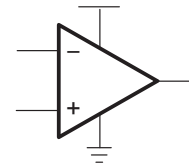


TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

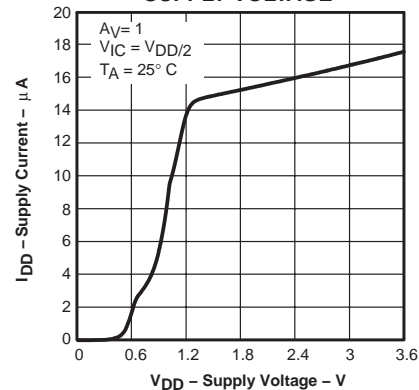
SLOS326E – JUNE 2000 – REVISED JANUARY 2005

- Low Supply Voltage . . . 1.8 V to 3.6 V
- Very Low Supply Current . . . 20 μ 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 μ V
- Wide Bandwidth . . . 500 kHz
- Slew Rate . . . 0.20 V/ μ s
- Specified Temperature Range:
 - 0°C to 70°C . . . Commercial Grade
 - 40°C to 85°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 μ 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 (± 1.8 V supplies down to ± 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_{DD} (V)	V_{IO} (μ V)	I_{DD}/Ch (μ A)	I_{IB} (pA)	GBW (MHz)	SR (V/ μ s)	$V_n, 1kHz$ (nV/ \sqrt{Hz})	I_O (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



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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

 **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 SHUTDOWN

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TLV2760 and TLV2761 AVAILABLE OPTIONS(1)

T _A	V _{IOMax} 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(1)

T _A	V _{IOMax} 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 —	— TLV2763IDGS	— 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(1)

T _A	V _{IOMax} 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).

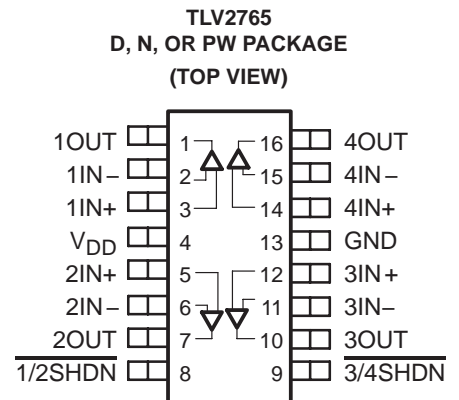
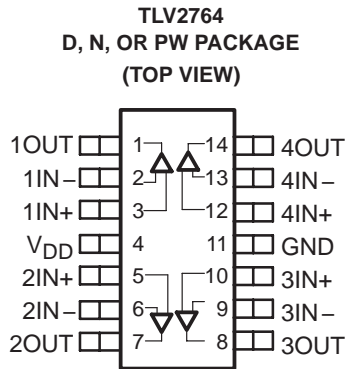
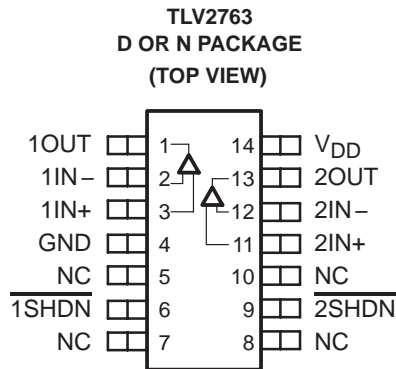
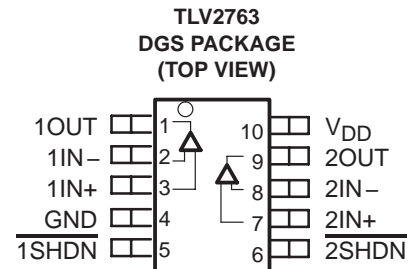
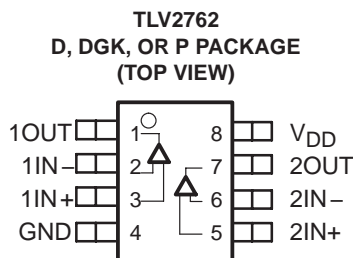
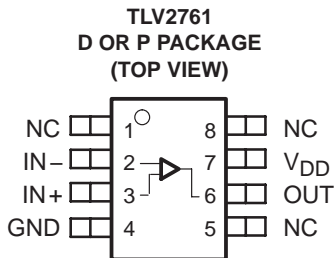
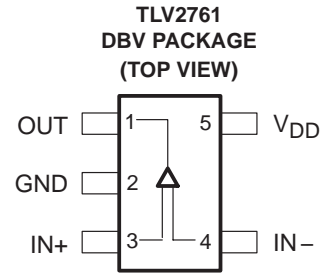
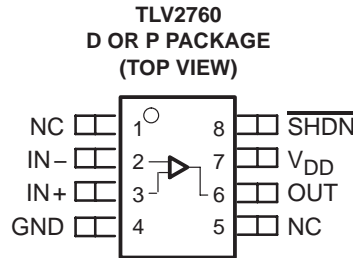
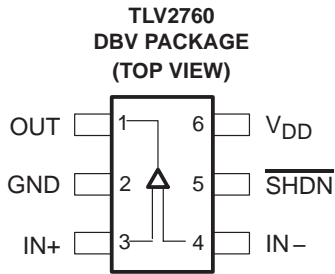
1. For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.



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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TLV276x PACKAGE PINOUTS



NC – No internal connection

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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		μV
				Full range		6800		
α_{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	$R_S = 50\ \Omega$		25°C	3	15		pA
			TLV276xC	Full range			100	
			TLV276xI	Full range			200	
$r_{i(d)}$	Differential input resistance			25°C	1000			G Ω
$C_{i(c)}$	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.



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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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 †	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 †	MIN	TYP	MAX	UNIT
I_{DD} Supply current (per channel)	$V_O = V_{DD}/2,$ $\overline{\text{SHDN}} = V_{DD}$	25°C		20	28		μA
		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.



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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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 †	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/ μ s
				Full range	0.09			
			$V_{DD} = 2.4\text{ V}$	25°C	0.11	0.22		V/ μ s
				Full range	0.09			
			$V_{DD} = 3.6\text{ V}$	25°C	0.11	0.23		V/ μ 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/ μ s
				Full range	0.07			
			$V_{DD} = 2.4\text{ V}$	25°C	0.10	0.18		V/ μ s
				Full range	0.09			
			$V_{DD} = 3.6\text{ V}$	25°C	0.10	0.22		V/ μ s
				Full range	0.09			
ϕ_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	$V_{DD} = 1.8\text{ V}, V_{(STEP)PP} = 1\text{ V},$ $A_V = -1, C_L = 10\text{ pF}, R_L = 300\text{ k}\Omega$	25°C	0.1%		6.4		μ s
				0.01%		13.7		
		$V_{DD} = 2.4\text{ V}, V_{(STEP)PP} = 1\text{ V},$ $A_V = -1, C_L = 10\text{ pF}, R_L = 300\text{ k}\Omega$	25°C	0.1%		6		
				0.01%		13.9		

† 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	$V_{DD} = 1.8\text{ V},$ $V_{O(PP)} = V_{DD}/2\text{ V},$ $R_L = 300\text{ k}\Omega,$ $f = 1\text{ kHz}$	25°C	$A_V = 1$		0.08%		μ s
				$A_V = 10$		0.10%		
				$A_V = 100$		0.27%		
		$V_{DD} = 2.4\text{ V},$ $V_{O(PP)} = V_{DD}/2\text{ V},$ $R_L = 300\text{ k}\Omega,$ $f = 1\text{ kHz}$	25°C	$A_V = 1$		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 †	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		μ s
$t_{(off)}$	Amplifier turnoff time (see Note 3)	$R_L = 300\text{ k}\Omega$	25°C		0.8		μ s

† 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.



