

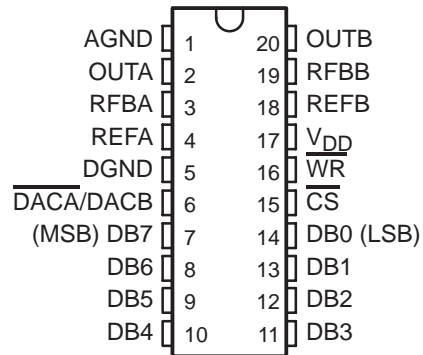
# TLC7628C DUAL 8-BIT MULTIPLYING DIGITAL-TO-ANALOG CONVERTER

SLAS063B – APRIL 1989 – REVISED MARCH 2007

- Easy Microprocessor Interface
- On-Chip Data Latches
- Digital Inputs Are TTL-Compatible With 10.8-V to 15.75-V Power Supply
- Monotonic Over the Entire A/D Conversion Range
- Fast Control Signaling for Digital Signal Processor (DSP) Applications Including Interface With TMS320
- CMOS Technology

| KEY PERFORMANCE SPECIFICATIONS |         |
|--------------------------------|---------|
| Resolution                     | 8 bits  |
| Linearity Error                | 1/2 LSB |
| Power Dissipation              | 20 mW   |
| Settling Time                  | 100 ns  |
| Propagation Delay Time         | 80 ns   |

DW OR N PACKAGE  
(TOP VIEW)



## description

The TLC7628C is a dual, 8-bit, digital-to-analog converter (DAC) designed with separate on-chip data latches and featuring exceptionally close DAC-to-DAC matching. Data are transferred to either of the two DAC data latches through a common, 8-bit input port. Control input  $\overline{DACA}/\overline{DACB}$  determines which DAC is loaded. The load cycle of this device is similar to the write cycle of a random-access memory, allowing easy interface to most popular microprocessor buses and output ports. Segmenting the high-order bits minimizes glitches during changes in the most significant bits, where glitch impulse is typically the strongest.

The TLC7628C operates from a 10.8-V to 15.75-V power supply and is TTL-compatible over this range. 2- or 4-quadrant multiplying makes this device a sound choice for many microprocessor-controlled gain-setting and signal-control applications.

The TLC7628C is characterized for operation from 0°C to +70°C.



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



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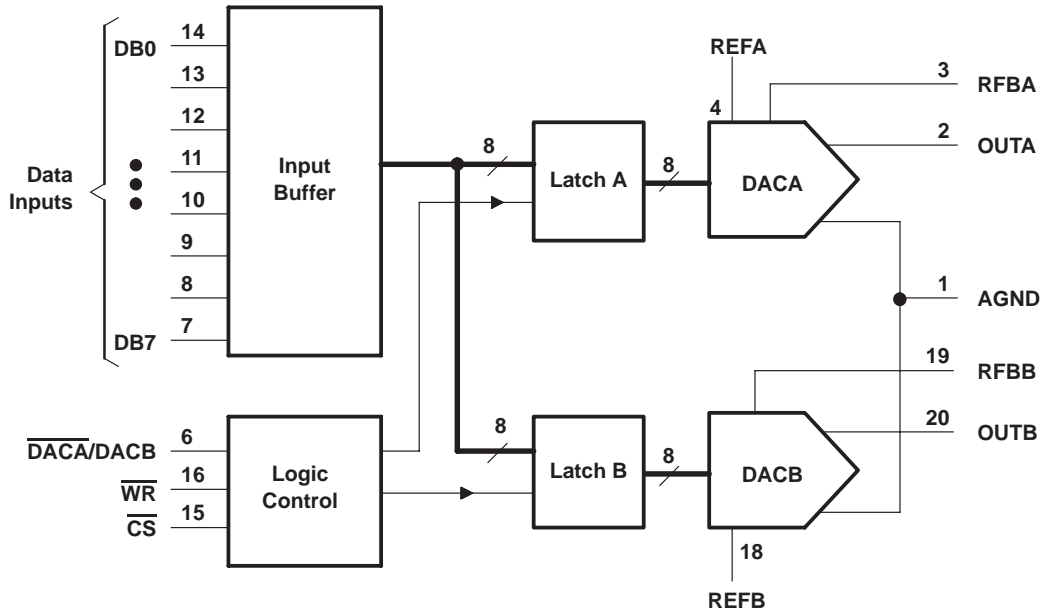
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# TLC7628C

## DUAL 8-BIT MULTIPLYING

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### functional block diagram



