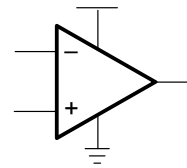


# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

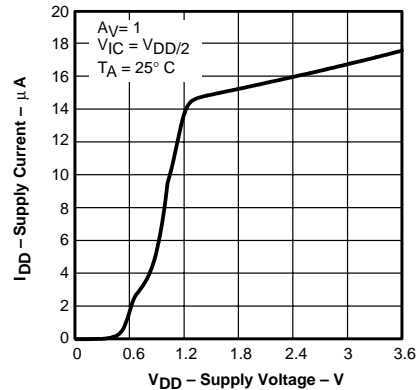
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- Low Supply Voltage . . . 1.8 V to 3.6 V
- Very Low Supply Current . . . 20  $\mu$ A (per channel)
- Ultralow Power Shut-Down Mode
  - $I_{DD}(SHDN) = 10$  nA/Channel
- CMOS Rail-to-Rail Input/Output
- Input Common-Mode Voltage Range . . .  $-0.2$  V to  $V_{DD} + 0.2$  V
- Input Offset Voltage . . . 550  $\mu$ V
- Wide Bandwidth . . . 500 kHz
- Slew Rate . . . 0.20 V/ $\mu$ s
- Specified Temperature Range
  - $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  . . . Commercial Grade
  - $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  . . . Industrial Grade
- Ultrasmall Packaging
  - 5 or 6 Pin SOT-23 (TLV2760/1)
  - 8 or 10 Pin MSOP (TLV2762/3)
- Universal Op-Amp EVM

Operational Amplifier



SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE



## description

The TLV276x single supply operational amplifiers provide 500 kHz bandwidth from only 20  $\mu$ A while operating down to 1.8 V over the industrial temperature range. The maximum recommended supply voltage is 3.6 V, which allows the devices to be operated from ( $\pm 1.8$  V supplies down to  $\pm 0.9$  V) two AA or AAA cells. The devices have been characterized at 1.8 V (end of life of 2 AA(A) cells) and at 2.4 V (nominal voltage of 2 Nicd/NiMH cells). The TLV276x have rail-to-rail input and output capability which is a necessity at 1.8 V.

The low supply current is coupled with extremely low input bias currents enabling them to be used with mega-ohm resistors. Low shutdown current of only 10 nA make these devices ideal for low frequency measurement applications desiring long active battery life.

All members are available in PDIP and SOIC with the singles in the small SOT-23 package, duals in the MSOP, and quads in the TSSOP package.

### SELECTION OF SINGLE SUPPLY AMPLIFIER PRODUCTS

DEVICE	V <sub>DD</sub> (V)	V <sub>IO</sub> ( $\mu$ V)	I <sub>DD</sub> /Ch ( $\mu$ A)	I <sub>B</sub> (pA)	GBW (MHz)	SR (V/ $\mu$ s)	V <sub>n</sub> ,1kHz (nV/rtHz)	I <sub>O</sub> (mA)	SHUT-DOWN	RAIL-TO-RAIL
TLV224x	2.5 – 12	600	1	100	0.0055	0.002	NA	0.2	—	I/O
TLV2211	2.7 – 10	450	13	1	0.065	0.025	21	0.4	—	O
TLV276x	1.8 – 3.6	550	20	3	0.5	0.23	95	5	Y	I/O
TLV245x(A)	2.7 – 6	20	23	500	0.22	0.11	49	2.5	Y	I/O
TLV246x(A)	2.7 – 6	150	550	1300	6.4	1.6	11	25	Y	I/O
TLV278x(A)	1.8 – 3.6	250	650	2.5	8	5	18	10	Y	I/O



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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.

**TEXAS  
INSTRUMENTS**

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# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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## TLV2760 and TLV2761 AVAILABLE OPTIONS

T <sub>A</sub>	V <sub>IOMax</sub> AT 25°C	PACKAGED DEVICES			
		SMALL OUTLINE (D)†	SOT-23		PLASTIC DIP (P)
			(DBV)‡	SYMBOL	
0°C to 70°C	3500 μV	TLV2760CD TLV2761CD	— —	— —	— —
–40°C to 85°C	3500 μV	TLV2760ID TLV2761ID	TLV2760IDBV TLV2761IDBV	VANI VAXI	TLV2760IP TLV2761IP

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2760CDR).

‡ This package is only available taped and reeled. For standard quantities (3,000 pieces per reel), add an R suffix (i.e., TLV2760CDBVR). For smaller quantities (250 pieces per mini-reel), add a T suffix to the part number (e.g. TLV2760CDBVT).

## TLV2762 and TLV2763 AVAILABLE OPTIONS

T <sub>A</sub>	V <sub>IOMax</sub> AT 25°C	PACKAGED DEVICES						
		SMALL OUTLINE (D)†	MSOP				PLASTIC DIP (N)	PLASTIC DIP (P)
			DGK†	SYMBOL	DGS†	SYMBOL		
0°C to 70°C	3500 μV	TLV2762CD TLV2763CD	— —	— —	— —	— —	— —	
–40°C to 85°C	3500 μV	TLV2762ID TLV2763ID	TLV2762IDGK —	xxTIAJP —	— TLV2763DGS	— xxTIAJR	— TLV2763IN	TLV2762IP —

† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2762CDR).

## TLV2764 and TLV2765 AVAILABLE OPTIONS

T <sub>A</sub>	V <sub>IOMax</sub> AT 25°C	PACKAGED DEVICES		
		SMALL OUTLINE (D)†	PLASTIC DIP (N)	TSSOP (PW)†
0°C to 70°C	3500 μV	TLV2764CD TLV2765CD	— —	— —
–40°C to 85°C	3500 μV	TLV2764ID TLV2765ID	TLV2764IN TLV2765IN	TLV2764IPW TLV2765IPW

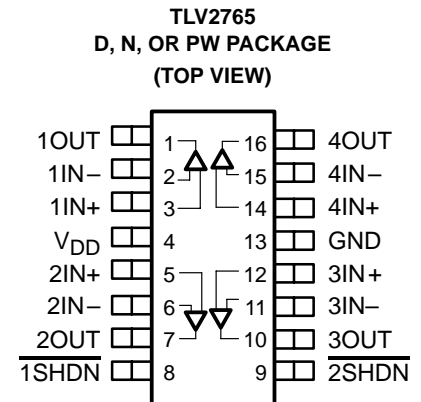
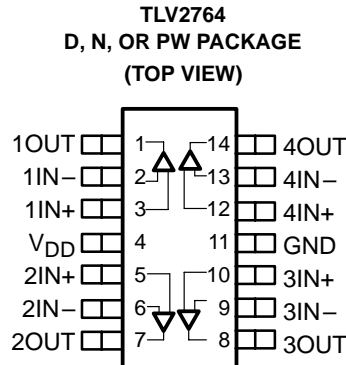
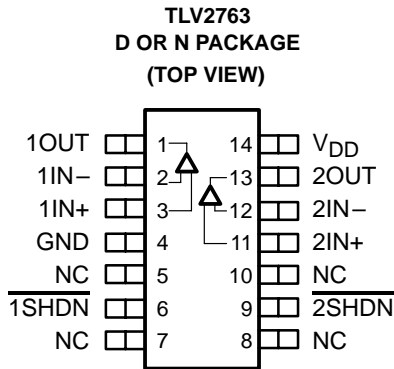
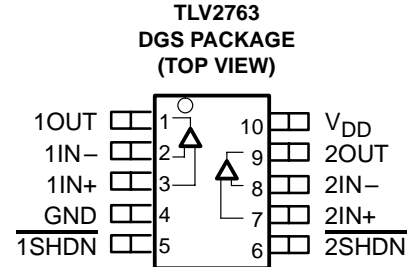
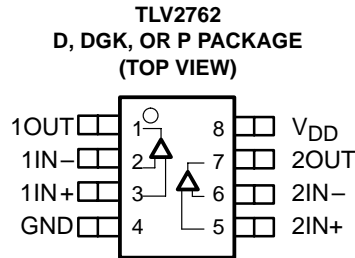
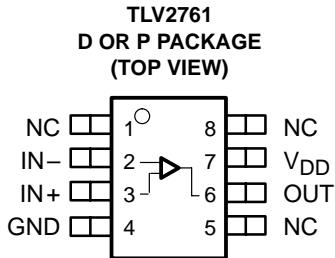
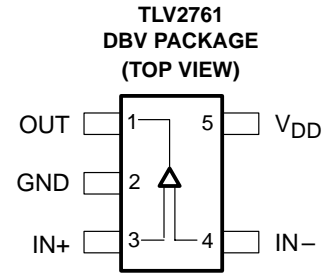
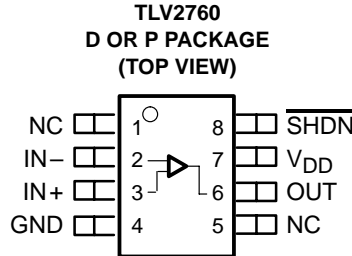
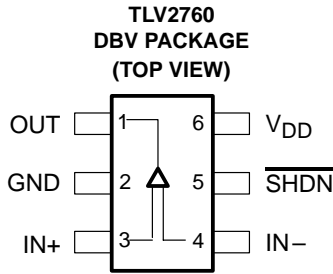
† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2764CDR).



# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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## TLV276x PACKAGE PINOUTS



NC – No internal connection

**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
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**absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†**

Supply voltage, $V_{DD}$ (see Note 1)	4 V
Differential input voltage range, $V_{ID}$	$\pm V_{DD}$
Input current range, $I_I$	$\pm 10$ mA
Output current range, $I_O$	$\pm 10$ mA
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 85°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 1: 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	$T_A = 85^\circ\text{C}$ POWER RATING
D (8)	38.3	176	710 mW	369 mW
D (14)	26.9	122	1022 mW	531 mW
D (16)	25.7	114	1090 mW	567 mW
DBV (5)	55	324	385 mW	201 mW
DBV (6)	55	294	425 mW	221 mW
DGK(8)	54.2	260	481 mW	250 mW
DGS(10)	54.1	258	485 mW	252 mW
N (14,16)	32	78	1600 mW	833 mW
P	41	104	1200 mW	625 mW
PW (14)	29.3	174	720 mW	374 mW
PW (16)	28.7	161	774 mW	403 mW

**recommended operating conditions**

		MIN	MAX	UNIT
Supply voltage, $V_{DD}$	Single supply	1.8	3.6	V
	Split supply	$\pm 0.8$	$\pm 1.8$	
Common-mode input voltage range, $V_{ICR}$		-0.2	$V_{DD}+0.2$	V
Operating free-air temperature, $T_A$	C-suffix	0	70	°C
	I-suffix	-40	85	
Shutdown on/off voltage level (see Note 2)	$V_{IH}$	$V_{DD} < 2.7$ V	$0.75 V_{DD}$	V
		$V_{DD} = 2.7$ to $3.6$ V	2	
	$V_{IL}$		0.6	

NOTE 2: Relative to GND



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electrical characteristics at recommended operating conditions,  $V_{DD} = 1.8\text{ V}, 2.4\text{ V}$  (unless otherwise noted)

**dc performance**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT
$V_{IO}$	Input offset voltage	$V_{IC} = V_{DD}/2,$ $V_O = V_{DD}/2,$ $R_L = 300\text{ k}\Omega,$ $R_S = 50\ \Omega$	TLV276x	25°C	550	3500		$\mu\text{V}$
				Full range		6800		
$\alpha_{VIO}$	Offset voltage drift				9			$\mu\text{V}/^\circ\text{C}$
CMRR	Common-mode rejection ratio	$V_{ICR} = 0\text{ V to }V_{DD},$ $R_S = 50\ \Omega$	$V_{DD} = 1.8\text{ V}$	25°C	50	70		dB
				Full range	48			
			$V_{DD} = 2.4\text{ V}$	25°C	53	72		dB
				Full range	50			
			$V_{DD} = 3.6\text{ V}$	25°C	55	76		dB
				Full range	55			
			$V_{DD} = 2.4\text{ V}, 3.6\text{ V}$	25°C	63	82		dB
				Full range	60			
$A_{VD}$	Large-signal differential voltage amplification	$R_L = 10\text{ k}\Omega,$ $V_O(PP) = V_{DD}/2$	$V_{DD} = 1.8\text{ V}$	25°C	20	60		V/mV
				Full range	18			
			$V_{DD} = 2.4\text{ V}$	25°C	28	78		V/mV
				Full range	23			
			$V_{DD} = 3.6\text{ V}$	25°C	45	120		V/mV
				Full range	37			

† Full range is 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix. If not specified, full range is –40°C to 85°C.

