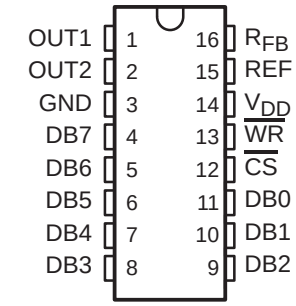
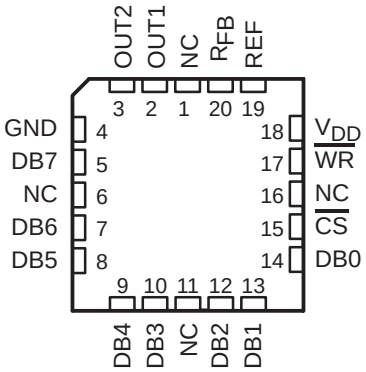
- **Easily Interfaced to Microprocessors**
- **On-Chip Data Latches**
- **Monotonic Over the Entire A/D Conversion Range**
- **Segmented High-Order Bits Ensure Low-Glitch Output**
- **Interchangeable With Analog Devices AD7524, PMI PM-7524, and Micro Power Systems MP7524**
- **Fast Control Signaling for Digital Signal-Processor Applications Including Interface With TMS320**
- **CMOS Technology**

KEY PERFORMANCE SPECIFICATIONS	
Resolution	8 Bits
Linearity error	1/2 LSB Max
Power dissipation at V_{DD} = 5 V	5 mW Max
Setting time	100 ns Max
Propagation delay time	80 ns Max

D, N, OR PW PACKAGE
(TOP VIEW)



FN PACKAGE
(TOP VIEW)



NC–No internal connection

description

The TLC7524C, TLC7524E, and TLC7524I are CMOS, 8-bit, digital-to-analog converters (DACs) designed for easy interface to most popular microprocessors.

The devices are 8-bit, multiplying DACs with input latches and load cycles similar to the write cycles of a random access memory. Segmenting the high-order bits minimizes glitches during changes in the most significant bits, which produce the highest glitch impulse. The devices provide accuracy to 1/2 LSB without the need for thin-film resistors or laser trimming, while dissipating less than 5 mW typically.

Featuring operation from a 5-V to 15-V single supply, these devices interface easily to most microprocessor buses or output ports. The 2- or 4-quadrant multiplying makes these devices an ideal choice for many microprocessor-controlled gain-setting and signal-control applications.

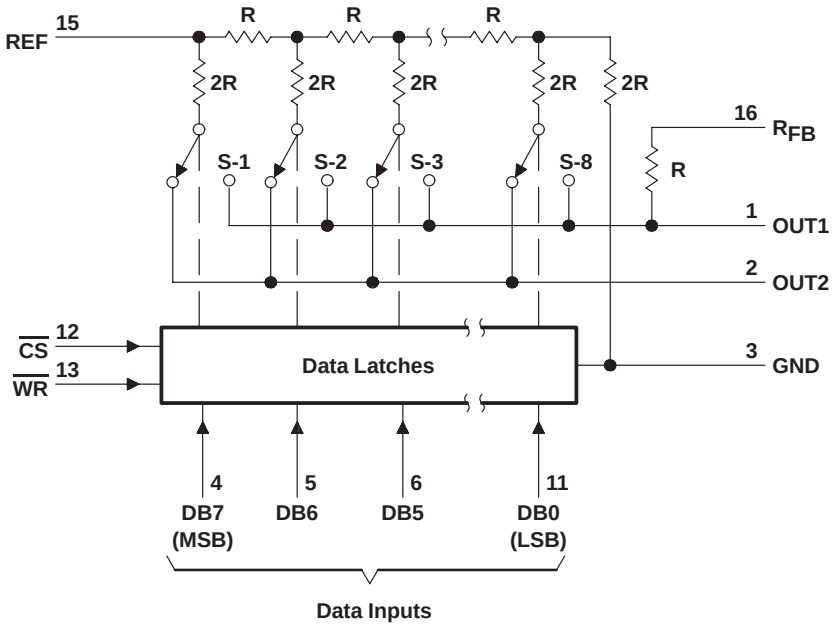
The TLC7524C is characterized for operation from 0°C to 70°C. The TLC7524I is characterized for operation from –25°C to 85°C. The TLC7524E is characterized for operation from – 40°C to 85°C.

AVAILABLE OPTIONS

T_A	PACKAGE			
	SMALL OUTLINE PLASTIC DIP (D)	PLASTIC CHIP CARRIER (FN)	PLASTIC DIP (N)	SMALL OUTLINE (PW)
0°C to 70°C	TLC7524CD	TLC7524CFN	TLC7524CN	TLC7524CPW
–25°C to 85°C	TLC7524ID	TLC7524IFN	TLC7524IN	TLC7524IPW
–40°C to 85°C	TLC7524ED	TLC7524EFN	TLC7524EN	–

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.

functional block diagram



Terminal numbers shown are for the D or N package.