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

|                                                                               |                            |
|-------------------------------------------------------------------------------|----------------------------|
| Supply voltage range, $V_{DD}$ (to AGND or DGND)                              | -0.3 V to 17 V             |
| Voltage between AGND and DGND                                                 | $V_{DD}$                   |
| Input voltage range, $V_I$ (to DGND)                                          | -0.3 V to $V_{DD} + 0.3$ V |
| Reference voltage range, $V_{refA}$ or $V_{refB}$ (to AGND)                   | $\pm 25$ V                 |
| Feedback voltage range, $V_{RFBA}$ or $V_{RFBB}$ (to AGND)                    | $\pm 25$ V                 |
| Output voltage range, $V_{OA}$ or $V_{OB}$ (to AGND)                          | $\pm 25$ V                 |
| Peak input current                                                            | 10 $\mu$ A                 |
| Operating free-air temperature range, $T_A$ : TLC7628C                        | 0°C to +70°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: DW or N package | +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.

**recommended operating conditions**

|                                                               | MIN      | NOM      | MAX   | UNIT   |
|---------------------------------------------------------------|----------|----------|-------|--------|
| Supply voltage, $V_{DD}$                                      | 10.8     |          | 15.75 | V      |
| Reference voltage, $V_{refA}$ or $V_{refB}$                   |          | $\pm 10$ |       | V      |
| High-level input voltage, $V_{IH}$                            | 2.4      |          |       | V      |
| Low-level input voltage, $V_{IL}$                             |          |          | 0.8   | V      |
| $\overline{CS}$ setup time, $t_{su}(CS)$                      | 50       |          |       | ns     |
| $\overline{CS}$ hold time, $t_h(CS)$ (see Figure 1)           | 0        |          |       | ns     |
| DAC select setup time, $t_{su}(DAC)$ (see Figure 1)           | 60       |          |       | ns     |
| DAC select hold time, $t_h(DAC)$ (see Figure 1)               | 10       |          |       | ns     |
| Data bus input setup time $t_{su}(D)$ (see Figure 1)          | 25       |          |       | ns     |
| Data bus input hold time $t_h(D)$ (see Figure 1)              | 10       |          |       | ns     |
| Pulse duration, $\overline{WR}$ low, $t_w(WR)$ (see Figure 1) | 50       |          |       | ns     |
| Operating free-air temperature, $T_A$                         | TLC7628C |          | 0     | +70 °C |

**electrical characteristics over recommended ranges of operating free-air temperature and  $V_{DD}$ ,  $V_{refA} = V_{refB} = 10$  V,  $V_{OA}$  and  $V_{OB}$  at 0 V (unless otherwise noted)**

| PARAMETER                                         |                                 | TEST CONDITIONS                                  | MIN                                                        | MAX        | UNIT       |    |     |
|---------------------------------------------------|---------------------------------|--------------------------------------------------|------------------------------------------------------------|------------|------------|----|-----|
| $I_{IH}$                                          | High-level input current        | $V_I = V_{DD}$                                   | Full range                                                 | 10         | $\mu A$    |    |     |
|                                                   |                                 |                                                  | 25°C                                                       | 1          |            |    |     |
| $I_{IL}$                                          | Low-level input current         | $V_I = 0$                                        | Full range                                                 | -10        | $\mu A$    |    |     |
|                                                   |                                 |                                                  | 25°C                                                       | -1         |            |    |     |
| Reference input impedance REFA or REFB to AGND    |                                 |                                                  | 5                                                          | 20         | k $\Omega$ |    |     |
| $I_{kg}$                                          | Output leakage current          | OUTA                                             | DAC data latch loaded with 00000000, $V_{refA} = \pm 10$ V | Full range | $\pm 200$  | nA |     |
|                                                   |                                 |                                                  | 25°C                                                       | $\pm 50$   |            |    |     |
|                                                   |                                 | OUTB                                             | DAC data latch loaded with 00000000, $V_{refB} = \pm 10$ V | Full range | $\pm 200$  |    |     |
|                                                   |                                 |                                                  | 25°C                                                       | $\pm 50$   |            |    |     |
| Input resistance match (REFA to REFB)             |                                 |                                                  |                                                            | $\pm 1\%$  |            |    |     |
| DC supply sensitivity $\Delta gain/\Delta V_{DD}$ |                                 | $\Delta V_{DD} = \pm 5\%$                        | Full range                                                 | 0.02       | %/%        |    |     |
|                                                   |                                 |                                                  | 25°C                                                       | 0.01       |            |    |     |
| $I_{DD}$                                          | Supply current                  | Quiescent                                        | All digital inputs at $V_{IHmin}$ or $V_{ILmax}$           |            | 2          | mA |     |
|                                                   |                                 | Standby                                          | All digital inputs at 0 V or $V_{DD}$                      |            | Full range |    | 0.5 |
|                                                   |                                 |                                                  |                                                            |            | 25°C       |    | 0.1 |
| $C_i$                                             | Input capacitance               | DB0-DB7                                          |                                                            |            | 10         | pF |     |
|                                                   |                                 | $\overline{WR}$ , $\overline{CS}$ ,<br>DACA/DACB |                                                            |            | 15         |    |     |
|                                                   |                                 |                                                  |                                                            |            |            |    |     |
| $C_o$                                             | Output capacitance (OUTA, OUTB) | DAC data latches loaded with 00000000            |                                                            | 25         | pF         |    |     |
|                                                   |                                 | DAC data latches loaded with 11111111            |                                                            | 60         |            |    |     |

