

# DAC4814

## Quad 12-Bit Digital-to-Analog Converter (Serial Interface)

### FEATURES

- COMPLETE QUAD DAC — INCLUDES INTERNAL REFERENCES AND OUTPUT AMPLIFIERS
- GUARANTEED SPECIFICATIONS OVER TEMPERATURE
- GUARANTEED MONOTONIC OVER TEMPERATURE
- HIGH-SPEED SERIAL INTERFACE (10MHz CLOCK)
- LOW POWER: 600mW (150mW/DAC)
- LOW GAIN DRIFT: 5ppm/°C
- LOW NONLINEARITY:  $\pm 1/2$  LSB max
- UNIPOLAR OR BIPOLAR OUTPUT
- CLEAR/RESET TO UNIPOLAR OR BIPOLAR ZERO

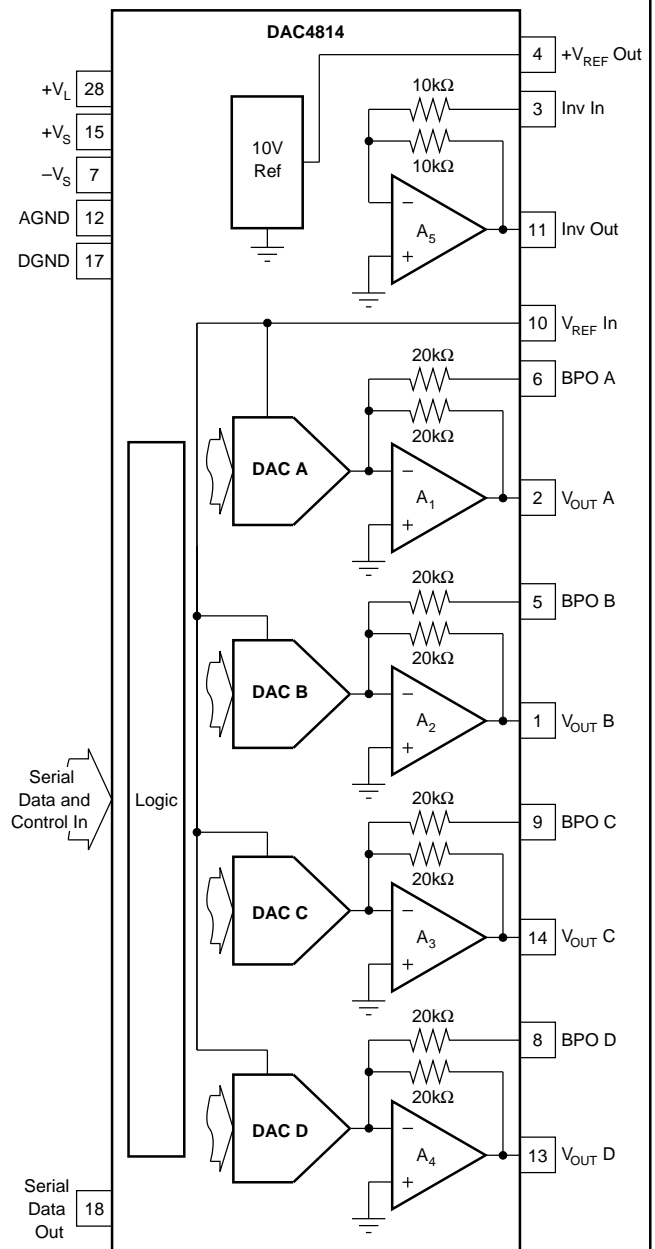
### DESCRIPTION

The DAC4814 is one in a family of dual and quad 12-bit digital-to-analog converters. Serial, 8-bit, 12-bit interfaces are available.

The DAC4814 is complete. It contains CMOS logic, switches, a high-performance buried-zener reference, and low-noise bipolar output amplifiers. No external components are required for either unipolar 0 to 10V, 0 to -10V, or bipolar  $\pm 10V$  output ranges.

The DAC4814 has a high-speed serial interface capable of being clocked at 10MHz. Serial data are clocked DAC D MSB first into a 48-bit shift register, then strobed into each DAC separately or simultaneously as required. The DAC has an asynchronous clear control for reset to unipolar or bipolar zero depending on the mode selected. This feature is useful for power-on reset or system calibration. The DAC4814 is packaged in a 28-pin plastic DIP rated for the -40°C to +85°C extended industrial temperature range.