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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
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
ϕ_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 SHUTDOWN

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

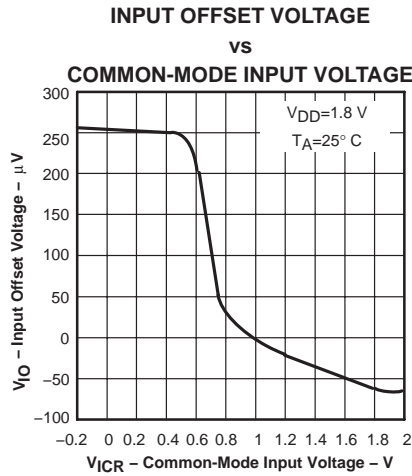


Figure 1

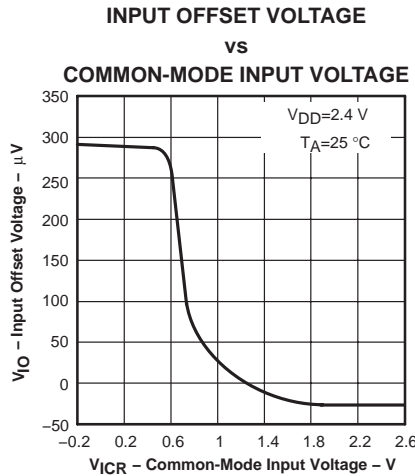


Figure 2

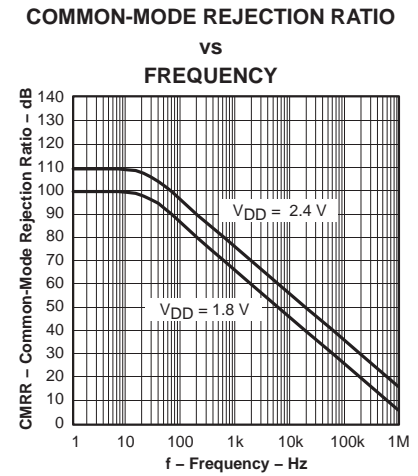


Figure 3

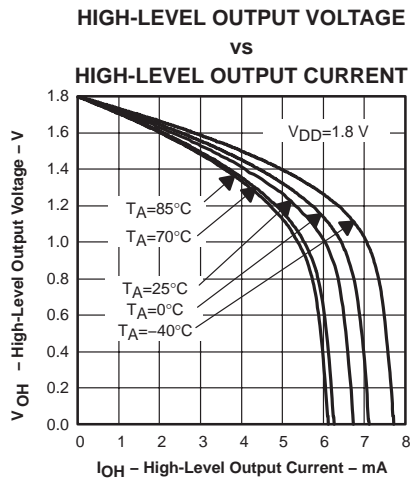


Figure 4

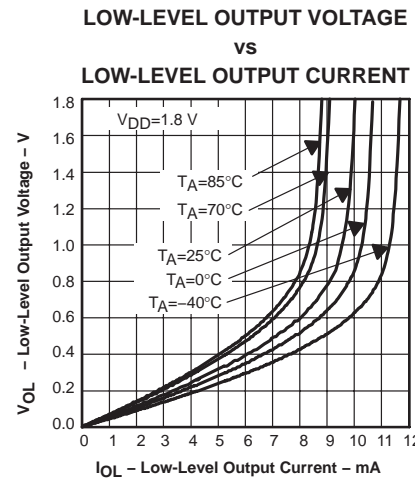


Figure 5

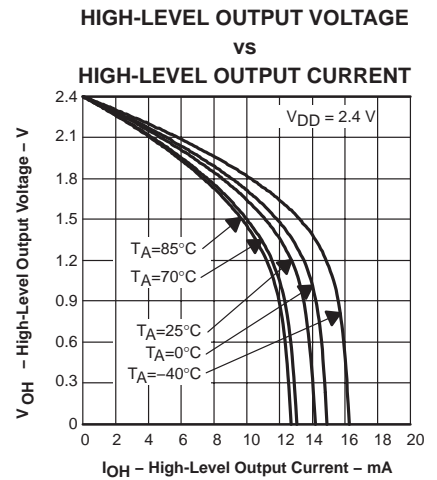


Figure 6

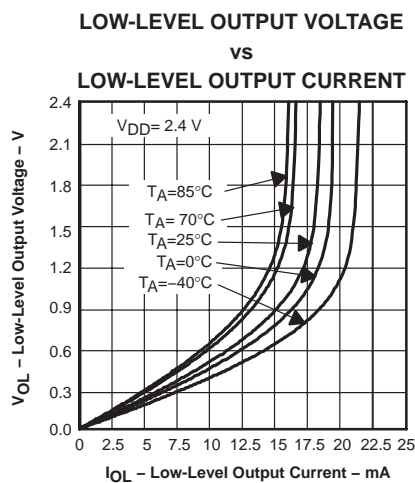


Figure 7

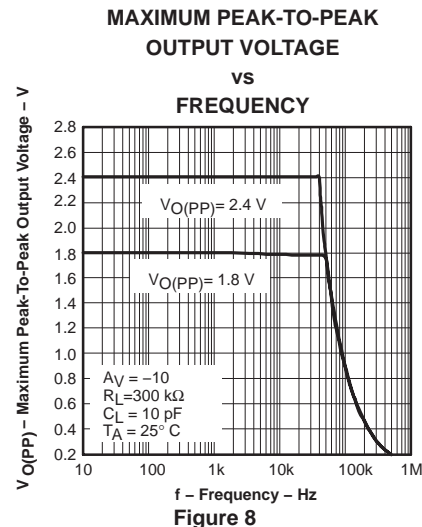


Figure 8

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

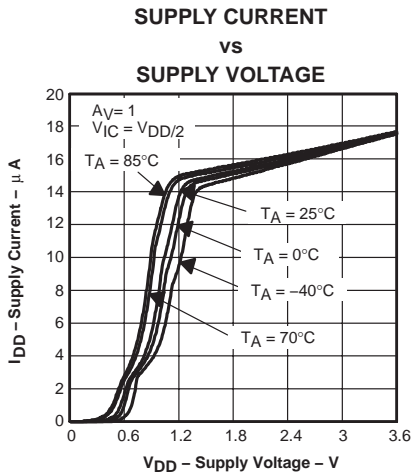


Figure 9

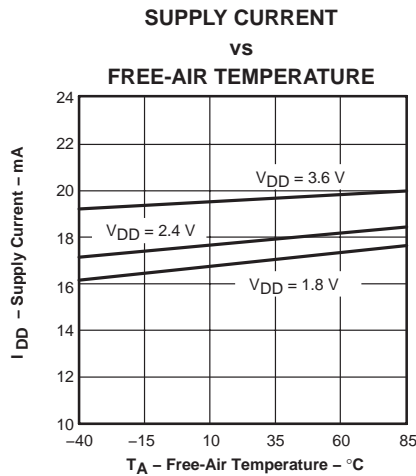


Figure 10

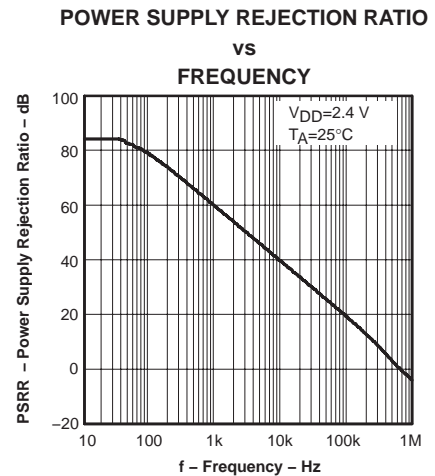


Figure 11

DIFFERENTIAL VOLTAGE GAIN AND PHASE

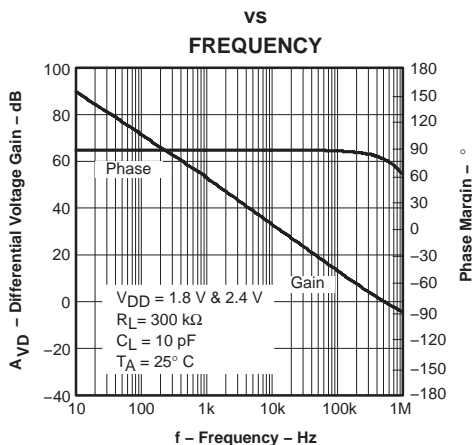


Figure 12

GAIN BANDWIDTH PRODUCT

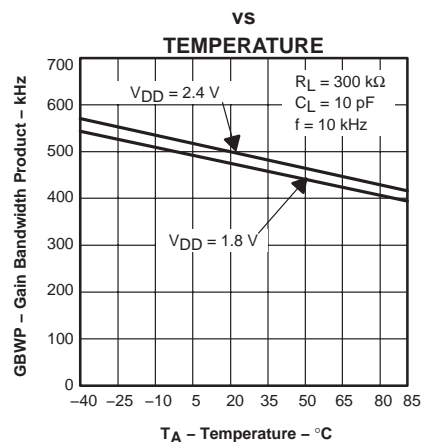


Figure 13

GAIN-BANDWIDTH PRODUCT

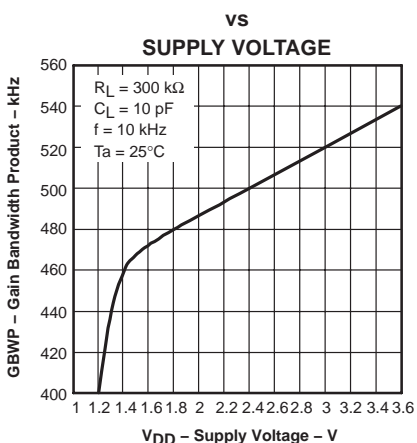


Figure 14

SLEW RATE

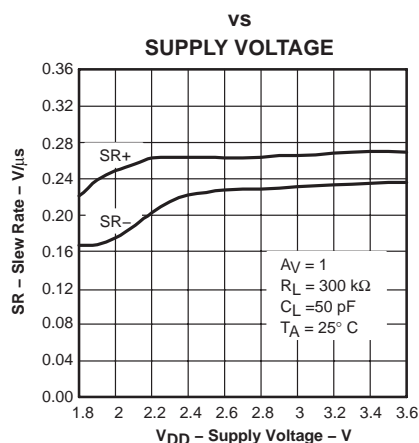


Figure 15

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

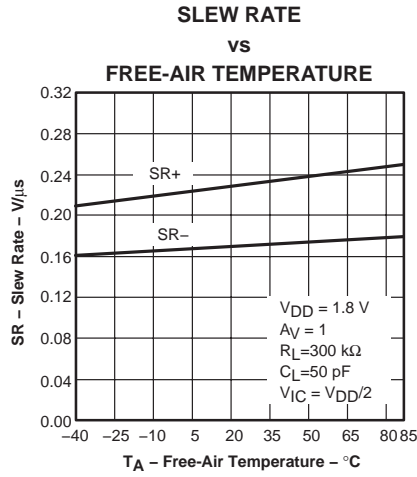


Figure 16

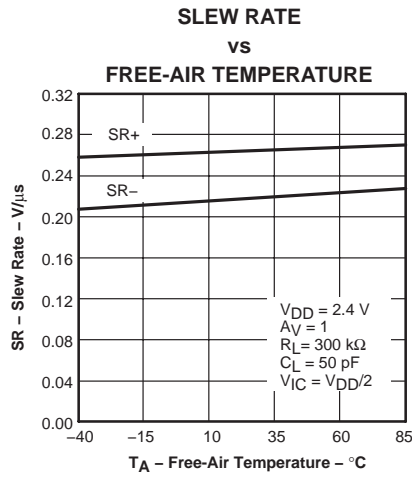


Figure 17