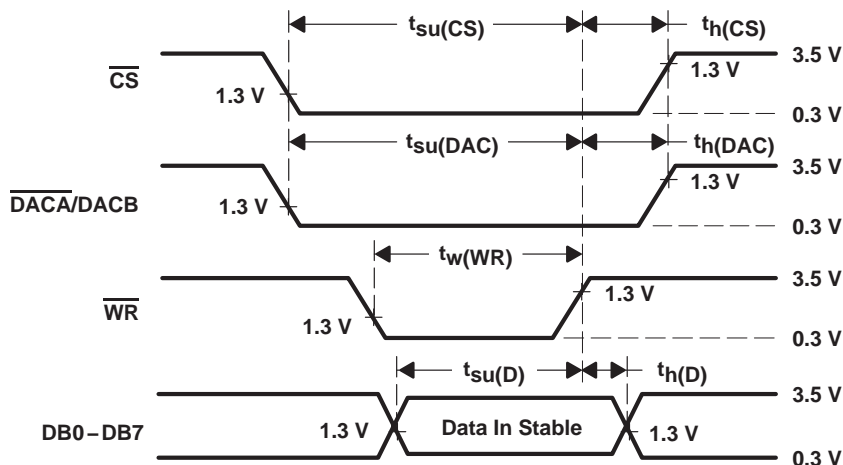
# TLC7628C DUAL 8-BIT MULTIPLYING

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operating characteristics over recommended ranges of operating free-air temperature and  $V_{DD}$ ,  $V_{refA} = V_{refB} = 10\text{ V}$ ,  $V_{OA}$  and  $V_{OB}$  at  $0\text{ V}$  (unless otherwise noted)

| PARAMETER                                                                    |              | TEST CONDITIONS                                                                  |            | MIN | TYP | MAX          | UNIT    |
|------------------------------------------------------------------------------|--------------|----------------------------------------------------------------------------------|------------|-----|-----|--------------|---------|
| Linearity error                                                              |              |                                                                                  |            |     |     | $\pm 1/2$    | LSB     |
| Settling time (to 1/2 LSB)                                                   |              | See Note 1                                                                       |            |     |     | 100          | ns      |
| Gain error                                                                   |              | See Note 2                                                                       | Full range |     |     | $\pm 3$      | LSB     |
|                                                                              |              |                                                                                  | 25°C       |     |     | $\pm 2$      |         |
| AC feedthrough                                                               | REFA to OUTA | See Note 3                                                                       | Full range |     |     | -65          | dB      |
|                                                                              | REFB to OUTB |                                                                                  | 25°C       |     |     | -75          |         |
| Temperature coefficient of gain                                              |              |                                                                                  |            |     |     | $\pm 0.0035$ | %FSR/°C |
| Propagation delay (from digital input to 90% of final analog output current) |              | See Note 4                                                                       |            |     |     | 80           | ns      |
| Channel-to-channel isolation                                                 | REFA to OUTB | See Note 5                                                                       | 25°C       |     |     | 80           | dB      |
|                                                                              | REFB to OUTA | See Note 6                                                                       | 25°C       |     |     | 80           |         |
| Digital-to-analog glitch impulse area                                        |              | Measured for code transition from 00000000 to 11111111, $T_A = 25^\circ\text{C}$ |            |     |     | 330          | nV•s    |
| Digital crosstalk                                                            |              | Measured for code transition from 00000000 to 11111111, $T_A = 25^\circ\text{C}$ |            |     |     | 60           | nV•s    |
| Harmonic distortion                                                          |              | $V_i = 6\text{ V}$ , $f = 1\text{ kHz}$ , $T_A = 25^\circ\text{C}$               |            |     |     | -85          | dB      |

