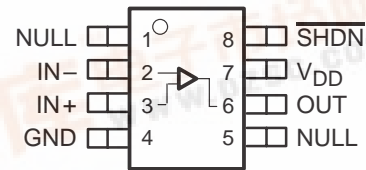


# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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- **Wide Bandwidth . . . 10 MHz**
- **High Output Drive**
  - $I_{OH}$  . . . 57 mA at  $V_{DD} - 1.5$
  - $I_{OL}$  . . . 55 mA at 0.5 V
- **High Slew Rate**
  - $SR+$  . . . 16 V/ $\mu$ s
  - $SR-$  . . . 19 V/ $\mu$ s
- **Wide Supply Range . . . 4.5 V to 16 V**
- **Supply Current . . . 1.9 mA/Channel**
- **Ultra-Low Power Shutdown Mode**  
 $I_{DD}$  . . . 125  $\mu$ A/Channel
- **Low Input Noise Voltage . . . 8.5 nV $\sqrt$ Hz**
- **Wide  $V_{ICR}$  . . . 0 to  $V_{DD} - 1$**
- **Input Offset Voltage . . . 60  $\mu$ V**
- **Ultra-Small Packages**
  - 8 or 10 Pin MSOP (TLC080/1/2/3)

TLC080  
D, DGN OR P PACKAGE  
(TOP VIEW)



## description

Introducing the first members of TI's new BiMOS general-purpose operational amplifier family—the TLC08x. The BiMOS family concept is simple: provide an upgrade path for BiFET users who are moving away from dual-supply to single-supply systems and demand higher ac and dc performance. With performance rated from 4.5 V to 16 V across commercial (0°C to 70°C) and an extended industrial temperature range (–40°C to 125°C), BiMOS suits a wide range of audio, automotive, industrial and instrumentation applications. Familiar features like offset nulling pins, and new features like MSOP PowerPAD™ packages and shutdown modes, enable higher levels of performance in a multitude of applications.

Developed in TI's patented LBC3 BiCMOS process, the new BiMOS amplifiers combine a very high input impedance, low-noise CMOS front end with a high-drive Bipolar output stage—thus providing the optimum performance features of both. AC performance improvements over the TL08x BiFET predecessors include a bandwidth of 10 MHz (an increase of 300%) and voltage noise of 8.5 nV/ $\sqrt$ Hz (an improvement of 60%). DC improvements include an ensured  $V_{ICR}$  that includes ground, a factor of 4 reduction in input offset voltage down to 1.5 mV (maximum) in the standard grade, and a power supply rejection improvement of greater than 40 dB to 130 dB. Added to this list of impressive features is the ability to drive  $\pm$ 50-mA loads comfortably from an ultra-small-footprint MSOP PowerPAD package, which positions the TLC08x as the ideal high-performance general-purpose operational amplifier family.

FAMILY PACKAGE TABLE

DEVICE	NO. OF CHANNELS	PACKAGE TYPES				SHUTDOWN	UNIVERSAL EVM BOARD
		MSOP	PDIP	SOIC	TSSOP		
TLC080	1	8	8	8	—	Yes	Refer to the EVM Selection Guide (Lit# SLOU060)
TLC081	1	8	8	8	—	—	
TLC082	2	8	8	8	—	—	
TLC083	2	10	14	14	—	Yes	
TLC084	4	—	14	14	20	—	
TLC085	4	—	16	16	20	Yes	

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.

PowerPAD is a trademark of Texas Instruments Incorporated.

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.

# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TLC080 and TLC081 AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES		PACKAGED DEVICES	
	SMALL OUTLINE (D)†	SMALL OUTLINE (DGN)†	SYMBOL	PLASTIC DIP (P)
0°C to 70°C	TLC080CD TLC081CD	TLC080CDGN TLC081CDGN	xxTIACW xxTIACY	TLC080CP TLC081CP
-40°C to 125°C	TLC080ID TLC081ID	TLC080IDGN TLC081IDGN	xxTIACX xxTIACZ	TLC080IP TLC081IP
	TLC080AID TLC081AID	— —	— —	TLC080AIP TLC081AIP

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC080CDR).

‡ Chip forms are tested at T<sub>A</sub> = 25°C only.

## TLC082 and TLC083 AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES						
	SMALL OUTLINE (D)†	MSOP				PLASTIC DIP (N)	PLASTIC DIP (P)
		(DGN)†	SYMBOL§	(DGQ)†	SYMBOL§		
0°C to 70°C	TLC082CD TLC083CD	TLC082CDGN —	xxTIADZ —	— TLC083CDGQ	— xxTIAEB	— TLC083CN	TLC082CP —
-40°C to 125°C	TLC082ID TLC083ID	TLC082IDGN —	xxTIAEA —	— TLC083IDGQ	— xxTIAEC	— TLC083IN	TLC082IP —
	TLC082AID TLC083AID	— —	— —	— —	— —	— TLC083AIN	TLC082AIP —

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC082CDR).

‡ Chip forms are tested at T<sub>A</sub> = 25°C only.

§ xx represents the device date code.

## TLC084 and TLC085 AVAILABLE OPTIONS

T <sub>A</sub>	PACKAGED DEVICES		
	SMALL OUTLINE (D)†	PLASTIC DIP (N)	TSSOP (PWP)†
0°C to 70°C	TLC084CD TLC085CD	TLC084CN TLC085CN	TLC084CPWP TLC085CPWP
-40°C to 125°C	TLC084ID TLC085ID	TLC084IN TLC085IN	TLC084IPWP TLC085IPWP
	TLC084AID TLC085AID	TLC084AIN TLC085AIN	TLC084AIPWP TLC085AIPWP

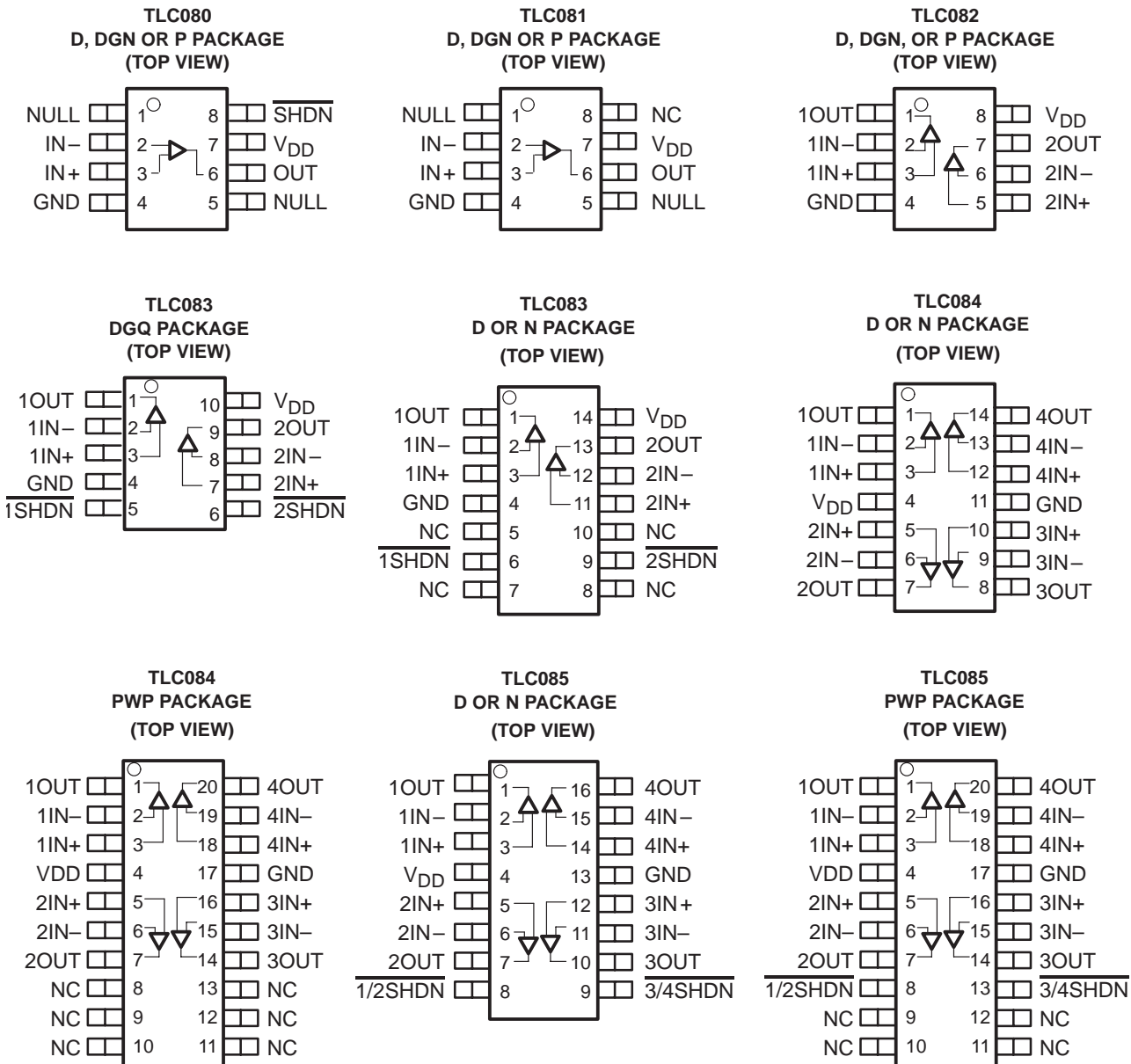
† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLC084CDR).

‡ Chip forms are tested at T<sub>A</sub> = 25°C only.

# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TLC08x PACKAGE PINOUTS



NC – No internal connection

# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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

Supply voltage, $V_{DD}$ (see Note 1)	17 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

† 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
DGN (8)	4.7	52.7	2.37 W
DGQ (10)	4.7	52.3	2.39 W
N (14, 16)	32	78	1600 mW
P (8)	41	104	1200 mW
PWP (20)	1.40	26.1	4.79 W

## recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, $V_{DD}$	Single supply	4.5	16	V
	Split supply	$\pm 2.25$	$\pm 8$	
Common-mode input voltage range, $V_{ICR}$		GND	$V_{DD}-1$	V
Operating free-air temperature, $T_A$	C-suffix	0	70	°C
	I-suffix	-40	125	

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

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{DD} = 5\text{ V}$ , $V_{IC} = 2.5$ , $V_O = 2.5$ , $R_S = 50\ \Omega$	TLC080/1/2/3	25°C	60	1000	$\mu\text{V}$	
				Full range		1500		
			TLC080/1/2/3A	25°C	20	750		
				Full range		1000		
			TLC084/5	25°C	390	1900		
				Full range		3000		
			TLC084/5A	25°C	390	1400		
				Full range		2000		
$\alpha_{VIO}$	Temperature coefficient of input offset voltage				1.2		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_{DD} = 5\text{ V}$ , $V_{IC} = 2.5$ , $V_O = 2.5$ , $R_S = 50\ \Omega$	TLC08XC TLC08XI	25°C	1.9	50	$\text{pA}$	
				Full range		100 700		
$I_{IB}$	Input bias current	$V_{DD} = 5\text{ V}$ , $V_{IC} = 2.5$ , $V_O = 2.5$ , $R_S = 50\ \Omega$	TLC08XC TLC08XI	25°C	3	50	$\text{pA}$	
				Full range		100 700		
$V_{ICR}$	Common-mode input voltage range	CMRR > 70 dB, $R_S = 50\ \Omega$		25°C	0 to 3.5		$\text{V}$	
		CMRR > 52 dB, $R_S = 50\ \Omega$		Full range	0 to 3.5			
$V_{OH}$	High-level output voltage	$V_{IC} = 2.5\text{ V}$	$I_{OH} = -1\text{ mA}$	25°C	4.1	4.3	$\text{V}$	
				Full range		3.9		
			$I_{OH} = -20\text{ mA}$	25°C	3.7	4		
				Full range		3.5		
			$I_{OH} = -35\text{ mA}$	25°C	3.4	3.8		
				Full range		3.2		
			$I_{OH} = -50\text{ mA}$	25°C	3.2	3.6		
				-40°C to 85°C	3			
$V_{OL}$	Low-level output voltage	$V_{IC} = 2.5\text{ V}$	$I_{OL} = 1\text{ mA}$	25°C	0.18	0.25	$\text{V}$	
				Full range		0.35		
			$I_{OL} = 20\text{ mA}$	25°C	0.35	0.39		
				Full range		0.45		
			$I_{OL} = 35\text{ mA}$	25°C	0.43	0.55		
				Full range		0.7		
			$I_{OL} = 50\text{ mA}$	25°C	0.45	0.63		
				-40°C to 85°C		0.7		
$I_{OS}$	Short-circuit output current	Sourcing		25°C	100	$\text{mA}$		
		Sinking		25°C	100			
$I_O$	Output current	$V_{OH} = 1.5\text{ V}$ from positive rail		25°C	57	$\text{mA}$		
		$V_{OL} = 0.5\text{ V}$ from negative rail		25°C	55			

$^\dagger$  Full range is 0°C to 70°C for C suffix and -40°C to 125°C for I suffix. If not specified, full range is -40°C to 125°C.