High-stability laser-trimmed thin film resistors assure high reliability and true 12-bit integral and differential linearity over the full specified temperature range.



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# SPECIFICATIONS (CONT), Guaranteed over $T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$ unless otherwise specified.

## ELECTRICAL

Specifications as shown for  $V_S = \pm 12\text{V}$  or  $\pm 15\text{V}$ ,  $V_L = +5\text{V}$ , and  $R_L = 2\text{k}\Omega$  unless otherwise noted.

PARAMETER	CONDITIONS	DAC4814AP			DAC4814BP			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>POWER SUPPLY</b>								
$+V_S$ and $-V_S$		$\pm 11.4$	$\pm 15$	$\pm 18$	*	*	*	V
$+V_L$		4.5	5	5.5	*	*	*	V
$+I_S$			+20	+24	*	*	*	mA
$-I_S$			-20	-25.5	*	*	*	mA
$+I_L$	Digital Inputs = $0\text{V}$ or $+V_L$		0.4	2	*	*	*	mA
$+I_L$	Digital Inputs = $V_{IL}$ or $V_{IH}$			10	*	*	*	mA
Total Power, All DACs			600	753	*	*	*	mW
<b>TEMPERATURE RANGE</b>								
Specified		-40		+85	*		*	$^{\circ}\text{C}$
Operating		-40		+85	*		*	$^{\circ}\text{C}$
Thermal Resistance, $\theta_{JA}$			75			*		$^{\circ}\text{C}/\text{W}$

NOTES: (1) End point linearity. (2) Guaranteed monotonic. (3) Change in bipolar full scale output. Includes voltage output DAC, voltage reference, and reference inverter. (4) Inverter output with inverter input connected to  $+V_{REF}$ . (5) Guaranteed to but not tested.

## ABSOLUTE MAXIMUM RATINGS

$+V_L$ to AGND .....	$0\text{V}$ , $+7\text{V}$
$+V_L$ to DGND .....	$0\text{V}$ , $+7\text{V}$
$+V_S$ to AGND .....	$0\text{V}$ , $+18\text{V}$
$-V_S$ to AGND .....	$0\text{V}$ , $-18\text{V}$
AGND to DGND .....	$\pm 0.3\text{V}$
Any digital input to DGND .....	$-0.3\text{V}$ , $+V_L + 0.3\text{V}$
Ref In to AGND .....	$\pm 25\text{V}$
Ref In to DGND .....	$\pm 25\text{V}$
Storage Temperature Range .....	$-55^{\circ}\text{C}$ to $+125^{\circ}\text{C}$
Operating Temperature Range .....	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$
Lead Temperature (soldering, 10s) .....	$+300^{\circ}\text{C}$
Junction Temperature .....	$+155^{\circ}\text{C}$
Output Short Circuit .....	Continuous to common or $\pm V_S$
Reference Short Circuit .....	Continuous to common or $+V_S$



## ELECTROSTATIC DISCHARGE SENSITIVITY

Electrostatic discharge can cause damage ranging from performance degradation to complete device failure. Burr-Brown Corporation recommends that all integrated circuits be handled and stored using appropriate ESD protection methods.

## PACKAGE INFORMATION

MODEL	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
DAC4814AP	28-Pin Plastic DBL Wide DIP	215
DAC4814BP	28-Pin Plastic DBL Wide DIP	215