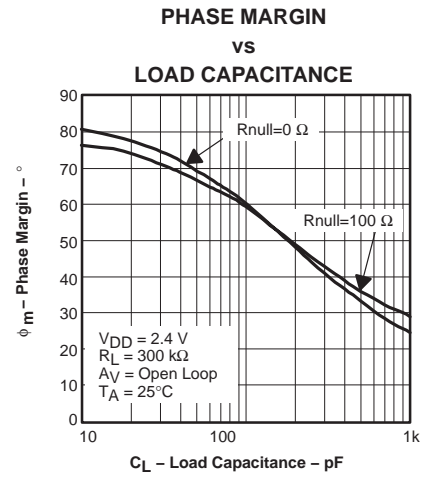


Figure 18

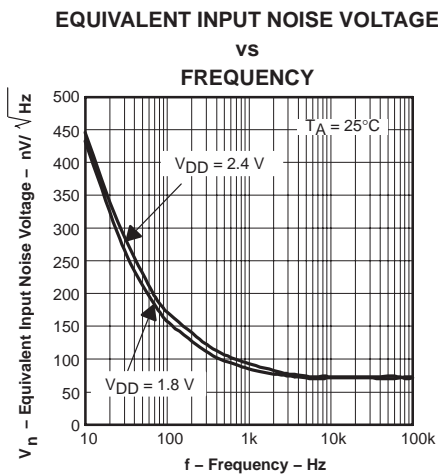


Figure 19

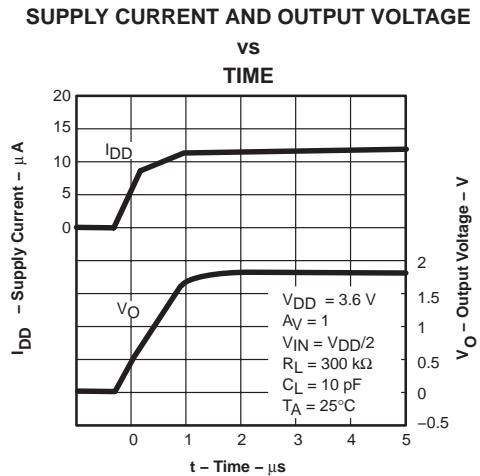


Figure 20

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE

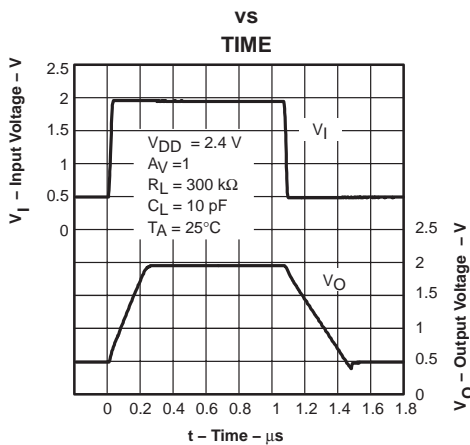


Figure 21

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE

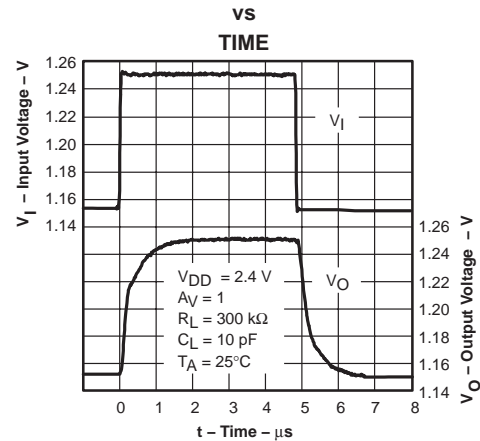


Figure 22

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL RESPONSE

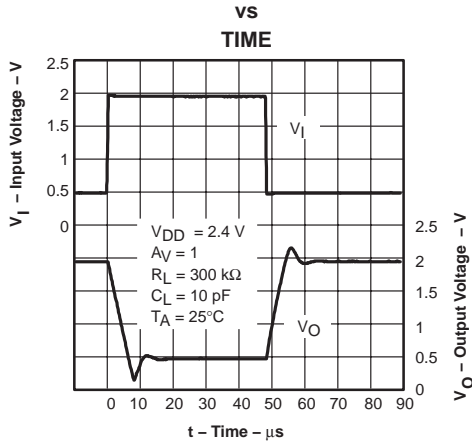


Figure 23

INVERTING SMALL-SIGNAL PULSE RESPONSE

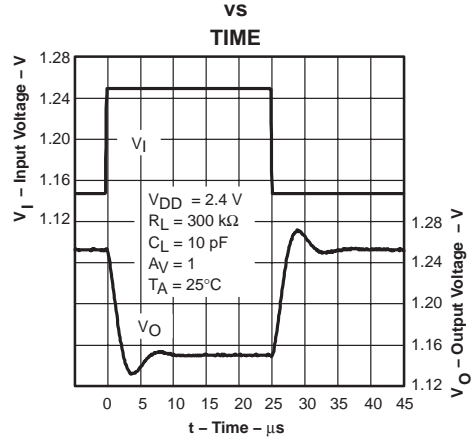


Figure 24

CROSSTALK
vs
FREQUENCY

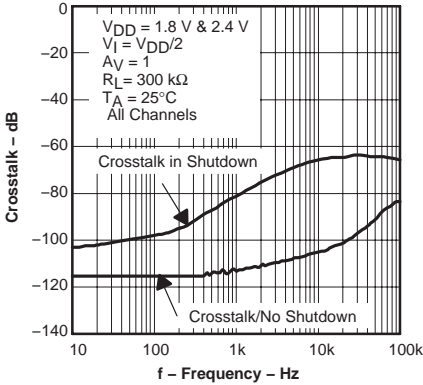


Figure 25

SHUTDOWN FORWARD AND
REVERSE ISOLATION
vs
FREQUENCY

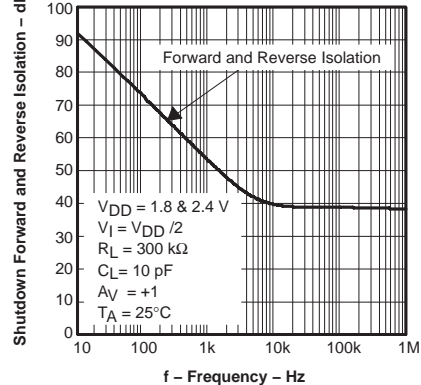


Figure 26

SHUTDOWN SUPPLY CURRENT
vs
SUPPLY VOLTAGE

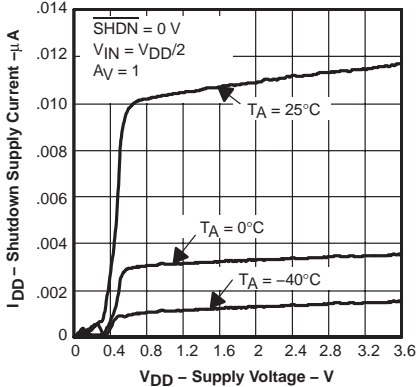


Figure 27

SHUTDOWN SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

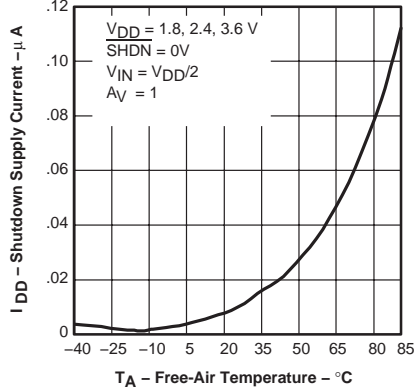


Figure 28

SHUTDOWN PIN LEAKAGE CURRENT
vs
SHUTDOWN PIN VOLTAGE

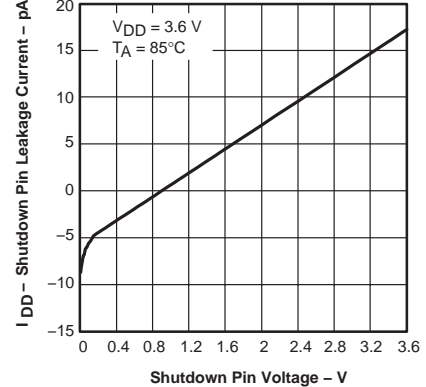


Figure 29

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

TYPICAL CHARACTERISTICS

SHUTDOWN SUPPLY CURRENT / OUTPUT VOLTAGE
VS
TIME

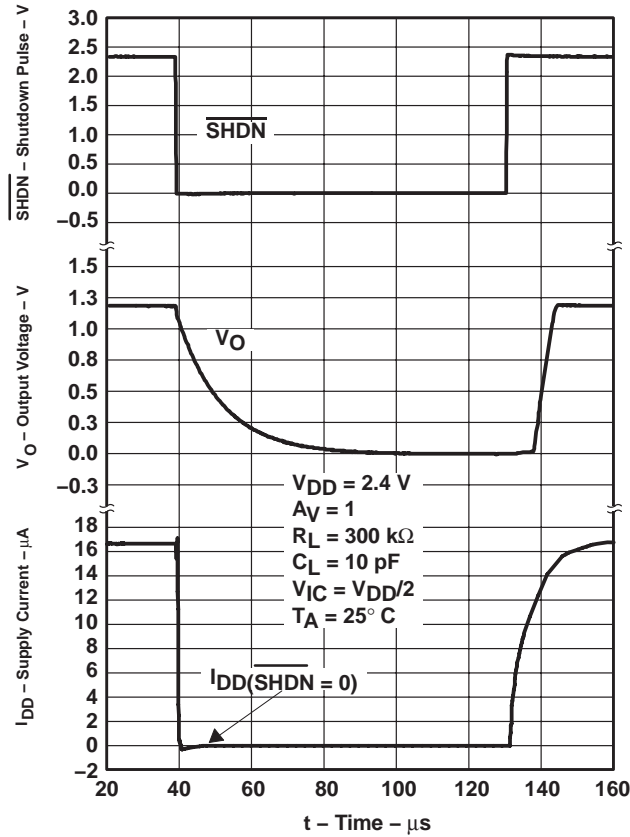


Figure 30

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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 Ω should work well for most applications.