**input characteristics**

PARAMETER		TEST CONDITIONS		$T_A$ †	MIN	TYP	MAX	UNIT
$I_{IO}$	Input offset current	$V_{IC} = V_{DD}/2,$ $V_O = V_{DD}/2,$ $R_L = 300\text{ k}\Omega,$ $R_S = 50\ \Omega$		25°C	3	15		pA
			TLV276xC	Full range			100	
			TLV276xI	Full range			200	
$I_{IB}$	Input bias current			25°C	3	15		pA
			TLV276xC	Full range			100	
			TLV276xI	Full range			200	
$r_{i(d)}$	Differential input resistance			25°C	1000			G $\Omega$
$C_{i(c)}$	Common-mode input capacitance	$f = 16\text{ kHz}$		25°C	10			pF

† Full range is 0°C to 70°C for the C suffix and –40°C to 85°C for the I suffix. If not specified, full range is –40°C to 85°C.



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electrical characteristics at recommended operating conditions,  $V_{DD} = 1.8\text{ V}, 2.4\text{ V}$  (unless otherwise noted) (continued)

**output characteristics**

PARAMETER	TEST CONDITIONS		$T_A^\dagger$	MIN	TYP	MAX	UNIT
$V_{OH}$ High-level output voltage	$V_{IC} = V_{DD}/2,$ $I_{OH} = -100\ \mu\text{A}$	$V_{DD} = 1.8\text{ V}$	25°C	1.77	1.79		V
			Full range	1.76			
		$V_{DD} = 2.4\text{ V}$	25°C	2.38	2.39		
			Full range	2.37			
		$V_{DD} = 3.6\text{ V}$	25°C	3.58	3.59		
			Full range	3.57			
	$V_{IC} = V_{DD}/2,$ $I_{OH} = -500\ \mu\text{A}$	$V_{DD} = 1.8\text{ V}$	25°C	1.725	1.75		
			Full range	1.7			
		$V_{DD} = 2.4\text{ V}$	25°C	2.325	2.35		
			Full range	2.3			
		$V_{DD} = 3.6\text{ V}$	25°C	3.525	3.55		
			Full range	3.5			
$V_{OL}$ Low-level output voltage	$V_{IC} = V_{DD}/2,$ $I_{OL} = 100\ \mu\text{A}$	25°C		10	20	mV	
		Full range			30		
	$V_{IC} = V_{DD}/2,$ $I_{OL} = 500\ \mu\text{A}$	25°C		50	75		
		Full range			100		
$I_O$ Output current	$V_{DD} = 1.8\text{ V},$ $V_O = 0.5\text{ V from}$	Positive rail	25°C	4.8		mA	
		Negative rail		7.2			
	$V_{DD} = 2.4\text{ V},$ $V_O = 0.5\text{ V from}$	Positive rail	25°C	7.3			
		Negative rail		10.2			
$I_{OS}$ Short-circuit output current	$V_{DD} = 1.8\text{ V}$	Sourcing	25°C	7		mA	
		Sinking		10			
	$V_{DD} = 2.4\text{ V}$	Sourcing	25°C	15			
		Sinking		19			

† Full range is 0°C to 70°C for the C suffix and -40°C to 85°C for the I suffix. If not specified, full range is -40°C to 85°C.

**power supply,  $V_{DD} = 1.8\text{ V}, 2.4\text{ V}, 3.6\text{ V}$  (unless otherwise noted)**

PARAMETER	TEST CONDITIONS		$T_A^\dagger$	MIN	TYP	MAX	UNIT
$I_{DD}$ Supply current (per channel)	$V_O = V_{DD}/2,$ $\overline{\text{SHDN}} = V_{DD}$	25°C		20	28		$\mu\text{A}$
		Full range				30	
$k_{SVR}$ Supply voltage rejection ratio ( $\Delta V_{DD} / \Delta V_{IO}$ )	$V_{DD} = 1.8\text{ V to } 2.4\text{ V},$ $V_{IC} = V_{DD}/2$	No load	25°C	65	85		dB
			Full range	63			
	$V_{DD} = 2.4\text{ V to } 3.6\text{ V},$ $V_{IC} = V_{DD}/2$	25°C	65	85			
		Full range	63				
	$V_{DD} = 1.8\text{ V to } 3.6\text{ V},$ $V_{IC} = V_{DD}/2$	25°C	65	85			
		Full range	63				

† Full range is 0°C to 70°C for the C suffix and -40°C to 85°C for the I suffix. If not specified, full range is -40°C to 85°C.



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electrical characteristics at recommended operating conditions,  $V_{DD} = 1.8\text{ V}, 2.4\text{ V}$  (unless otherwise noted) (continued)

**dynamic performance**

PARAMETER		TEST CONDITIONS		$T_A^\dagger$	MIN	TYP	MAX	UNIT
UGBW	Unity gain bandwidth	$R_L = 300\text{ k}\Omega,$	$C_L = 10\text{ pF}$	25°C		500		kHz
SR+	Positive slew rate at unity gain	$V_{O(PP)} = 1\text{ V}, R_L = 300\text{ k}\Omega,$ $C_L = 50\text{ pF},$	$V_{DD} = 1.8\text{ V}$	25°C	0.11	0.20		V/ $\mu$ s
				Full range	0.09			
			$V_{DD} = 2.4\text{ V}$	25°C	0.11	0.22		V/ $\mu$ s
				Full range	0.09			
			$V_{DD} = 3.6\text{ V}$	25°C	0.11	0.23		V/ $\mu$ s
				Full range	0.09			
SR-	Negative slew rate at unity gain	$V_{O(PP)} = 1\text{ V}, R_L = 300\text{ k}\Omega,$ $C_L = 50\text{ pF},$	$V_{DD} = 1.8\text{ V}$	25°C	0.08	0.15		V/ $\mu$ s
				Full range	0.07			
			$V_{DD} = 2.4\text{ V}$	25°C	0.10	0.18		V/ $\mu$ s
				Full range	0.09			
			$V_{DD} = 3.6\text{ V}$	25°C	0.10	0.22		V/ $\mu$ s
				Full range	0.09			
$\phi_m$	Phase margin	$R_L = 300\text{ k}\Omega,$	$C_L = 100\text{ pF}$	25°C		63		°
	Gain margin			25°C		20		dB
$t_s$	Settling time	$V_{DD} = 1.8\text{ V}, V_{(STEP)PP} = 1\text{ V},$ $A_V = -1, C_L = 10\text{ pF}, R_L = 300\text{ k}\Omega$	0.1%	25°C		6.4		$\mu$ s
						0.01%		
		$V_{DD} = 2.4\text{ V}, V_{(STEP)PP} = 1\text{ V},$ $A_V = -1, C_L = 10\text{ pF}, R_L = 300\text{ k}\Omega$	0.1%			6		
						0.01%		

$^\dagger$  Full range is 0°C to 70°C for the C suffix and -40°C to 85°C for the I suffix. If not specified, full range is -40°C to 85°C.

**noise/distortion**

PARAMETER		TEST CONDITIONS		$T_A$	MIN	TYP	MAX	UNIT
THD + N	Total harmonic distortion plus noise	$V_{DD} = 1.8\text{ V},$ $V_{O(PP)} = V_{DD}/2\text{ V},$ $R_L = 300\text{ k}\Omega,$ $f = 1\text{ kHz}$	$A_V = 1$	25°C	0.08%			
			$A_V = 10$		0.10%			
			$A_V = 100$		0.27%			
		$V_{DD} = 2.4\text{ V},$ $V_{O(PP)} = V_{DD}/2\text{ V},$ $R_L = 300\text{ k}\Omega,$ $f = 1\text{ kHz}$	$A_V = 1$	25°C	0.06%			
			$A_V = 10$		0.08%			
			$A_V = 100$		0.24%			
$V_n$	Equivalent input noise voltage	$f = 1\text{ kHz}$		25°C	95			nV/ $\sqrt{\text{Hz}}$
		$f = 10\text{ kHz}$		25°C	75			
$I_n$	Equivalent input noise current	$f = 1\text{ kHz}$		25°C	0.8			fA/ $\sqrt{\text{Hz}}$

**shutdown characteristics**

PARAMETER		TEST CONDITIONS	$T_A^\dagger$	MIN	TYP	MAX	UNIT
$I_{DD(SHDN)}$	Supply current, all channels in shutdown mode (TLV2760, TLV2763, TLV2765) (per channel)	$\overline{\text{SHDN}} = 0\text{ V}$	25°C	10	50		nA
			Full range			400	
$t_{(on)}$	Amplifier turnon time (see Note 3)	$R_L = 300\text{ k}\Omega$	25°C	5			$\mu$ s
$t_{(off)}$	Amplifier turnoff time (see Note 3)	$R_L = 300\text{ k}\Omega$	25°C	0.8			$\mu$ s

$^\dagger$  Full range is 0°C to 70°C for the C suffix and -40°C to 85°C for the I suffix. If not specified, full range is -40°C to 85°C.

NOTE 3: 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.



