

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

SLOS415D – JUNE 2003 – REVISED OCTOBER 2004

- **Qualification in Accordance With AEC-Q100†**
- **Qualified for Automotive Applications**
- **Customer-Specific Configuration Control Can Be Supported Along With Major-Change Approval**
- **2.7-V and 5-V Performance**
- **No Crossover Distortion**
- **Low Supply Current:**
 LMV321 . . . 130 μ A Typ
 LMV358 . . . 210 μ A Typ
 LMV324 . . . 410 μ A Typ
- **Rail-to-Rail Output Swing**

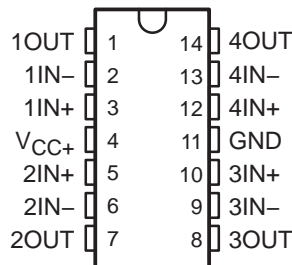
†Contact factory for details. Q100 qualification data available on request.

description/ordering information

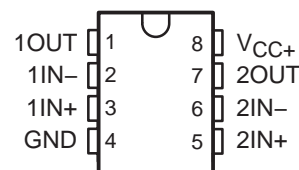
The LMV321, LMV358, and LMV324 are single, dual, and quad low-voltage (2.7 V to 5.5 V) operational amplifiers with rail-to-rail output swing.

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/ μ s slew rate.

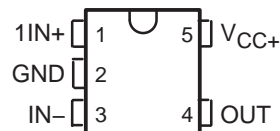
LMV324 . . . D OR PW PACKAGE
(TOP VIEW)



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



LMV321 . . . DBV PACKAGE
(TOP VIEW)



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.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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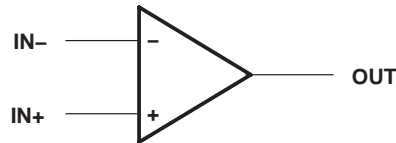
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ORDERING INFORMATION

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

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

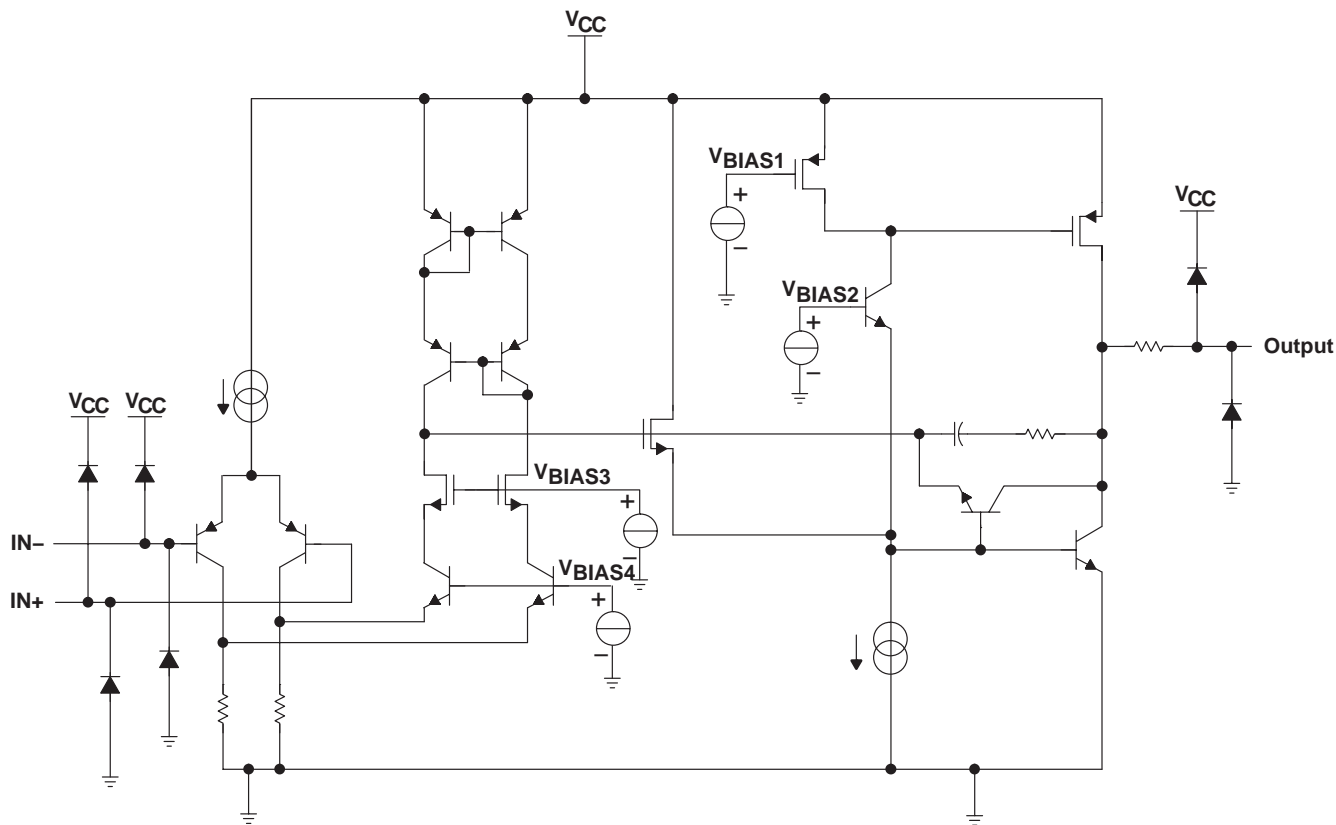
symbol (each amplifier)



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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) $T_A = 25^\circ\text{C}$, $V_{CC} \leq 5.5$ 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 $T_J(\text{max})$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(\text{max}) - T_A)/\theta_{JA}$. Selecting the maximum of 150°C can affect reliability.
 5. The package thermal impedance is calculated in accordance with JESD 51-7.

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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
α _{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, $V_{CC+} = 5\text{ V}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A^\dagger	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		$\mu\text{V}/^\circ\text{C}$
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	$V_{CM} = 0\text{ to }4\text{ V}$	25°C	50	65		dB
k_{SVR}	Supply-voltage rejection ratio	$V_{CC} = 2.7\text{ V to }5\text{ V}$, $V_O = 1\text{ V}$, $V_{CM} = 1\text{ V}$	25°C	50	60		dB
V_{ICR}	Common-mode input voltage range	$CMMR \geq 50\text{ dB}$	25°C	0 to 4	-0.2 to 4.2		V
Output swing	$R_L = 2\text{ k}\Omega\text{ to }2.5\text{ V}$	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	
	$R_L = 10\text{ k}\Omega\text{ to }2.5\text{ V}$	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	$R_L = 2\text{ k}\Omega$	25°C	15	100		V/mV
			Full range		10		
I_{OS}	Output short-circuit current	Sourcing, $V_O = 0\text{ V}$	25°C	5	60		mA
		Sinking, $V_O = 5\text{ V}$		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	$C_L = 200\text{ pF}$	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	$f = 1\text{ kHz}$	25°C		39		$\text{nV}/\sqrt{\text{Hz}}$
I_n	Equivalent input noise current	$f = 1\text{ kHz}$	25°C		0.21		$\text{pA}/\sqrt{\text{Hz}}$
SR	Slew rate		25°C		1		$\text{V}/\mu\text{s}$

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



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LOW-VOLTAGE RAIL-TO-RAIL OUTPUT
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TYPICAL CHARACTERISTICS

