- **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**

D OR N PACKAGE
(TOP VIEW)

OUT1	1		16	R_{FB}
OUT2	2		15	REF
GND	3		14	V_{DD}
DB7	4		13	$\overline{WR}$
DB6	5		12	$\overline{CS}$
DB5	6		11	DB0
DB4	7		10	DB1
DB3	8		9	DB2

FN PACKAGE
(TOP VIEW)

Pins (top, left to right): OUT2 (3), OUT1 (2), NC (1), R_{FB} (20), REF (19)

GND	4	18 V_{DD}
DB7	5	17 $\overline{WR}$
NC	6	16 NC
DB6	7	15 $\overline{CS}$
DB5	8	14 DB0

Pins (bottom, left to right): DB4 (9), DB3 (10), NC (11), DB2 (12), DB1 (13)

NC–No internal connection

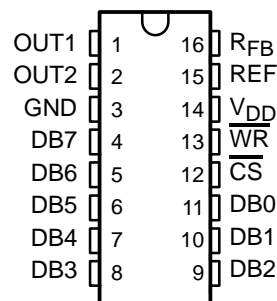| KEY PERFORMANCE SPECIFICATIONS	
Resolution	8 Bits
Linearity error	1/2 LSB Max
Power dissipation at V_{DD} = 5 V	5 mW Max
Setting time	100 ns Max
Propagation delay time	80 ns Max

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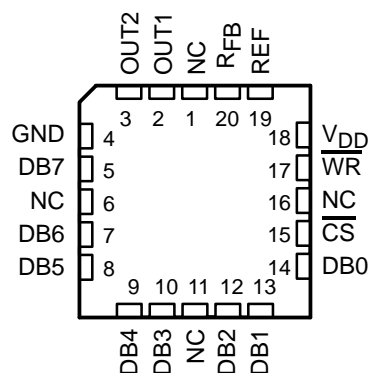
Featuring operation from a 5-V to 15-V single supply, these devices interface easily to most microprocessor buses or output ports. The 2- or 4-quadrant multiplying makes these devices an ideal choice for many microprocessor-controlled gain-setting and signal-control applications.

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

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

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TEXAS INSTRUMENTS

functional block diagram
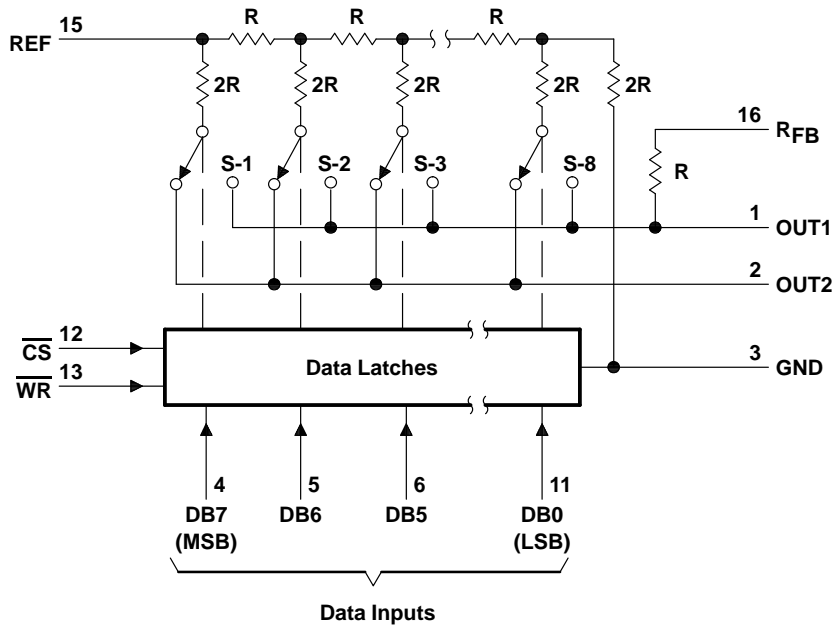
Terminal numbers shown are for the D or N package.

