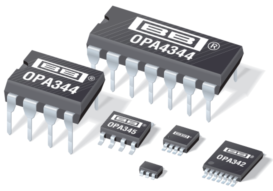
OPA344
OPA2344
OPA4344

OPA345
OPA2345
OPA4345



www.ti.com

SBOS107A – APRIL 2000 – REVISED AUGUST 2008

LOW POWER, SINGLE-SUPPLY, RAIL-TO-RAIL OPERATIONAL AMPLIFIERS

*Micro**Amplifier*™ Series

FEATURES

- **RAIL-TO-RAIL INPUT**
- **RAIL-TO-RAIL OUTPUT (within 1mV)**
- **LOW QUIESCENT CURRENT: 150μA typ**
- ***Micro*SIZE PACKAGES**
  - **SOT23-5**
  - **MSOP-8**
  - **TSSOP-14**
- **GAIN-BANDWIDTH**
  - **OPA344: 1MHz, G ≥ 1**
  - **OPA345: 3MHz, G ≥ 5**
- **SLEW RATE**
  - **OPA344: 0.8V/μs**
  - **OPA345: 2V/μs**
- **THD + NOISE: 0.006%**

APPLICATIONS

- **PCMCIA CARDS**
- **DATA ACQUISITION**
- **PROCESS CONTROL**
- **AUDIO PROCESSING**
- **COMMUNICATIONS**
- **ACTIVE FILTERS**
- **TEST EQUIPMENT**

DESCRIPTION

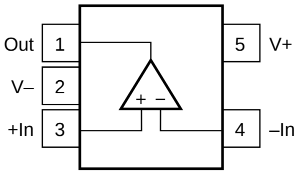
The OPA344 and OPA345 series rail-to-rail CMOS operational amplifiers are designed for precision, low-power, miniature applications. The OPA344 is unity gain stable, while the OPA345 is optimized for gains greater than or equal to five, and has a gain-bandwidth product of 3MHz.

The OPA344 and OPA345 are optimized to operate on a single supply from 2.5V and up to 5.5V with an input common-mode voltage range that extends 300mV beyond the supplies. Quiescent current is only 250μA (max).

Rail-to-rail input and output make them ideal for driving sampling analog-to-digital converters. They are also well suited for general purpose and audio applications and providing I/V conversion at the output of D/A converters. Single, dual and quad versions have identical specs for design flexibility.

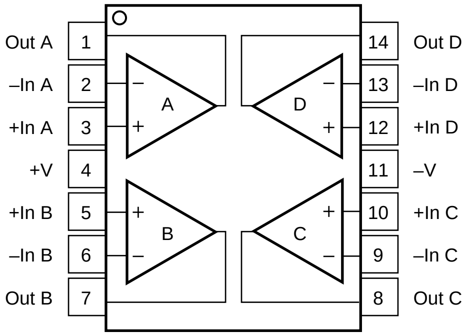
A variety of packages are available. All are specified for operation from –40ºC to 85ºC. A SPICE macromodel for design analysis is available for download from www.ti.com.

OPA344, OPA345



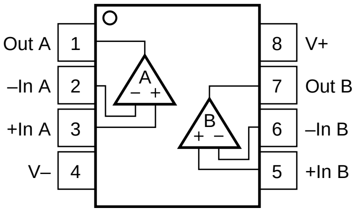
SOT23-5

OPA4344, OPA4345



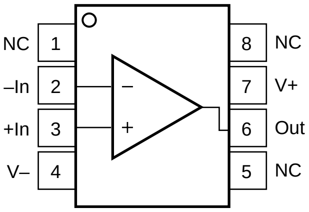
TSSOP-14, SO-14, 14-PIn DIP (OPA4344 Only)

OPA2344, OPA2345



SO-8, MSOP-8, 8-Pin DIP (OPA2344 Only)

OPA344, OPA345



SO-8, 8-Pin DIP (OPA344 Only)

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

SPECIFICATIONS: V_S = 2.7V to 5.5V

At T_A = +25°C, R_L = 10kΩ connected to $V_S/2$ and V_{OUT} = $V_S/2$, unless otherwise noted.
Boldface limits apply over the temperature range, T_A = –40°C to +85°C.

PARAMETER	CONDITION	OPA344NA, UA, PA OPA2344EA, UA, PA OPA4344EA, UA, PA			UNITS
		MIN	TYP	MAX	
OFFSET VOLTAGE					
Input Offset Voltage V_{OS}	V_S = +5.5V, V_{CM} = $V_S/2$		±0.2	±1	mV
Over Temperature			**±0.8**	**±1.2**	mV
vs Temperature dV_{OS}/dT			**±3**		µV/°C
vs Power Supply PSRR	V_S = 2.7V to 5.5V, V_{CM} < (V+) -1.8V		30	200	µV/V
Over Temperature	**V_S = 2.7V to 5.5V, V_{CM} < (V+) -1.8V**			**250**	µV/V
Channel Separation, dc			0.2		µV/V
f = 1kHz			130		dB
INPUT BIAS CURRENT					
Input Bias Current I_B			±0.2	±10	pA
Over Temperature			**See Typical Curve**		pA
Input Offset Current I_{OS}			±0.2	±10	pA
NOISE					
Input Voltage Noise	f = 0.1 to 50kHz		8		µVrms
Input Voltage Noise Density e_n	f = 10kHz		30		nV/√Hz
Current Noise Density i_n	f = 10kHz		0.5		fA/√Hz
INPUT VOLTAGE RANGE					
Common-Mode Voltage Range V_{CM}		–0.3		(V+) + 0.3	V
Common-Mode Rejection Ratio CMRR	V_S = +5.5V, –0.3V < V_{CM} < (V+)-1.8	76	92		dB
Over Temperature	**V_S = +5.5V, –0.3V < V_{CM} < (V+)-1.8**	**74**			dB
Common-Mode Rejection CMRR	V_S = +5.5V, –0.3V < V_{CM} < 5.8V	70	84		dB
Over Temperature	**V_S = +5.5V, –0.3V < V_{CM} < 5.8V**	**68**			dB
Common-Mode Rejection CMRR	V_S = +2.7V, –0.3V < V_{CM} < 3V	66	80		dB
Over Temperature	**V_S = +2.7V, –0.3V < V_{CM} < 3V**	**64**			dB
INPUT IMPEDANCE					
Differential			10^{13} || 3		Ω || pF
Common-Mode			10^{13} || 6		Ω || pF
OPEN-LOOP GAIN					
Open-Loop Voltage Gain A_{OL}	R_L = 100kΩ, 10mV < V_O < (V+) –10mV	104	122		dB
Over Temperature	**R_L = 100kΩ, 10mV < V_O < (V+) –10mV**	**100**			dB
	R_L = 5kΩ, 400mV < V_O < (V+) –400mV	96	120		dB
Over Temperature	**R_L = 5kΩ, 400mV < V_O < (V+) –400mV**	**90**			dB
FREQUENCY RESPONSE	C_L = 100pF				
Gain-Bandwidth Product GBW			1		MHz
Slew Rate SR			0.8		V/µs
Settling Time, 0.1%	V_S = 5.5V, 2V Step		5		µs
0.01%	V_S = 5.5V, 2V Step		8		µs
Overload Recovery Time	V_{IN} • G = V_S		2.5		µs
Total Harmonic Distortion + Noise THD+N	V_S = 5.5V, V_O = 3Vp-p, G = 1, f = 1kHz		0.006		%
OUTPUT					
Voltage Output Swing from Rail(1)	R_L = 100kΩ, A_{OL} ≥ 96dB		1		mV
	R_L = 100kΩ, A_{OL} ≥ 104dB		3	10	mV
Over Temperature	**R_L = 100kΩ, A_{OL} ≥ 100dB**			**10**	mV
	R_L = 5kΩ, A_{OL} ≥ 96dB		40	400	mV
Over Temperature	**R_L = 5kΩ, A_{OL} ≥ 90dB**			**400**	mV
Short-Circuit Current I_{SC}			±15		mA
Capacitive Load Drive C_{LOAD}			See Typical Curve		
POWER SUPPLY					
Specified Voltage Range V_S		2.7		5.5	V
Operating Voltage Range			2.5 to 5.5		V
Quiescent Current (per amplifier) I_Q	V_S = 5.5V, I_O = 0		150	250	µA
Over Temperature				**300**	µA
TEMPERATURE RANGE					
Specified Range		–40		85	°C
Operating Range		–55		125	°C
Storage Range		–65		150	°C
Thermal Resistance θ_{JA}					
SOT23-5 Surface Mount			200		°C/W
MSOP-8 Surface Mount			150		°C/W
8-Pin DIP			100		°C/W
SO-8 Surface Mount			150		°C/W
TSSOP-14 Surface Mount			100		°C/W
14-Pin DIP			80		°C/W
SO-14 Surface Mount			100		°C/W

NOTE: (1) Output voltage swings are measured between the output and power-supply rails.

SPECIFICATIONS: V_S = 2.7V to 5.5V

At T_A = +25°C, R_L = 10kΩ connected to $V_S/2$ and V_{OUT} = $V_S/2$, unless otherwise noted.
Boldface limits apply over the temperature range, T_A = –40°C to +85°C.

PARAMETER		CONDITION	OPA345NA, UA OPA2345EA, UA OPA4345EA, UA			UNITS
			MIN	TYP	MAX	
OFFSET VOLTAGE						
Input Offset Voltage	V_{OS}	V_S = +5.5V, V_{CM} = $V_S/2$		±0.2	±1	mV
Over Temperature				**±0.8**	**±1.2**	mV
vs Temperature	**dV_{OS}/dT**			**±3**		µV/°C
vs Power Supply	PSRR	V_S = 2.7V to 5.5V, V_{CM} < (V+) -1.8V		30	200	µV/V
Over Temperature		**V_S = 2.7V to 5.5V, V_{CM} < (V+) -1.8V**			**250**	µV/V
Channel Separation, dc				0.2		µV/V
f = 1kHz				130		dB
INPUT BIAS CURRENT						
Input Bias Current	I_B			±0.2	±10	pA
Over Temperature				**See Typical Curve**		pA
Input Offset Current	I_{OS}			±0.2	±10	pA
NOISE						
Input Voltage Noise		f = 0.1 to 50kHz		8		µVrms
Input Voltage Noise Density	e_n	f = 10kHz		30		nV/√Hz
Current Noise Density	i_n	f = 10kHz		0.5		fA/√Hz
INPUT VOLTAGE RANGE						
Common-Mode Voltage Range	V_{CM}		–0.3		(V+) + 0.3	V
Common-Mode Rejection Ratio	CMRR	V_S = +5.5V, –0.3V < V_{CM} < (V+)-1.8	76	92		dB
Over Temperature		**V_S = +5.5V, –0.3V < V_{CM} < (V+)-1.8**	**74**			dB
Common-Mode Rejection Ratio	CMRR	V_S = +5.5V, –0.3V < V_{CM} < 5.8V	70	84		dB
Over Temperature		**V_S = +5.5V, –0.3V < V_{CM} < 5.8V**	**68**			dB
Common-Mode Rejection Ratio	CMRR	V_S = +2.7V, –0.3V < V_{CM} < 3V	66	80		dB
Over Temperature		**V_S = +2.7V, –0.3V < V_{CM} < 3V**	**64**			dB
INPUT IMPEDANCE						
Differential				10^{13} || 3		Ω || pF
Common-Mode				10^{13} || 6		Ω || pF
OPEN-LOOP GAIN						
Open-Loop Voltage Gain	A_{OL}	R_L = 100kΩ, 10mV < V_O < (V+) –10mV	104	122		dB
Over Temperature		**R_L = 100kΩ, 10mV < V_O < (V+) –10mV**	**100**			dB
		R_L = 5kΩ, 400mV < V_O < (V+) –400mV	96	120		dB
Over Temperature		**R_L = 5kΩ, 400mV < V_O < (V+) –400mV**	**90**			dB
FREQUENCY RESPONSE		C_L = 100pF				
Gain-Bandwidth Product	GBW			3		MHz
Slew Rate	SR			2		V/µs
Settling Time, 0.1%		G = 5, 2V Output Step		1.5		µs
0.01%		G = 5, 2V Output Step		1.6		µs
Overload Recovery Time		V_{IN} • G = V_S		2.5		µs
Total Harmonic Distortion + Noise	THD+N	V_S = 5.5V, V_O = 2.5Vp-p, G = 5, f = 1kHz		0.006		%
OUTPUT						
Voltage Output Swing from Rail(1)		R_L = 100kΩ, A_{OL} ≥ 96dB		1		mV
		R_L = 100kΩ, A_{OL} ≥ 104dB		3	10	mV
Over Temperature		**R_L = 100kΩ, A_{OL} ≥ 100dB**			**10**	mV
		R_L = 5kΩ, A_{OL} ≥ 96dB		40	400	mV
Over Temperature		**R_L = 5kΩ, A_{OL} ≥ 90dB**			**400**	mV
Short-Circuit Current	I_{SC}			±15		mA
Capacitive Load Drive	C_{LOAD}			See Typical Curve		
POWER SUPPLY						
Specified Voltage Range	V_S		2.7		5.5	V
Operating Voltage Range				2.5 to 5.5		V
Quiescent Current (per amplifier)	I_Q	V_S = 5.5V, I_O = 0		150	250	µA
Over Temperature					**300**	µA
TEMPERATURE RANGE						
Specified Range			–40		85	°C
Operating Range			–55		125	°C
Storage Range			–65		150	°C
Thermal Resistance	θ_{JA}					
SOT23-5 Surface Mount				200		°C/W
MSOP-8 Surface Mount				150		°C/W
SO-8 Surface Mount				150		°C/W
TSSOP-14 Surface Mount				100		°C/W
SO-14 Surface Mount				100		°C/W

NOTE: (1) Output voltage swings are measured between the output and power-supply rails.

ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, V+ to V-	7.5V
Signal Input Terminals, Voltage(2)	(V–) –0.5V to (V+) +0.5V
Current(2)	10mA
Output Short-Circuit(3)	Continuous
Operating Temperature	–55°C to +125°C
Storage Temperature	–65°C to +150°C
Junction Temperature	150°C
Lead Temperature (soldering, 10s)	300°C
ESD Tolerance (Human Body Model)	4000V

NOTES: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only. Functional operation of the device at these conditions, or beyond the specified operating conditions, is not implied. (2) Input terminals are diode-clamped to the power supply rails. Input signals that can swing more than 0.5V beyond the supply rails should be current-limited to 10mA or less. (3) Short-circuit to ground, one amplifier per package.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION(1)

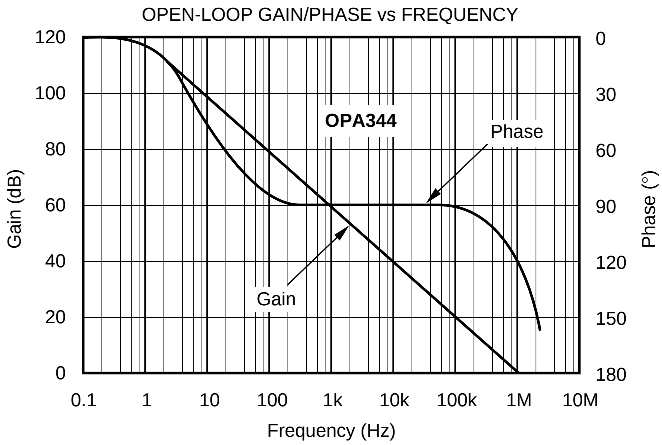
PRODUCT	PACKAGE	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER(2)	TRANSPORT MEDIA
OPA344NA	SOT23-5	DBV	–40°C to +85°C	B44	OPA344NA/250	Tape and Reel
"	"	"	"	"	OPA344NA/3K	Tape and Reel
OPA344UA	SO-8	D	–40°C to +85°C	OPA344UA	OPA344UA	Rails
"	"	"	"	"	OPA344UA/2K5	Tape and Reel
OPA344PA	8-Pin Dip	P	–40° C to +85°C	OPA344PA	OPA344PA	Rails
OPA2344EA	MSOP-8	DGK	–40°C to +85°C	C44	OPA2344EA/250	Tape and Reel
"	"	"	"	"	OPA2344EA/2K5	Tape and Reel
OPA2344UA	SO-8	D	–40°C to +85°C	OPA2344UA	OPA2344UA	Rails
"	"	"	"	"	OPA2344UA/2K5	Tape and Reel
OPA2344PA	8-Pin DIP	P	–40°C to +85°C	OPA2344PA	OPA2344PA	Rails
OPA4344EA	TSSOP-14	PW	–40°C to +85°C	OPA4344EA	OPA4344EA/250	Rails
"	"	"	"	"	OPA4344EA/2K5	Tape and Reel
OPA4344UA	SO-14	D	–40°C to +85°C	OPA4344UA	OPA4344UA	Rails
"	"	"	"	"	OPA4344UA/2K5	Tape and Reel
OPA4344PA	14-Pin DIP	N	–40°C to +85°C	OPA4344PA	OPA4344PA	Rails
OPA345NA	SOT23-5	DBV	–40°C to +85°C	A45	OPA345NA/250	Tape and Reel
"	"	"	"	"	OPA345NA/3K	Tape and Reel
OPA345UA	SO-8	D	–40°C to +85°C	OPA345UA	OPA345UA	Rails
"	"	"	"	"	OPA345UA/2K5	Tape and Reel
OPA2345EA	MSOP-8	DGK	–40°C to +85°C	B45	OPA2345EA/250	Tape and Reel
"	"	"	"	"	OPA2345EA/2K5	Tape and Reel
OPA2345UA	SO-8	D	–40°C to +85°C	OPA2345UA	OPA2345UA	Rails
"	"	"	"	"	OPA2345UA/2K5	Tape and Reel
OPA4345EA	TSSOP-14	PW	–40°C to +85°C	OPA4345EA	OPA4345EA/250	Tape and Reel
"	"	"	"	"	OPA4345EA/2K5	Tape and Reel
OPA4345UA	SO-14	D	–40°C to +85°C	OPA4345UA	OPA4345UA	Rails
"	"	"	"	"	OPA4345UA/2K5	Tape and Reel

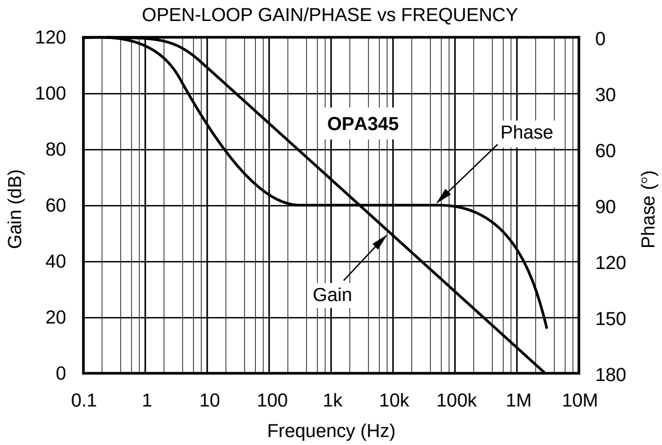
NOTES: (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

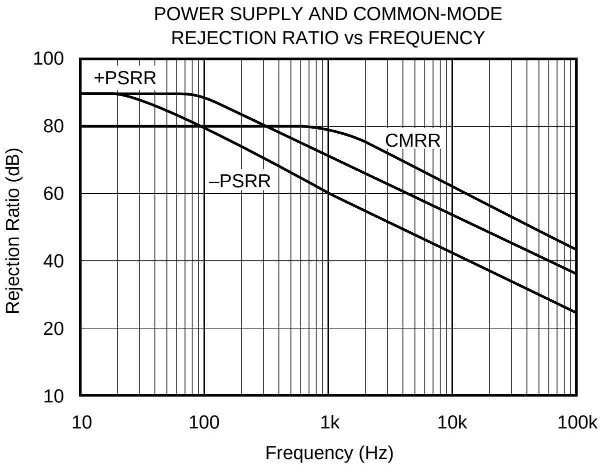
(2) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of “OPA344UA/2K5” will get a single 2500-piece Tape and Reel.

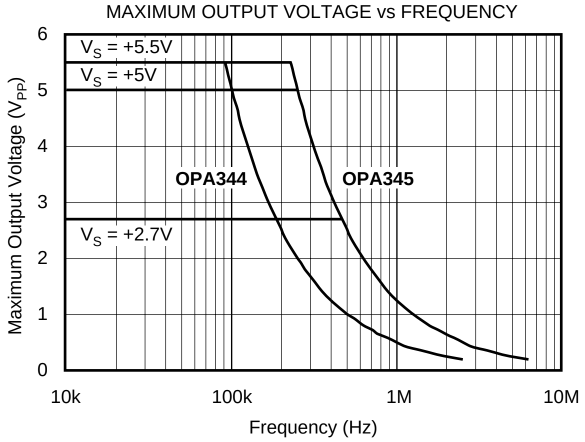
TYPICAL PERFORMANCE CURVES

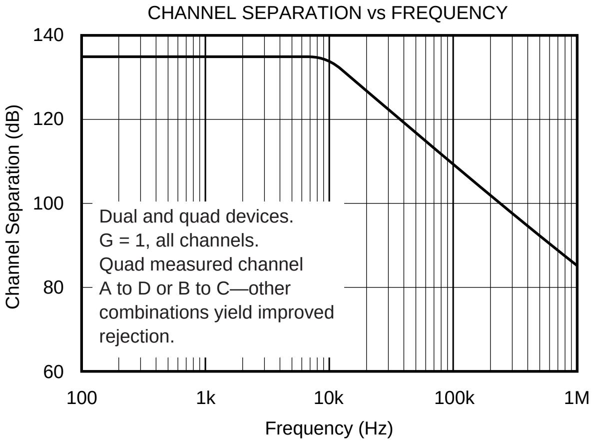
At $T_A = +25°C$, $V_S = +5V$, and $R_L = 10k\Omega$ connected to $V_S/2$, unless otherwise noted.



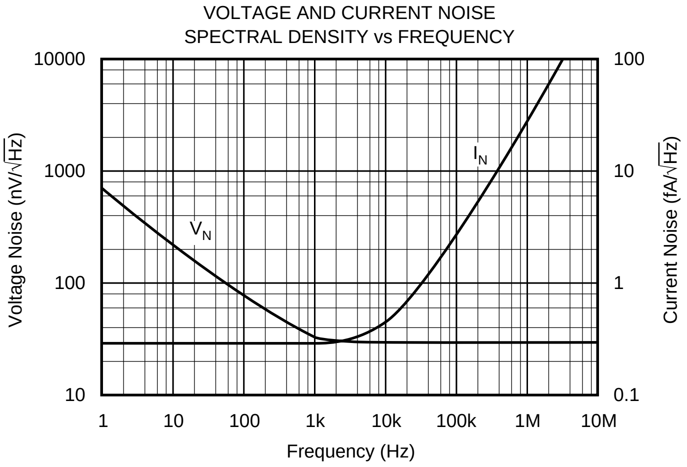








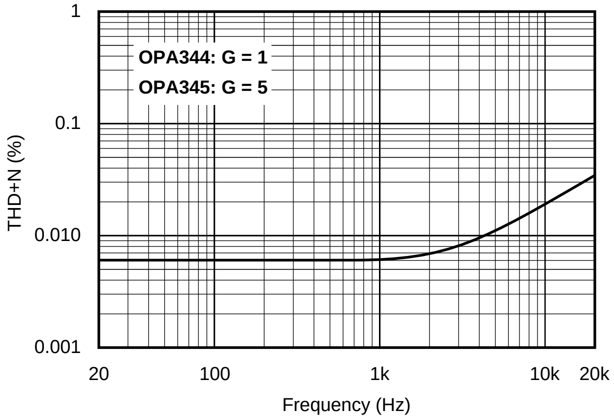
Dual and quad devices.
G = 1, all channels.
Quad measured channel
A to D or B to C—other
combinations yield improved
rejection.



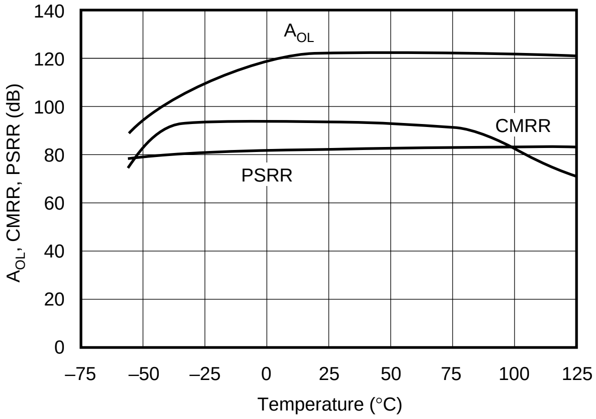
TYPICAL PERFORMANCE CURVES (Cont.)

At T_A = +25°C, V_S = +5V, and R_L = 10kΩ connected to V_S/2, unless otherwise noted.