**GAIN AND PHASE MARGIN
VS
FREQUENCY**

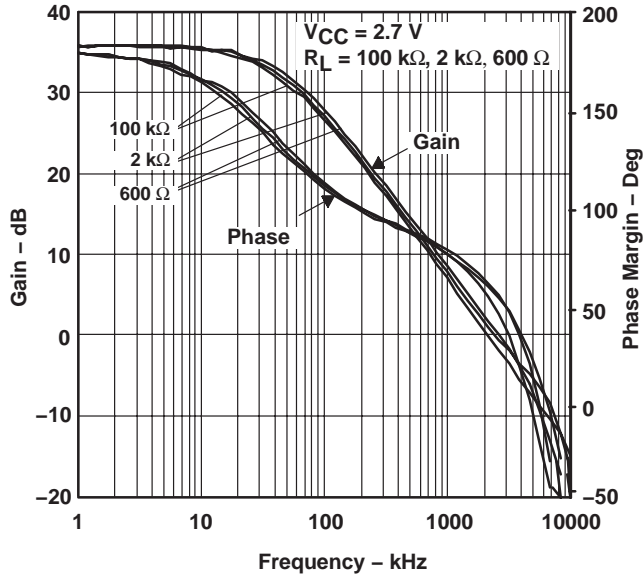


Figure 1

**GAIN AND PHASE MARGIN
VS
FREQUENCY**

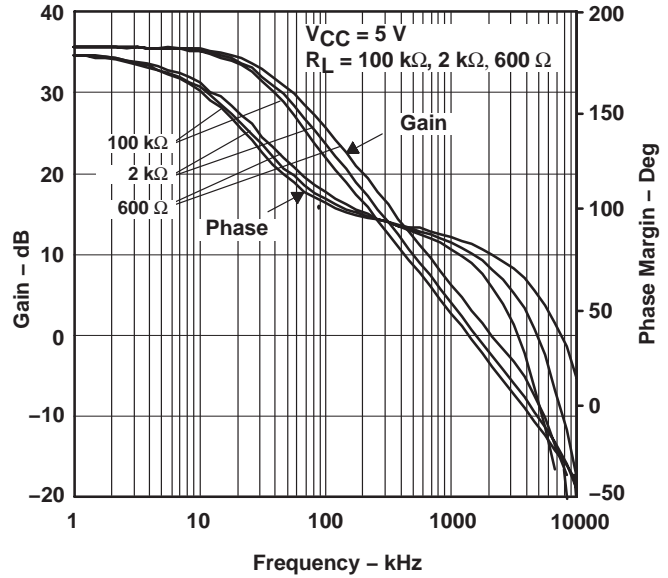


Figure 2

**GAIN AND PHASE MARGIN
VS
FREQUENCY**

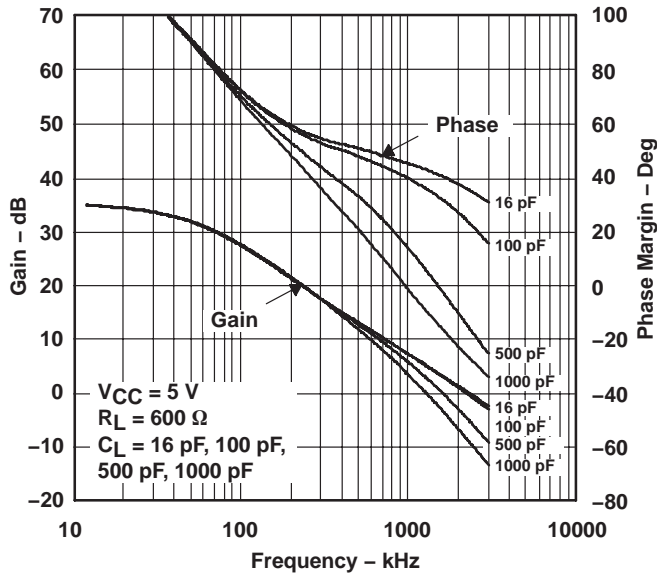


Figure 3

**GAIN AND PHASE MARGIN
VS
FREQUENCY**

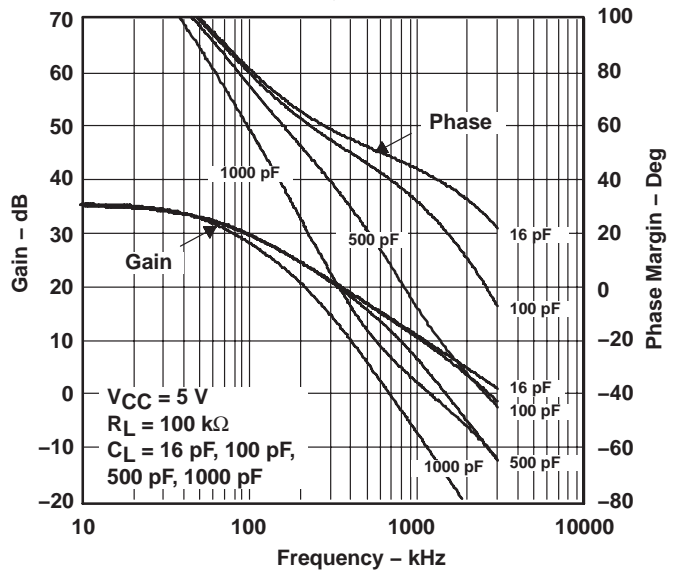


Figure 4



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

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TYPICAL CHARACTERISTICS

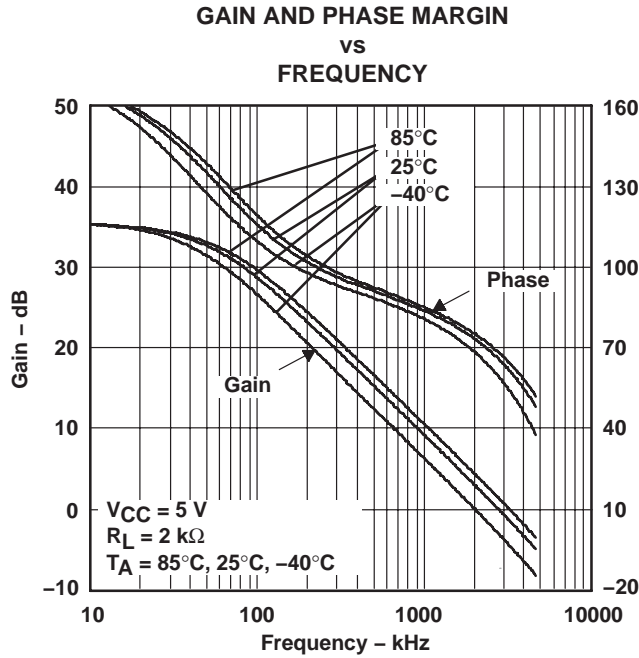


Figure 5

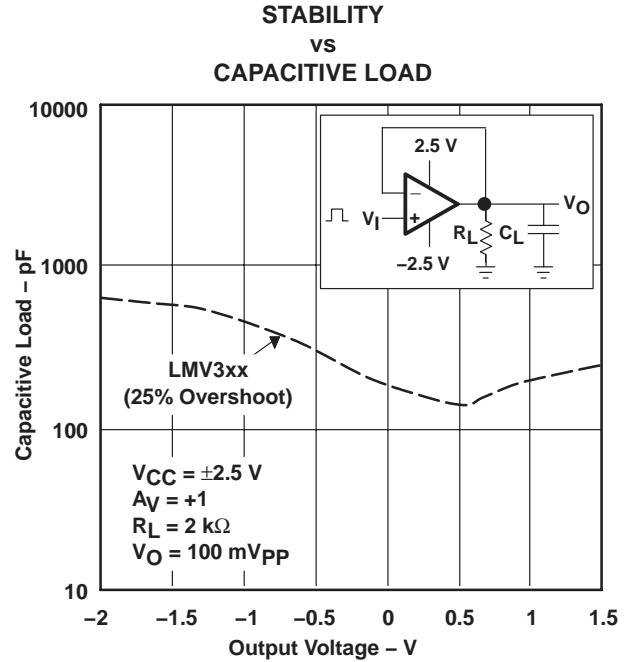


Figure 6