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**TYPICAL CHARACTERISTICS**

**Table of Graphs**

			<b>FIGURE</b>
$V_{IO}$	Input offset voltage	vs Common-mode input voltage	1, 2
CMRR	Common-mode rejection ratio	vs Frequency	3
$V_{OH}$	High-level output voltage	vs High-level output current	4, 6
$V_{OL}$	Low-level output voltage	vs Low-level output current	5, 7
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	8
$I_{DD}$	Supply current	vs Supply voltage	9
$I_{DD}$	Supply current	vs Free-air temperature	10
PSRR	Power supply rejection ratio	vs Frequency	11
$A_{VD}$	Differential voltage amplification & phase	vs Frequency	12
	Gain-bandwidth product	vs Temperature	13
		vs Supply voltage	14
SR	Slew rate	vs Supply voltage	15
		vs Free-air temperature	16, 17
$\phi_m$	Phase margin	vs Load capacitance	18
$V_n$	Equivalent input noise voltage	vs Frequency	19
	Supply current and output voltage	vs Time	20
	Voltage-follower large-signal pulse response	vs Time	21
	Voltage-follower small-signal pulse response	vs Time	22
	Inverting large-signal response	vs Time	23
	Inverting small-signal response	vs Time	24
	Crosstalk	vs Frequency	25
	Shutdown forward & reverse isolation	vs Frequency	26
$I_{DD(SHDN)}$	Shutdown supply current	vs Supply voltage	27
$I_{DD(SHDN)}$	Shutdown supply current	vs Free-air temperature	28
$I_{DD(SHDN)}$	Shutdown pin leakage current	vs Shutdown pin voltage	29
$I_{DD(SHDN)}$	Shutdown supply current/output voltage	vs Time	30





# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

SLOS326D – JUNE 2000 – REVISED FEBRUARY 2001

## TYPICAL CHARACTERISTICS

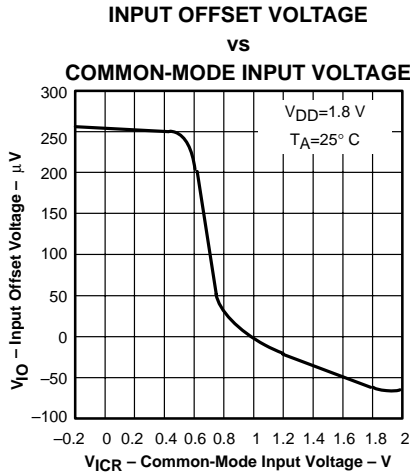


Figure 1

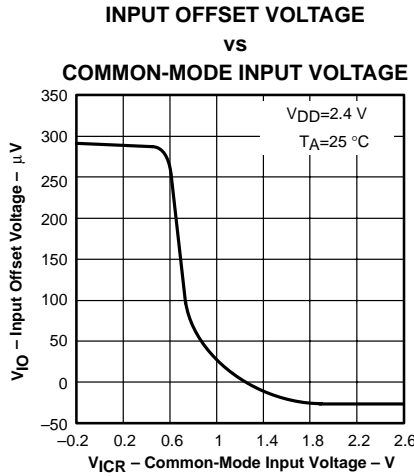


Figure 2

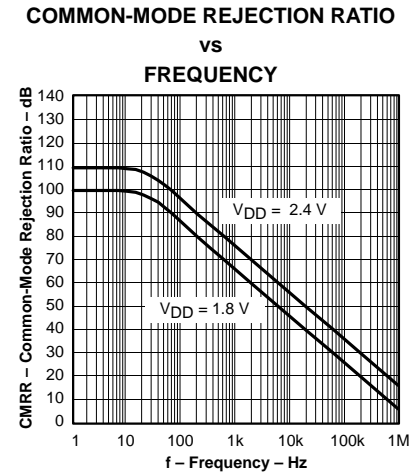


Figure 3

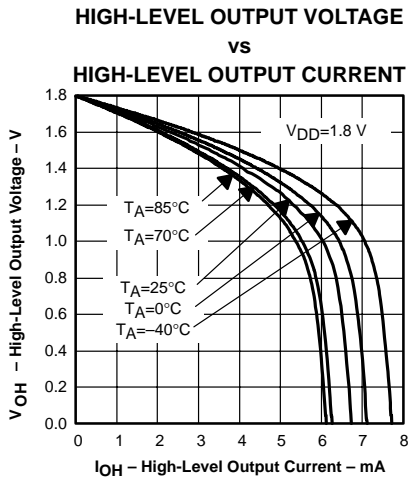


Figure 4

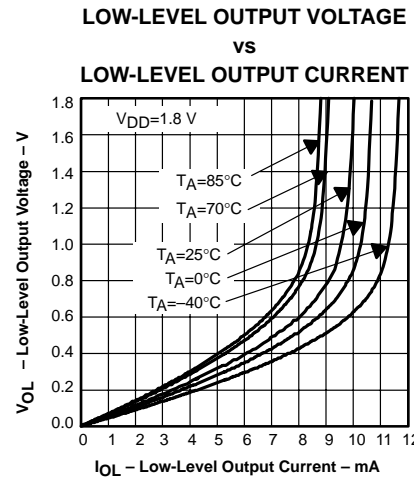


Figure 5

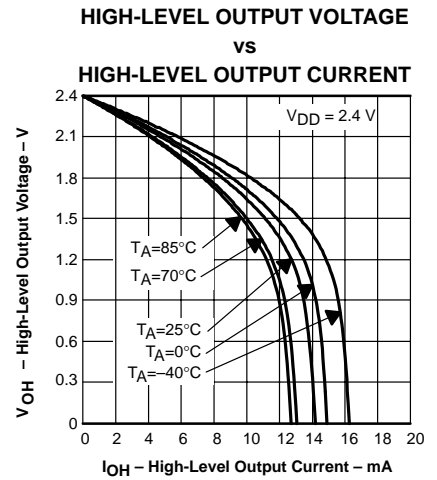


Figure 6

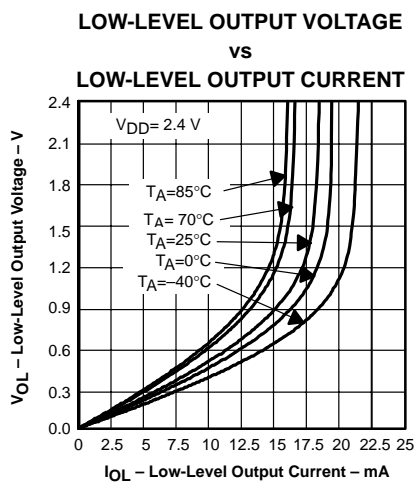


Figure 7

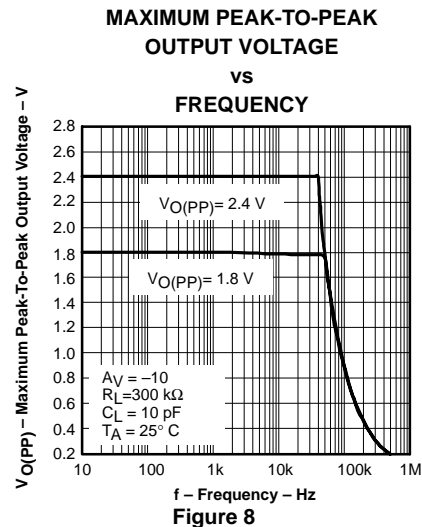


Figure 8

# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROWPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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## TYPICAL CHARACTERISTICS

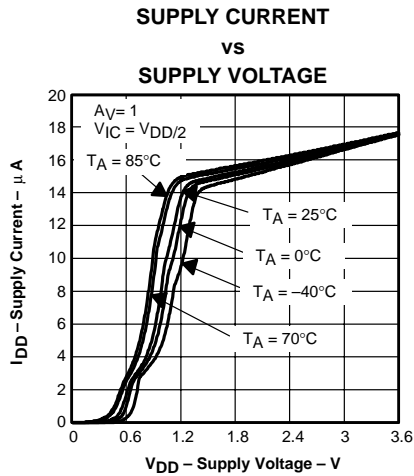


Figure 9

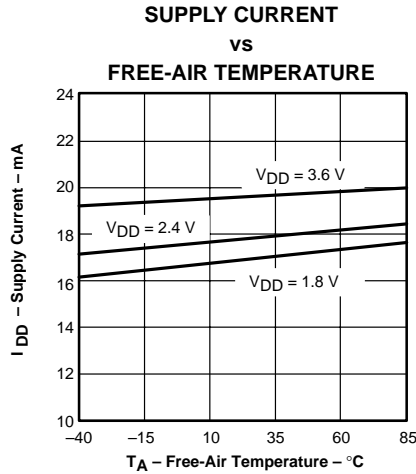


Figure 10

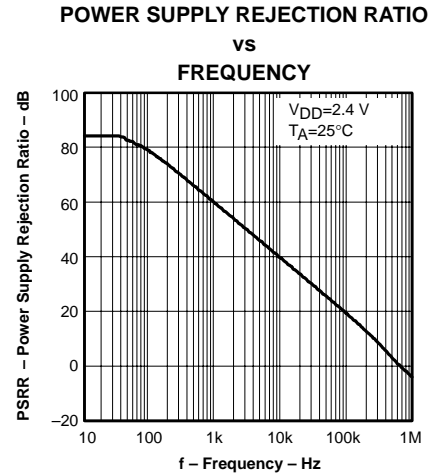


Figure 11

### DIFFERENTIAL VOLTAGE GAIN AND PHASE

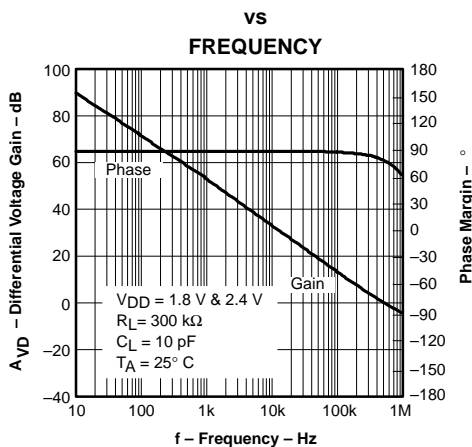


Figure 12

### GAIN BANDWIDTH PRODUCT

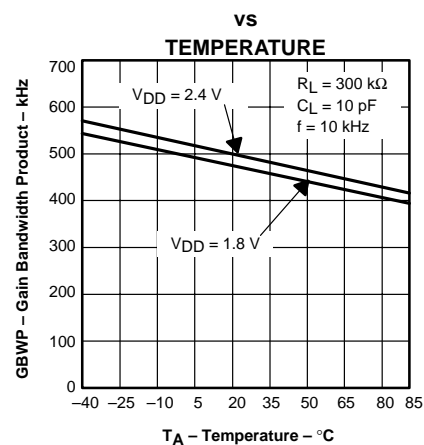


Figure 13

### GAIN-BANDWIDTH PRODUCT

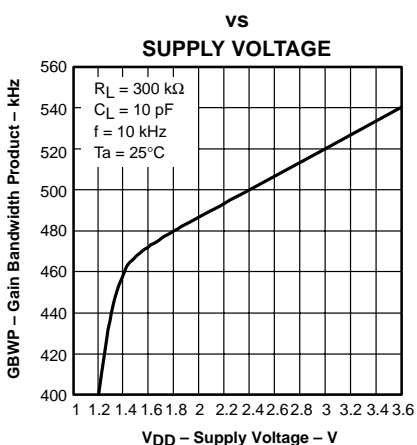


Figure 14

### SLEW RATE

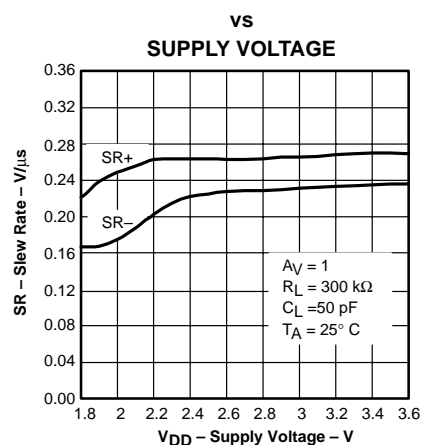


Figure 15



# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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## TYPICAL CHARACTERISTICS