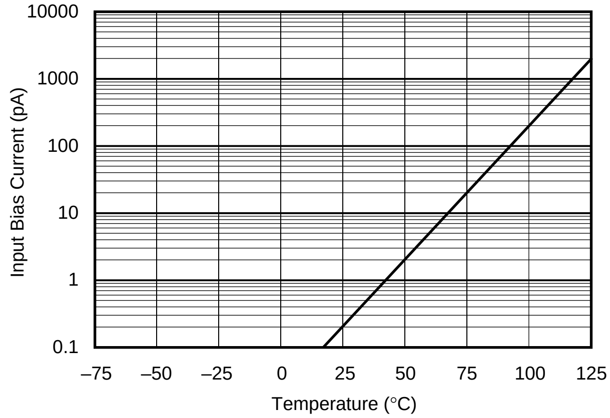
TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



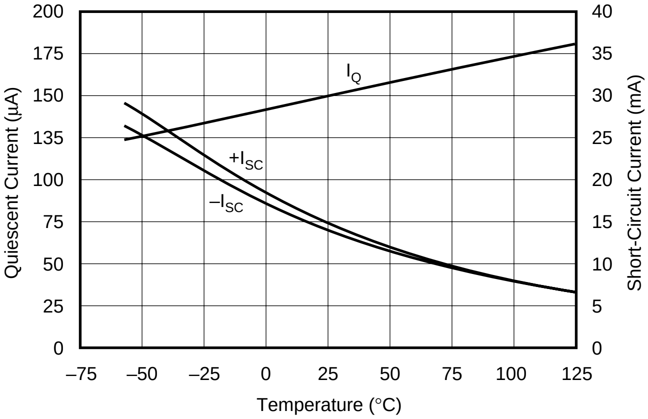
OPEN-LOOP GAIN, COMMON-MODE REJECTION RATIO, AND POWER-SUPPLY REJECTION vs TEMPERATURE



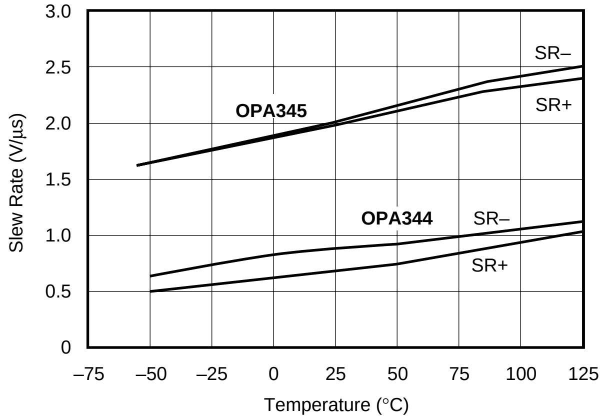
INPUT BIAS CURRENT vs TEMPERATURE



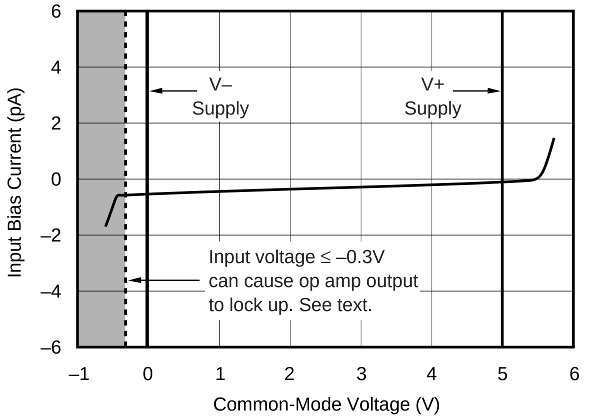
QUIESCENT CURRENT AND SHORT-CIRCUIT CURRENT vs TEMPERATURE



SLEW RATE vs TEMPERATURE

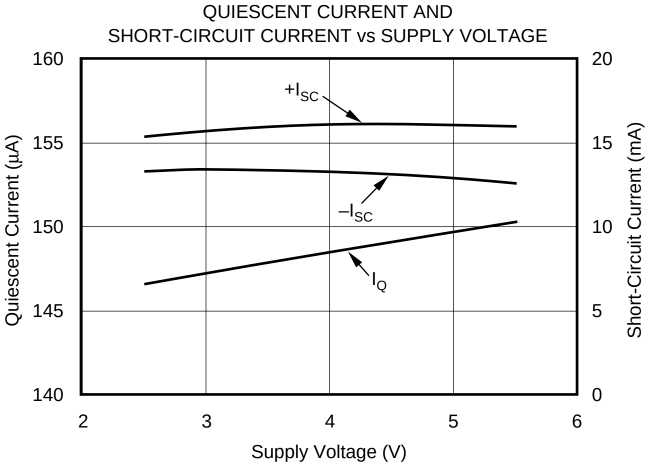


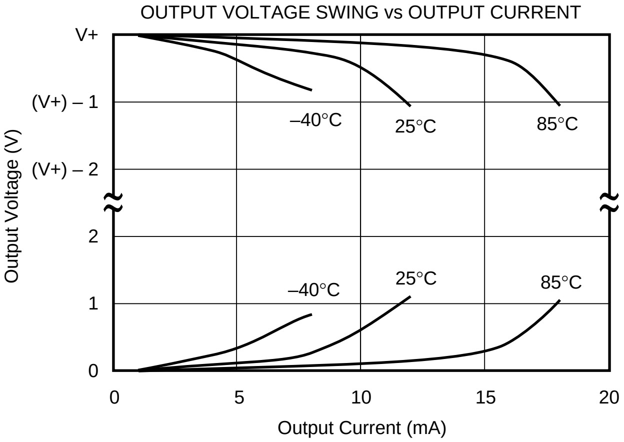
INPUT BIAS CURRENT vs COMMON-MODE VOLTAGE

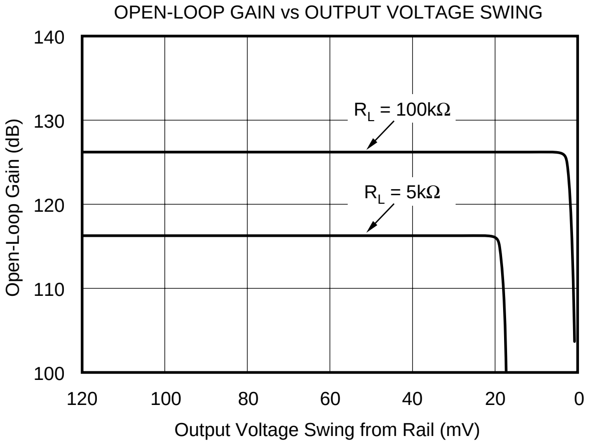


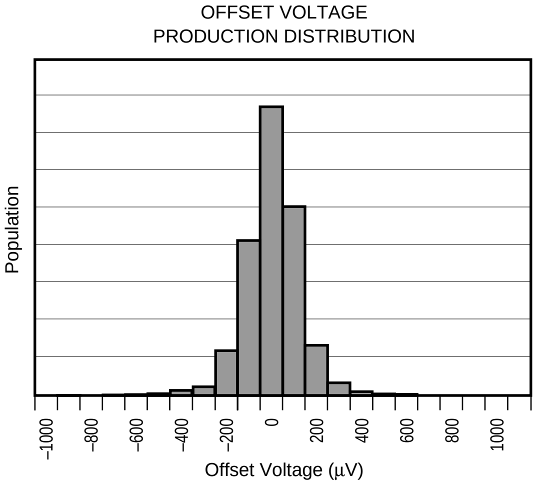
TYPICAL PERFORMANCE CURVES (Cont.)

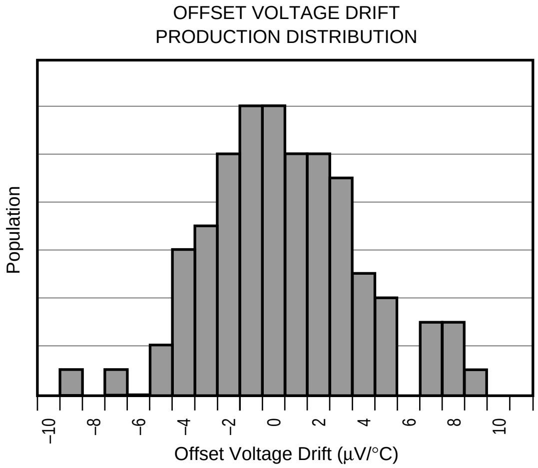
At T_A = +25°C, V_S = +5V, and R_L = 10kΩ connected to V_S/2, unless otherwise noted.

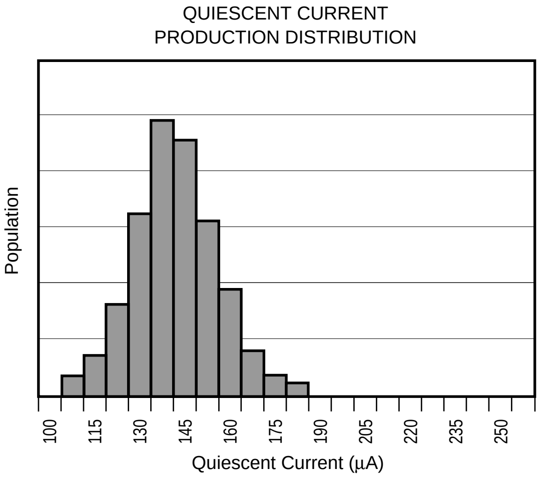








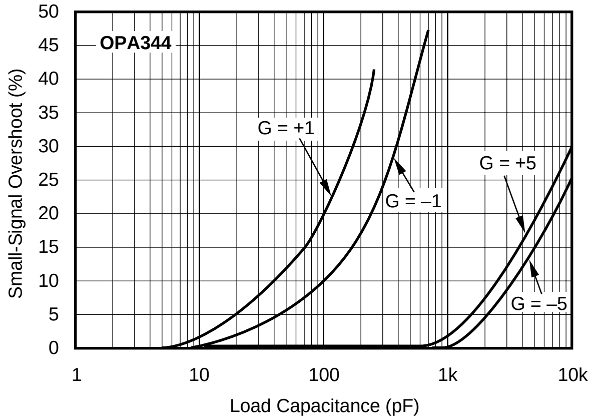




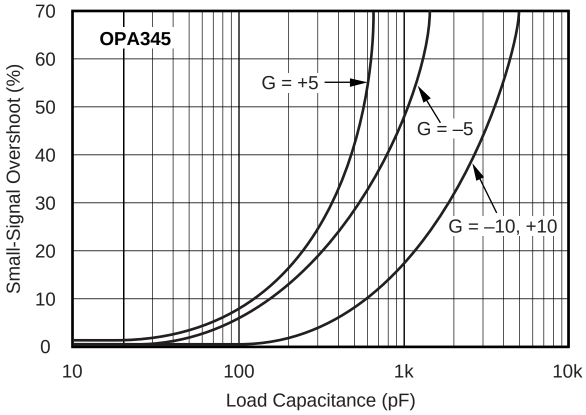
TYPICAL PERFORMANCE CURVES (Cont.)

At $T_A = +25°C$, $V_S = +5V$, and $R_L = 10k\Omega$ connected to $V_S/2$, unless otherwise noted.

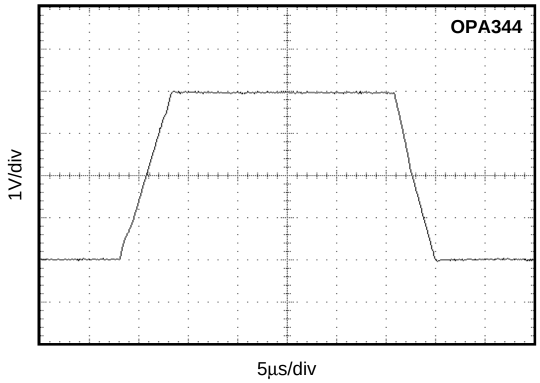
SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE



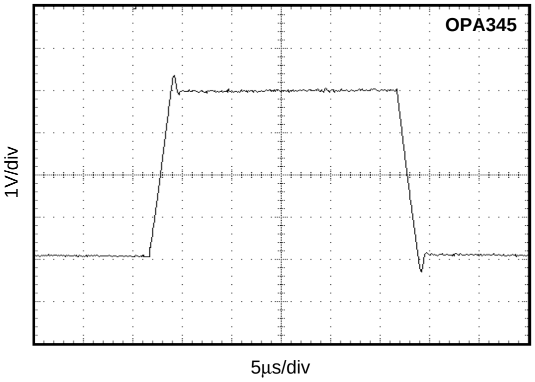
SMALL-SIGNAL OVERSHOOT vs LOAD CAPACITANCE



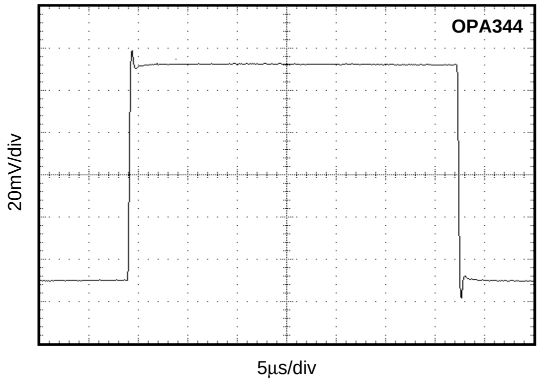
LARGE-SIGNAL STEP RESPONSE: OPA344
G = +1, $R_L = 10k\Omega$, $C_L = 100pF$



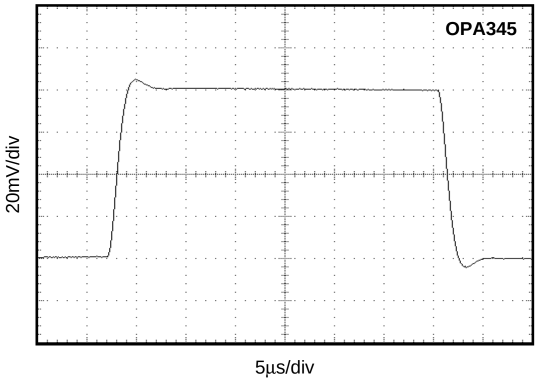
LARGE-SIGNAL STEP RESPONSE: OPA345
G = +5, $R_L = 10k\Omega$, $C_L = 100pF$



SMALL-SIGNAL STEP RESPONSE: OPA344
G = +1, $R_L = 10k\Omega$, $C_L = 100pF$



SMALL-SIGNAL STEP RESPONSE: OPA345
G = +5, $R_L = 10k\Omega$, $C_L = 100pF$



APPLICATIONS INFORMATION

OPA344 series op amps are unity gain stable and can operate on a single supply, making them highly versatile and easy to use. OPA345 series op amps are optimized for applications requiring higher speeds with gains of 5 or greater.