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

Supply voltage range, V_{DD} . . . . . –0.3 V to 16.5 V
Digital input voltage range, V_I . . . . . –0.3 V to V_{DD} + 0.3 V
Reference voltage, V_{ref} . . . . . ±25 V
Peak digital input current, I_I . . . . . 10 μA
Operating free-air temperature range, T_A: TLC7524C . . . . . 0°C to 70°C
TLC7524I . . . . . –25°C to 85°C
TLC7524E . . . . . –40°C to 85°C
Storage temperature range, T_{stg} . . . . . –65°C to 150°C
Case temperature for 10 seconds, T_C: FN package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, N, or PW package . . . . . 260°C

recommended operating conditions

		V_{DD} = 5 V			V_{DD} = 15 V			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{DD}		4.75	5	5.25	14.5	15	15.5	V
Reference voltage, V_{ref}			±10			±10		V
High-level input voltage, V_{IH}		2.4			13.5			V
Low-level input voltage, V_{IL}				0.8			1.5	V
CS setup time, $t_{su(CS)}$		40			40			ns
CS hold time, $t_{h(CS)}$		0			0			ns
Data bus input setup time, $t_{su(D)}$		25			25			ns
Data bus input hold time, $t_{h(D)}$		10			10			ns
Pulse duration, $\overline{WR}$ low, $t_{w(WR)}$		40			40			ns
Operating free-air temperature, T_A	TLC7524C	0		70	0		70	°C
	TLC7524I	–25		85	–25		85	
	TLC7524E	–40		85	–40		85	

electrical characteristics over recommended operating free-air temperature range, V_{ref} = ±10 V, OUT1 and OUT2 at GND (unless otherwise noted)

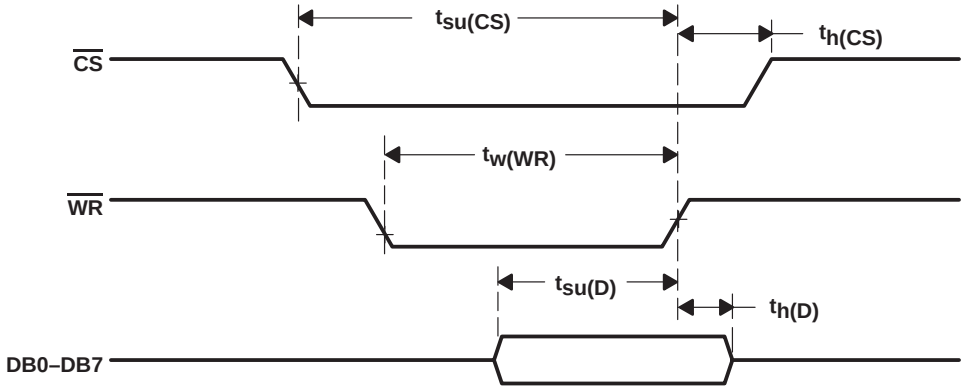
PARAMETER			TEST CONDITIONS	V_{DD} = 5 V			V_{DD} = 15 V			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
I_{IH}	High-level input current		$V_I = V_{DD}$			10			10	µA
I_{IL}	Low-level input current		V_I = 0			–10			–10	µA
I_{lkg}	Output leakage current	OUT1	DB0–DB7 at 0 V, $\overline{WR}$, $\overline{CS}$ at 0 V, V_{ref} = ±10 V			±400			±200	nA
		OUT2	DB0–DB7 at V_{DD}, $\overline{WR}$, $\overline{CS}$ at 0 V, V_{ref} = ±10 V			±400			±200	
I_{DD}	Supply current	Quiescent	DB0–DB7 at V_{IH}min or V_{IL}max			1			2	mA
		Standby	DB0–DB7 at 0 V or V_{DD}			500			500	µA
k_{SVS}	Supply voltage sensitivity, Δgain/ΔV_{DD}		ΔV_{DD} = ±10%		0.01	0.16		0.005	0.04	%FSR/%
C_i	Input capacitance, DB0–DB7, $\overline{WR}$, $\overline{CS}$		V_I = 0			5			5	pF
C_o	Output capacitance	OUT1	DB0–DB7 at 0 V, $\overline{WR}$, $\overline{CS}$ at 0 V			30			30	pF
		OUT2				120			120	
		OUT1	DB0–DB7 at V_{DD}, $\overline{WR}$, $\overline{CS}$ at 0 V			120			120	
		OUT2				30			30	
	Reference input impedance (REF to GND)			5		20	5		20	kΩ

operating characteristics over recommended operating free-air temperature range, V_{ref} = ±10 V, OUT1 and OUT2 at GND (unless otherwise noted)

PARAMETER	TEST CONDITIONS	V_{DD} = 5 V			V_{DD} = 15 V			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Linearity error				±0.5			±0.5	LSB
Gain error	See Note 1			±2.5			±2.5	LSB
Settling time (to 1/2 LSB)	See Note 2			100			100	ns
Propagation delay from digital input to 90% of final analog output current	See Note 2			80			80	ns
Feedthrough at OUT1 or OUT2	Vref = ±10 V (100-kHz sinewave) $\overline{WR}$ and $\overline{CS}$ at 0 V, DB0–DB7 at 0 V			0.5			0.5	%FSR
Temperature coefficient of gain	T_A = 25°C to MAX		±0.004			±0.001		%FSR/°C

NOTES: 1. Gain error is measured using the internal feedback resistor. Nominal full-scale range (FSR) = V_{ref} – 1 LSB.
2. OUT1 load = 100 Ω, C_{ext} = 13 pF, $\overline{WR}$ at 0 V, $\overline{CS}$ at 0 V, DB0 – DB7 at 0 V to V_{DD} or V_{DD} to 0 V.

operating sequence



PRINCIPLES OF OPERATION

voltage-mode operation

It is possible to operate the current-multiplying DAC in these devices in a voltage mode. In the voltage mode, a fixed voltage is placed on the current output terminal. The analog output voltage is then available at the reference voltage terminal. Figure 1 is an example of a current-multiplying DAC, which is operated in voltage mode.

