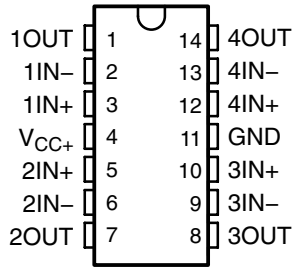
LMV321-Q1 SINGLE, LMV358-Q1 DUAL, LMV324-Q1 QUAD LOW-VOLTAGE RAIL-TO-RAIL OUTPUT OPERATIONAL AMPLIFIERS

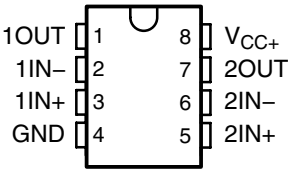
SLOS415E – JUNE 2003 – REVISED APRIL 2008

- **Qualified for Automotive Applications**
- **2.7-V and 5-V Performance**
- **No Crossover Distortion**
- **Low Supply Current:**
  - **LMV321 . . . 130 μA Typ**
  - **LMV358 . . . 210 μA Typ**
  - **LMV324 . . . 410 μA Typ**
- **Rail-to-Rail Output Swing**

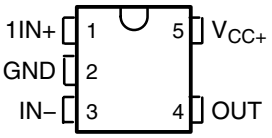
LMV324 . . . D OR PW PACKAGE
(TOP VIEW)



LMV358 . . . D OR PW PACKAGE
(TOP VIEW)



LMV321 . . . DBV PACKAGE
(TOP VIEW)



description/ordering information

The LMV321, LMV358, and LMV324 are single, dual, and quad low-voltage (2.7 V to 5.5 V) operational amplifiers with rail-to-rail output swing.

The LMV321, LMV358, and LMV324 are the most cost-effective solution for applications where low-voltage operation, space saving, and low price are required. These amplifiers were designed specifically for low-voltage (2.7 V to 5 V) operation, with performance specifications meeting or exceeding the LM358 and LM324 devices that operate from 5 V to 30 V. Additional features of the LMV3xx devices are a common-mode input voltage range that includes ground, 1-MHz unity-gain bandwidth, and 1-V/μs slew rate.

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.

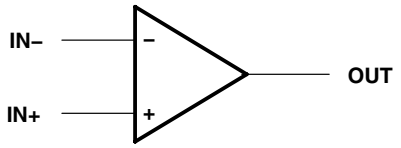
ORDERING INFORMATION†

T_A		PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	Single	SOT23-5 (DBV)	Reel of 3000	LMV321IDBVRQ1	RC1B
–40°C to 85°C	Dual	SOIC (D)	Tube of 75	LMV358IDQ1	358IQ1
			Reel of 2500	LMV358IDRQ1	
		TSSOP (PW)	Reel of 2000	LMV358IPWRQ1	358IQ1
–40°C to 85°C	Quad	SOIC (D)	Tube of 50	LMV324IDQ1	LMV324IQ1
			Reel of 2500	LMV324IDRQ1	
		TSSOP (PW)	Reel of 2000	LMV324IPWRQ1	V324IQ1
–40°C to 125°C	Single	SOT23-5 (DBV)	Reel of 3000	LMV321QDBVRQ1	RCCB
–40°C to 125°C	Dual	SOIC (D)	Tube of 75	LMV358QDQ1	V358Q1
			Reel of 2500	LMV358QDRQ1	
		TSSOP (PW)	Reel of 2000	LMV358QPWRQ1	V358Q1
–40°C to 125°C	Quad	SOIC (D)	Tube of 50	LMV324QDQ1	LMV324Q1
			Reel of 2500	LMV324QDRQ1	
		TSSOP (PW)	Reel of 2000	LMV324QPWRQ1	MV324Q1

† 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 http://www.ti.com.

‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.

symbol (each amplifier)



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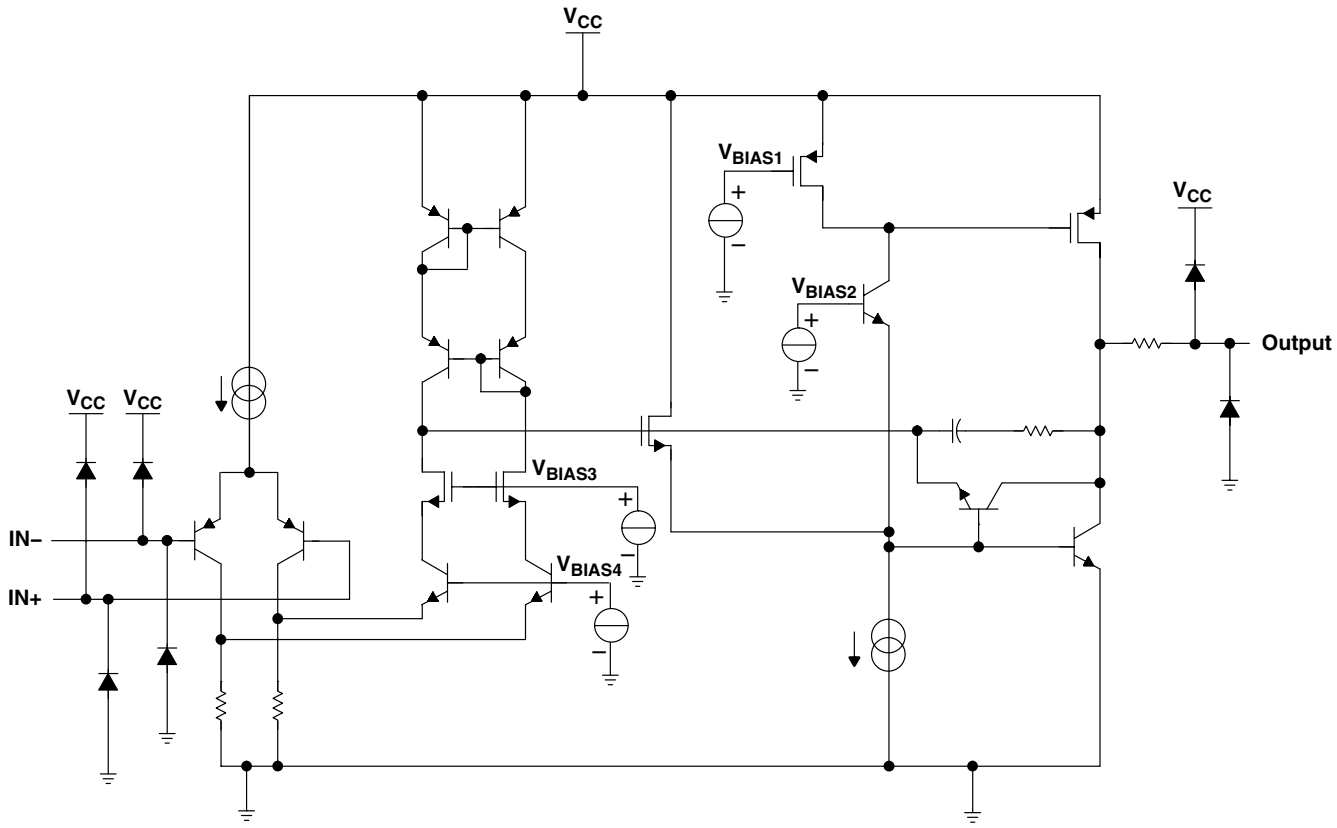
LMV324 simplified schematic



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{CC} (see Note 1)		5.5 V
Differential input voltage, V_{ID} (see Note 2)		±5.5 V
Input voltage, V_I (either input)		0 to 5.5 V
Duration of output short circuit (one amplifier) to ground at (or below) $T_A = 25°C$, $V_{CC} \le 5.5$ V (see Note 3)		Unlimited
Package thermal impedance, θ_{JA} (see Notes 4 and 5):	D (8-pin) package	97°C/W
	D (14-pin) package	86°C/W
	DBV (5-pin) package	206°C/W
	PW (8-pin) package	149°C/W
	PW (14-pin) package	113°C/W
Operating virtual junction temperature, T_J		150°C
Storage temperature range, T_{stg}		–65 to 150°C

† Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTES:
1. All voltage values (except differential voltages and V_{CC} specified for the measurement of I_{OS}) are with respect to the network GND.
2. Differential voltages are at IN+ with respect to IN–.
3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.
4. Maximum power dissipation is a function of $T_J(max)$, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Selecting the maximum of 150°C can affect reliability.
5. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions (see Note 6)

			MIN	MAX	UNIT
V_{CC}	Supply voltage (single-supply operation)		2.7	5.5	V
V_{IH}	Amplifier turn-on voltage level	V_{CC} = 2.7 V	1.7		V
		V_{CC} = 5 V	3.5		
V_{IL}	Amplifier turn-off voltage level	V_{CC} = 2.7 V		0.7	V
		V_{CC} = 5 V		1.5	
T_A	Operating free-air temperature	I suffix	–40	85	°C
		Q suffix	–40	125	

NOTE 6: All unused control inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

electrical characteristics at T_A = 25°C, V_{CC+} = 2.7 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage				1.7	7	mV
$\alpha_{V_{IO}}$	Average temperature coefficient of input offset voltage				5		µV/°C
I_{IB}	Input bias current				11	250	nA
I_{IO}	Input offset current				5	50	nA
CMRR	Common-mode rejection ratio	V_{CM} = 0 to 1.7 V		50	63		dB
k_{SVR}	Supply-voltage rejection ratio	V_{CC} = 2.7 V to 5 V,	V_O = 1 V	50	60		dB
V_{ICR}	Common-mode input voltage range	CMRR ≥ 50 dB		0 to 1.7	–0.2 to 1.9		V
	Output swing	R_L = 10 kΩ to 1.35 V	High level	V_{CC} – 100	V_{CC} – 10		mV
			Low level		60	180	
I_{CC}	Supply current	LMV321			80	170	µA
		LMV358 (both amplifiers)			140	340	
		LMV324 (all four amplifiers)			260	680	
B_1	Unity-gain bandwidth	C_L = 200 pF			1		MHz
ϕ_m	Phase margin				60		deg
G_m	Gain margin				10		dB
V_n	Equivalent input noise voltage	f = 1 kHz			46		nV/√Hz
I_n	Equivalent input noise current	f = 1 kHz			0.17		pA/√Hz

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electrical characteristics at specified free-air temperature range, V_{CC+} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		T_A†	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage			25°C		1.7	7	mV
				Full range			9	
$\alpha_{V_{IO}}$	Average temperature coefficient of input offset voltage			25°C		5		μV/°C
I_{IB}	Input bias current			25°C		15	250	nA
				Full range			500	
I_{IO}	Input offset current			25°C		5	50	nA
				Full range			150	
CMRR	Common-mode rejection ratio	V_{CM} = 0 to 4 V		25°C	50	65		dB
k_{SVR}	Supply-voltage rejection ratio	V_{CC} = 2.7 V to 5 V, V_O = 1 V, V_{CM} = 1 V		25°C	50	60		dB
V_{ICR}	Common-mode input voltage range	CMMR ≥ 50 dB		25°C	0 to 4	–0.2 to 4.2		V
Output swing		R_L = 2 kΩ to 2.5 V	High level	25°C	V_{CC} – 300	V_{CC} – 40		mV
				Full range	V_{CC} – 400			
			Low level	25°C		120	300	
				Full range			400	
		R_L = 10 kΩ to 2.5 V	High level	25°C	V_{CC} – 100	V_{CC} – 10		
				Full range	V_{CC} – 200			
			Low level	25°C		65	180	
				Full range			280	
A_{VD}	Large-signal differential voltage gain	R_L = 2 kΩ		25°C	15	100		V/mV
				Full range	10			
I_{OS}	Output short-circuit current	Sourcing, V_O = 0 V		25°C	5	60		mA
		Sinking, V_O = 5 V			10	160		
I_{CC}	Supply current	LMV321		25°C		130	250	μA
				Full range			350	
		LMV358 (both amplifiers)		25°C		210	440	
				Full range			615	
		LMV324 (all four amplifiers)		25°C		410	830	
				Full range			1160	
B_1	Unity-gain bandwidth	C_L = 200 pF		25°C		1		MHz
ϕ_m	Phase margin			25°C		60		deg
G_m	Gain margin			25°C		10		dB
V_n	Equivalent input noise voltage	f = 1 kHz		25°C		39		nV/√Hz
I_n	Equivalent input noise current	f = 1 kHz		25°C		0.21		pA/√Hz
SR	Slew rate			25°C		1		V/μs

† Full range is –40°C to 85°C for I-level part, –40°C to 125°C for Q-level part.

