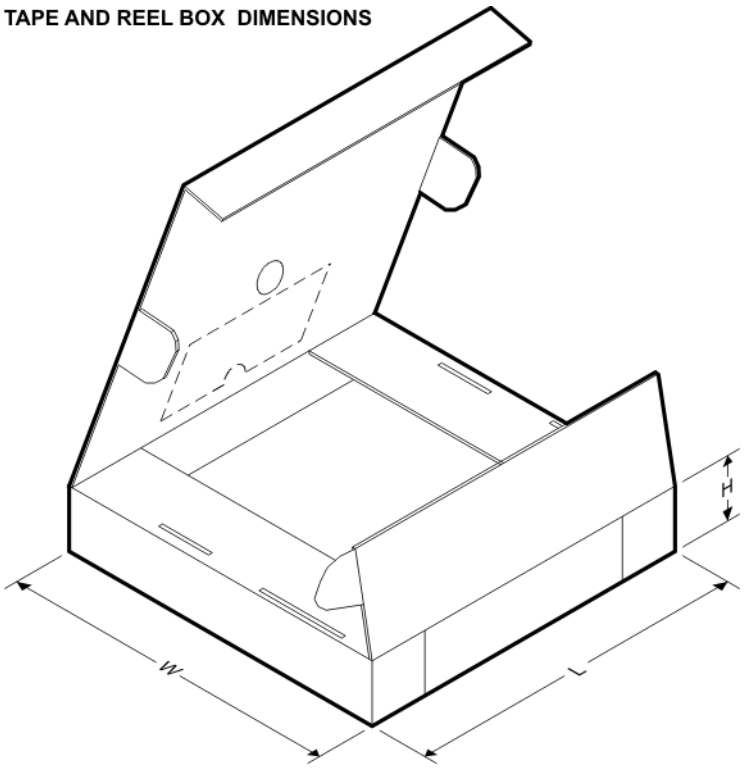
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
OPA140AIDBVR	SOT-23	DBV	5	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
OPA140AIDBVT	SOT-23	DBV	5	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
OPA140AIDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA140AIDGKT	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA140AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA2140AIDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2140AIDGKT	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2140AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA4140AIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
OPA4140AIPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

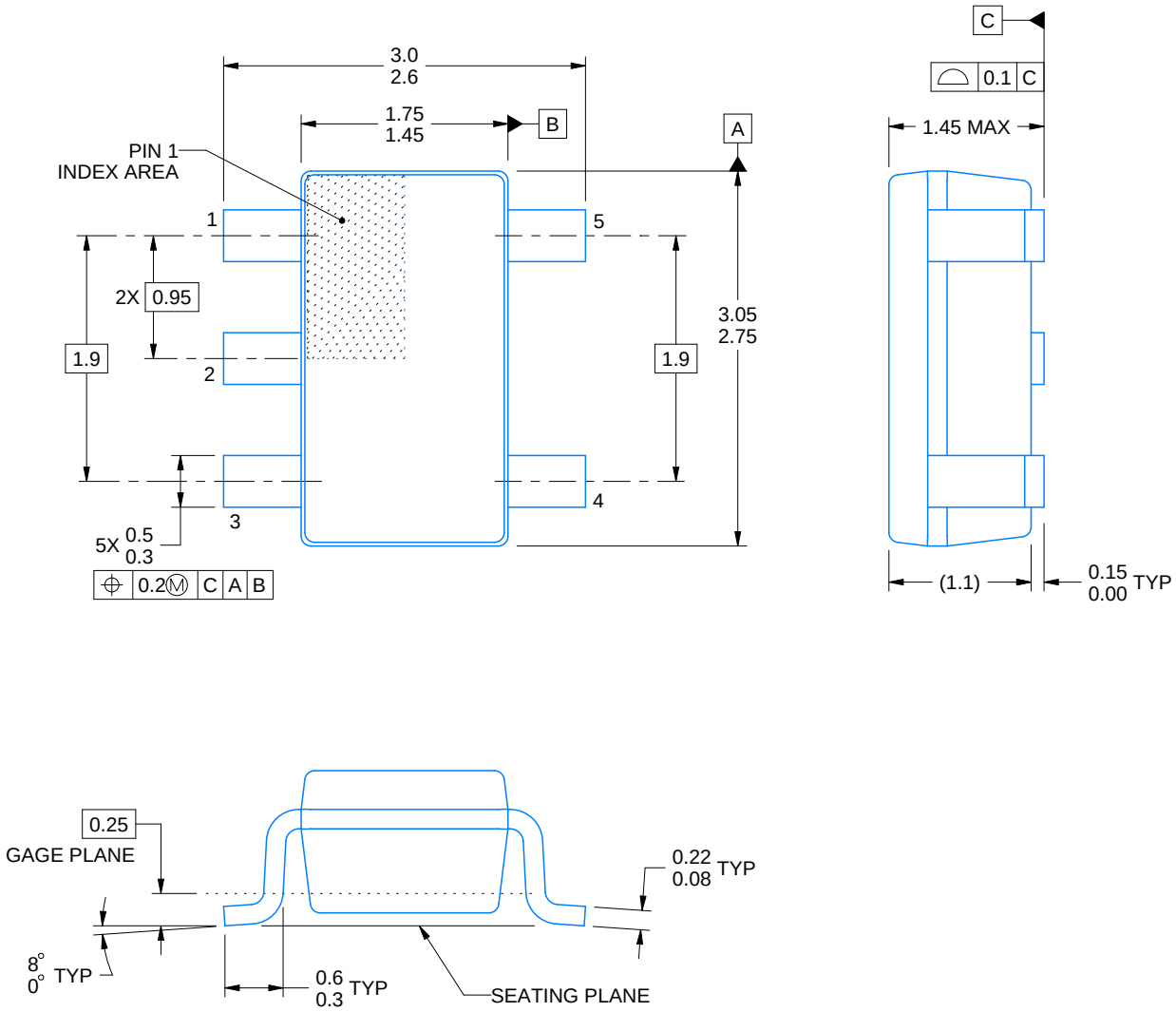
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA140AIDBVR	SOT-23	DBV	5	3000	202.0	201.0	28.0
OPA140AIDBVT	SOT-23	DBV	5	250	202.0	201.0	28.0
OPA140AIDGKR	VSSOP	DGK	8	2500	367.0	367.0	35.0
OPA140AIDGKT	VSSOP	DGK	8	250	210.0	185.0	35.0
OPA140AIDR	SOIC	D	8	2500	367.0	367.0	35.0
OPA2140AIDGKR	VSSOP	DGK	8	2500	367.0	367.0	35.0
OPA2140AIDGKT	VSSOP	DGK	8	250	210.0	185.0	35.0
OPA2140AIDR	SOIC	D	8	2500	367.0	367.0	35.0
OPA4140AIDR	SOIC	D	14	2500	367.0	367.0	38.0
OPA4140AIPWR	TSSOP	PW	14	2000	367.0	367.0	35.0