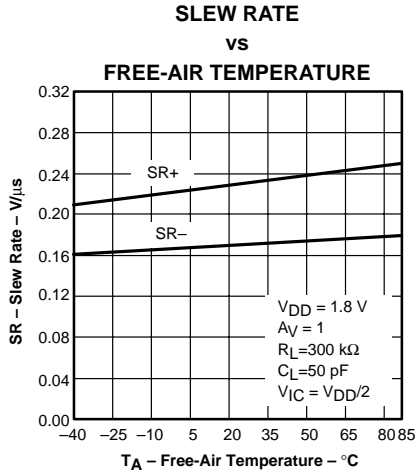


Figure 16

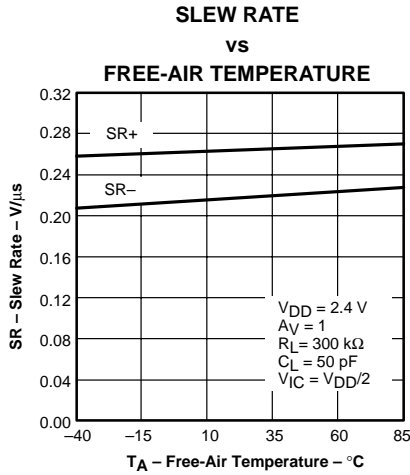


Figure 17

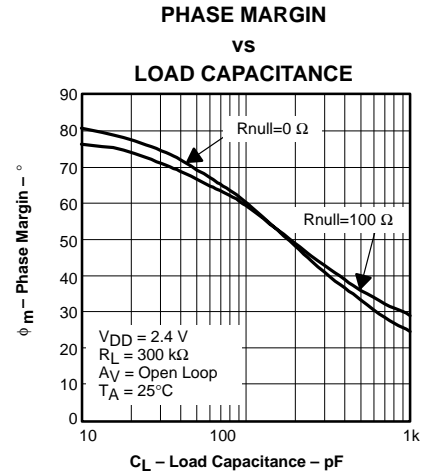


Figure 18

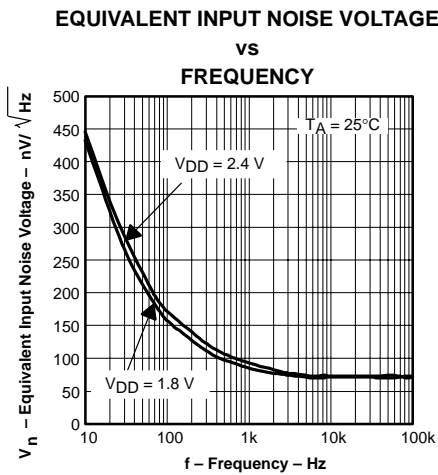


Figure 19

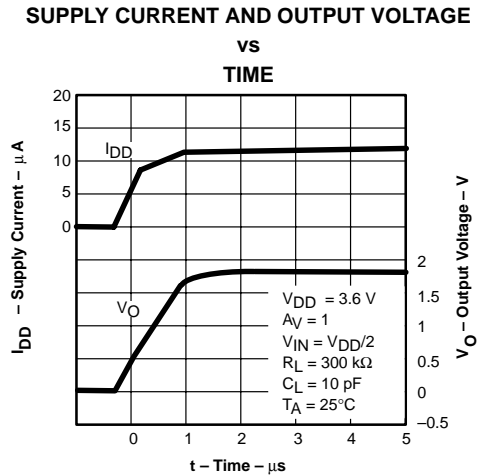


Figure 20

### VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

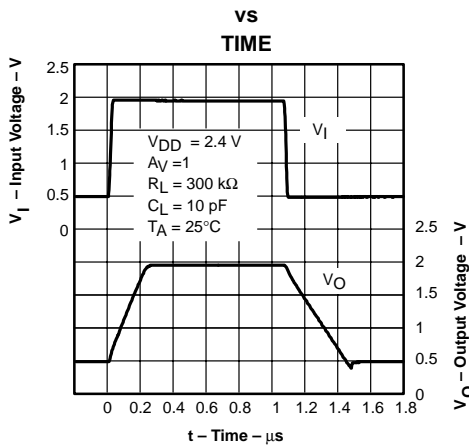


Figure 21

### VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

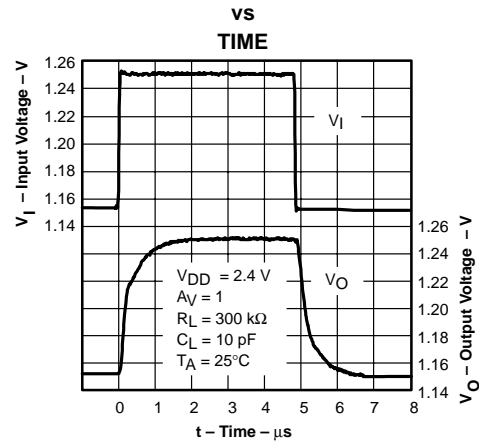


Figure 22



# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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## TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL RESPONSE

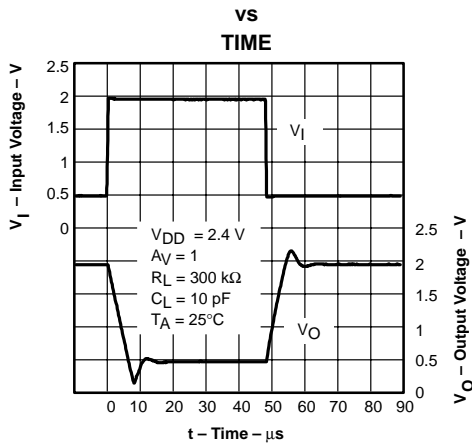


Figure 23

INVERTING SMALL-SIGNAL PULSE RESPONSE

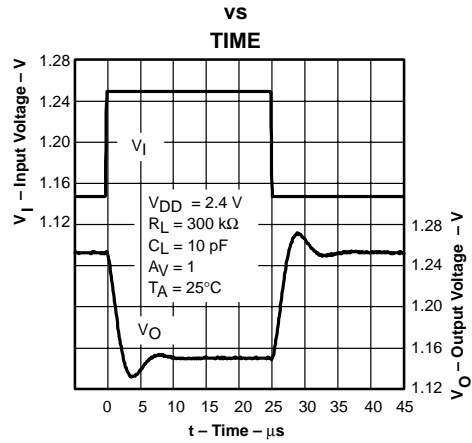


Figure 24

CROSSTALK  
vs  
FREQUENCY

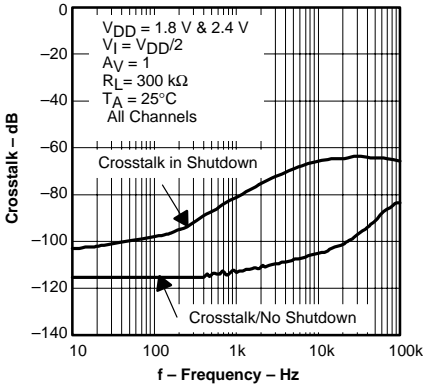


Figure 25

SHUTDOWN FORWARD AND  
REVERSE ISOLATION  
vs  
FREQUENCY

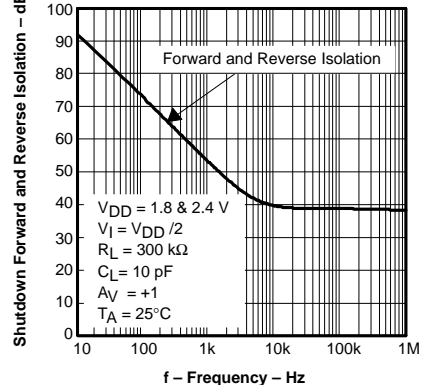


Figure 26

SHUTDOWN SUPPLY CURRENT  
vs  
SUPPLY VOLTAGE

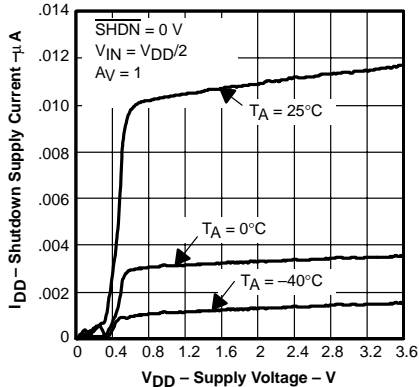


Figure 27

SHUTDOWN SUPPLY CURRENT  
vs  
FREE-AIR TEMPERATURE

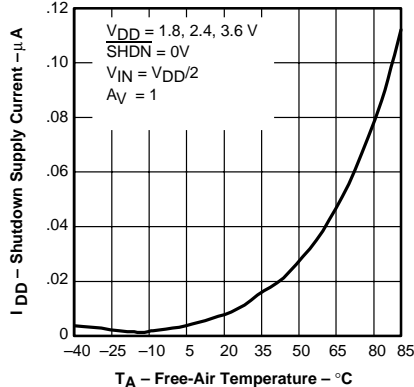


Figure 28

SHUTDOWN PIN LEAKAGE CURRENT  
vs  
SHUTDOWN PIN VOLTAGE

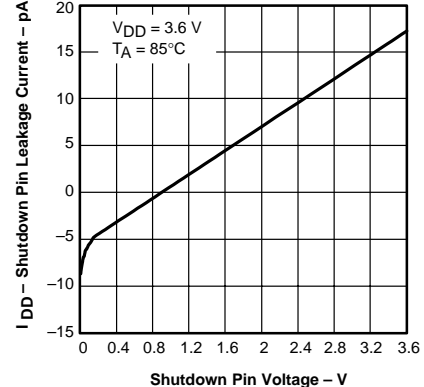


Figure 29



TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765  
FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT  
OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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TYPICAL CHARACTERISTICS

