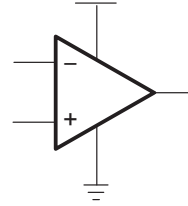


# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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- Supply Current . . . 23  $\mu$ A/Channel
- Gain-Bandwidth Product . . . 220 kHz
- Output Drive Capability . . .  $\pm$ 10 mA
- Input Offset Voltage . . . 20  $\mu$ V (typ)
- $V_{DD}$  Range . . . 2.7 V to 6 V
- Power Supply Rejection Ratio . . . 106 dB
- Ultralow-Power Shutdown Mode  
 $I_{DD}$  . . . 16 nA/ch
- Rail-To-Rail Input/Output (RRIO)
- Ultrasmall Packaging
  - 5 or 6 Pin SOT-23 (TLV2450/1)
  - 8 or 10 Pin MSOP (TLV2452/3)

Operational Amplifier



## description

The TLV245x is a family of rail-to-rail input/output operational amplifiers that sets a new performance point for supply current and ac performance. These devices consume a mere 23  $\mu$ A/channel while offering 220 kHz of gain-bandwidth product, much higher than competitive devices with similar supply current levels. Along with increased ac performance, the amplifier provides high output drive capability, solving a major shortcoming of older micropower rail-to-rail input/output operational amplifiers. The TLV245x can swing to within 250 mV of each supply rail while driving a 2.5-mA load. Both the inputs and outputs swing rail-to-rail for increased dynamic range in low-voltage applications. This performance makes the TLV245x family ideal for portable medical equipment, patient monitoring systems, and data acquisition circuits.

FAMILY PACKAGE TABLE

DEVICE	NUMBER OF CHANNELS	PACKAGE TYPES					SHUTDOWN	UNIVERSAL EVM BOARD
		PDIP	SOIC	SOT-23	TSSOP	MSOP		
TLV2450	1	8	8	6	—	—	Yes	Refer to the EVM Selection Guide (Lit# SLOU060)
TLV2451	1	8	8	5	—	—	—	
TLV2452	2	8	8	—	—	8	—	
TLV2453	2	14	14	—	—	10	Yes	
TLV2454	4	14	14	—	14	—	—	
TLV2455	4	16	16	—	16	—	Yes	

A SELECTION OF SINGLE-SUPPLY OPERATIONAL AMPLIFIER PRODUCTS†

DEVICE	$V_{DD}$ (V)	BW (MHz)	SLEW RATE (V/ $\mu$ s)	$I_{DD}$ (per channel) ( $\mu$ A)	RAIL-TO-RAIL
TLV245X	2.7 – 6.0	0.22	0.11	23	I/O
TLV247X	2.7 – 6.0	2.8	1.5	600	I/O
TLV246X	2.7 – 6.0	6.4	1.6	550	I/O
TLV277X	2.5 – 6.0	5.1	10.5	1000	O

† All specifications measured at 5 V.



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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# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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## description (continued)

Three members of the family (TLV2450/3/5) offer a shutdown terminal for conserving battery life in portable applications. During shutdown, the outputs are placed in a high-impedance state and the amplifier consumes only 16 nA/channel. The family is fully specified at 3 V and 5 V across an expanded industrial temperature range (–40°C to 125°C). The singles and duals are available in the SOT23 and MSOP packages, while the quads are available in TSSOP. The TLV2450 offers an amplifier with shutdown functionality all in a 6-pin SOT23 package, making it perfect for high density circuits.

TLV2450 and TLV2451 AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES			
	SMALL OUTLINE (D) <sup>†</sup>	SOT-23		PLASTIC DIP (P)
		(DBV)	SYMBOL	
0°C to 70°C	TLV2450CD TLV2451CD	TLV2450CDBV TLV2451CDBV	VAQC VARC	TLV2450CP TLV2451CP
–40°C to 125°C	TLV2450ID TLV2451ID	TLV2450IDBV TLV2451IDBV	VAQI VARI	TLV2450IP TLV2451IP
	TLV2450AID TLV2451AID	— —	— —	TLV2450AIP TLV2451AIP

<sup>†</sup> This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2450CDR).

TLV2452 and TLV2453 AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES						
	SMALL OUTLINE (D) <sup>†</sup>	MSOP				PLASTIC DIP (N)	PLASTIC DIP (P)
		(DGK) <sup>†</sup>	SYMBOL <sup>‡</sup>	(DGS) <sup>†</sup>	SYMBOL <sup>‡</sup>		
0°C to 70°C	TLV2452CD TLV2453CD	TLV2452CDGK —	xxTIABI —	— TLV2453CDGS	— xxTIABK	— TLV2453CN	TLV2452CP —
–40°C to 125°C	TLV2452ID TLV2453ID	TLV2452IDGK —	xxTIABJ —	— TLV2453IDGS	— xxTIABL	— TLV2453IN	TLV2452IP —
	TLV2452AID TLV2453AID	— —	— —	— —	— —	— TLV2453AIN	TLV2452AIP —

<sup>†</sup> This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2452CDR).

<sup>‡</sup> xx represents the device date code.

TLV2454 and TLV2455 AVAILABLE OPTIONS

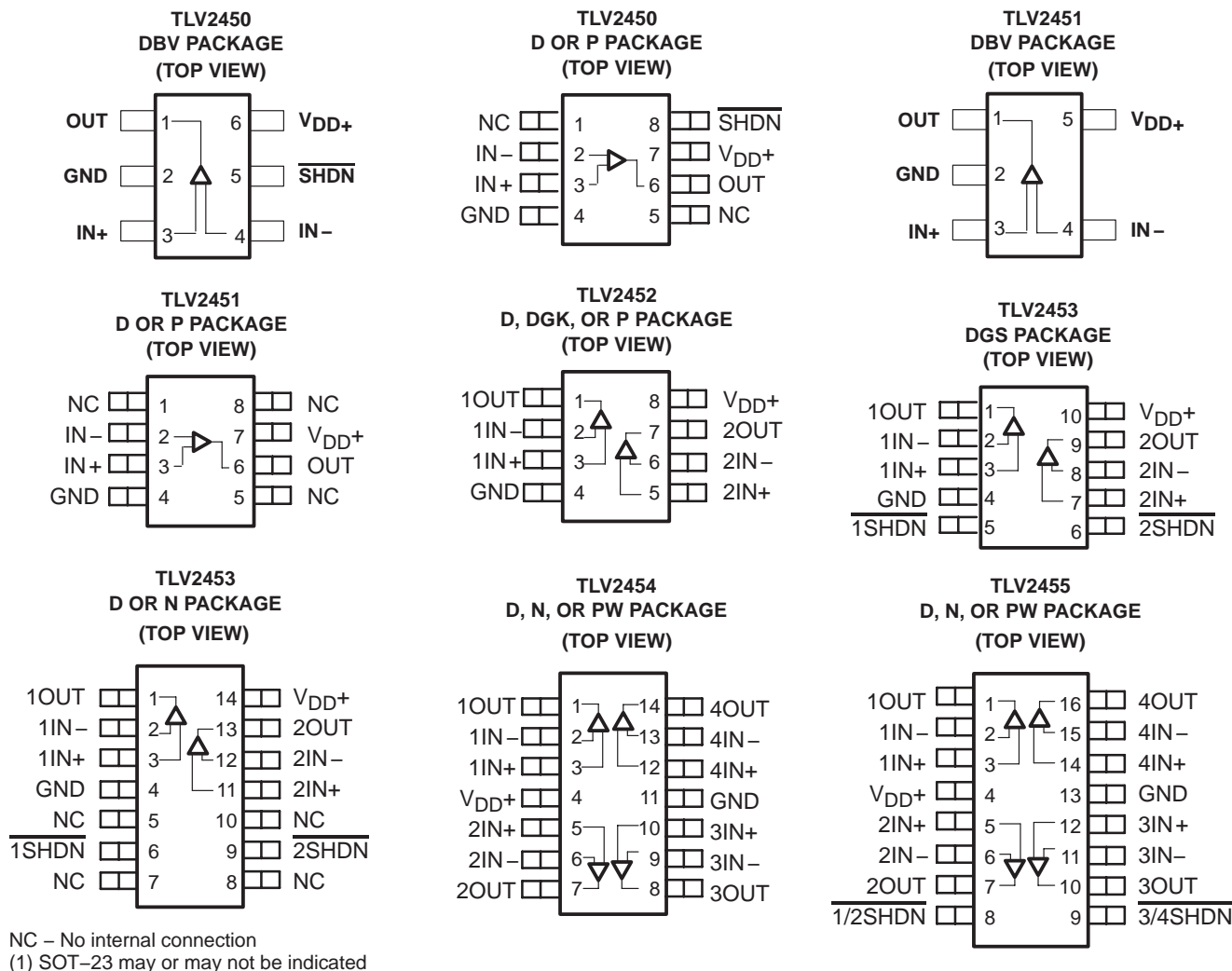
T <sub>A</sub>	PACKAGED DEVICES		
	SMALL OUTLINE (D) <sup>†</sup>	PLASTIC DIP (N)	TSSOP (PW) <sup>†</sup>
0°C to 70°C	TLV2454CD TLV2455CD	TLV2454CN TLV2455CN	TLV2454CPW TLV2455CPW
–40°C to 125°C	TLV2454ID TLV2455ID	TLV2454IN TLV2455IN	TLV2454IPW TLV2455IPW
	TLV2454AID TLV2455AID	TLV2454AIN TLV2455AIN	TLV2454AIPW TLV2455AIPW

<sup>†</sup> This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2454CDR).

# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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## TLV245x PACKAGE PINOUTS(1)



## TYPICAL PIN 1 INDICATORS



# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA

## FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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### absolute maximum ratings over operating free-air temperature range (unless otherwise noted)<sup>†</sup>

Supply voltage, $V_{DD}$ (see Note 1)	7 V
Differential input voltage, $V_{ID}$	$\pm V_{DD}$
Continuous total power dissipation	See Dissipation Rating Table
Operating free-air temperature range, $T_A$ : C suffix	0°C to 70°C
I suffix	-40°C to 125°C
Maximum junction temperature, $T_J$	150°C
Storage temperature range, $T_{stg}$	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

<sup>†</sup> 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.

NOTE: All voltage values, except differential voltages, are with respect to GND.

DISSIPATION RATING TABLE

PACKAGE	$\theta_{JC}$ (°C/W)	$\theta_{JA}$ (°C/W)	$T_A \leq 25^\circ\text{C}$ POWER RATING
D (8)	38.3	176	710 mW
D (14)	26.9	122.3	1022 mW
D (16)	25.7	114.7	1090 mW
DBV (5)	55	324.1	385 mW
DBV (6)	55	294.3	425 mW
DGK (8)	54.2	259.9	481 mW
DGS (10)	54.1	257.7	485 mW
N (14, 16)	32	78	1600 mW
P (8)	41	104	1200 mW
PW (14)	29.3	173.6	720 mW
PW (16)	28.7	161.4	774 mW

### recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, $V_{DD}$	Single supply	2.7	6	V
	Split supply	$\pm 1.35$	$\pm 3$	
Common-mode input voltage range, $V_{ICR}$		0	$V_{DD}$	V
Operating free-air temperature, $T_A$	C-suffix	0	70	°C
	I-suffix	-40	125	
Shutdown on/off voltage level <sup>‡</sup>	$V_{IH}$	2		V
	$V_{IL}$		0.8	

<sup>‡</sup> Relative to voltage on the GND terminal of the device.

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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**electrical characteristics at specified free-air temperature,  $V_{DD} = 3$  V (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage	TLV245x	$V_{DD} = \pm 1.5$ V $V_{IC} = 0,$ $V_O = 0,$ $R_S = 50 \Omega$	25°C	300	1500		$\mu$ V	
				Full range		2000			
		TLV245xA		25°C	300	1000			
				Full range		1300			
$\alpha_{VIO}$	Temperature coefficient of input offset voltage					0.3		$\mu$ V/°C	
$I_{IO}$	Input offset current				25°C	0.3	4.5		nA
					Full range		5.5		
$I_{IB}$	Input bias current				25°C	0.9	5		nA
				Full range		7			
$V_{OH}$	High-level output voltage	$V_{IC} = 1.5$ V,	$I_{OH} = -500 \mu$ A	25°C	2.85	2.95		V	
				Full range	2.83				
$V_{OL}$	Low-level output voltage	$V_{IC} = 1.5$ V,	$I_{OL} = 500 \mu$ A	25°C		0.09	0.16	V	
				Full range			0.2		
$I_{OS}$	Short-circuit output current	Sourcing		25°C	4	12		mA	
				Full range	3				
		Sinking		25°C	2	7			
				Full range	1				
$I_O$	Output current	$V_O = 0.5$ V from rail		25°C		$\pm 4$	mA		
$A_{VD}$	Large-signal differential voltage amplification	$V_{O(PP)} = 1$ V, $R_L = 10$ k $\Omega$		25°C	96	110		dB	
				Full range	91				
$r_{i(d)}$	Differential input resistance			25°C		$10^9$		$\Omega$	
$C_{IC}$	Common-mode input capacitance	$f = 10$ kHz		25°C		4.5		pF	
$z_o$	Closed-loop output impedance	$f = 10$ kHz,	$A_V = 10$	25°C		80		$\Omega$	
CMRR	Common-mode rejection ratio	$V_{IC} = 0$ to 3 V, $R_S = 50 \Omega$			25°C	70	80	dB	
				TLV245xC	Full range	66			
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 2.7$ V to 6 V, No load		$V_{IC} = V_{DD}/2,$	25°C	76	89	dB	
					Full range	74			
		$V_{DD} = 3$ V to 5 V, No load		$V_{IC} = V_{DD}/2,$	25°C	88	106		
					Full range	84			
$I_{DD}$	Supply current (per channel)	$V_O = 1.5$ V, No load			25°C	23	35	$\mu$ A	
				TLV245xC	Full range		40		
				TLV245xl	Full range		45		
$I_{DD(SHDN)}$	Supply current in shutdown mode (TLV2450, TLV2453, TLV2455) (per channel)	$\overline{SHDN} < 0.8$ V			25°C	12	65	nA	
				TLV245xC	Full range		70		
				TLV245xl	Full range		80		

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for l suffix.

