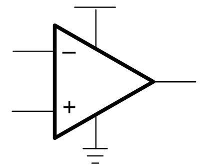
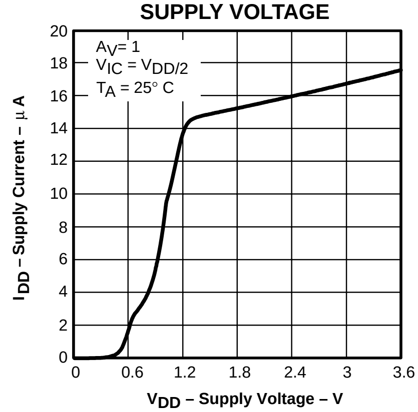
- **Low Supply Voltage . . . 1.8 V to 3.6 V**
- **Very Low Supply Current . . . 20 μA (per channel)**
- **Ultralow Power Shut-Down Mode**
  - **$I_{DD(SHDN)}$ = 10 nA/Channel**
- **CMOS Rail-to-Rail Input/Output**
- **Input Common-Mode Voltage Range . . . –0.2 V to V_{DD} + 0.2 V**
- **Input Offset Voltage . . . 550 μV**
- **Wide Bandwidth . . . 500 kHz**
- **Slew Rate . . . 0.20 V/μs**
- **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 μA 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} (μV)	I_{DD}/Ch (μA)	I_{IB} (pA)	GBW (MHz)	SR (V/μs)	Vn,1kHz (nV/rtHz)	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.

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TLV2760 and TLV2761 AVAILABLE OPTIONS

T_A	V_{IO}max AT 25°C	PACKAGED DEVICES			
		SMALL OUTLINE (D)†	SOT-23 (DBV)‡	SOT-23 SYMBOL	PLASTIC DIP (P)
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_A	V_{IO}max AT 25°C	PACKAGED DEVICES						
		SMALL OUTLINE (D)†	MSOP DGK†	MSOP SYMBOL	MSOP DGS†	MSOP SYMBOL	PLASTIC DIP (N)	PLASTIC DIP (P)
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).

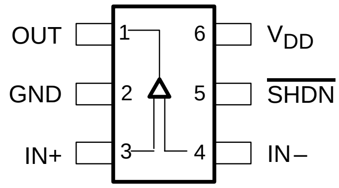
TLV2764 and TLV2765 AVAILABLE OPTIONS

T_A	V_{IO}max 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

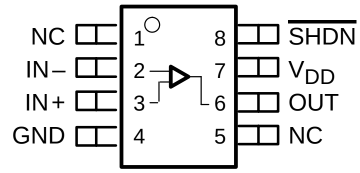
† This package is available taped and reeled. To order this packaging option, add an R suffix to the part number (e.g., TLV2764CDR).

TLV276x PACKAGE PINOUTS

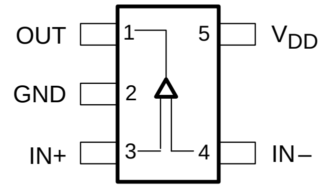
TLV2760
DBV PACKAGE
(TOP VIEW)



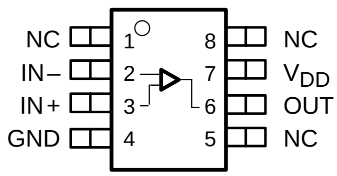
TLV2760
D OR P PACKAGE
(TOP VIEW)



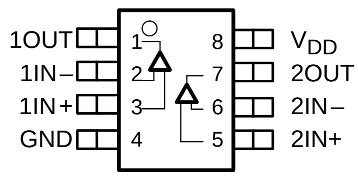
TLV2761
DBV PACKAGE
(TOP VIEW)



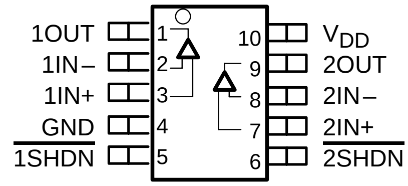
TLV2761
D OR P PACKAGE
(TOP VIEW)



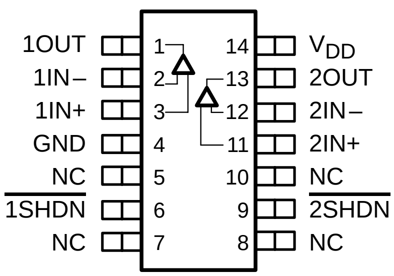
TLV2762
D, DGK, OR P PACKAGE
(TOP VIEW)



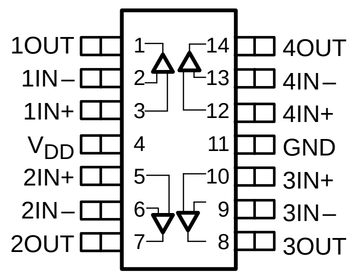
TLV2763
DGS PACKAGE
(TOP VIEW)



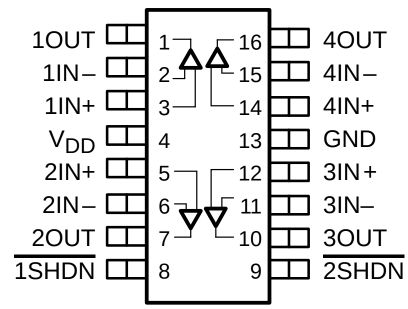
TLV2763
D OR N PACKAGE
(TOP VIEW)



TLV2764
D, N, OR PW PACKAGE
(TOP VIEW)



TLV2765
D, N, OR PW PACKAGE
(TOP VIEW)



NC – No internal connection

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 .... ±10 mA
Output current range, I_O .... ±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	Θ_{JC} (°C/W)	Θ_{JA} (°C/W)	$T_A \le 25°C$ POWER RATING	$T_A = 85°C$ 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		±0.8	±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

electrical characteristics at recommended operating conditions, V_{DD} = 1.8 V, 2.4 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 kΩ, R_S = 50 Ω	TLV276x	25°C		550	3500	µV
				Full range			6800	
α_{VIO}	Offset voltage drift					9		µV/°C
CMRR	Common-mode rejection ratio	V_{ICR} = 0 V to V_{DD}, R_S = 50 Ω	V_{DD} = 1.8 V	25°C	50	70		dB
				Full range	48			
			V_{DD} = 2.4 V	25°C	53	72		dB
				Full range	50			dB
			V_{DD} = 3.6 V	25°C	55	76		dB
				Full range	55			
		V_{ICR} = 1.2 V to V_{DD}, R_S = 50 Ω	V_{DD} = 2.4 V, 3.6 V	25°C	63	82		dB
				Full range	60			
A_{VD}	Large-signal differential voltage amplification	R_L = 10 kΩ, $V_{O(PP)} = V_{DD}/2$	V_{DD} = 1.8 V	25°C	20	60		V/mV
				Full range	18			
			V_{DD} = 2.4 V	25°C	28	78		
				Full range	23			
			V_{DD} = 3.6 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 kΩ, R_S = 50 Ω		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		GΩ
$c_{i(c)}$	Common-mode input capacitance	f = 16 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.

electrical characteristics at recommended operating conditions, V_{DD} = 1.8 V, 2.4 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 µA	V_{DD} = 1.8V	25°C	1.77	1.79		V
				Full range	1.76			
			V_{DD} = 2.4V	25°C	2.38	2.39		
				Full range	2.37			
			V_{DD} = 3.6V	25°C	3.58	3.59		
				Full range	3.57			
		$V_{IC} = V_{DD}/2$, I_{OH} = –500 µA	V_{DD} = 1.8V	25°C	1.725	1.75		
				Full range	1.7			
			V_{DD} = 2.4V	25°C	2.325	2.35		
				Full range	2.3			
			V_{DD} = 3.6V	25°C	3.525	3.55		
				Full range	3.5			
V_{OL}	Low-level output voltage	$V_{IC} = V_{DD}/2$,	I_{OL} = 100 µA	25°C		10	20	mV
				Full range			30	
		$V_{IC} = V_{DD}/2$,	I_{OL} = 500 µA	25°C		50	75	
				Full range			100	
I_O	Output current	V_{DD} = 1.8 V, V_O = 0.5 V from	Positive rail	25°C		4.8		mA
			Negative rail			7.2		
		V_{DD} = 2.4 V, V_O = 0.5 V from	Positive rail	25°C		7.3		
			Negative rail			10.2		
I_{OS}	Short-circuit output current	V_{DD} = 1.8 V	Sourcing	25°C		7		mA
			Sinking			10		
		V_{DD} = 2.4 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 V, 2.4 V, 3.6 V (unless otherwise noted)