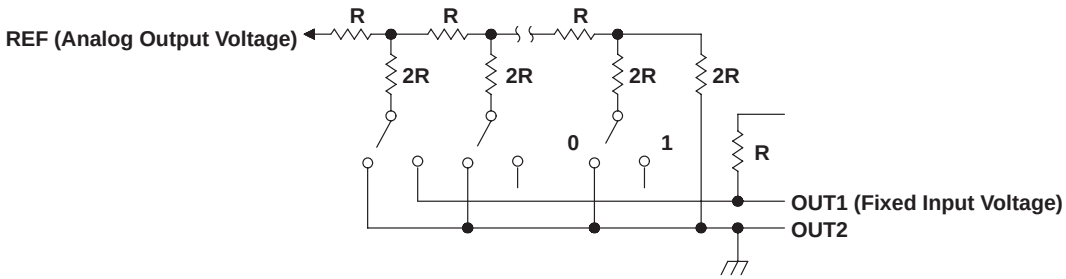


Figure 1. Voltage Mode Operation

The relationship between the fixed-input voltage and the analog-output voltage is given by the following equation:

$$V_O = V_I (D/256)$$

where

V_O = analog output voltage
V_I = fixed input voltage
D = digital input code converted to decimal

In voltage-mode operation, these devices meet the following specification:

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Linearity error at REF	V_{DD} = 5 V, OUT1 = 2.5 V, OUT2 at GND, T_A = 25°C		1	LSB

PRINCIPLES OF OPERATION

The TLC7524C, TLC7524E, and TLC7524I are 8-bit multiplying DACs consisting of an inverted R-2R ladder, analog switches, and data input latches. Binary-weighted currents are switched between the OUT1 and OUT2 bus lines, thus maintaining a constant current in each ladder leg independent of the switch state. The high-order bits are decoded. These decoded bits, through a modification in the R-2R ladder, control three equally-weighted current sources. Most applications only require the addition of an external operational amplifier and a voltage reference.

The equivalent circuit for all digital inputs low is seen in Figure 2. With all digital inputs low, the entire reference current, I_{ref}, is switched to OUT2. The current source I/256 represents the constant current flowing through the termination resistor of the R-2R ladder, while the current source I_{lkg} represents leakage currents to the substrate. The capacitances appearing at OUT1 and OUT2 are dependent upon the digital input code. With all digital inputs high, the off-state switch capacitance (30 pF maximum) appears at OUT2 and the on-state switch capacitance (120 pF maximum) appears at OUT1. With all digital inputs low, the situation is reversed as shown in Figure 2. Analysis of the circuit for all digital inputs high is similar to Figure 2; however, in this case, I_{ref} would be switched to OUT1.

The DAC on these devices interfaces to a microprocessor through the data bus and the $\overline{CS}$ and $\overline{WR}$ control signals. When $\overline{CS}$ and $\overline{WR}$ are both low, analog output on these devices responds to the data activity on the DB0–DB7 data bus inputs. In this mode, the input latches are transparent and input data directly affects the analog output. When either the $\overline{CS}$ signal or $\overline{WR}$ signal goes high, the data on the DB0–DB7 inputs are latched until the $\overline{CS}$ and $\overline{WR}$ signals go low again. When $\overline{CS}$ is high, the data inputs are disabled regardless of the state of the $\overline{WR}$ signal.

These devices are capable of performing 2-quadrant or full 4-quadrant multiplication. Circuit configurations for 2-quadrant or 4-quadrant multiplication are shown in Figure 3 and Figure 4. Table 1 and Table 2 summarize input coding for unipolar and bipolar operation respectively.

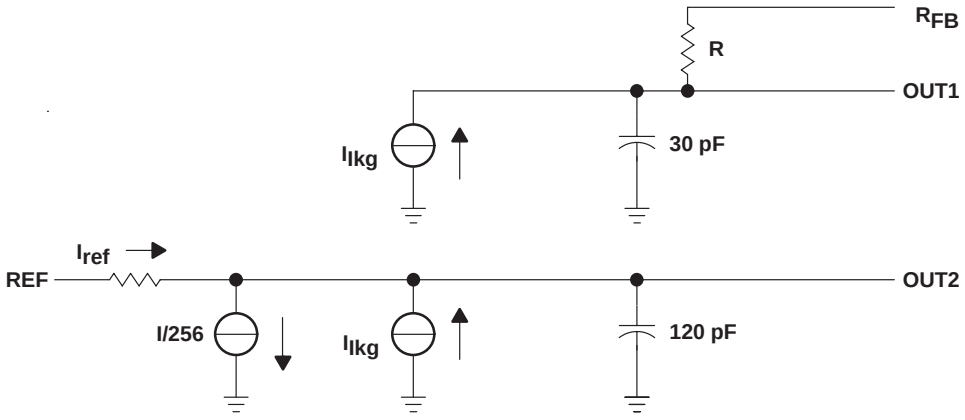
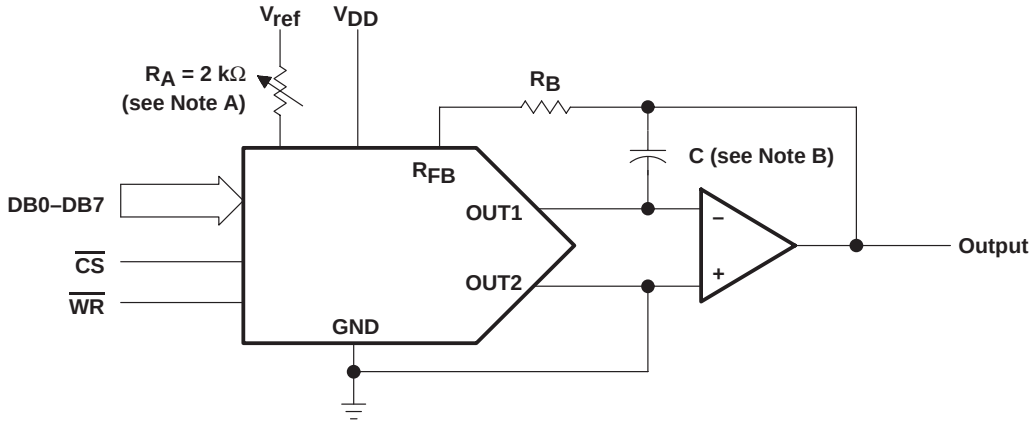