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

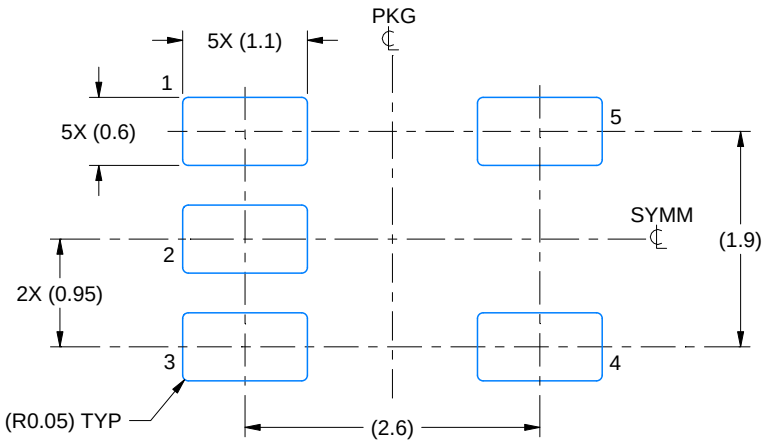
SMALL OUTLINE TRANSISTOR



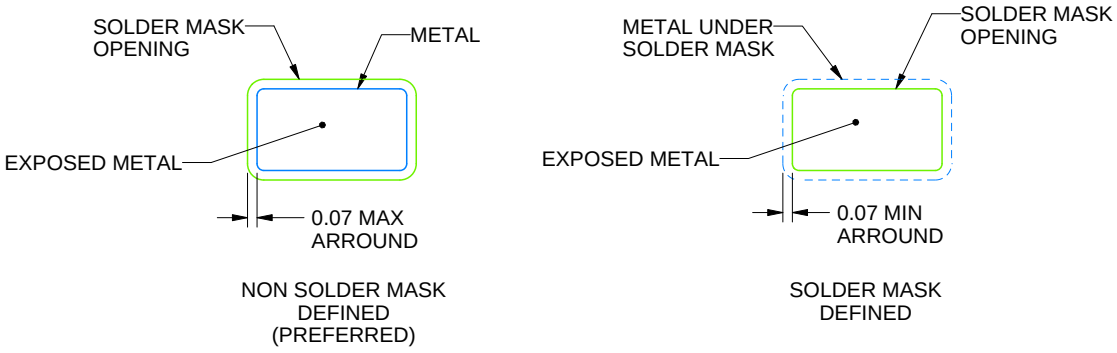
4214839/D 11/2018

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. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