Rail-to-rail input and output swing significantly increases dynamic range, especially in low supply applications. Figure 1 shows the input and output waveforms for the OPA344 in unity-gain configuration. Operation is from V_S = +5V with a 10kΩ load connected to $V_S/2$. The input is a 5Vp-p sinusoid. Output voltage is approximately 4.997Vp-p.

Power supply pins should be bypassed with 0.01µF ceramic capacitors.

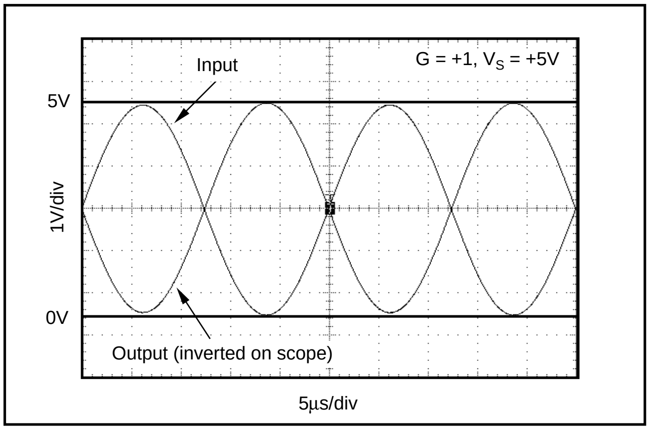


FIGURE 1. Rail-to-Rail Input and Output.

OPERATING VOLTAGE

OPA344 and OPA345 series op amps are fully specified and ensured from +2.7V to +5.5V. In addition, many specifications apply from –40ºC to +85ºC. Parameters that vary significantly with operating voltages or temperature are shown in the Typical Performance Curves.

RAIL-TO-RAIL INPUT

The input common-mode voltage range of the OPA344 and OPA345 series extends 300mV beyond the supply rails. This is achieved with a complementary input stage—an N-channel input differential pair in parallel with a P-channel differential pair (see Figure 2). The N-channel pair is active for input voltages close to the positive rail, typically (V+) – 1.3V to 300mV above the positive supply, while the P-channel pair is on for inputs from 300mV below the negative supply to approximately (V+) –1.3V. There is a small transition region, typically (V+) – 1.5V to (V+) – 1.1V, in which both pairs are on. This 400mV transition region can vary 300mV with process variation. Thus, the transition region (both stages on) can range from (V+) – 1.8V to (V+) – 1.4V on the low end, up to (V+) – 1.2V to (V+) – 0.8V on the high end. Within the 400mV transition region PSRR, CMRR, offset voltage, offset drift, and THD may be degraded compared to operation outside this region. For more information on designing with rail-to-rail input op amps, see Figure 3 "Design Optimization with Rail-to-Rail Input Op Amps."

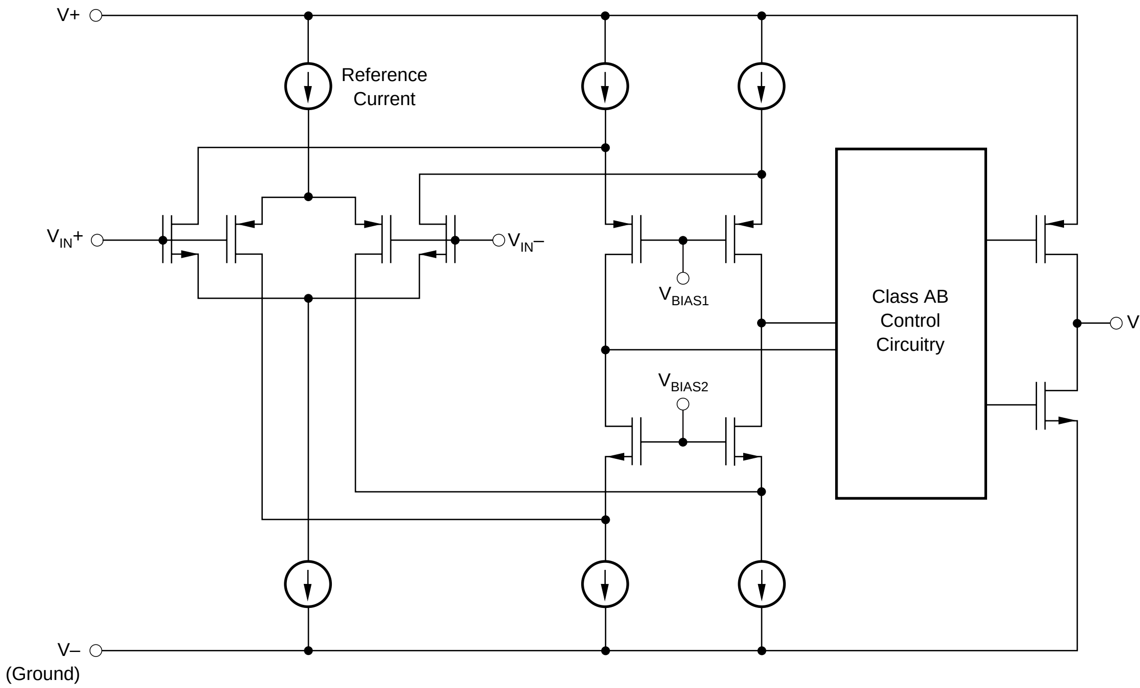


FIGURE 2. Simplified Schematic.

DESIGN OPTIMIZATION WITH RAIL-TO-RAIL INPUT OP AMPS

Rail-to-rail op amps can be used in virtually any op amp configuration. To achieve optimum performance, however, applications using these special double-input-stage op amps may benefit from consideration of their special behavior.

In many applications, operation remains within the common-mode range of only one differential input pair. However some applications exercise the amplifier through the transition region of both differential input stages. Although the two input stages are laser trimmed for excellent matching, a small discontinuity may occur in this transition. Careful selection of the circuit configuration, signal levels and biasing can often avoid this transition region.

With a unity-gain buffer, for example, signals will traverse this transition at approximately 1.3V below V+ supply and may exhibit a small discontinuity at this point.

The common-mode voltage of the non-inverting amplifier is equal to the input voltage. If the input signal always remains less than the transition voltage, no discontinuity will be created. The closed-loop gain of this configuration can still produce a rail-to-rail output.

Inverting amplifiers have a constant common-mode voltage equal to V_B. If this bias voltage is constant, no discontinuity will be created. The bias voltage can generally be chosen to avoid the transition region.

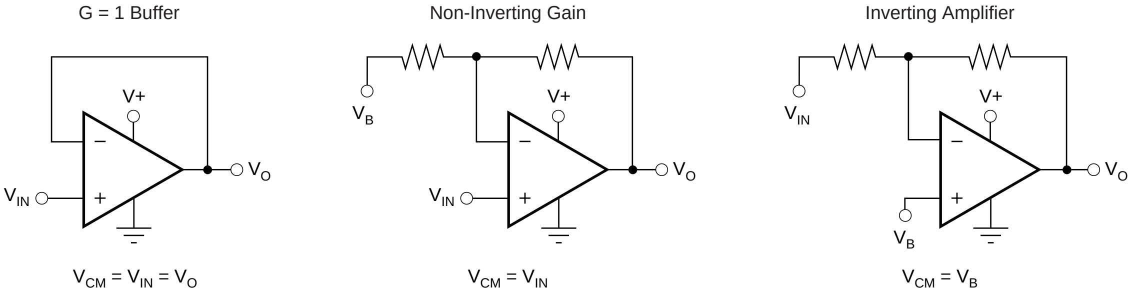


FIGURE 3. Design Optimization with Rail-to-Rail Input Op Amps.

COMMON-MODE REJECTION

The CMRR for the OPA344 and OPA345 is specified in several ways so the best match for a given application may be used. First, the CMRR of the device in the common-mode range below the transition region (V_{CM} < (V+) – 1.8V) is given. This specification is the best indicator of the capability of the device when the application requires use of one of the differential input pairs. Second, the CMRR at V_S = 5.5V over the entire common-mode range is specified. Third, the CMRR at V_S = 2.7V over the entire common-mode range is provided. These last two values include the variations seen through the transition region.

INPUT VOLTAGE BEYOND THE RAILS

If the input voltage can go more than 0.3V below the negative power supply rail (single-supply ground), special precautions are required. If the input voltage goes sufficiently negative, the op amp output may lock up in an inoperative state. A Schottky diode clamp circuit will prevent this—see Figure 4. The series resistor prevents excessive current (greater than 10mA) in the Schottky diode and in the internal ESD protection diode, if the input voltage can exceed the positive supply voltage. If the signal source is limited to less than 10mA, the input resistor is not required.

RAIL-TO-RAIL OUTPUT

A class AB output stage with common-source transistors is used to achieve rail-to-rail output. This output stage is capable of driving 600Ω loads connected to any potential between V+ and ground. For light resistive loads (> 50kΩ), the output voltage can typically swing to within 1mV from supply rail. With moderate resistive loads (2kΩ to 50kΩ), the output can swing to within a few tens of millivolts from the supply rails while maintaining high open-loop gain. See the typical performance curve "Output Voltage Swing vs Output Current."

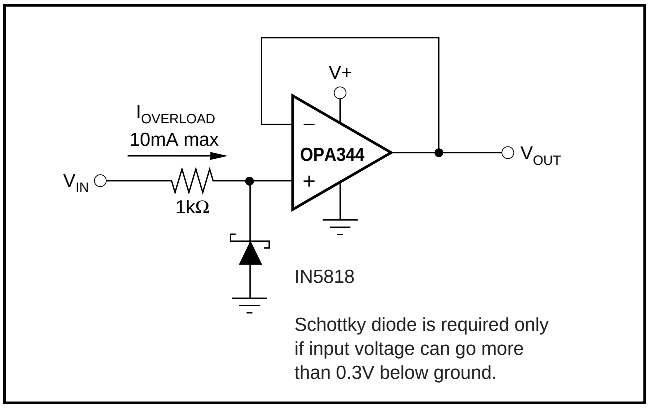


FIGURE 4. Input Current Protection for Voltages Exceeding the Supply Voltage.

CAPACITIVE LOAD AND STABILITY

The OPA344 in a unity-gain configuration and the OPA345 in gains greater than 5 can directly drive up to 250pF pure capacitive load. Increasing the gain enhances the amplifier's ability to drive greater capacitive loads. See the typical performance curve “Small-Signal Overshoot vs Capacitive Load.” In unity-gain configurations, capacitive load drive can be improved by inserting a small (10Ω to 20Ω) resistor, R_S, in series with the output, as shown in Figure 5. This significantly reduces ringing while maintaining dc performance for purely capacitive loads. However, if there is a resistive load in parallel with the capacitive load, a voltage divider is created, introducing a dc error at the output and slightly reducing the output swing. The error introduced is proportional to the ratio R_S/R_L, and is generally negligible.

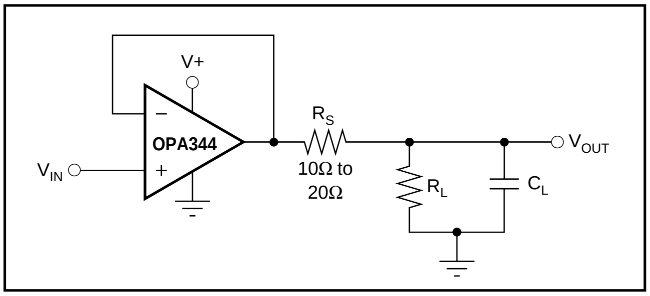


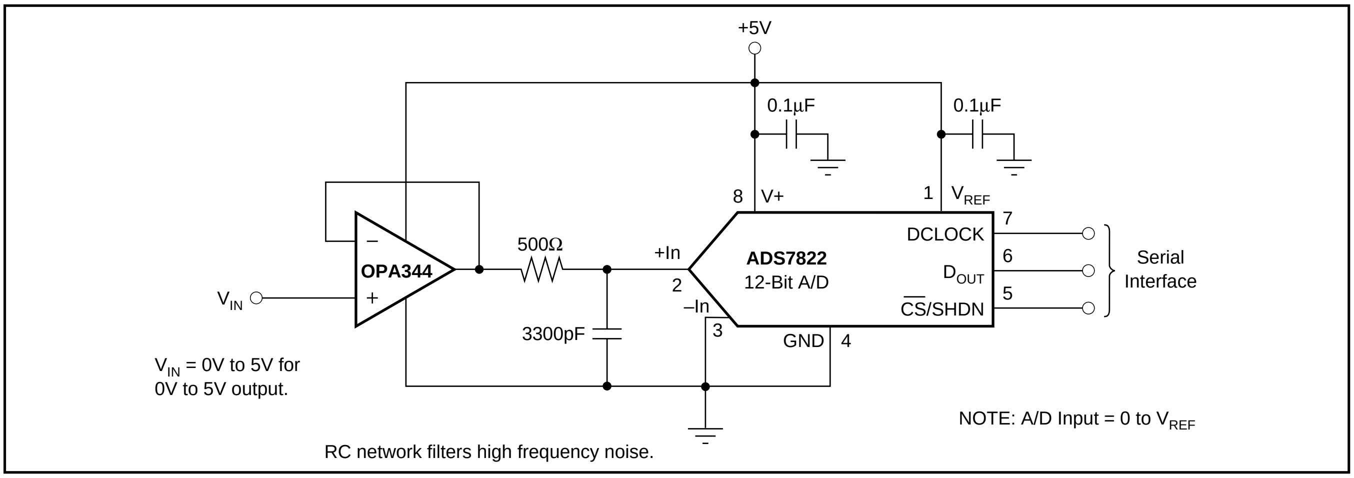
FIGURE 5. Series Resistor in Unity-Gain Configuration Improves Capacitive Load Drive.