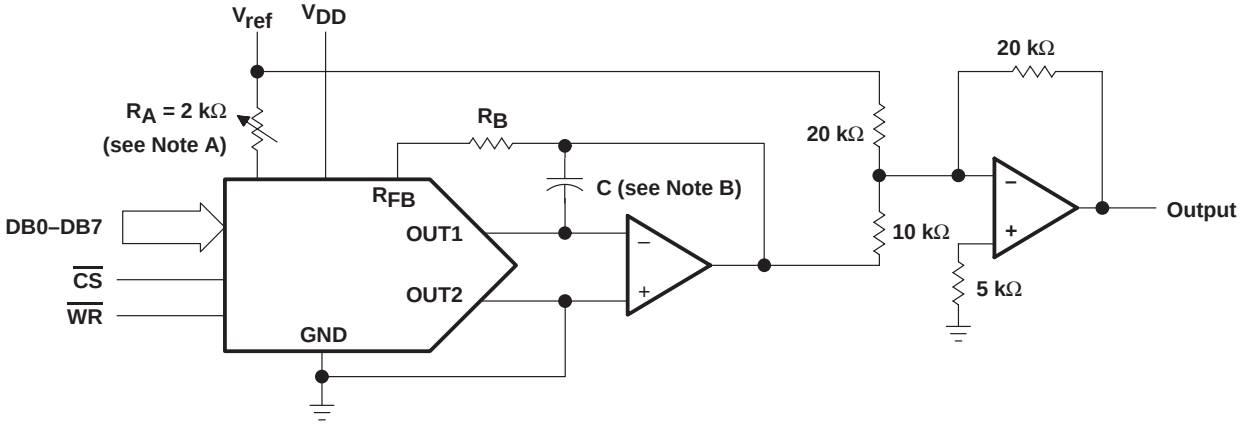
Figure 2. TLC7524 Equivalent Circuit With All Digital Inputs Low

PRINCIPLES OF OPERATION



NOTES: A. R_A and R_B used only if gain adjustment is required.
B. C phase compensation (10-15 pF) is required when using high-speed amplifiers to prevent ringing or oscillation.

Figure 3. Unipolar Operation (2-Quadrant Multiplication)



NOTES: A. R_A and R_B used only if gain adjustment is required.
B. C phase compensation (10-15 pF) is required when using high-speed amplifiers to prevent ringing or oscillation.

Figure 4. Bipolar Operation (4-Quadrant Operation)

Table 1. Unipolar Binary Code

DIGITAL INPUT (see Note 3) MSB LSB	ANALOG OUTPUT
1 1 1 1 1 1 1 1	$-V_{ref}$ (255/256)
1 0 0 0 0 0 0 1	$-V_{ref}$ (129/256)
1 0 0 0 0 0 0 0	$-V_{ref}$ (128/256) = $-V_{ref}/2$
0 1 1 1 1 1 1 1	$-V_{ref}$ (127/256)
0 0 0 0 0 0 0 1	$-V_{ref}$ (1/256)
0 0 0 0 0 0 0 0	0

NOTE 3: LSB = 1/256 (V_{ref})

Table 2. Bipolar (Offset Binary) Code

DIGITAL INPUT (see Note 4) MSB LSB	ANALOG OUTPUT
1 1 1 1 1 1 1 1	V_{ref} (127/128)
1 0 0 0 0 0 0 1	V_{ref} (1/128)
1 0 0 0 0 0 0 0	0
0 1 1 1 1 1 1 1	$-V_{ref}$ (1/128)
0 0 0 0 0 0 0 1	$-V_{ref}$ (127/128)
0 0 0 0 0 0 0 0	$-V_{ref}$

NOTE 4: LSB = 1/128 (V_{ref})