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

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

dynamic performance

PARAMETER		TEST CONDITIONS		T_A†	MIN	TYP	MAX	UNIT
UGBW	Unity gain bandwidth	R_L = 300 kΩ,	C_L = 10 pF	25°C		500		kHz
SR+	Positive slew rate at unity gain	$V_{O(PP)}$ = 1 V, R_L = 300 kΩ, C_L = 50 pF,	V_{DD} = 1.8 V	25°C	0.11	0.20		V/μs
				Full range	0.09			
			V_{DD} = 2.4 V	25°C	0.11	0.22		
				Full range	0.09			
			V_{DD} = 3.6 V	25°C	0.11	0.23		V/μs
				Full range	0.09			
SR–	Negative slew rate at unity gain	$V_{O(PP)}$ = 1 V, R_L = 300 kΩ, C_L = 50 pF,	V_{DD} = 1.8 V	25°C	0.08	0.15		V/μs
				Full range	0.07			
			V_{DD} = 2.4 V	25°C	0.10	0.18		
				Full range	0.09			
			V_{DD} = 3.6 V	25°C	0.10	0.22		V/μs
				Full range	0.09			
ϕ_m	Phase margin	R_L = 300 kΩ,	C_L = 100 pF	25°C		63		°
	Gain margin			25°C		20		dB
t_s	Settling time	V_{DD} = 1.8 V, $V_{(STEP)PP}$ = 1 V, A_V = –1, C_L = 10 pF, R_L = 300 kΩ	0.1%	25°C		6.4		μs
			0.01%			13.7		
		V_{DD} = 2.4 V, $V_{(STEP)PP}$ = 1 V, A_V = –1, C_L = 10 pF, R_L = 300 kΩ	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 V, $V_{O(PP)}$ = V_{DD}/2 V, R_L = 300 kΩ, f = 1 kHz	A_V = 1	25°C		0.08%		
			A_V = 10			0.10%		
			A_V = 100			0.27%		
		V_{DD} = 2.4 V, $V_{O(PP)}$ = V_{DD}/2 V, R_L = 300 kΩ, f = 1 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 kHz		25°C		95		$nV/\sqrt{Hz}$
		f = 10 kHz		25°C		75		
I_n	Equivalent input noise current	f = 1 kHz		25°C		0.8		$fA/\sqrt{Hz}$

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)	$\overline{SHDN}$ = 0 V	25°C		10	50	nA
			Full range			400	
$t_{(on)}$	Amplifier turnon time (see Note 3)	R_L = 300 kΩ	25°C		5		μs
$t_{(off)}$	Amplifier turnoff time (see Note 3)	R_L = 300 kΩ	25°C		0.8		μs

† 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.