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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operating characteristics at specified free-air temperature,  $V_{DD} = 3\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT	
SR	Slew rate at unity gain	$V_{O(PP)} = 0.8\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 150\text{ pF}$	25°C	0.05	0.11		V/ $\mu$ s	
				Full range	0.02				
$V_n$	Equivalent input noise voltage	f = 100 Hz		25°C		49		nV/ $\sqrt{\text{Hz}}$	
		f = 1 kHz		25°C		51			
$I_n$	Equivalent input noise current	f = 1 kHz		25°C		3.5		pA/ $\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_{O(PP)} = 1.5\text{ V}$ , $R_L = 10\text{ k}\Omega$ , f = 1 kHz	$A_V = 1$	25°C	0.04%				
					$A_V = 10$	0.3%			
					$A_V = 100$	1.5%			
$t_{(on)}$	Amplifier turnon time	$A_V = 5$ , $R_L = \text{OPEN}$ ,		25°C		59		$\mu$ s	
$t_{(off)}$	Amplifier turnoff time	Measured at 50% point		25°C		836		ns	
	Gain-bandwidth product	f = 10 kHz,	$R_L = 10\text{ k}\Omega$	25°C		200		kHz	
$t_s$	Settling time	$V_{(STEP)PP} = 2\text{ V}$ , $A_V = -1$ , $C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%	25°C	26			$\mu$ s	
			0.01%		31				
		$V_{(STEP)PP} = 2\text{ V}$ , $A_V = -1$ , $C_L = 56\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%		26				
			0.01%		31				
$\phi_m$	Phase margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 1000\text{ pF}$	25°C		56°			
	Gain margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 1000\text{ pF}$	25°C		7		dB	

† Full range is 0°C to 70°C for C suffix and -40°C to 125°C for I suffix.

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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**electrical characteristics at specified free-air temperature,  $V_{DD} = 5$  V (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT	
$V_{IO}$	Input offset voltage			25°C	300	1500		$\mu$ V	
				Full range		2000			
				25°C	300	1000			
				Full range		1300			
$\alpha_{VIO}$	Temperature coefficient of input offset voltage		$V_{DD} = \pm 2.5$ V $V_{IC} = 0$ , $V_O = 0$ , $R_S = 50$ $\Omega$			0.3		$\mu$ V/°C	
$I_{IO}$	Input offset current			25°C	0.3	4.5		nA	
				Full range		5.5			
$I_{IB}$	Input bias current			25°C	0.5	5		nA	
				Full range		7			
$V_{OH}$	High-level output voltage		$V_{IC} = 2.5$ V, $I_{OH} = -500$ $\mu$ A	25°C	4.87	4.97		V	
				Full range	4.85				
$V_{OL}$	Low-level output voltage		$V_{IC} = 2.5$ V, $I_{OL} = 500$ $\mu$ A	25°C	0.07	0.15		V	
				Full range		0.16			
$I_{OS}$	Short-circuit output current			Sourcing		25°C	20	32	mA
				Full range		18			
				Sinking		25°C	12	18	
				Full range		10			
$I_O$	Output current		$V_O = 0.5$ V from rail	25°C		$\pm 10$		mA	
$A_{VD}$	Large-signal differential voltage amplification		$V_{O(PP)} = 3$ V, $R_L = 10$ k $\Omega$	25°C	96	103		dB	
				Full range	91				
$r_{i(d)}$	Differential input resistance			25°C		$10^9$		$\Omega$	
$C_{IC}$	Common-mode input capacitance		$f = 10$ kHz	25°C		4.5		pF	
$z_o$	Closed-loop output impedance		$f = 10$ kHz, $A_V = 10$	25°C		45		$\Omega$	
CMRR	Common-mode rejection ratio		$V_{IC} = 0$ to 5 V, $R_S = 50$ $\Omega$	25°C	70	80		dB	
				TLV245xC	Full range	68			
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )		$V_{DD} = 2.7$ V to 6 V, No load $V_{IC} = V_{DD}/2$	25°C	76	89		dB	
				Full range	74				
				25°C	88	106			
				Full range	84				
$I_{DD}$	Supply current (per channel)		$V_O = 2.5$ V, No load	25°C		23	42	$\mu$ A	
				TLV245xC	Full range		44		
				TLV245xl	Full range		46		
$I_{DD(SHDN)}$	Supply current in shutdown mode (TLV2450, TLV2453, TLV2455) (per channel)		$\overline{SHDN} < 0.8$ V	25°C		16	70	nA	
				TLV245xC	Full range		70		
				TLV245xl	Full range		80		

† Full range is 0°C to 70°C for C suffix and -40°C to 125°C for l suffix.

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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operating characteristics at specified free-air temperature,  $V_{DD} = 5\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	$V_{O(PP)} = 2\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 150\text{ pF}$	25°C	0.05	0.11		V/ $\mu$ s
				Full range	0.02			
$V_n$	Equivalent input noise voltage	f = 100 Hz		25°C		49		nV/ $\sqrt{\text{Hz}}$
		f = 1 kHz		25°C		52		
$I_n$	Equivalent input noise current	f = 1 kHz		25°C		3.5		pA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_{O(PP)} = 3\text{ V}$ , $R_L = 10\text{ k}\Omega$ , f = 1 kHz	$A_V = 1$	25°C		0.02%		
			$A_V = 10$			0.18%		
			$A_V = 100$			0.9%		
$t_{(on)}$	Amplifier turnon time	$A_V = 5$ , $R_L = \text{OPEN}$ ,		25°C		59		$\mu$ s
$t_{(off)}$	Amplifier turnoff time	Measured at 50% point		25°C		836		ns
	Gain-bandwidth product	f = 10 kHz,	$R_L = 10\text{ k}\Omega$	25°C		220		kHz
$t_s$	Settling time	$V_{(\text{STEP})PP} = 2\text{ V}$ , $A_V = -1$ , $C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%	25°C		24		$\mu$ s
			0.01%			30		
		$V_{(\text{STEP})PP} = 2\text{ V}$ , $A_V = -1$ , $C_L = 56\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%			25		
			0.01%			30		
$\phi_m$	Phase margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 1000\text{ pF}$	25°C		56°		
	Gain margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 1000\text{ pF}$	25°C		7		dB

† Full range is 0°C to 70°C for C suffix and -40°C to 125°C for I suffix.



**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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**TYPICAL CHARACTERISTICS**

**Table of Graphs**

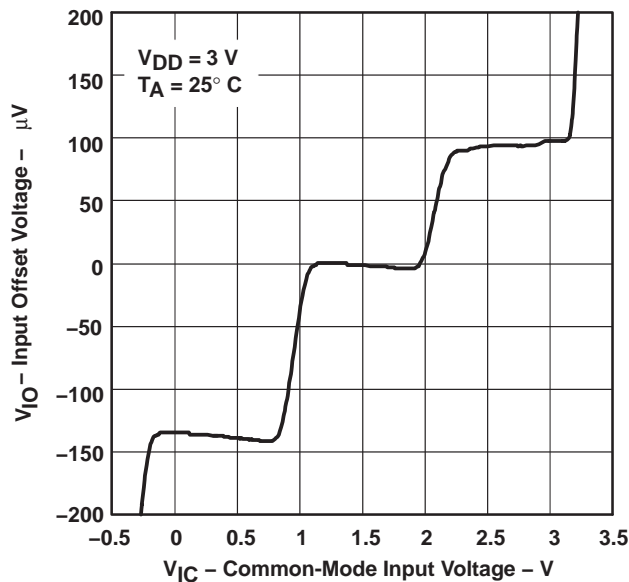
			FIGURE
$V_{IO}$	Input offset voltage	vs Common-mode input voltage	1, 2
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**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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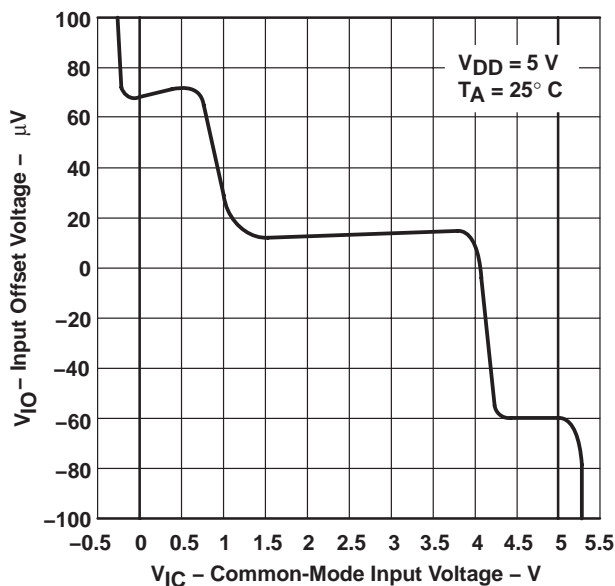
**TYPICAL CHARACTERISTICS**

**INPUT OFFSET VOLTAGE**  
**vs**  
**COMMON-MODE INPUT VOLTAGE**



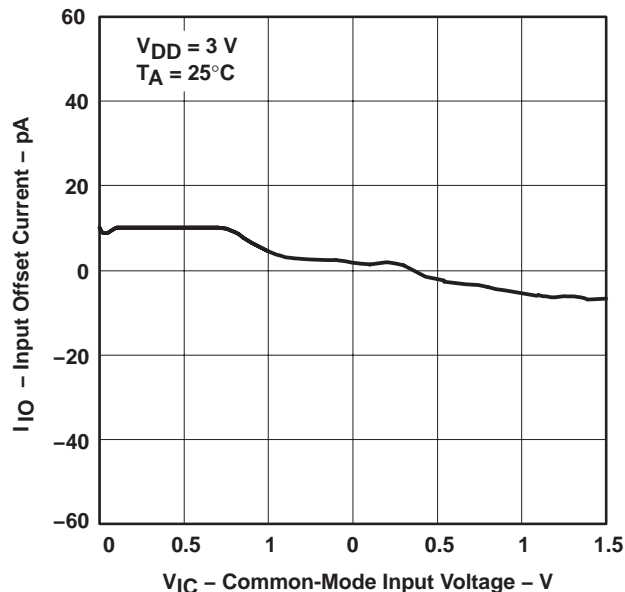
**Figure 1**

**INPUT OFFSET VOLTAGE**  
**vs**  
**COMMON-MODE INPUT VOLTAGE**



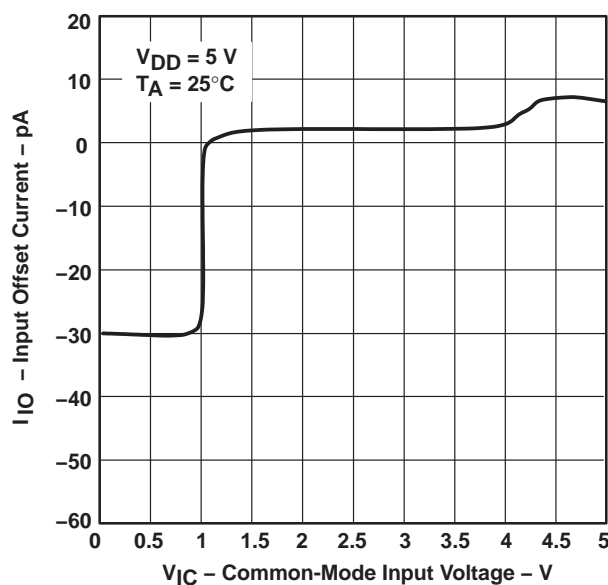
**Figure 2**

**INPUT OFFSET CURRENT**  
**vs**  
**COMMON-MODE INPUT VOLTAGE**



**Figure 3**

**INPUT OFFSET CURRENT**  
**vs**  
**COMMON-MODE INPUT VOLTAGE**



**Figure 4**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-KHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