TYPICAL CHARACTERISTICS

GAIN AND PHASE MARGIN vs FREQUENCY

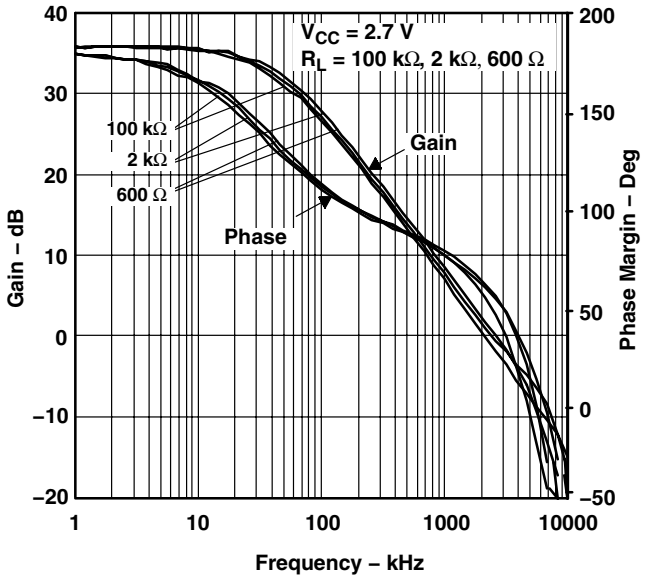

Figure 1

GAIN AND PHASE MARGIN vs FREQUENCY

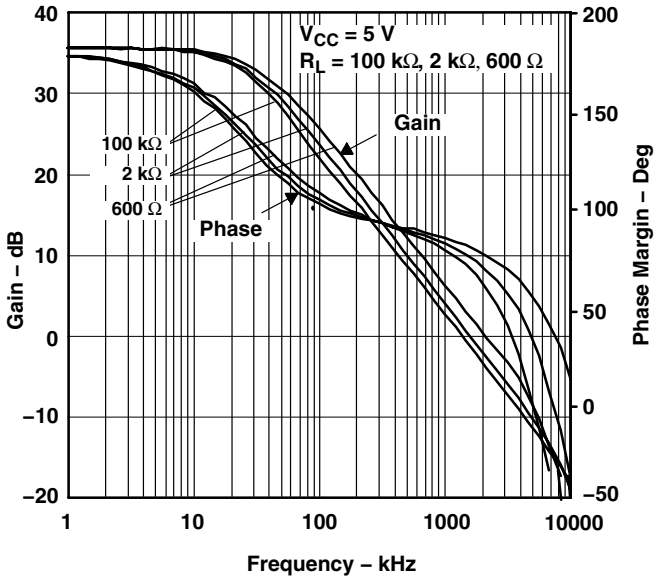

Figure 2

GAIN AND PHASE MARGIN vs FREQUENCY

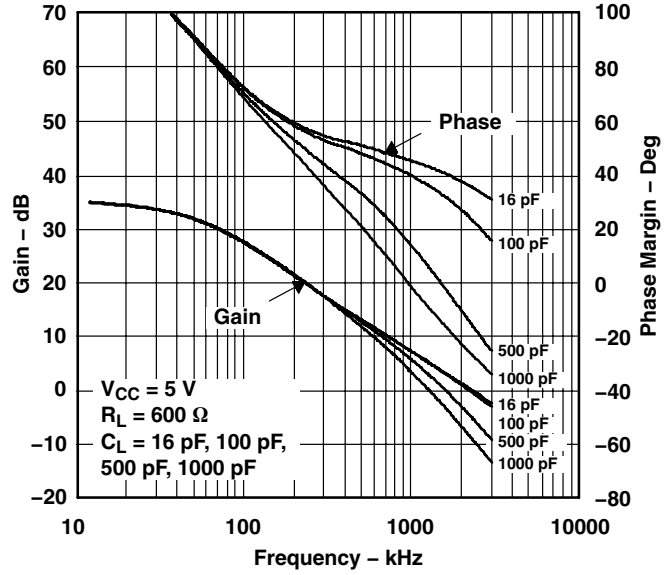

Figure 3

GAIN AND PHASE MARGIN vs FREQUENCY

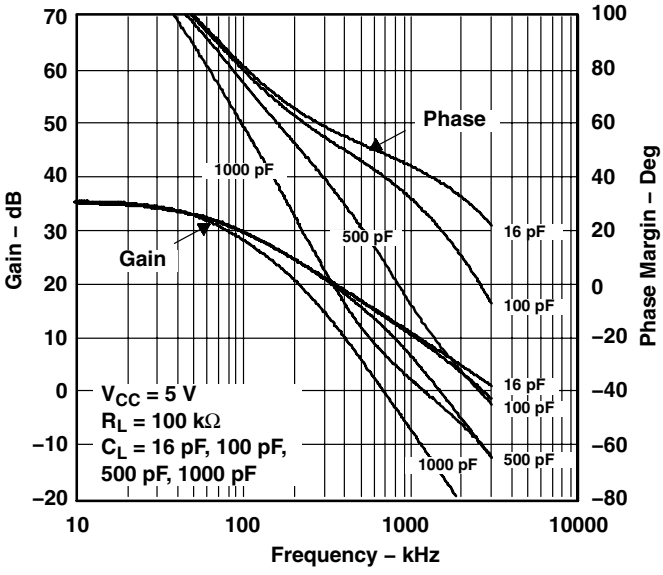

Figure 4

TYPICAL CHARACTERISTICS

GAIN AND PHASE MARGIN
vs
FREQUENCY

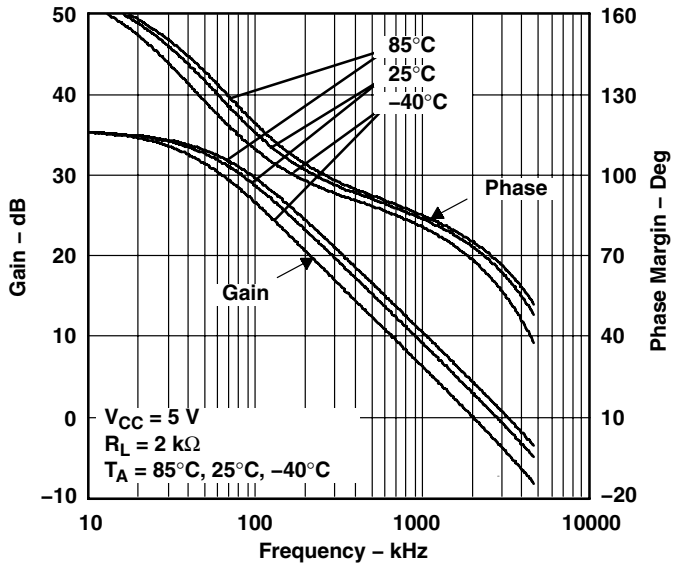

Figure 5

STABILITY
vs
CAPACITIVE LOAD

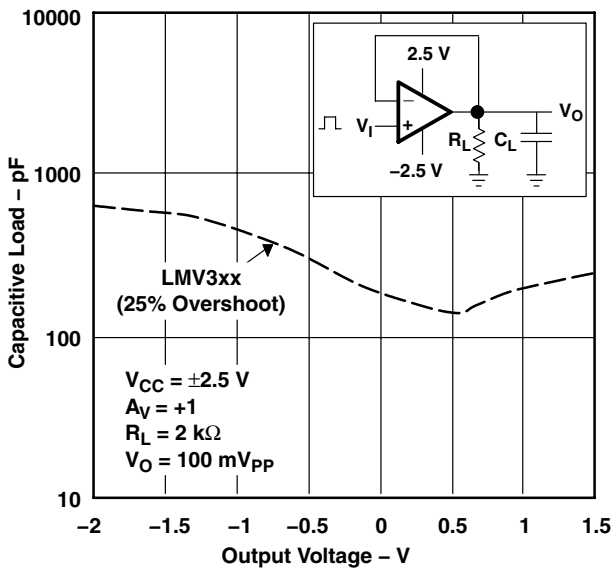

Figure 6

STABILITY
vs
CAPACITIVE LOAD

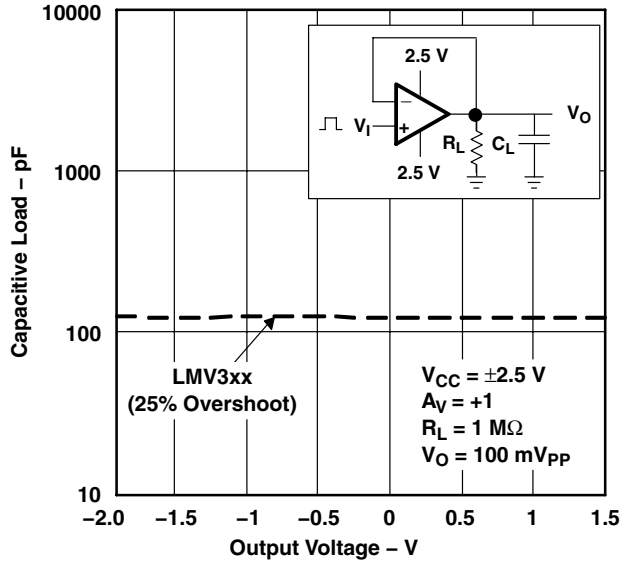

Figure 7

STABILITY
vs
CAPACITIVE LOAD

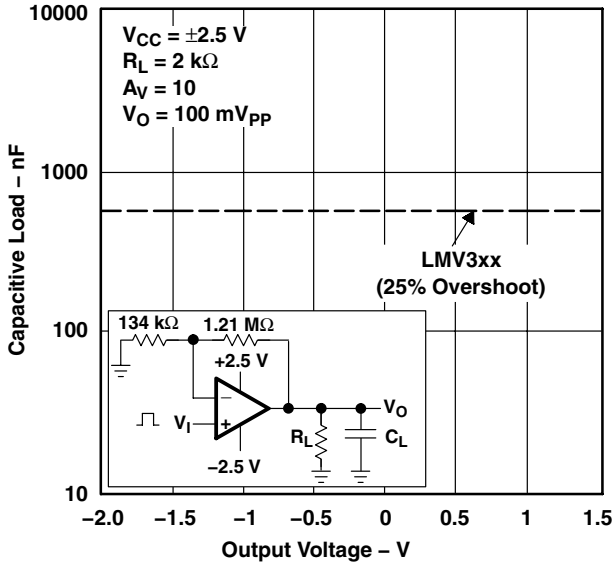

Figure 8

TYPICAL CHARACTERISTICS

STABILITY vs CAPACITIVE LOAD

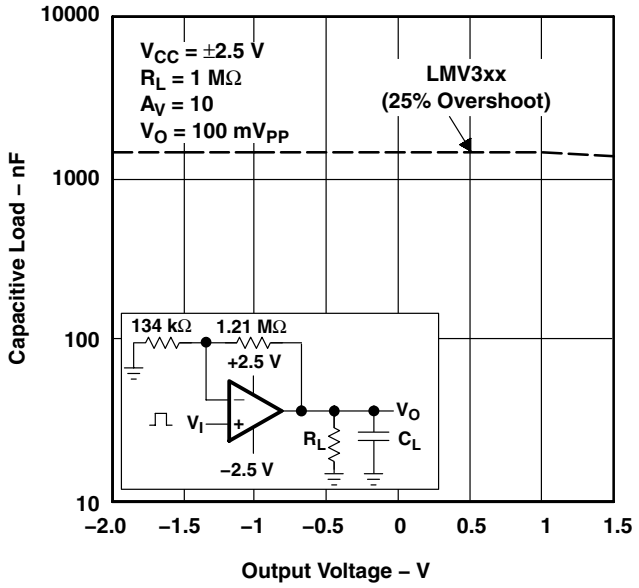

Figure 9

SLEW RATE vs SUPPLY VOLTAGE

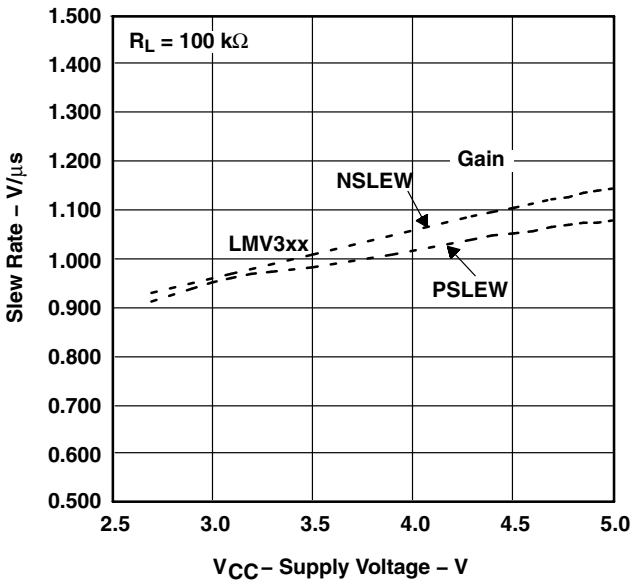

Figure 10

SUPPLY CURRENT vs SUPPLY VOLTAGE – QUAD AMPLIFIER

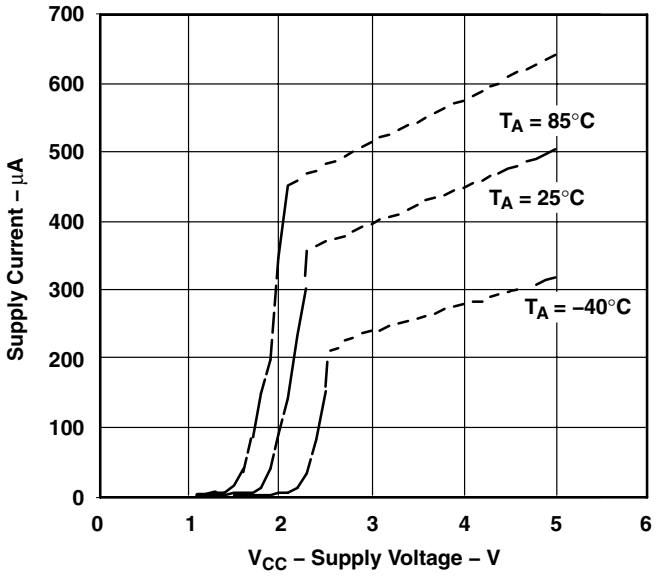

Figure 11

INPUT CURRENT vs TEMPERATURE

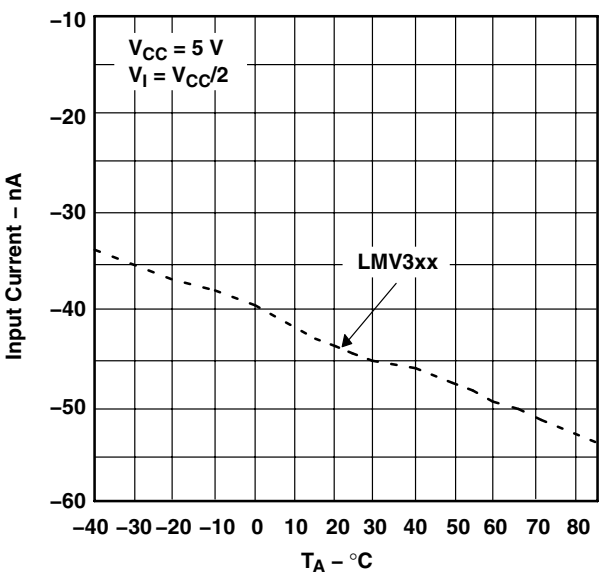

Figure 12

TYPICAL CHARACTERISTICS

SOURCE CURRENT
vs
OUTPUT VOLTAGE

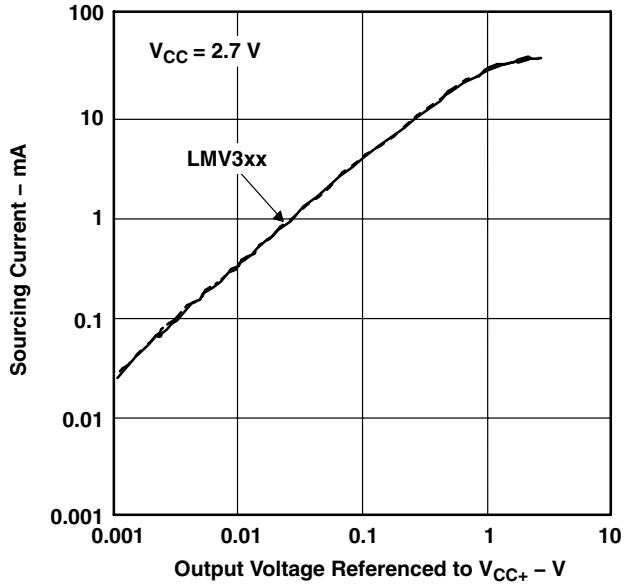