PRINCIPLES OF OPERATION

microprocessor interfaces

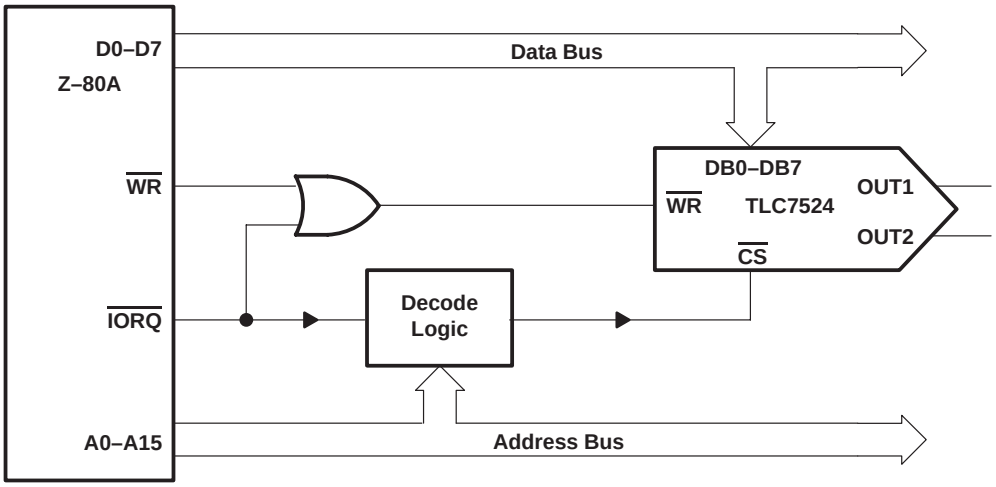


Figure 5. TLC7524 – Z-80A Interface

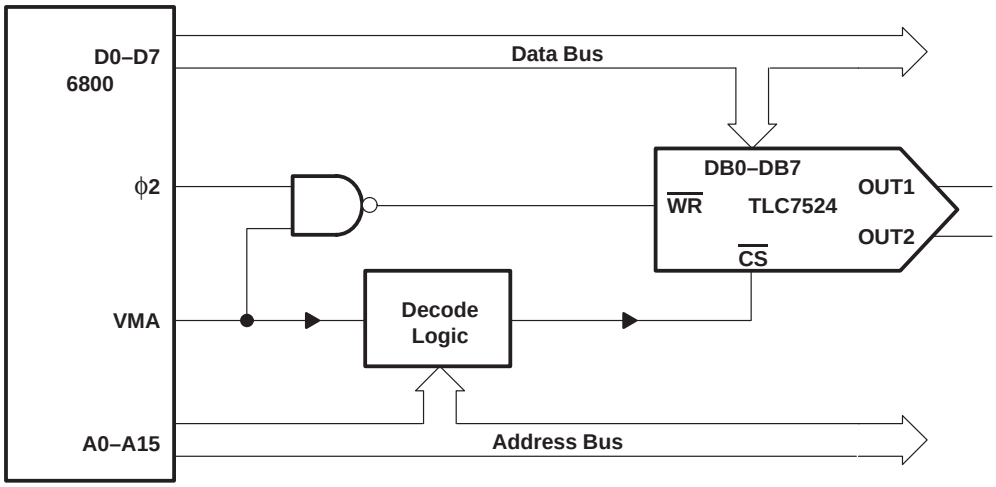


Figure 6. TLC7524 – 6800 Interface

PRINCIPLES OF OPERATION

microprocessor interfaces (continued)

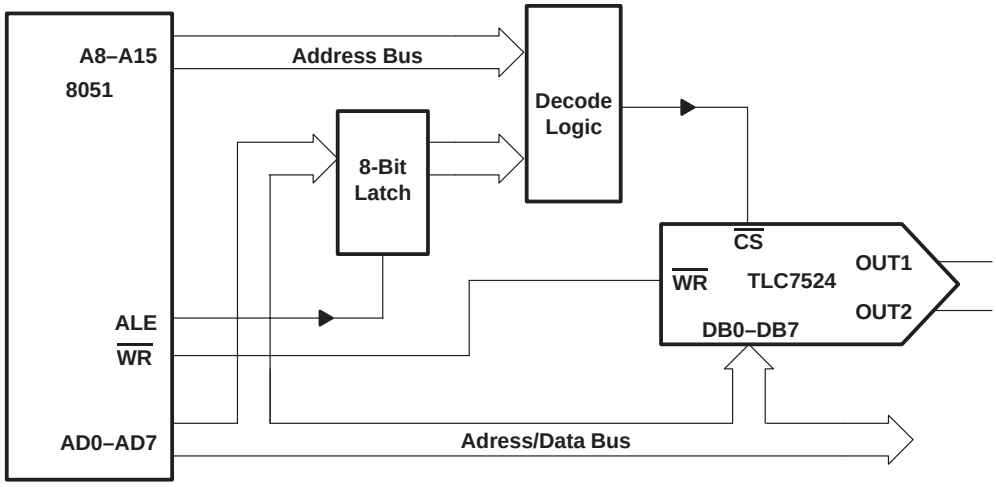


Figure 7. TLC7524 – 8051 Interface

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TLC7524CD	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CFN	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM
TLC7524CFNR	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM
TLC7524CFNRG3	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM
TLC7524CN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524CNE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524CNS	ACTIVE	SO	NS	16	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CNSG4	ACTIVE	SO	NS	16	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CNSR	ACTIVE	SO	NS	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CPWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524CPWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524ED	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524EDG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524EDR	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524EDRG4	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524EN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524ENE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524ID	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524IDG4	ACTIVE	SOIC	D	16	40	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524IFN	ACTIVE	PLCC	FN	20	46	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM
TLC7524IFNR	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	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]
TLC7524IFNRG3	ACTIVE	PLCC	FN	20	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM
TLC7524IN	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524INE4	ACTIVE	PDIP	N	16	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type
TLC7524IPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524IPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TLC7524IPWRG4	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.

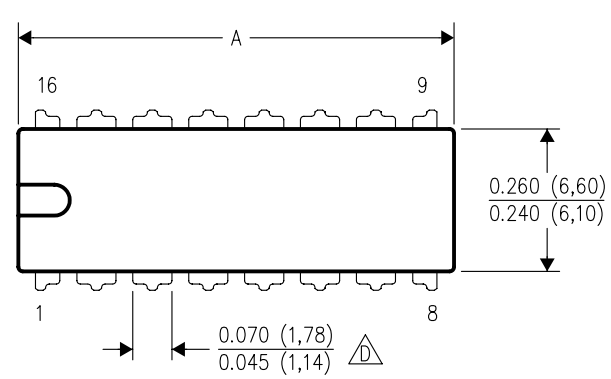
[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been 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.