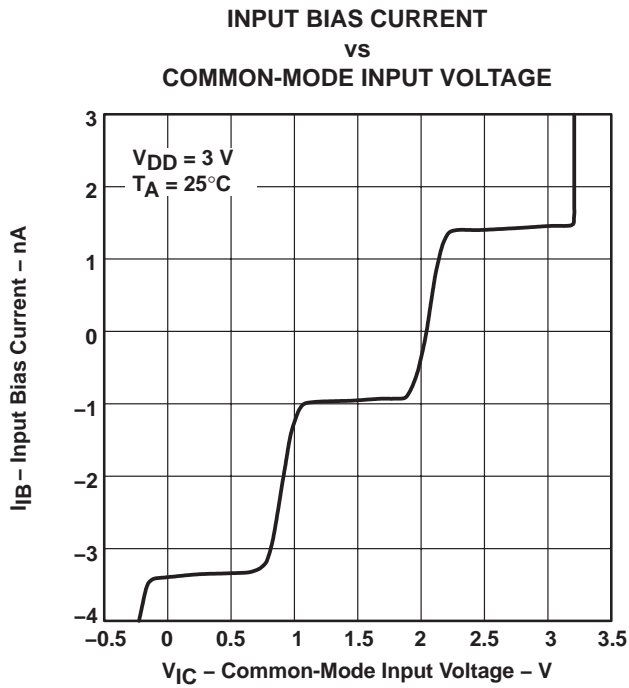


Figure 5

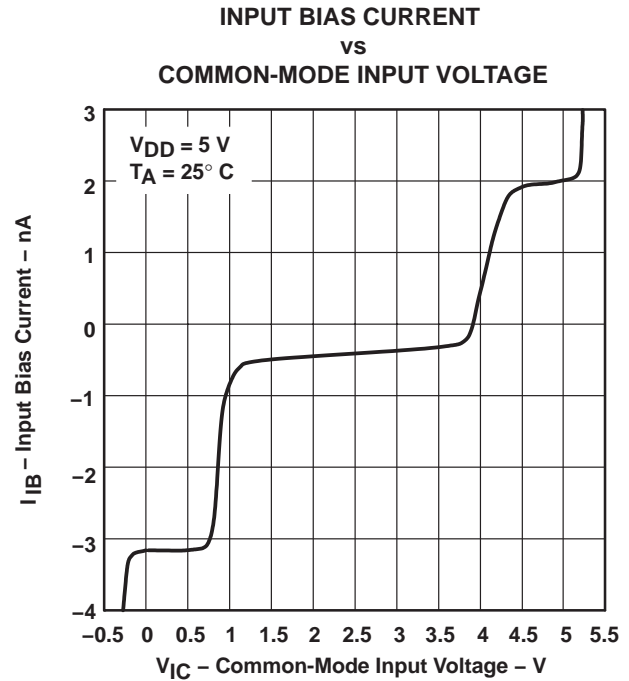


Figure 6

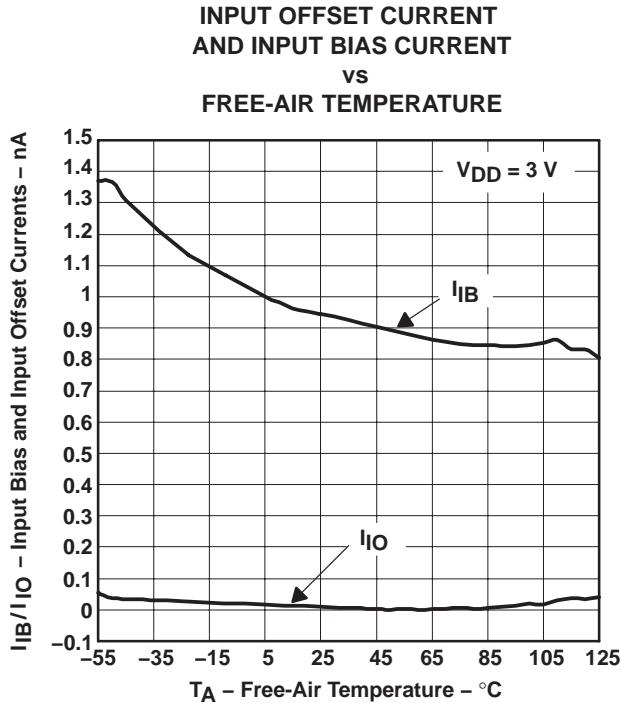


Figure 7

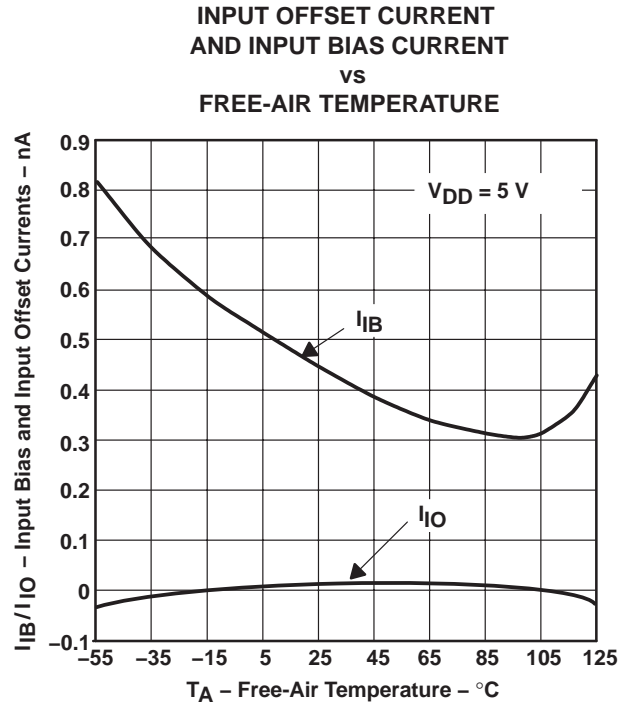


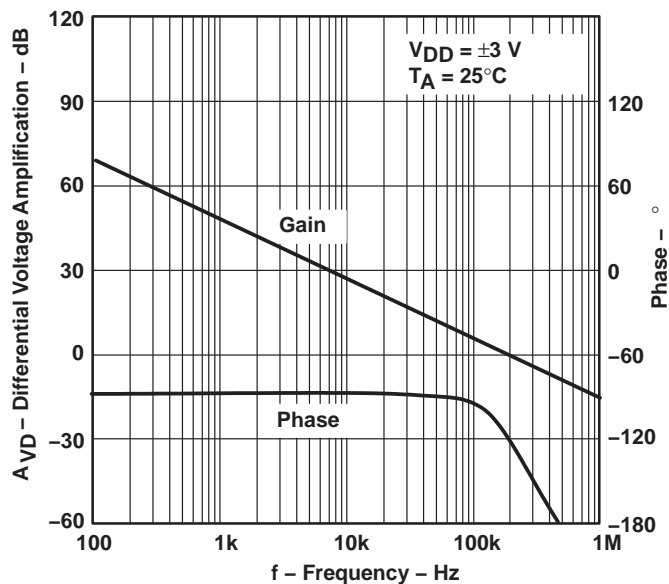
Figure 8

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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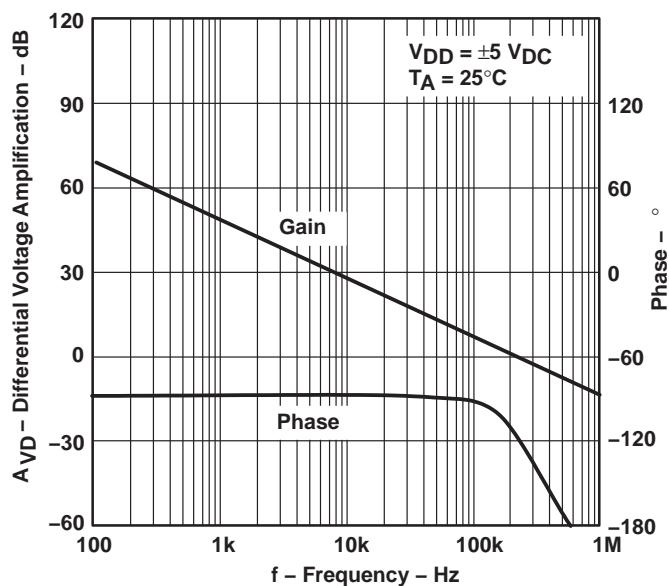
**TYPICAL CHARACTERISTICS**

**DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE**  
**vs**  
**FREQUENCY**



**Figure 9**

**DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE**  
**vs**  
**FREQUENCY**



**Figure 10**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-KHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