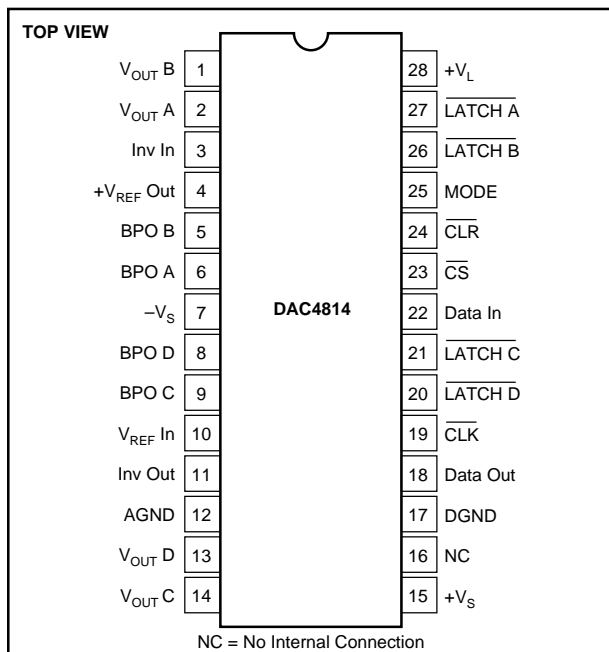
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

The information provided herein is believed to be reliable; however, BURR-BROWN assumes no responsibility for inaccuracies or omissions. BURR-BROWN assumes no responsibility for the use of this information, and all use of such information shall be entirely at the user's own risk. Prices and specifications are subject to change without notice. No patent rights or licenses to any of the circuits described herein are implied or granted to any third party. BURR-BROWN does not authorize or warrant any BURR-BROWN product for use in life support devices and/or systems.

## PIN DESIGNATIONS

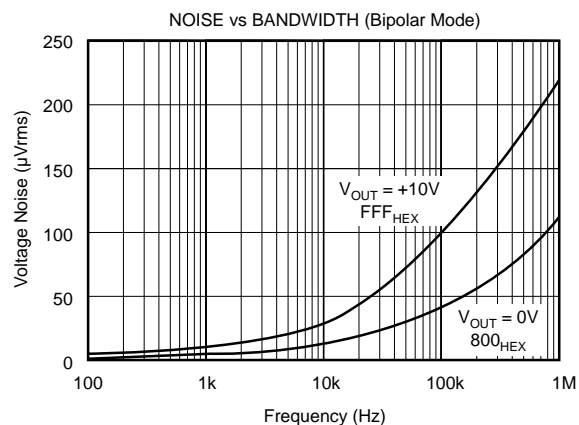
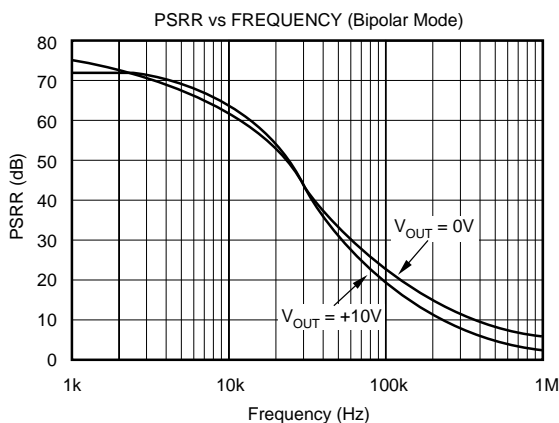
PIN	DESCRIPTOR	FUNCTION	PIN	DESCRIPTOR	FUNCTION
1	V <sub>OUT B</sub>	Analog output voltage, DAC B	28	+V <sub>L</sub>	Positive logic power supply, +5V input
2	V <sub>OUT A</sub>	Analog output voltage, DAC A	27	LATCH A	Latch data update, logic input, DAC A
3	Inv In	Inverter (A <sub>5</sub> ) input	26	LATCH B	Latch data update, logic input, DAC B
4	+V <sub>REF</sub> Out	Positive reference voltage output (+10V output)	25	MODE	Selection input for unipolar or bipolar reset to zero
5	BPO B	Bipolar offset input, DAC B	24	CLR	Asynchronous input reset to zero
6	BPO A	Bipolar offset input, DAC A	23	CS	Chip select enable, DAC A, B, C, and D
7	-V <sub>S</sub>	Negative analog power supply, -15V input	22	Data In	Serial data input
8	BPO D	Bipolar offset input, DAC D	21	LATCH C	Latch data update, logic input, DAC C
9	BPO C	Bipolar offset input, DAC C	20	LATCH D	Latch data update, logic input, DAC D
10	V <sub>REF</sub> In	± Reference voltage input	19	CLK	Clock input
11	Inv Out	Inverter (A <sub>5</sub> ) output	18	Data Out	Serial data output
12	AGND	Analog common	17	DGND	Digital common
13	V <sub>OUT D</sub>	Analog output voltage, DAC D	16	NC	No internal connection
14	V <sub>OUT C</sub>	Analog output voltage, DAC C	15	+V <sub>S</sub>	Positive analog power supply, +15V input