- NOTES: 1.  $OUTA$ ,  $OUTB$  load =  $100\ \Omega$ ,  $C_{ext} = 13\text{ pF}$ ;  $\overline{WR}$  and  $\overline{CS}$  at  $0\text{ V}$ ;  $DB0$ – $DB7$  at  $0\text{ V}$  to  $V_{DD}$  or  $V_{DD}$  to  $0\text{ V}$ .  
 2. Gain error is measured using an internal feedback resistor. Nominal full scale range (FSR) =  $V_{ref} - 1\text{ LSB}$ . Both DAC latches are loaded with 11111111.  
 3.  $V_{ref} = 20\text{ V}$  peak-to-peak, 10-kHz sine wave  
 4.  $V_{refA} = V_{refB} = 10\text{ V}$ ;  $OUTA/OUTB$  load =  $100\ \Omega$ ,  $C_{ext} = 13\text{ pF}$ ;  $\overline{WR}$  and  $\overline{CS}$  at  $0\text{ V}$ ;  $DB0$ – $DB7$  at  $0\text{ V}$  to  $V_{DD}$  or  $V_{DD}$  to  $0\text{ V}$ .  
 5.  $V_{refA} = 20\text{ V}$  peak-to-peak, 10-kHz sine wave;  $V_{refB} = 0$   
 6.  $V_{refB} = 20\text{ V}$  peak-to-peak, 10-kHz sine wave;  $V_{refA} = 0$



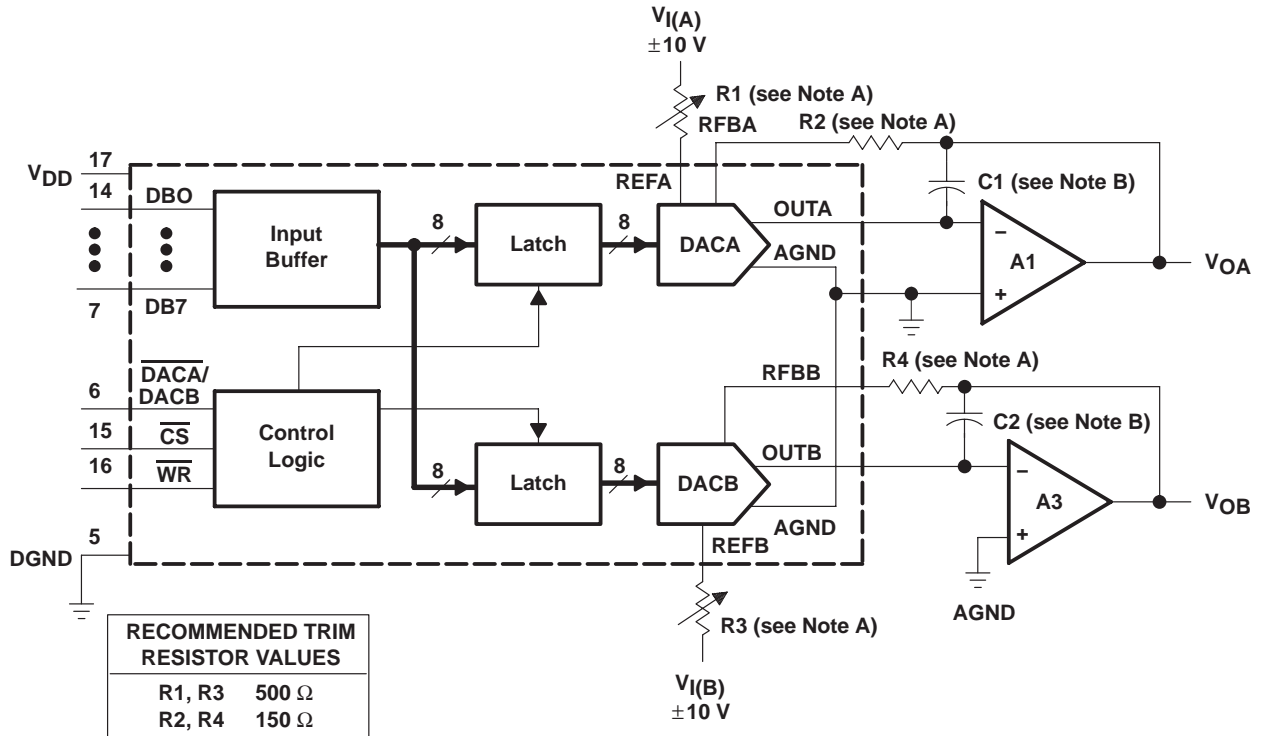
For all input signals,  $t_r = t_f = 5\text{ ns}$  (10% to 90% points).