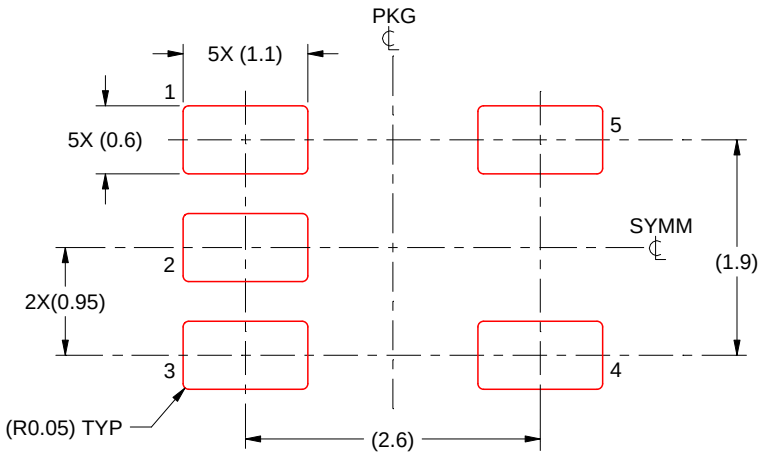


SOLDER MASK DETAILS

4214839/D 11/2018

NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



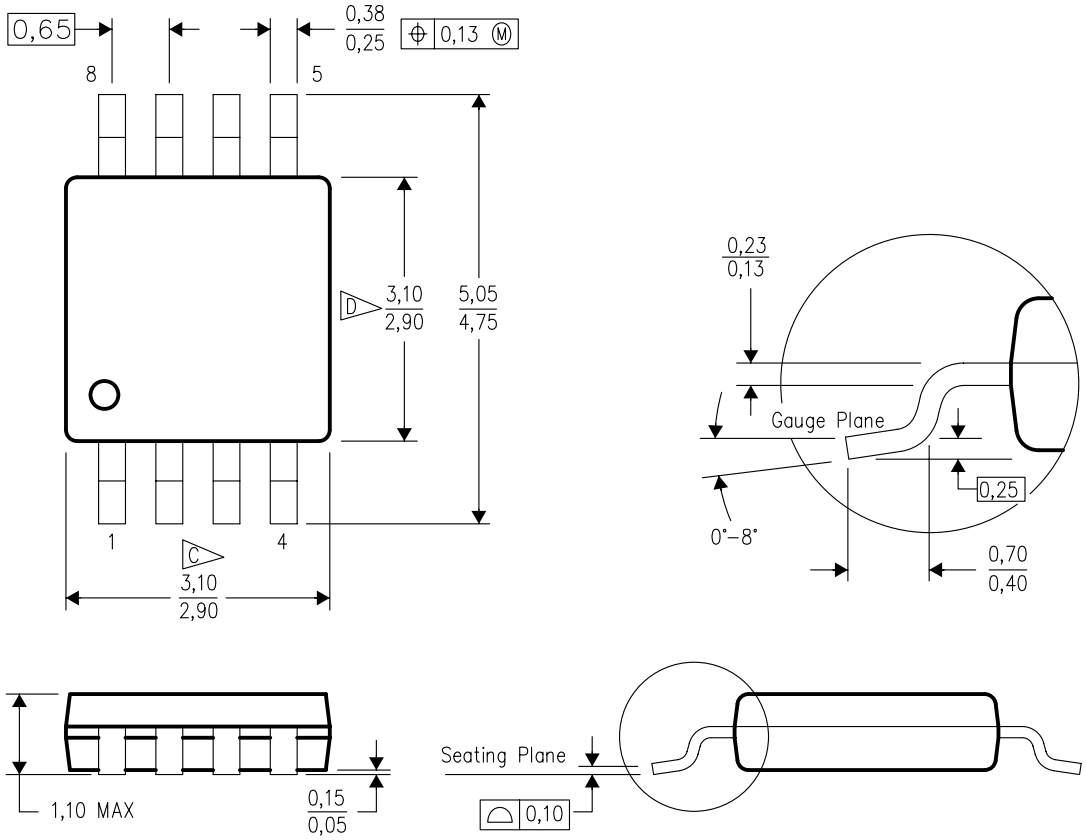
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/D 11/2018

NOTES: (continued)