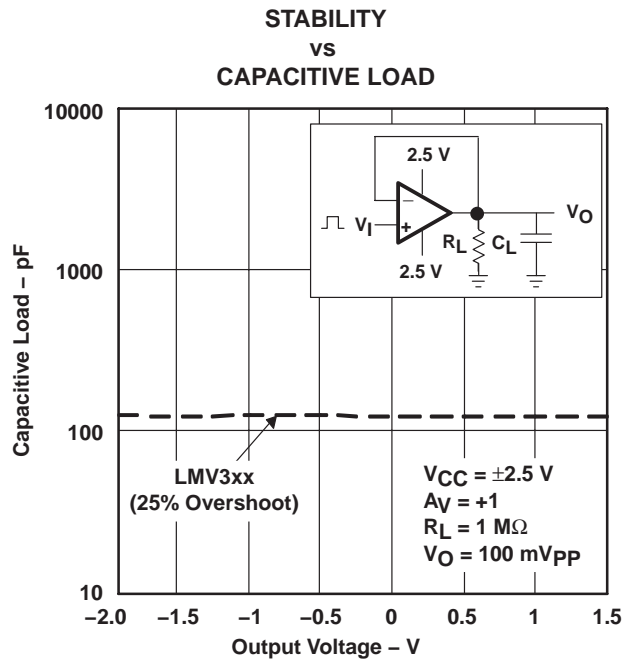


Figure 7

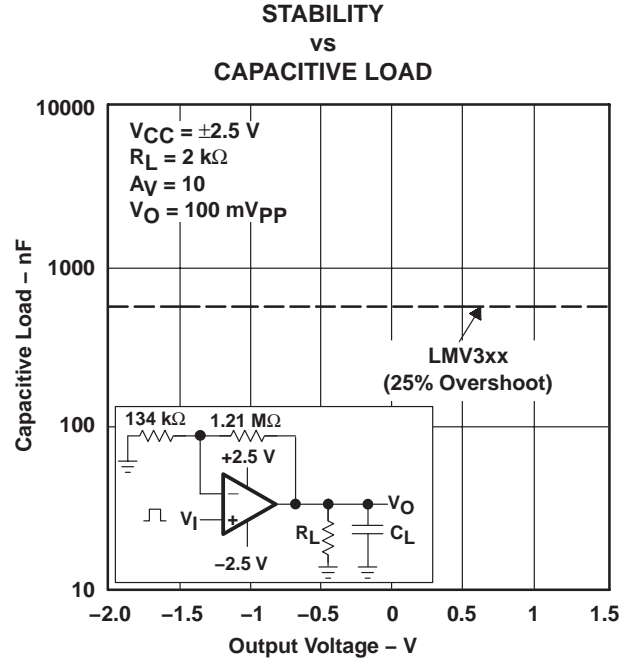


Figure 8

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

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TYPICAL CHARACTERISTICS

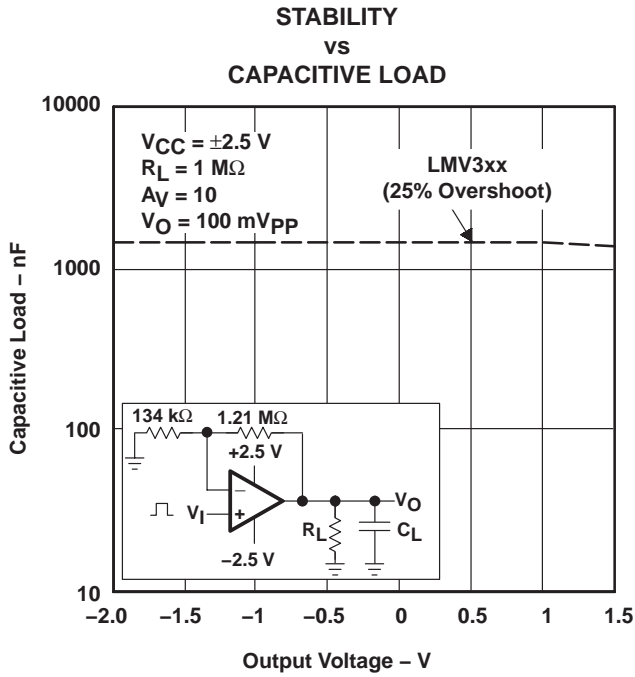


Figure 9

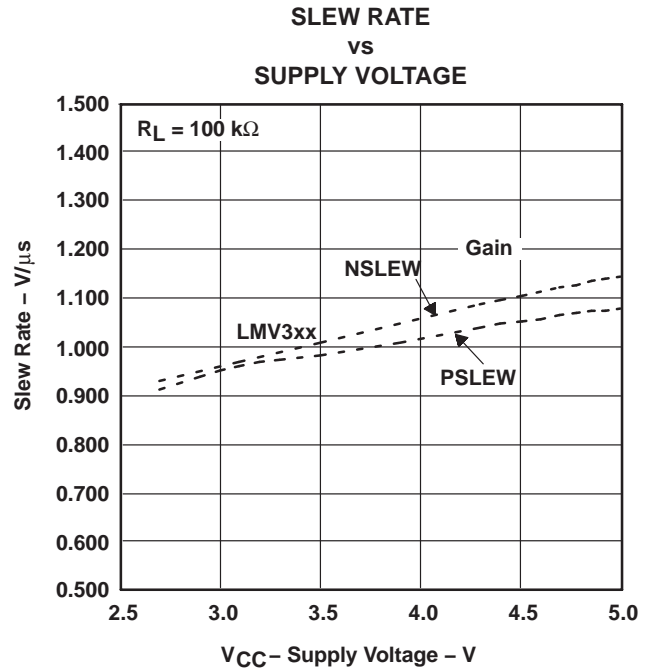


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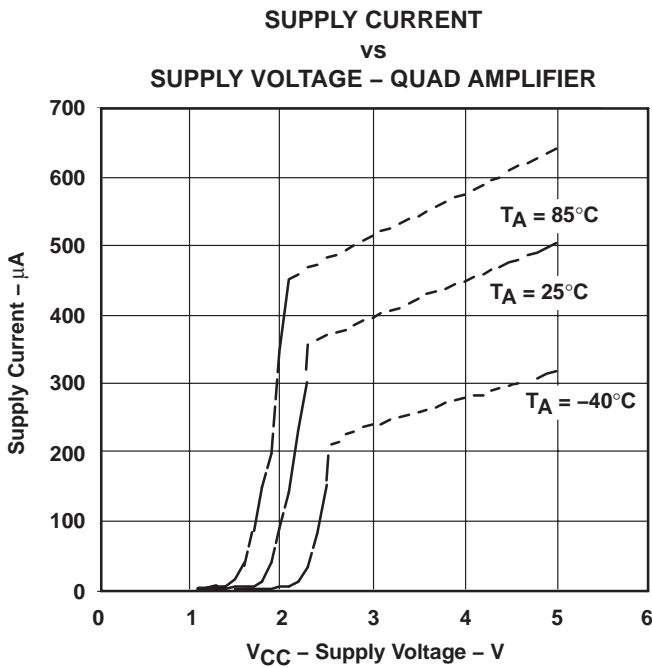


Figure 11

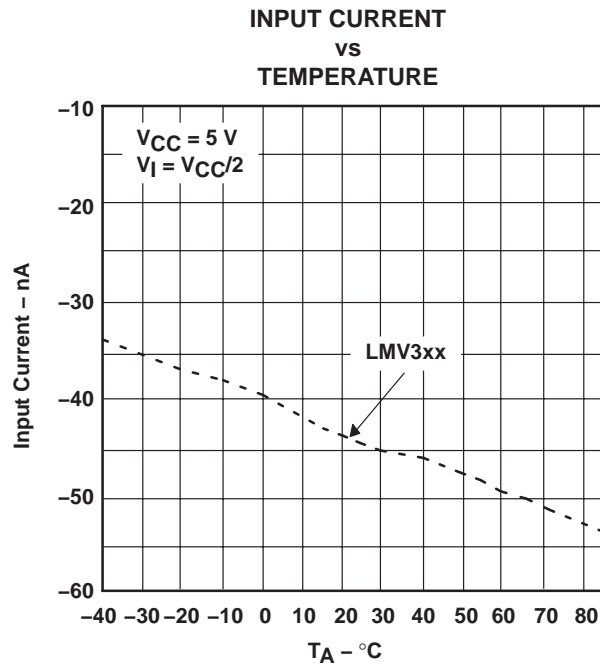
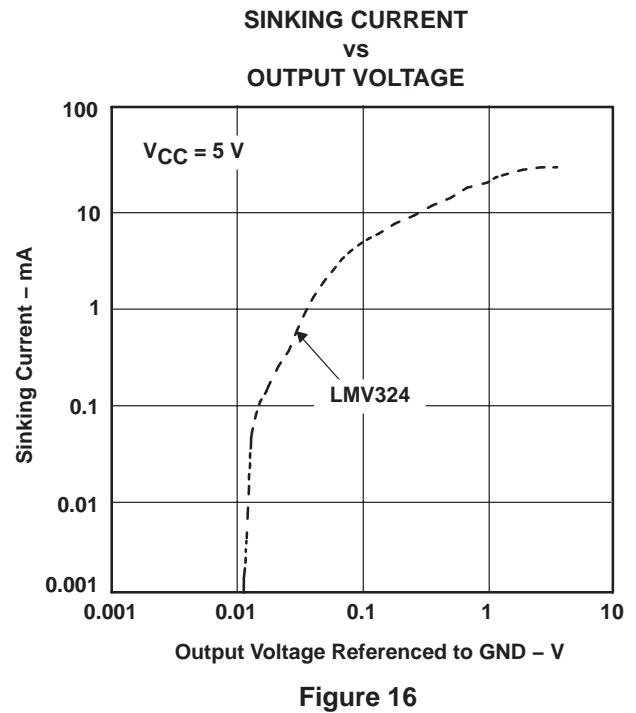
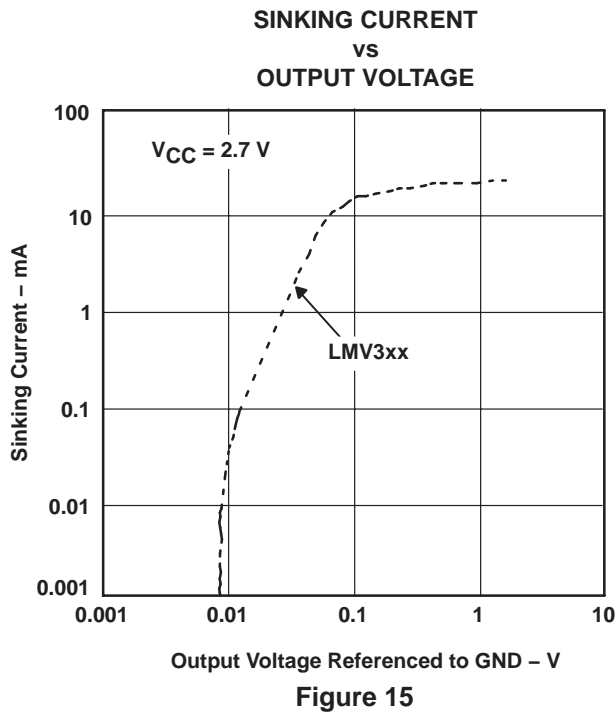
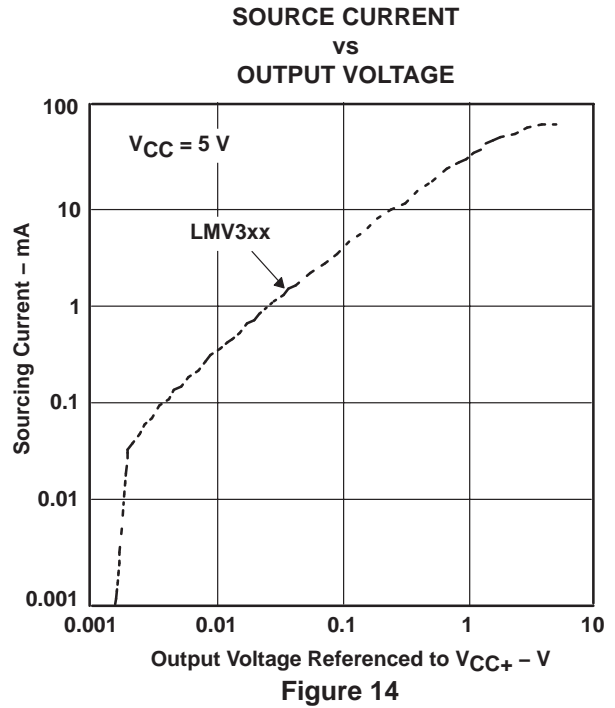
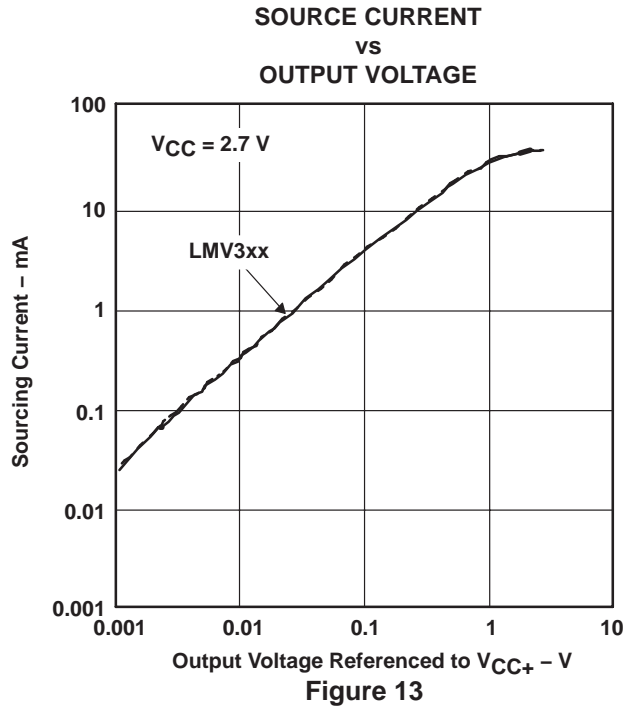