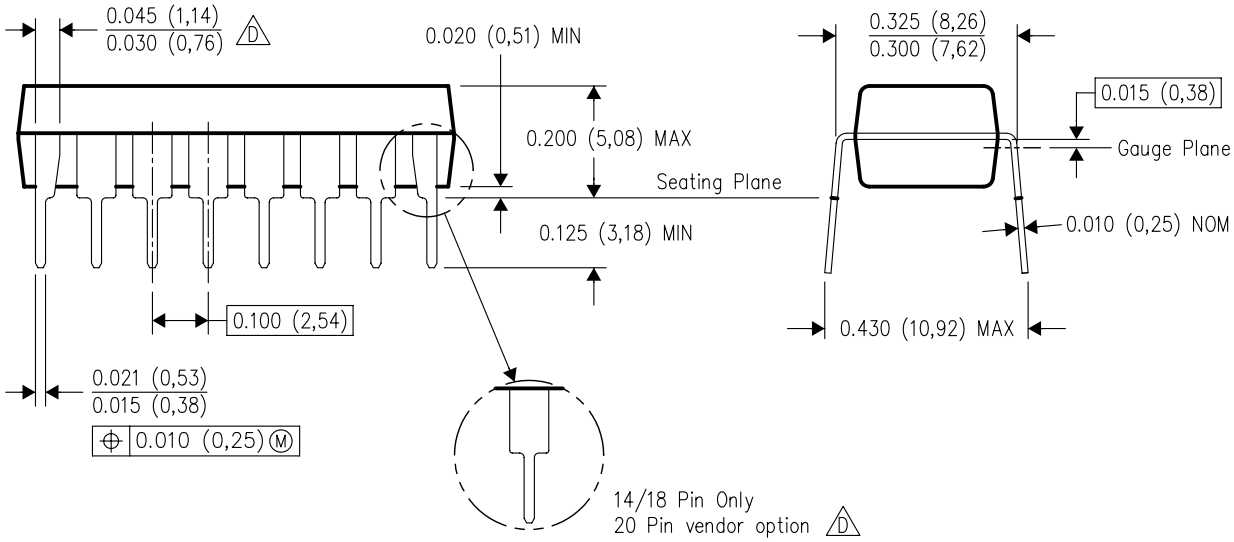
N (R–PDIP–T**)

PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS–001 VARIATION (C)	AA	BB	AC	AD



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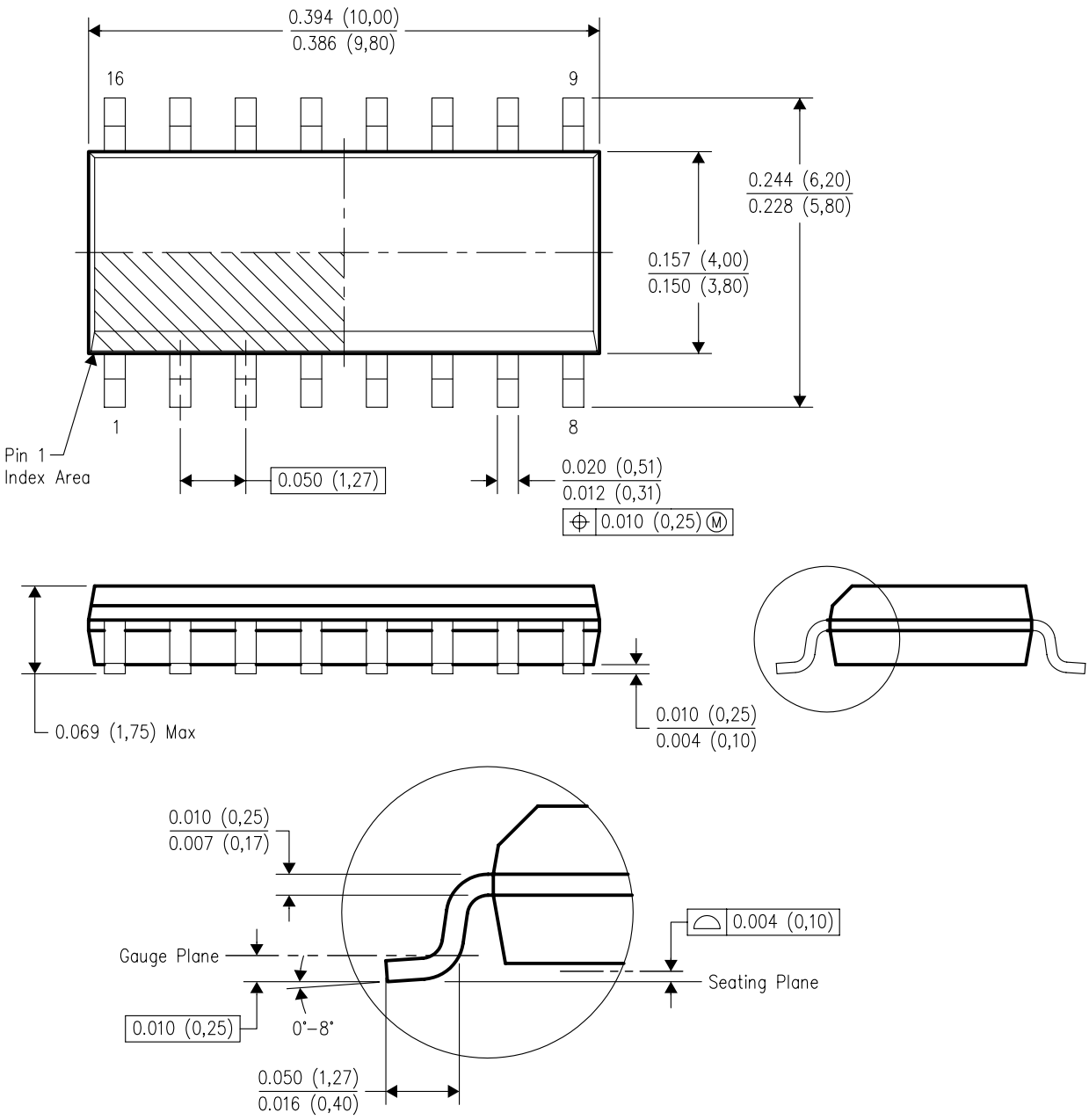
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