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

TYPICAL CHARACTERISTICS

INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

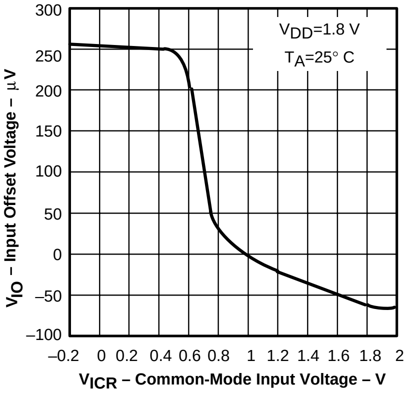


Figure 1

INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

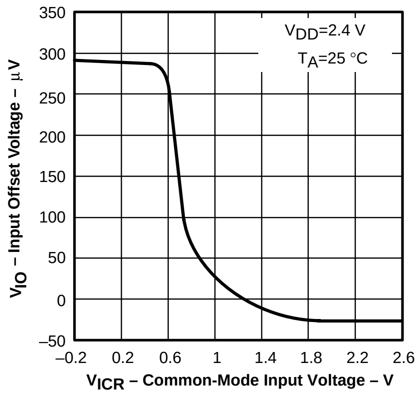


Figure 2

COMMON-MODE REJECTION RATIO vs FREQUENCY

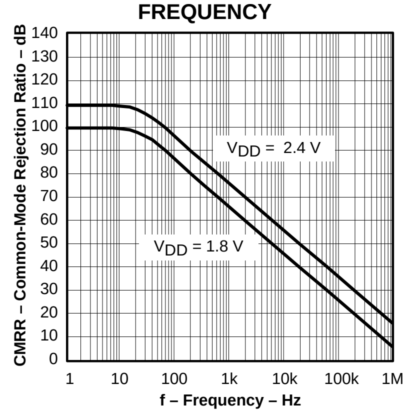


Figure 3

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

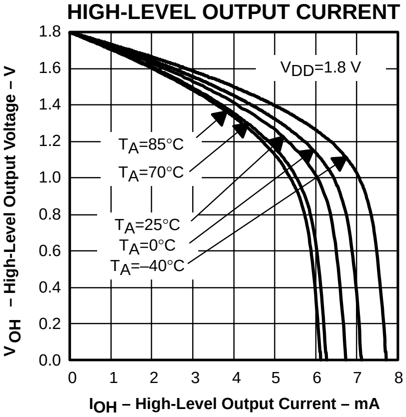


Figure 4

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

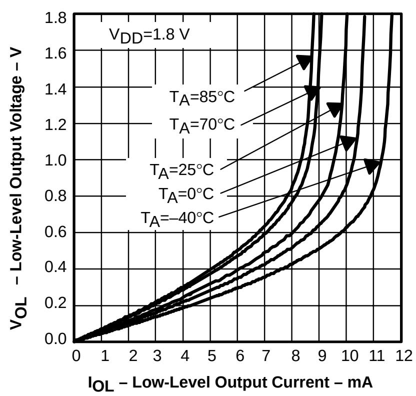


Figure 5

HIGH-LEVEL OUTPUT VOLTAGE vs HIGH-LEVEL OUTPUT CURRENT

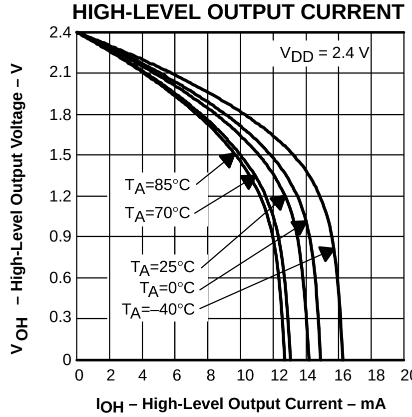


Figure 6

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

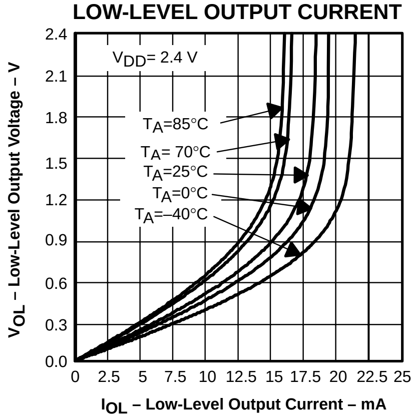


Figure 7

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

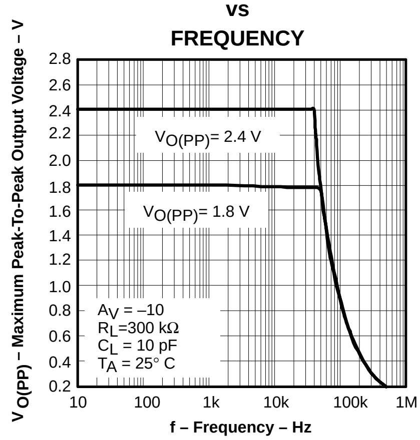


Figure 8

TYPICAL CHARACTERISTICS

SUPPLY CURRENT vs SUPPLY VOLTAGE

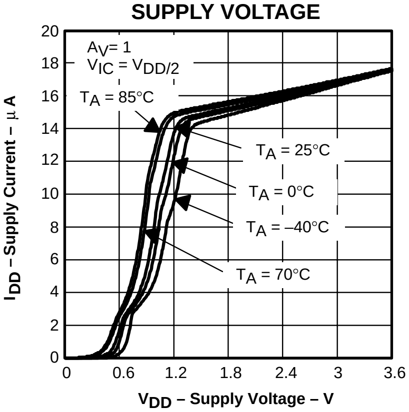


Figure 9

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

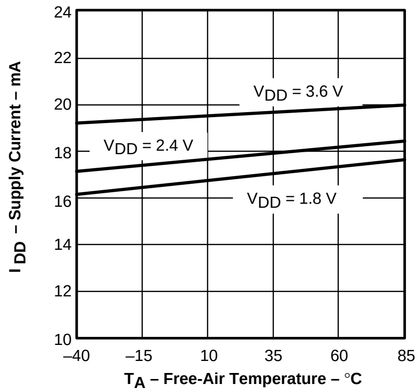


Figure 10

POWER SUPPLY REJECTION RATIO vs FREQUENCY

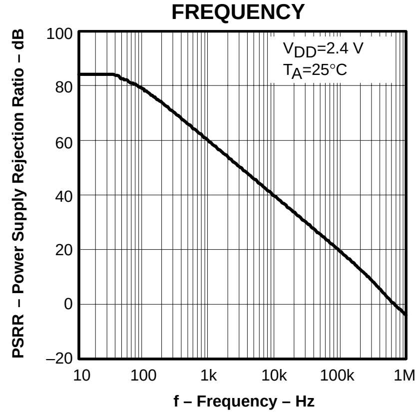


Figure 11

DIFFERENTIAL VOLTAGE GAIN AND PHASE vs FREQUENCY

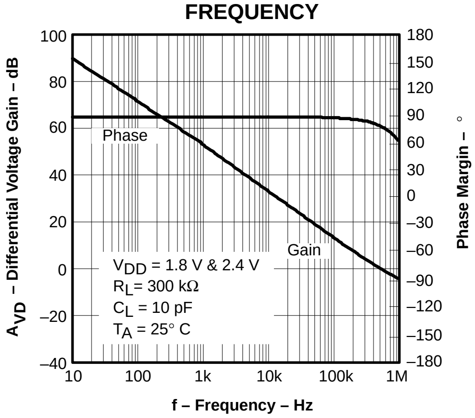


Figure 12

GAIN BANDWIDTH PRODUCT vs TEMPERATURE

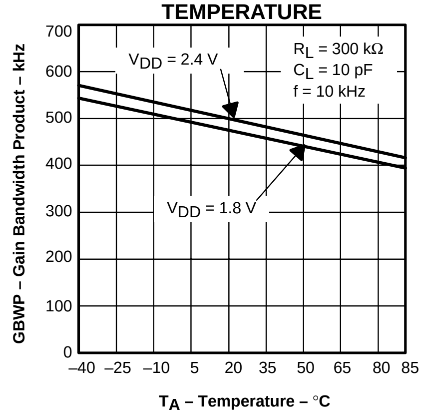


Figure 13

GAIN-BANDWIDTH PRODUCT vs SUPPLY VOLTAGE

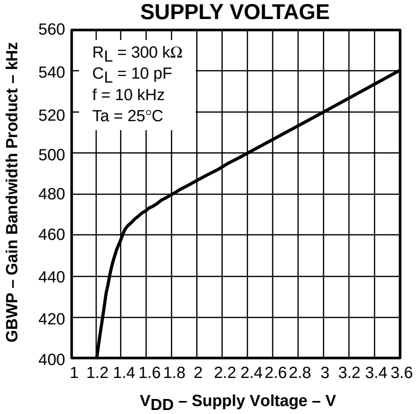


Figure 14

SLEW RATE vs SUPPLY VOLTAGE

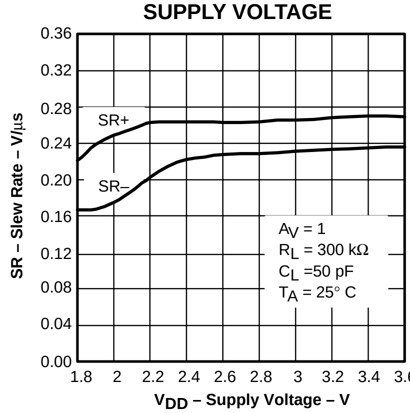


Figure 15

TYPICAL CHARACTERISTICS

SLEW RATE vs FREE-AIR TEMPERATURE

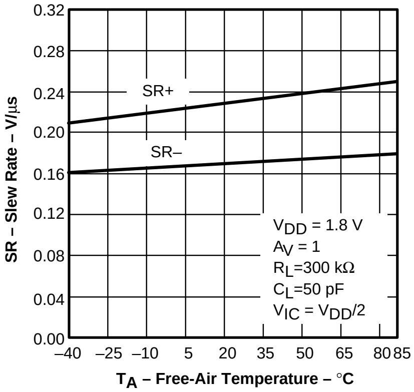


Figure 16

SLEW RATE vs FREE-AIR TEMPERATURE

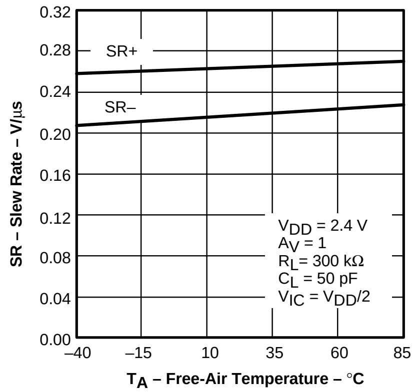


Figure 17

PHASE MARGIN vs LOAD CAPACITANCE

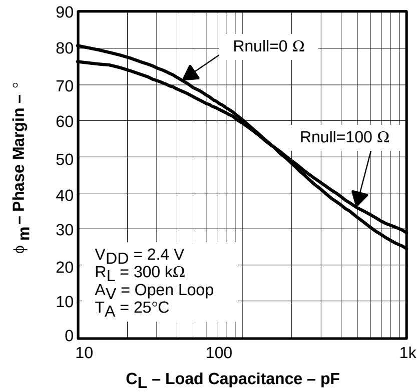