Figure 13

SOURCE CURRENT
vs
OUTPUT VOLTAGE

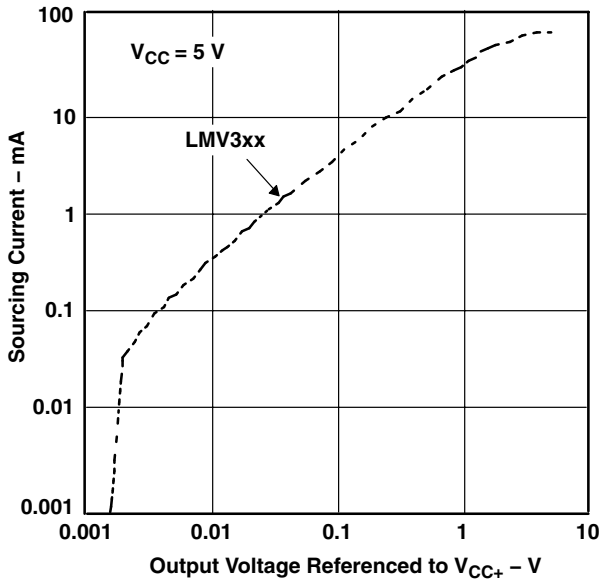

Figure 14

SINKING CURRENT
vs
OUTPUT VOLTAGE

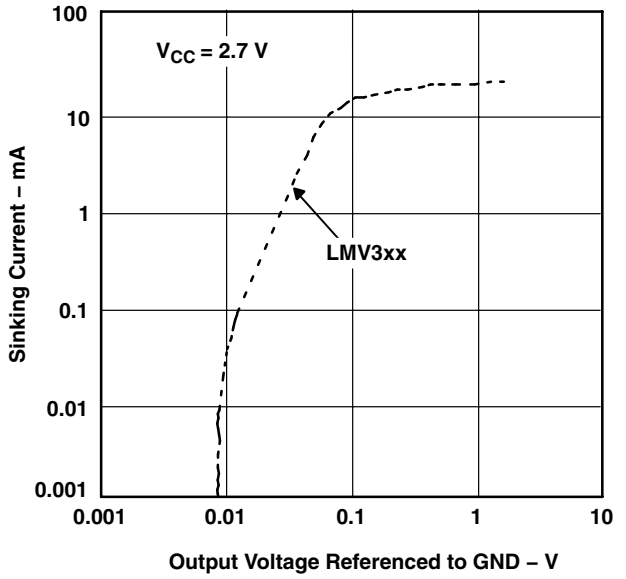

Figure 15

SINKING CURRENT
vs
OUTPUT VOLTAGE

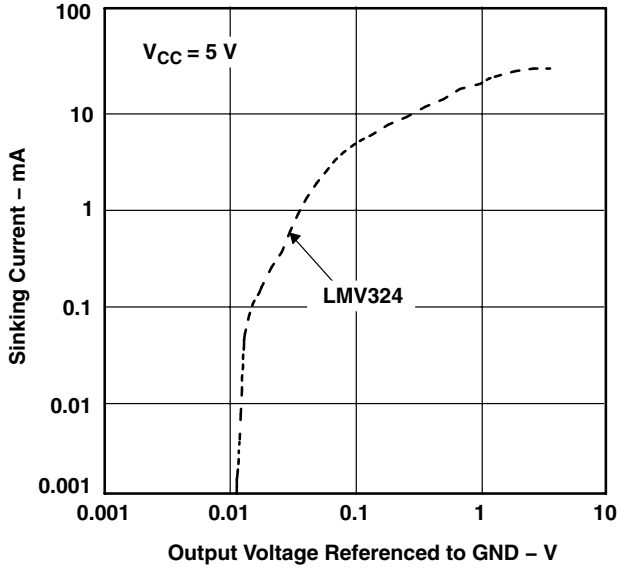

Figure 16

TYPICAL CHARACTERISTICS

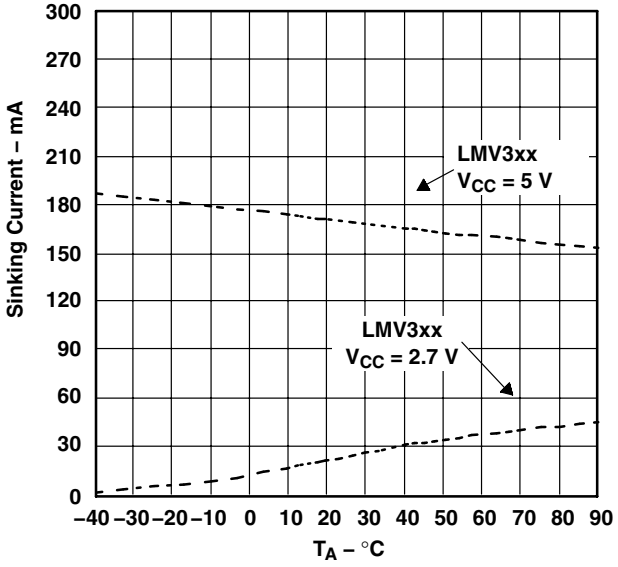

Figure 17

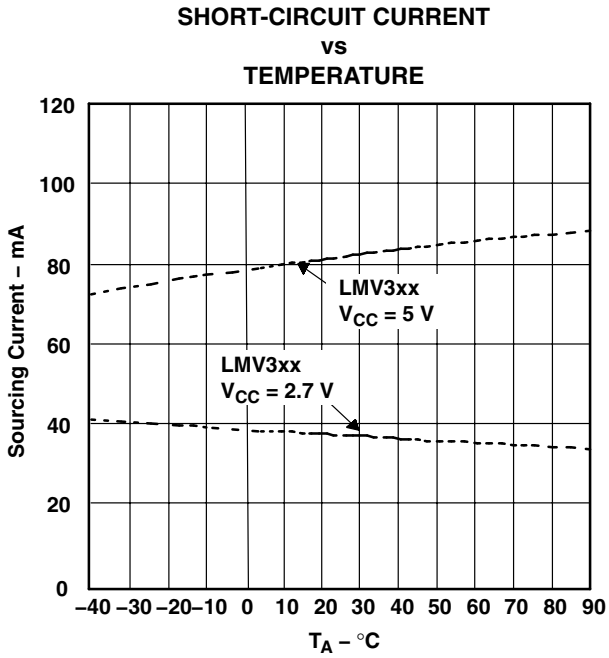

Figure 18

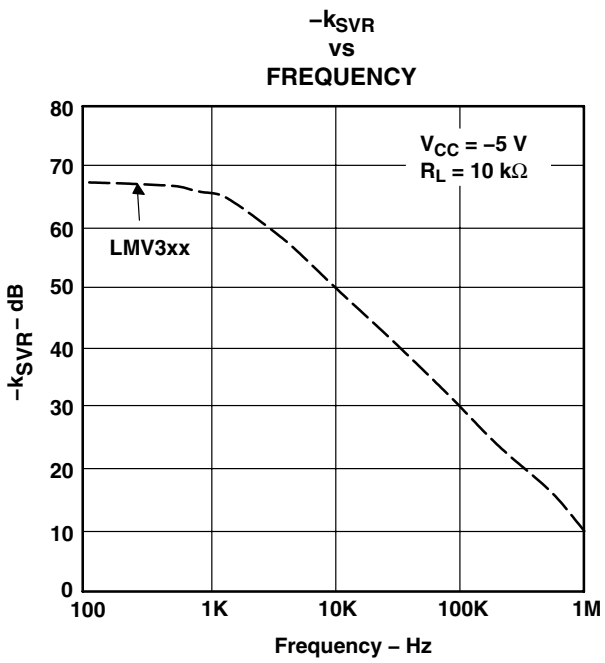

Figure 19

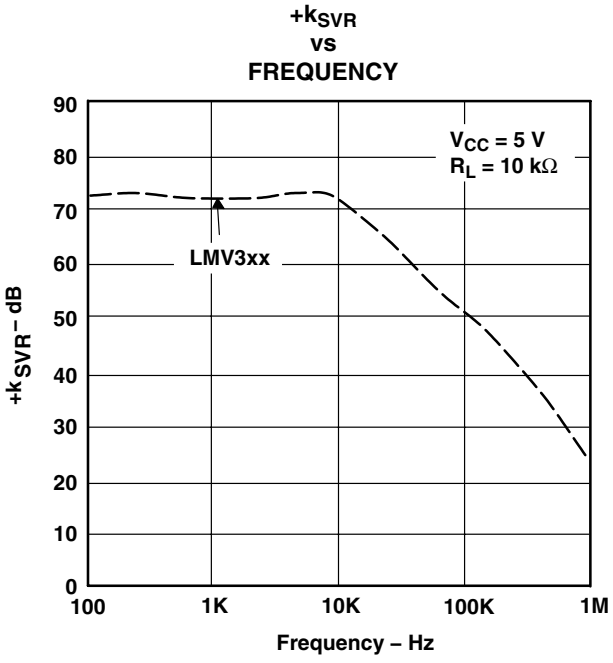

Figure 20

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TYPICAL CHARACTERISTICS

$-k_{SVR}$ vs FREQUENCY

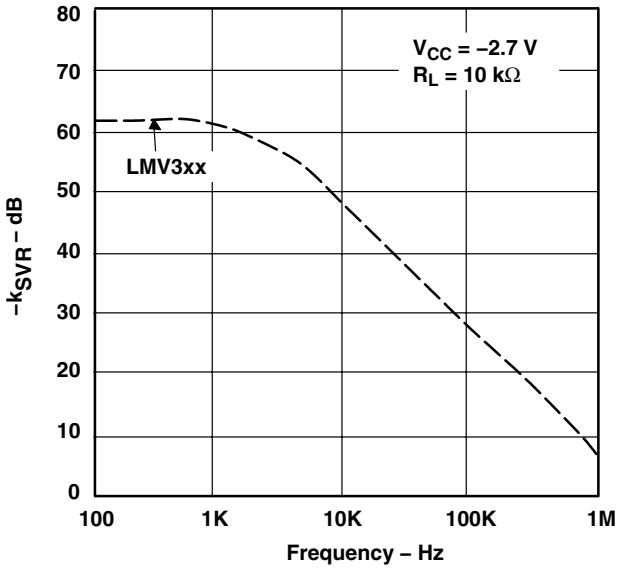

Figure 21

$+k_{SVR}$ vs FREQUENCY

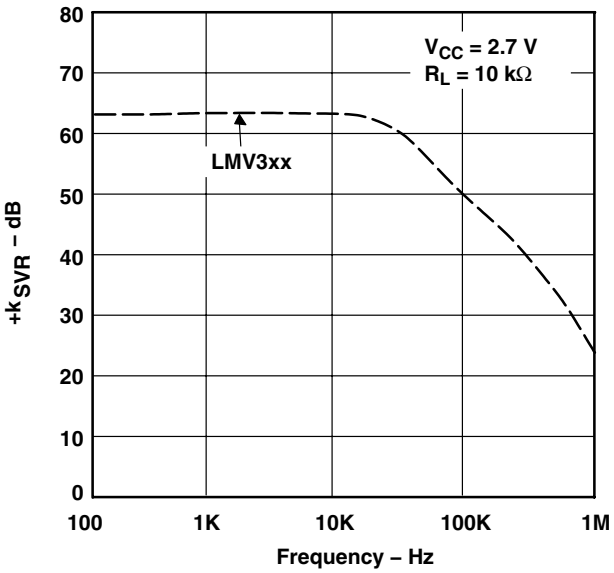

Figure 22

OUTPUT VOLTAGE SWING vs SUPPLY VOLTAGE

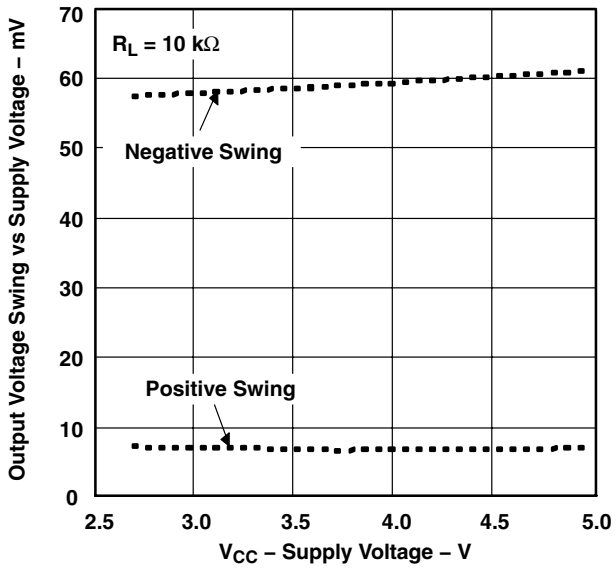

Figure 23

OUTPUT VOLTAGE vs FREQUENCY

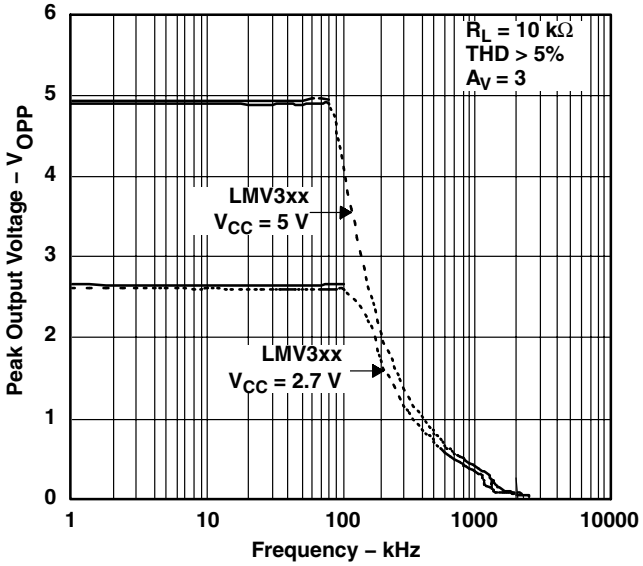

Figure 24

TYPICAL CHARACTERISTICS

OPEN-LOOP OUTPUT IMPEDANCE vs FREQUENCY

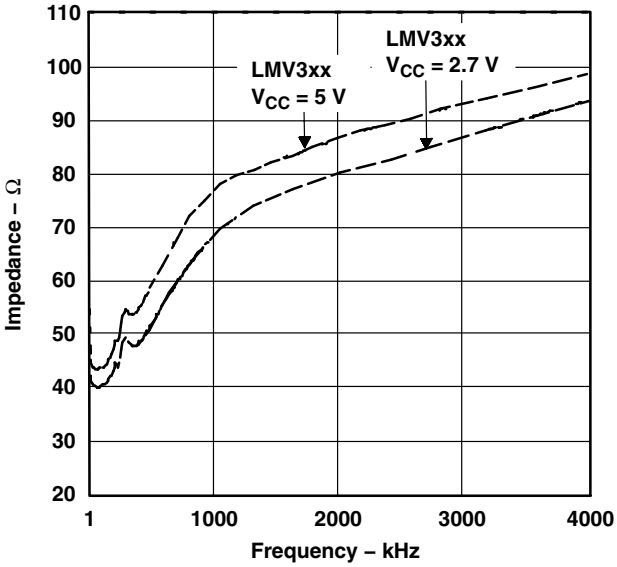

Figure 25

CROSSTALK REJECTION vs FREQUENCY

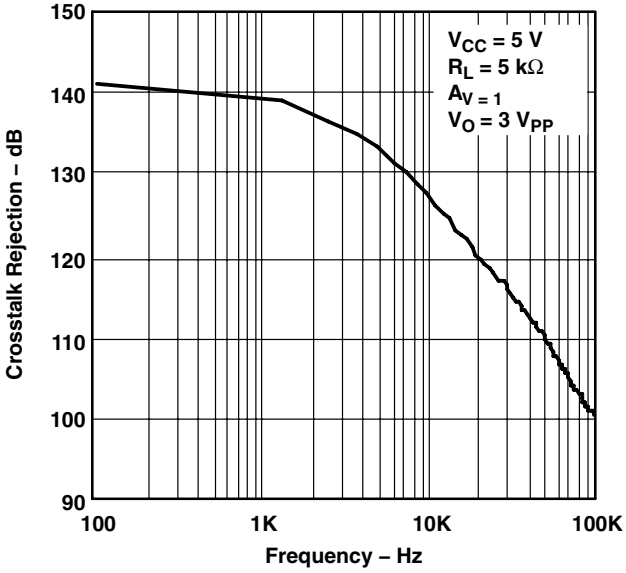

Figure 26

TYPICAL CHARACTERISTICS

NONINVERTING LARGE-SIGNAL PULSE RESPONSE