LOW-LEVEL OUTPUT VOLTAGE  
 vs  
 LOW-LEVEL OUTPUT CURRENT

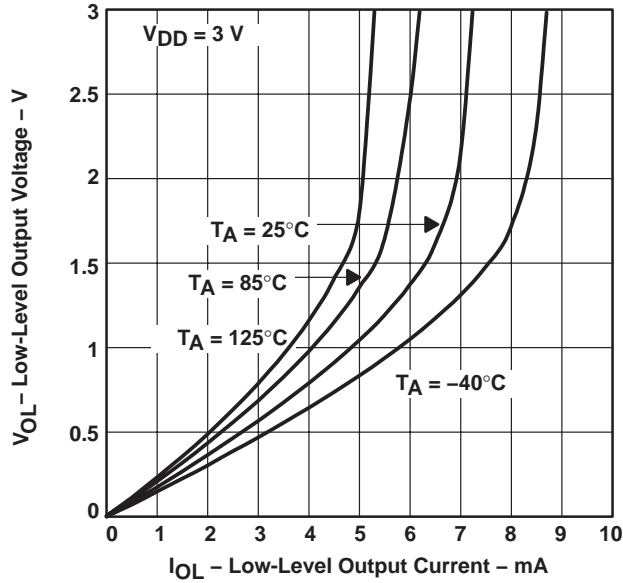


Figure 11

HIGH-LEVEL OUTPUT VOLTAGE  
 vs  
 HIGH-LEVEL OUTPUT CURRENT

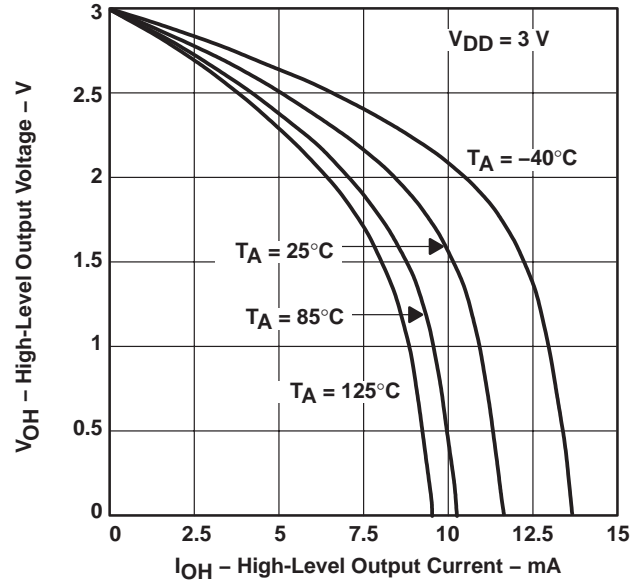


Figure 12

LOW-LEVEL OUTPUT VOLTAGE  
 vs  
 LOW-LEVEL OUTPUT CURRENT

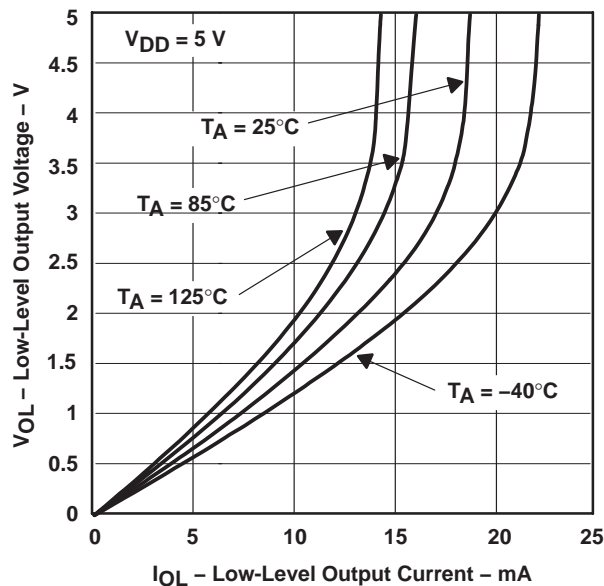


Figure 13

HIGH-LEVEL OUTPUT VOLTAGE  
 vs  
 HIGH-LEVEL OUTPUT CURRENT

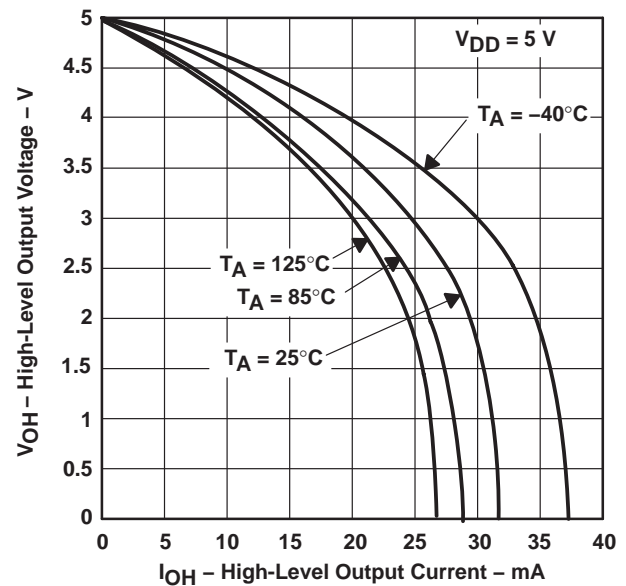


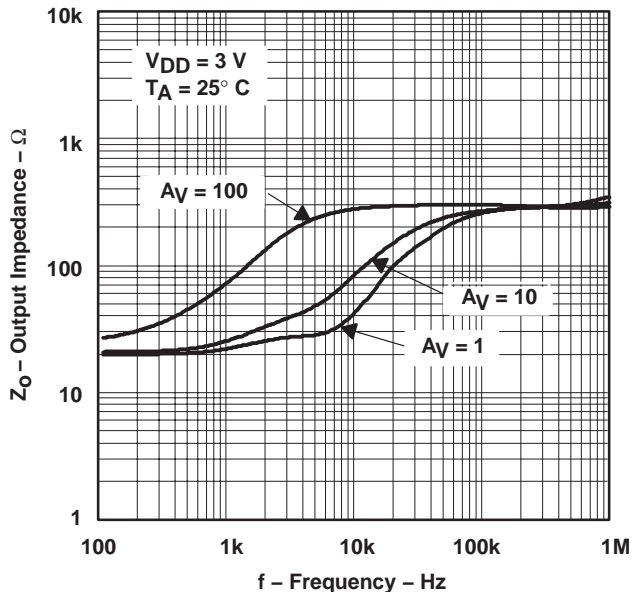
Figure 14

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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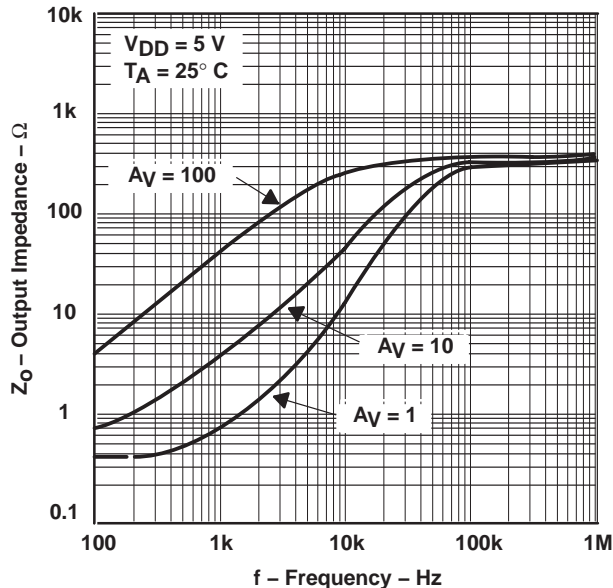
**TYPICAL CHARACTERISTICS**

**OUTPUT IMPEDANCE  
VS  
FREQUENCY**



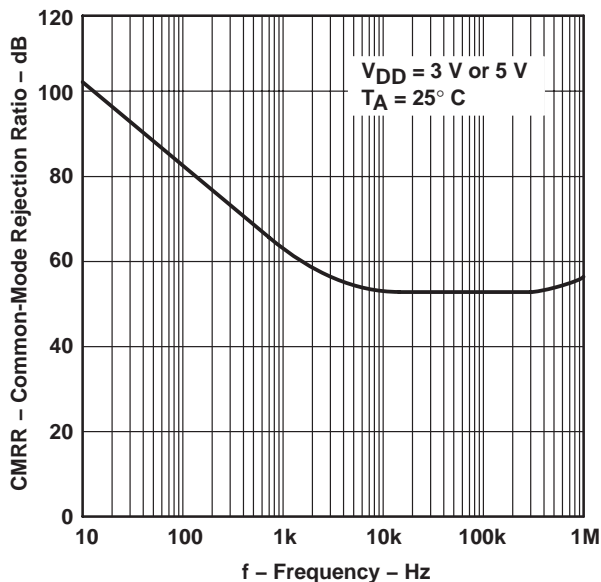
**Figure 15**

**OUTPUT IMPEDANCE  
VS  
FREQUENCY**



**Figure 16**

**COMMON-MODE REJECTION RATIO  
VS  
FREQUENCY**



**Figure 17**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

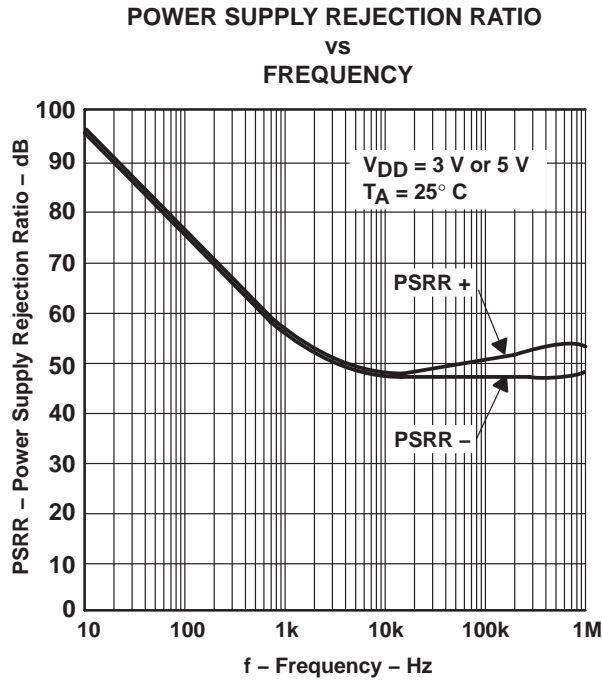


Figure 18

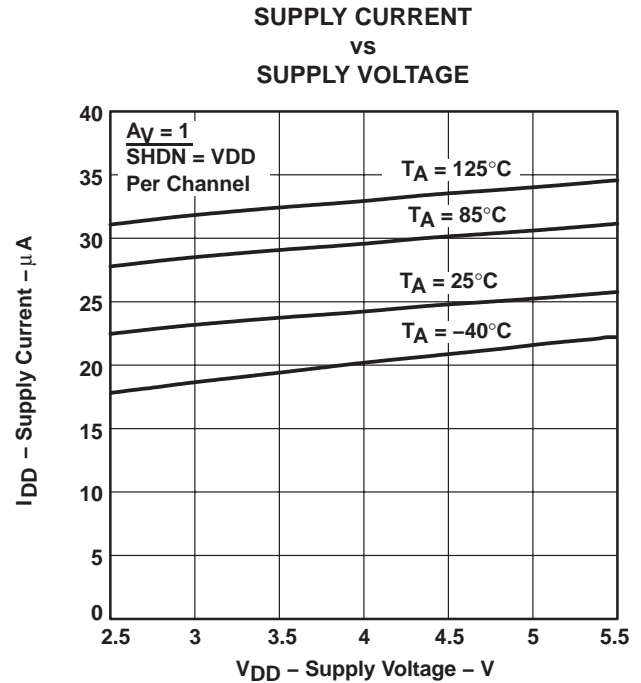


Figure 19

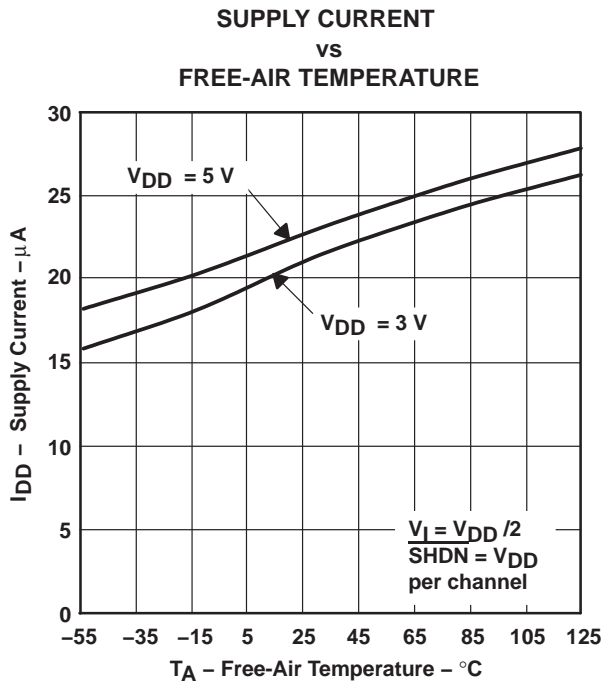


Figure 20

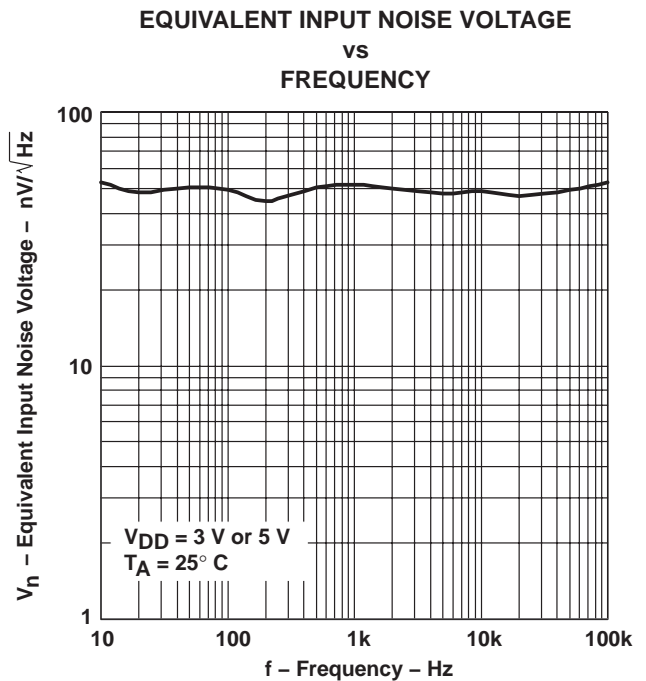


Figure 21

# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA

## FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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### TYPICAL CHARACTERISTICS

**TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY**

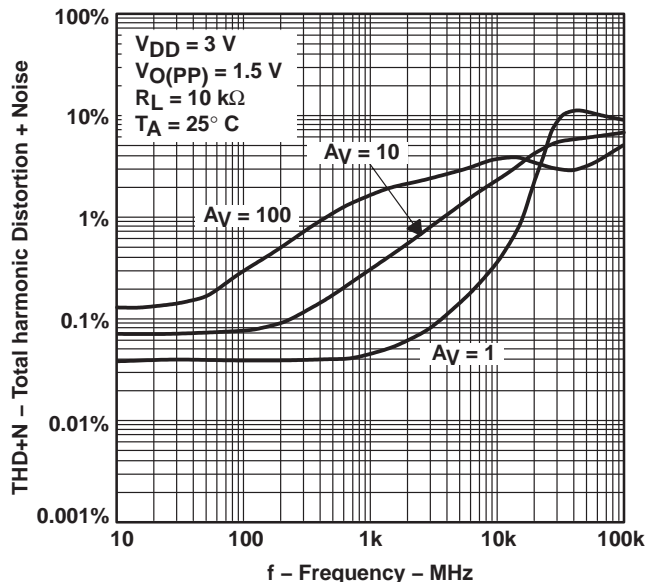


Figure 22

**TOTAL HARMONIC DISTORTION PLUS NOISE  
VS  
FREQUENCY**

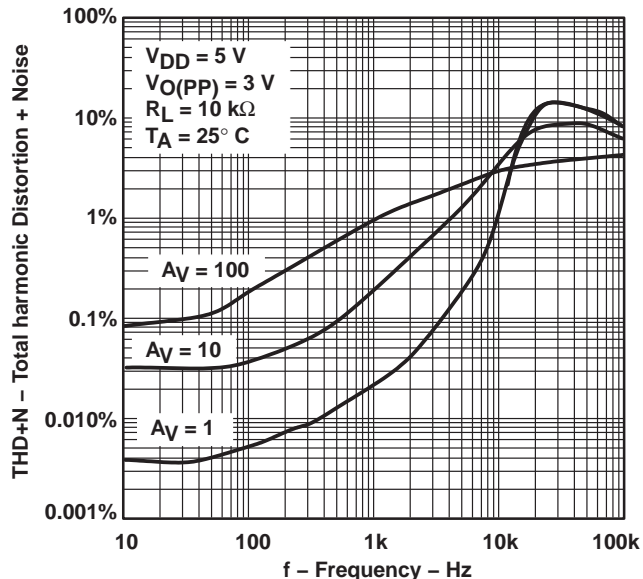


Figure 23

**PHASE MARGIN  
VS  
LOAD CAPACITANCE**

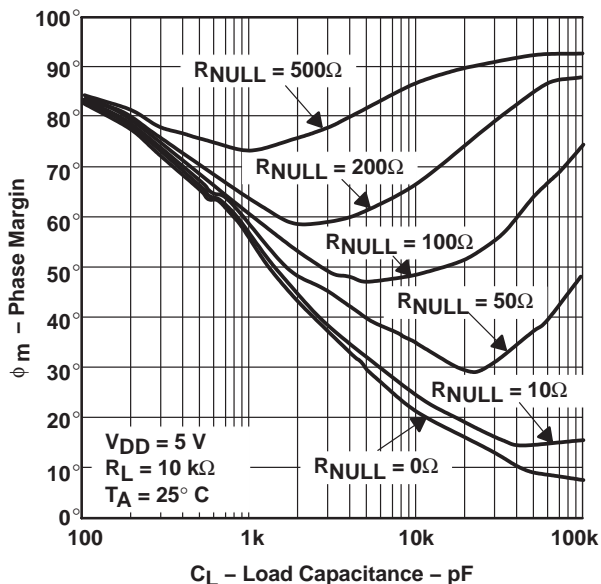


Figure 24

**GAIN-BANDWIDTH PRODUCT  
VS  
SUPPLY VOLTAGE**

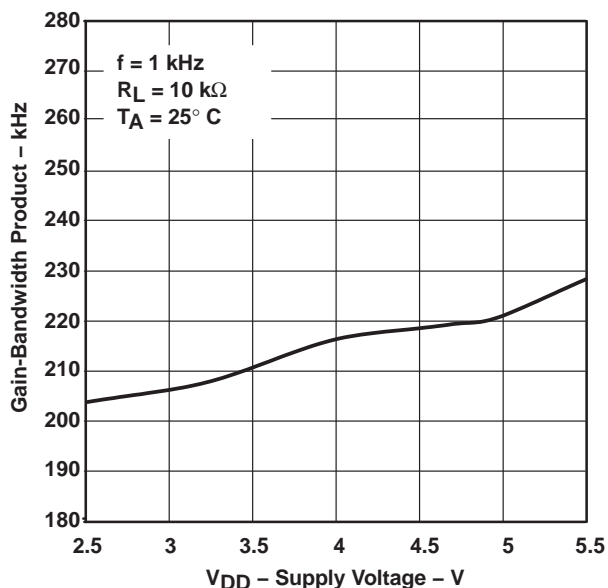


Figure 25



TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

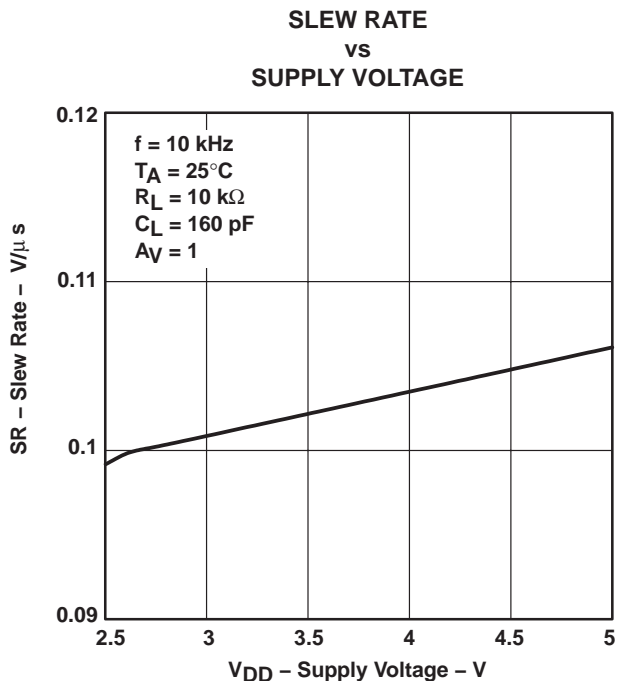


Figure 26

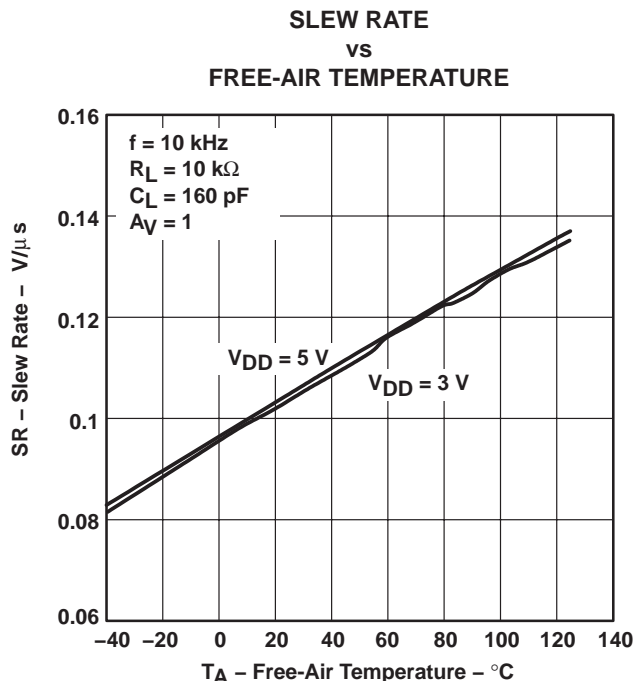


Figure 27

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE  
vs  
FREQUENCY**

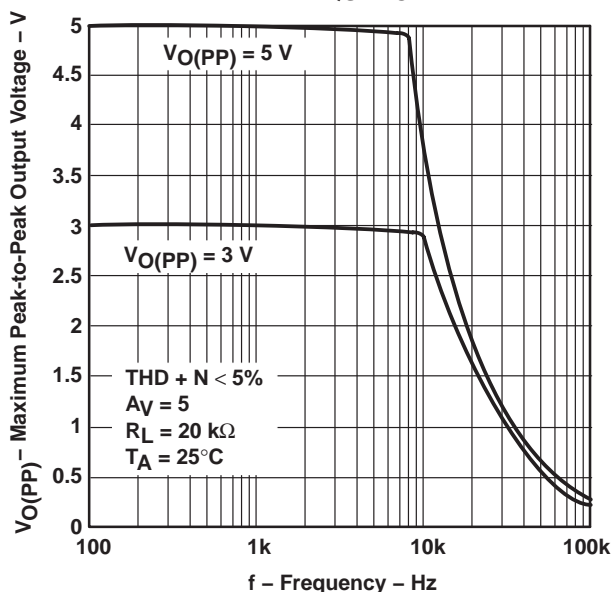


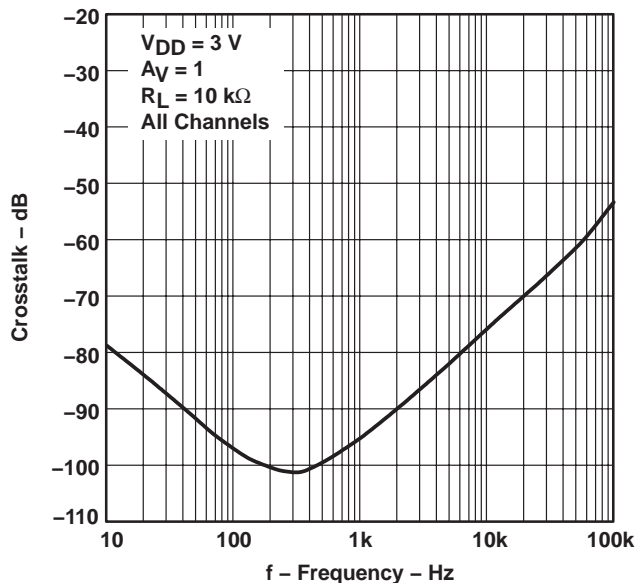
Figure 28

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
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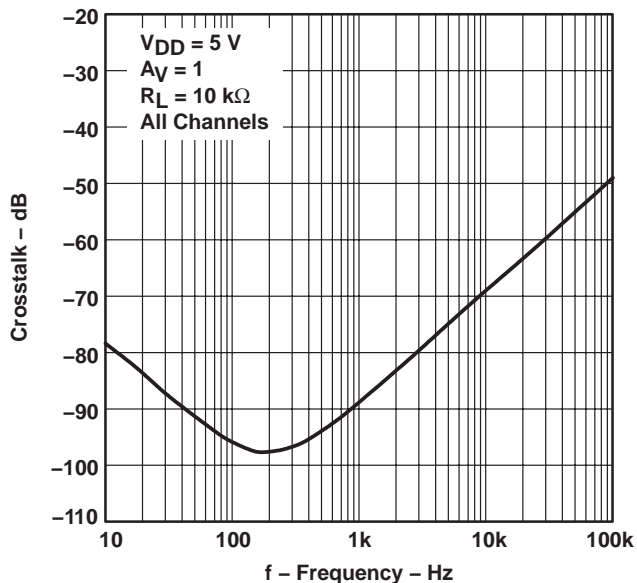
**TYPICAL CHARACTERISTICS**

**CROSTALK**  
**vs**  
**FREQUENCY**



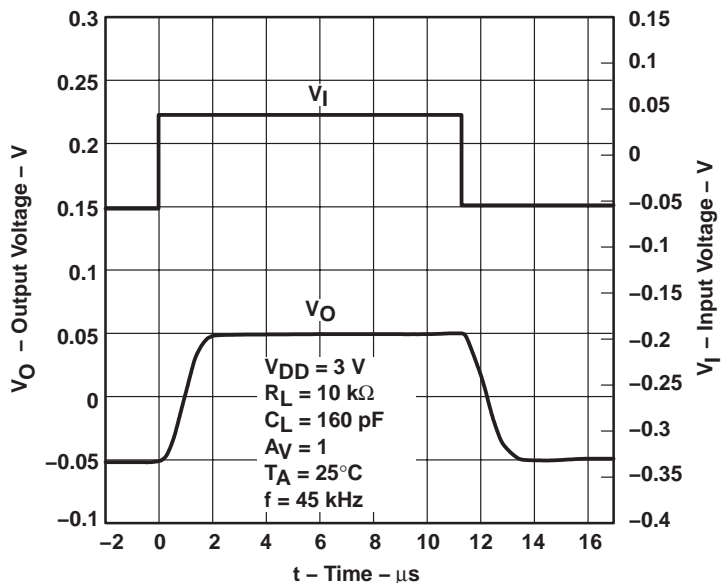
**Figure 29**

**CROSTALK**  
**vs**  
**FREQUENCY**



**Figure 30**

**SMALL-SIGNAL FOLLOWER PULSE RESPONSE**  
**vs**  
**TIME**



**Figure 31**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

LARGE-SIGNAL FOLLOWER PULSE RESPONSE  
 vs  
 TIME

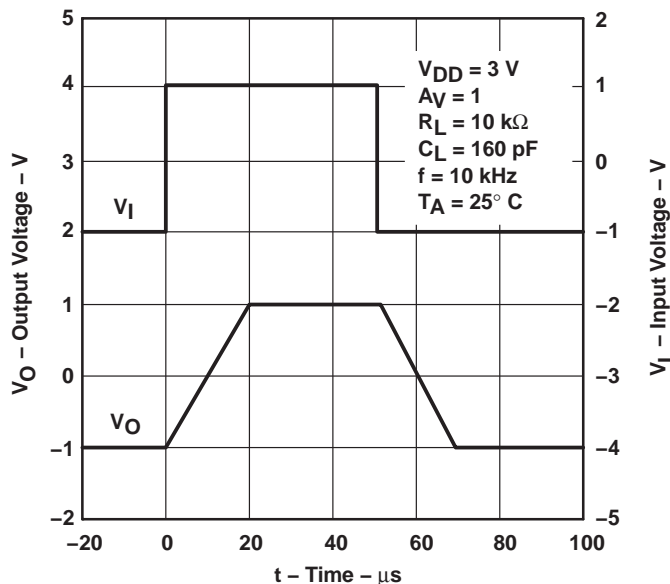


Figure 32

SMALL-SIGNAL FOLLOWER PULSE RESPONSE  
 vs  
 TIME

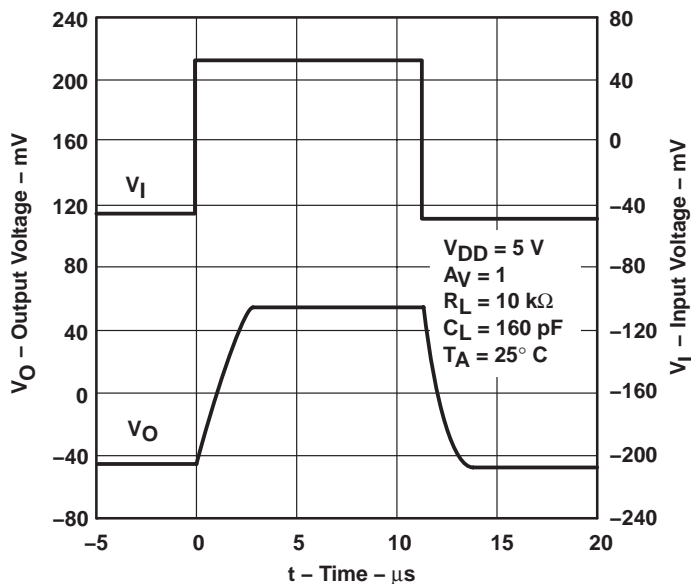


Figure 33

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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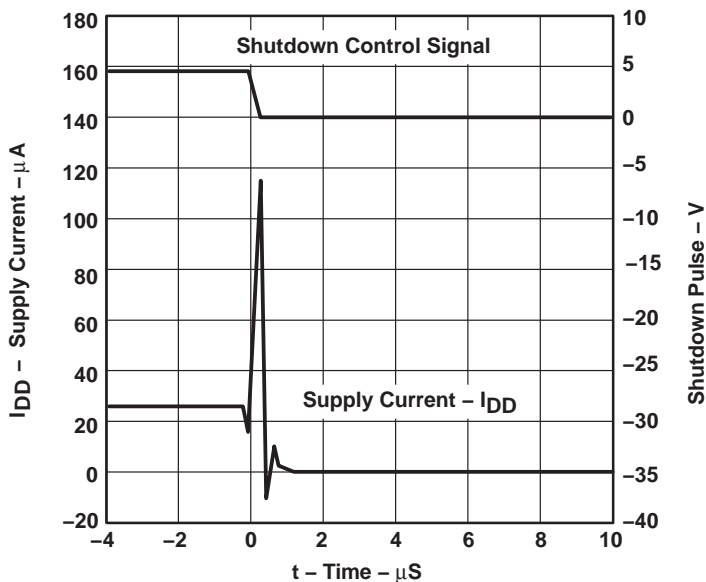
**TYPICAL CHARACTERISTICS**