## PIN CONFIGURATION



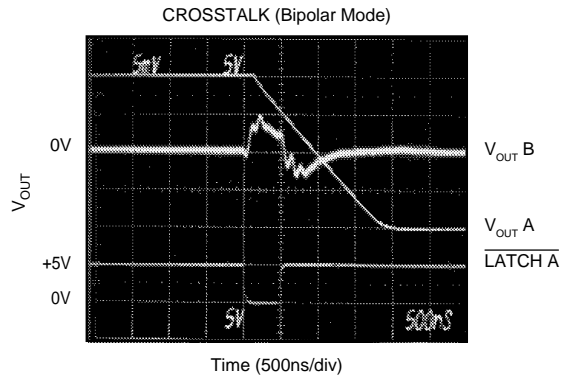
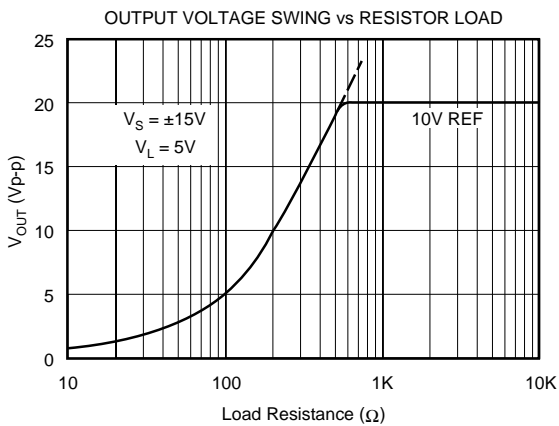
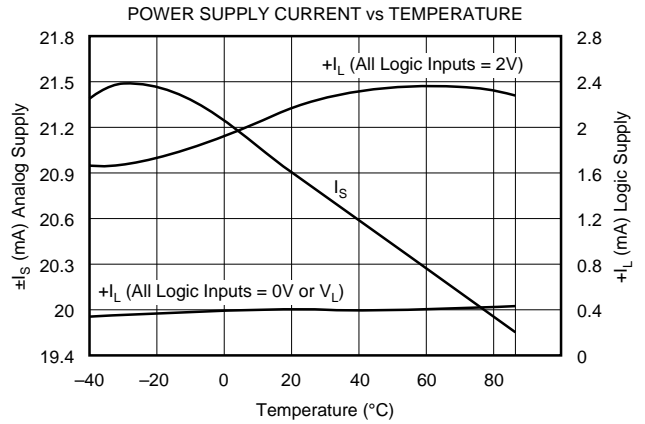
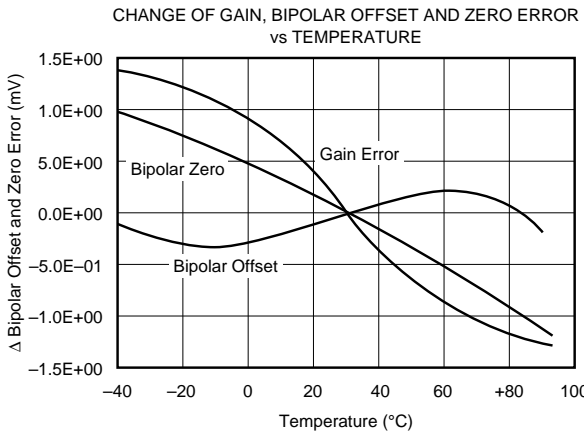
## TYPICAL PERFORMANCE CURVES

T<sub>A</sub> = +25°C, V<sub>S</sub> = ±12V or ±15V, V<sub>L</sub> = +5V unless otherwise noted.