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

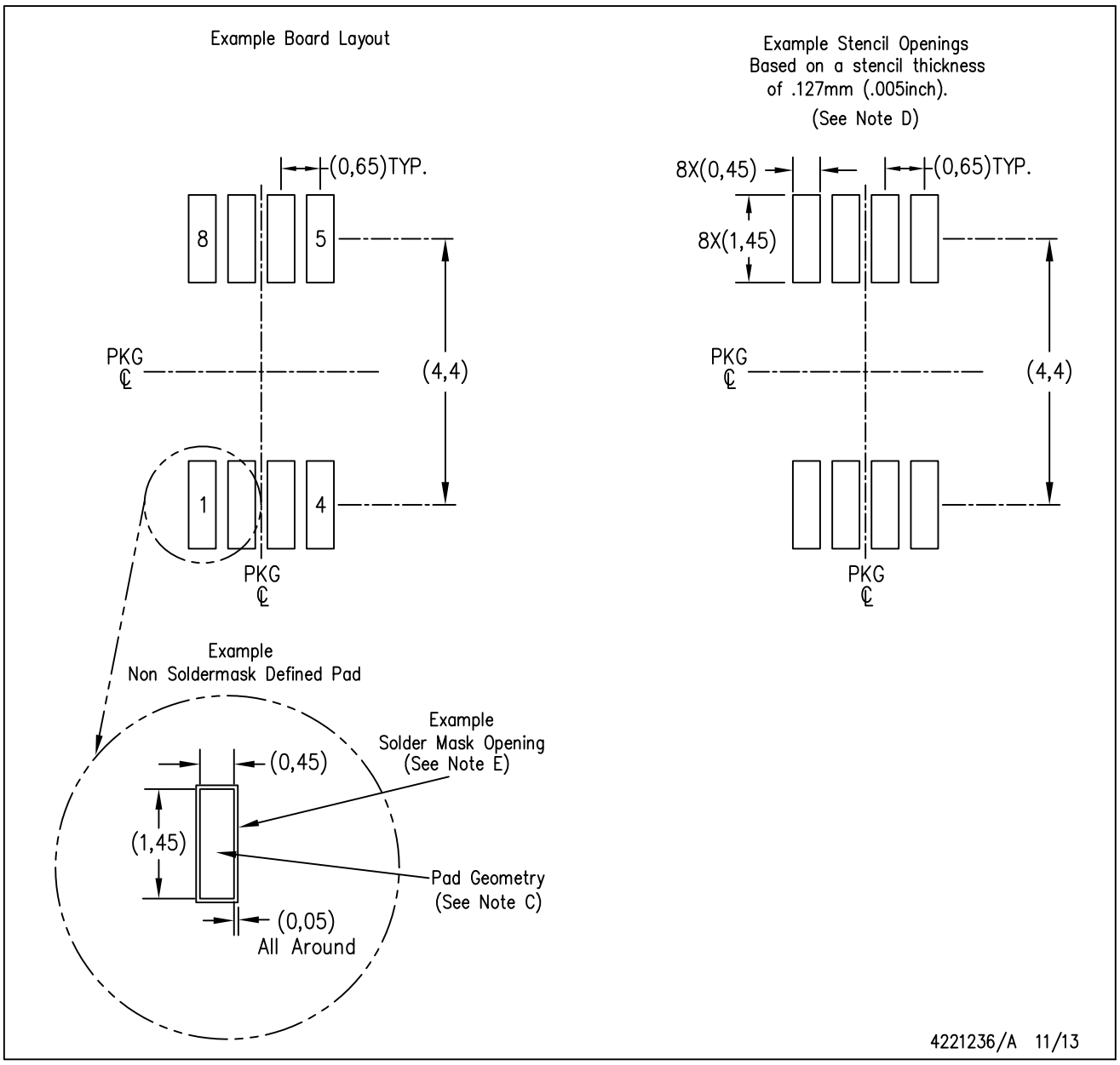
DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



4073329/E 05/06

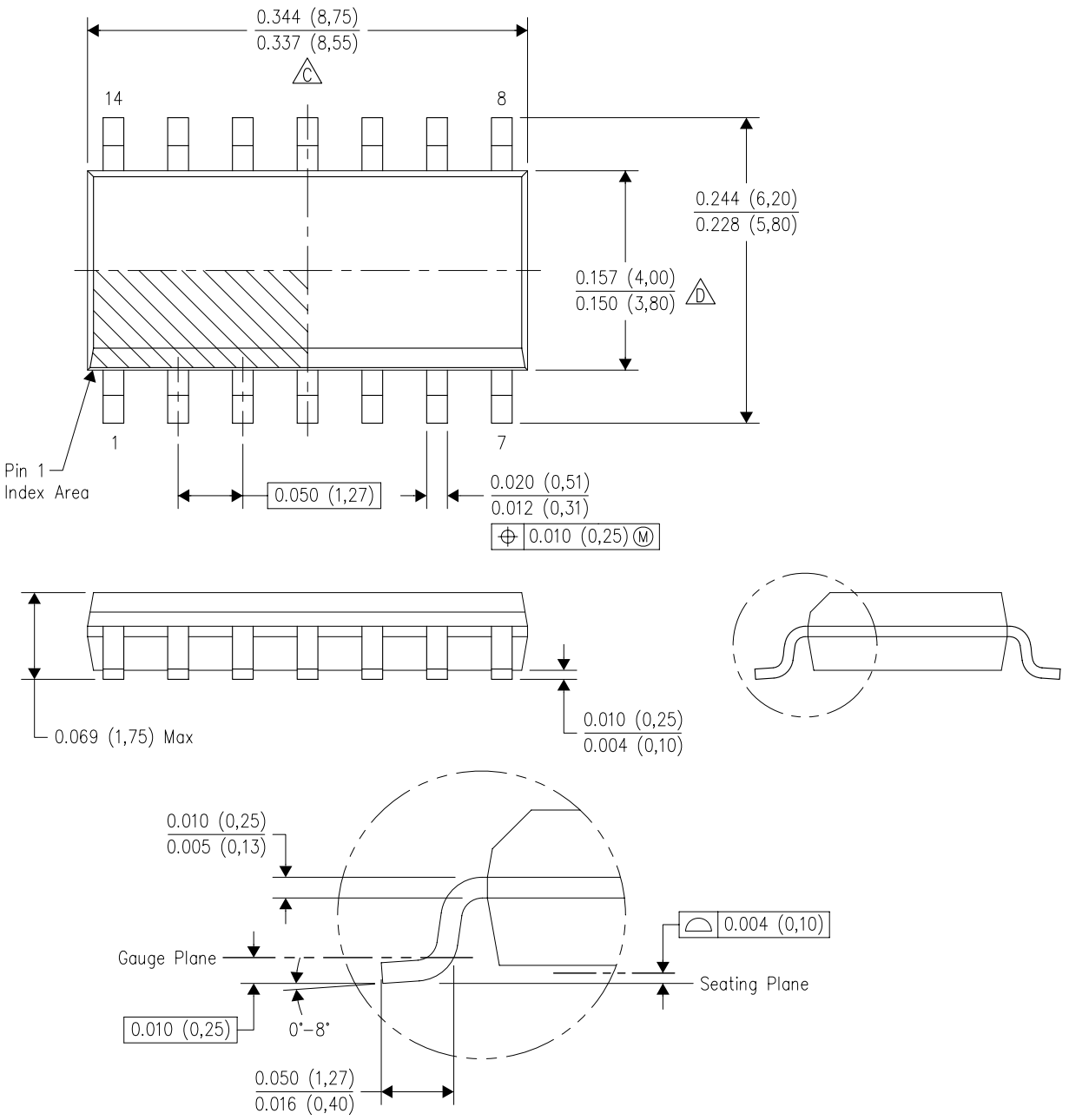
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO–187 variation AA, except interlead flash.