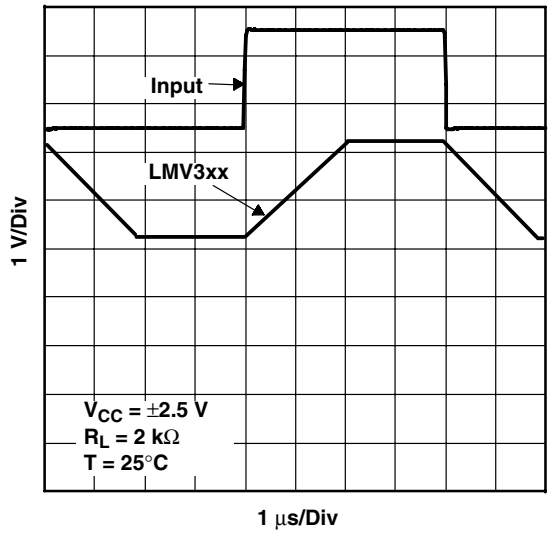

Figure 27

NONINVERTING LARGE-SIGNAL PULSE RESPONSE

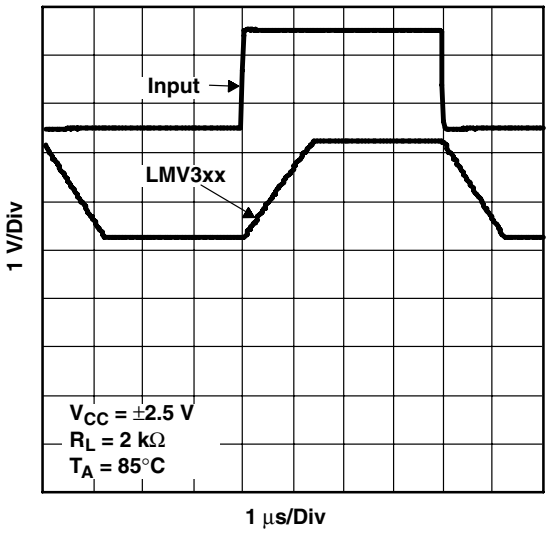

Figure 28

NONINVERTING LARGE-SIGNAL PULSE RESPONSE

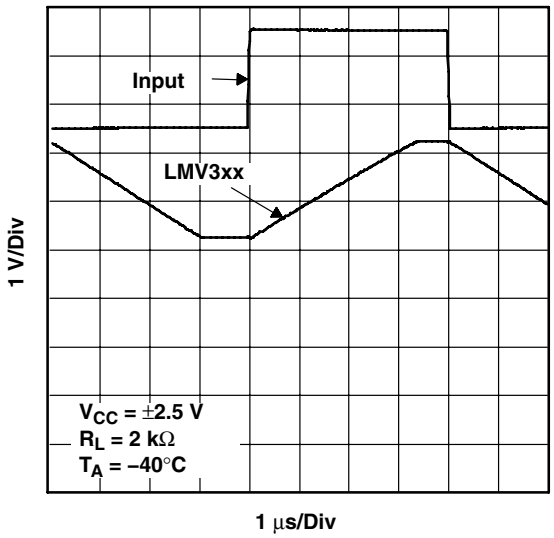

Figure 29

TYPICAL CHARACTERISTICS

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

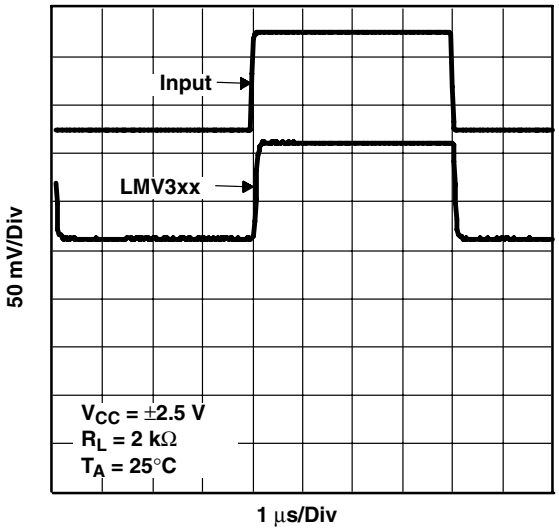

Figure 30

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

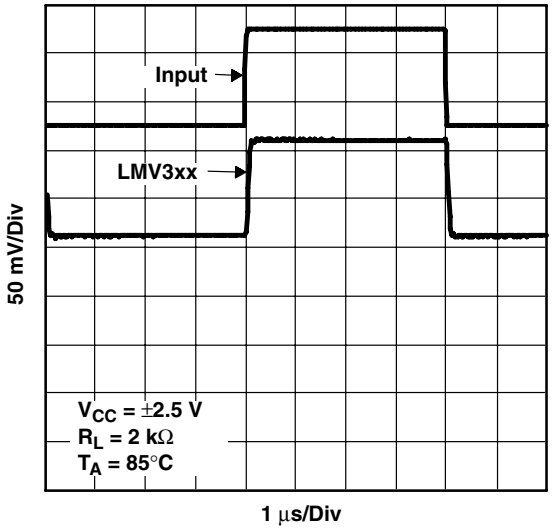

Figure 31

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

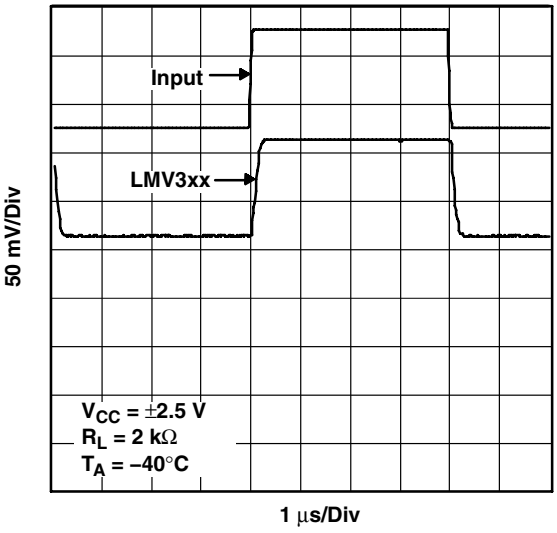

Figure 32

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL
PULSE RESPONSE

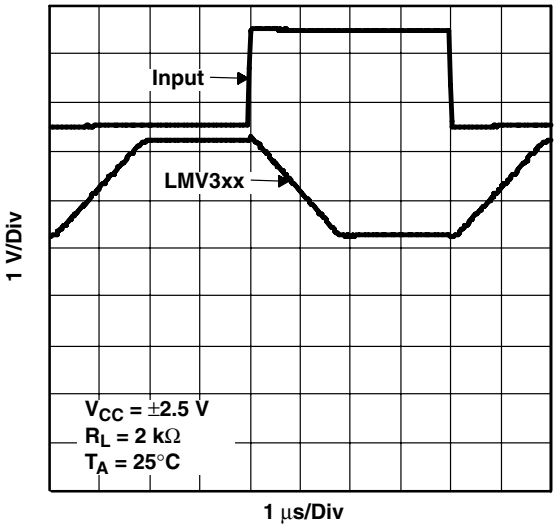

Figure 33

INVERTING LARGE-SIGNAL
PULSE RESPONSE

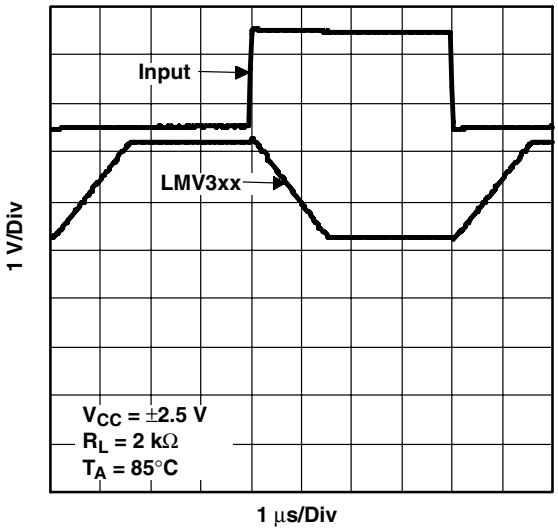

Figure 34

INVERTING LARGE-SIGNAL
PULSE RESPONSE

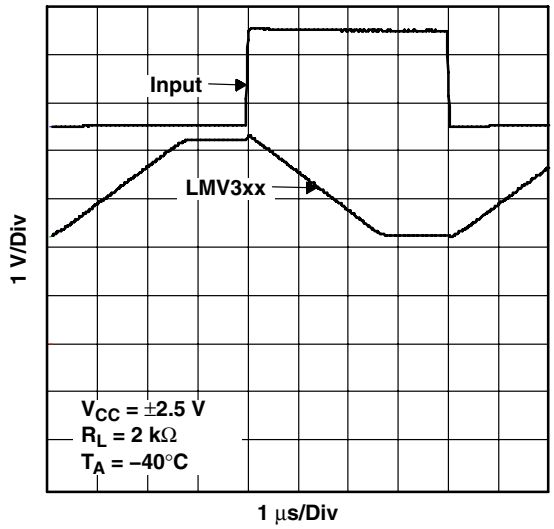

Figure 35

TYPICAL CHARACTERISTICS

INVERTING SMALL-SIGNAL PULSE RESPONSE

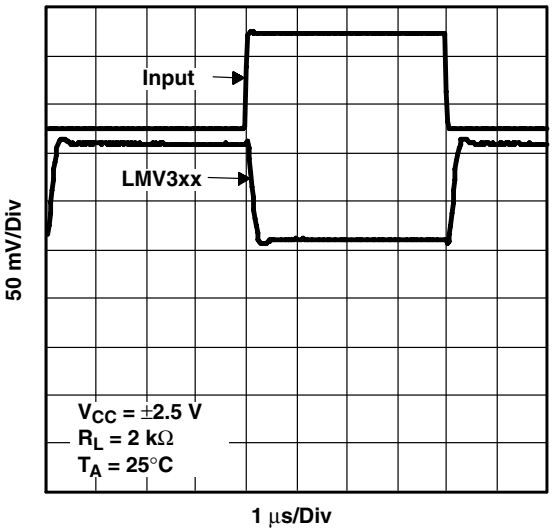

Figure 36

INVERTING SMALL-SIGNAL PULSE RESPONSE

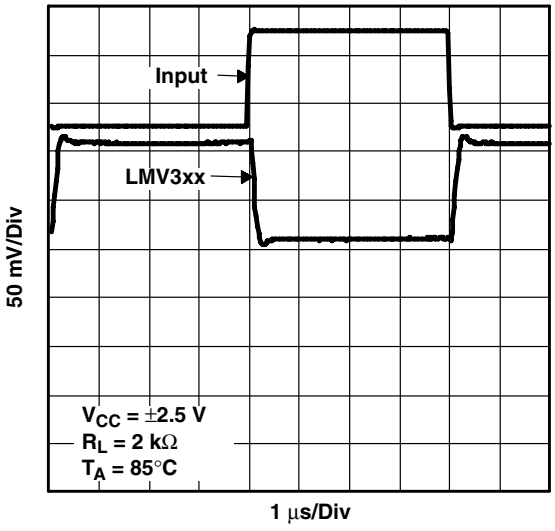

Figure 37

INVERTING SMALL-SIGNAL PULSE RESPONSE

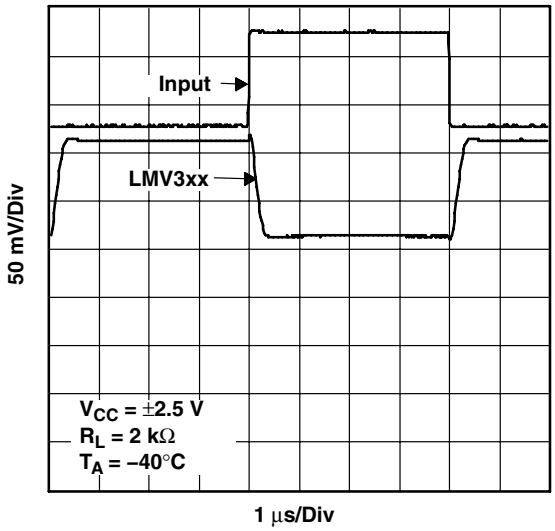