DRIVING A/D CONVERTERS

The OPA344 and OPA345 series op amps are optimized for driving medium-speed sampling A/D converters. The OPA344 and OPA345 op amps buffer the A/D’s input capacitance and resulting charge injection while providing signal gain.

Figures 6 shows the OPA344 in a basic noninverting configuration driving the ADS7822. The ADS7822 is a 12-bit, micro-power sampling converter in the MSOP-8 package. When used with the low-power, miniature packages of the OPA344, the combination is ideal for space-limited, low-power applications. In this configuration, an RC network at the A/D’s input can be used to filter charge injection.

Figure 7 shows the OPA2344 driving an ADS7822 in a speech bandpass filtered data acquisition system. This small, low-cost solution provides the necessary amplification and signal conditioning to interface directly with an electret microphone. This circuit will operate with V_S = +2.7V to +5V with less than 500µA quiescent current.

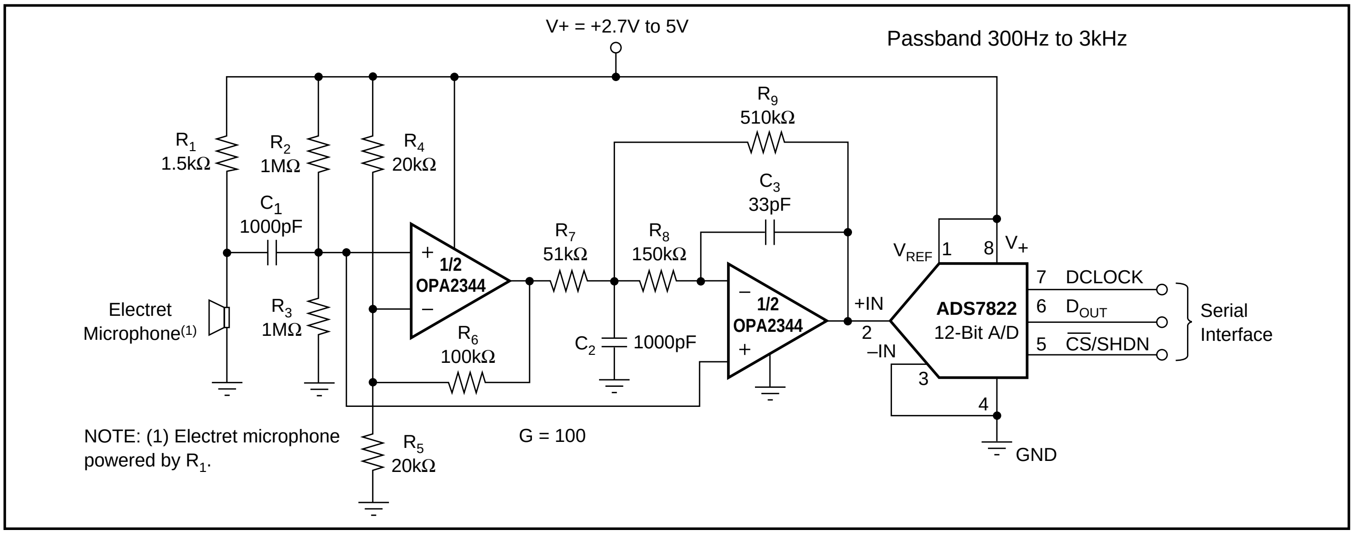


V_{IN} = 0V to 5V for
0V to 5V output.

NOTE: A/D Input = 0 to V_{REF}

RC network filters high frequency noise.

FIGURE 6. OPA344 in Noninverting Configuration Driving ADS7822.



Passband 300Hz to 3kHz

G = 100

NOTE: (1) Electret microphone
powered by R_1.

FIGURE 7. Speech Bandpass Filtered Data Acquisition System.

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
OPA2344EA/250	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	C44	Samples
OPA2344EA/250G4	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	C44	Samples
OPA2344EA/2K5	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	C44	Samples
OPA2344EA/2K5G4	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	C44	Samples
OPA2344PA	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA2344PA	Samples
OPA2344PAG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA2344PA	Samples
OPA2344UA	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2344UA	Samples
OPA2344UA/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2344UA	Samples
OPA2344UA/2K5G4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2344UA	Samples
OPA2344UAG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2344UA	Samples
OPA2345EA/250	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	B45	Samples
OPA2345UA	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2345UA	Samples
OPA2345UA/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2345UA	Samples
OPA2345UAG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 2345UA	Samples
OPA344NA/250	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B44	Samples
OPA344NA/250G4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B44	Samples
OPA344NA/3K	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B44	Samples

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
OPA344NA/3KG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	B44	Samples
OPA344PA	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA344PA	Samples
OPA344PAG4	ACTIVE	PDIP	P	8	50	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA344PA	Samples
OPA344UA	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 344UA	Samples
OPA344UA/2K5	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 344UA	Samples
OPA344UA/2K5G4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 344UA	Samples
OPA344UAG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 344UA	Samples
OPA345NA/250	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	A45	Samples
OPA345NA/250G4	ACTIVE	SOT-23	DBV	5		TBD	Call TI	Call TI	-40 to 85		Samples
OPA345NA/3K	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	A45	Samples
OPA345UA	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 345UA	Samples
OPA345UAG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 345UA	Samples
OPA4344EA/250	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OPA 4344EA	Samples
OPA4344EA/250G4	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OPA 4344EA	Samples
OPA4344EA/2K5	ACTIVE	TSSOP	PW	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	OPA 4344EA	Samples
OPA4344PA	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA4344PA	Samples
OPA4344PAG4	ACTIVE	PDIP	N	14	25	Green (RoHS & no Sb/Br)	CU NIPDAU	N / A for Pkg Type	-40 to 85	OPA4344PA	Samples
OPA4344UA	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4344UA	Samples

PACKAGE OPTION ADDENDUM

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
OPA4344UA/2K5	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4344UA	Samples
OPA4344UA/2K5G4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4344UA	Samples
OPA4344UAG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4344UA	Samples
OPA4345EA/250	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA 4345EA	Samples
OPA4345UA	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4345UA	Samples
OPA4345UAG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	OPA4345UA	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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

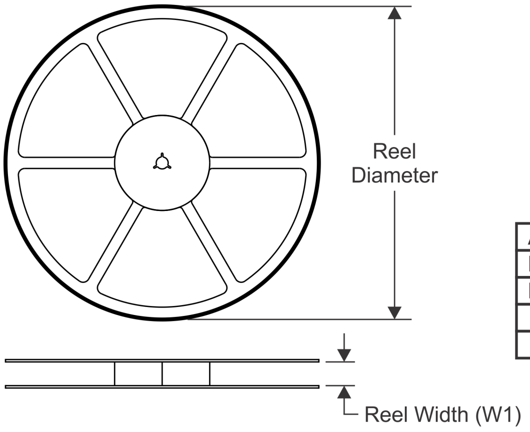
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

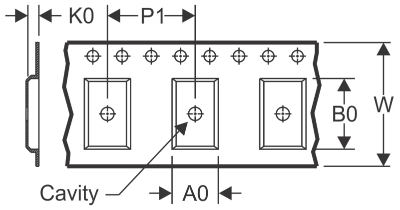
[6] Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

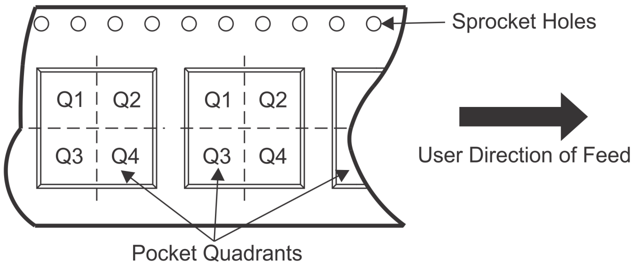


TAPE DIMENSIONS



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

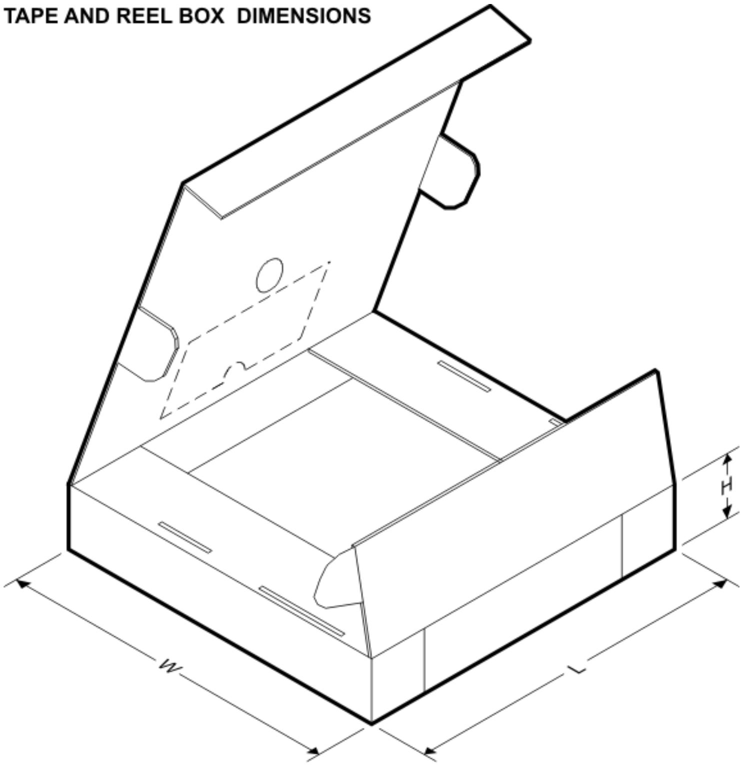
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
OPA2344EA/250	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2344EA/2K5	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2345EA/250	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
OPA2345UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA344NA/250	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
OPA344NA/3K	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
OPA344UA/2K5	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
OPA345NA/250	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
OPA345NA/3K	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
OPA4344EA/250	TSSOP	PW	14	250	180.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
OPA4344EA/2K5	TSSOP	PW	14	2500	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
OPA4344UA/2K5	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
OPA4345EA/250	TSSOP	PW	14	250	180.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