Figure 12

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

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TYPICAL CHARACTERISTICS



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

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TYPICAL CHARACTERISTICS

**SHORT-CIRCUIT CURRENT
vs
TEMPERATURE**

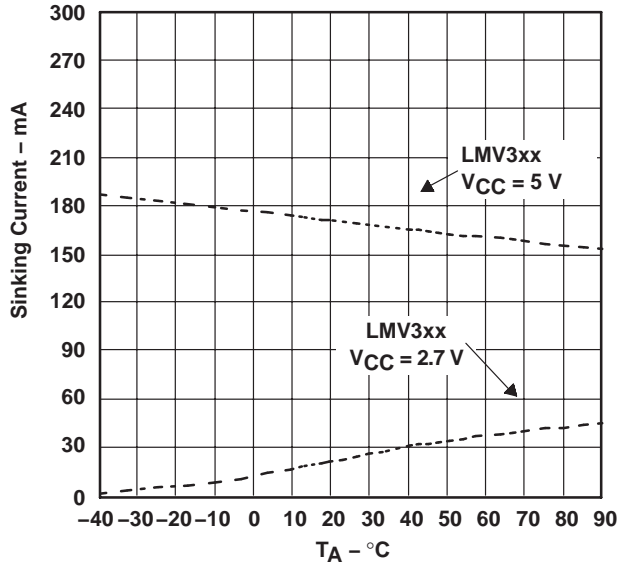


Figure 17

**SHORT-CIRCUIT CURRENT
vs
TEMPERATURE**

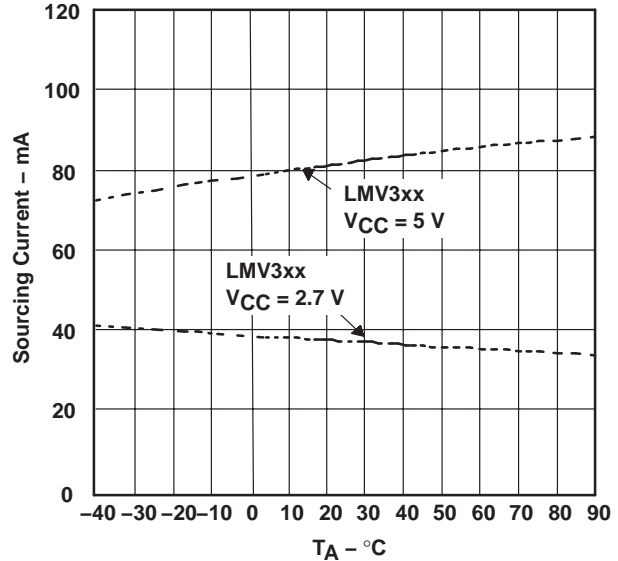


Figure 18

**-k_{SVR}
vs
FREQUENCY**

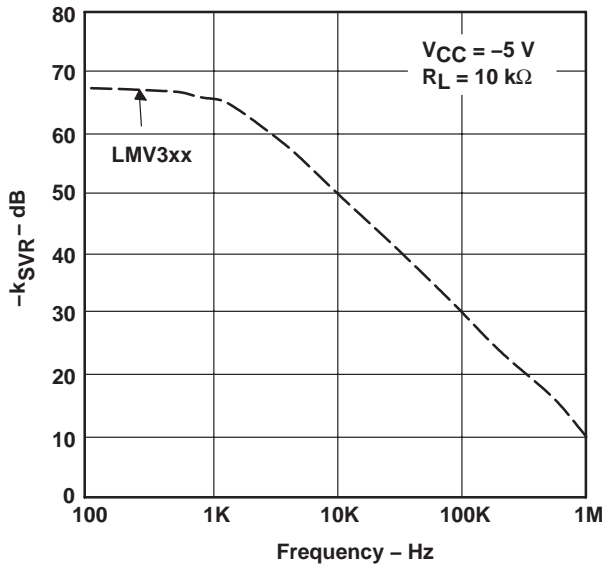


Figure 19

**+k_{SVR}
vs
FREQUENCY**

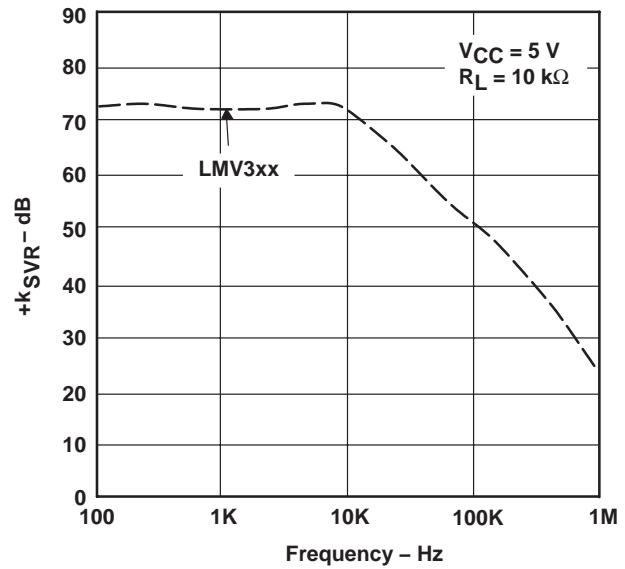
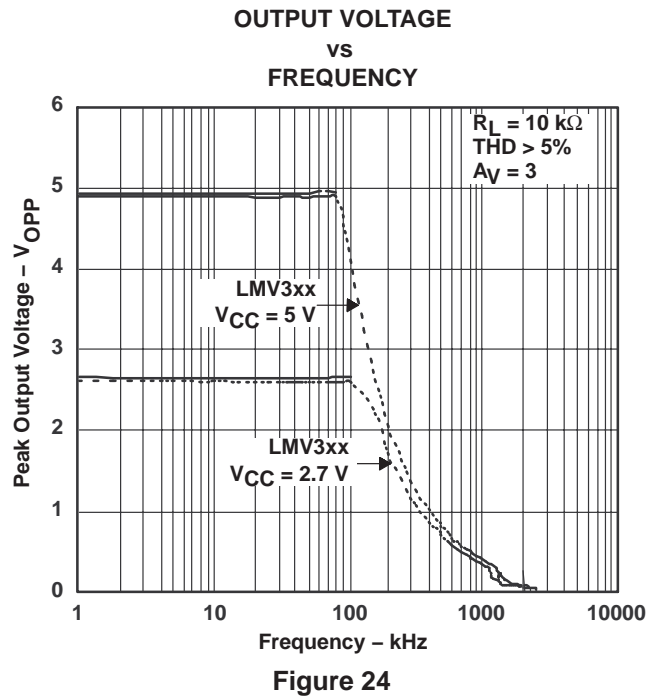