Figure 18

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

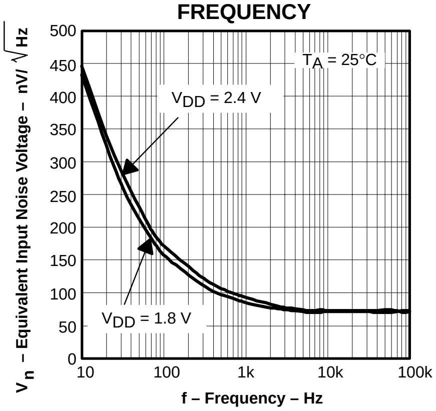


Figure 19

SUPPLY CURRENT AND OUTPUT VOLTAGE vs TIME

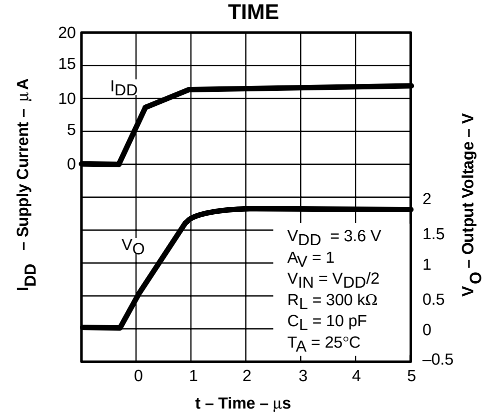


Figure 20

VOLTAGE-FOLLOWER LARGE-SIGNAL PULSE RESPONSE vs TIME

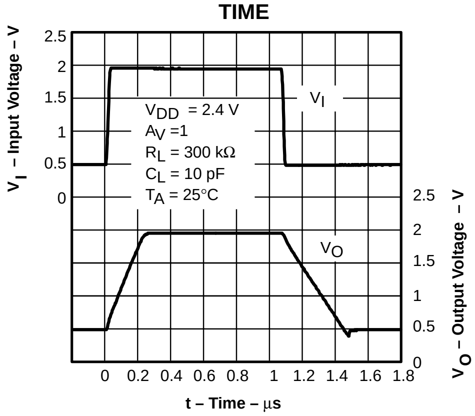


Figure 21

VOLTAGE-FOLLOWER SMALL-SIGNAL PULSE RESPONSE vs TIME

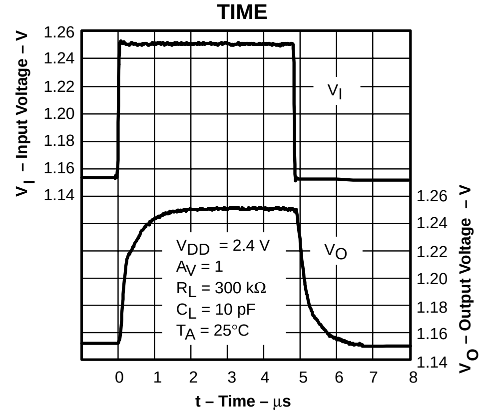


Figure 22

TYPICAL CHARACTERISTICS

INVERTING LARGE-SIGNAL RESPONSE vs TIME

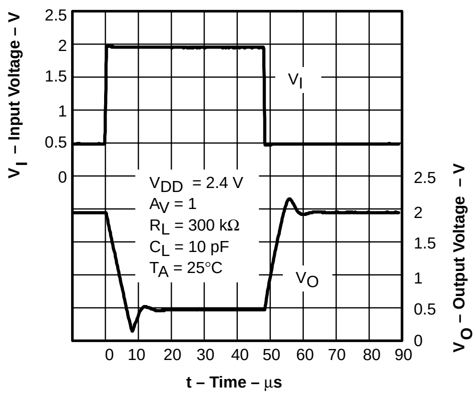


Figure 23

INVERTING SMALL-SIGNAL PULSE RESPONSE vs TIME

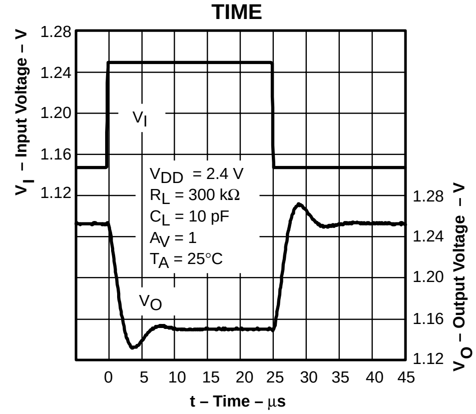


Figure 24

CROSSTALK vs FREQUENCY

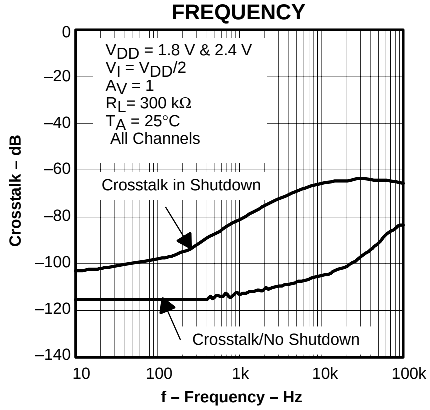


Figure 25

SHUTDOWN FORWARD AND REVERSE ISOLATION vs FREQUENCY

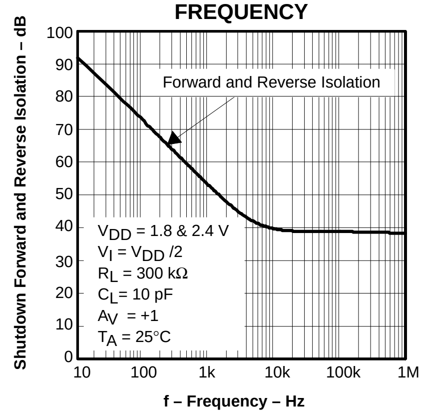


Figure 26

SHUTDOWN SUPPLY CURRENT vs SUPPLY VOLTAGE

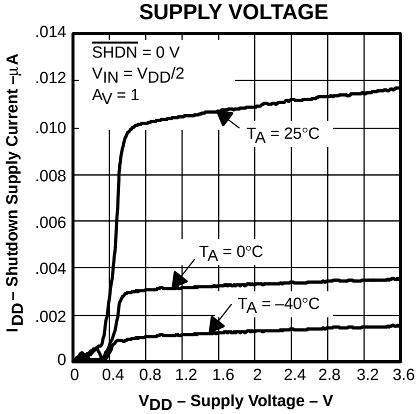


Figure 27

SHUTDOWN SUPPLY CURRENT vs FREE-AIR TEMPERATURE

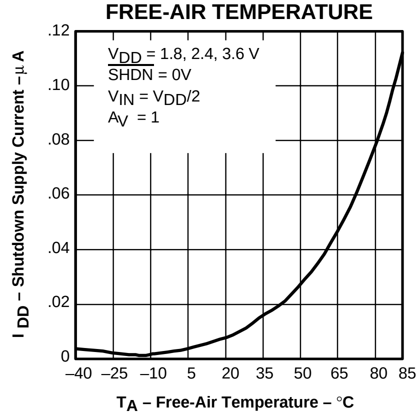


Figure 28

SHUTDOWN PIN LEAKAGE CURRENT vs SHUTDOWN PIN VOLTAGE

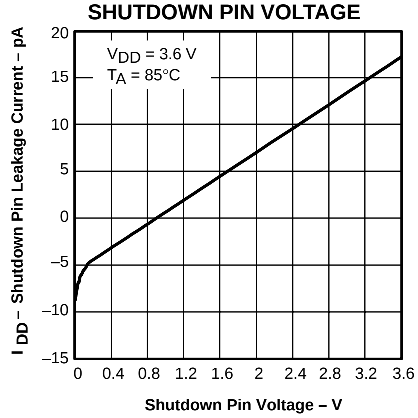


Figure 29

TYPICAL CHARACTERISTICS

SHUTDOWN SUPPLY CURRENT / OUTPUT VOLTAGE vs TIME

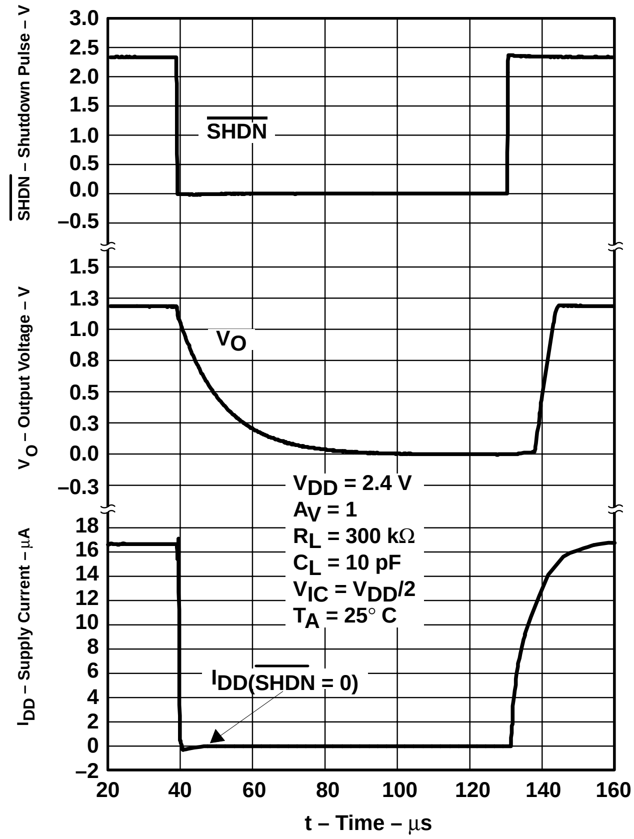


Figure 30

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.

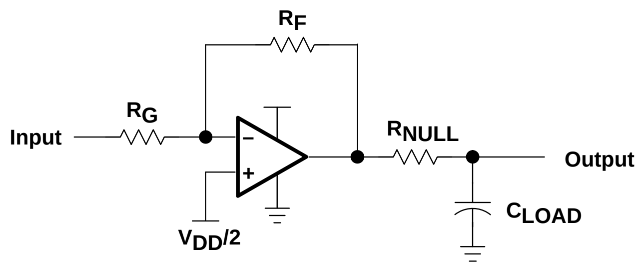
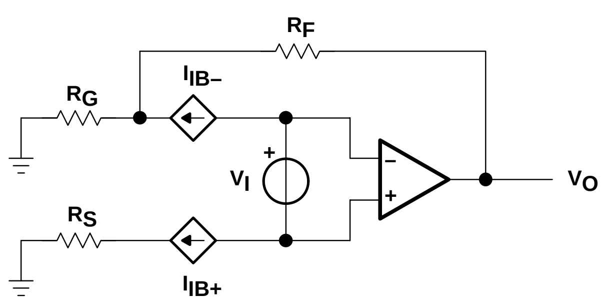


Figure 31. Driving a Capacitive Load

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:



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

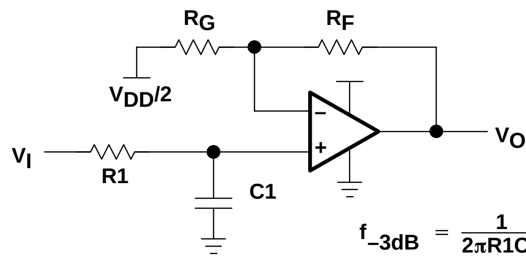
Figure 32. Output Offset Voltage Model

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)

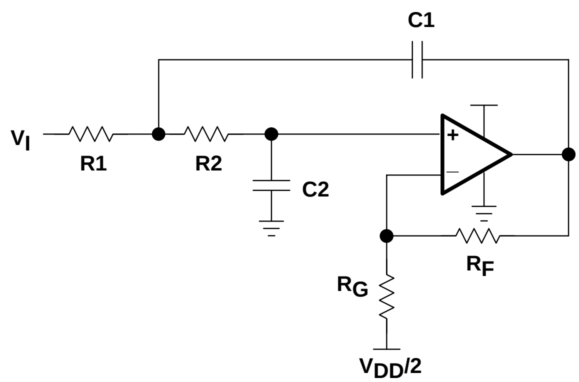


$$f_{-3dB} = \frac{1}{2\pi R1C1}$$

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

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.