Figure 1. Setup and Hold Times



**APPLICATION INFORMATION**

This device is capable of performing 2-quadrant or full 4-quadrant multiplication. Circuit configurations for 2-quadrant and 4-quadrant multiplication are shown in Figures 2 and 3. Input coding for unipolar and bipolar operation are summarized in Tables 2 and 3, respectively.



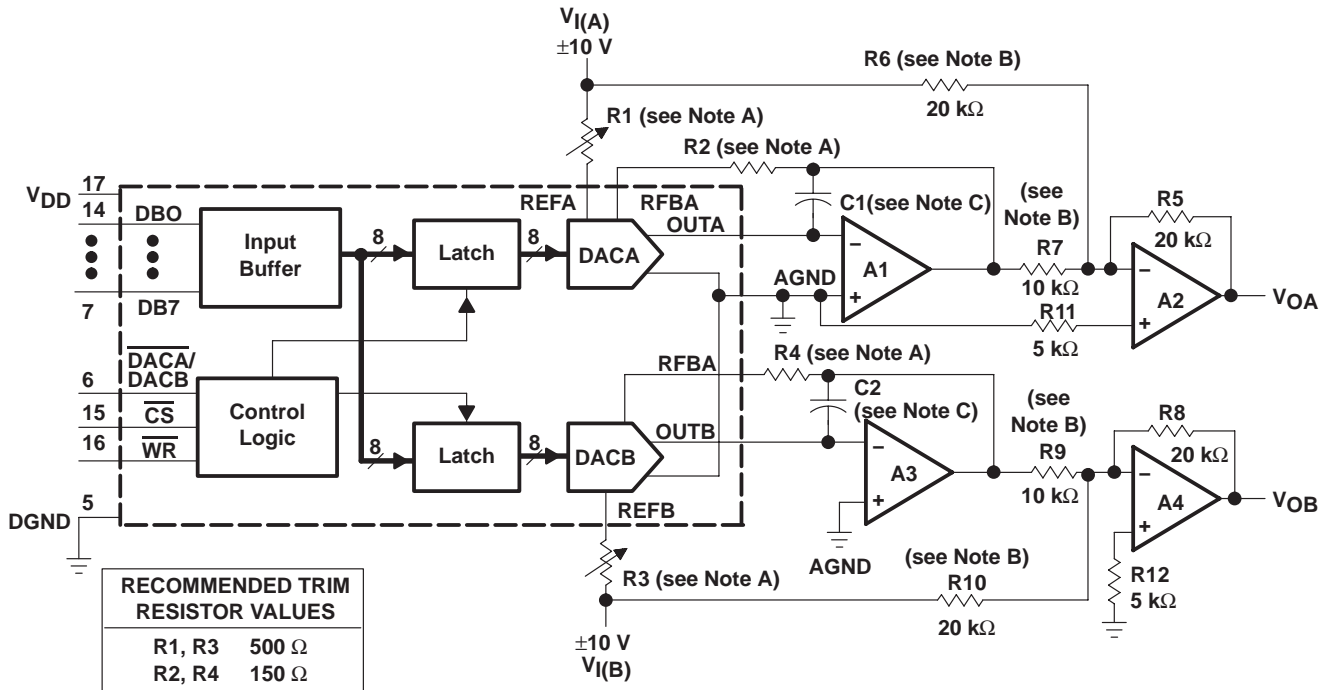
- NOTES: A. R1, R2, R3, and R4 are used only if gain adjustment is required. See table for recommended values. Make gain adjustment with digital input of 255.
- B. C1 and C2 phase compensation capacitors (10 pF to 15 pF) are required when using high-speed amplifiers to prevent ringing or oscillation.