D (R–PDSO–G16) PLASTIC SMALL–OUTLINE PACKAGE



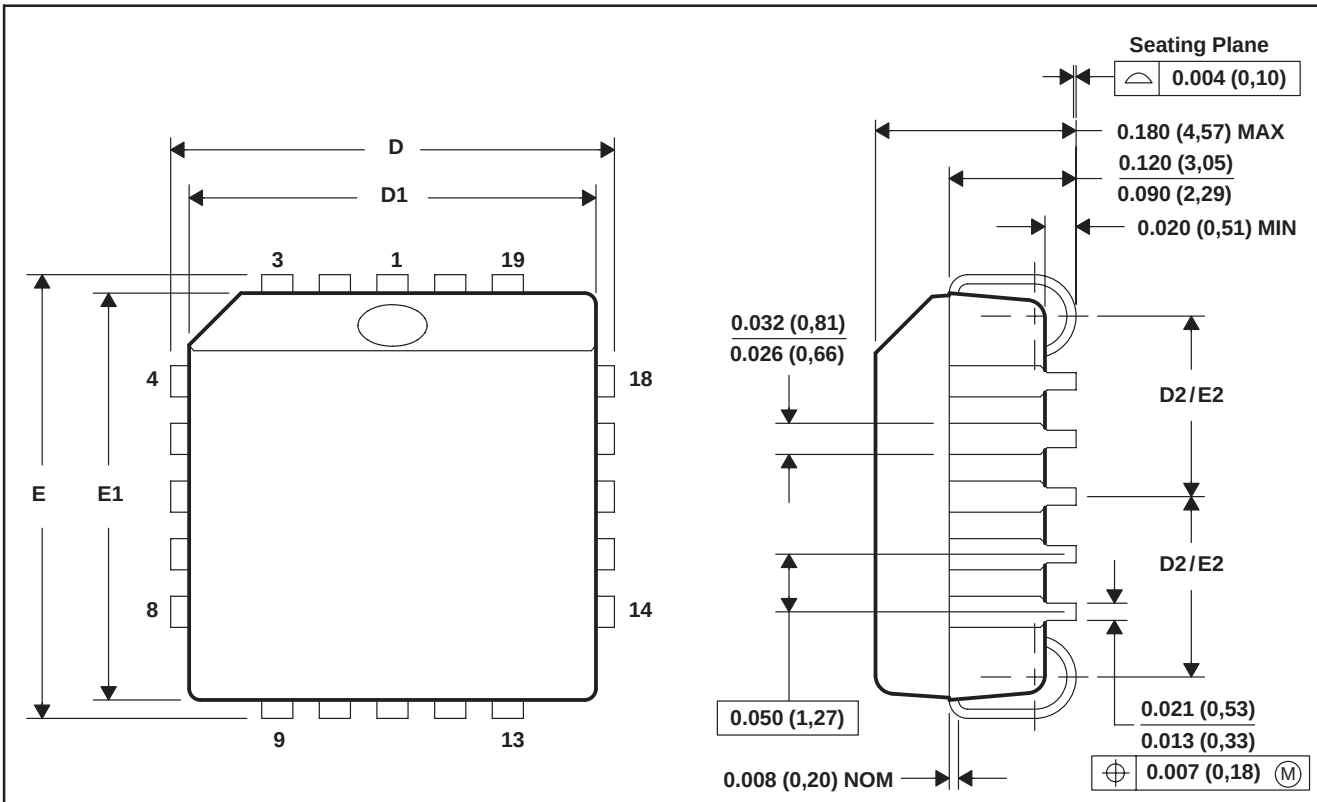
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
D. Falls within JEDEC MS–012 variation AC.

MPLC004A – OCTOBER 1994

FN (S-PQCC-J**)

PLASTIC J-LEADED CHIP CARRIER

20 PIN SHOWN



NO. OF PINS **	D/E		D1/E1		D2/E2	
	MIN	MAX	MIN	MAX	MIN	MAX
20	0.385 (9,78)	0.395 (10,03)	0.350 (8,89)	0.356 (9,04)	0.141 (3,58)	0.169 (4,29)
28	0.485 (12,32)	0.495 (12,57)	0.450 (11,43)	0.456 (11,58)	0.191 (4,85)	0.219 (5,56)
44	0.685 (17,40)	0.695 (17,65)	0.650 (16,51)	0.656 (16,66)	0.291 (7,39)	0.319 (8,10)
52	0.785 (19,94)	0.795 (20,19)	0.750 (19,05)	0.756 (19,20)	0.341 (8,66)	0.369 (9,37)
68	0.985 (25,02)	0.995 (25,27)	0.950 (24,13)	0.958 (24,33)	0.441 (11,20)	0.469 (11,91)
84	1.185 (30,10)	1.195 (30,35)	1.150 (29,21)	1.158 (29,41)	0.541 (13,74)	0.569 (14,45)