R1 = R2 = R
C1 = C2 = C
Q = Peaking Factor
(Butterworth Q = 0.707)

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

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

Figure 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.

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:

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

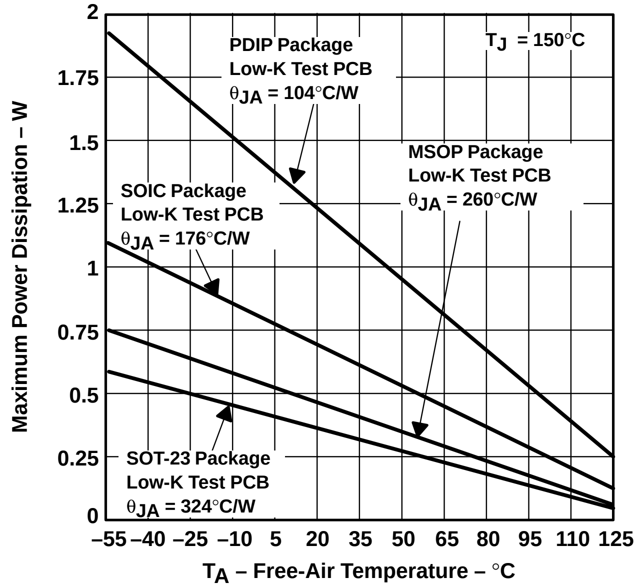
Where:

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)

APPLICATION INFORMATION

general power dissipation considerations (continued)

MAXIMUM POWER DISSIPATION
vs
FREE-AIR TEMPERATURE



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

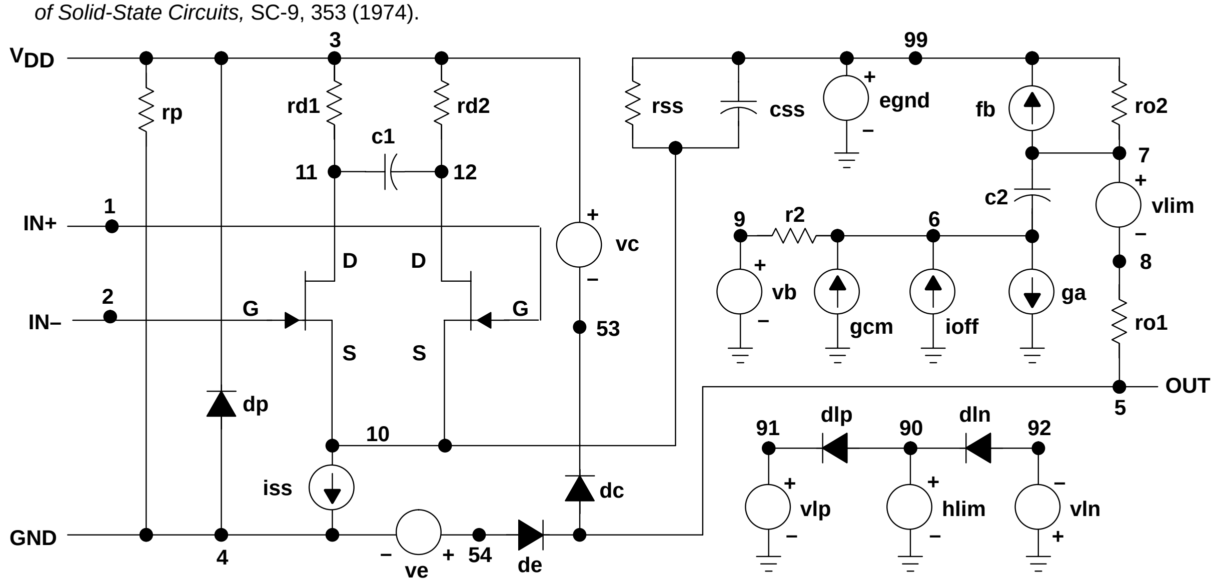
APPLICATION INFORMATION

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°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     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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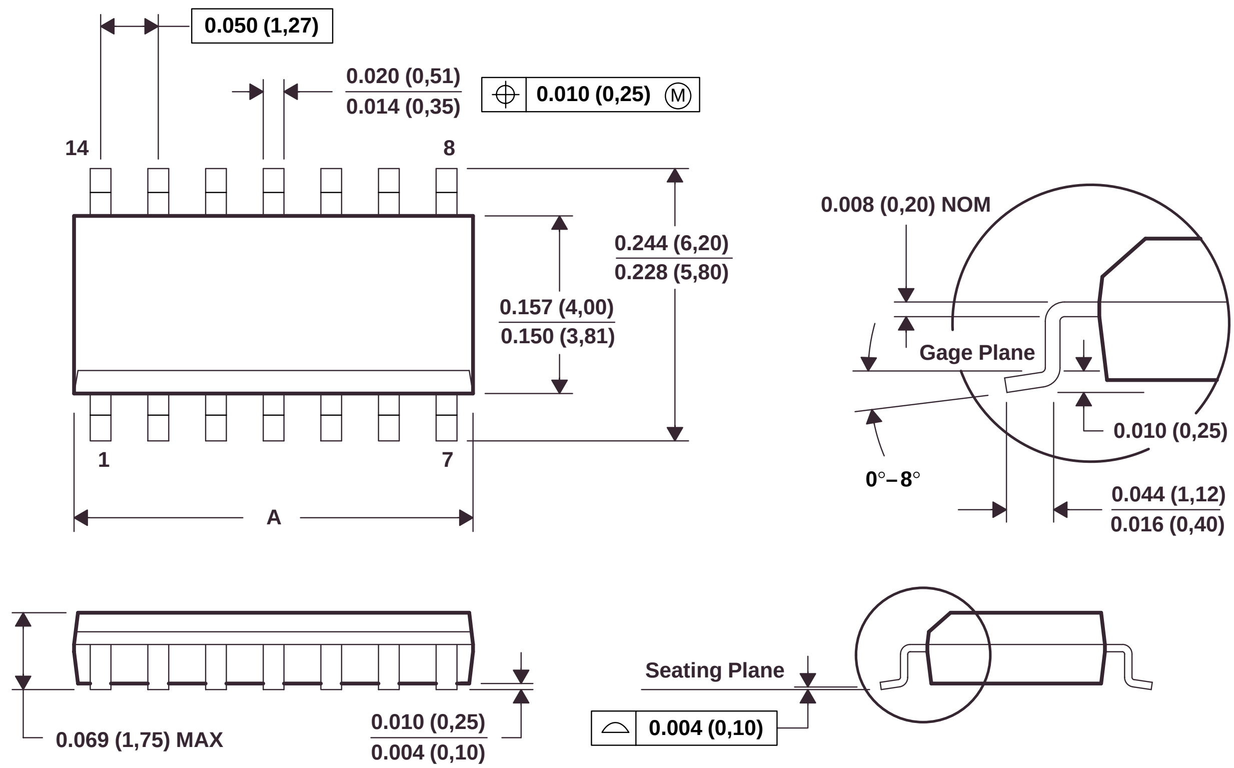
MECHANICAL DATA