**Figure 2. Unipolar Operation (2-Quadrant Multiplication)**

# TLC7628C DUAL 8-BIT MULTIPLYING

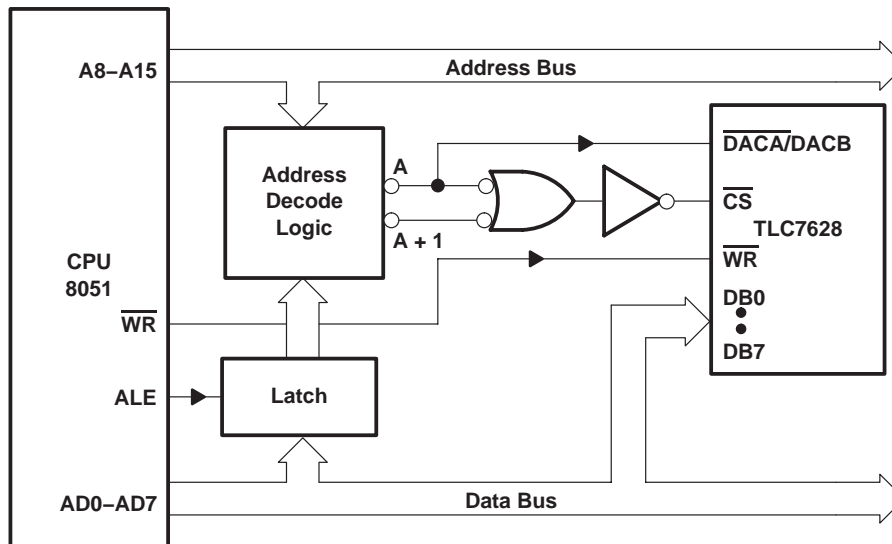
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## APPLICATION INFORMATION



- NOTES: A. R1, R2, R3, and R4 are used only if gain adjustment is required. See table for recommended values. Adjust R1 for  $V_{OA} = 0\text{ V}$  with code 10000000 in DACA latch. Adjust R3 for  $V_{OB} = 0\text{ V}$  with 10000000 in DACB latch.  
 B. Matching and tracking are essential for resistor pairs R6, R7, R9, and R10.  
 C. C1 and C2 phase compensation capacitors (10 pF to 15 pF) may be required if A1 and A3 are high-speed amplifiers.

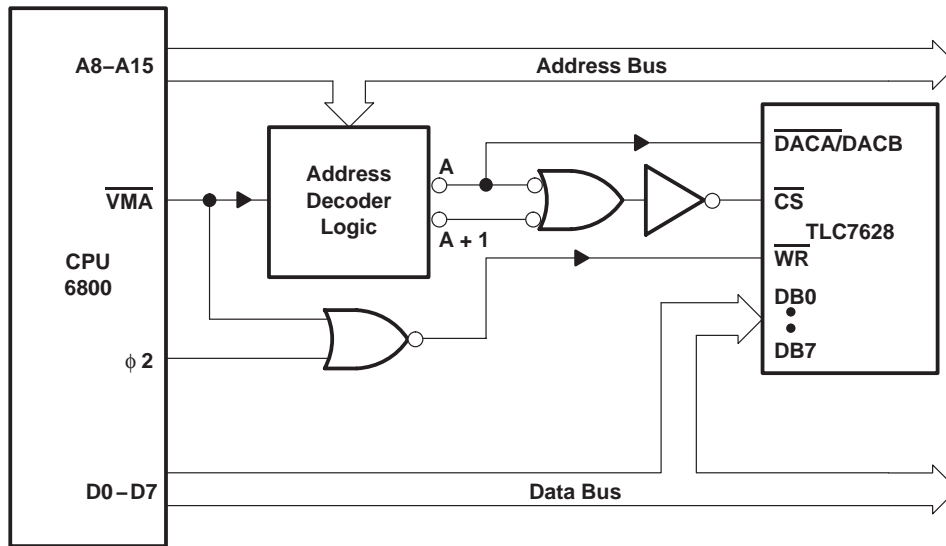
Figure 3. Bipolar Operation (4-Quadrant Operation)



NOTE D: A = decoded address for TLC7628 DACA  
 A + 1 = decoded address for TLC7628 DACB

Figure 4. TLC7628 — Intel 8051 Interface

APPLICATION INFORMATION



NOTE D: A = decoded address for TLC7628 DACA  
A + 1 = decoded address for TLC7628 DACB

Figure 5. TLC7628 – 6800 Interface

voltage-mode operation

The current-multiplying DAC in the TLC7628C can be operated 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. An example of a current-multiplying DAC operating in voltage mode is shown in Figure 6. The relationship between the fixed input voltage and the analog output voltage is given by the following equation:

$$\text{Analog output voltage} = \text{fixed input voltage} (D/256)$$

where D = the digital input. In voltage-mode operation, these devices meet the following specification:

| LINEARITY ERROR                      | TEST CONDITIONS                                                                                    | MIN | MAX | UNIT |
|--------------------------------------|----------------------------------------------------------------------------------------------------|-----|-----|------|
| Analog output voltage for REFA, REFB | $V_{DD} = 12\text{ V}$ , $\text{OUTA}$ or $\text{OUTB}$ at $5\text{ V}$ , $T_A = 25^\circ\text{C}$ |     | 1   | LSB  |