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

PARAMETER		TEST CONDITIONS	$T_A$ †	MIN	TYP	MAX	UNIT
A <sub>VD</sub>	Large-signal differential voltage amplification	$V_{O(PP)} = 3\text{ V}$ , $R_L = 10\text{ k}\Omega$	25°C	100	120		dB
			Full range	100			
$r_{i(d)}$	Differential input resistance		25°C		1000		G $\Omega$
$C_{iC}$	Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		22.9		pF
$z_o$	Closed-loop output impedance	$f = 10\text{ kHz}$ , $A_V = 10$	25°C		0.25		$\Omega$
CMRR	Common-mode rejection ratio	$V_{iC} = 0\text{ to }3\text{ V}$ , $R_S = 50\ \Omega$	25°C	100	140		dB
			Full range	100			
k <sub>SVR</sub>	Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{iO}$ )	$V_{DD} = 4.5\text{ V to }16\text{ V}$ , No load $V_{iC} = V_{DD}/2$	25°C	95	130		dB
			Full range	95			
I <sub>DD</sub>	Supply current (per channel)	$V_O = 2.5\text{ V}$ , No load	25°C		1.8	2.5	mA
			Full range			3.5	
$V_{(ON)}$	Turnon voltage level	Relative to GND	25°C		1.41		V
$V_{(OFF)}$	Turnoff voltage level	Relative to GND	25°C		1.4		V
I <sub>DD(SHDN)</sub>	Supply current in shutdown mode (per channel) (TLC080, TLC083, TLC085)	$\overline{\text{SHDN}} \leq 1.45\text{ V}$	25°C		125	200	$\mu\text{A}$
			Full range			250	

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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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+	Positive slew rate at unity gain	$V_{O(PP)} = 0.8\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 50\text{ pF}$	25°C	10	16		V/ $\mu\text{s}$
				Full range	9.5			
SR–	Negative slew rate at unity gain	$V_{O(PP)} = 0.8\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 50\text{ pF}$	25°C	12.5	19		V/ $\mu\text{s}$
				Full range	10			
$V_n$	Equivalent input noise voltage			f = 100 Hz	25°C	12		nV/ $\sqrt{\text{Hz}}$
				f = 1 kHz	25°C	8.5		
$I_n$	Equivalent input noise current			f = 1 kHz	25°C	0.6		fA/ $\sqrt{\text{Hz}}$
THD + N	Total harmonic distortion plus noise	$V_{O(PP)} = 3\text{ V}$ , $R_L = 10\text{ k}\Omega$ and $250\ \Omega$ , f = 1 kHz		$A_V = 1$	25°C	0.002%		
				$A_V = 10$		0.012%		
				$A_V = 100$		0.085%		
$t_{(on)}$	Amplifier turnon time‡	$R_L = 10\text{ k}\Omega$		25°C		0.15		$\mu\text{s}$
$t_{(off)}$	Amplifier turnoff time‡			25°C		1.3		$\mu\text{s}$
Gain-bandwidth product		f = 10 kHz,	$R_L = 10\text{ k}\Omega$	25°C		10		MHz
$t_s$	Settling time	$V_{(STEP)PP} = 1\text{ V}$ , $A_V = -1$ , $C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%	25°C		0.18	$\mu\text{s}$	
			0.01%			0.39		
		$V_{(STEP)PP} = 1\text{ V}$ , $A_V = -1$ , $C_L = 47\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%			0.18		
			0.01%			0.39		
$\phi_m$	Phase margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 50\text{ pF}$	25°C		32°		
		$R_L = 10\text{ k}\Omega$ ,	$C_L = 0\text{ pF}$			40°		
	Gain margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 50\text{ pF}$	25°C		2.2	dB	
		$R_L = 10\text{ k}\Omega$ ,	$C_L = 0\text{ pF}$			3.3		

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

‡ Disable time and enable time are defined as the interval between application of the logic signal to SHDN and the point at which the supply current has reached half its final value.

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**electrical characteristics at specified free-air temperature,  $V_{DD} = 12\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{DD} = 12\text{ V}$ $V_{IC} = 6,$ $V_O = 6,$ $R_S = 50\ \Omega$	TLC080/1/2/3	25°C	60	1000	$\mu\text{V}$	
				Full range		1500		
			TLC080/1/2/3A	25°C	20	750		
				Full range		1000		
			TLC084/5	25°C	390	1900		
				Full range		3000		
TLC084/5A	25°C	390	1400					
	Full range		2000					
$\alpha_{VIO}$	Temperature coefficient of input offset voltage				1.2		$\mu\text{V}/^\circ\text{C}$	
$I_{IO}$	Input offset current	$V_{DD} = 12\text{ V}$ $V_{IC} = 6,$ $V_O = 6,$ $R_S = 50\ \Omega$	TLC08xC	25°C	1.5	50	$\text{pA}$	
				Full range		100		
$I_{IB}$	Input bias current	$V_{DD} = 12\text{ V}$ $V_{IC} = 6,$ $V_O = 6,$ $R_S = 50\ \Omega$	TLC08xl	25°C	2	50	$\text{pA}$	
				Full range		700		
$V_{ICR}$	Common-mode input voltage range	CMRR > 70 dB	$R_S = 50\ \Omega$	25°C	0	10.5	$\text{V}$	
				Full range		0 to 10.5		
		CMRR > 52 dB	$R_S = 50\ \Omega$	25°C	0	10.5	$\text{V}$	
				Full range		0 to 10.5		
$V_{OH}$	High-level output voltage	$V_{IC} = 6\text{ V}$	$I_{OH} = -1\text{ mA}$	25°C	11.1	11.2	$\text{V}$	
				Full range		11		
			$I_{OH} = -20\text{ mA}$	25°C	10.8	11		
				Full range		10.7		
			$I_{OH} = -35\text{ mA}$	25°C	10.6	10.7		
				Full range		10.3		
			$I_{OH} = -50\text{ mA}$	25°C	10.3	10.5		
				-40°C to 85°C		10.2		
$V_{OL}$	Low-level output voltage	$V_{IC} = 6\text{ V}$	$I_{OL} = 1\text{ mA}$	25°C	0.17	0.25	$\text{V}$	
				Full range		0.35		
			$I_{OL} = 20\text{ mA}$	25°C	0.35	0.45		
				Full range		0.5		
			$I_{OL} = 35\text{ mA}$	25°C	0.4	0.52		
				Full range		0.6		
			$I_{OL} = 50\text{ mA}$	25°C	0.45	0.6		
				-40°C to 85°C		0.65		
$I_{OS}$	Short-circuit output current	Sourcing	25°C	150	$\text{mA}$			
		Sinking	25°C	150				
$I_O$	Output current	$V_{OH} = 1.5\text{ V}$ from positive rail	25°C	57	$\text{mA}$			
		$V_{OL} = 0.5\text{ V}$ from negative rail	25°C	55				

† Full range is 0°C to 70°C for C suffix and -40°C to 125°C for I suffix. If not specified, full range is -40°C to 125°C.



**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**electrical characteristics at specified free-air temperature,  $V_{DD} = 12\text{ V}$  (unless otherwise noted) (continued)**

PARAMETER		TEST CONDITIONS	$T_A$ †	MIN	TYP	MAX	UNIT
$A_{VD}$	Large-signal differential voltage amplification	$V_{O(PP)} = 8\text{ V}$ , $R_L = 10\text{ k}\Omega$	25°C	120	140		dB
			Full range	120			
$r_{i(d)}$	Differential input resistance		25°C		1000		$G\Omega$
$C_{IC}$	Common-mode input capacitance	$f = 10\text{ kHz}$	25°C		21.6		pF
$z_o$	Closed-loop output impedance	$f = 10\text{ kHz}$ , $A_V = 10$	25°C		0.25		$\Omega$
CMRR	Common-mode rejection ratio	$V_{IC} = 0\text{ to }10\text{ V}$ , $R_S = 50\ \Omega$	25°C	100	140		dB
			Full range	100			
$k_{SVR}$	Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 4.5\text{ V to }16\text{ V}$ , No load $V_{IC} = V_{DD}/2$	25°C	95	130		dB
			Full range	95			
$I_{DD}$	Supply current (per channel)	$V_O = 7.5\text{ V}$ , No load	25°C		1.9	2.9	mA
			Full range			3.5	
$V_{(ON)}$	Turnon voltage level	Relative to GND	25°C		1.39		V
$V_{(OFF)}$	Turnoff voltage level	Relative to GND	25°C		1.38		V
$I_{DD(SHDN)}$	Supply current in shutdown mode (TLC080, TLC083, TLC085) (per channel)	$\overline{SHDN} \leq 1.45\text{ V}$	25°C		125	200	$\mu\text{A}$
			Full range			250	

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**operating characteristics at specified free-air temperature,  $V_{DD} = 12\text{ V}$  (unless otherwise noted)**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	$V_{O(PP)} = 2\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 50\text{ pF}$	25°C	10	16		$\text{V}/\mu\text{s}$
				Full range	9.5			
SR–	Negative slew rate at unity gain	$V_{O(PP)} = 2\text{ V}$ , $R_L = 10\text{ k}\Omega$	$C_L = 50\text{ pF}$	25°C	12.5	19		$\text{V}/\mu\text{s}$
				Full range	10			
$V_n$	Equivalent input noise voltage			f = 100 Hz	25°C		14	$\text{nV}/\sqrt{\text{Hz}}$
				f = 1 kHz	25°C		8.5	
$I_n$	Equivalent input noise current	f = 1 kHz		25°C		0.6	$\text{fA}/\sqrt{\text{Hz}}$	
THD + N	Total harmonic distortion plus noise	$V_{O(PP)} = 8\text{ V}$ , $R_L = 10\text{ k}\Omega$ and $250\ \Omega$ , f = 1 kHz	$A_V = 1$	25°C	0.002%			
			$A_V = 10$		0.005%			
			$A_V = 100$		0.022%			
$t_{(on)}$	Amplifier turnon time‡	$R_L = 10\text{ k}\Omega$		25°C	0.47		$\mu\text{s}$	
$t_{(off)}$	Amplifier turnoff time‡			25°C	2.5		$\mu\text{s}$	
Gain-bandwidth product		f = 10 kHz,	$R_L = 10\text{ k}\Omega$	25°C		10	MHz	
$t_s$	Settling time	$V_{(STEP)PP} = 1\text{ V}$ , $A_V = -1$ , $C_L = 10\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%	25°C	0.17		$\mu\text{s}$	
			0.01%		0.22			
		$V_{(STEP)PP} = 1\text{ V}$ , $A_V = -1$ , $C_L = 47\text{ pF}$ , $R_L = 10\text{ k}\Omega$	0.1%		0.17			
			0.01%		0.29			
$\phi_m$	Phase margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 50\text{ pF}$	25°C	37°			
		$R_L = 10\text{ k}\Omega$ ,	$C_L = 0\text{ pF}$		42°			
	Gain margin	$R_L = 10\text{ k}\Omega$ ,	$C_L = 50\text{ pF}$	25°C	3.1		dB	
		$R_L = 10\text{ k}\Omega$ ,	$C_L = 0\text{ pF}$		4			

† Full range is 0°C to 70°C for C suffix and –40°C to 125°C for I suffix. If not specified, full range is –40°C to 125°C.

‡ Disable time and enable time are defined as the interval between application of the logic signal to SHDN and the point at which the supply current has reached half its final value.