**LARGE-SIGNAL FOLLOWER PULSE RESPONSE**  
**vs**  
**TIME**



**Figure 34**

**SHUTDOWN ON SUPPLY CURRENT**  
**vs**  
**TIME**



**Figure 35**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

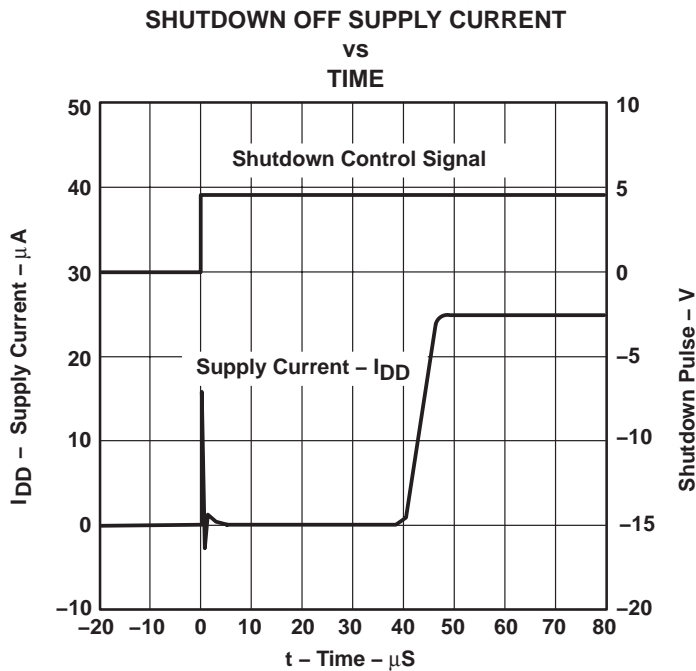


Figure 36



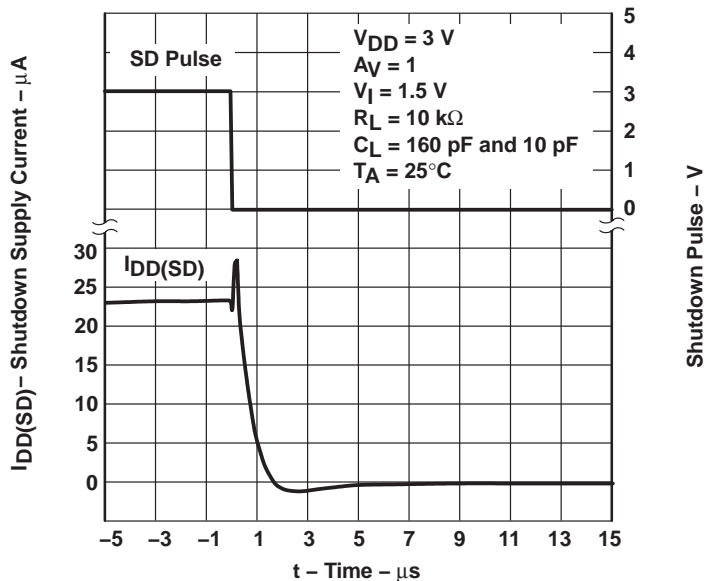
Figure 37

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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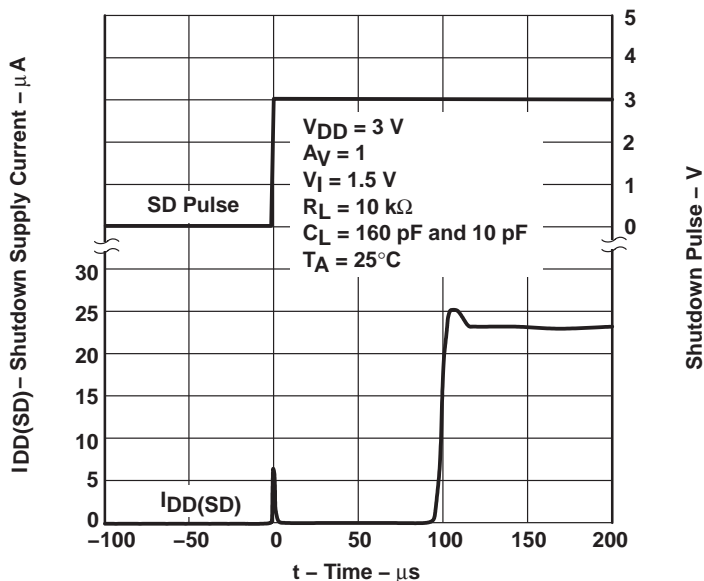
**TYPICAL CHARACTERISTICS**

**SHUTDOWN SUPPLY CURRENT AND SHUTDOWN PULSE**  
**vs**  
**TIME**



**Figure 38**

**SHUTDOWN SUPPLY CURRENT AND SHUTDOWN PULSE**  
**vs**  
**TIME**



**Figure 39**

TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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TYPICAL CHARACTERISTICS

SHUTDOWN SUPPLY CURRENT AND SHUTDOWN PULSE  
 vs  
 TIME

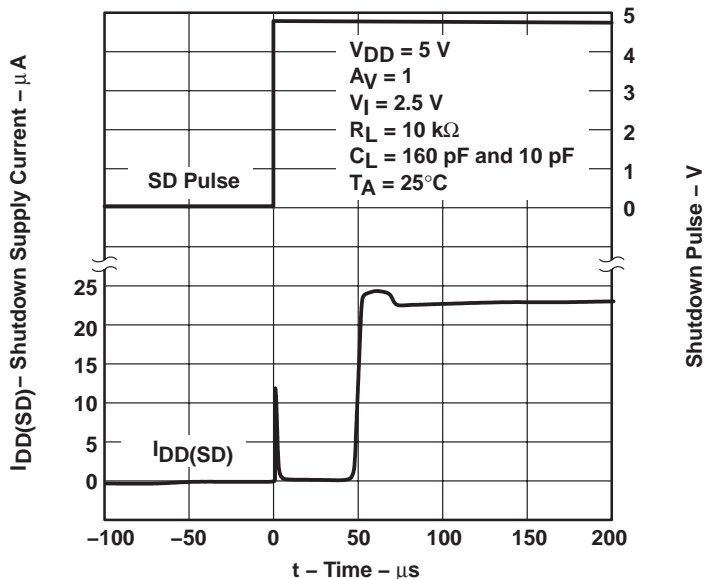


Figure 40

SHUTDOWN SUPPLY CURRENT AND SHUTDOWN PULSE  
 vs  
 TIME

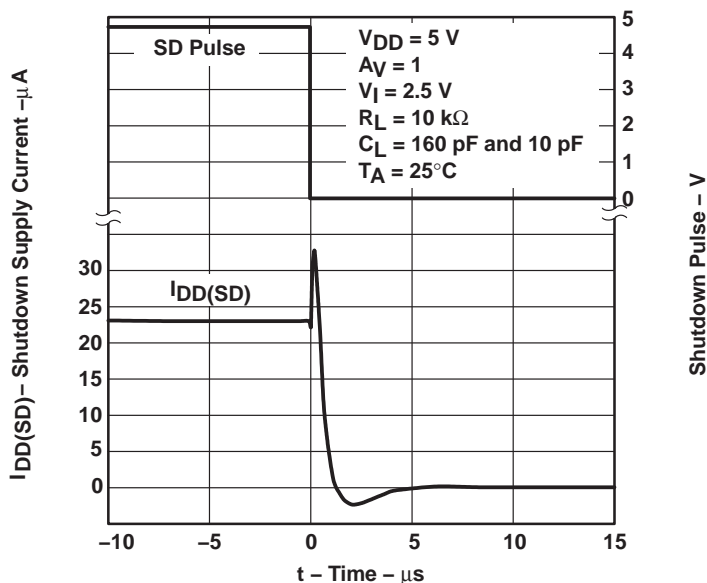


Figure 41

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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**TYPICAL CHARACTERISTICS**

**SHUTDOWN OFF PULSE RESPONSE**  
**VS**  
**TIME**



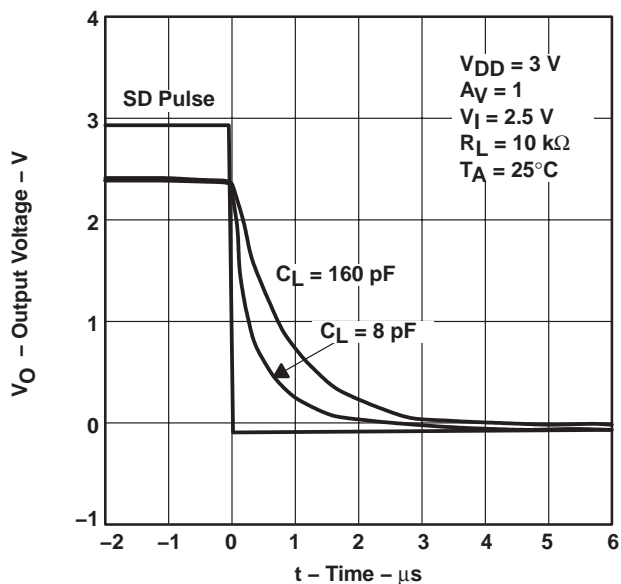
**Figure 42**

**SHUTDOWN OFF PULSE RESPONSE**  
**VS**  
**TIME**



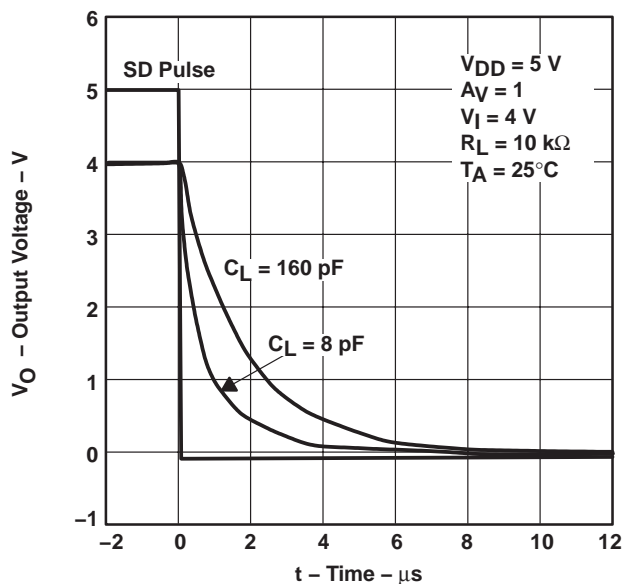
**Figure 43**

**SHUTDOWN ON PULSE RESPONSE**  
**VS**  
**TIME**



**Figure 44**

**SHUTDOWN ON PULSE RESPONSE**  
**VS**  
**TIME**



**Figure 45**

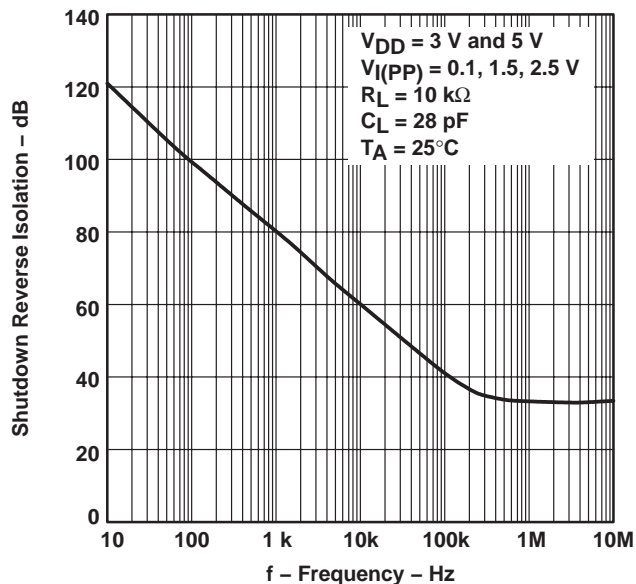


TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA  
 FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT  
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