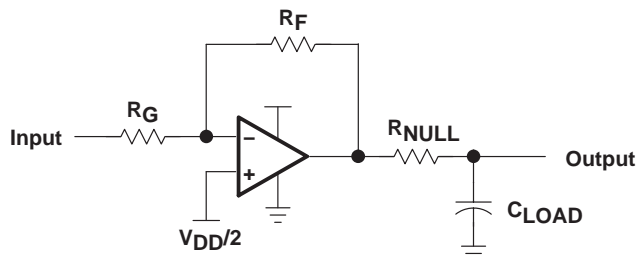


Figure 31. Driving a Capacitive Load

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:

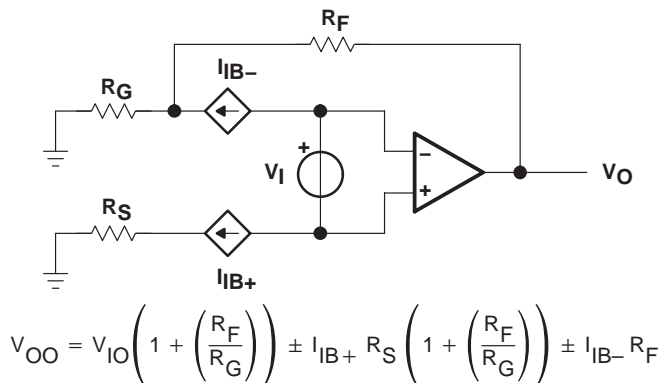


Figure 32. Output Offset Voltage Model

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)

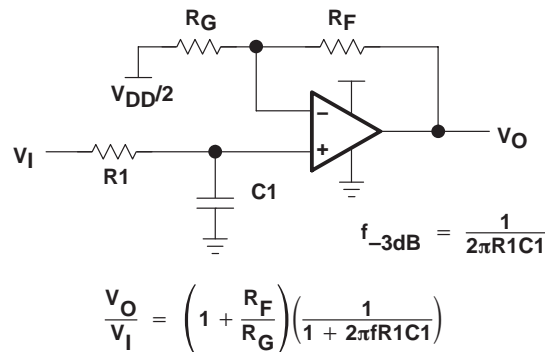


Figure 33. Single-Pole Low-Pass Filter

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.

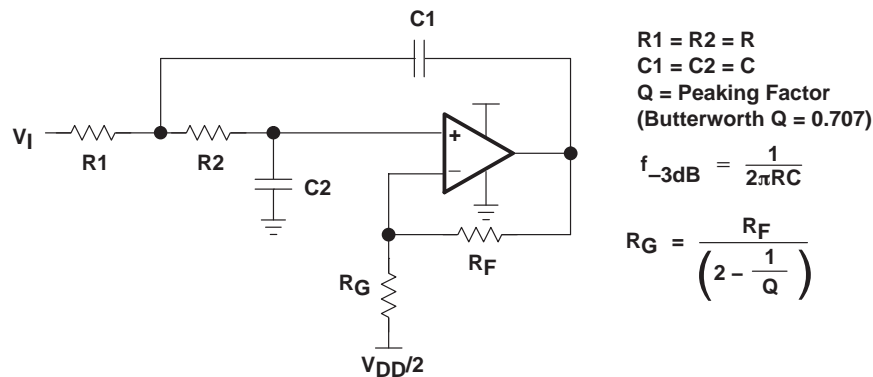


Figure 34. 2-Pole Low-Pass Sallen-Key Filter

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.

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

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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. ± 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 θ_{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)

θ_{JA} = $\theta_{JC} + \theta_{CA}$

θ_{JC} = Thermal coefficient from junction to case

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



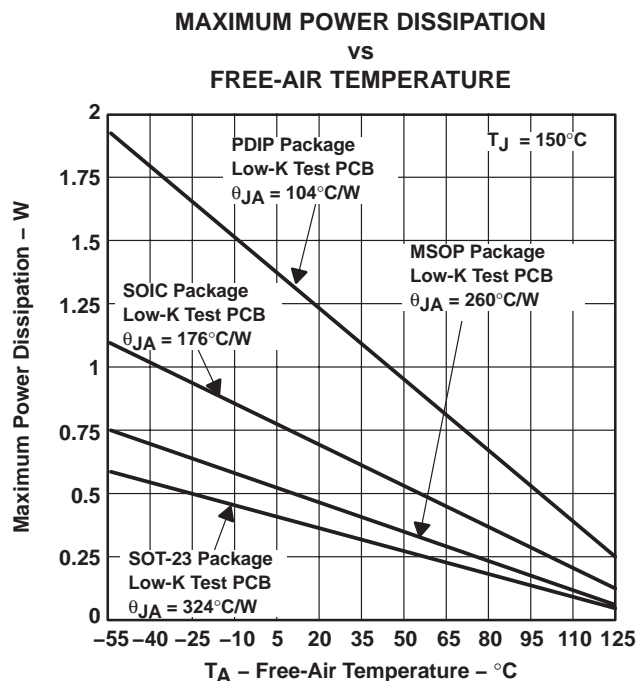
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TLV2760, TLV2761, TLV2762, TLV2763, TLV2764, TLV2765
 FAMILY OF 1.8 V MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT
 OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

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 MICROPOWER RAIL-TO-RAIL INPUT/OUTPUT OPERATIONAL AMPLIFIERS WITH SHUTDOWN