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA  
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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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$I_{IB}$	Input bias current	vs Free-air temperature	3, 4
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$Z_o$	Output impedance	vs Frequency	9
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CMRR	Common-mode rejection ratio	vs Frequency	12
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## TYPICAL CHARACTERISTICS

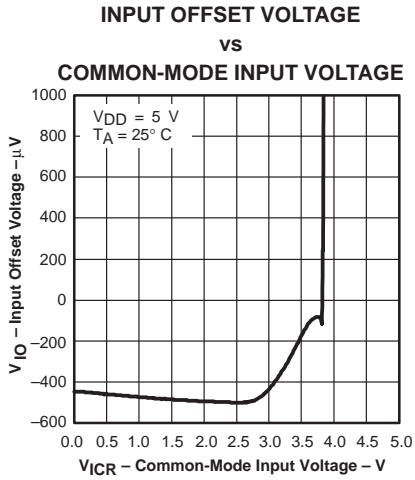


Figure 1

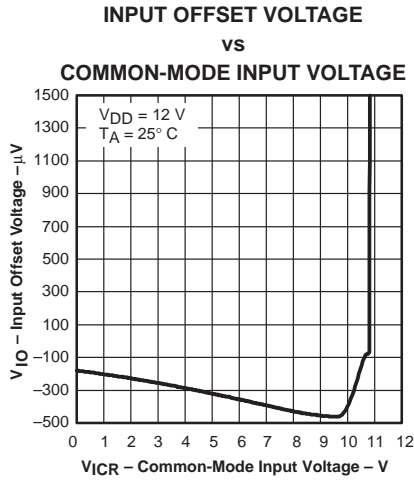


Figure 2

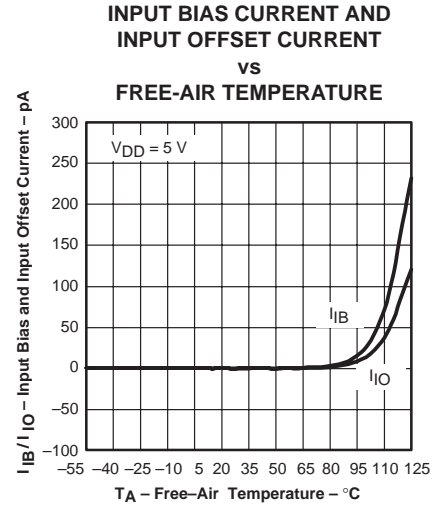


Figure 3

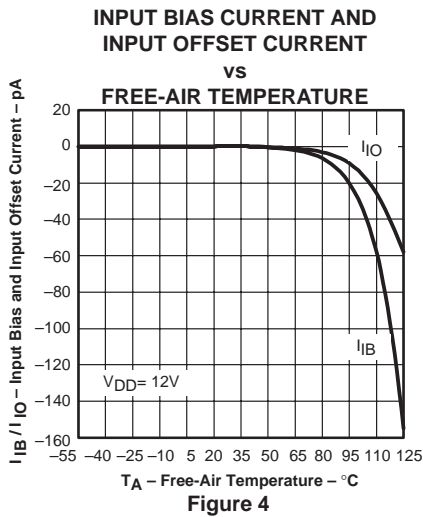


Figure 4

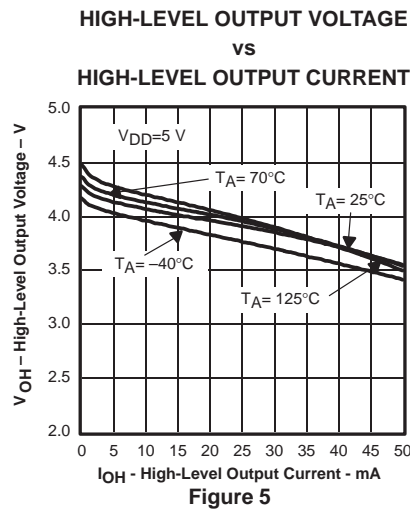


Figure 5

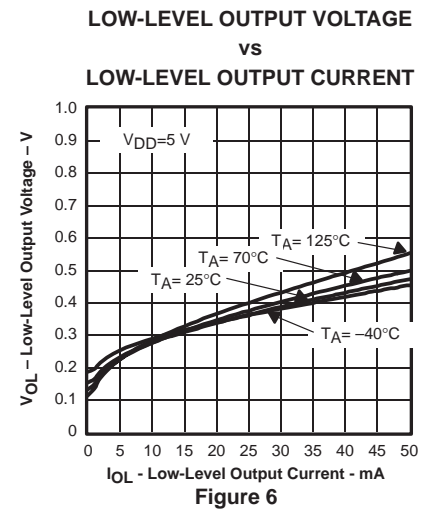


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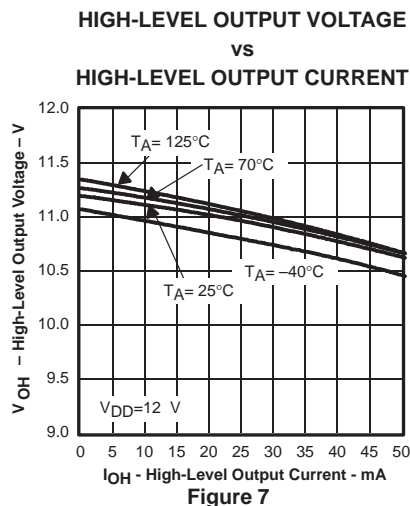


Figure 7

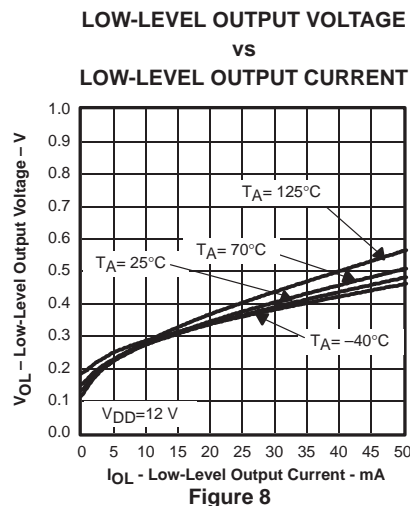


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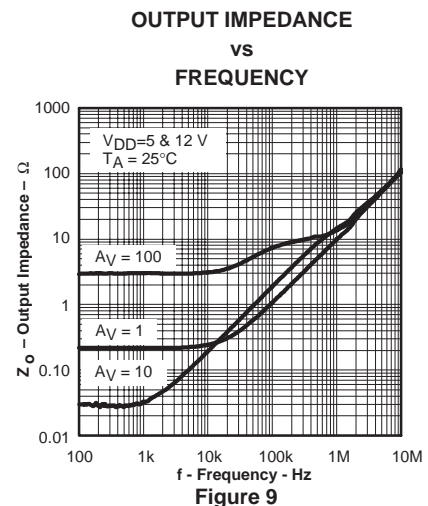
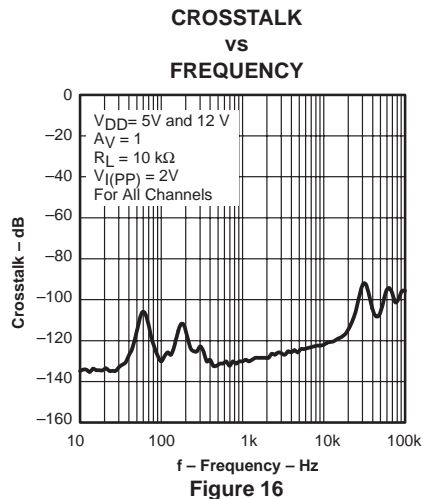
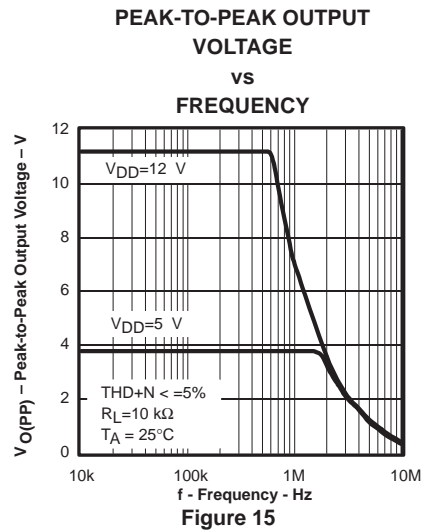
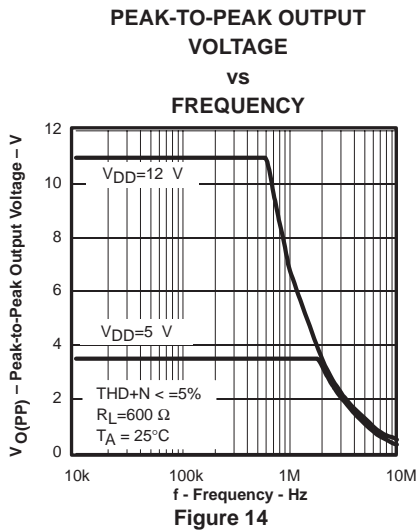
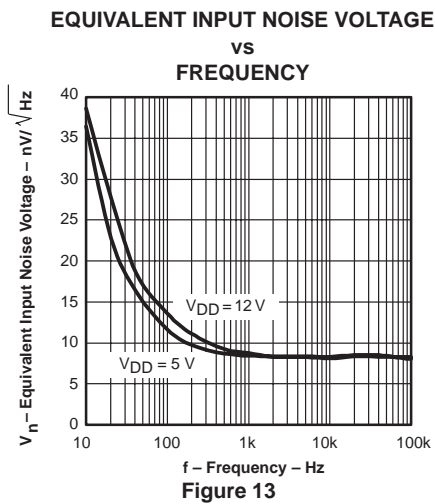
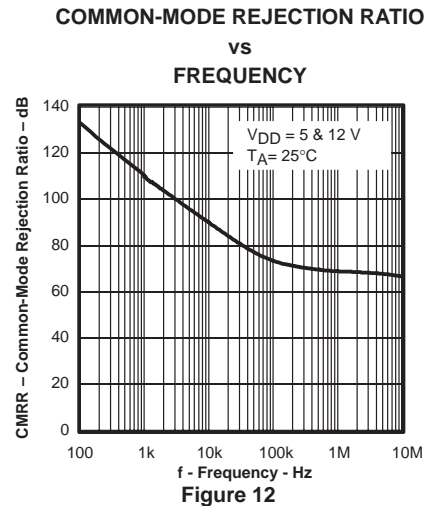
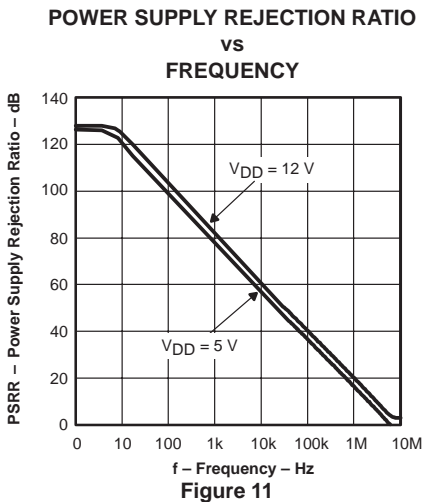
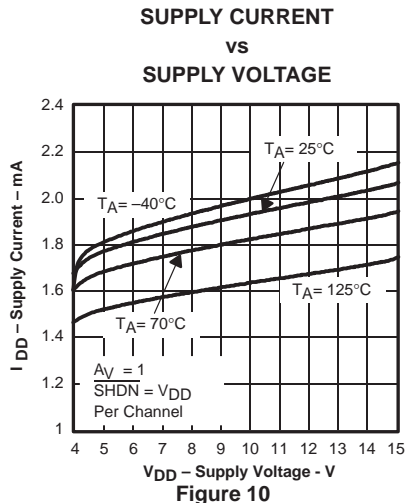