DGK (S–PDSO–G8) PLASTIC SMALL OUTLINE PACKAGE



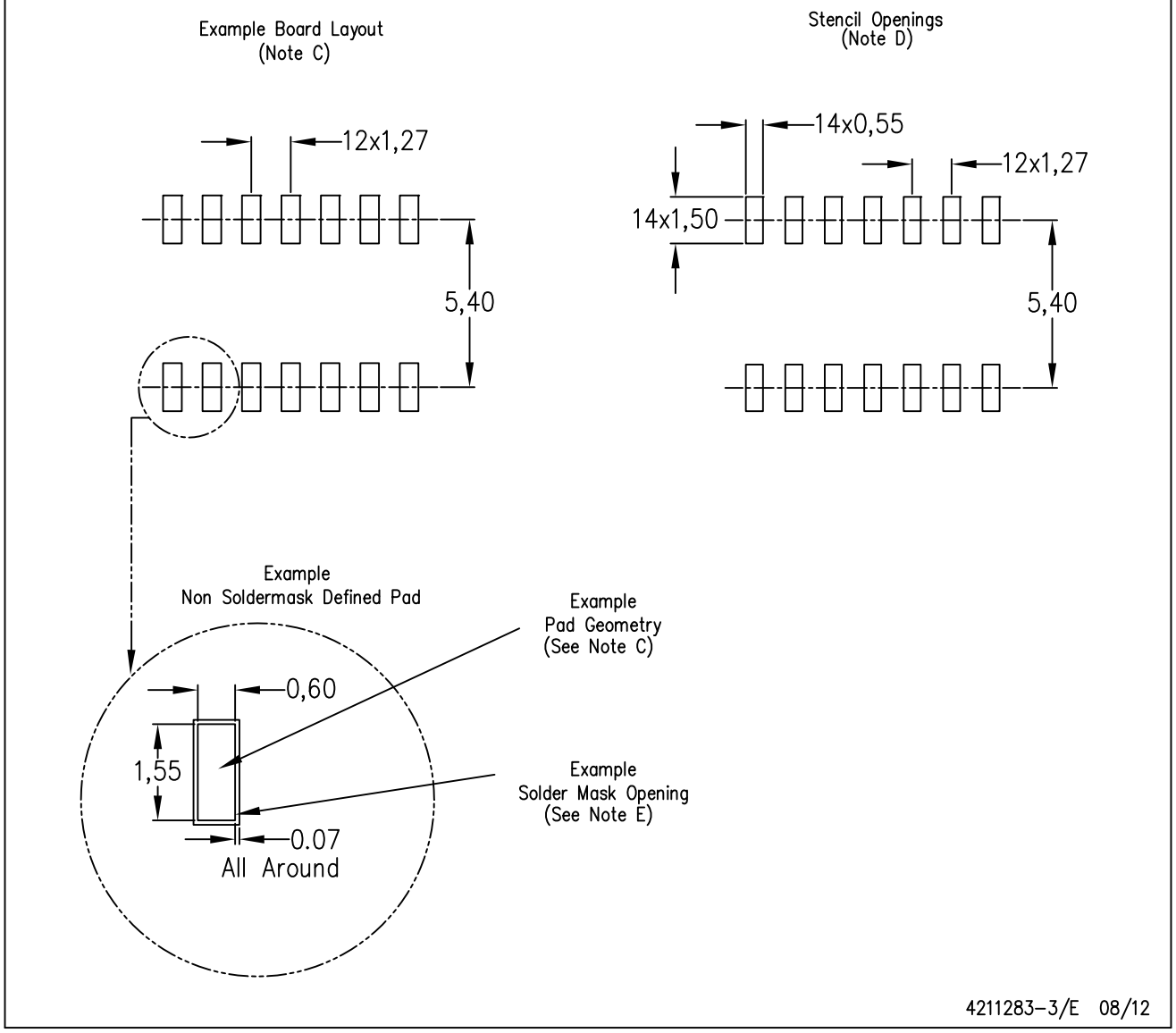
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