SLOS326E – JUNE 2000 – REVISED JANUARY 2005

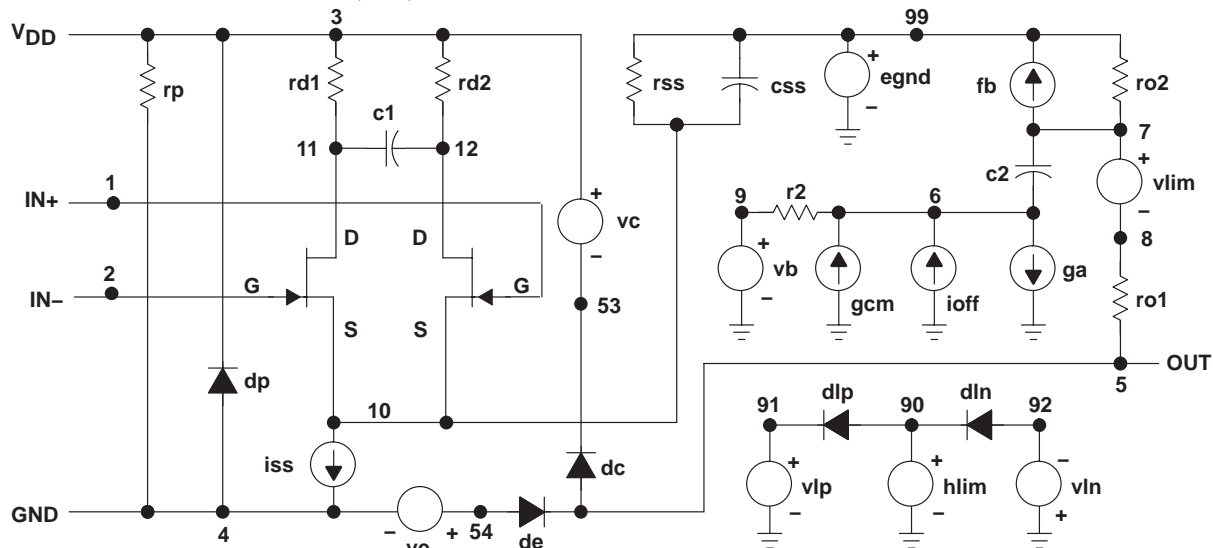
APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™ Release 9.1, the model generation software used with Microsim *PSpice*™. 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
```

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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
dip 90 91 dx
din 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 vlim 1K
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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PACKAGING INFORMATION

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLV2760CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IDBVR	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IDBVRG4	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IDBVT	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IDBVTG4	ACTIVE	SOT-23	DBV	6	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2760IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2760IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2761CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2761IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2761IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2762CD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762CDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762CDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762CDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLV2762ID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDGK	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDGKG4	ACTIVE	MSOP	DGK	8	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2762IP	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2762IPE4	ACTIVE	PDIP	P	8	50	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2763CD	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763CDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763CDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763CDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763DGS	ACTIVE	MSOP	DGS	10	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763DGS4	ACTIVE	MSOP	DGS	10	80	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763DGSR	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763DGSRG4	ACTIVE	MSOP	DGS	10	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763IDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763IDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2763IN	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2763INE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2764CD	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764CDG4	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764CDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764CDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764ID	ACTIVE	SOIC	D	14	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

Orderable Device	Status ⁽¹⁾	Package Type	Package Drawing	Pins	Package Qty	Eco Plan ⁽²⁾	Lead/Ball Finish	MSL Peak Temp ⁽³⁾
TLV2764IDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764IDRG4	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764IN	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2764INE4	ACTIVE	PDIP	N	14	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLV2764IPW	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764IPWG4	ACTIVE	TSSOP	PW	14	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764IPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2764IPWRG4	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765CD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765CDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765ID	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IPWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLV2765IPWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

⁽¹⁾ The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

⁽²⁾ Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

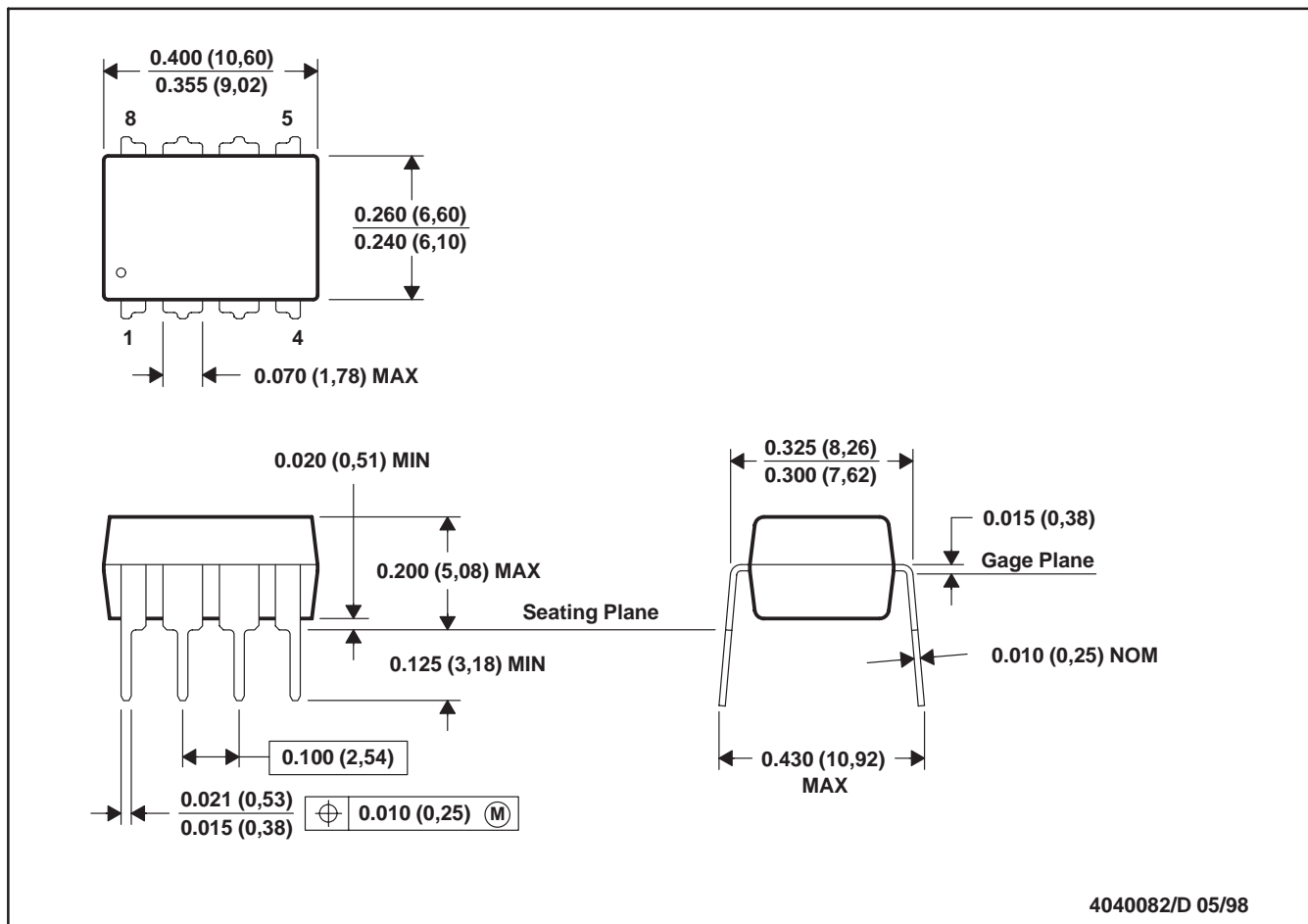
⁽³⁾ MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE



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

For the latest package information, go to http://www.ti.com/sc/docs/package/pkg_info.htm

N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

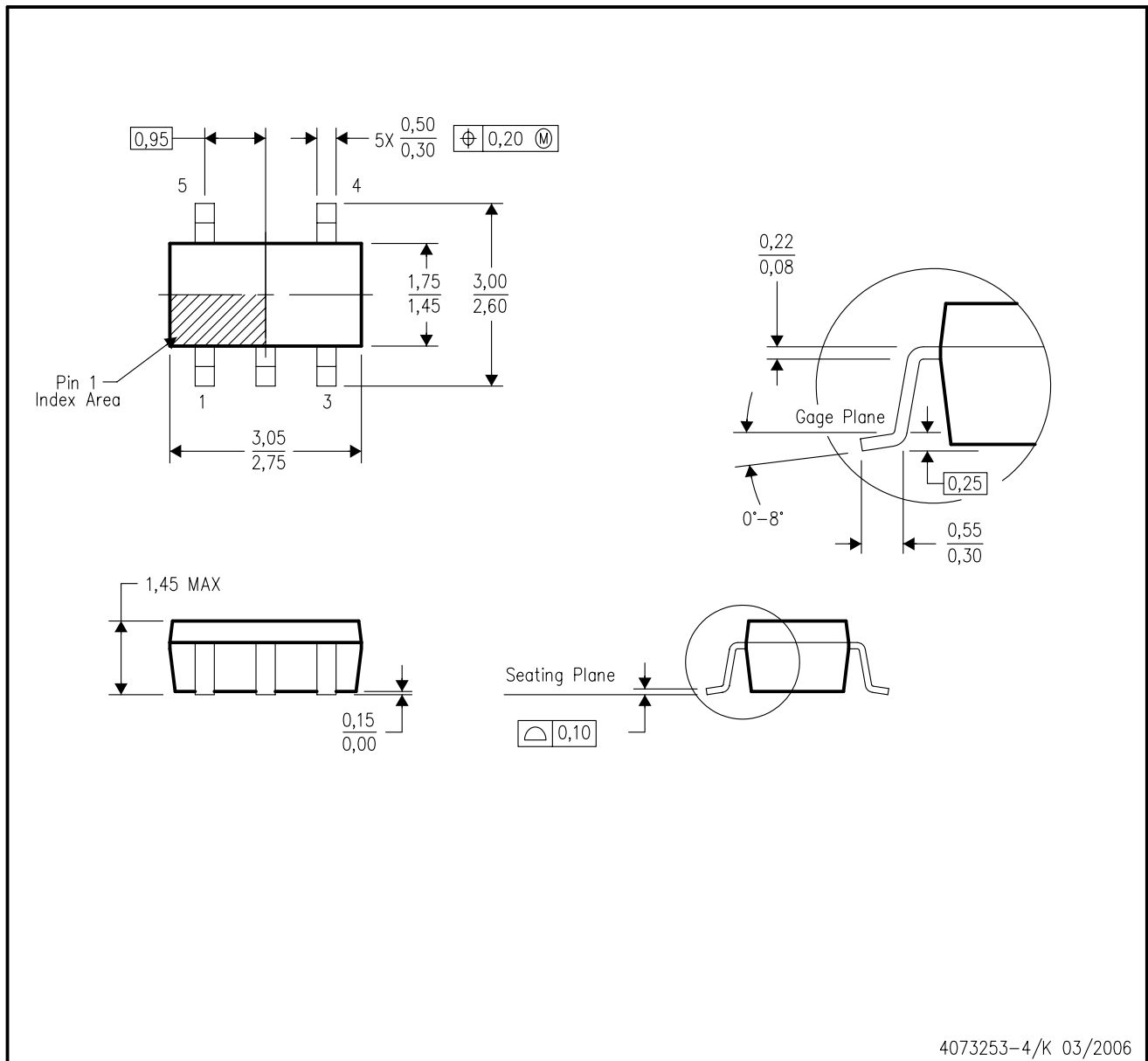