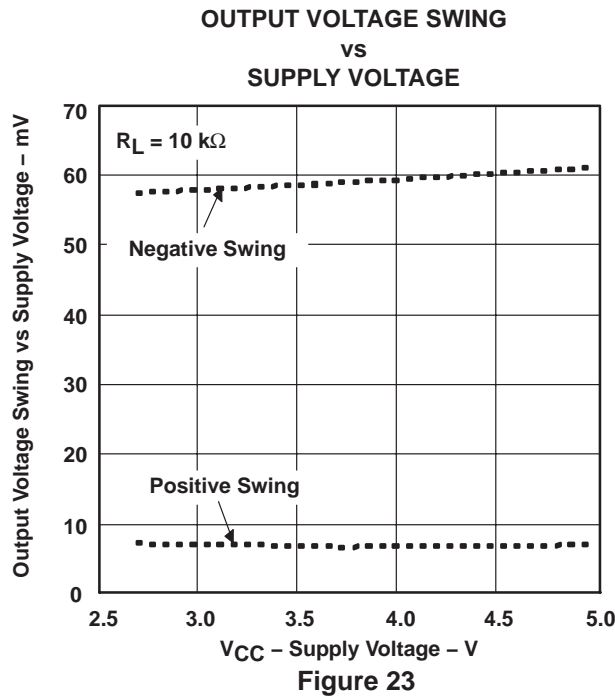
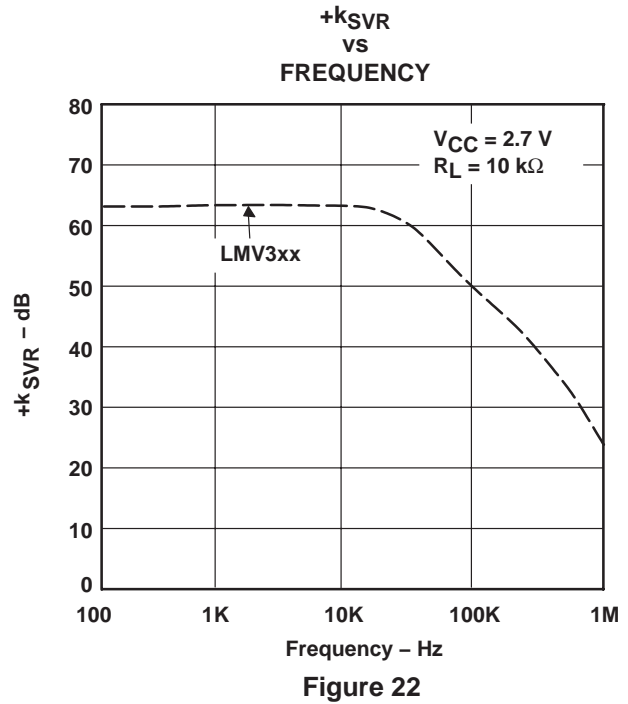
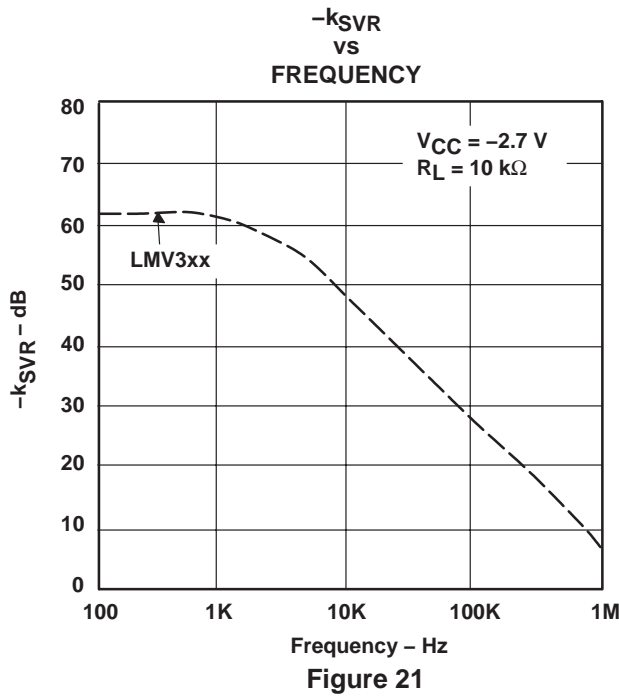


Figure 20

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

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TYPICAL CHARACTERISTICS



**LMV321-Q1 SINGLE, LMV358-Q1 DUAL, LMV324-Q1 QUAD
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OPERATIONAL AMPLIFIERS**

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TYPICAL CHARACTERISTICS

**OPEN-LOOP OUTPUT IMPEDANCE
VS
FREQUENCY**

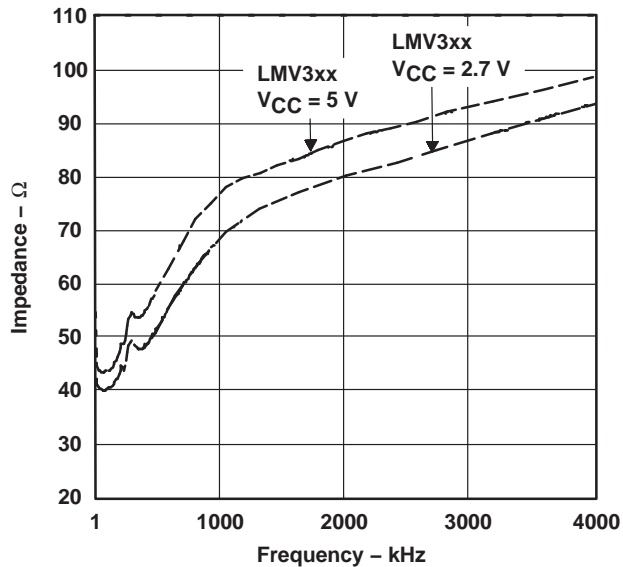


Figure 25

**CROSSTALK REJECTION
VS
FREQUENCY**

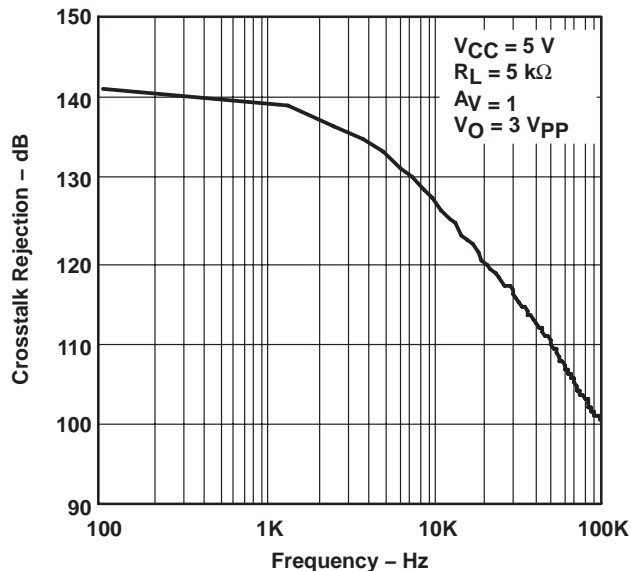
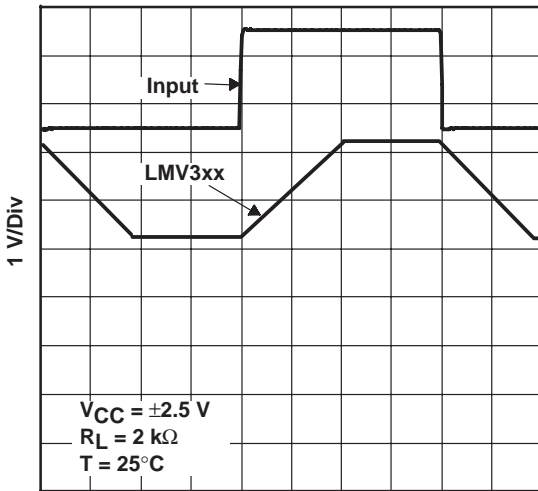