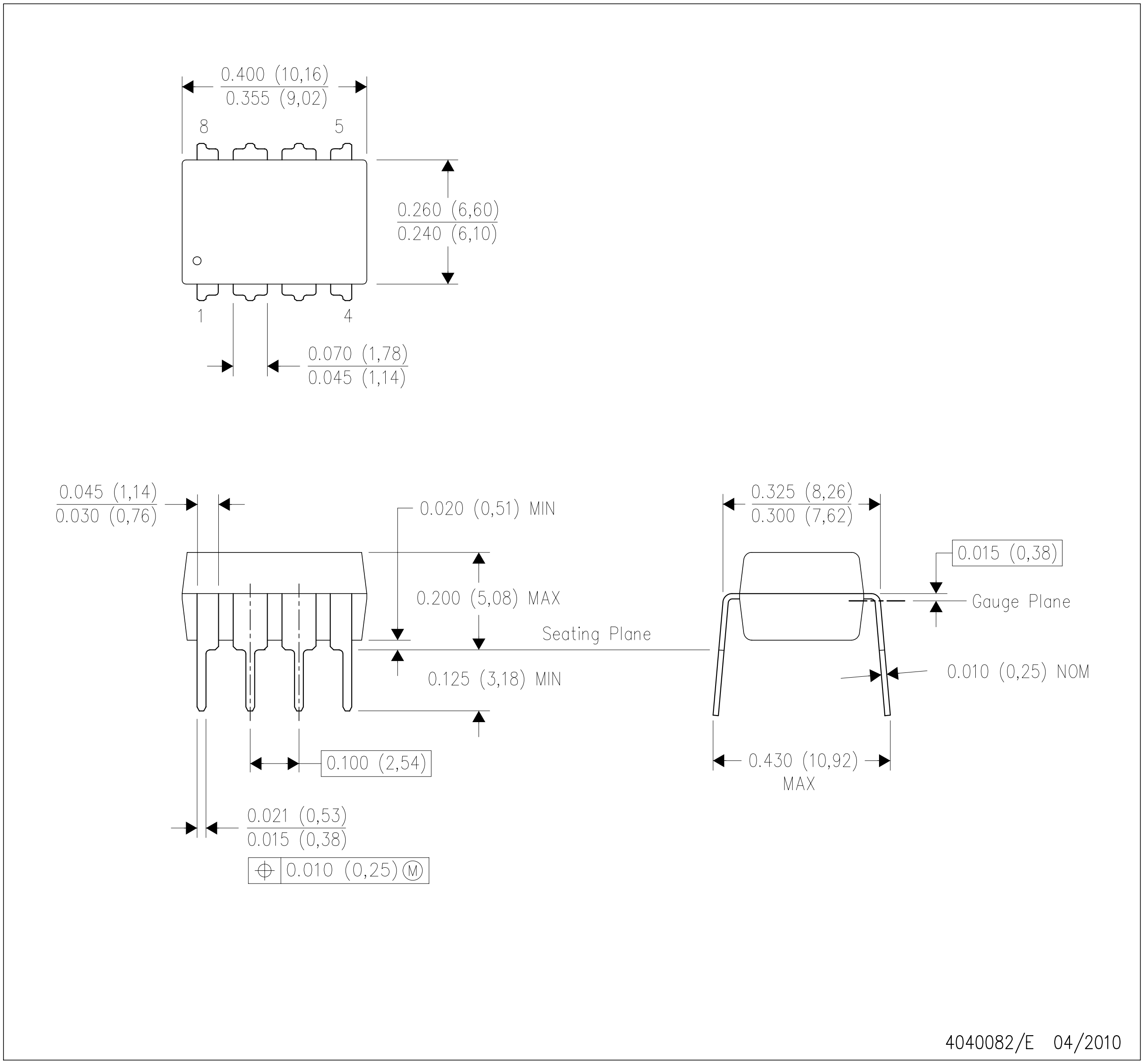
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

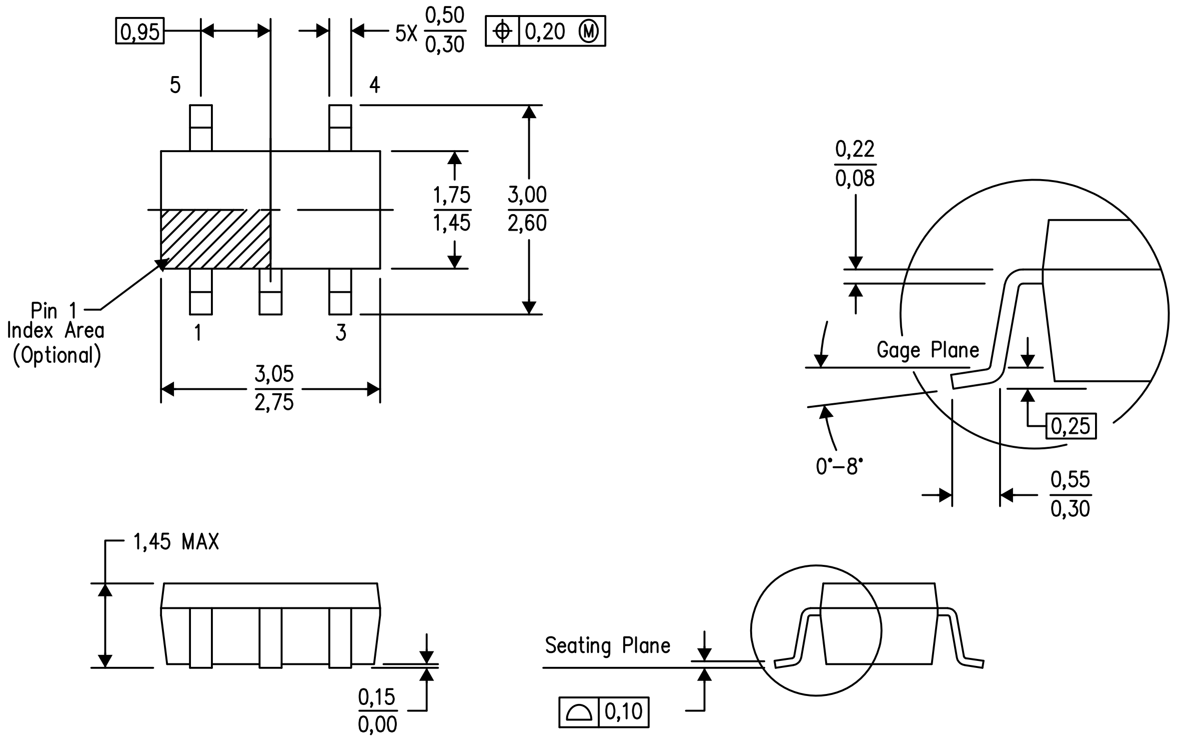
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA2344EA/250	VSSOP	DGK	8	250	210.0	185.0	35.0
OPA2344EA/2K5	VSSOP	DGK	8	2500	367.0	367.0	35.0
OPA2345EA/250	VSSOP	DGK	8	250	210.0	185.0	35.0
OPA2345UA/2K5	SOIC	D	8	2500	367.0	367.0	35.0
OPA344NA/250	SOT-23	DBV	5	250	180.0	180.0	18.0
OPA344NA/3K	SOT-23	DBV	5	3000	180.0	180.0	18.0
OPA344UA/2K5	SOIC	D	8	2500	367.0	367.0	35.0
OPA345NA/250	SOT-23	DBV	5	250	180.0	180.0	18.0
OPA345NA/3K	SOT-23	DBV	5	3000	180.0	180.0	18.0
OPA4344EA/250	TSSOP	PW	14	250	210.0	185.0	35.0
OPA4344EA/2K5	TSSOP	PW	14	2500	367.0	367.0	35.0
OPA4344UA/2K5	SOIC	D	14	2500	367.0	367.0	38.0
OPA4345EA/250	TSSOP	PW	14	250	210.0	185.0	35.0

P (R–PDIP–T8) PLASTIC DUAL–IN–LINE PACKAGE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001 variation BA.

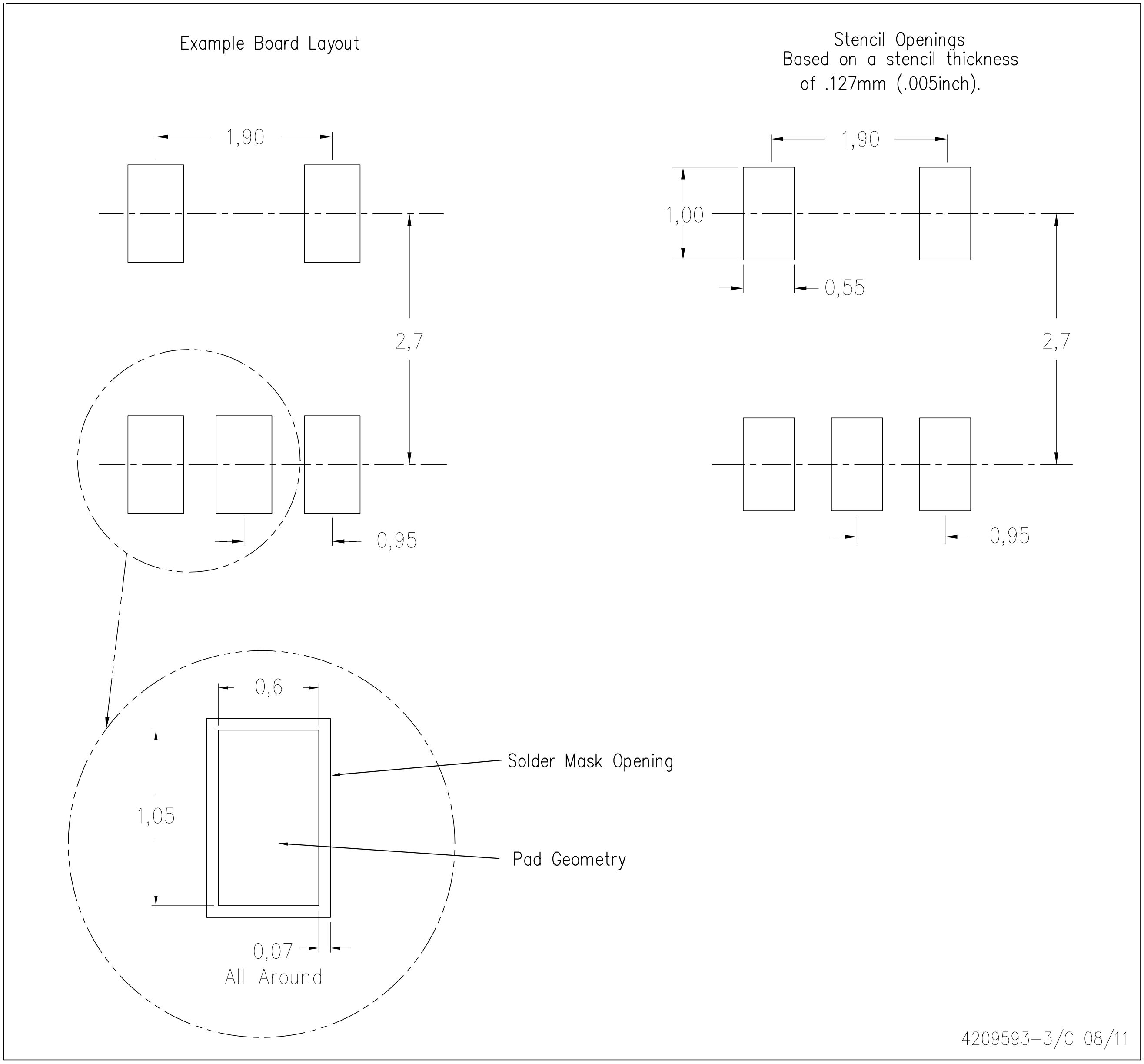
DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4073253–4/L 08/2013

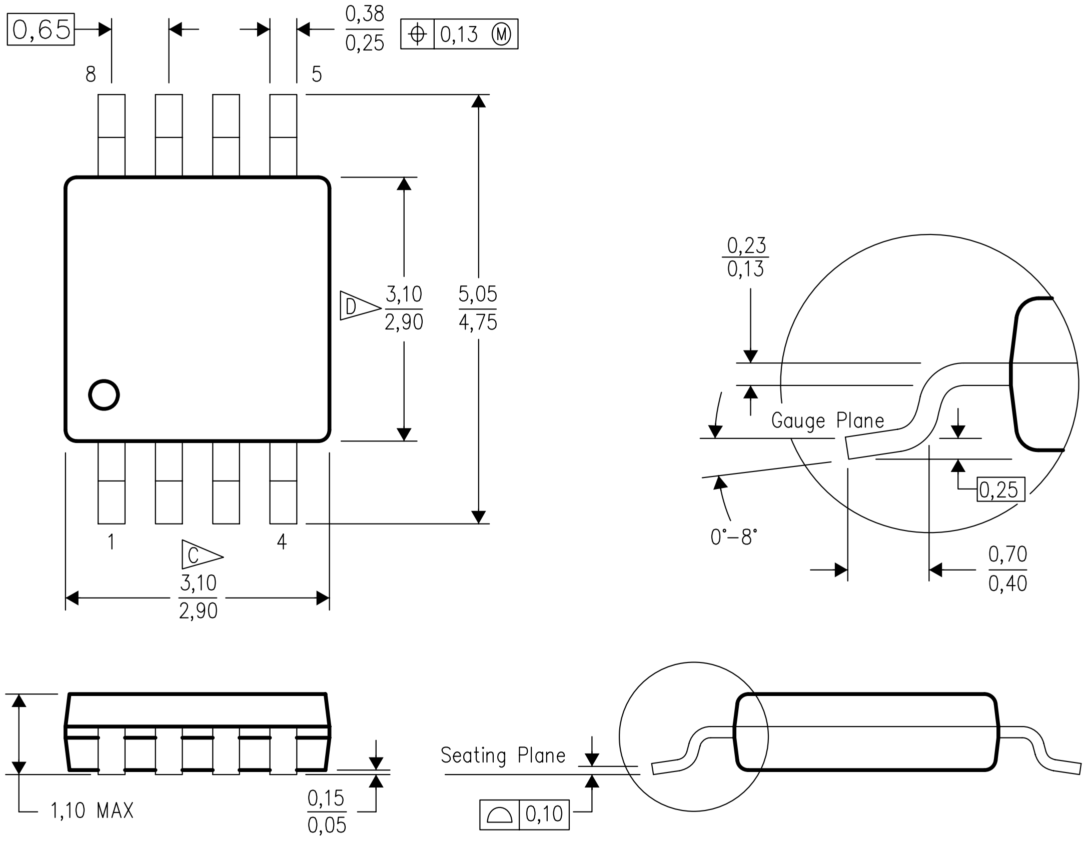
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
- D. Falls within JEDEC MO–178 Variation AA.