16 PINS SHOWN



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

DBV (R-PDSO-G5)

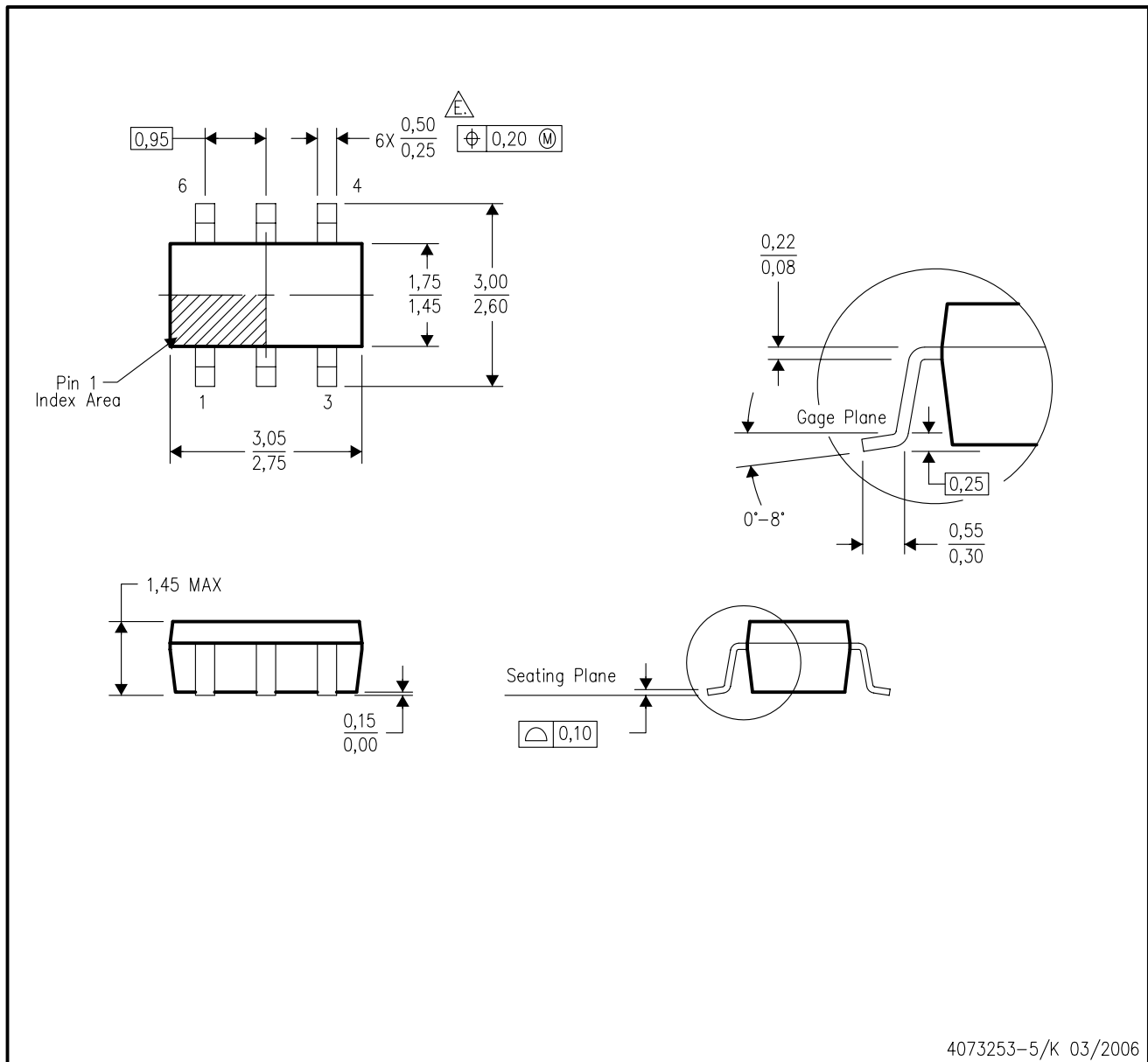
PLASTIC SMALL-OUTLINE PACKAGE



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

DBV (R-PDSO-G6)

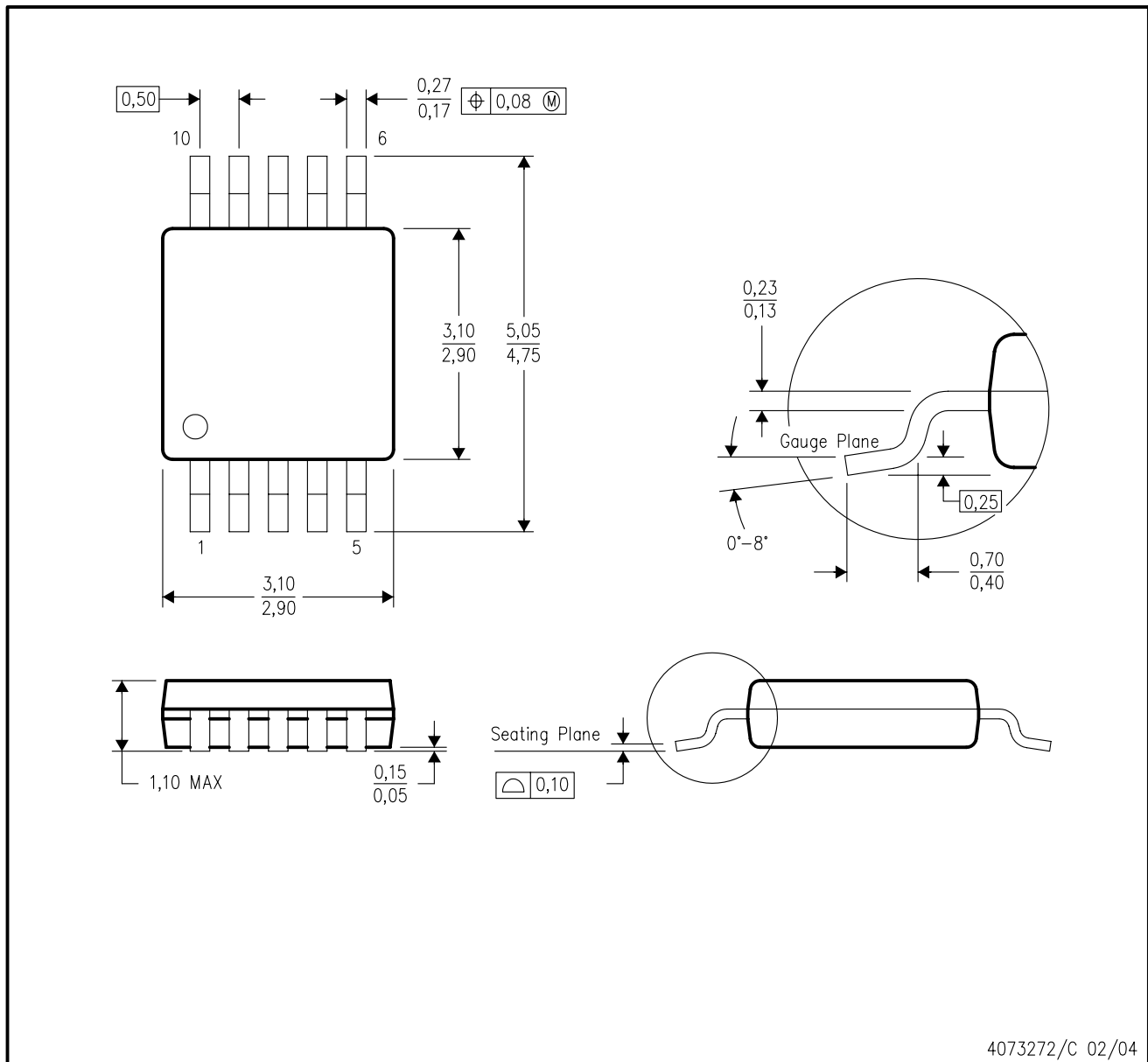
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
 - D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
- $\triangle E$ Falls within JEDEC MO-178 Variation AB, except minimum lead width.

DGS (S-PDSO-G10)

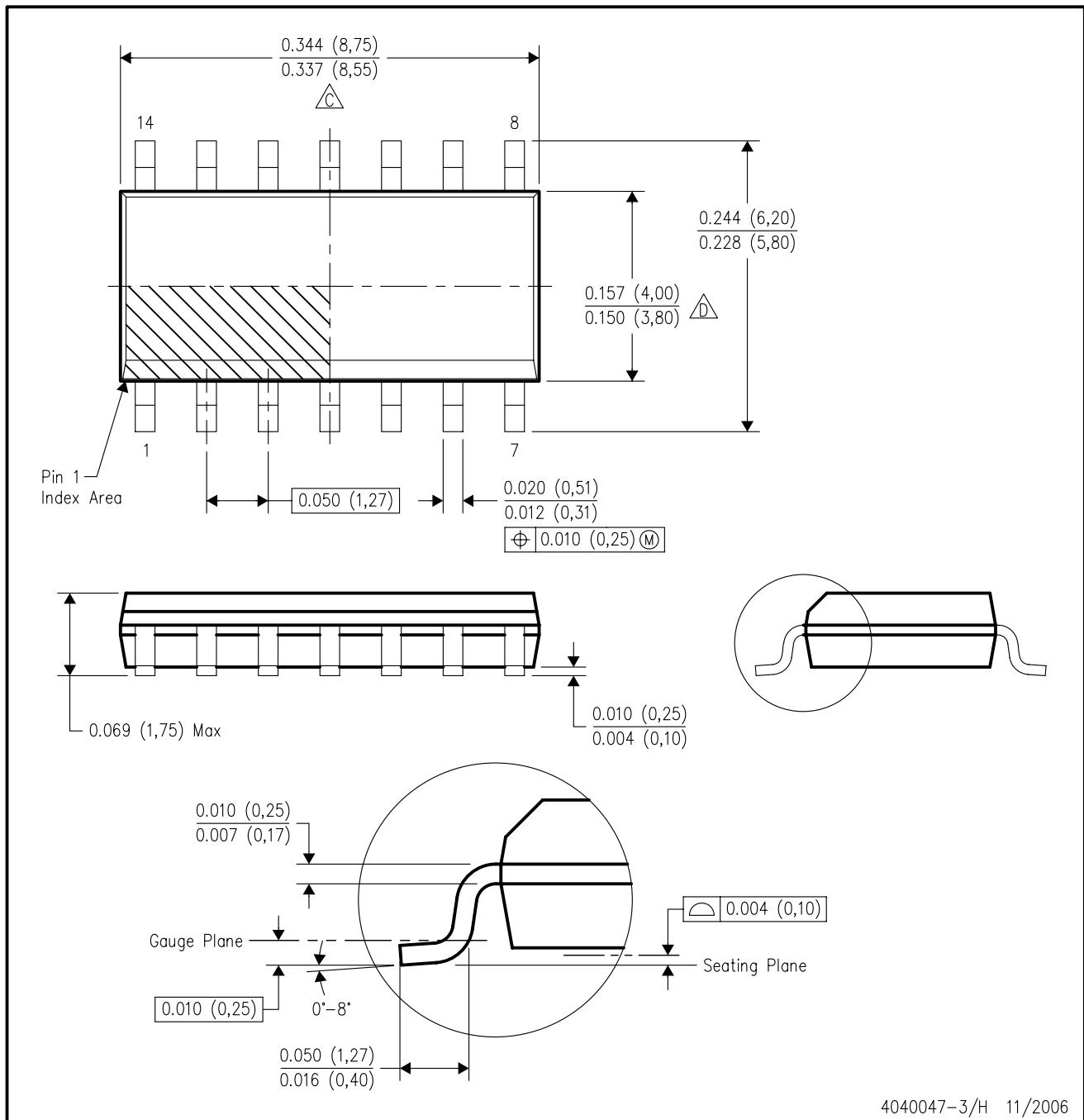
PLASTIC SMALL-OUTLINE PACKAGE



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

D (R-PDSO-G14)

PLASTIC SMALL-OUTLINE PACKAGE

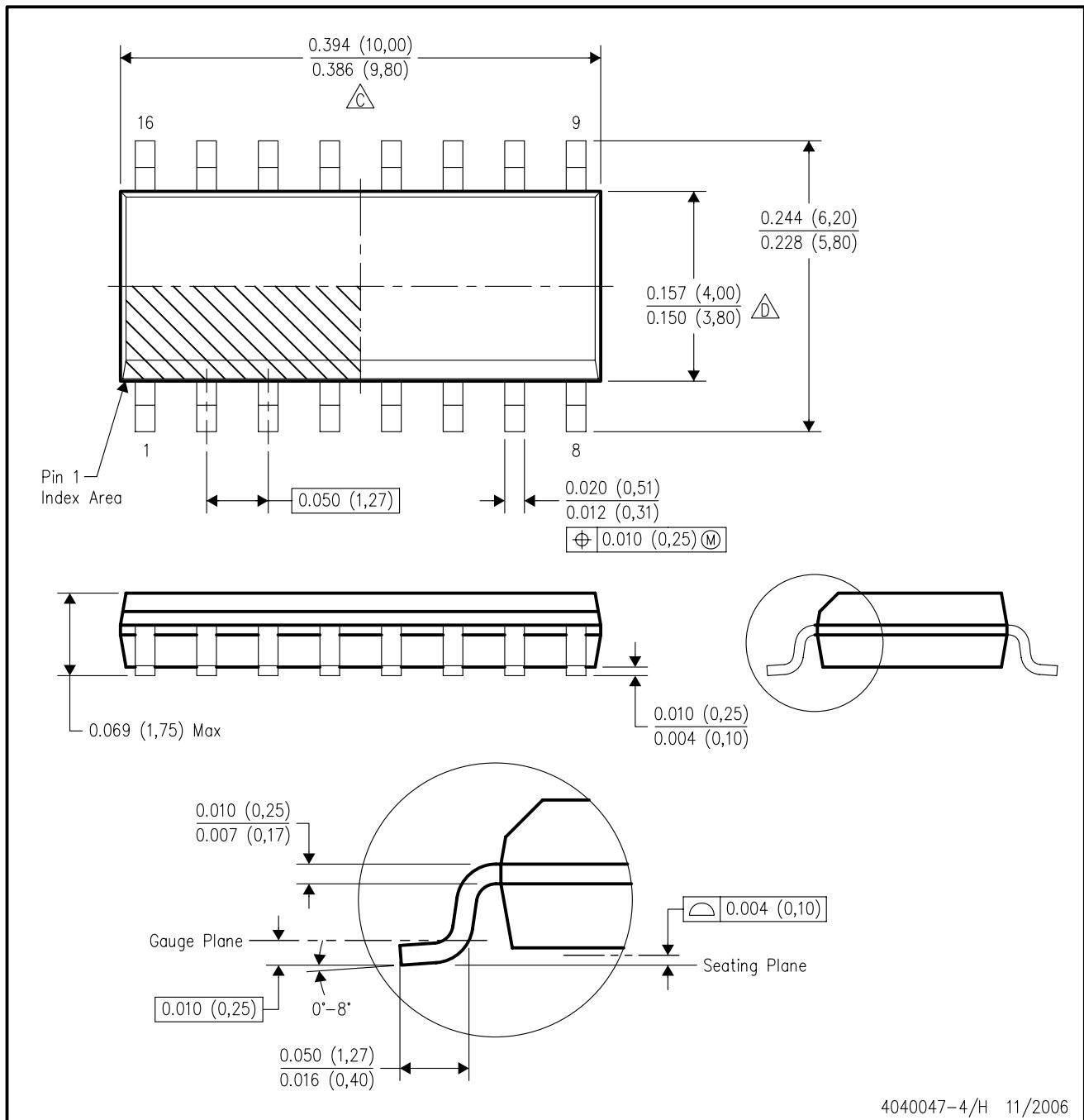


4040047-3/H 11/2006

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

D (R-PDSO-G16)

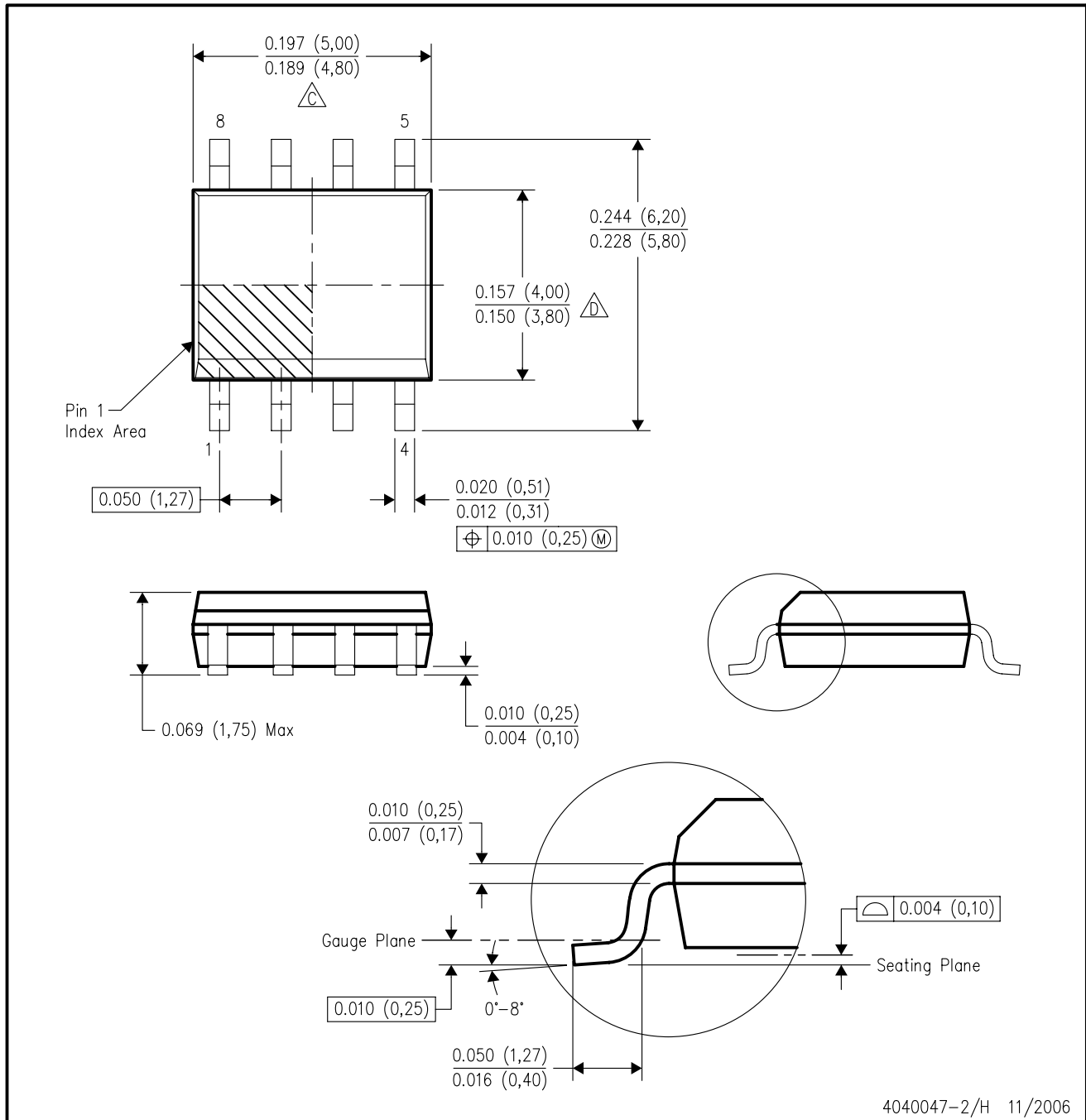
PLASTIC SMALL-OUTLINE PACKAGE



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

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

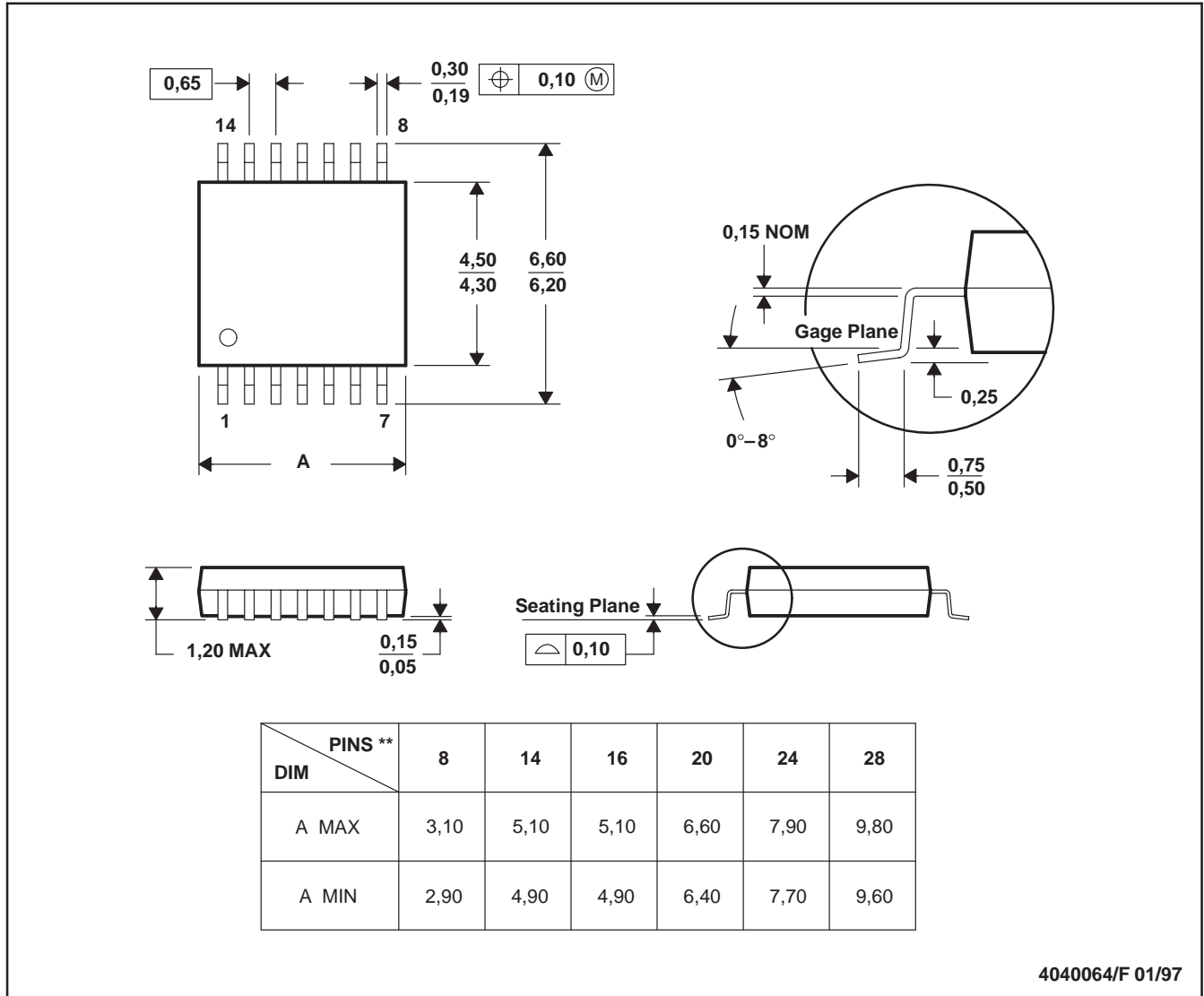


- NOTES:
- A. All linear dimensions are in inches (millimeters).
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
 - D. Body width does not include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

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



4040064/F 01/97

- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

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