SHUTDOWN SUPPLY CURRENT / OUTPUT VOLTAGE  
vs  
TIME

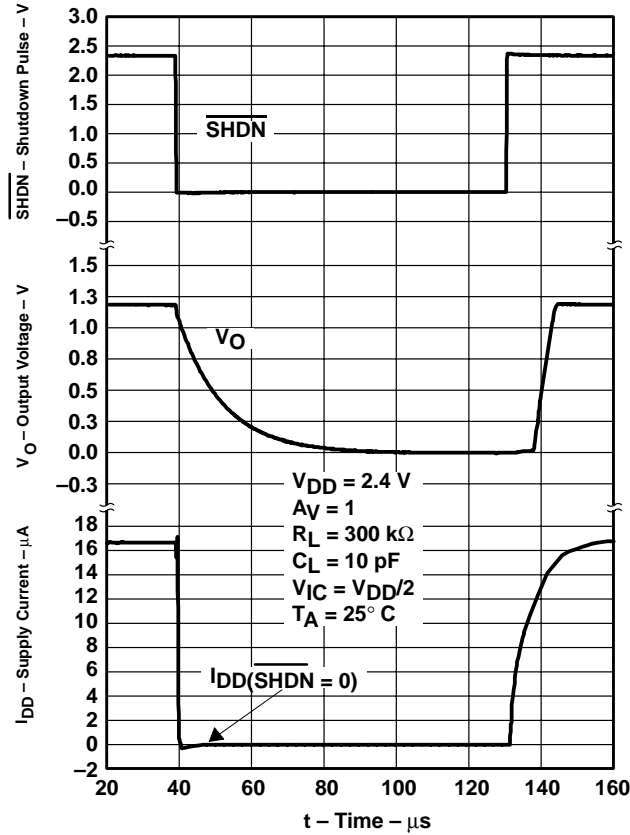


Figure 30

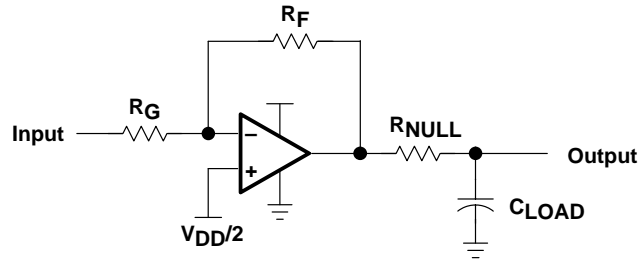
**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

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**APPLICATION INFORMATION**

**driving a capacitive load**

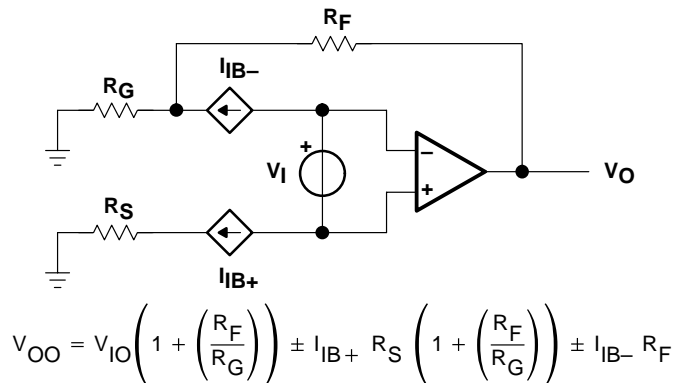
When the amplifier is configured in this manner, capacitive loading directly on the output will decrease the device’s phase margin leading to high frequency ringing or oscillations. Therefore, for capacitive loads of greater than 10 pF, it is recommended that a resistor be placed in series ( $R_{NULL}$ ) with the output of the amplifier, as shown in Figure 31. A minimum value of 20  $\Omega$  should work well for most applications.



**Figure 31. 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:



**Figure 32. 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 33).



APPLICATION INFORMATION

general configurations (continued)

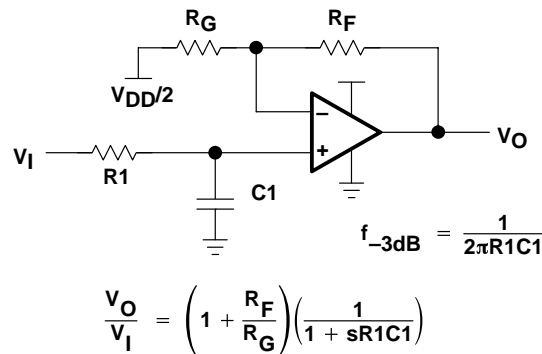


Figure 33. Single-Pole Low-Pass Filter

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.

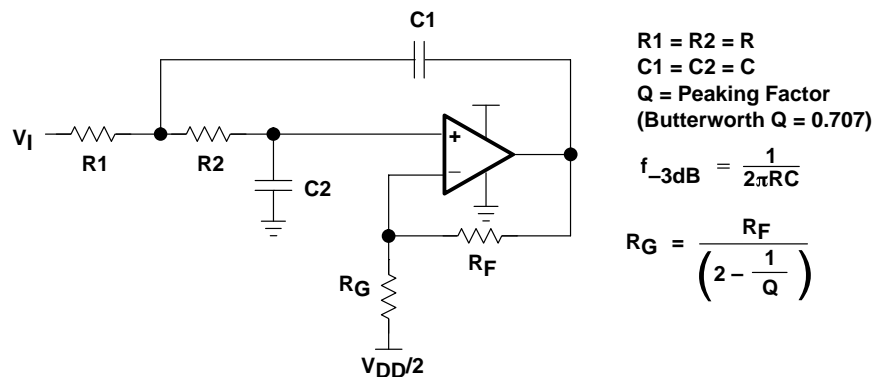


Figure 34. 2-Pole Low-Pass Sallen-Key Filter

circuit layout considerations

To achieve the levels of high performance of the TLV276x, 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-μF tantalum capacitor in parallel with a 0.1-μF 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-μF ceramic capacitor should always be used on the supply terminal of every amplifier. In addition, the 0.1-μF 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.

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## APPLICATION INFORMATION

### circuit layout considerations (continued)

- 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.

### shutdown function

Three members of the TLV276x family (TLV2760/3/5) have a shutdown terminal for conserving battery life in portable applications. When the shutdown terminal is pulled low, the supply current is reduced to 10 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. If the shutdown feature is not desired, directly tie the shutdown terminal to the positive rail. 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.  $\pm 1.8$  V), the shutdown terminal needs to be pulled to the negative rail, not the system ground, to disable the operational amplifier.

The amplifier is powered with a single 2.4-V supply and configured as a noninverting configuration with a unity gain. Turnon and turnoff times are defined as the interval between application of the logic signal to the shutdown pin and the point at which the supply current has reached half its final value. The times for the single, dual, and quad are listed in the data tables.

### general power dissipation considerations

For a given  $\theta_{JA}$ , the maximum power dissipation is shown in Figure 35 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 TLV276x 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)



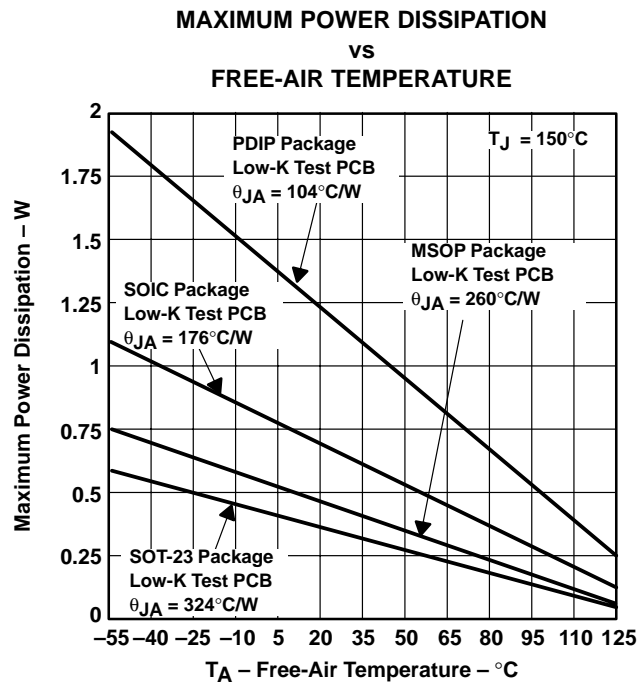


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APPLICATION INFORMATION

general power dissipation considerations (continued)



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

Figure 35. Maximum Power Dissipation vs Free-Air Temperature

# TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROWPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUT DOWN

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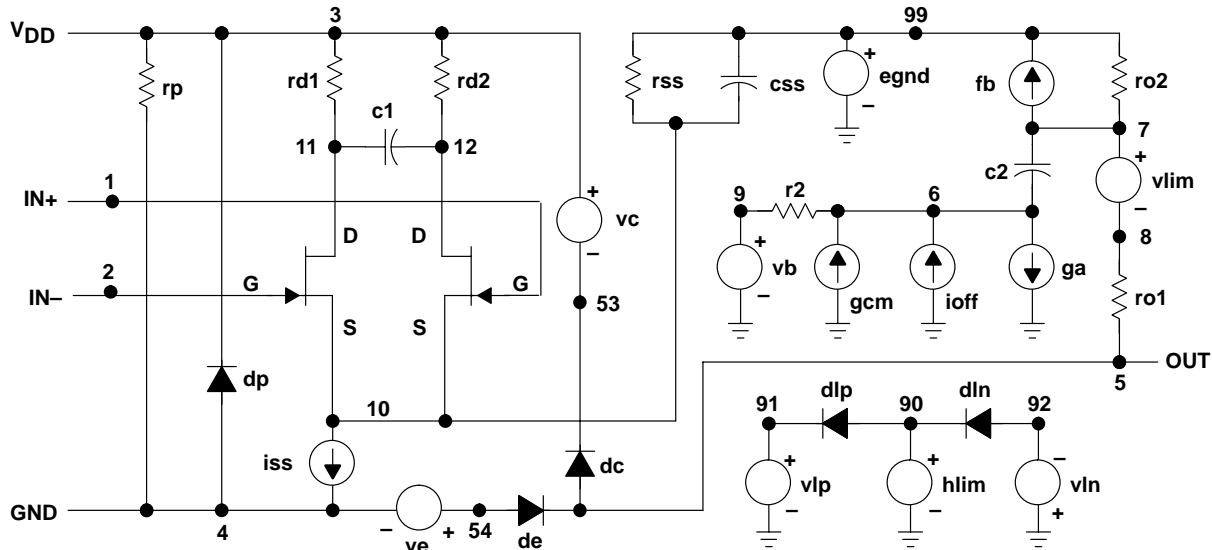
## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*<sup>™</sup> Release 9.1, the model generation software used with Microsim *PSPice*<sup>™</sup>. The Boyle macromodel (see Note 4) and subcircuit in Figure 36 are generated using TLV276x 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 4: 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).



```
*DEVICE=amp_tlv276x_highVdd,OPAMP,NJF,INT
* amp_tlv_276x_highVdd operational amplifier "macromodel"
* subcircuit updated using Model Editor release 9.1 on 05/15/00
* at 14:40 Model Editor is an OrCAD product.
```