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 or N package	260°C

recommended operating conditions

		V_{DD} = 5 V MIN	NOM	MAX	V_{DD} = 15 V MIN	NOM	MAX	UNIT
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						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 MIN	TYP	MAX	V_{DD} = 15 V MIN	TYP	MAX	UNIT
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}		$\Delta V_{DD} = ±10\%$		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

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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
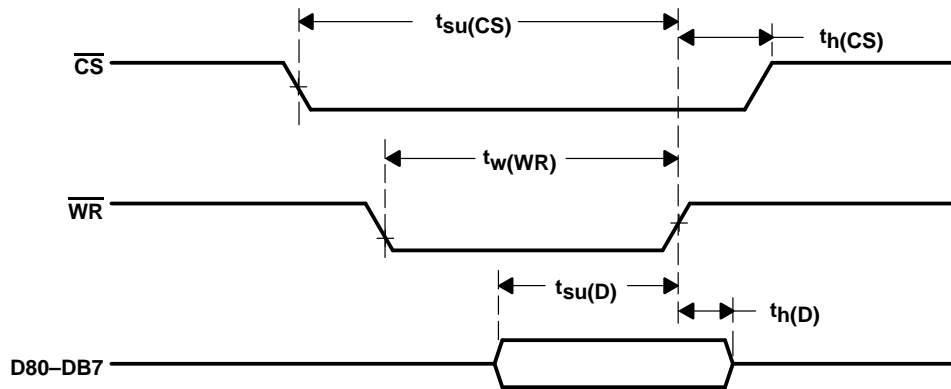
APPLICATION INFORMATION

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.
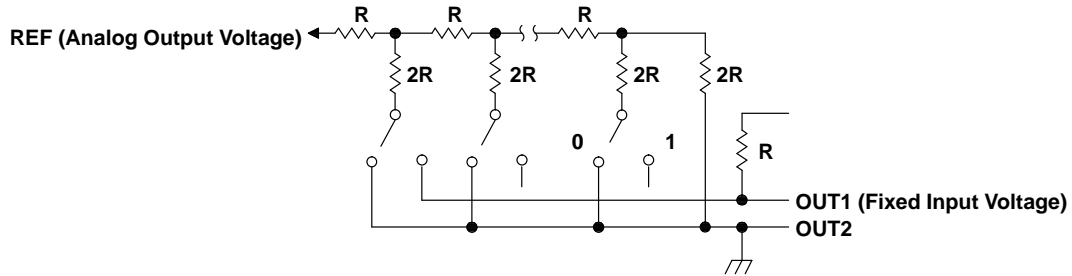

Figure 1. Voltage Mode Operation

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 Figures 3 and 4. Tables 1 and 2 summarize input coding for unipolar and bipolar operation respectively.
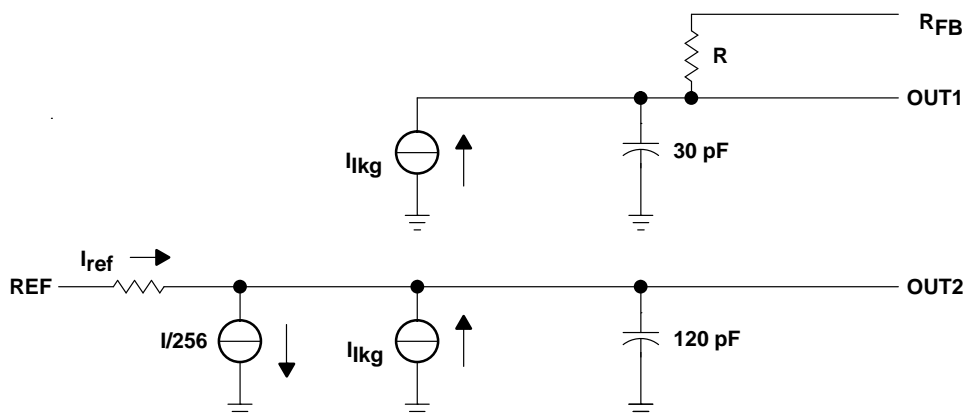