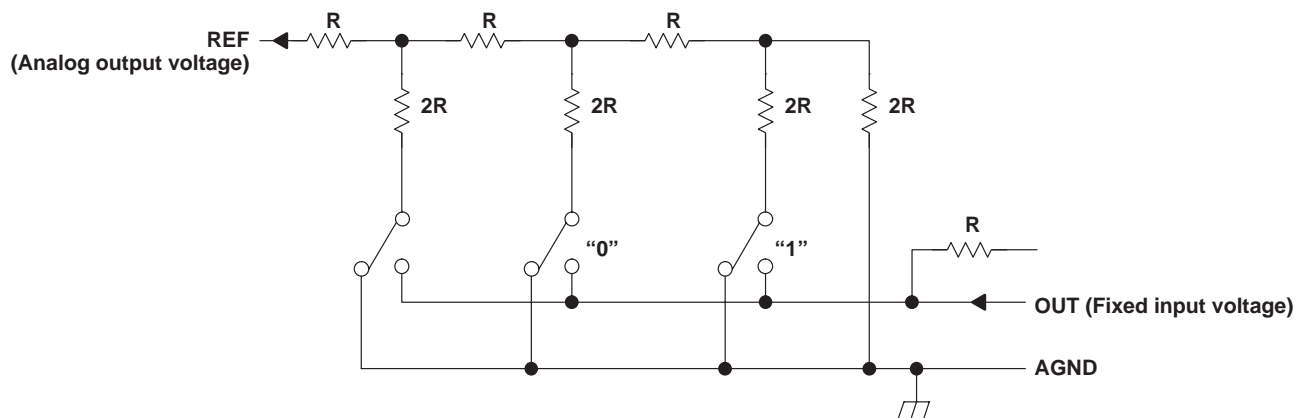


Figure 6. Current-Multiplying DAC Operating in Voltage Mode

# TLC7628C

## DUAL 8-BIT MULTIPLYING

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### PRINCIPLES OF OPERATION

This device contains two, identical, 8-bit, multiplying DACs: DACA and DACB. Each DAC consists of an inverted R-2R ladder, analog switches, and input data latches. Binary-weighted currents are switched between the DAC output and AGND, thus maintaining a constant current in each ladder leg independent of the switch state. Most applications require only the addition of an external operational amplifier and voltage reference. A simplified D/A circuit for DACA or DACB with all digital inputs low is shown in Figure 7.

Figure 8 shows the DACA or DACB equivalent circuit. Both DACs share the analog ground terminal 1 (AGND). With all digital inputs high, the reference current flows to OUTA. A small leakage current ( $I_{lkg}$ ) flows across internal junctions, and as with most semiconductor devices, doubles every 10°C. The  $C_O$  is caused by the parallel combination of the NMOS switches and has a value that depends on the number of switches connected to the output. The range of  $C_O$  is 25 pF to 60 pF maximum. The equivalent output resistance ( $r_O$ ) varies with the input code from 0.8R to 3R where R is the nominal value of the ladder resistor in the R-2R network.

The TLC7628C interfaces to a microprocessor through the data bus,  $\overline{CS}$ ,  $\overline{WR}$ , and  $\overline{DACA/DACB}$  control signals. When  $\overline{CS}$  and  $\overline{WR}$  are both low, the analog output on this device, specified by the  $\overline{DACA/DACB}$  control line, responds to the 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.

The digital inputs of the TLC7628C provides TTL compatibility when operated from a supply voltage of 10.8 V to 15.75 V.