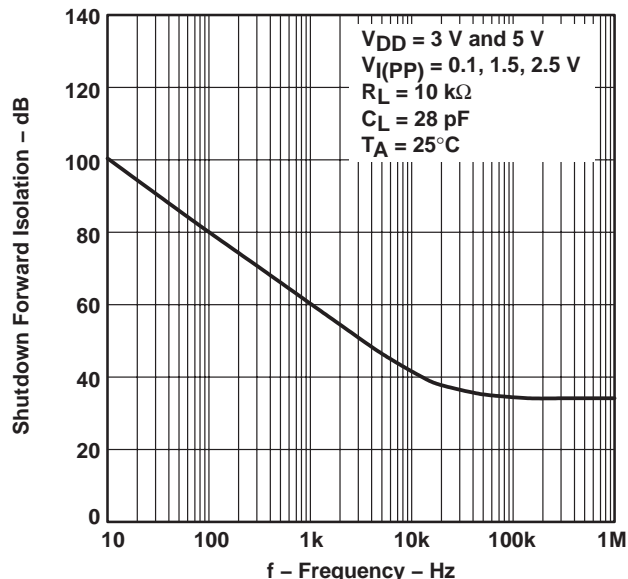
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TYPICAL CHARACTERISTICS

SHUTDOWN REVERSE ISOLATION  
 VS  
 FREQUENCY



SHUTDOWN FORWARD ISOLATION  
 VS  
 FREQUENCY



PARAMETER MEASUREMENT INFORMATION

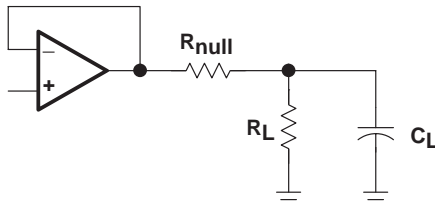


Figure 48

# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

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## APPLICATION INFORMATION

### shutdown function

Three members of the TLV245x family (TLV2450/3/5) have a shutdown terminal for conserving battery life in portable applications. When the shutdown terminal is pulled to the voltage level on the GND terminal of the device, the supply current is reduced to 16 nA/channel, the amplifier is disabled, and the outputs are placed in a high impedance mode. To enable the amplifier, the shutdown terminal must be pulled high. The shutdown terminal should never be left floating. The shutdown terminal threshold is always referenced to the GND terminal of the device. Therefore, when operating the device with split supply voltages (e.g.  $\pm 2.5$  V), the shutdown terminal needs to be pulled to  $V_{DD-}$  (not system ground) to disable the operational amplifier.

The amplifier's output with a shutdown pulse is shown in Figures 42, 43, 44, and 45. The amplifier is powered with a single 5-V supply and configured as a noninverting configuration with a gain of 5. The amplifier turnon and turnoff times are measured from the 50% point of the shutdown pulse to the 50% point of the output waveform. The times for the single, dual, and quad are listed in the data tables.

Figures 46 and 47 show the amplifier's forward and reverse isolation in shutdown. The operational amplifier is powered by  $\pm 1.35$ -V supplies and configured as a voltage follower ( $A_V = 1$ ). The isolation performance is plotted across frequency using 0.1- $V_{PP}$ , 1.5- $V_{PP}$ , and 2.5- $V_{PP}$  input signals. During normal operation, the amplifier would not be able to handle a 2.5- $V_{PP}$  input signal with a supply voltage of  $\pm 1.35$  V since it exceeds the common-mode input voltage range ( $V_{ICR}$ ). However, this curve illustrates that the amplifier remains in shutdown even under a worst case scenario.

### driving a capacitive load

When the amplifier is configured in this manner, capacitive loading directly on the output will decrease the device's phase margin leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series ( $R_{NULL}$ ) with the output of the amplifier, as shown in Figure 49. A minimum value of 20  $\Omega$  should work well for most applications.

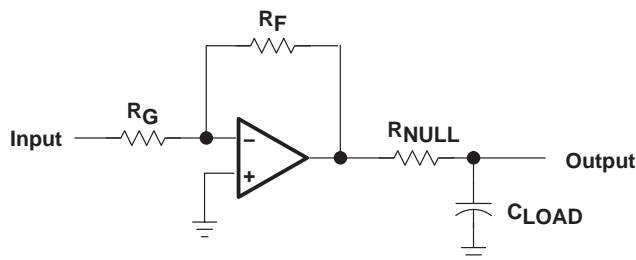
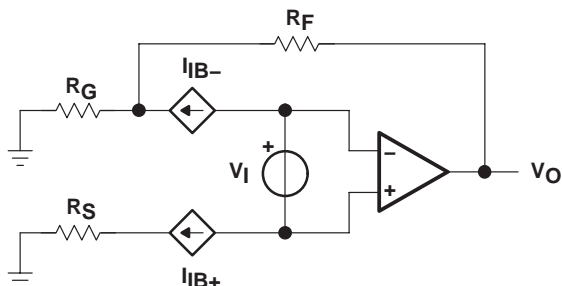


Figure 49. Driving a Capacitive Load

APPLICATION INFORMATION

offset voltage

The output offset voltage, ( $V_{OO}$ ) is the sum of the input offset voltage ( $V_{IO}$ ) and both input bias currents ( $I_{IB}$ ) times the corresponding gains. The following schematic and formula can be used to calculate the output offset voltage:

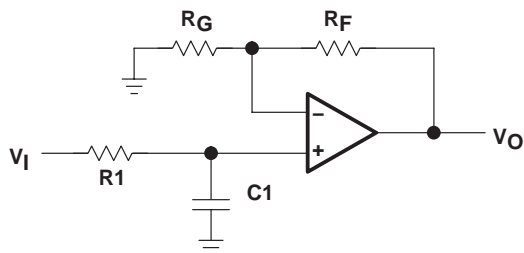


$$V_{OO} = V_{IO} \left( 1 + \left( \frac{R_F}{R_G} \right) \right) \pm I_{IB+} R_S \left( 1 + \left( \frac{R_F}{R_G} \right) \right) \pm I_{IB-} R_F$$

Figure 50. Output Offset Voltage Model

general configurations

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to accomplish this is to place an RC filter at the noninverting terminal of the amplifier (see Figure 51).

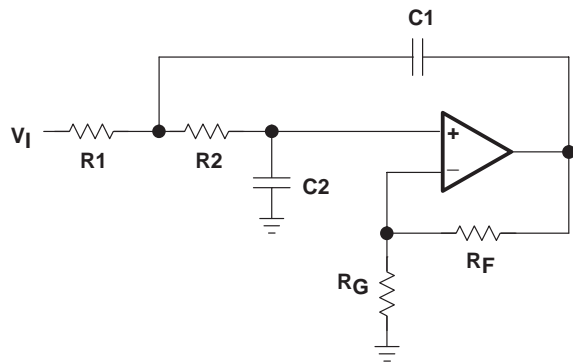


$$\frac{V_O}{V_I} = \left( 1 + \frac{R_F}{R_G} \right) \left( \frac{1}{1 + sR1C1} \right)$$

$$f_{-3dB} = \frac{1}{2\pi R1C1}$$

Figure 51. Single-Pole Low-Pass Filter

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter can be used for this task. For best results, the amplifier should have a bandwidth that is 8 to 10 times the filter frequency bandwidth. Failure to do this can result in phase shift of the amplifier.



$R1 = R2 = R$   
 $C1 = C2 = C$   
 $Q = \text{Peaking Factor}$   
 (Butterworth  $Q = 0.707$ )

$$f_{-3dB} = \frac{1}{2\pi RC}$$

$$R_G = \frac{R_F}{\left( 2 - \frac{1}{Q} \right)}$$

Figure 52. 2-Pole Low-Pass Sallen-Key Filter

**TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA**  
**FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUTDOWN**

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**APPLICATION INFORMATION**

**general power dissipation considerations**

For a given  $\theta_{JA}$ , the maximum power dissipation is shown in Figure 53 and is calculated by the following formula:

$$P_D = \left( \frac{T_{MAX} - T_A}{\theta_{JA}} \right)$$

Where:

- $P_D$  = Maximum power dissipation of TLV245x IC (watts)
- $T_{MAX}$  = Absolute maximum junction temperature (150°C)
- $T_A$  = Free-ambient air temperature (°C)
- $\theta_{JA}$  =  $\theta_{JC} + \theta_{CA}$
- $\theta_{JC}$  = Thermal coefficient from junction to case
- $\theta_{CA}$  = Thermal coefficient from case to ambient air (°C/W)



NOTE A: Results are with no air flow and using JEDEC Standard Low-K test PCB.

**Figure 53. Maximum Power Dissipation vs Free-Air Temperature**

# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS218E – DECEMBER 1998 – REVISED FEBRUARY 2004

## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*<sup>™</sup>, the model generation software used with Microsim *PSpice*<sup>™</sup>. The Boyle macromodel (see Note 1) and subcircuit in Figure 54 are generated using the TLV245x typical electrical and operating characteristics at  $T_A = 25^\circ\text{C}$ . Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

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

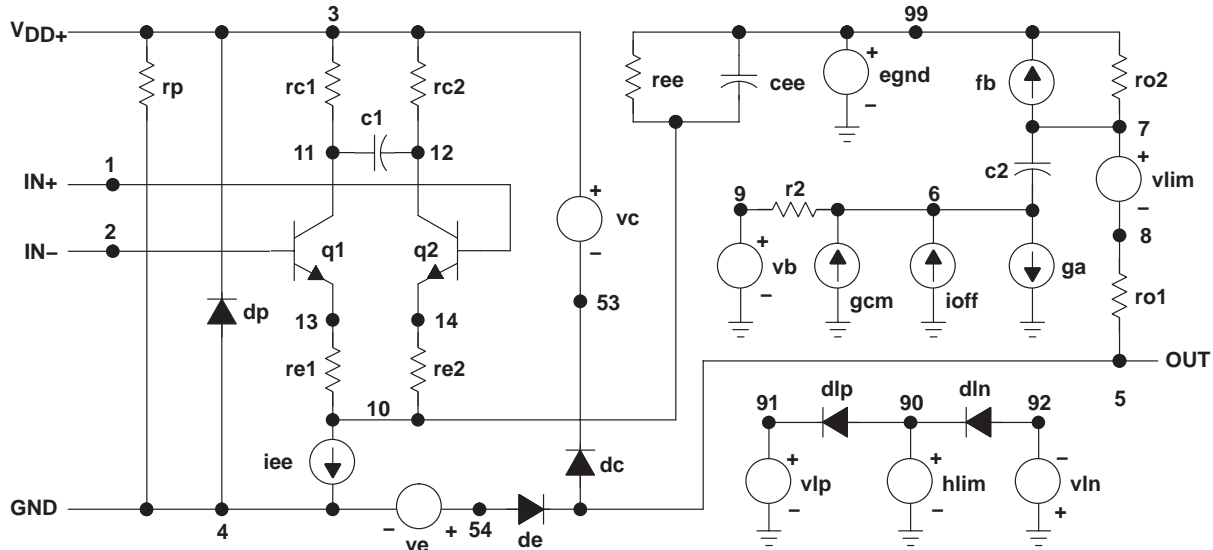
NOTE 1: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers," *IEEE Journal of Solid-State Circuits*, SC-9, 353 (1974).

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# TLV2450, TLV2451, TLV2452, TLV2453, TLV2454, TLV2455, TLV245xA FAMILY OF 23- $\mu$ A 220-kHz RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS218E – DECEMBER 1998 – REVISED FEBRUARY 2004

## APPLICATION INFORMATION



\* AMP\_TLV2450-X operational amplifier "macromodel" subcircuit  
\* created using Parts release 8.0 on 10/12/98 at 11:06  
\* Parts is a MicroSim product.