D (R–PDSO–G14) PLASTIC SMALL OUTLINE



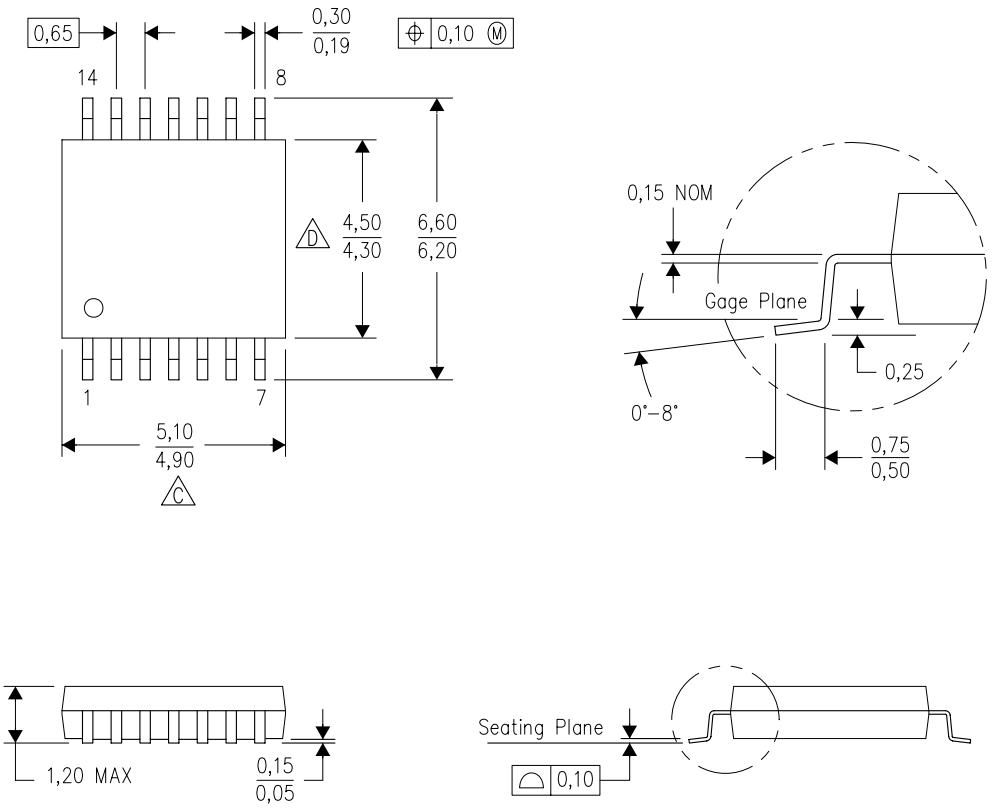
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AB.