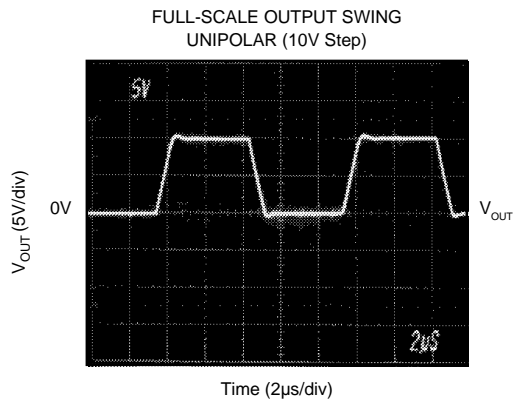
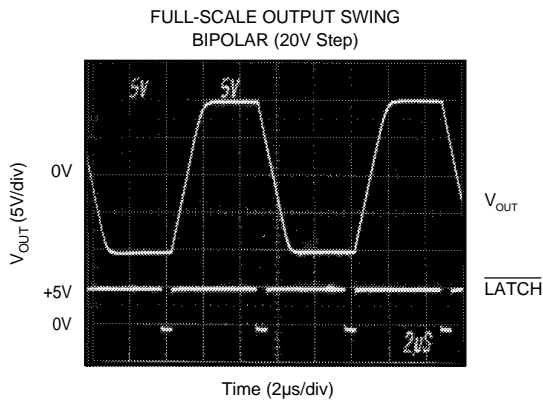


# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 12\text{V}$  or  $\pm 15\text{V}$ ,  $V_L = +5\text{V}$  unless otherwise noted.

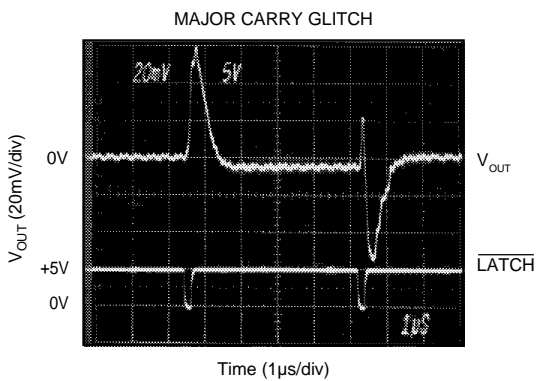
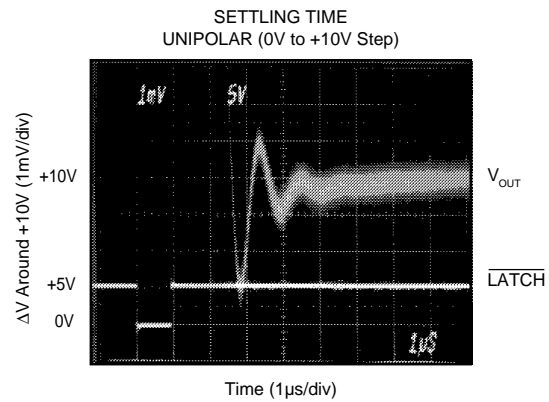
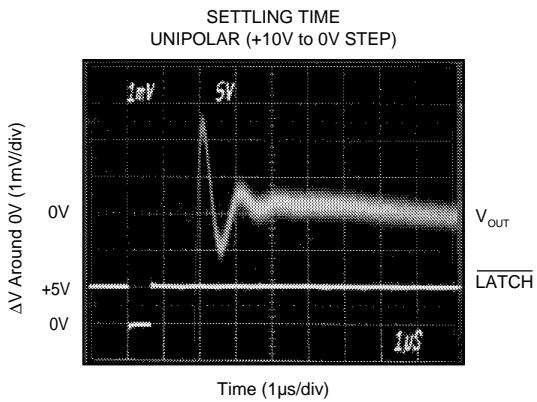
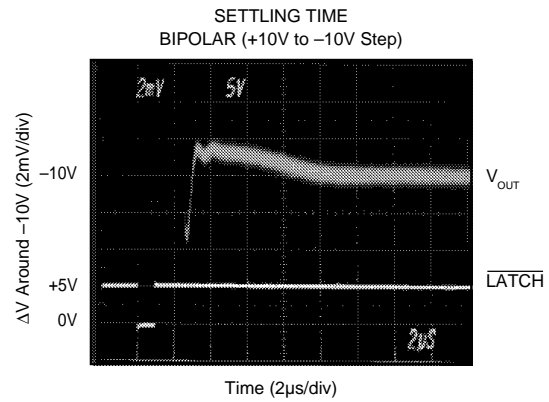
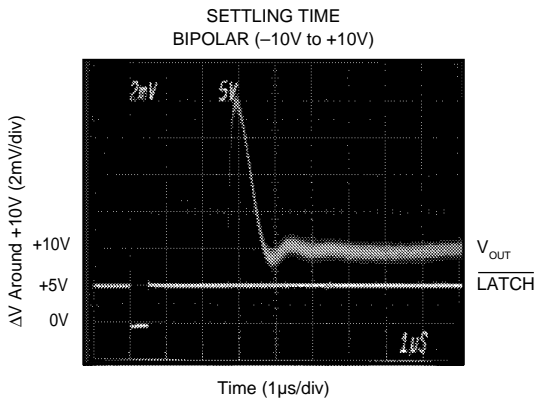