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

```
.subckt amp_tlv276x_highVdd 1 2 3 4 5
*
c1      11      12      457.48E-15
c2      6        7        5.0000E-12
css     10      99      1.1431E-12
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
                             176.02E6 -1E3 1E3 180E6
                             -180E6
```

```
ga      6        0        11 12 16.272E-6
gcm     0        6        10 99 6.8698E-9
iss     10      4        dc 1.3371E-6
hlim    90      0
j1      11      2        10 jx1
j2      12      1        10 jx2
r2      6        9        100.00E3
rd1     3        11      61.456E3
rd2     3        12      61.456E3
ro1     8        5        10
ro2     7        99      10
rp      3        4        150.51E3
rss     10      99      149.58E6
vb      9        0        dc 0
vc      3        53      dc .78905
ve      54      4        dc .78905
vlim    7        8        dc 0
vlp     91      0        dc 14.200
vln     0        92      dc 14.200
.model  dx      D(Is=800.00E-18)
.model  dy      D(Is=800.00E-18 Rs=1m Cjo=10p)
.model  jx1     NJF(Is=500.00E-15 Beta=198.03E-6 Vto=-1)
.model  jx2     NJF(Is=500.00E-15 Beta=198.03E-6 Vto=-1)
.ends
```

**Figure 36. Boyle Macromodel and Subcircuit**

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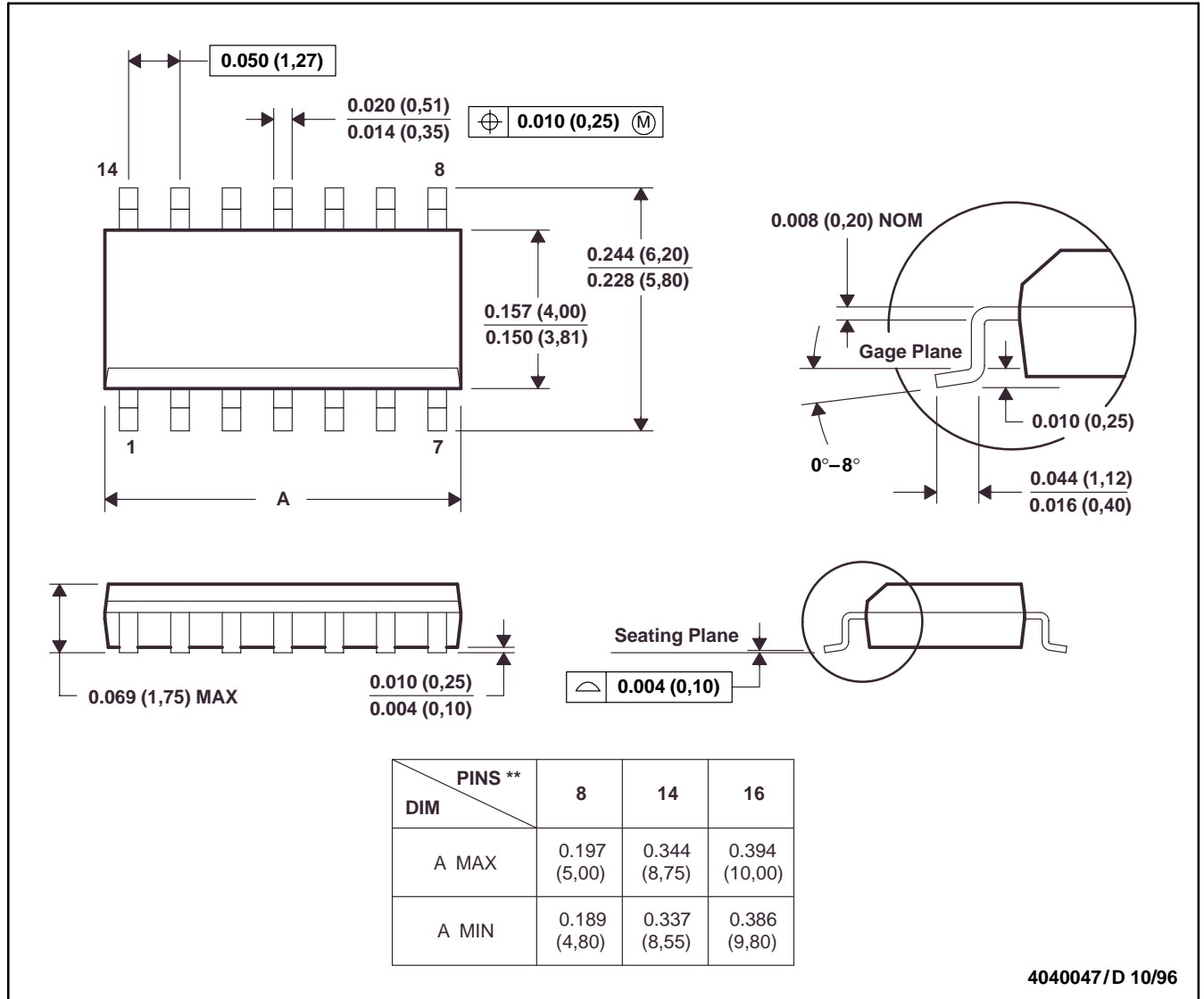
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MECHANICAL DATA

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

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



- NOTES: 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

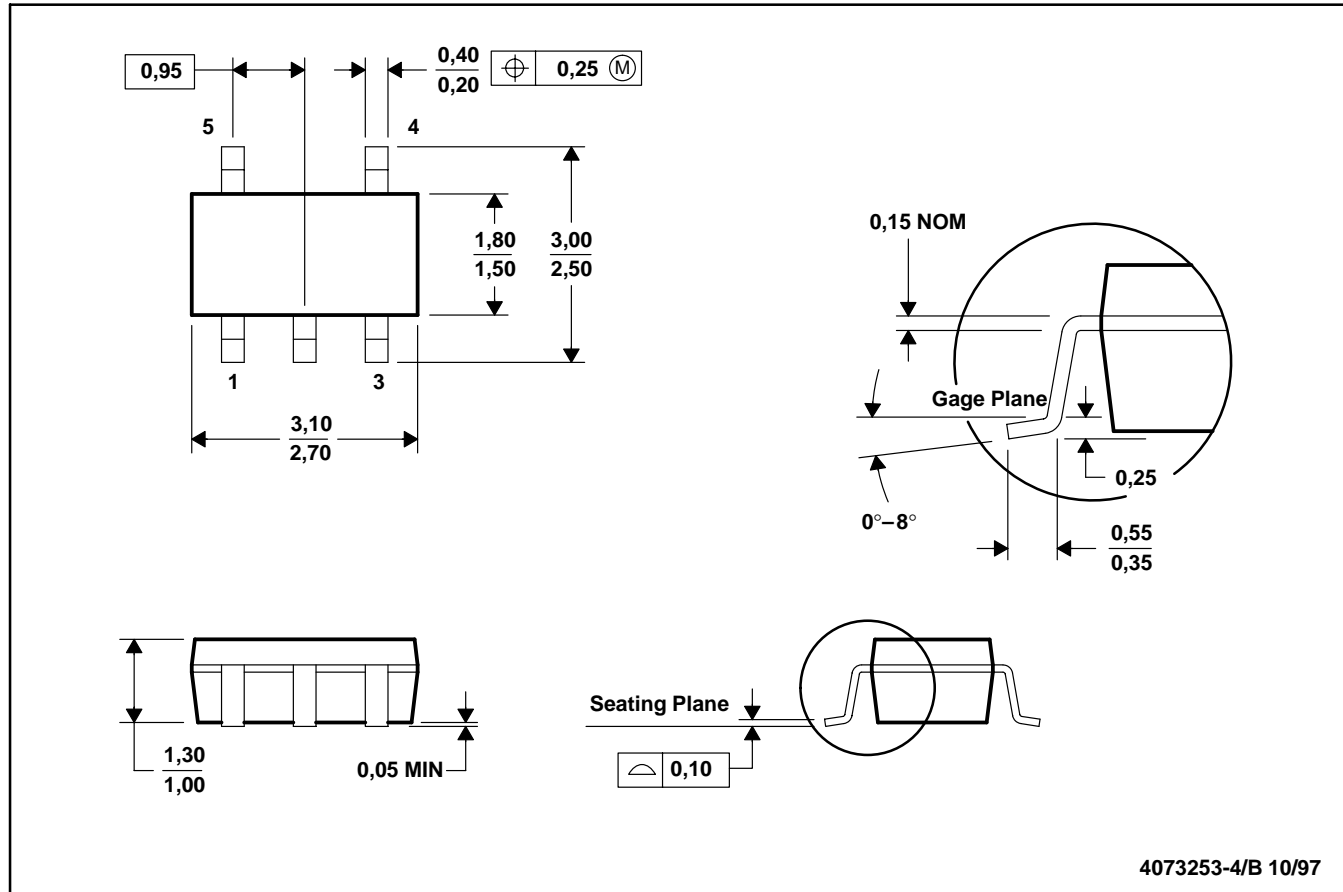
**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

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**MECHANICAL DATA**

**DBV (R-PDSO-G5)**

**PLASTIC SMALL-OUTLINE PACKAGE**



4073253-4/B 10/97

- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions include mold flash or protrusion.

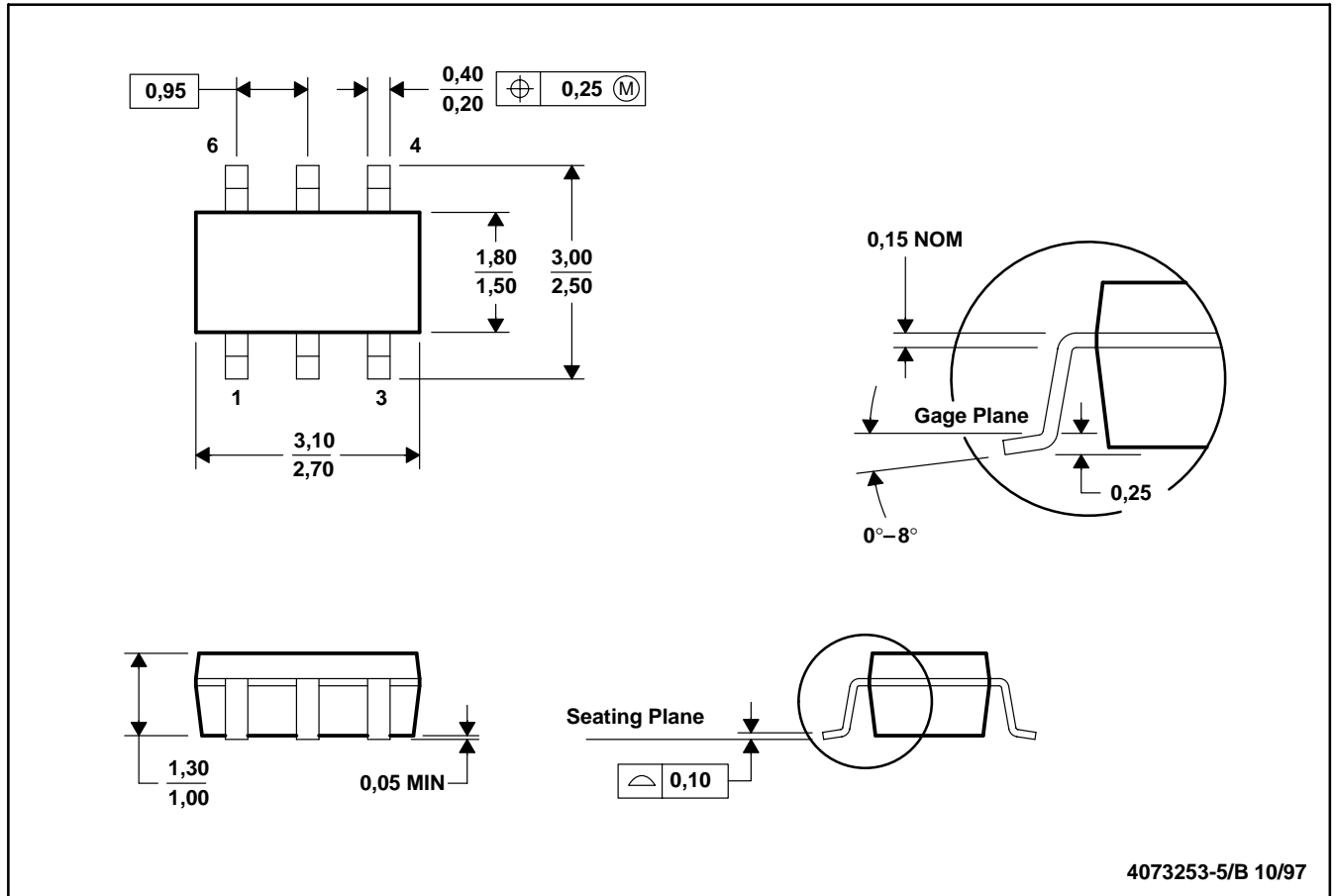
TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765  
 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT  
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MECHANICAL DATA