Figure 38

TYPICAL CHARACTERISTICS

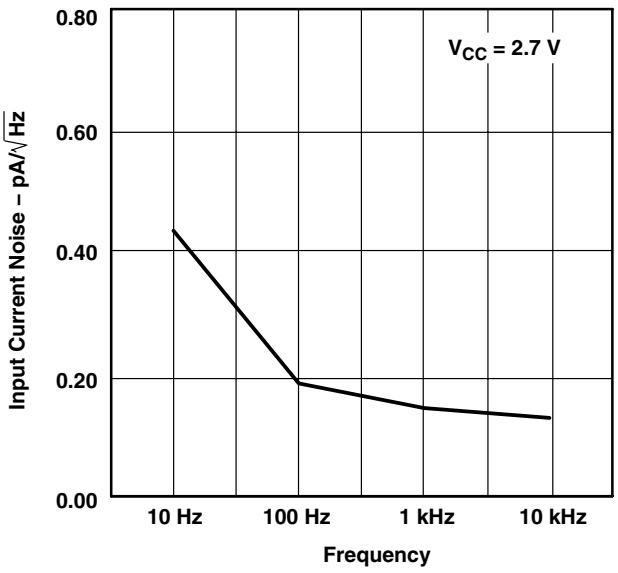

Figure 39

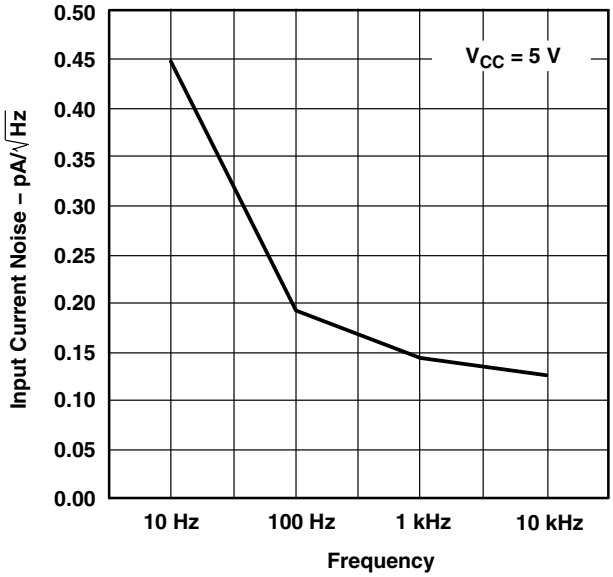

Figure 40

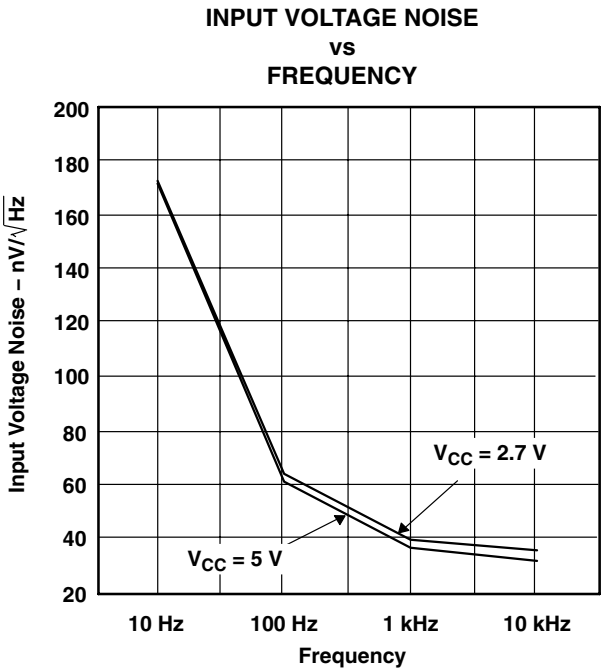

Figure 41

TYPICAL CHARACTERISTICS

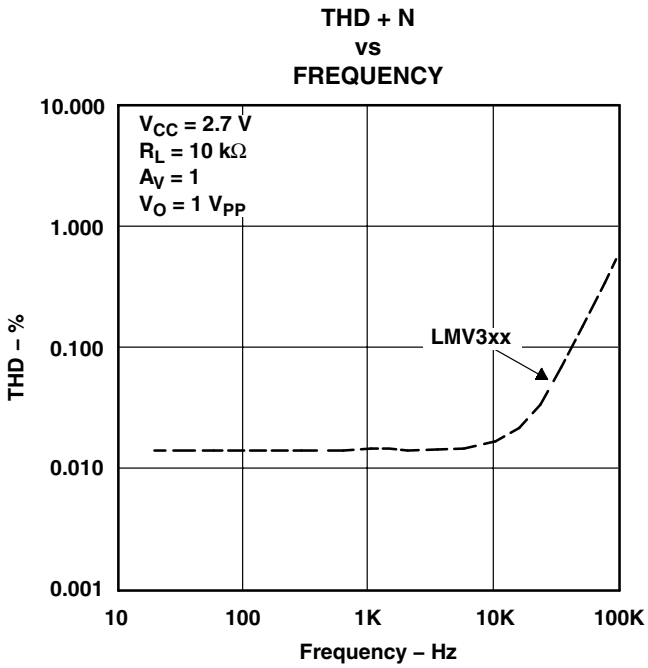

Figure 42

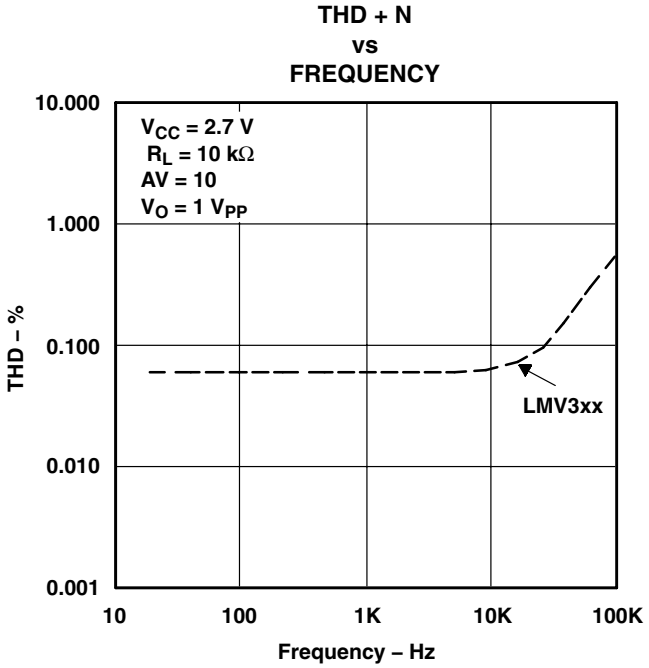

Figure 43

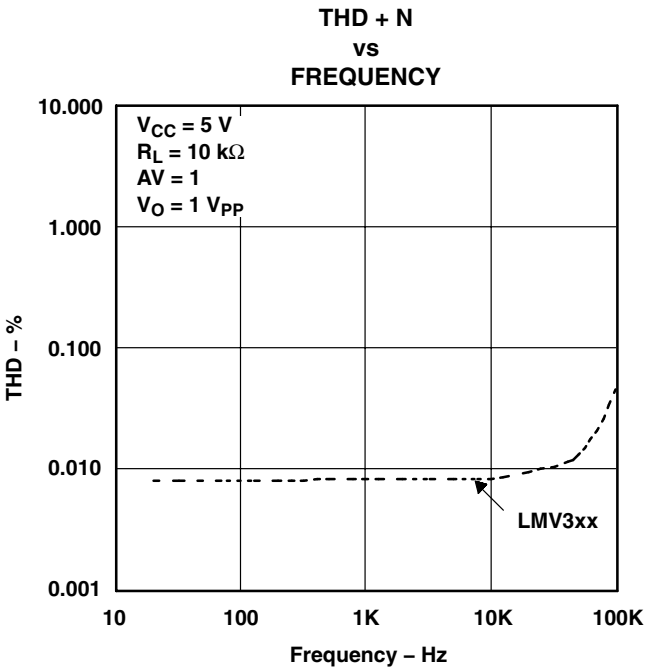

Figure 44

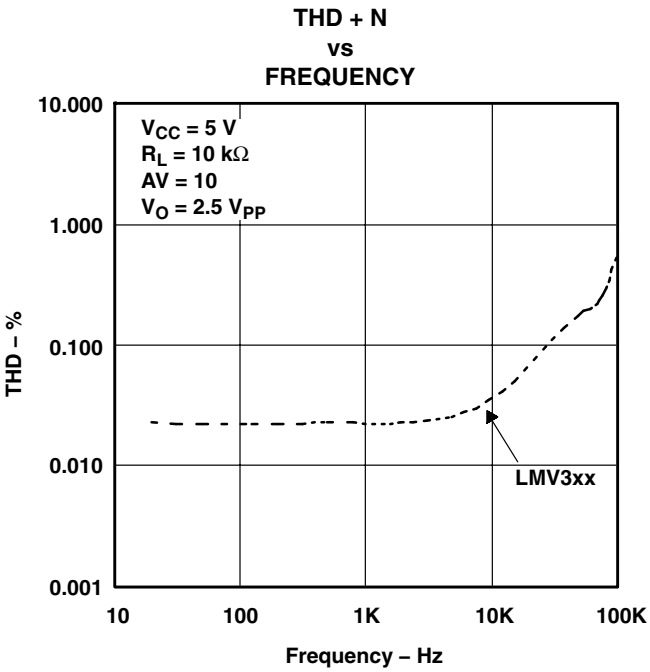

Figure 45

TEXAS INSTRUMENTS
POST OFFICE BOX 655303 • DALLAS, TEXAS 75265
POST OFFICE BOX 1443 • HOUSTON, TEXAS 77251–1443

TEXAS INSTRUMENTS

www.ti.com

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Pea
LMV321IDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV321QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324IDRG4Q1	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324IDRQ1	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324IPWRG4Q1	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324IPWRQ1	ACTIVE	TSSOP	PW	14	2000	TBD	CU NIPDAU	Level-1-250
LMV324QDQ1	OBSOLETE	SOIC	D	14		TBD	Call TI	Call TI
LMV324QDRG4Q1	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324QDRQ1	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324QPWRG4Q1	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV324QPWRQ1	ACTIVE	TSSOP	PW	14	2000	TBD	CU NIPDAU	Level-1-250
LMV358IDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358IDRQ1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358IPWRG4Q1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358IPWRQ1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358QDQ1	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI
LMV358QDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358QDRQ1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358QPWQ1	OBSOLETE	TSSOP	PW	8		TBD	Call TI	Call TI

www.ti.com

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Pea
LMV358QPWRG4Q1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260
LMV358QPWRQ1	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-250

(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
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.
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
lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable fo
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,
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 retard
in homogeneous material)