DBV (R–PDSO–G5) PLASTIC SMALL OUTLINE



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
- D. Publication IPC–7351 is recommended for alternate designs.
- E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

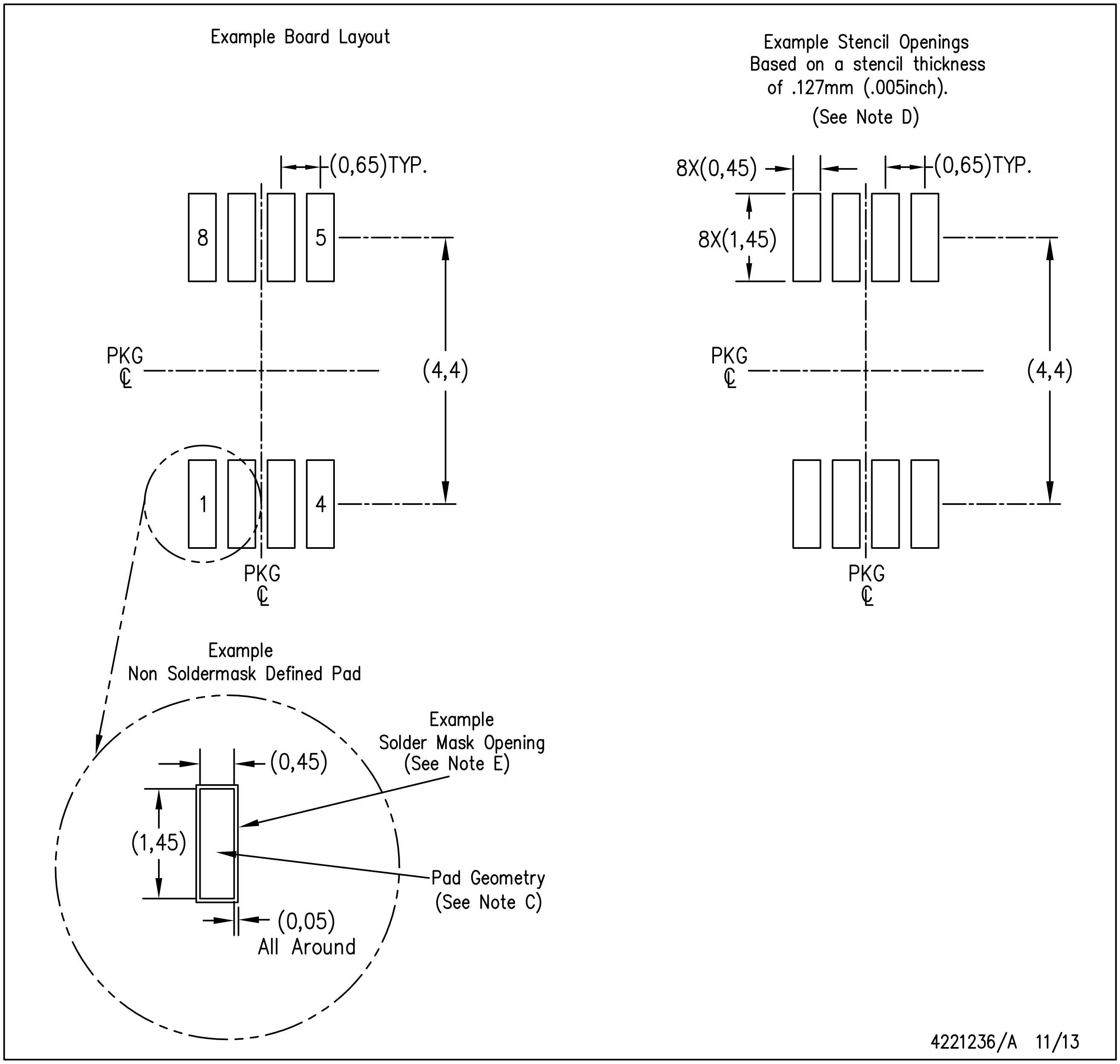
DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

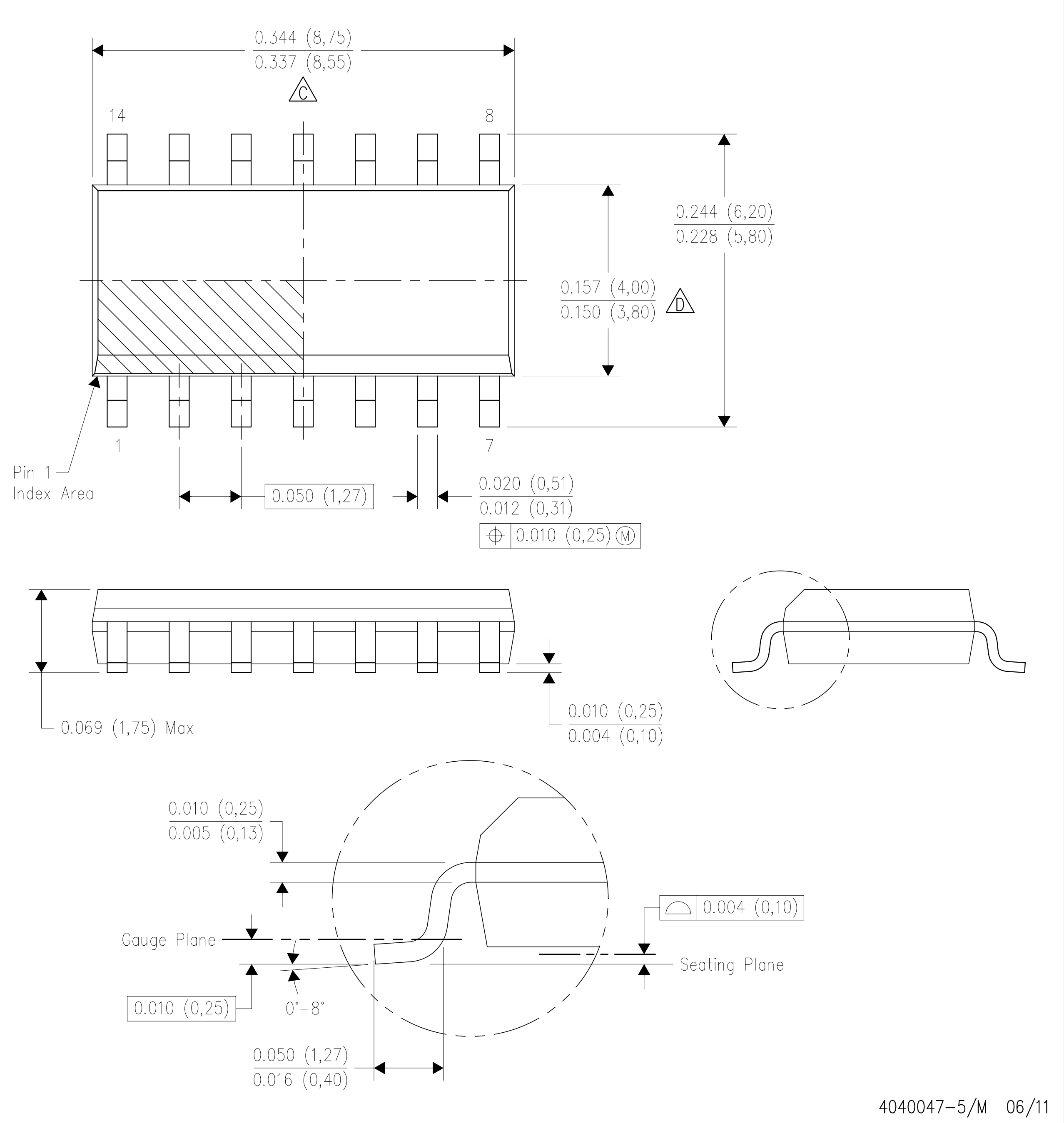
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D Body width does not include interlead flash. Interlead 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



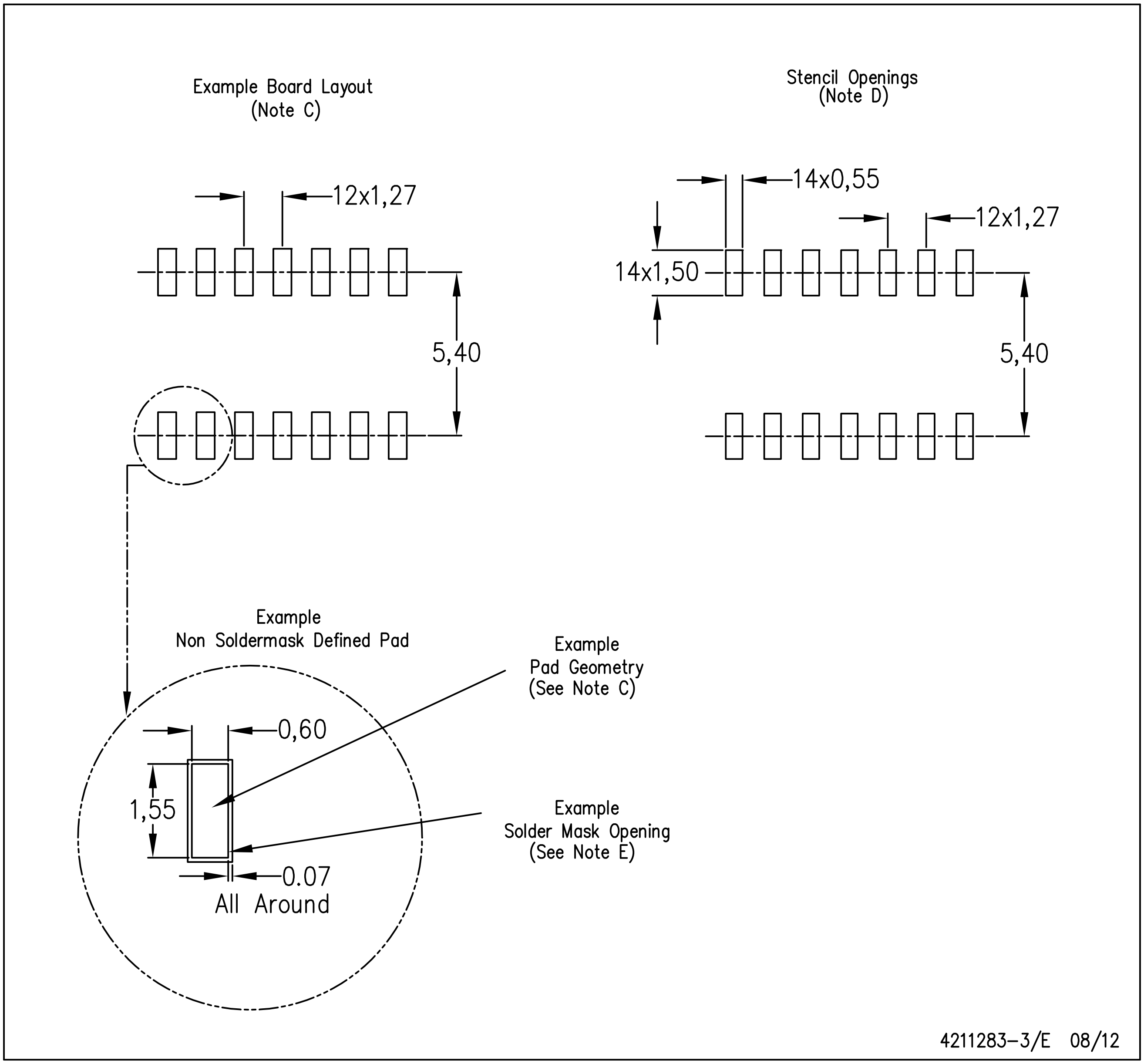
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should 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



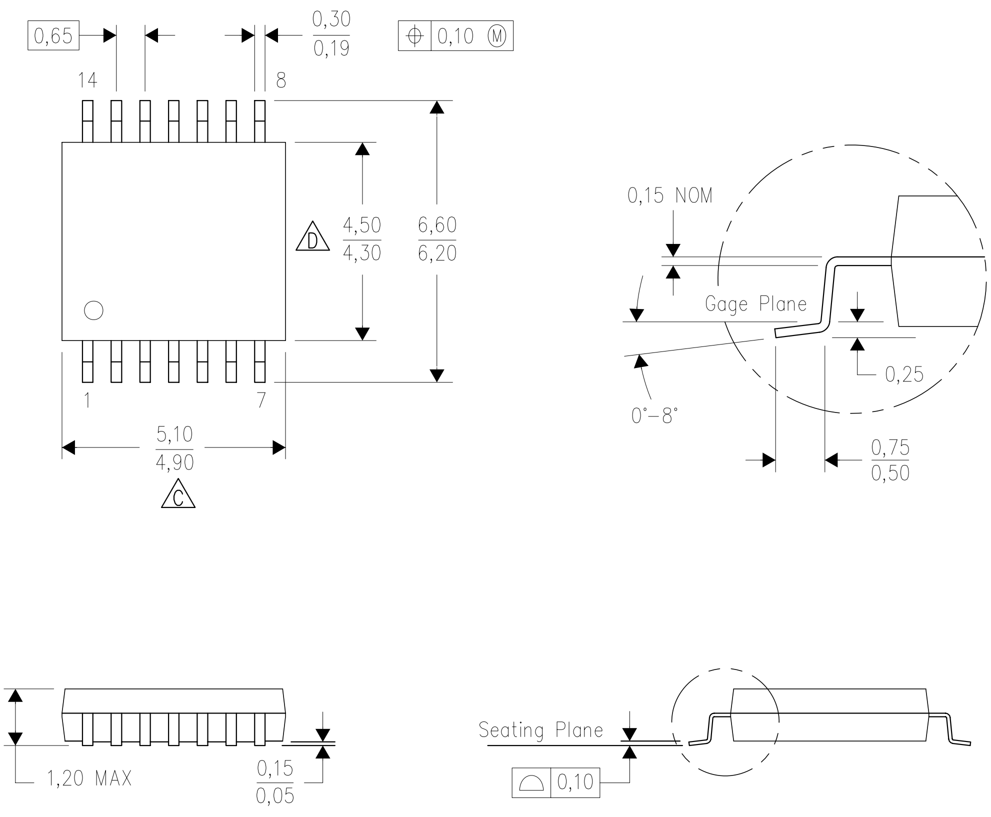
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
- D Body width does not include 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.