Figure 9

# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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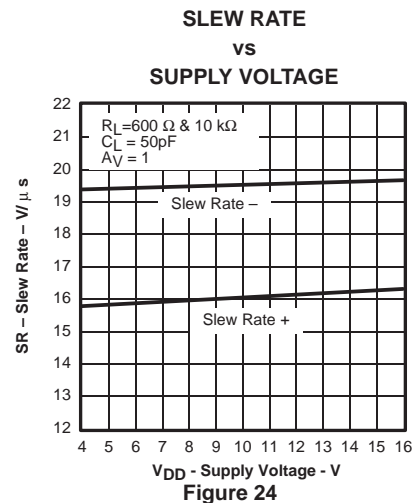
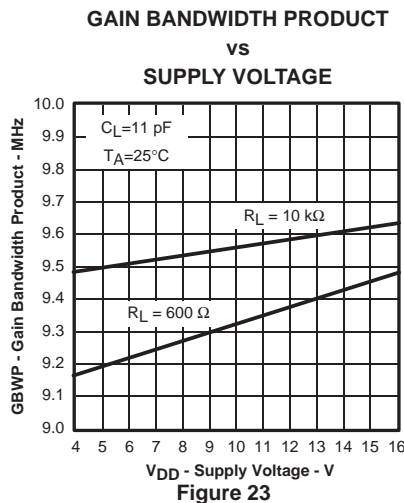
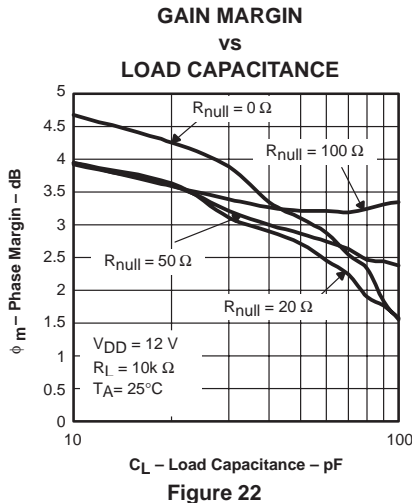
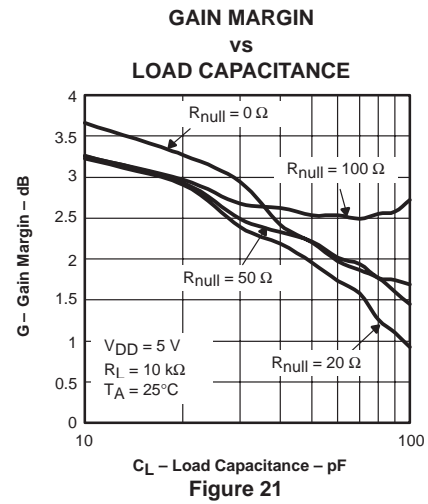
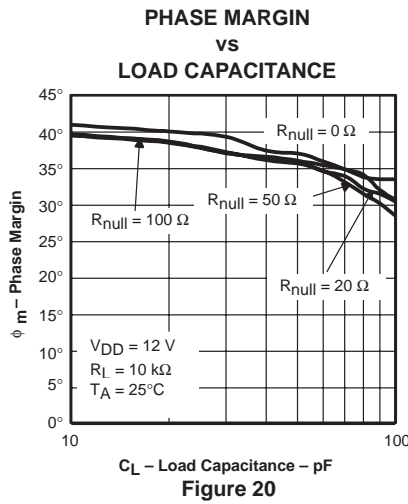
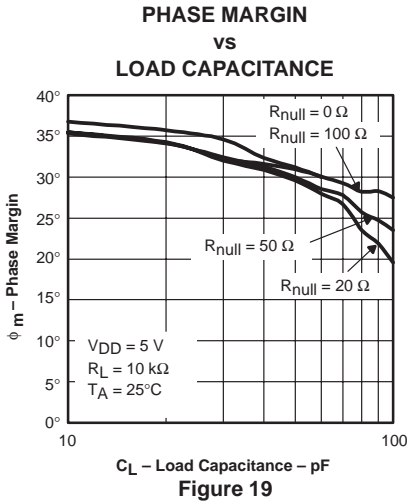
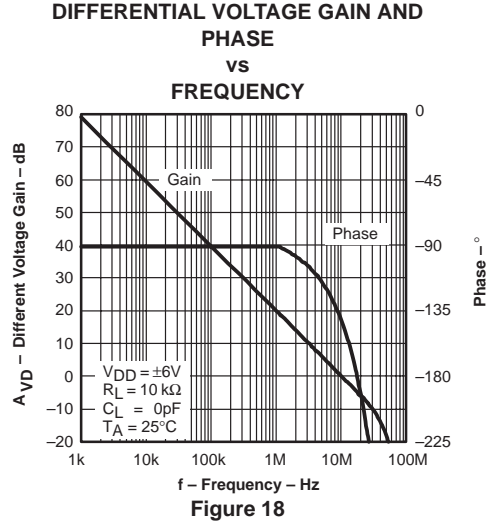
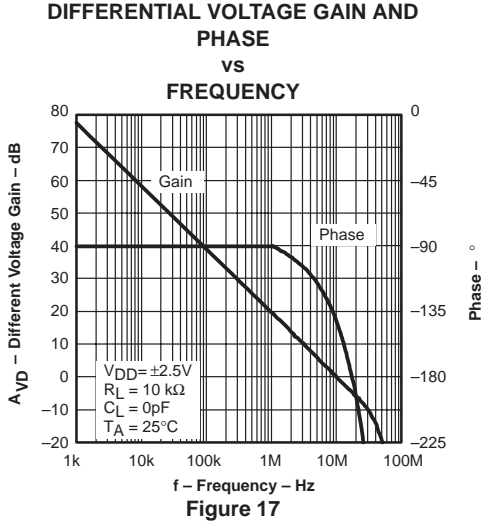
## TYPICAL CHARACTERISTICS



# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS



# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

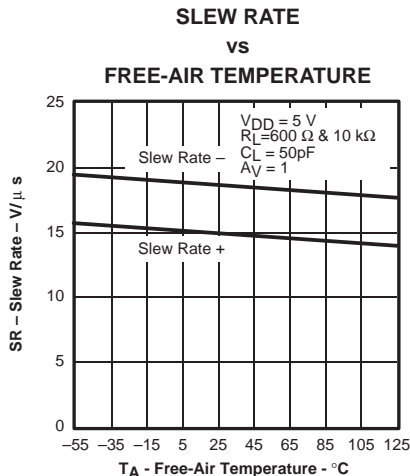


Figure 25

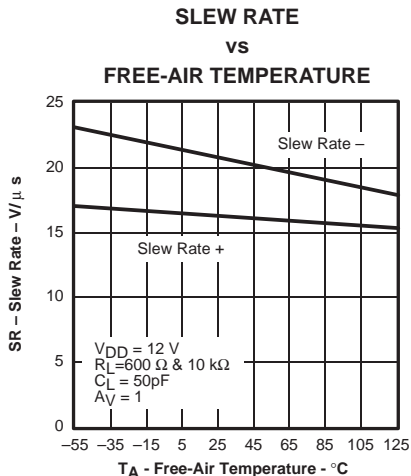


Figure 26

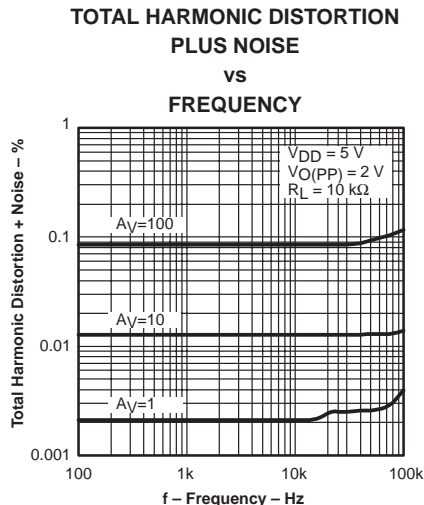


Figure 27

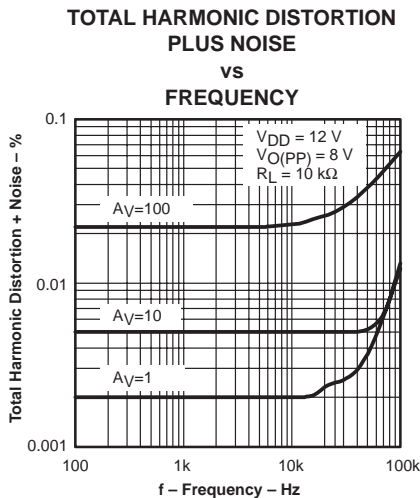


Figure 28

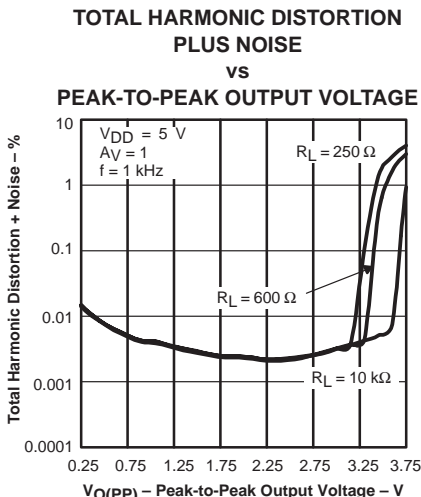


Figure 29

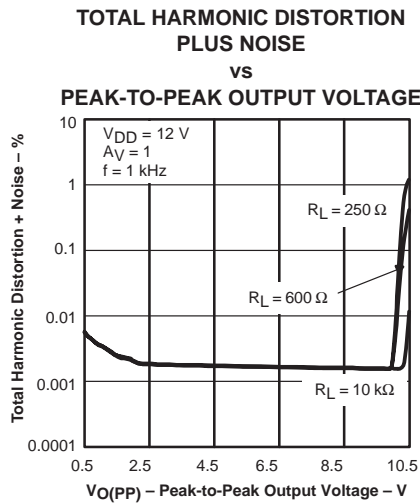


Figure 30

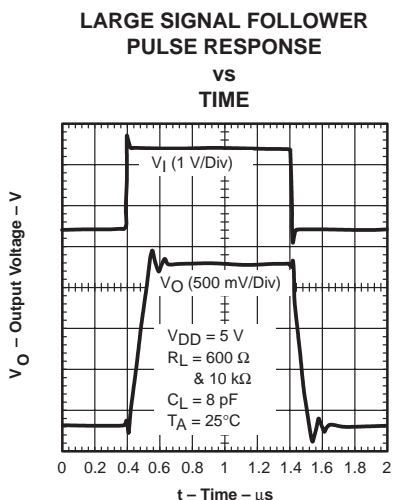


Figure 31

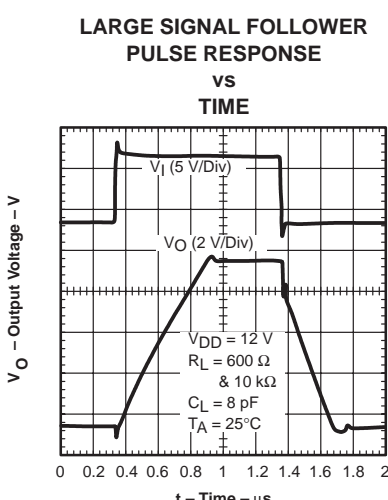


Figure 32

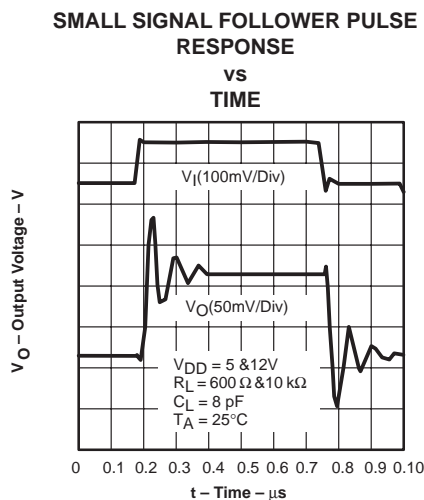


Figure 33

# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS

**LARGE SIGNAL INVERTING  
PULSE RESPONSE  
VS  
TIME**

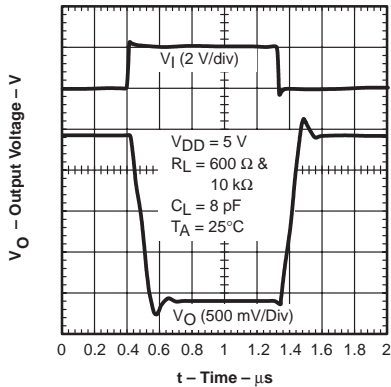


Figure 34

**LARGE SIGNAL INVERTING  
PULSE RESPONSE  
VS  
TIME**

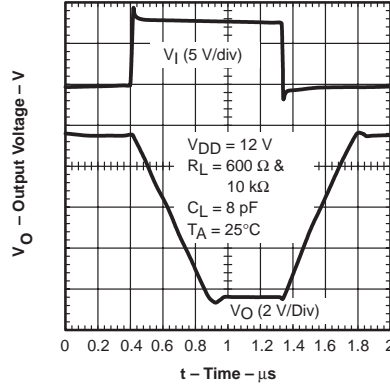


Figure 35

**SMALL SIGNAL INVERTING  
PULSE RESPONSE  
VS  
TIME**

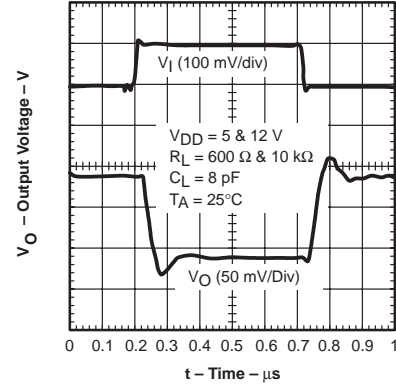


Figure 36

**SHUTDOWN FORWARD  
ISOLATION  
VS  
FREQUENCY**

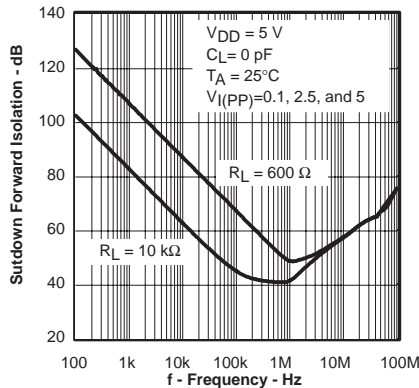


Figure 37

**SHUTDOWN FORWARD  
ISOLATION  
VS  
FREQUENCY**

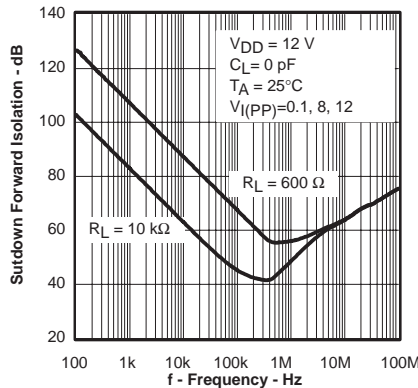


Figure 38

**SHUTDOWN REVERSE  
ISOLATION  
VS  
FREQUENCY**

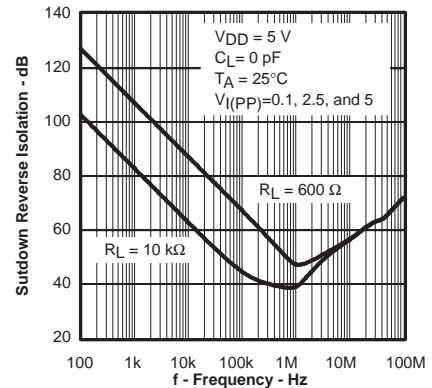


Figure 39

**SHUTDOWN REVERSE  
ISOLATION  
VS  
FREQUENCY**

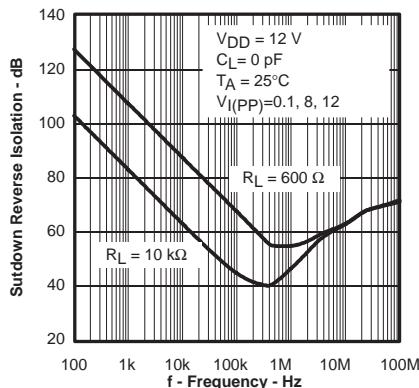


Figure 40

**SHUTDOWN SUPPLY CURRENT  
VS  
SUPPLY VOLTAGE**

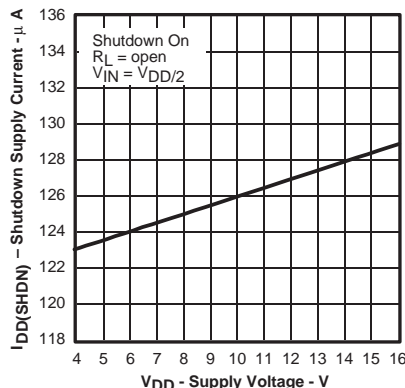


Figure 41

**SHUTDOWN SUPPLY CURRENT  
VS  
FREE-AIR TEMPERATURE**

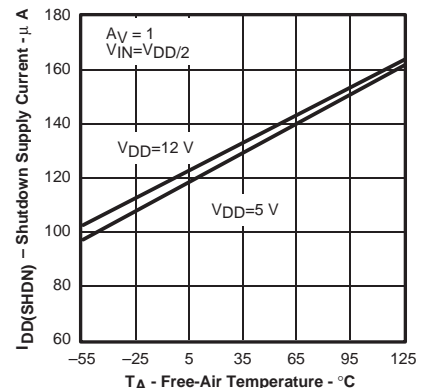


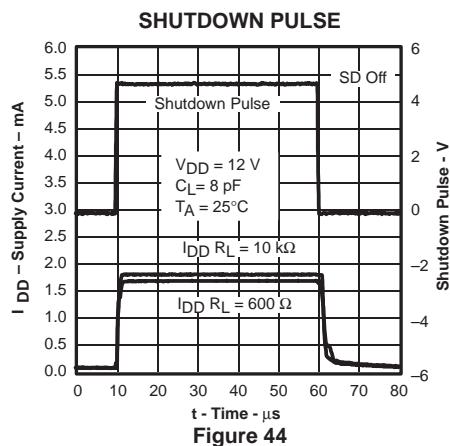
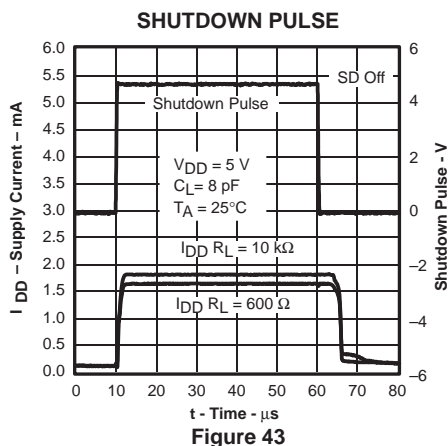
Figure 42



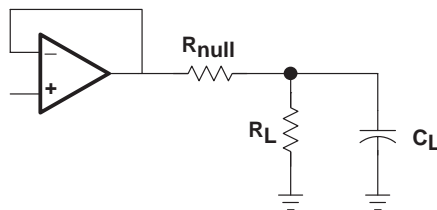
# TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY OPERATIONAL AMPLIFIERS

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## TYPICAL CHARACTERISTICS



## PARAMETER MEASUREMENT INFORMATION

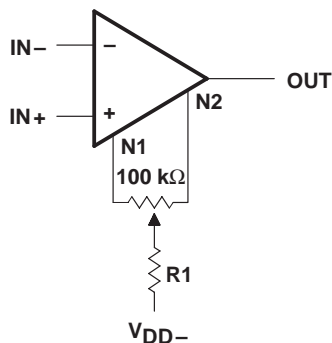


**Figure 45**

## APPLICATION INFORMATION

### input offset voltage null circuit

The TLC080 and TLC081 has an input offset nulling function. Refer to Figure 46 for the diagram.



NOTE A: If R1 = 5.6 kΩ for offset voltage adjustment of ±10 mV.  
If R1 = 20 kΩ for offset voltage adjustment of ±3 mV.

**Figure 46. Input Offset Voltage Null Circuit**

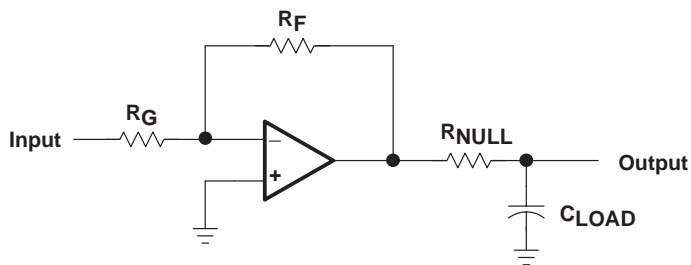
**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**APPLICATION INFORMATION**

**driving a capacitive load**

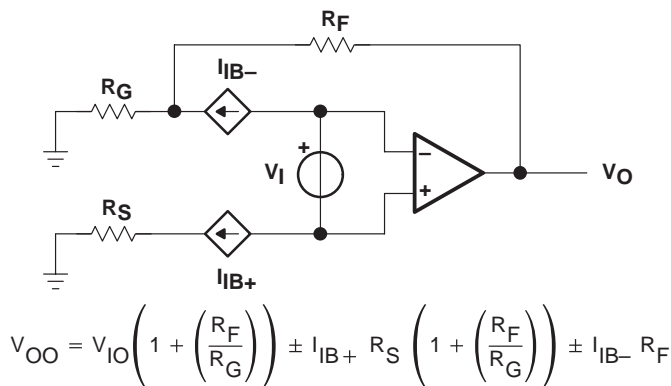
When the amplifier is configured in this manner, capacitive loading directly on the output will decrease the device's phase margin leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series ( $R_{NULL}$ ) with the output of the amplifier, as shown in Figure 47. A minimum value of 20  $\Omega$  should work well for most applications.



**Figure 47. Driving a Capacitive Load**

**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 48. Output Offset Voltage Model**

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## APPLICATION INFORMATION

### high speed CMOS input amplifiers

The TLC08x is a family of high-speed low-noise CMOS input operational amplifiers and has an input capacitance of the order of 20 pF. Any resistor used in the feedback path adds a pole in the transfer function equivalent to the input capacitance multiplied by the combination of source resistance and feedback resistance. For example, a gain of  $-10$ , source resistance of  $1\text{ k}\Omega$  and a feedback resistance of  $10\text{ k}\Omega$  adds an additional pole at approximately 8 MHz. This is more apparent with CMOS amplifiers than bipolar amplifiers due to their greater input capacitance.

This is of little consequence on slower CMOS amplifiers, as this pole normally occurs at frequencies above their unity-gain bandwidth. However, the TLC08x with its 10-MHz bandwidth means that this pole normally occurs at frequencies where there is on the order of 5dB gain left and the phase shift adds considerably.

The effect of this pole is the strongest with large feedback resistances at small closed loop gains. As the feedback resistance is increased, the gain peaking increases at a lower frequency and the  $180^\circ$  phase shift crossover point also moves down in frequency, decreasing the phase margin.

For the TLC08x, the maximum feedback resistor recommended is  $5\text{ k}\Omega$ , larger resistances can be used but a capacitor in parallel with the feedback resistor is recommended to counter the effects of the input capacitance pole.

The TLC083 with a 1-V step response has an 80% overshoot with a natural frequency of 3.5 MHz when configured as a unity gain buffer and with a  $10\text{-k}\Omega$  feedback resistor. By adding a  $10\text{-pF}$  capacitor in parallel with the feedback resistor, the overshoot is reduced to 40% and eliminates the natural frequency, resulting in a much faster settling time (see Figure 49). The  $10\text{-pF}$  capacitor was chosen for convenience only.

Load capacitance had little effect on these measurements due to the excellent output drive capability of the TLC08x.

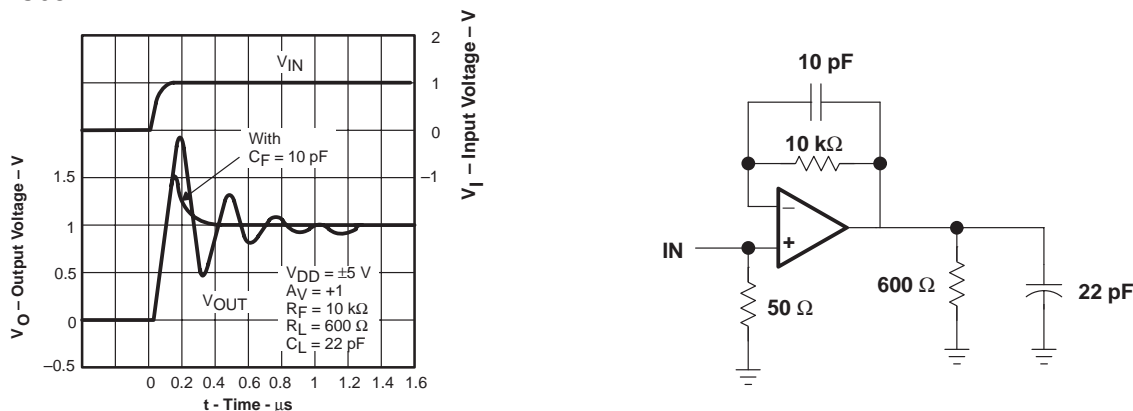


Figure 49. 1-V Step Response

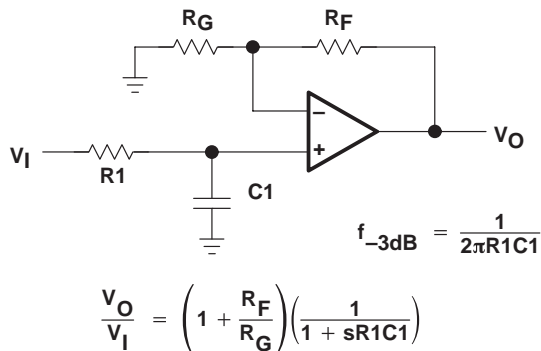
**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**APPLICATION INFORMATION**

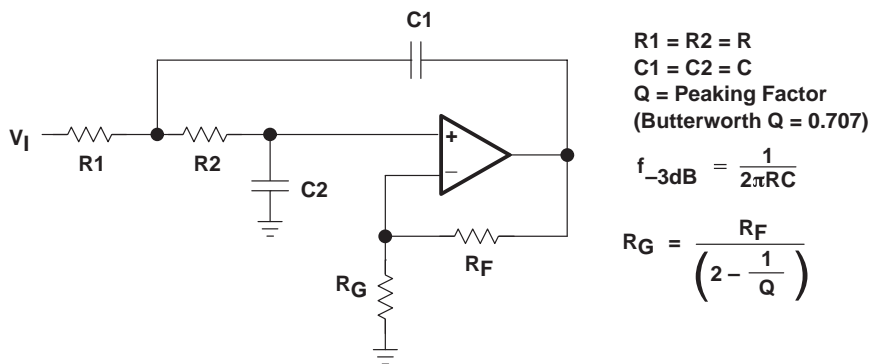
**general configurations**

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 50).



**Figure 50. 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.



**Figure 51. 2-Pole Low-Pass Sallen-Key Filter**

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## APPLICATION INFORMATION

### shutdown function

Three members of the TLC08x family (TLC080/3/5) have a shutdown terminal ( $\overline{\text{SHDN}}$ ) for conserving battery life in portable applications. When the shutdown terminal is tied low, 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 can either be left floating or pulled high. When the shutdown terminal is left floating, care should be taken to ensure that parasitic leakage current at the shutdown terminal does not inadvertently place the operational amplifier into shutdown. The shutdown terminal threshold is always referenced to  $V_{DD}/2$ . 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 GND) to disable the operational amplifier.