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

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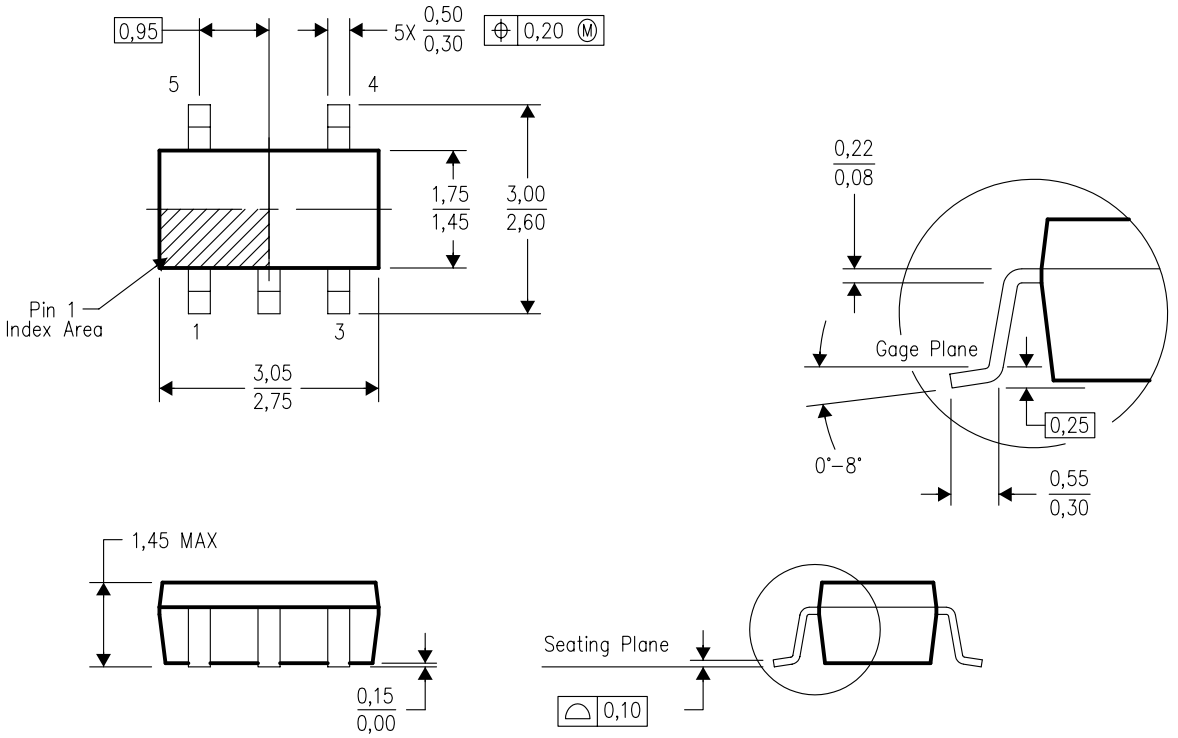
OTHER QUALIFIED VERSIONS OF LMV321-Q1, LMV324-Q1, LMV358-Q1 :

- Catalog: LMV321, LMV324, LMV358

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

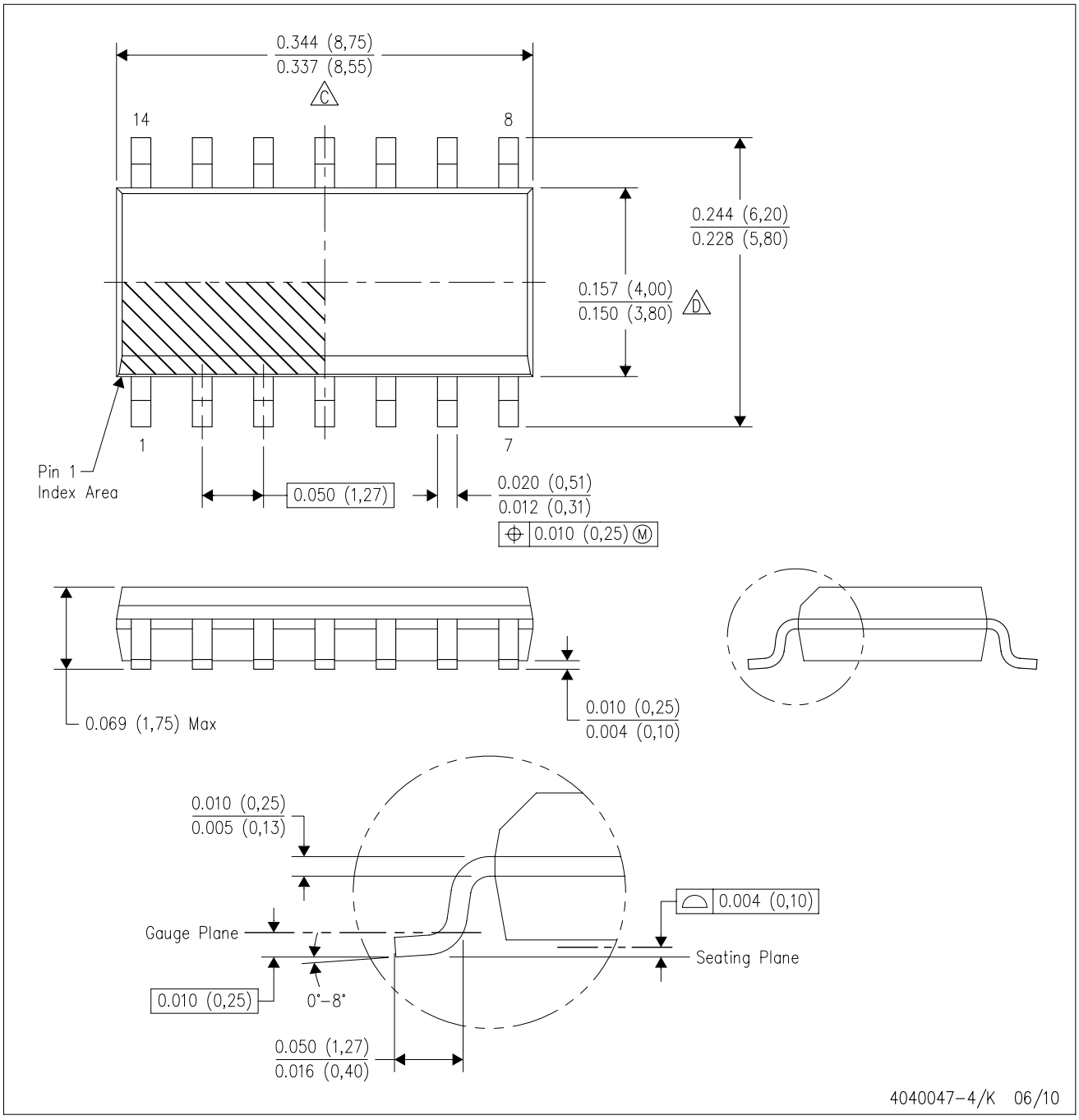
DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4073253–4/K 03/2006

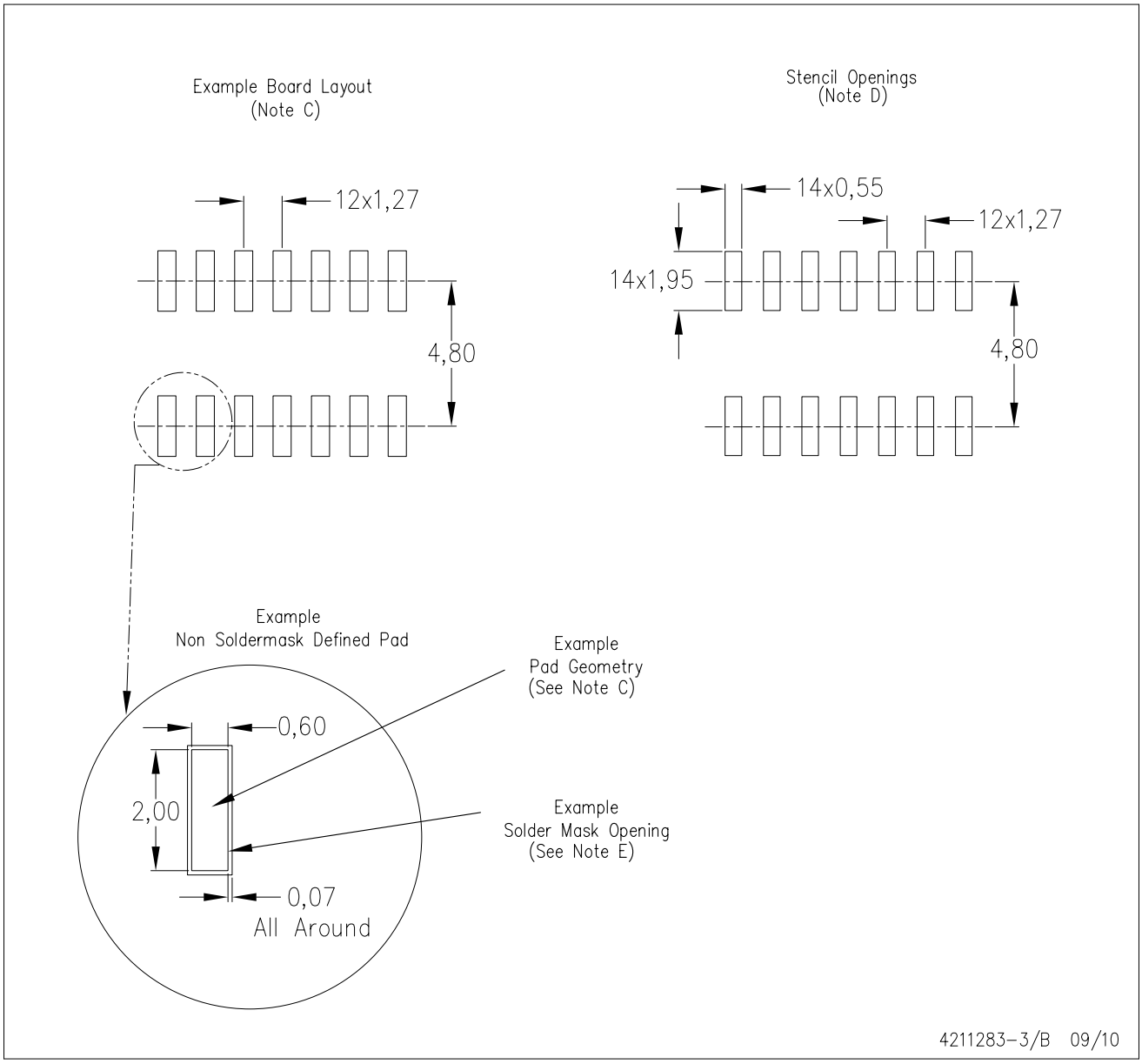
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–178 Variation AA.

D (R–PDSO–G14) PLASTIC SMALL–OUTLINE PACKAGE



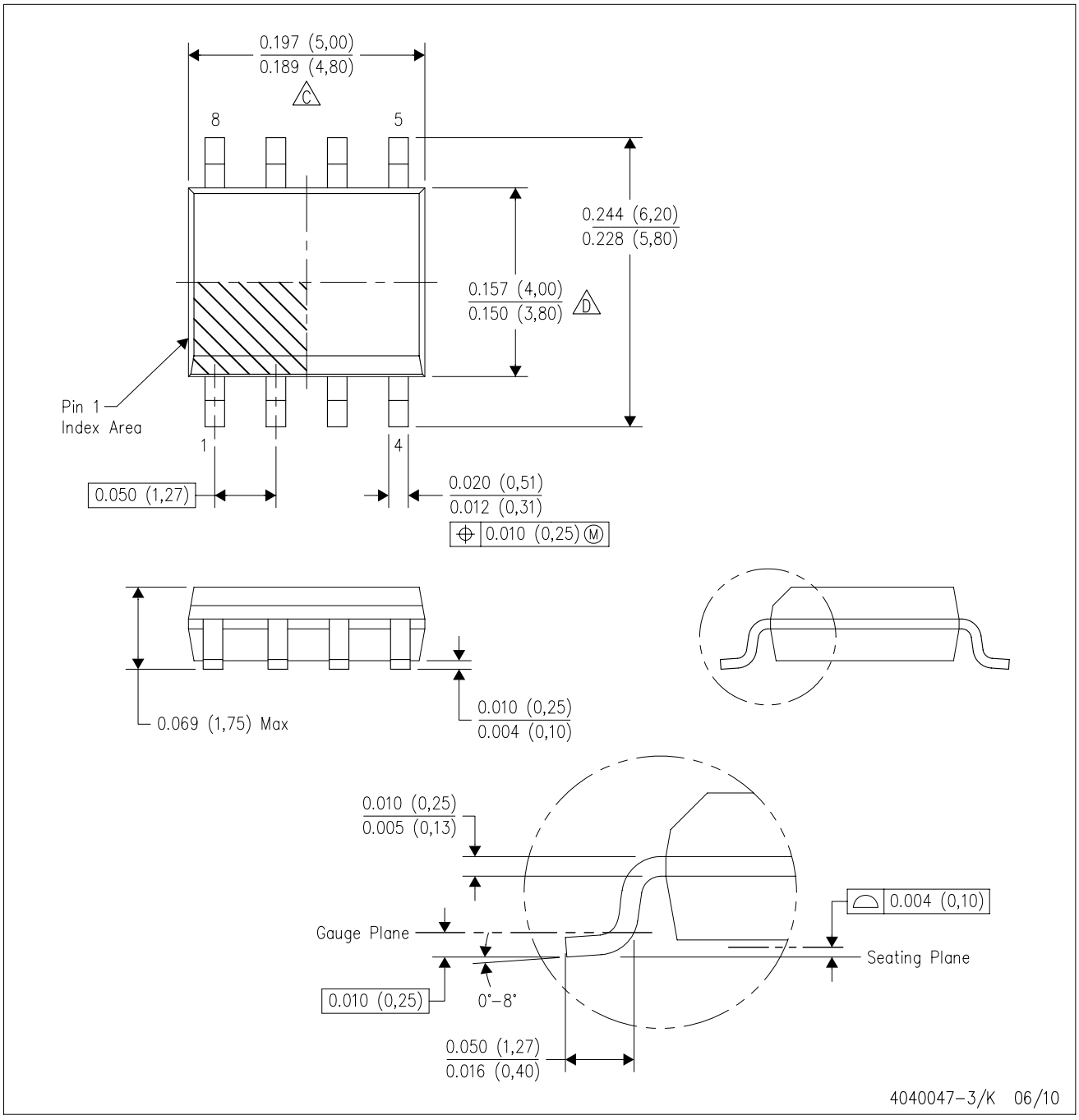
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS–012 variation AB.