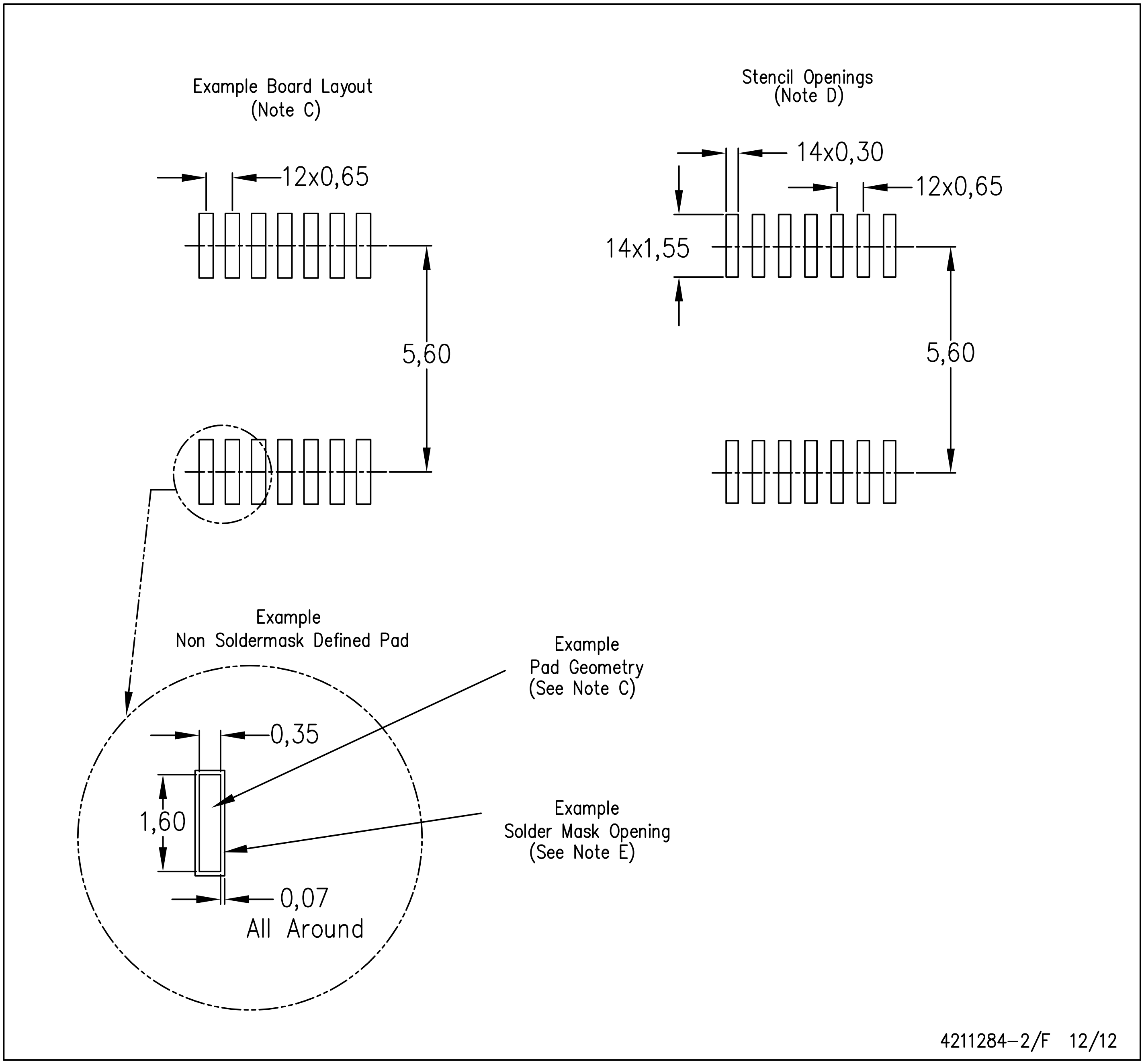
PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



4040064–3/G 02/11

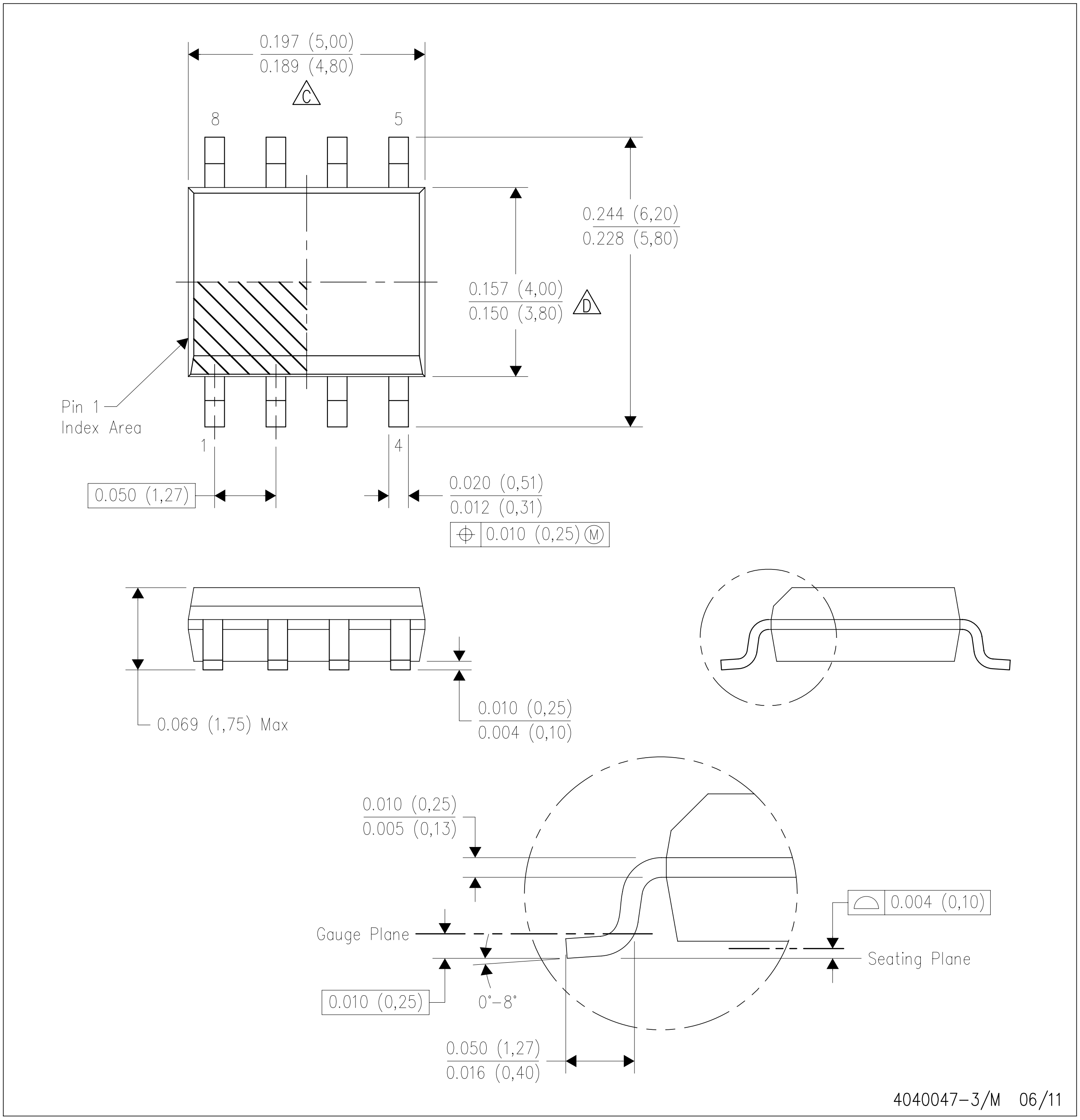
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D.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

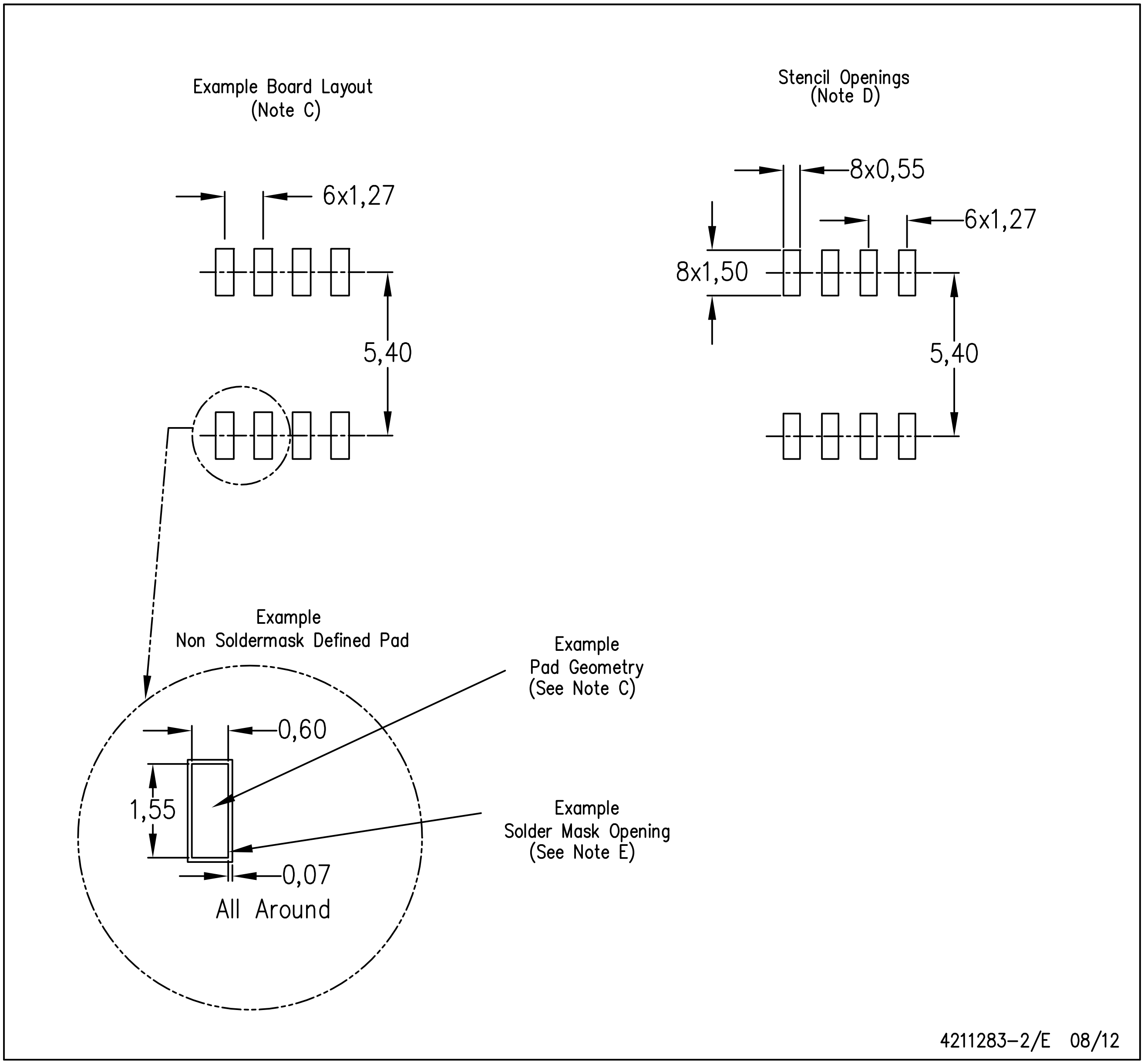
D (R-PDSO-G8) PLASTIC SMALL OUTLINE



4040047–3/M 06/11

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 AA.

D (R-PDSO-G8) 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.

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