DBV (R-PDSO-G6)

PLASTIC SMALL-OUTLINE PACKAGE



4073253-5/B 10/97

- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions include mold flash or protrusion.

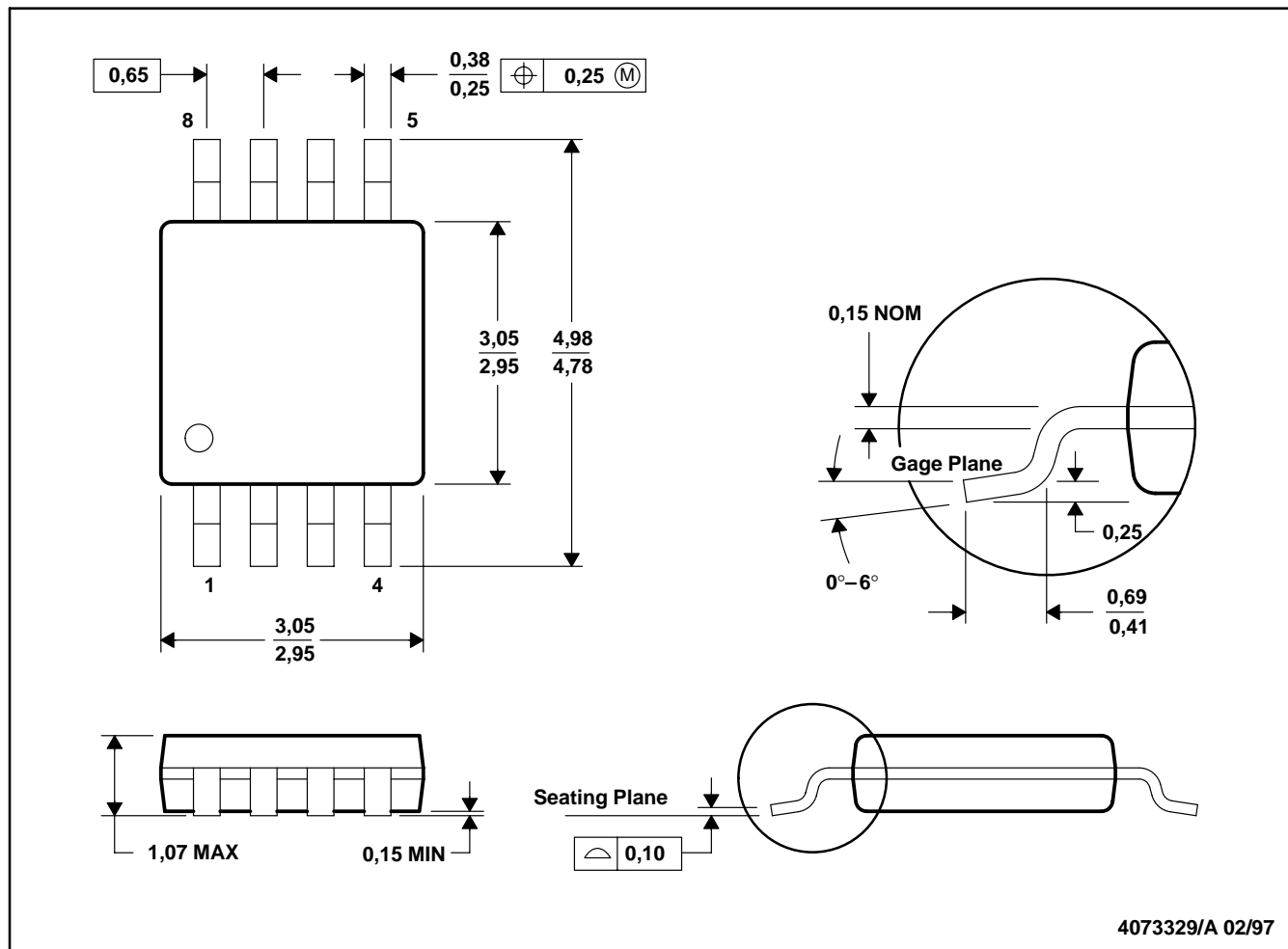
**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

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**MECHANICAL DATA**

**DGK (R-PDSO-G8)**

**PLASTIC SMALL-OUTLINE PACKAGE**



4073329/A 02/97

- 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.  
 D. Falls within JEDEC MO-187

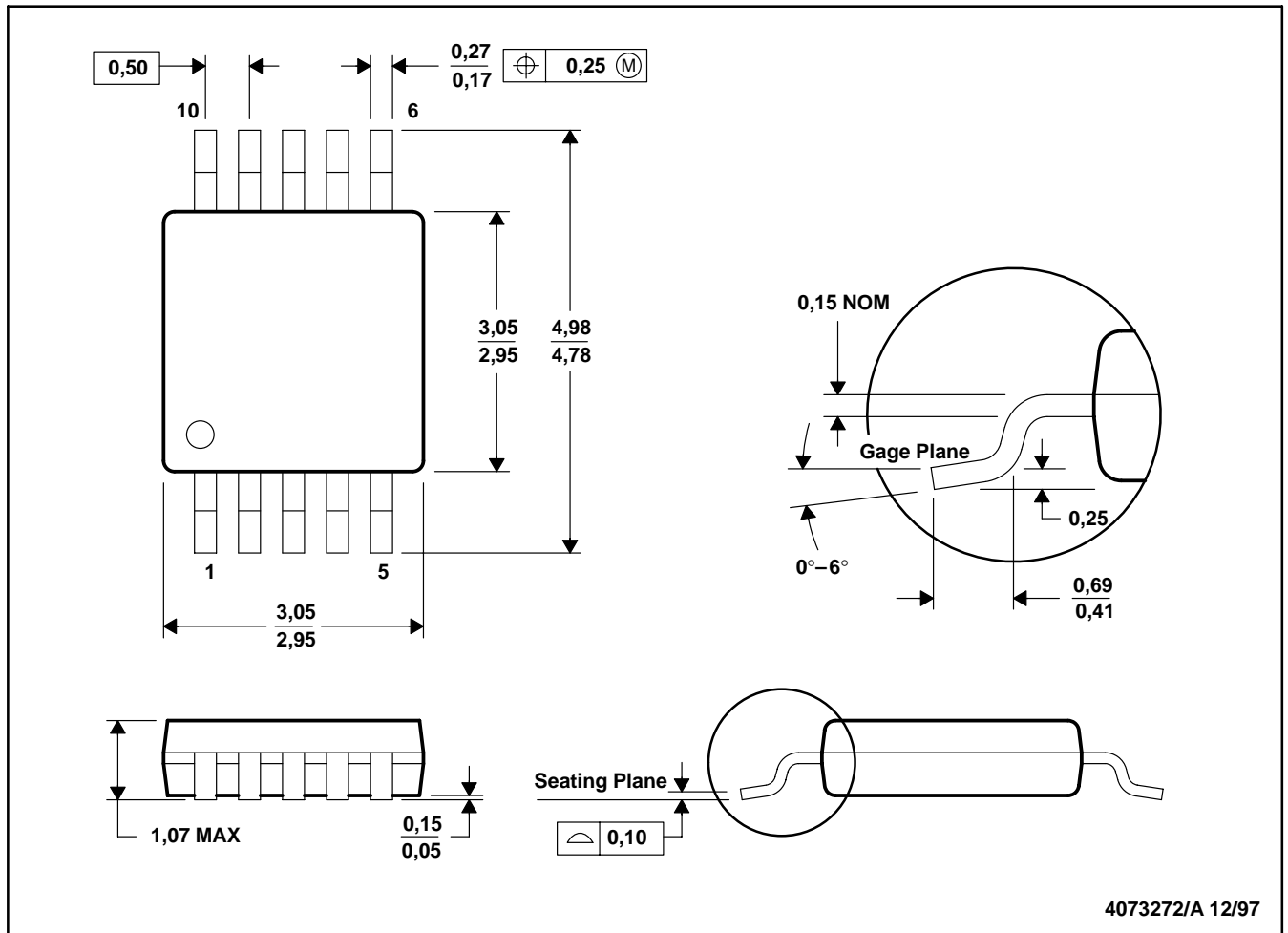
TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765  
 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT  
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MECHANICAL DATA

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.