D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



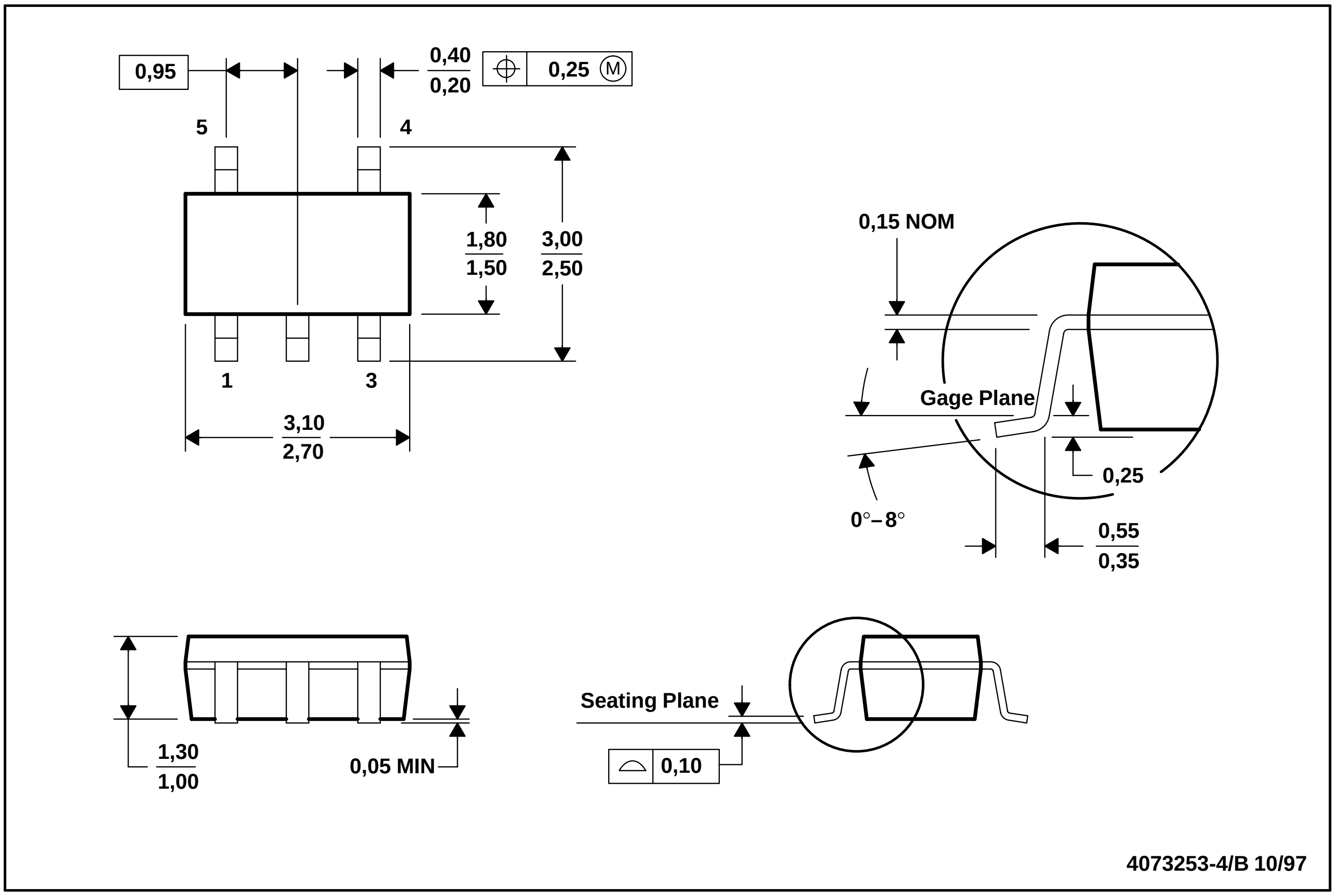
DIM \ PINS **	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047 / D 10/96

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

MECHANICAL DATA

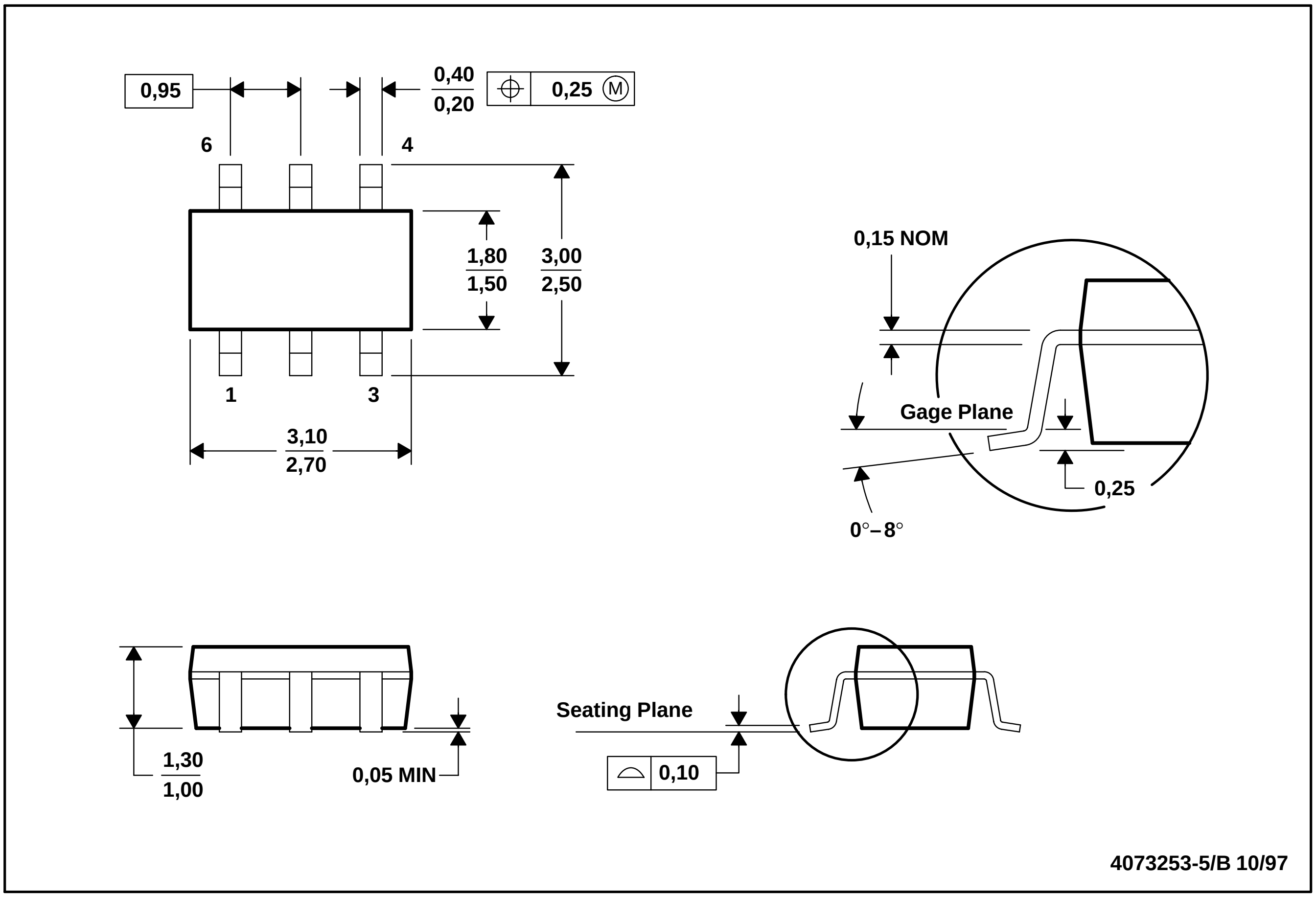
DBV (R-PDSO-G5) **PLASTIC SMALL-OUTLINE PACKAGE**