Figure 2. TLC7524 Equivalent Circuit With All Digital Inputs Low
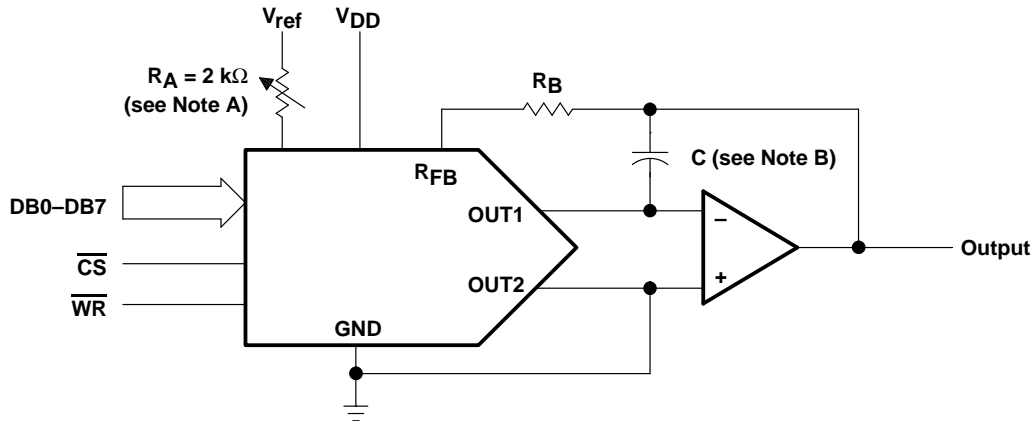
PRINCIPLES OF OPERATION

Figure 3. Unipolar Operation (2-Quadrant Multiplication)
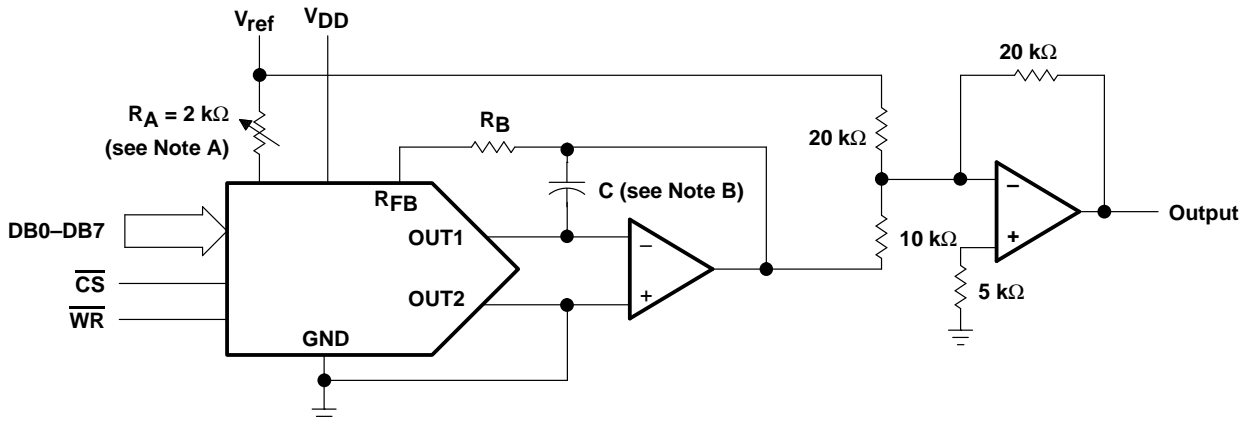

Figure 4. Bipolar Operation (4-Quadrant Operation)

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.

Table 1. Unipolar Binary Code

DIGITAL INPUT (see Note 3)		ANALOG OUTPUT
MSB	LSB	
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

Table 2. Bipolar (Offset Binary) Code

DIGITAL INPUT (see Note 4)		ANALOG OUTPUT
MSB	LSB	
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	$-V_{ref}$

NOTES: 3. LSB = 1/256 (V_{ref})
       4. LSB = 1/128 (V_{ref})