**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

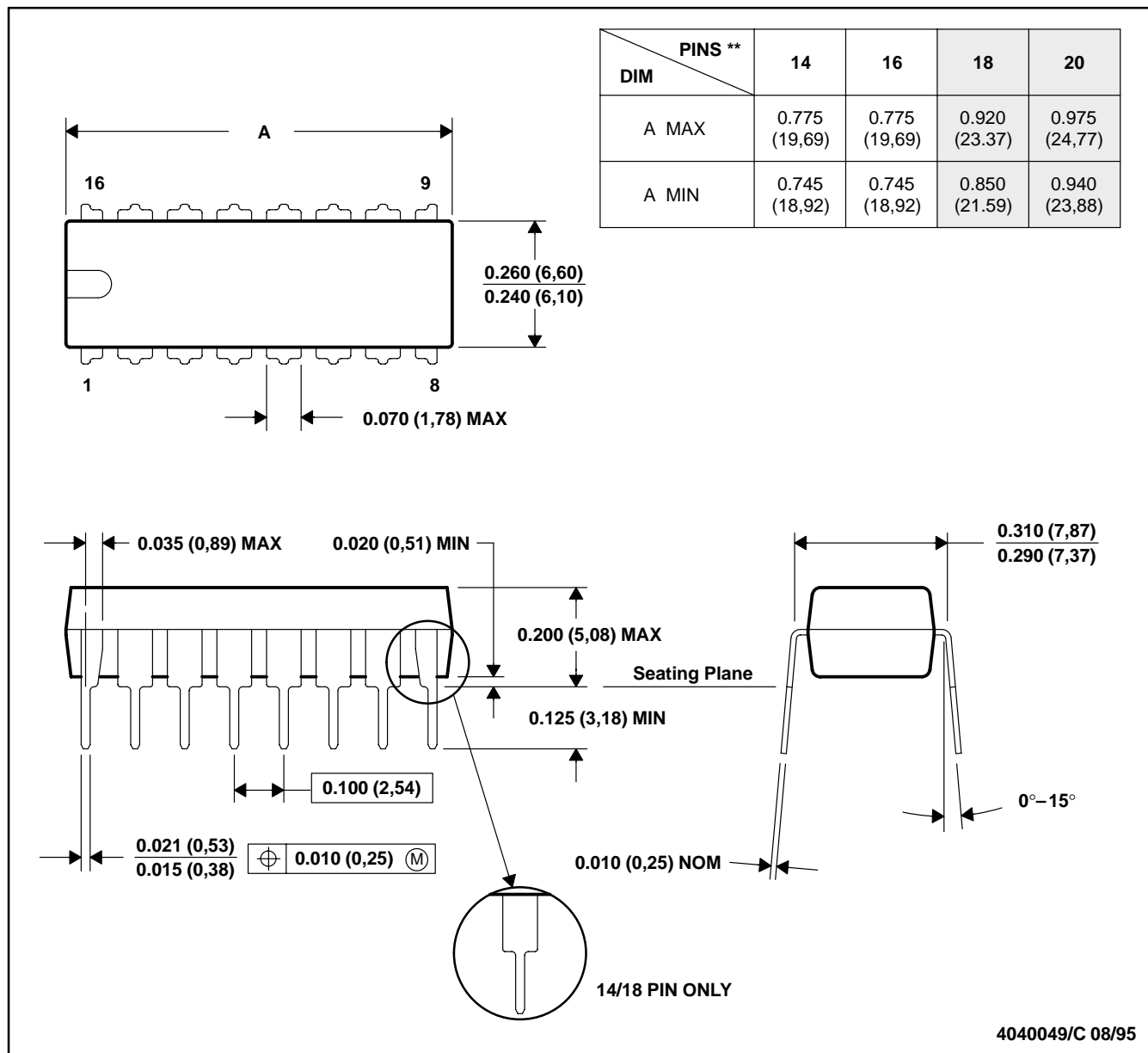
SLOS326D – JUNE 2000 – REVISED FEBRUARY 2001

**MECHANICAL DATA**

**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.)



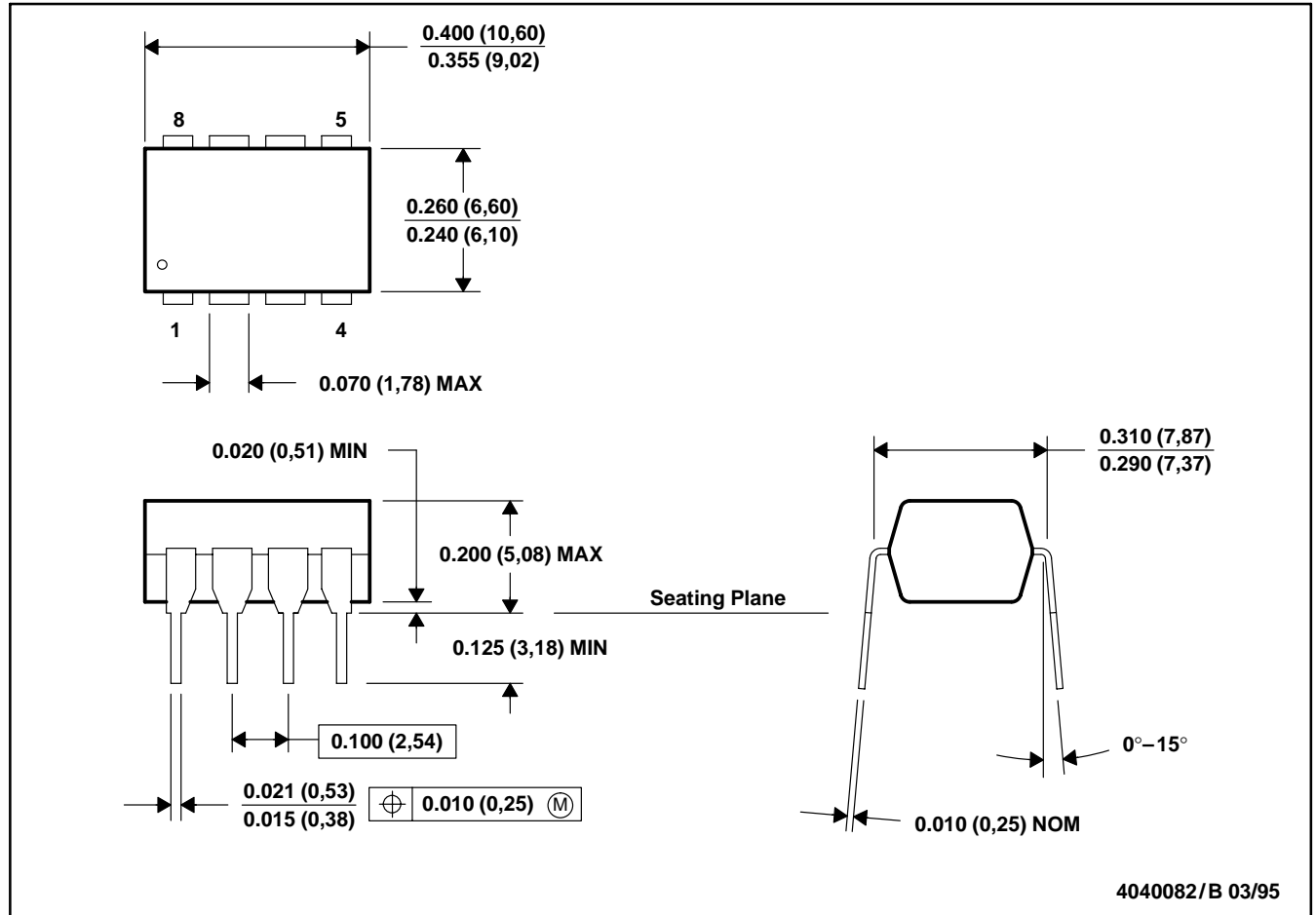
**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

SLOS326D – JUNE 2000 – REVISED FEBRUARY 2001

**MECHANICAL DATA**

**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

**TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765**  
**FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT**  
**OPERATIONAL AMPLIFIERS WITH SHUT DOWN**

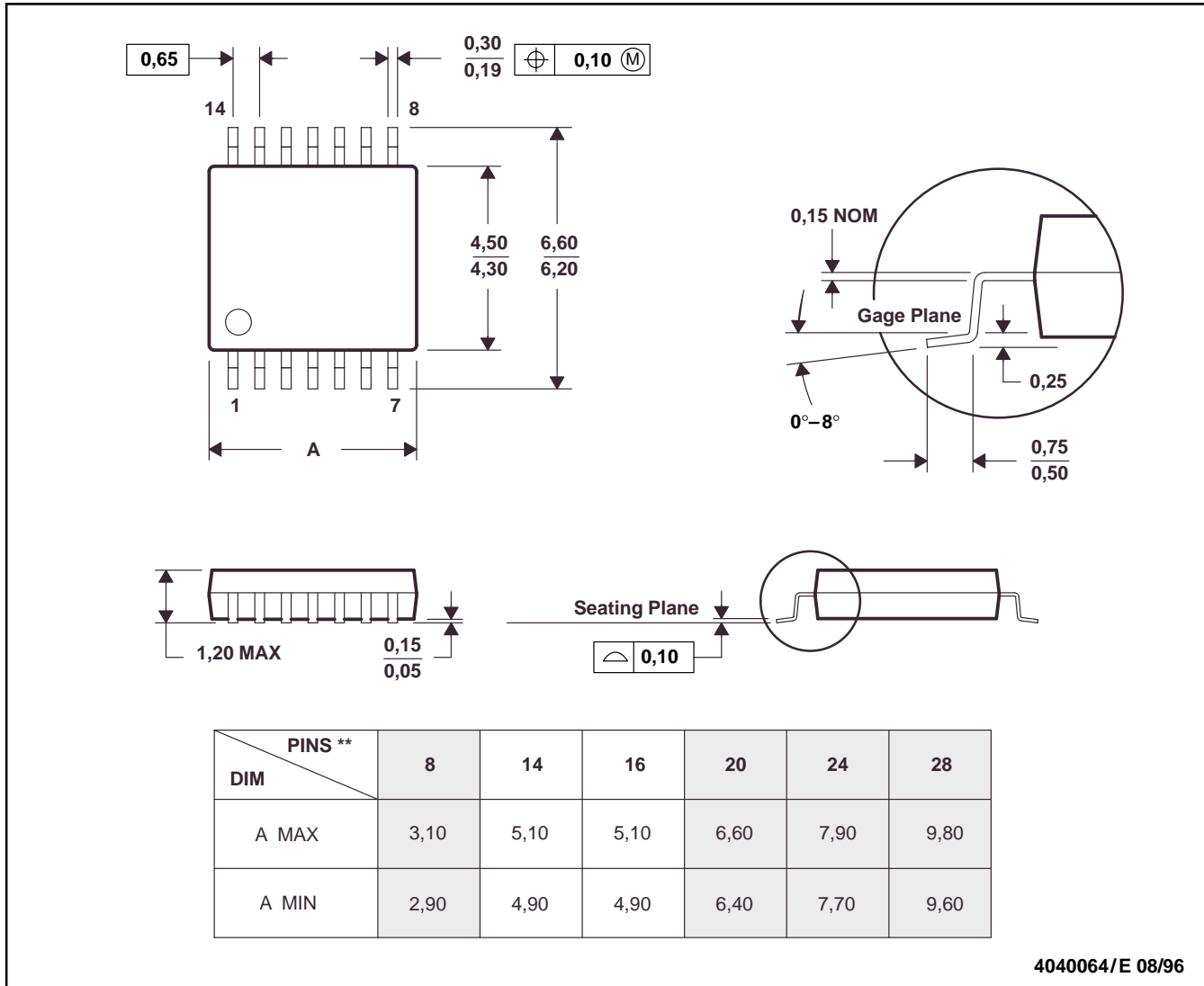
SLOS326D – JUNE 2000 – REVISED FEBRUARY 2001

**MECHANICAL DATA**

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

**PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



4040064/E 08/96

- 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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