The amplifier's output with a shutdown pulse is shown in Figures 43 and 44. The amplifier is powered with a single 5-V supply and is configured as noninverting 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 37, 38, 39, and 40 show the amplifier's forward and reverse isolation in shutdown. The operational amplifier is configured as a voltage follower ( $A_V = 1$ ). The isolation performance is plotted across frequency using 0.1 V<sub>PP</sub>, 2.5 V<sub>PP</sub>, and 5 V<sub>PP</sub> input signals at  $\pm 2.5$  V supplies and 0.1 V<sub>PP</sub>, 8 V<sub>PP</sub>, and 12 V<sub>PP</sub> input signals at  $\pm 6$  V supplies.

### circuit layout considerations

To achieve the levels of high performance of the TLC08x, follow proper printed-circuit board design techniques. A general set of guidelines is given in the following.

- Ground planes – It is highly recommended that a ground plane be used on the board to provide all components with a low inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize the stray capacitance.
- Proper power supply decoupling – Use a 6.8- $\mu$ F tantalum capacitor in parallel with a 0.1- $\mu$ F ceramic capacitor on each supply terminal. It may be possible to share the tantalum among several amplifiers depending on the application, but a 0.1- $\mu$ F ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1- $\mu$ F capacitor should be placed as close as possible to the supply terminal. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. The designer should strive for distances of less than 0.1 inches between the device power terminals and the ceramic capacitors.
- Sockets – Sockets can be used but are not recommended. The additional lead inductance in the socket pins will often lead to stability problems. Surface-mount packages soldered directly to the printed-circuit board is the best implementation.
- Short trace runs/compact part placements – Optimum high performance is achieved when stray series inductance has been minimized. To realize this, the circuit layout should be made as compact as possible, thereby minimizing the length of all trace runs. Particular attention should be paid to the inverting input of the amplifier. Its length should be kept as short as possible. This will help to minimize stray capacitance at the input of the amplifier.
- Surface-mount passive components – Using surface-mount passive components is recommended for high performance amplifier circuits for several reasons. First, because of the extremely low lead inductance of surface-mount components, the problem with stray series inductance is greatly reduced. Second, the small size of surface-mount components naturally leads to a more compact layout thereby minimizing both stray inductance and capacitance. If leaded components are used, it is recommended that the lead lengths be kept as short as possible.

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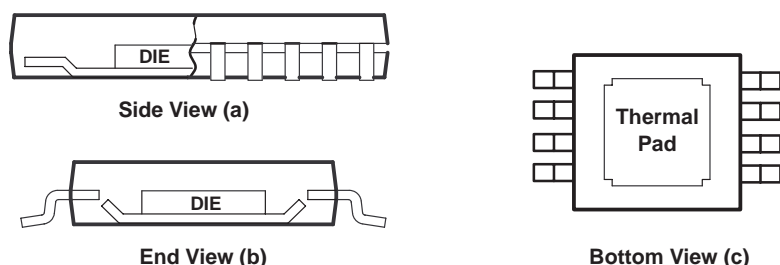
## APPLICATION INFORMATION

### general PowerPAD™ design considerations

The TLC08x is available in a thermally-enhanced PowerPAD family of packages. These packages are constructed using a downset leadframe upon which the die is mounted [see Figure 52(a) and Figure 52(b)]. This arrangement results in the lead frame being exposed as a thermal pad on the underside of the package [see Figure 52(c)]. Because this thermal pad has direct thermal contact with the die, excellent thermal performance can be achieved by providing a good thermal path away from the thermal pad.

The PowerPAD package allows for both assembly and thermal management in one manufacturing operation. During the surface-mount solder operation (when the leads are being soldered), the thermal pad can also be soldered to a copper area underneath the package. Through the use of thermal paths within this copper area, heat can be conducted away from the package into either a ground plane or other heat dissipating device.

The PowerPAD package represents a breakthrough in combining the small area and ease of assembly of surface mount with the, heretofore, awkward mechanical methods of heatsinking.



NOTE B: The thermal pad is electrically isolated from all terminals in the package.

Figure 52. Views of Thermally Enhanced DGN Package

Although there are many ways to properly heatsink the PowerPAD package, the following steps illustrate the recommended approach.

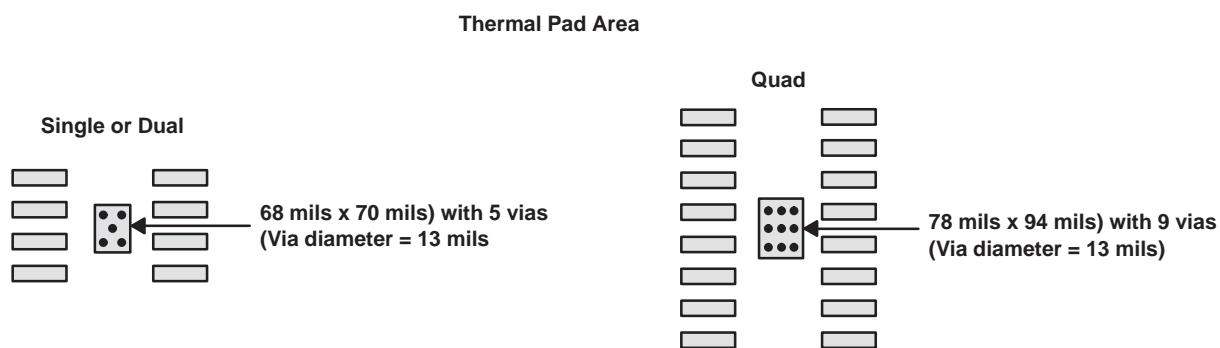


Figure 53. PowerPAD PCB Etch and Via Pattern

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**APPLICATION INFORMATION**

**general PowerPAD design considerations (continued)**

1. Prepare the PCB with a top side etch pattern as shown in Figure 53. There should be etch for the leads as well as etch for the thermal pad.
2. Place five holes (dual) or nine holes (quad) in the area of the thermal pad. These holes should be 13 mils in diameter. Keep them small so that solder wicking through the holes is not a problem during reflow.
3. Additional vias may be placed anywhere along the thermal plane outside of the thermal pad area. This helps dissipate the heat generated by the TLC08x IC. These additional vias may be larger than the 13-mil diameter vias directly under the thermal pad. They can be larger because they are not in the thermal pad area to be soldered so that wicking is not a problem.
4. Connect all holes to the internal ground plane.
5. When connecting these holes to the ground plane, **do not** use the typical web or spoke via connection methodology. Web connections have a high thermal resistance connection that is useful for slowing the heat transfer during soldering operations. This makes the soldering of vias that have plane connections easier. In this application, however, low thermal resistance is desired for the most efficient heat transfer. Therefore, the holes under the TLC08x PowerPAD package should make their connection to the internal ground plane with a complete connection around the entire circumference of the plated-through hole.
6. The top-side solder mask should leave the terminals of the package and the thermal pad area with its five holes (dual) or nine holes (quad) exposed. The bottom-side solder mask should cover the five or nine holes of the thermal pad area. This prevents solder from being pulled away from the thermal pad area during the reflow process.
7. Apply solder paste to the exposed thermal pad area and all of the IC terminals.
8. With these preparatory steps in place, the TLC08x IC is simply placed in position and run through the solder reflow operation as any standard surface-mount component. This results in a part that is properly installed.

For a given  $\theta_{JA}$ , the maximum power dissipation is shown in Figure 54 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 TLC08x 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

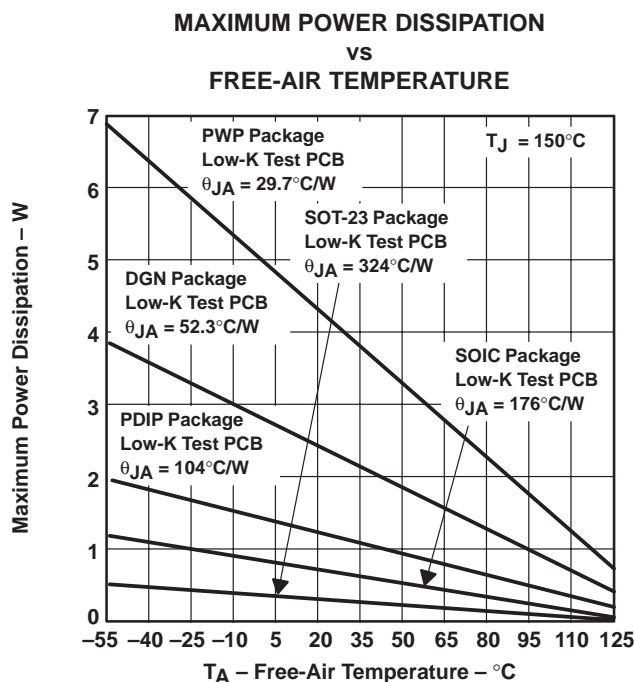
$\theta_{CA}$  = Thermal coefficient from case to ambient air (°C/W)

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**APPLICATION INFORMATION**

**general PowerPAD design considerations (continued)**



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

**Figure 54. Maximum Power Dissipation vs Free-Air Temperature**

The next consideration is the package constraints. The two sources of heat within an amplifier are quiescent power and output power. The designer should never forget about the quiescent heat generated within the device, especially multi-amplifier devices. Because these devices have linear output stages (Class A-B), most of the heat dissipation is at low output voltages with high output currents.

The other key factor when dealing with power dissipation is how the devices are mounted on the PCB. The PowerPAD devices are extremely useful for heat dissipation. But, the device should always be soldered to a copper plane to fully use the heat dissipation properties of the PowerPAD. The SOIC package, on the other hand, is highly dependent on how it is mounted on the PCB. As more trace and copper area is placed around the device,  $\theta_{JA}$  decreases and the heat dissipation capability increases. The currents and voltages shown in these graphs are for the total package. For the dual or quad amplifier packages, the sum of the RMS output currents and voltages should be used to choose the proper package.



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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 55 are generated using the TLC08x 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):

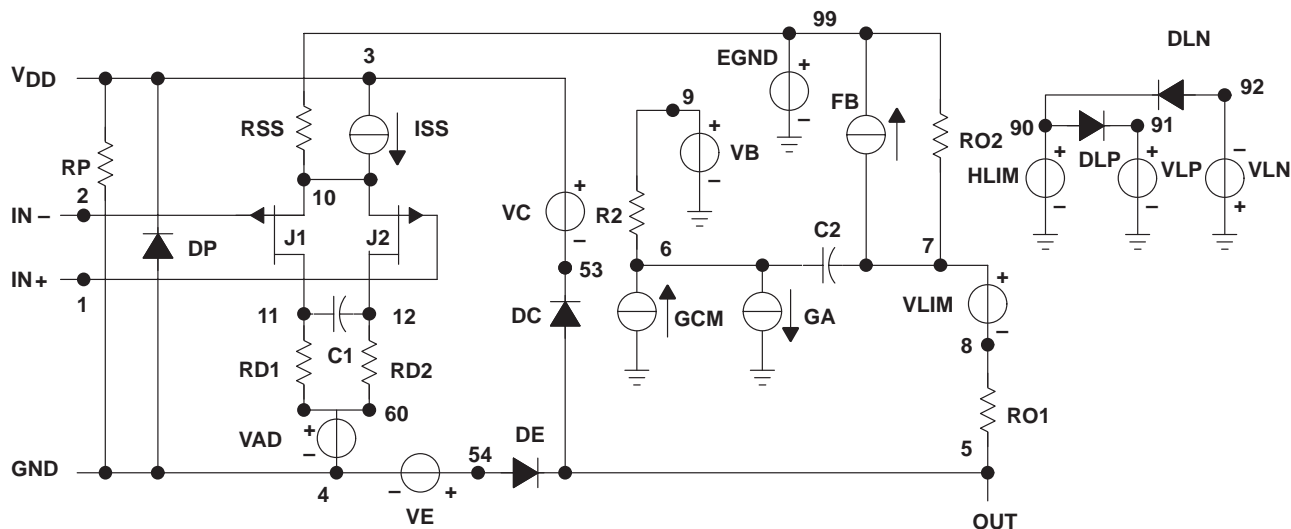
- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit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



\*DEVICE=TLC08X, OPAMP,NPN,INT\*  
+OPAMP,NPN,INT

\* TLC08X operational amplifier "macromodel" subcircuit  
\* created using Parts release 8.0 on 07/02/99 at 13:14  
\* Parts is a MicroSim product.