Figure 26

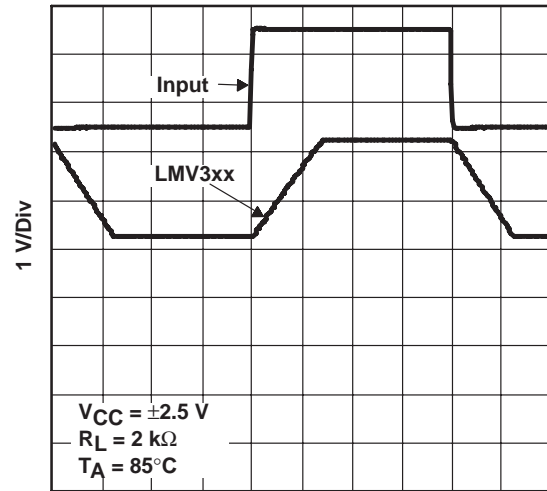
TYPICAL CHARACTERISTICS

NONINVERTING LARGE-SIGNAL
PULSE RESPONSE



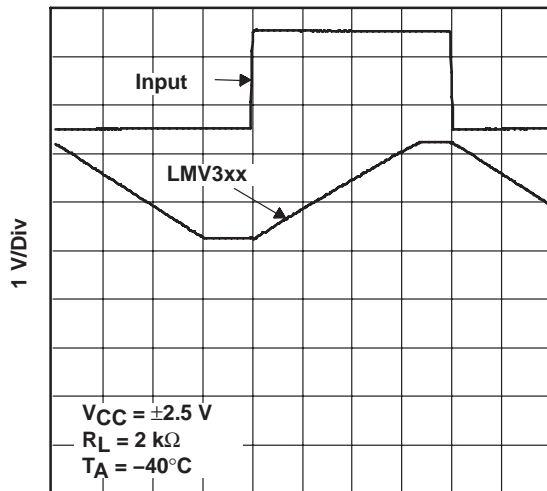
1 $\mu\text{s}/\text{Div}$
Figure 27

NONINVERTING LARGE-SIGNAL
PULSE RESPONSE



1 $\mu\text{s}/\text{Div}$
Figure 28

NONINVERTING LARGE-SIGNAL
PULSE RESPONSE



1 $\mu\text{s}/\text{Div}$
Figure 29

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

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TYPICAL CHARACTERISTICS

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

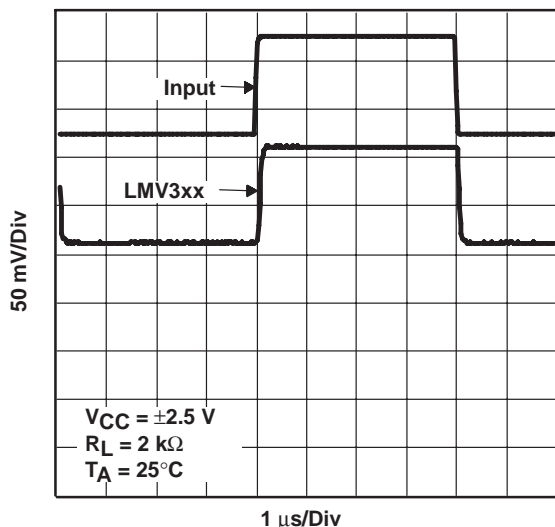


Figure 30

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

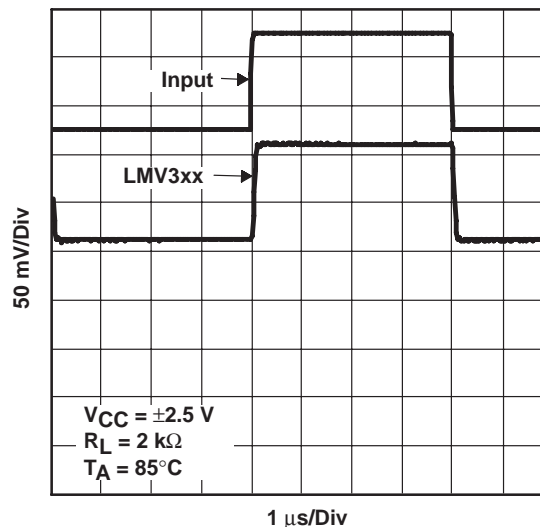


Figure 31

NONINVERTING SMALL-SIGNAL PULSE RESPONSE

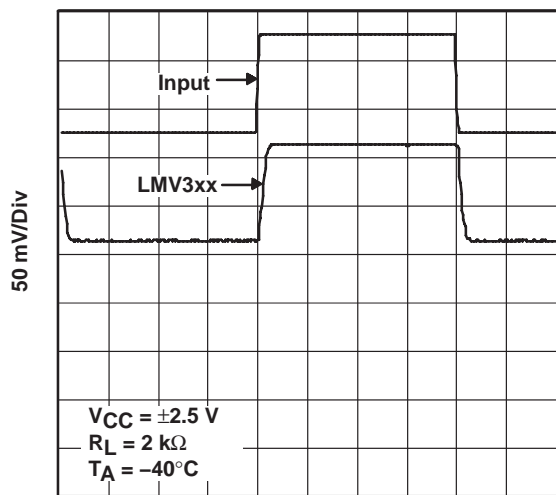


Figure 32

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL
PULSE RESPONSE

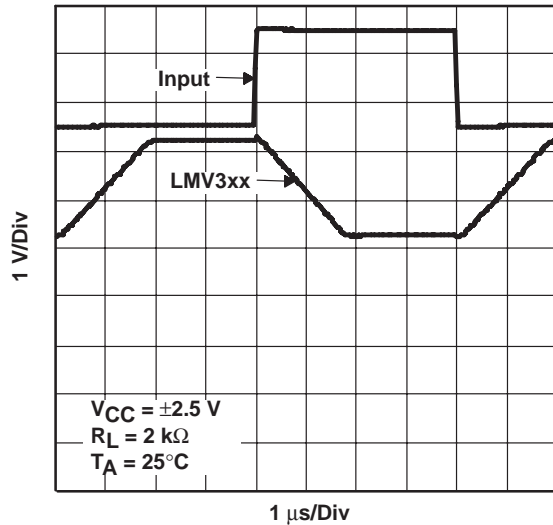


Figure 33

INVERTING LARGE-SIGNAL
PULSE RESPONSE

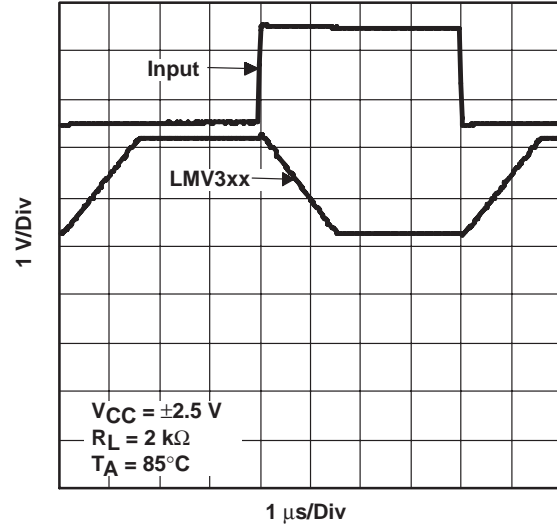


Figure 34

INVERTING LARGE-SIGNAL
PULSE RESPONSE

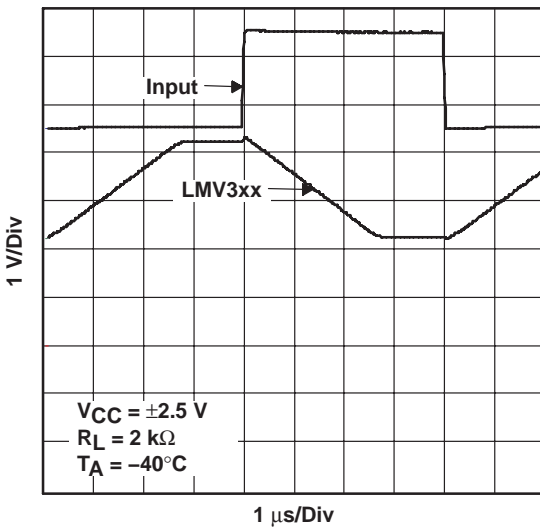


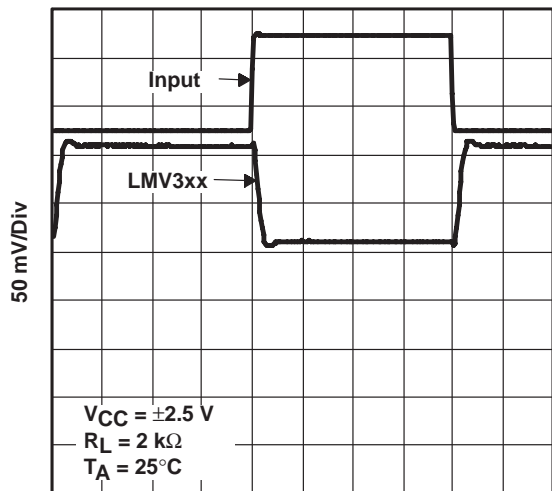
Figure 35

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

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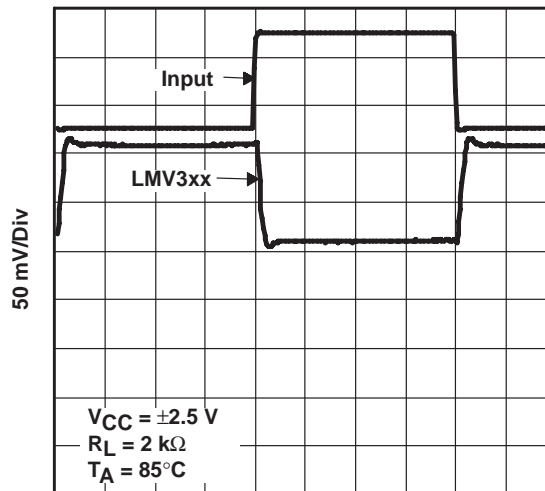
TYPICAL CHARACTERISTICS