\* connections:           noninverting input  
\*                            |           inverting input  
\*                            |           positive power supply  
\*                            |           negative power supply  
\*                            |           output  
\*                            |  
\*                            |  
\* .subckt AMP\_TLV2450-X 1 2 3 4 5

C1	11	12	354.48E-15
C2	6	7	7.5000E-12
CEE	10	99	42.237E-15
DC	5	53	dy
DE	54	5	dy
DLP	90	91	dx
DLN	92	90	dx
DP	4	3	dx
EGND	99	0	poly(2) (3,0) (4,0) 0 .5 .5
FB	7	99	poly(5) vb vc ve vlp vln 0
+ 207.31E6 -1E3 1E3 210E6 -210E6			
GA	6	0	11 12 15.254E-6
GCM	0	6	10 99 48.237E-12

IEE	10	4	dc	938.61E-9
HLIM	90	0	vlim	1K
Q1	11	2	13	qx1
Q2	12	1	14	qx2
R2	6	9	100.00E3	
RC1	3	11	65.557E3	
RC2	3	12	65.557E3	
RE1	13	10	10.367E3	
RE2	14	10	10.367E3	
REE	10	99	213.08E6	
RO1	8	5	10	
RO2	7	99	10	
RP	3	4	147.06	
VB	9	0	dc	0
VC	3	53	dc	.82
VE	54	4	dc	.82
VLIM	7	8	dc	0
VLP	91	0	dc	38
VLN	0	92	dc	38
.model dx D(Is=800.00E-18)				
.model dy D(Is=800.00E-18 Rs=1m Cjo=10p)				
.model qx1 NPN(Is=800.00E-18 Bf=843.08)				
.model qx2 NPN(Is=800.0000E-18 Bf=843.08)				
.ends				

Figure 54. Boyle Macromodel and Subcircuit

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE



4040082/D 05/98

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

For the latest package information, go to [http://www.ti.com/sc/docs/package/pkg\\_info.htm](http://www.ti.com/sc/docs/package/pkg_info.htm)



N (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN

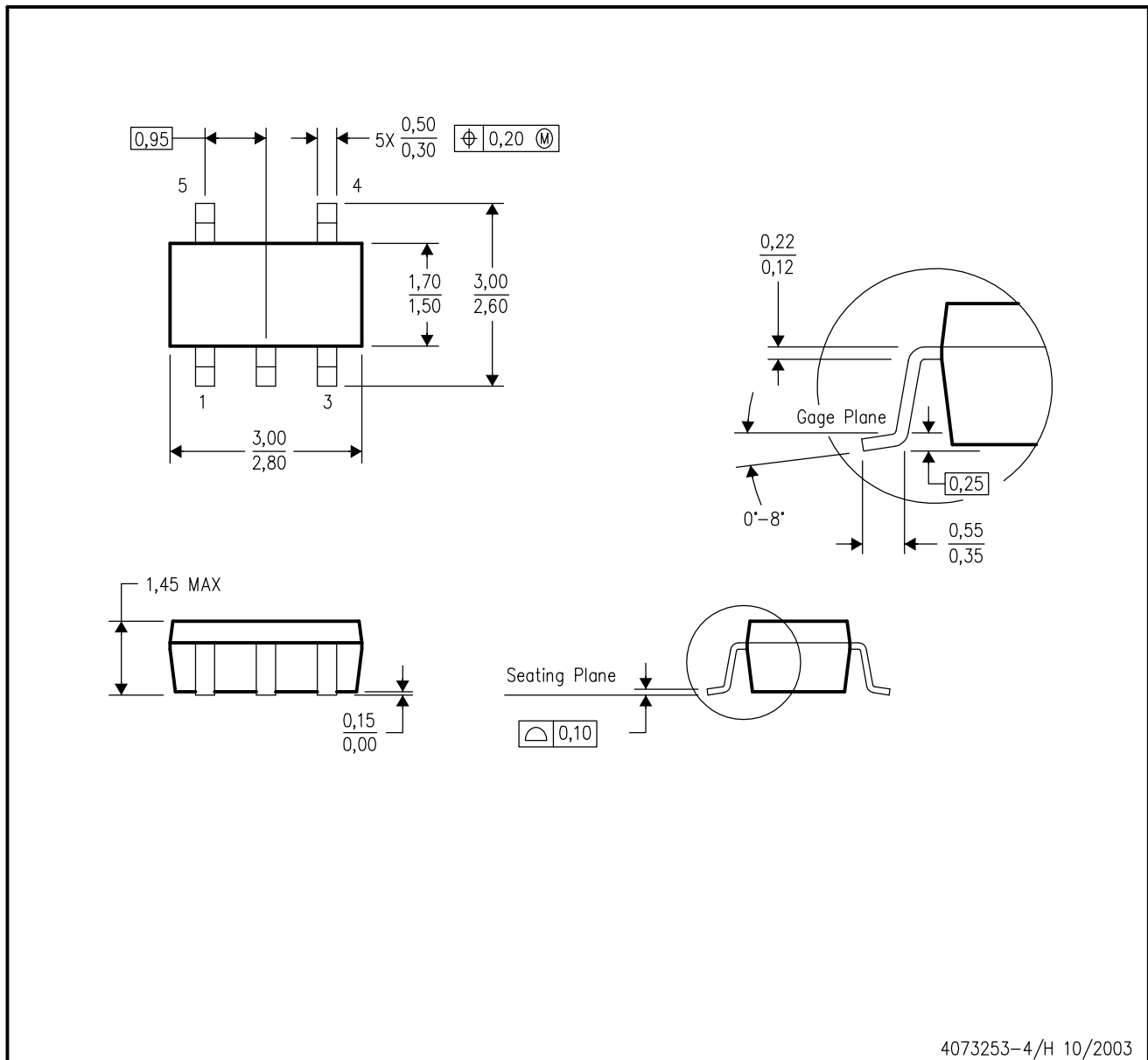


- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
  - The 20 pin end lead shoulder width is a vendor option, either half or full width.



DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE

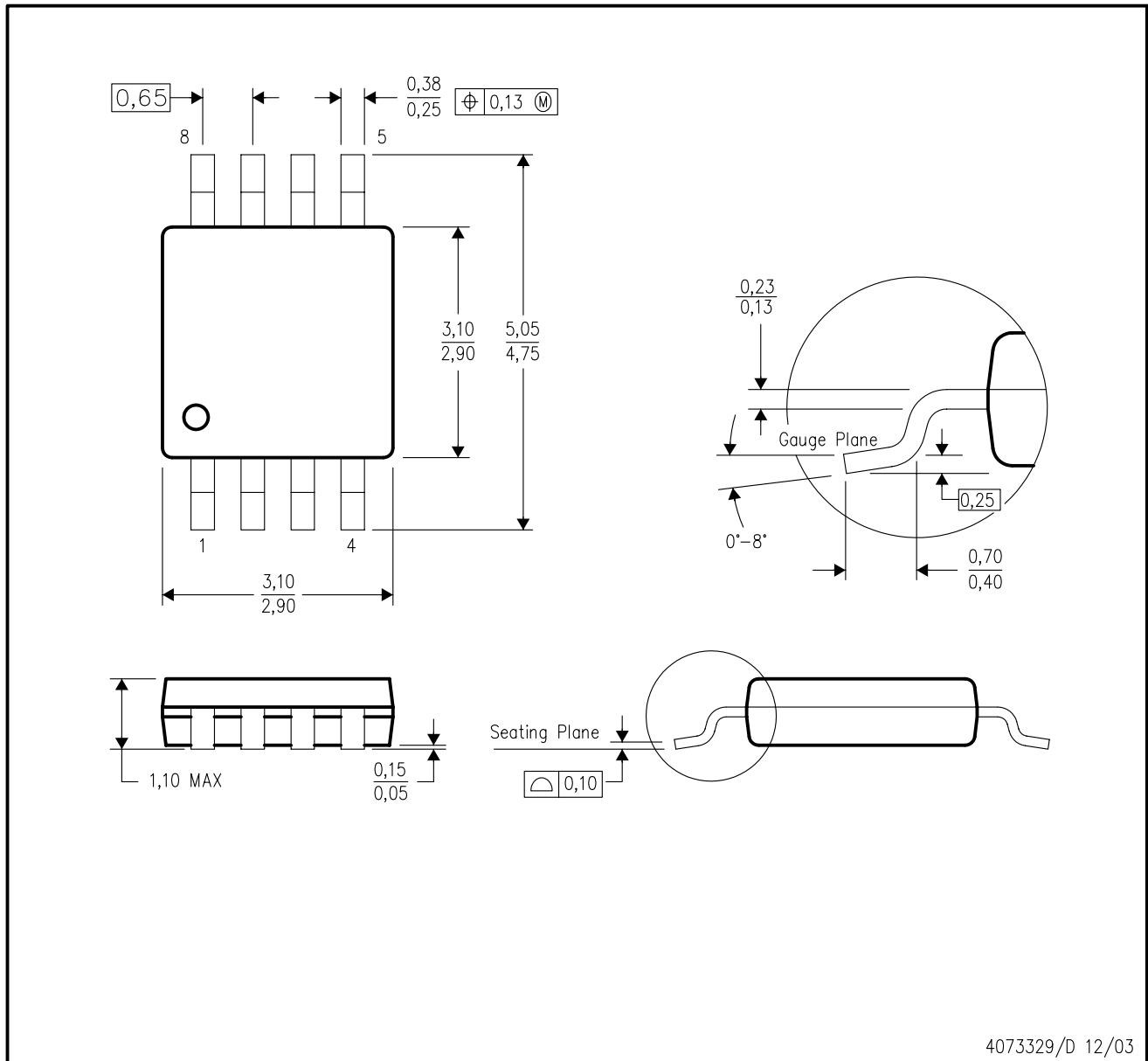


- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion.
  - D. Falls within JEDEC MO-178 Variation AA.



DGK (S-PDSO-G8)

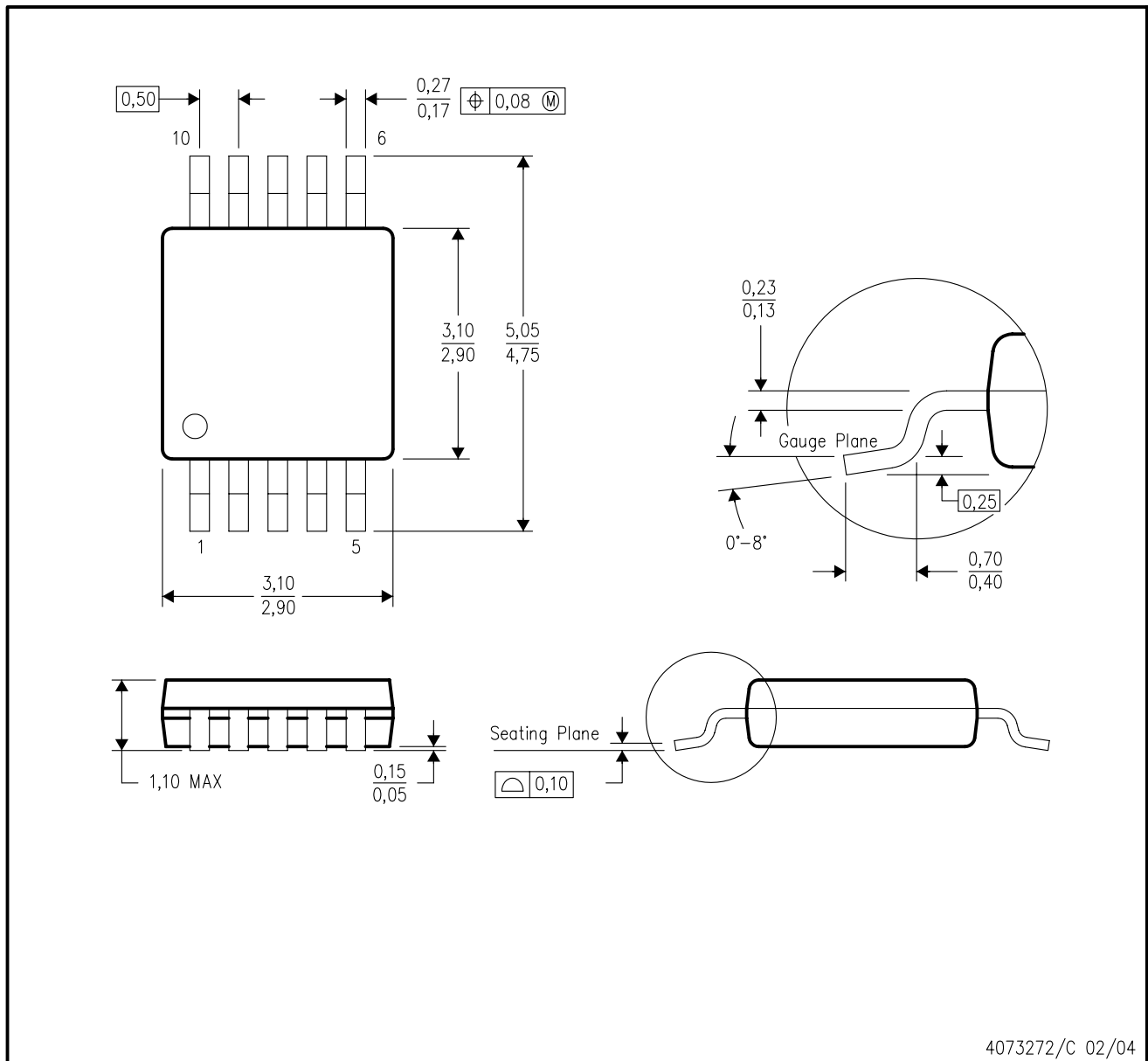
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion.
  - D. Falls within JEDEC MO-187 variation AA.

DGS (S-PDSO-G10)

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.
  - D. Falls within JEDEC MO-187 variation BA.

D (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

8 PINS SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).  
 D. Falls within JEDEC MS-012

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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