D (R–PDSO–G14) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

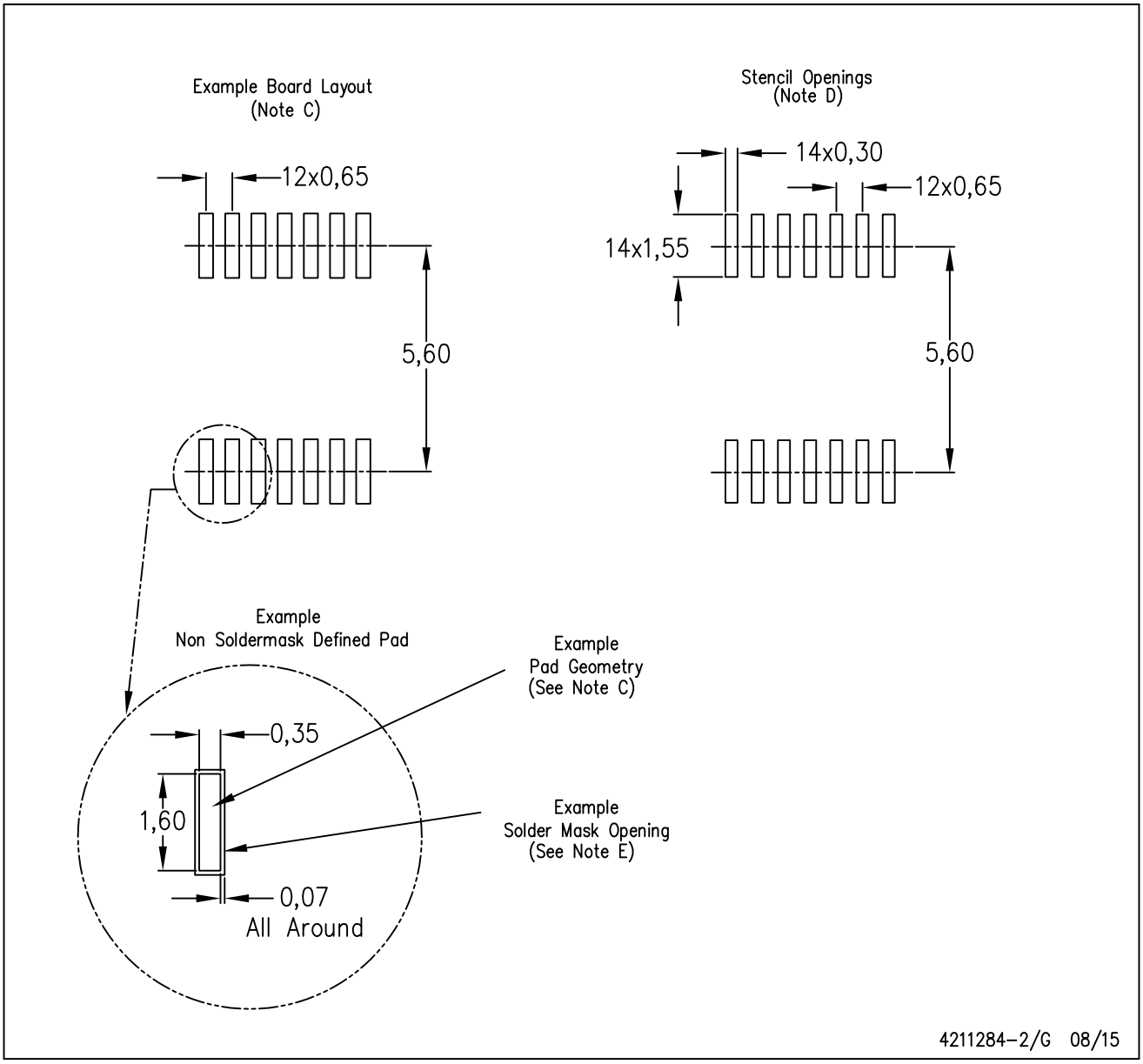
PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



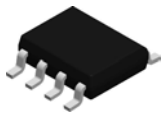
4040064–3/G 02/11

NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
E. Falls within JEDEC MO–153

PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

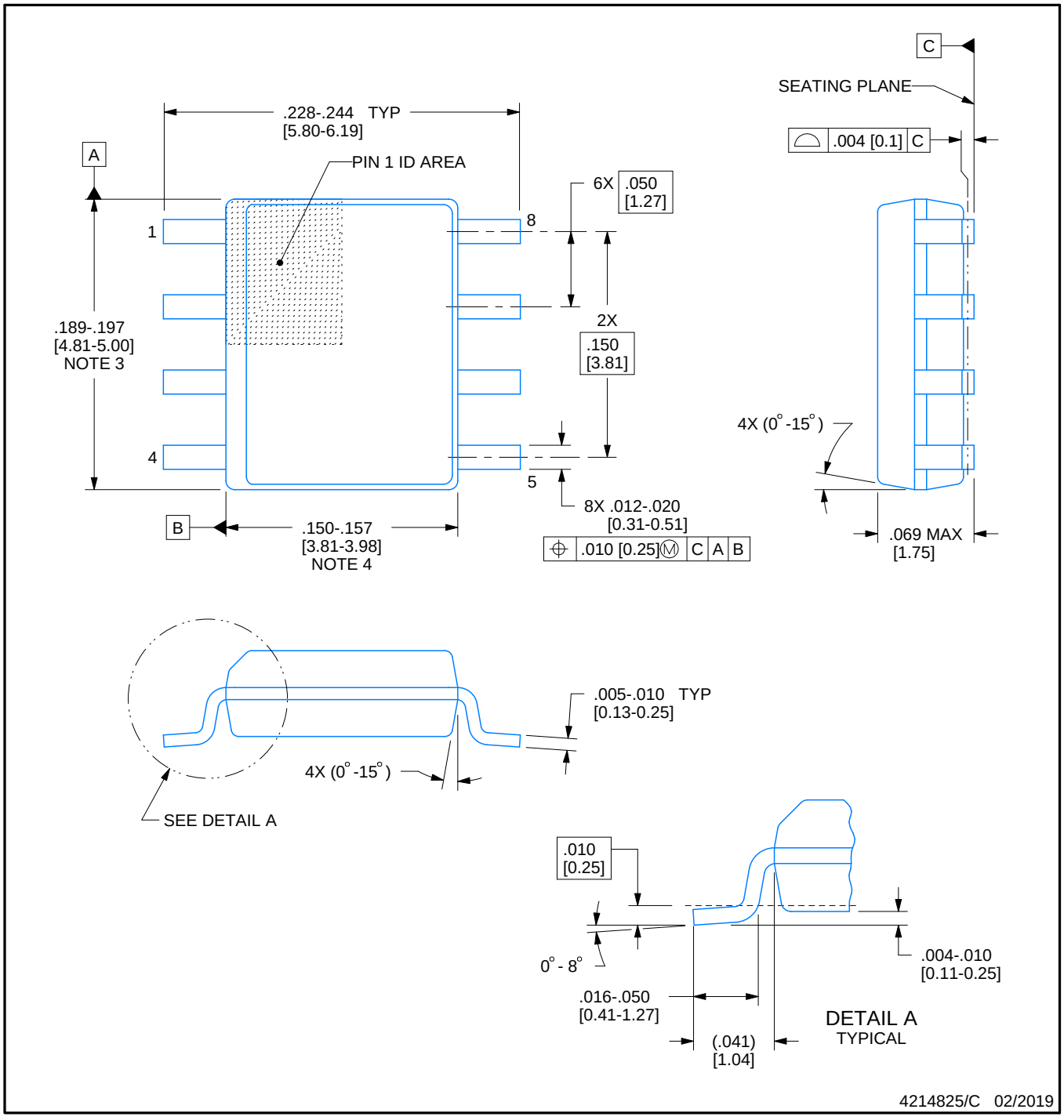


PACKAGE OUTLINE

D0008A

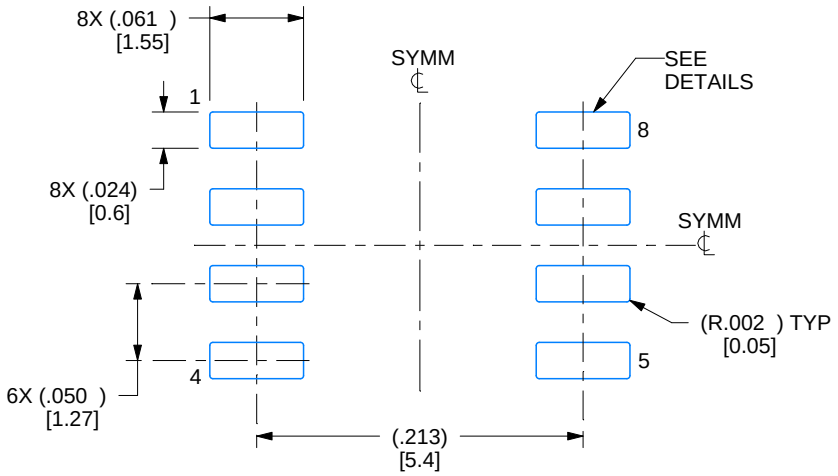
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

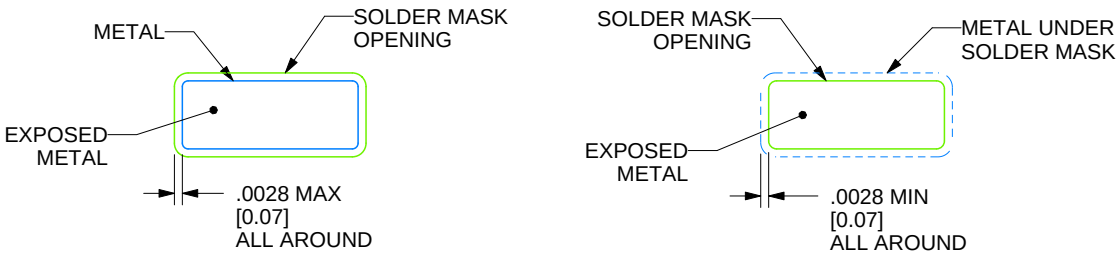


NOTES:

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

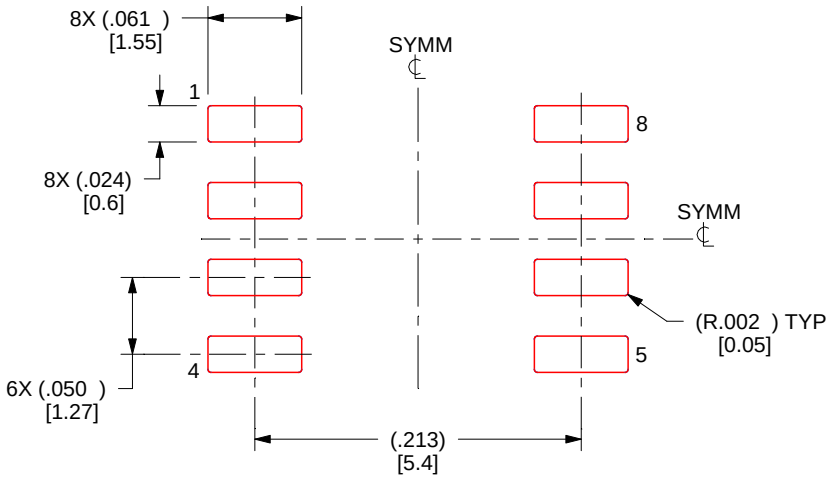
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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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