INVERTING SMALL-SIGNAL PULSE RESPONSE



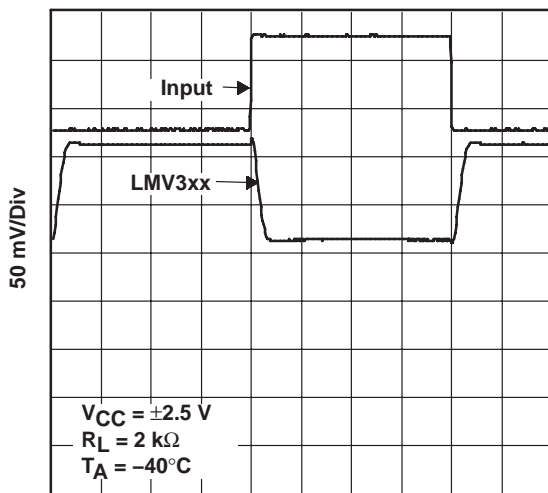
1 $\mu\text{s}/\text{Div}$
Figure 36

INVERTING SMALL-SIGNAL PULSE RESPONSE



1 $\mu\text{s}/\text{Div}$
Figure 37

INVERTING SMALL-SIGNAL PULSE RESPONSE



1 $\mu\text{s}/\text{Div}$
Figure 38

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

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TYPICAL CHARACTERISTICS

INPUT CURRENT NOISE
 vs
 FREQUENCY

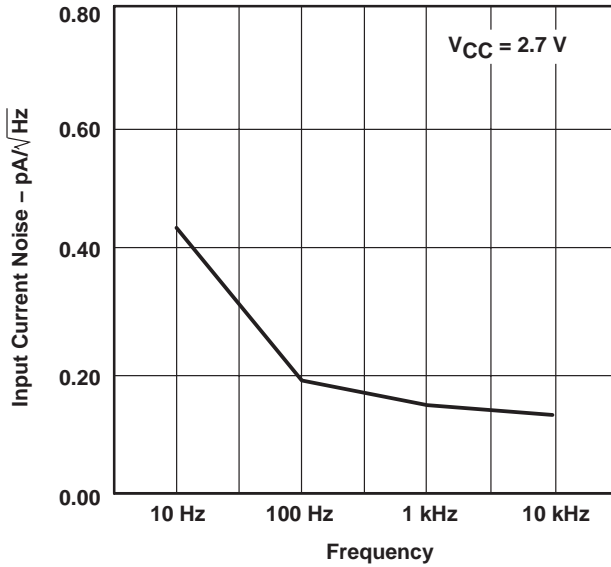


Figure 39

INPUT CURRENT NOISE
 vs
 FREQUENCY

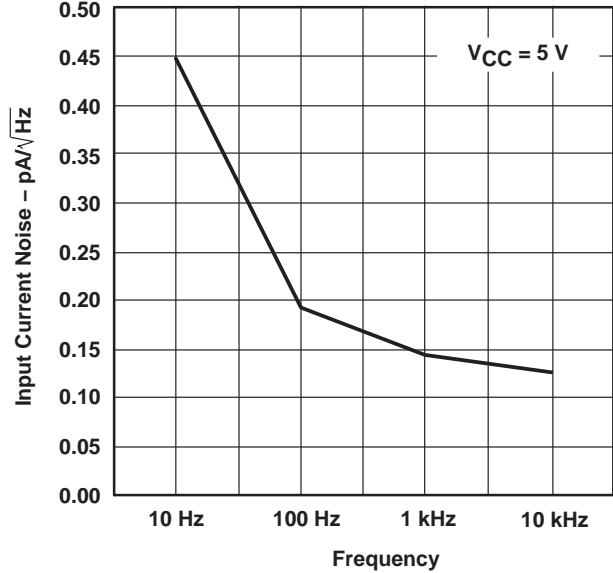


Figure 40

INPUT VOLTAGE NOISE
 vs
 FREQUENCY

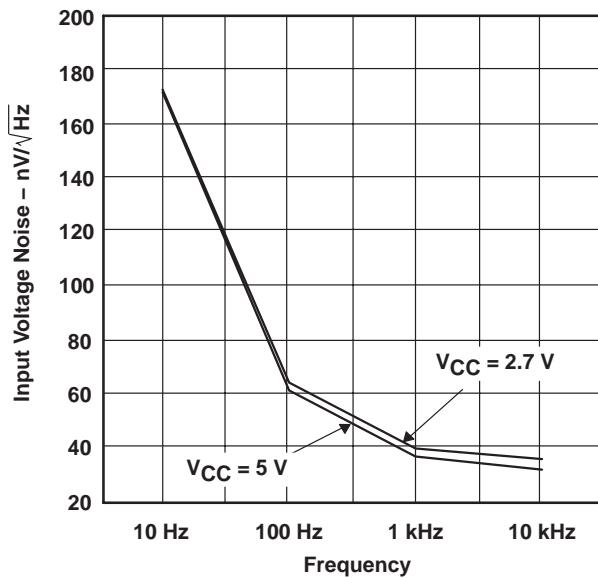
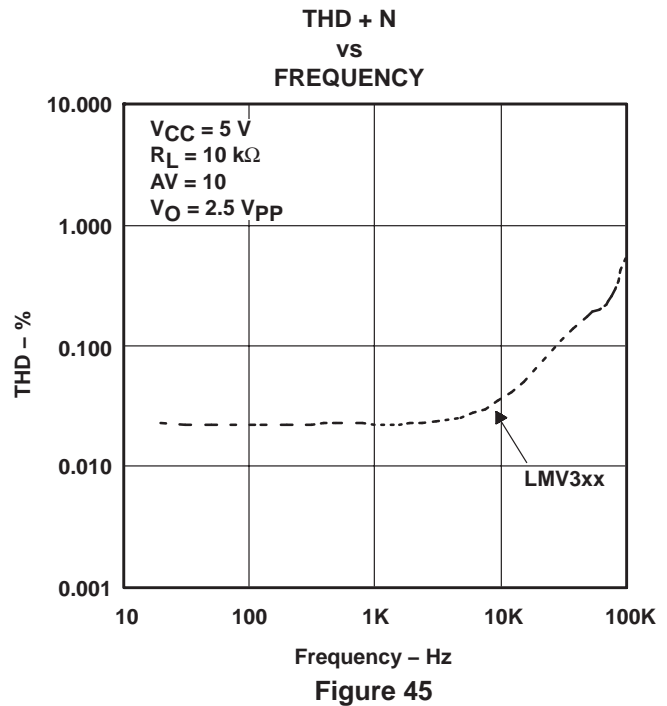
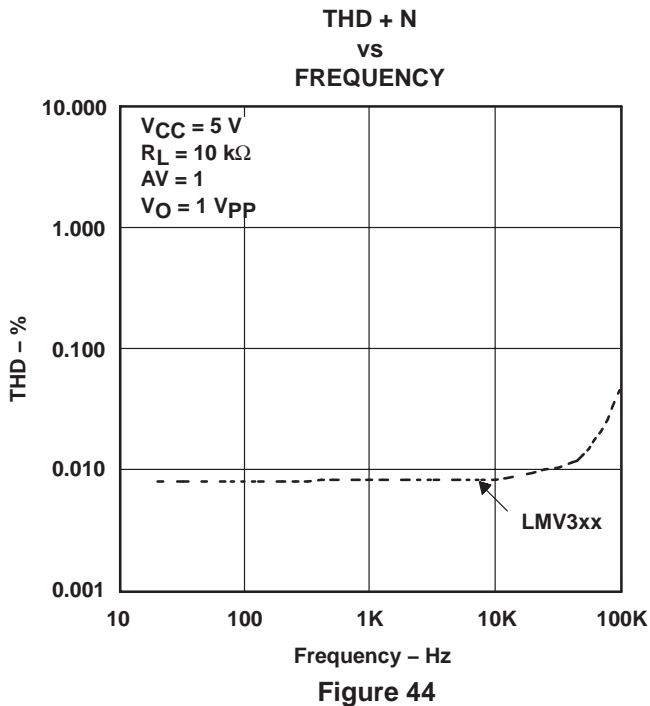
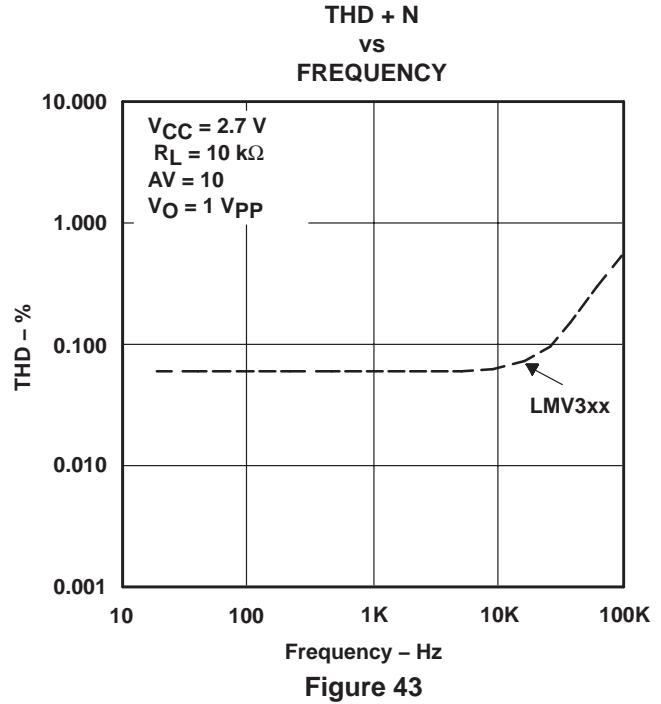
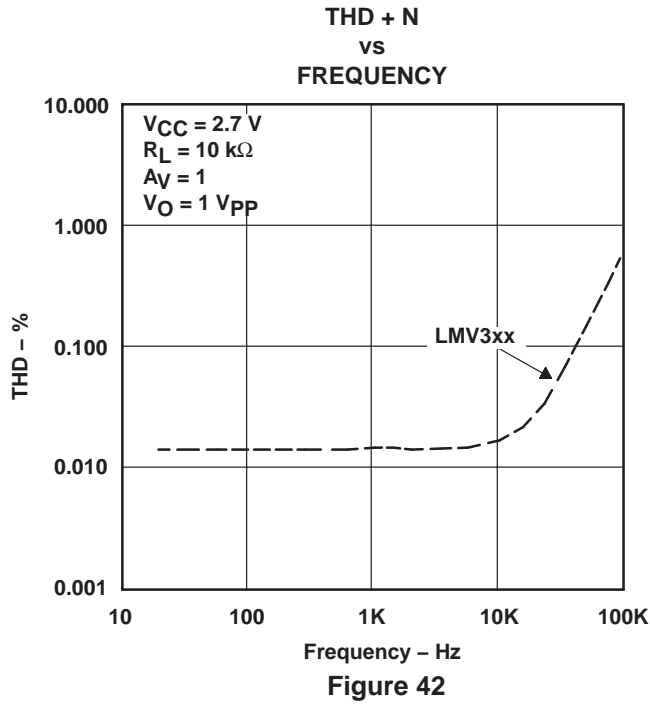