D (R–PDSO–G14) PLASTIC SMALL OUTLINE



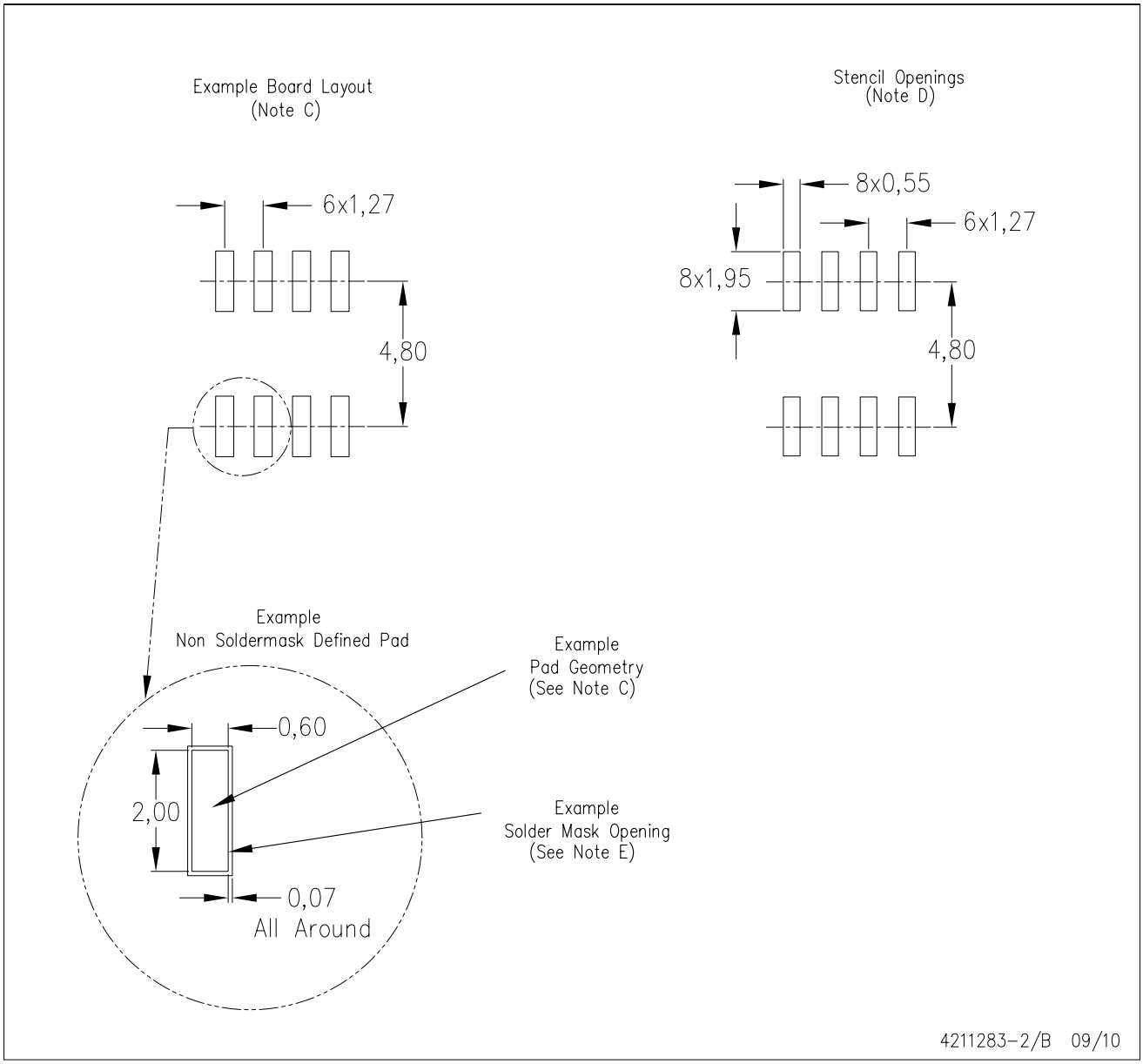
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

D (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



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 .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS–012 variation AA.

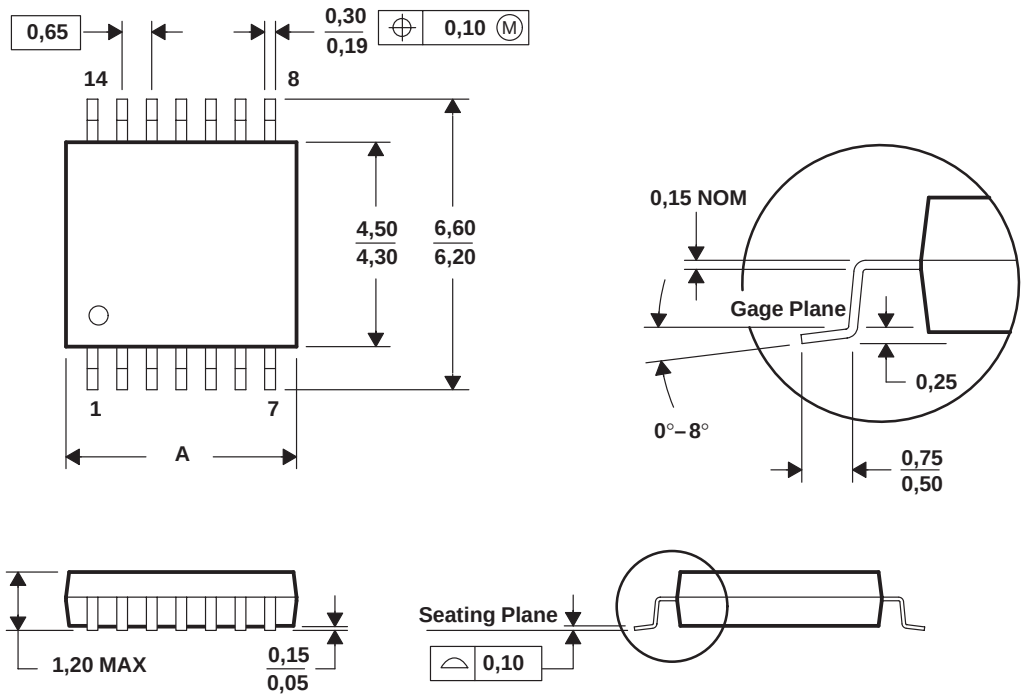
D (R–PDSO–G8) PLASTIC SMALL OUTLINE



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.

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN

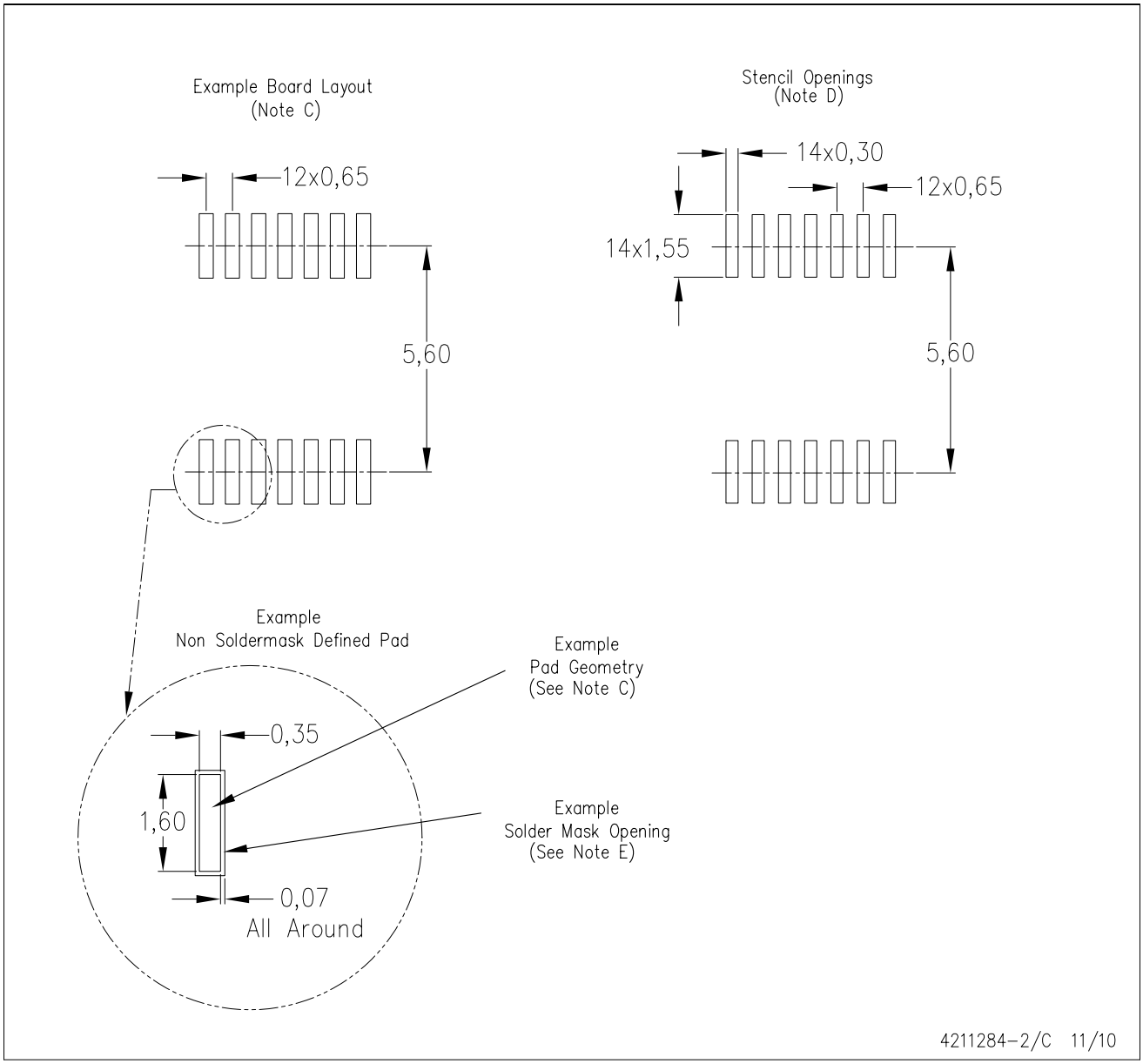


DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

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 not to exceed 0,15.
D. 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.

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