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

MECHANICAL DATA

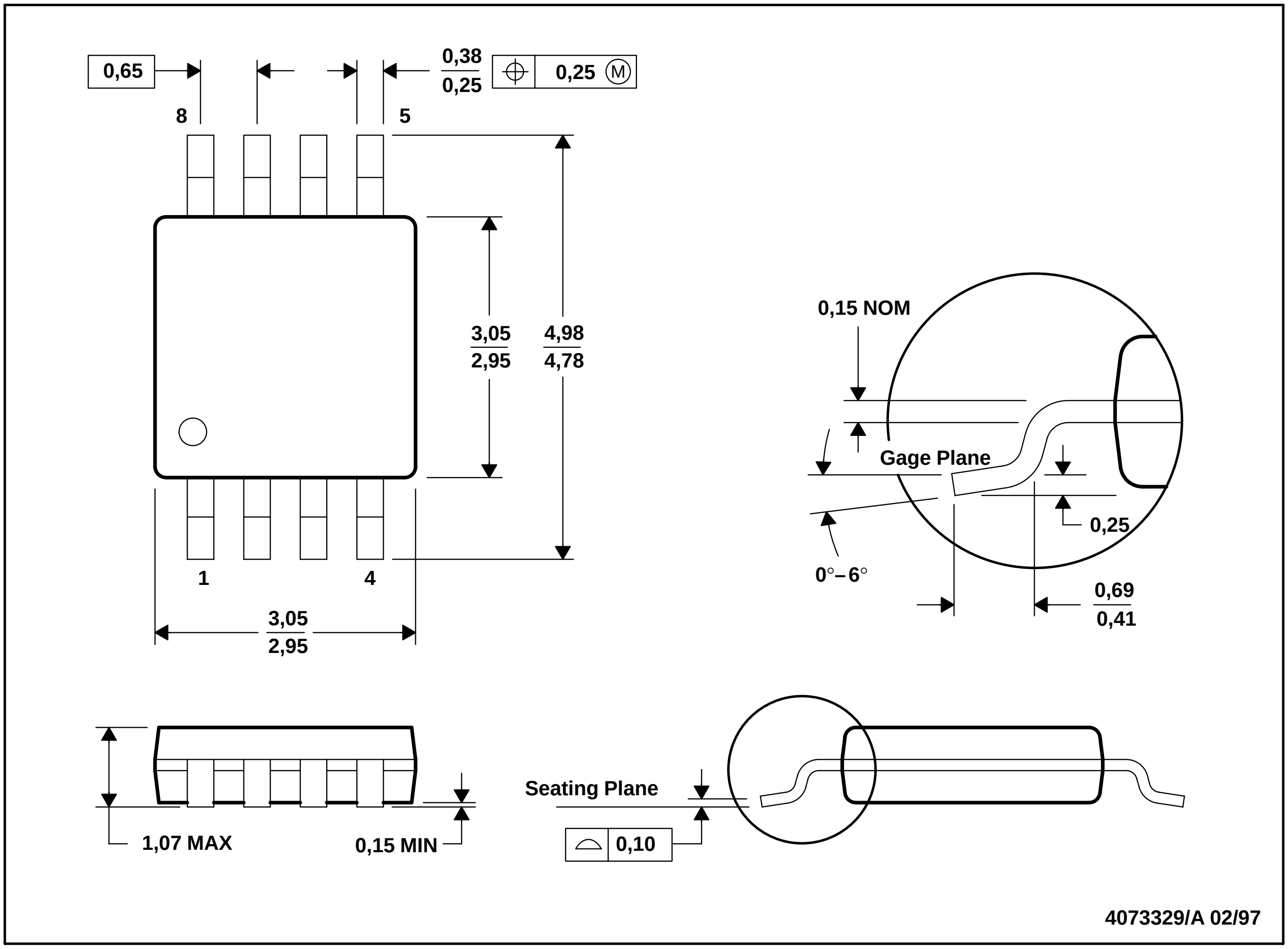
DBV (R-PDSO-G6) **PLASTIC SMALL-OUTLINE PACKAGE**



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

MECHANICAL DATA

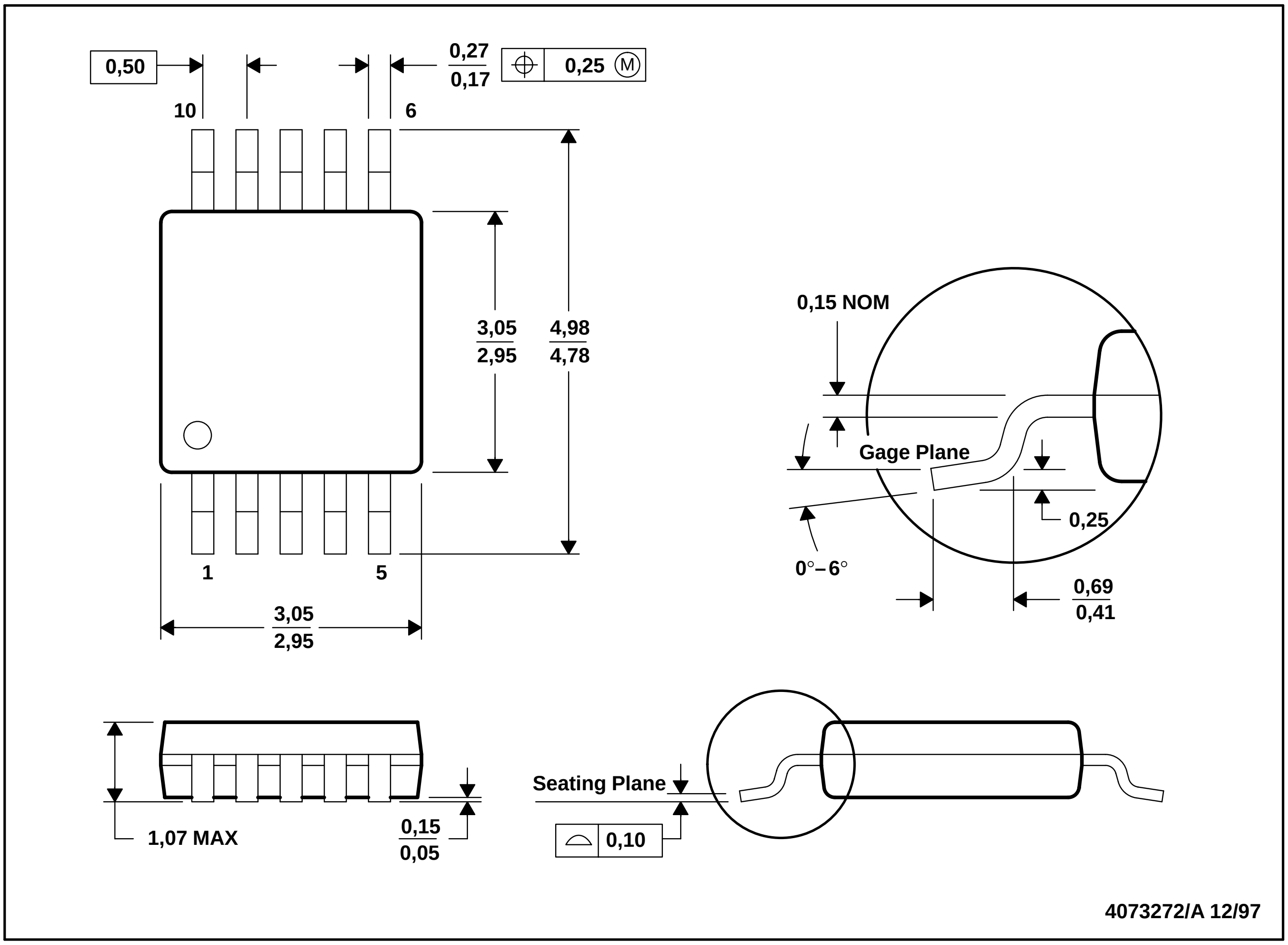
DGK (R-PDSO-G8) **PLASTIC SMALL-OUTLINE PACKAGE**



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

MECHANICAL DATA

DGS (S-PDSO-G10) **PLASTIC SMALL-OUTLINE PACKAGE**



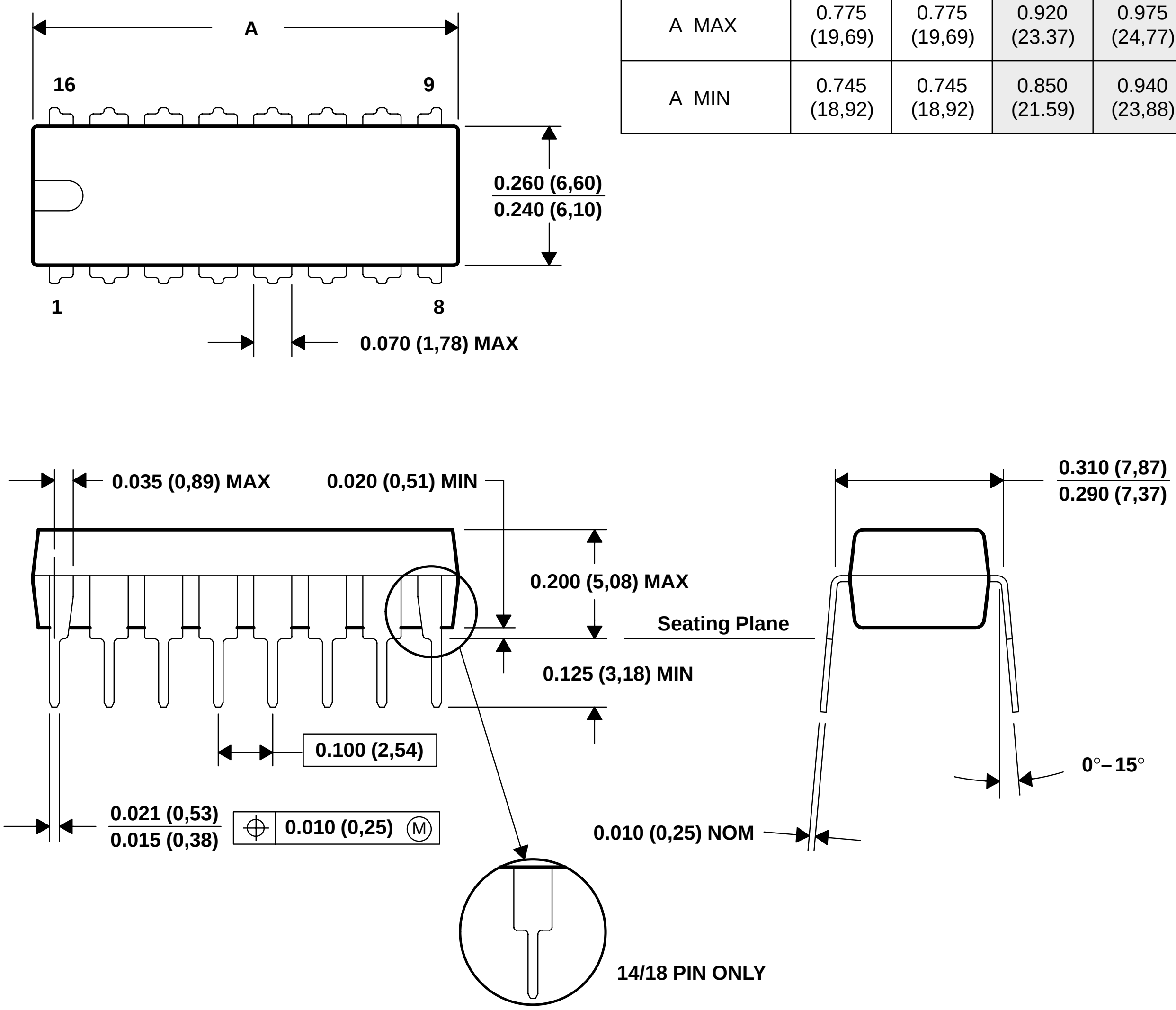
NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.