Figure 41

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

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TYPICAL CHARACTERISTICS



PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
LMV321IDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
LMV321QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
LMV324IDRQ1	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
LMV324IPWRQ1	ACTIVE	TSSOP	PW	14	2000	TBD	CU NIPDAU	Level-1-250C-UNLIM
LMV324QDQ1	OBSOLETE	SOIC	D	14		TBD	Call TI	Call TI
LMV324QDRG4Q1	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
LMV324QDRQ1	ACTIVE	SOIC	D	14	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
LMV324QPWRQ1	ACTIVE	TSSOP	PW	14	2000	TBD	CU NIPDAU	Level-1-250C-UNLIM
LMV358IDRQ1	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
LMV358IPWRQ1	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-250C-UNLIM
LMV358QDQ1	OBSOLETE	SOIC	D	8		TBD	Call TI	Call TI
LMV358QDRQ1	ACTIVE	SOIC	D	8	2500	Pb-Free (RoHS)	CU NIPDAU	Level-2-250C-1 YEAR/ Level-1-235C-UNLIM
LMV358QPWQ1	OBSOLETE	TSSOP	PW	8		TBD	Call TI	Call TI
LMV358QPWRQ1	ACTIVE	TSSOP	PW	8	2000	TBD	CU NIPDAU	Level-1-250C-UNLIM

⁽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.

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DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



- 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)

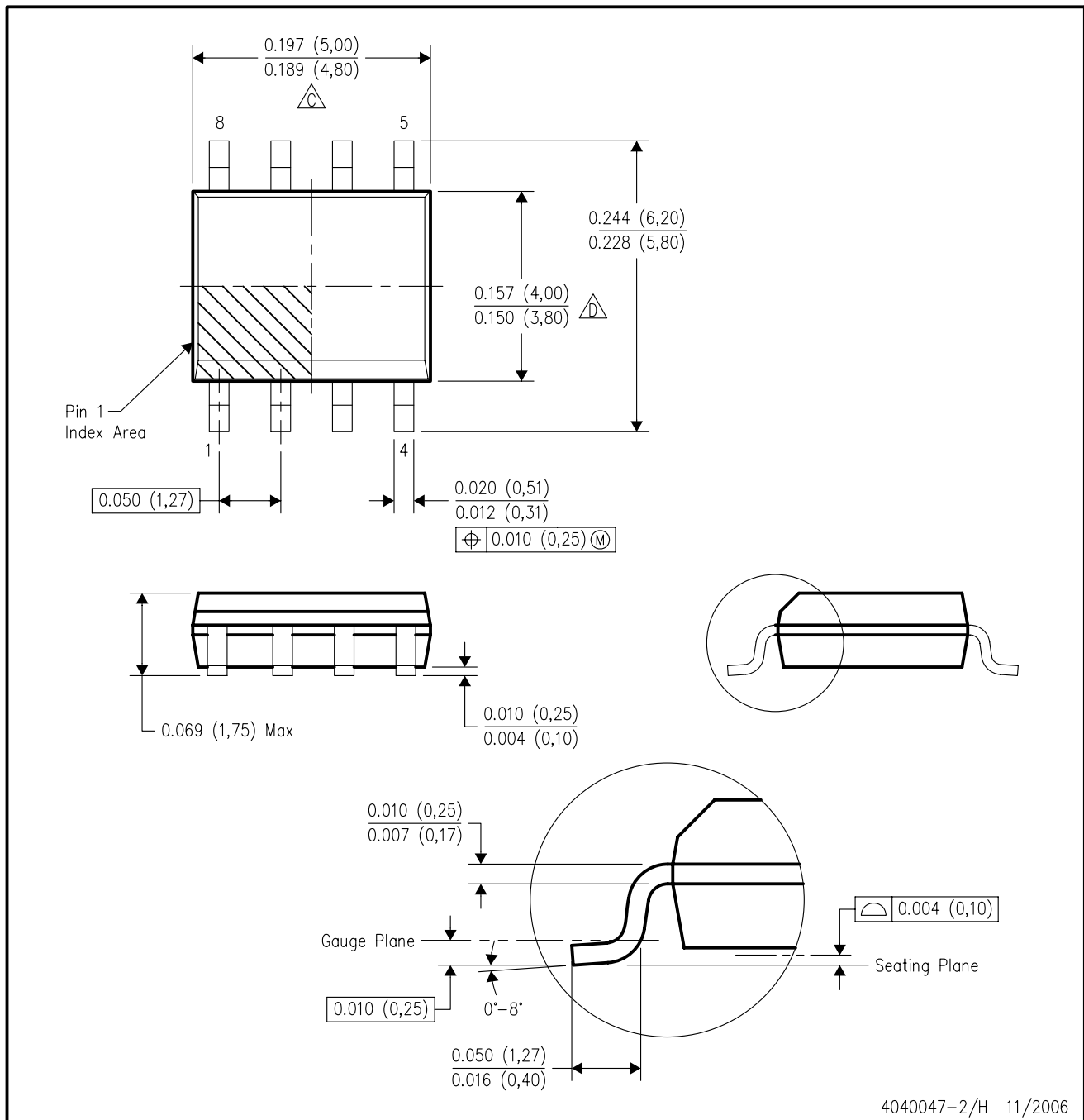
PLASTIC SMALL-OUTLINE PACKAGE



- 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-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.

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



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

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