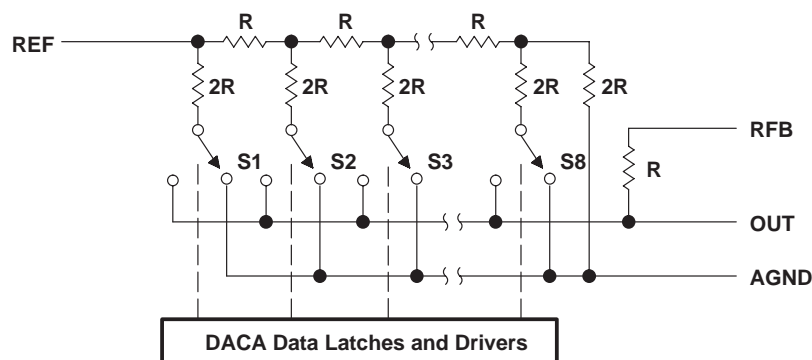
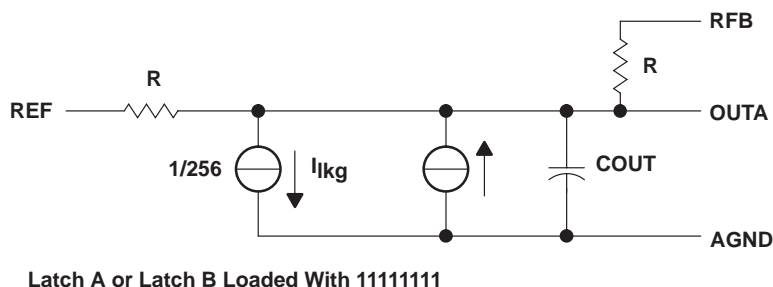


Figure 7. Simplified Functional Circuit for DACA or DACB



Latch A or Latch B Loaded With 11111111

Figure 8. TLC7628 Equivalent Circuit for DACA or DACB



PRINCIPLES OF OPERATION

Table 1. Mode Selection Table

| DACA/DACB | $\overline{\text{CS}}$ | $\overline{\text{WR}}$ | DACA  | DACB  |
|-----------|------------------------|------------------------|-------|-------|
| L         | L                      | L                      | Write | Hold  |
| H         | L                      | L                      | Hold  | Write |
| X         | H                      | X                      | Hold  | Hold  |
| X         | X                      | H                      | Hold  | Hold  |

L = low level, H = high level, X = don't care

Table 2. Unipolar Binary Code

| DAC LATCH CONTENTS<br>(see Note 7) |         | ANALOG OUTPUT             |
|------------------------------------|---------|---------------------------|
| MSB                                | LSB     |                           |
| 1                                  | 1111111 | $-V_I (255/256)$          |
| 1                                  | 0000001 | $-V_I (129/256)$          |
| 1                                  | 0000000 | $-V_I (128/256) = -V_I/2$ |
| 0                                  | 1111111 | $-V_I (127/256)$          |
| 0                                  | 0000001 | $-V_I (1/256)$            |
| 0                                  | 0000000 | $-V_I (0/256) = 0$        |

Table 3. Bipolar (Offset Binary) Code

| DAC LATCH CONTENTS<br>(see Note 8) |         | ANALOG OUTPUT    |
|------------------------------------|---------|------------------|
| MSB                                | LSB     |                  |
| 1                                  | 1111111 | $V_I (127/128)$  |
| 1                                  | 0000001 | $V_I (1/128)$    |
| 1                                  | 0000000 | 0 V              |
| 0                                  | 1111111 | $-V_I (1/128)$   |
| 0                                  | 0000001 | $-V_I (127/128)$ |
| 0                                  | 0000000 | $-V_I (128/128)$ |

- NOTES: 7. 1 LSB =  $(2^{-8})V_I$   
8. 1 LSB =  $(2^{-7})V_I$

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TLC7628CDW       | ACTIVE        | SOIC         | DW              | 20   | 25          | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-1-260C-UNLIM   | 0 to 70      | TLC7628C                | <a href="#">Samples</a> |
| TLC7628CDWR      | ACTIVE        | SOIC         | DW              | 20   | 2000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-1-260C-UNLIM   | 0 to 70      | TLC7628C                | <a href="#">Samples</a> |
| TLC7628CN        | ACTIVE        | PDIP         | N               | 20   | 20          | Pb-Free (RoHS)          | NIPDAU                  | N / A for Pkg Type   | 0 to 70      | TLC7628CN               | <a href="#">Samples</a> |

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC7628CDWR | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC7628CDWR | SOIC         | DW              | 20   | 2000 | 350.0       | 350.0      | 43.0        |

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.
  - 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.

4040049/E 12/2002

# DW0020A



# PACKAGE OUTLINE

## SOIC - 2.65 mm max height

SOIC



4220724/A 05/2016

**NOTES:**

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm per side.
5. Reference JEDEC registration MS-013.

# EXAMPLE BOARD LAYOUT

DW0020A

SOIC - 2.65 mm max height

SOIC



LAND PATTERN EXAMPLE  
SCALE:6X



SOLDER MASK DETAILS

4220724/A 05/2016

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



# EXAMPLE STENCIL DESIGN

DW0020A

SOIC - 2.65 mm max height

SOIC



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:6X

4220724/A 05/2016

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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