MECHANICAL DATA

N (R-PDIP-T)** **PLASTIC DUAL-IN-LINE PACKAGE**

16 PIN SHOWN

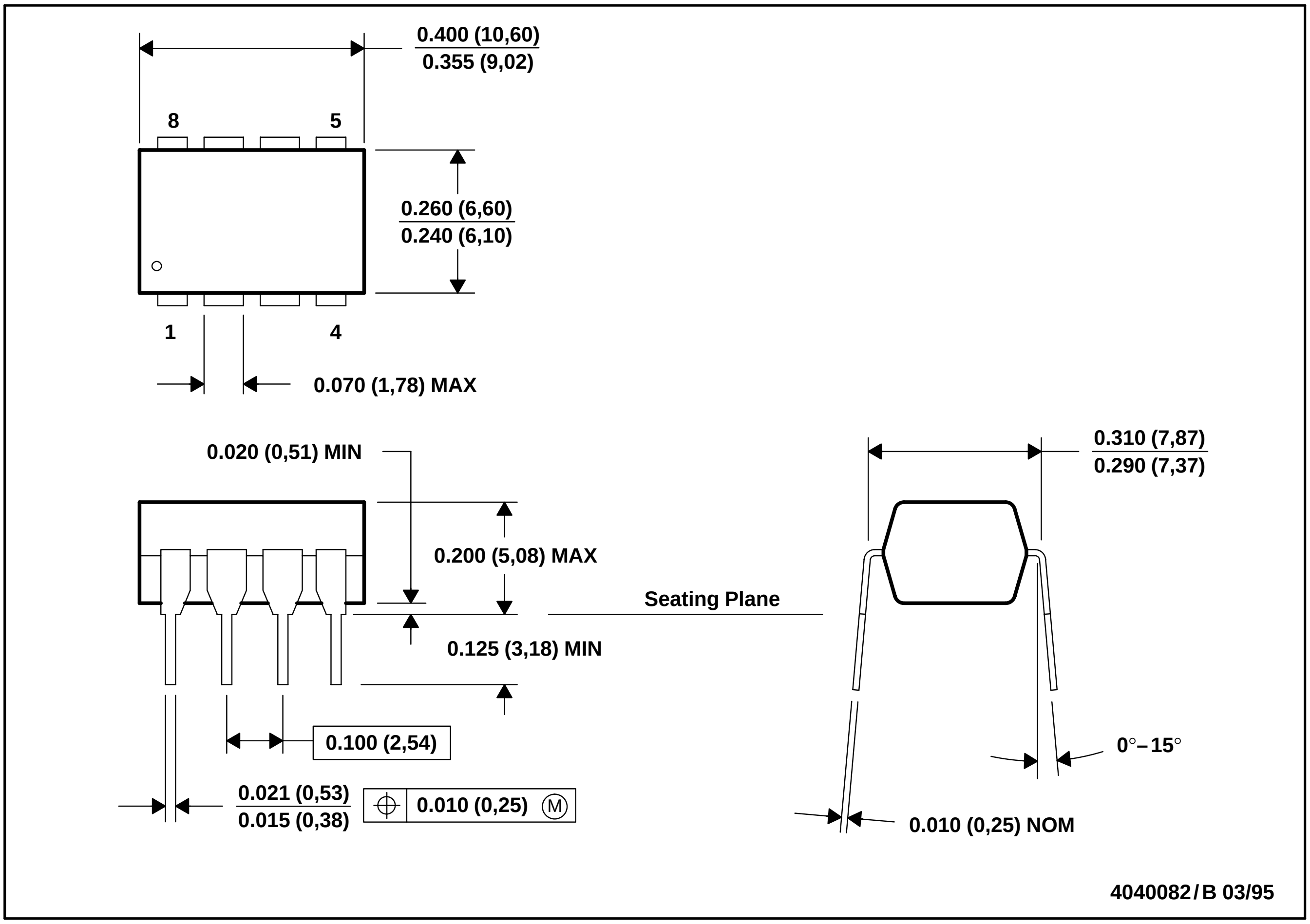
PINS ** / DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23.37)	0.975 (24,77)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21.59)	0.940 (23,88)



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 then MS-001.)

MECHANICAL DATA

P (R-PDIP-T8) **PLASTIC DUAL-IN-LINE PACKAGE**

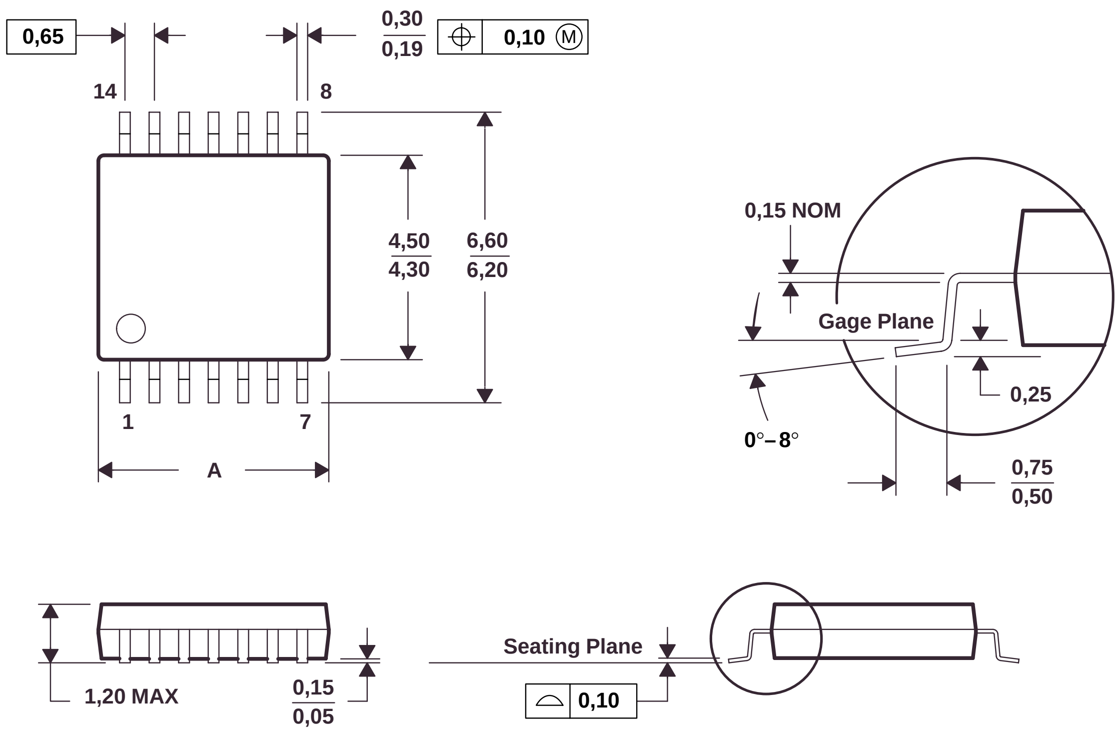


NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

MECHANICAL DATA

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PIN SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

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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