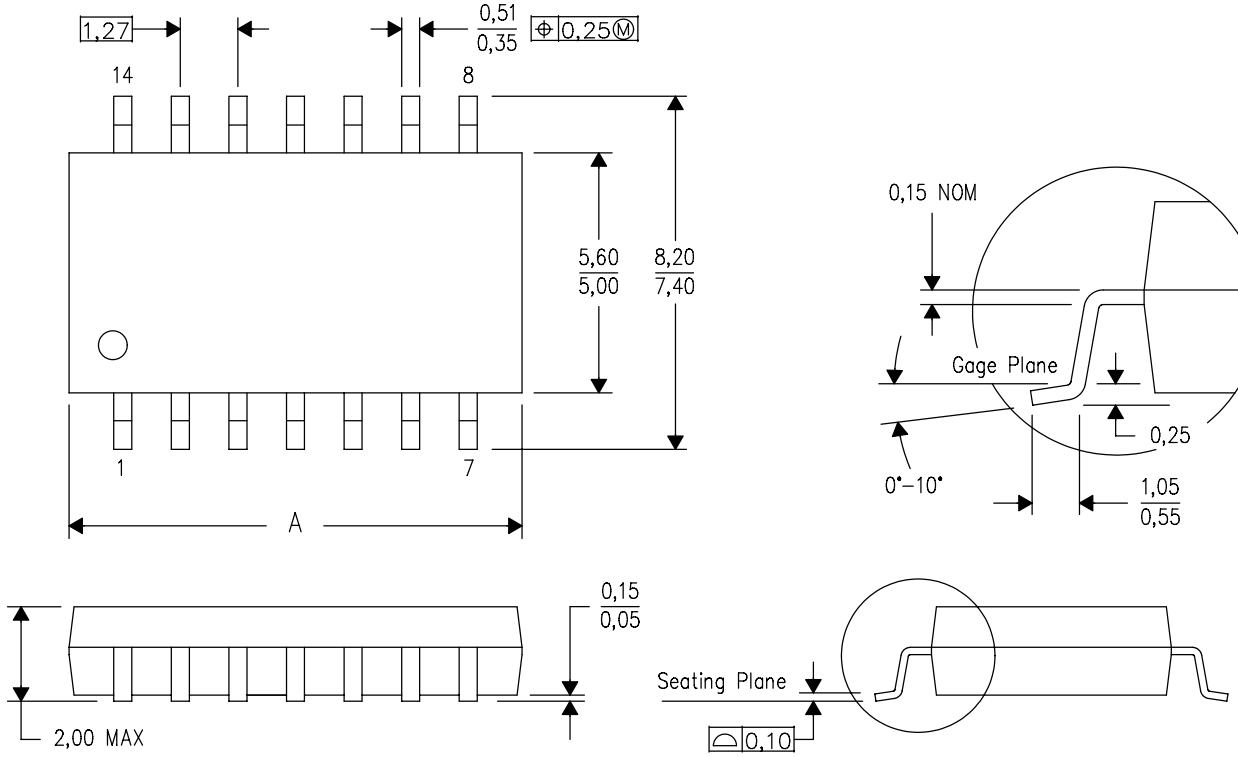
4040005/B 03/95

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-018

MECHANICAL DATA

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

14-PINS SHOWN



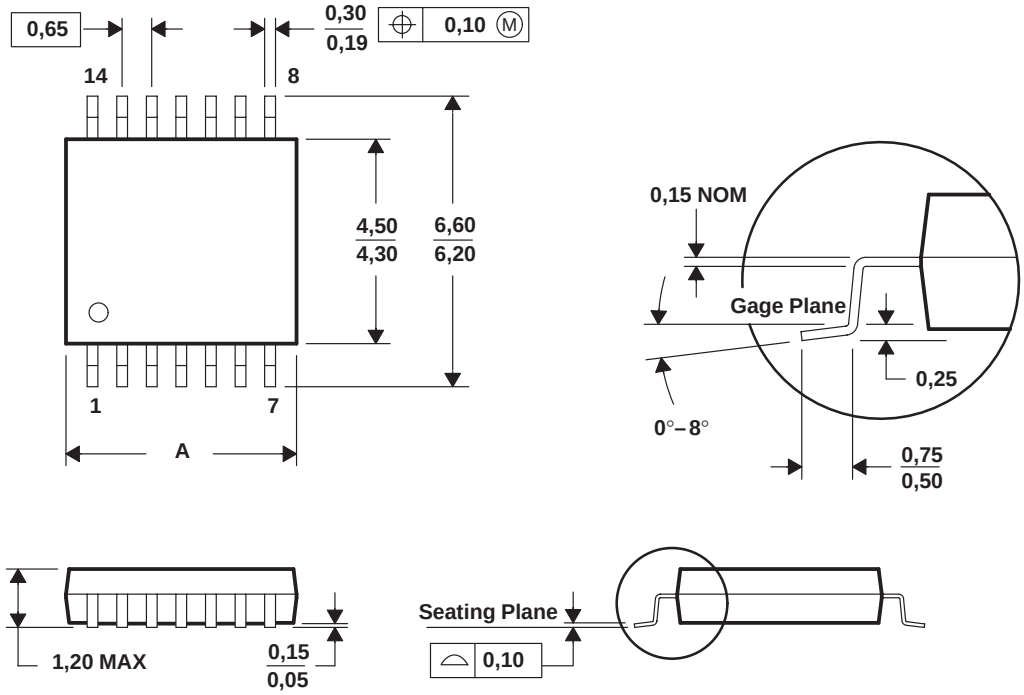
DIM \ PINS **	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

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.

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

14 PINS SHOWN



DIM \ PINS **	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/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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