PRINCIPLES OF OPERATION

microprocessor interfaces
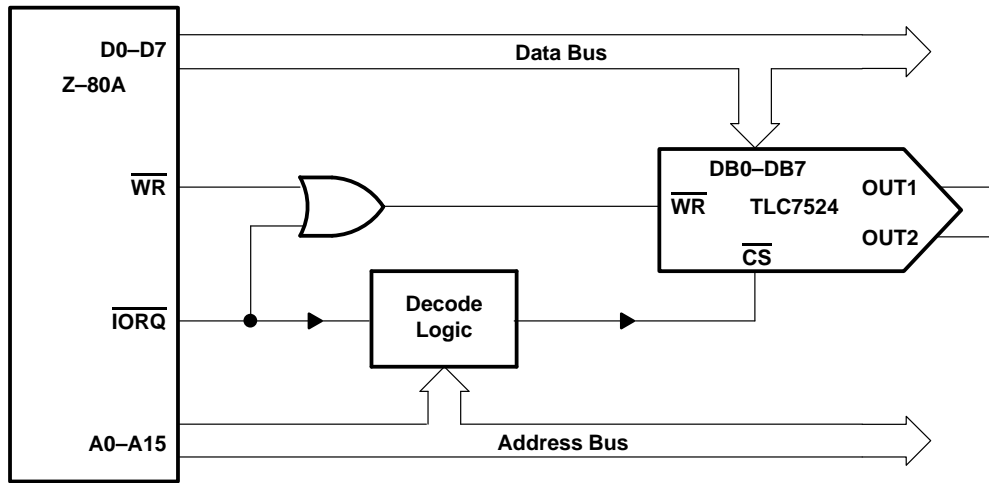
Figure 5. TLC7524 – Z-80A Interface
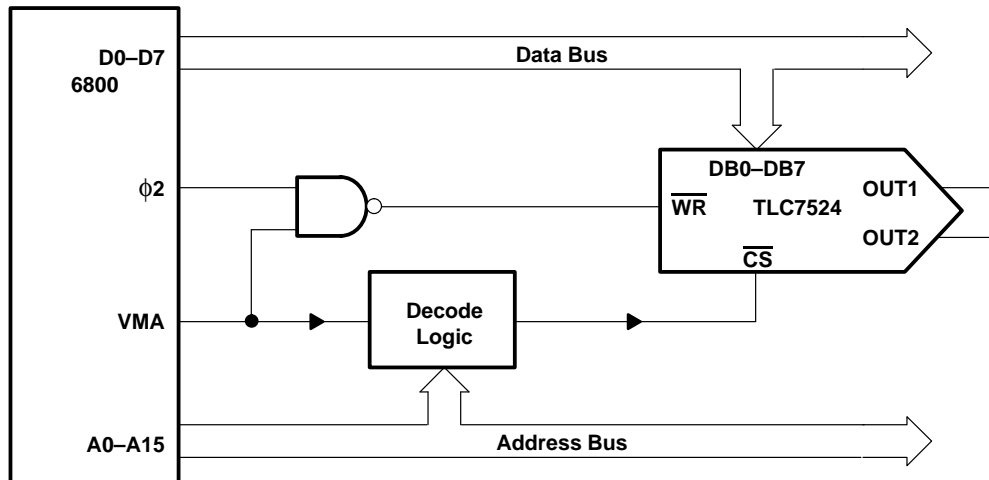
Figure 6. TLC7524 – 6800 Interface
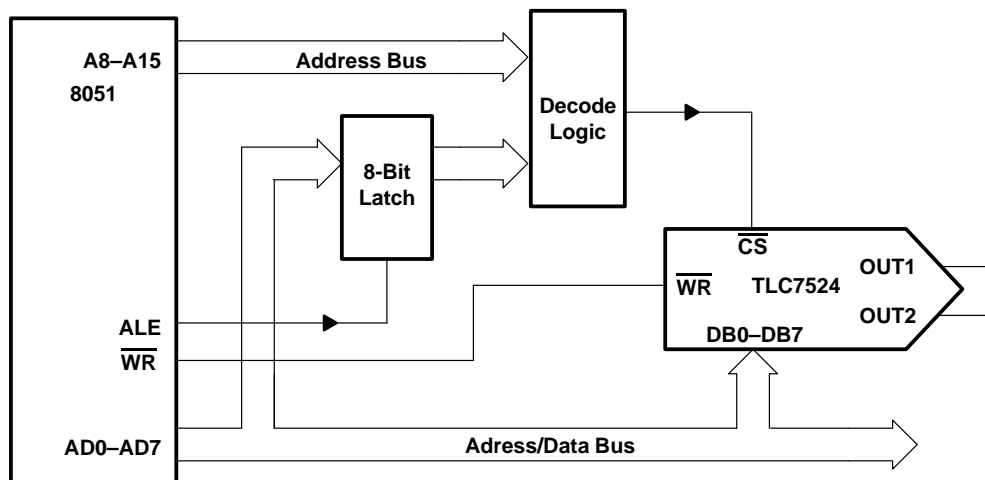
microprocessor interfaces (continued)

Figure 7. TLC7524 – 8051 Interface

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