\* connections: non-inverting input  
\* | inverting input  
\* | positive power supply  
\* | negative power supply  
\* | output

.subckt TLC08X 1 2 3 4 5

```
c1 11 12 4.6015E-12
c2 6 7 8.0000E-12
cee 10 99 993.10E-15
dc 5 53 dy
de 54 5 dy
dip 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 13.984E6 -1E3 1E3
+14E6 -14E6
ga 6 0 11 12 402.12E-6
gcm 0 6 10 99 1.5735E-6
```

```
iee 10 4 dc 130.40E-6
ioff 0 6 dc 1.235E-6
hlim 90 0 vlim 1K
q1 11 2 13 qx1
q2 12 1 14 qx2
r2 6 9 100.00E3
rc1 3 11 2.4868E3
rc2 3 12 2.4868E3
re1 13 10 2.0901E3
re2 14 10 2.0901E3
ree 10 99 1.5337E6
ro1 8 5 10
ro2 7 99 10
rp 3 4 3.0495E3
vb 9 0 dc 0
vc 3 53 dc 1.5537
ve 54 4 dc .84373
vlim 7 8 dc 0
vlp 91 0 dc 117.60
vln 0 92 dc 117.60
.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=407.50E6)
.model qx2 NPN(Is=800.0000E-18 Bf=407.50E6)
.ends
*$
```

Figure 55. Boyle Macromodel and Subcircuit

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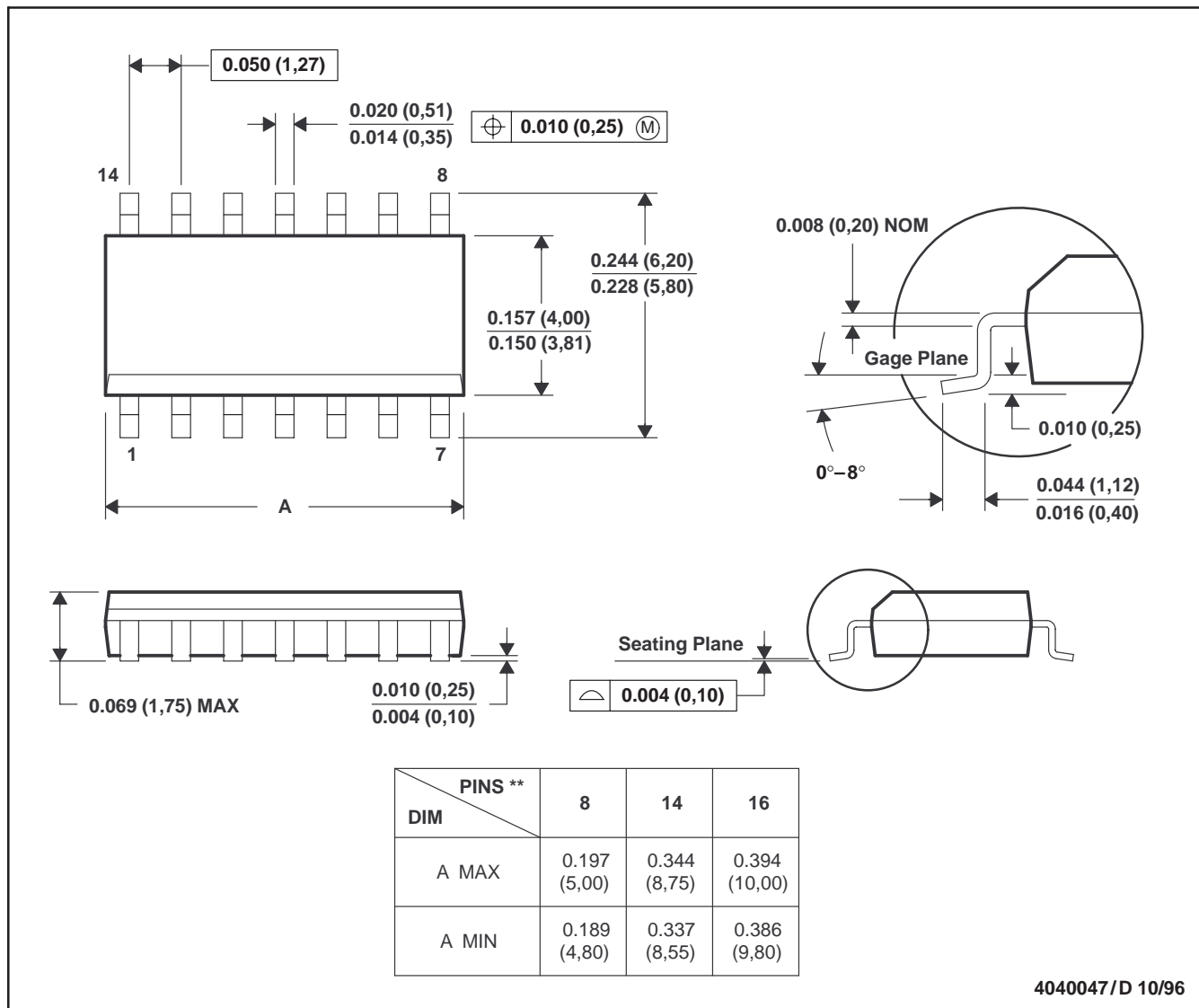
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**MECHANICAL DATA**

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

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



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

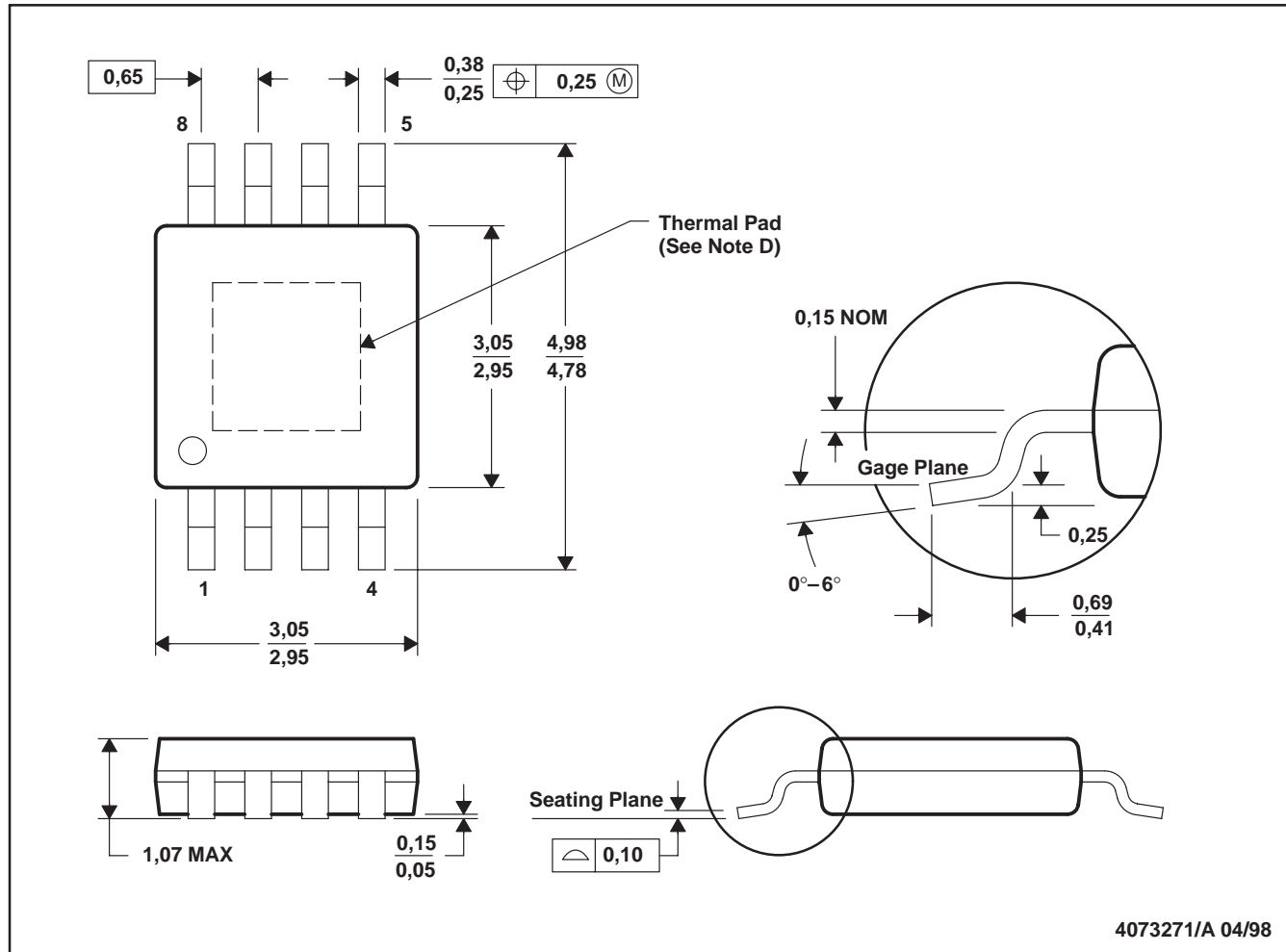
**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
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**MECHANICAL INFORMATION**

**DGN (S-PDSO-G8)**

**PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE**



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions include mold flash or protrusions.  
 D. The package thermal performance may be enhanced by attaching an external heat sink to the thermal pad. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.  
 E. Falls within JEDEC MO-187

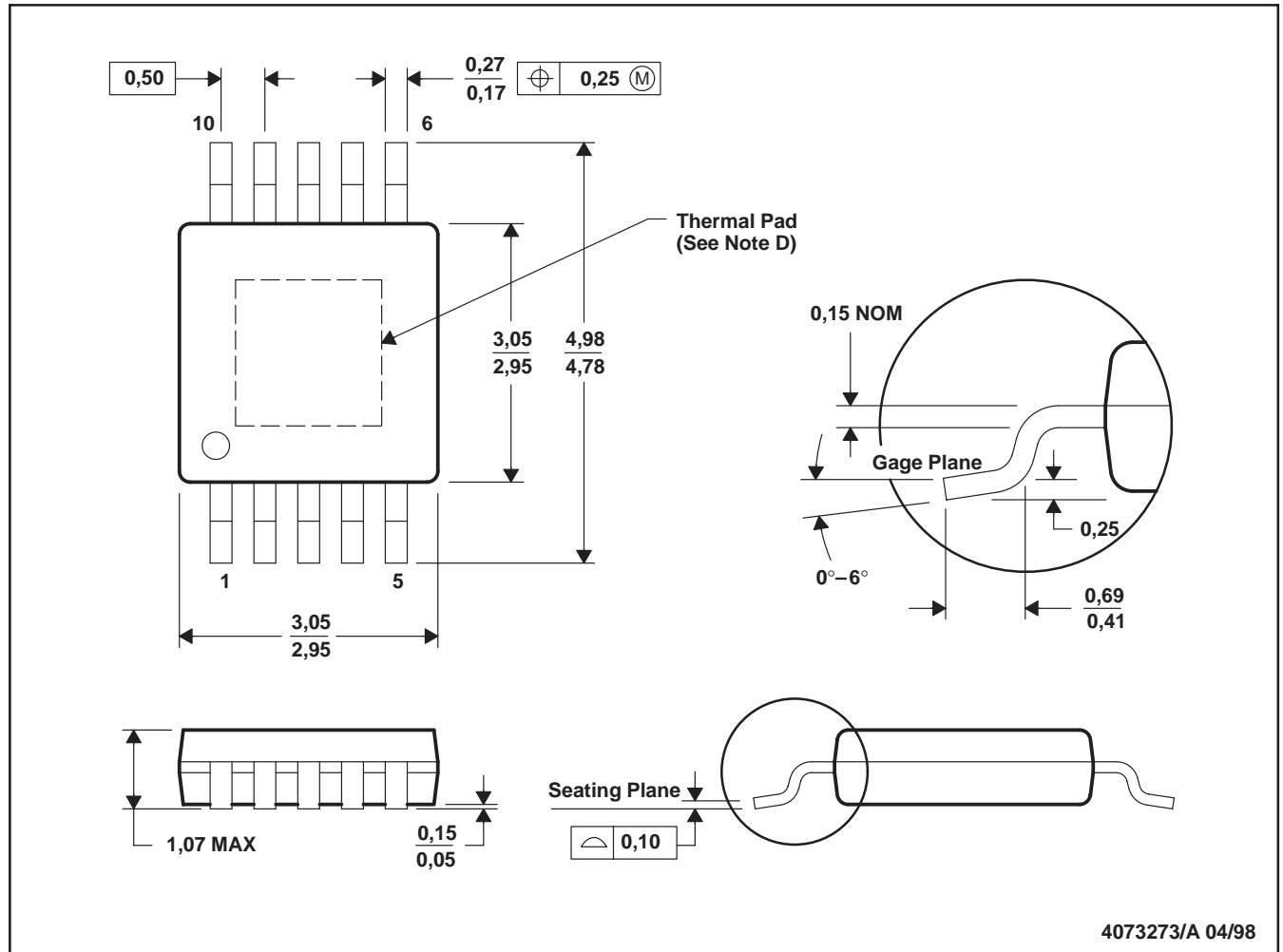
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MECHANICAL INFORMATION

DGQ (S-PDSO-G10)

PowerPAD™ PLASTIC SMALL-OUTLINE PACKAGE



4073273/A 04/98

- 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. The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
**FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY**  
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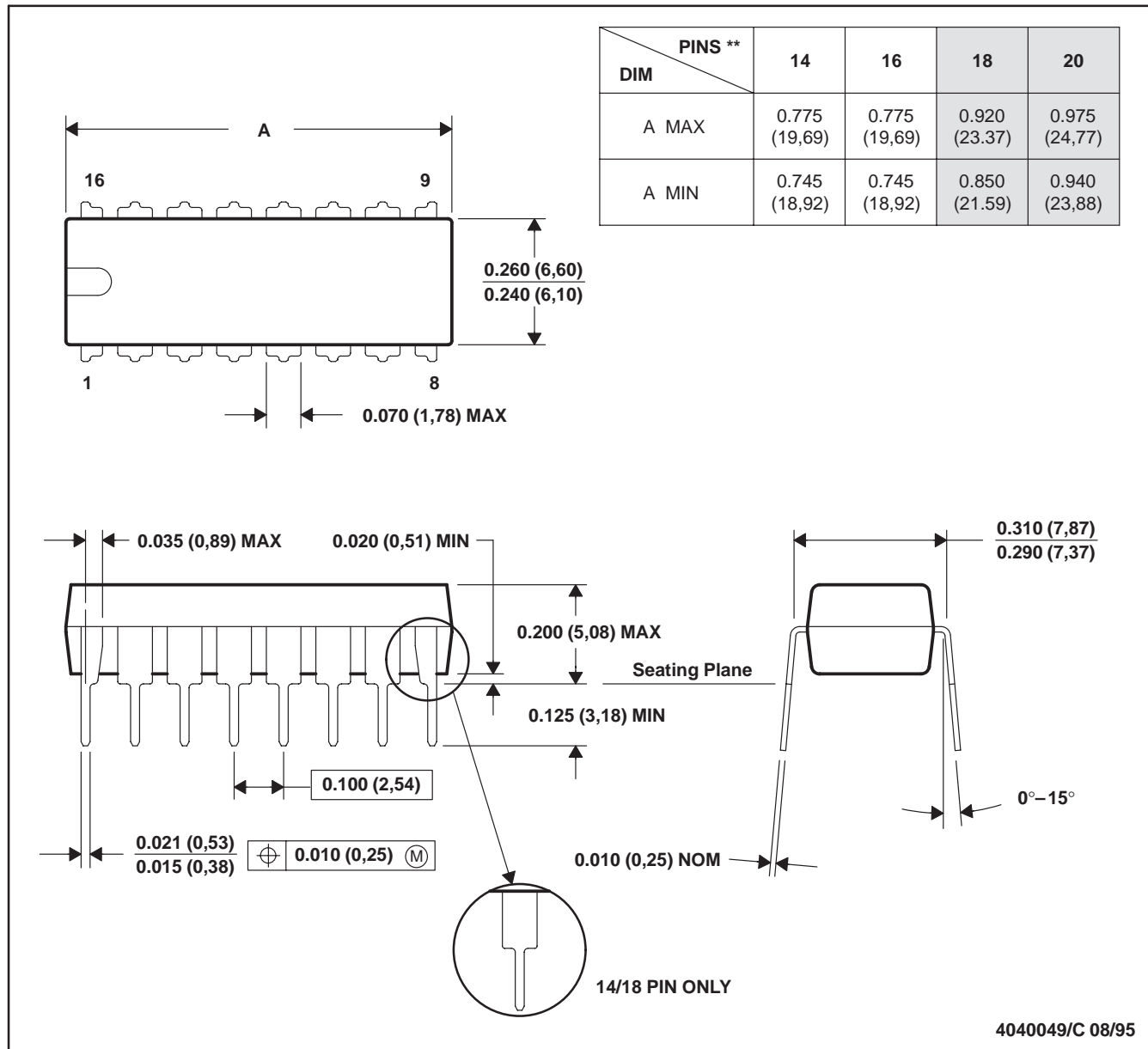
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**MECHANICAL INFORMATION**

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

**PLASTIC DUAL-IN-LINE PACKAGE**

16 PIN SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001 (20 pin package is shorter than MS-001.)

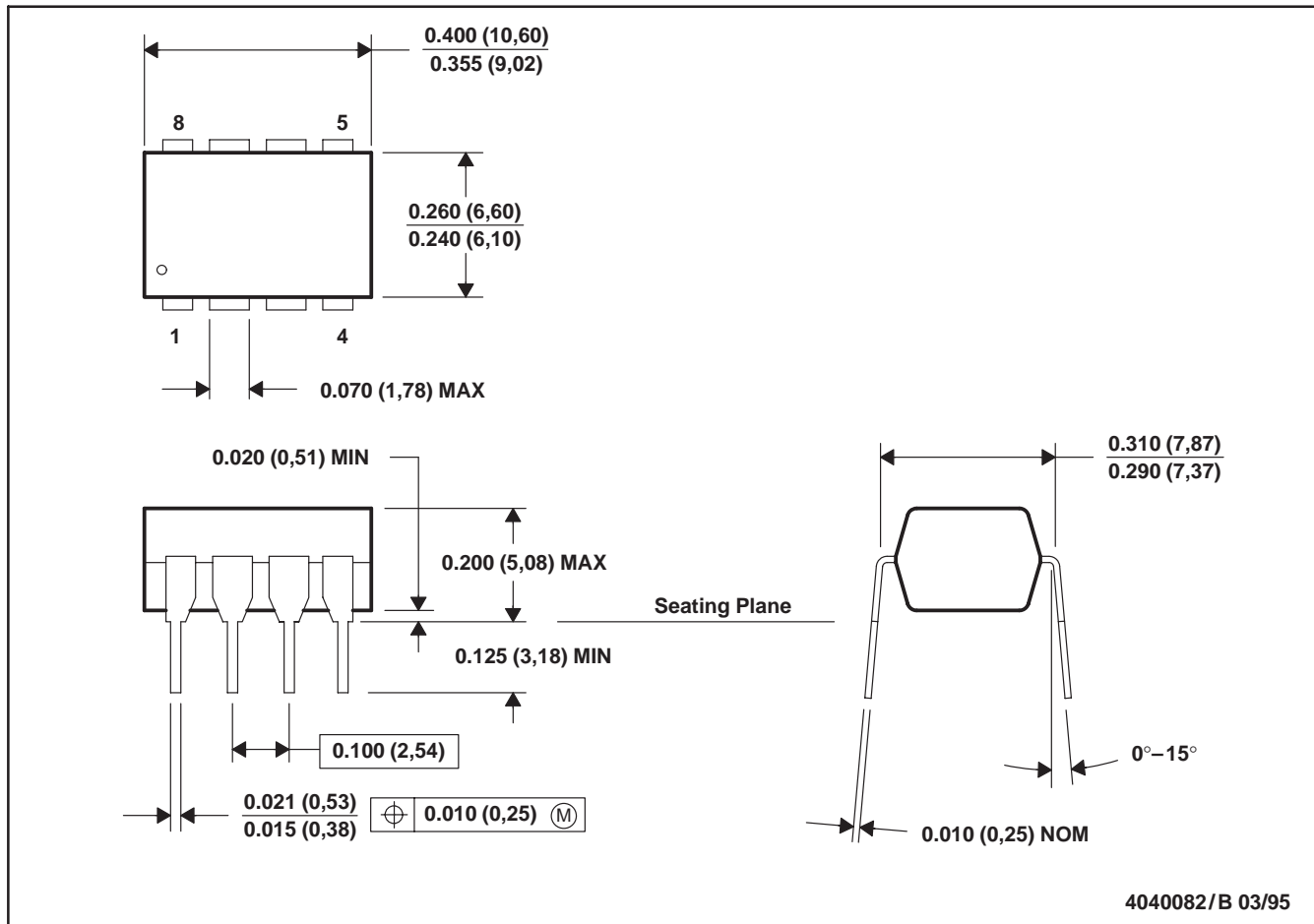
TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA  
 FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY  
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MECHANICAL INFORMATION

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



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

**TLC080, TLC081, TLC082, TLC083, TLC084, TLC085, TLC08xA**  
**FAMILY OF WIDE-BANDWIDTH HIGH-OUTPUT-DRIVE SINGLE SUPPLY**  
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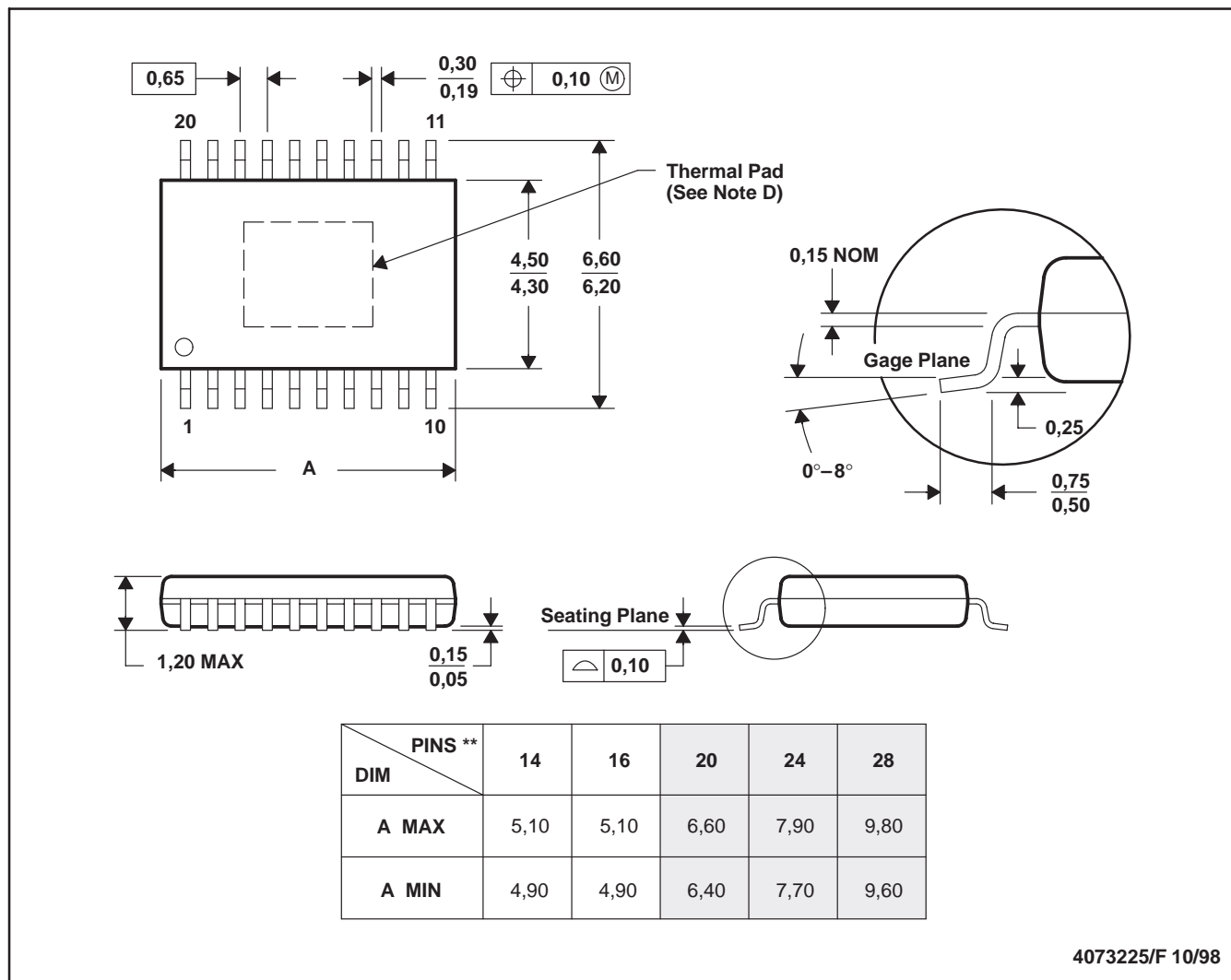
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**MECHANICAL INFORMATION**

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

**PowerPAD™ PLASTIC SMALL-OUTLINE**

20 PINS SHOWN



- 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 protrusions.  
 D. The package thermal performance may be enhanced by bonding the thermal pad to an external thermal plane. This pad is electrically and thermally connected to the backside of the die and possibly selected leads.  
 E. Falls within JEDEC MO-153



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