NOTE: Crosstalk is dominated by digital crosstalk/feedthrough of the LATCH signal.

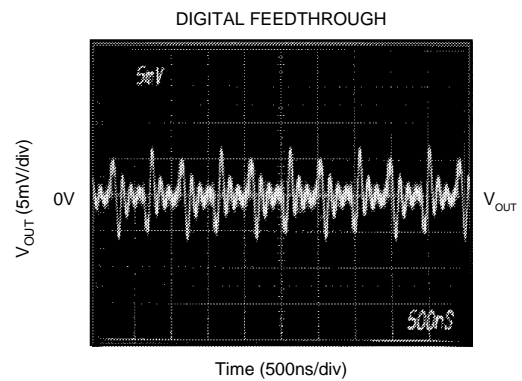


# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_S = \pm 12\text{V}$  or  $\pm 15\text{V}$ ,  $V_L = +5\text{V}$  unless otherwise noted.



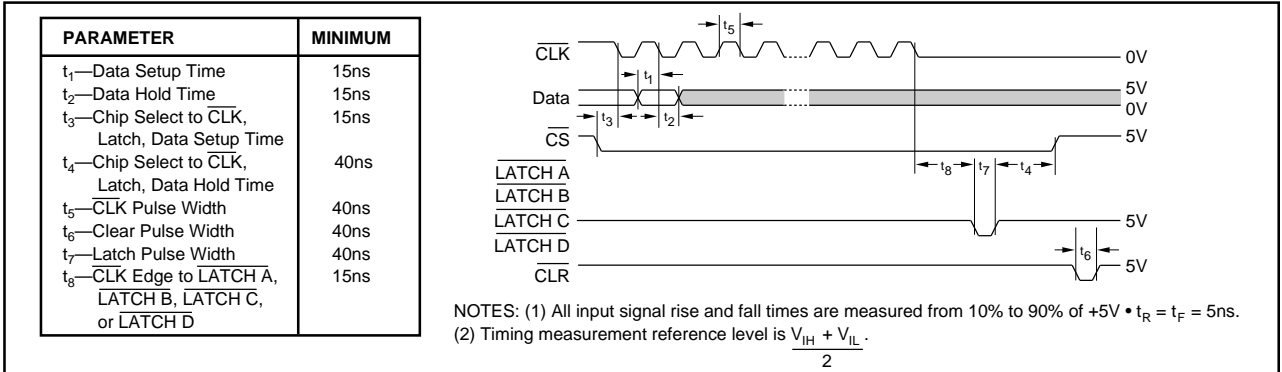
NOTE: Data transition 800<sub>HEX</sub> to 7FF<sub>HEX</sub>.



DAC output noise due to activity on digital inputs with latch disabled.

## TIMING CHARACTERISTICS

$V_S = \pm 15V$ ,  $V_L = +5V$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ .

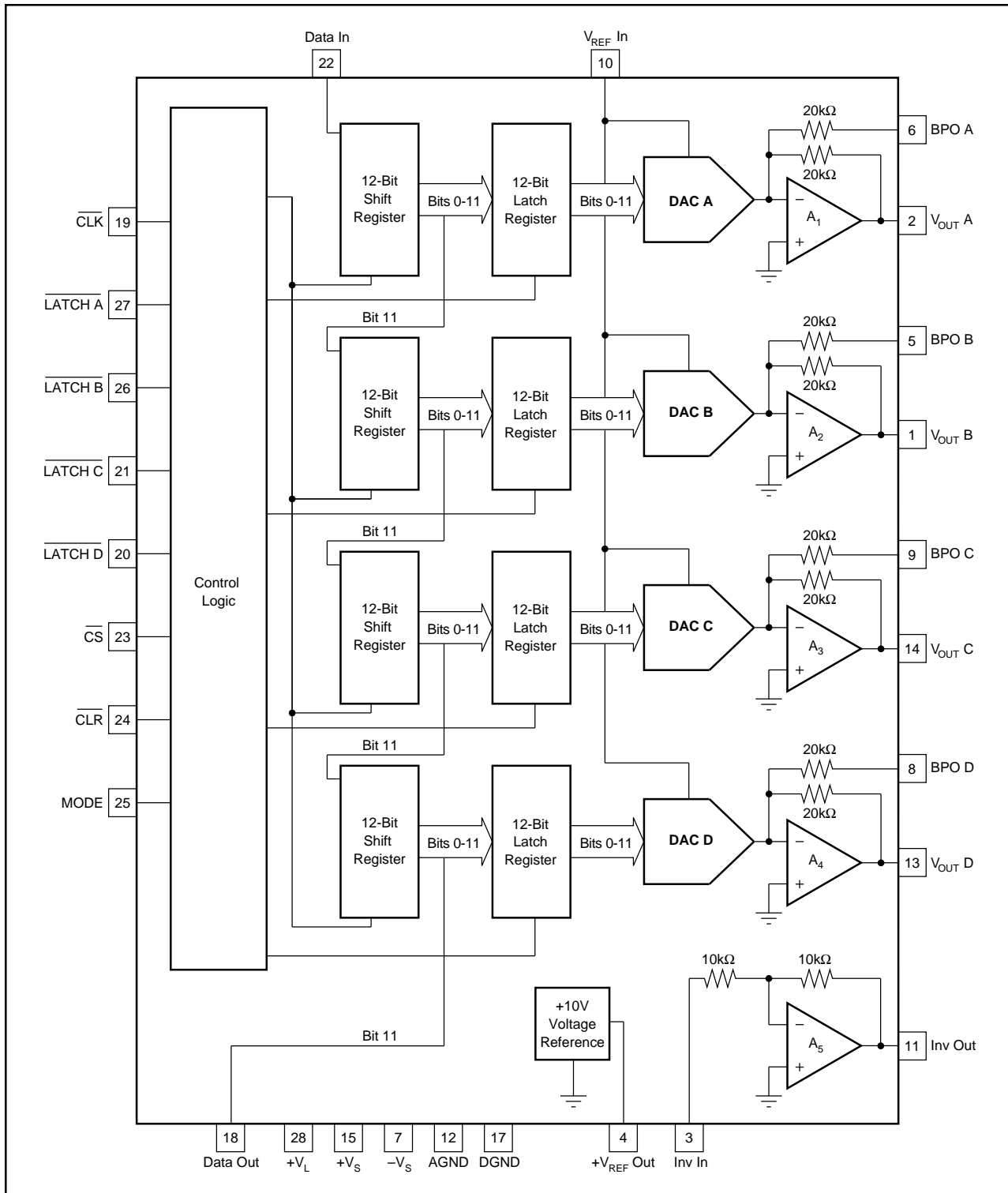


## INTERFACE LOGIC TRUTH TABLE

MODE	$\overline{CLR}$	$\overline{CLK}$	$\overline{CS}$	LATCH A	LATCH B	LATCH C	LATCH D	FUNCTION
X	1	↓	0	X	X	X	X	Data clocked in
X	1	X	1	X	X	X	X	No data transfer
X	1	X	0	0	1	1	1	DAC A register updated
X	1	X	0	1	0	1	1	DAC B register updated
X	1	X	0	1	1	0	1	DAC C register updated
X	1	X	0	1	1	1	0	DAC D register updated
X	1	X	0	0	0	0	0	All DAC registers updated simultaneously
0	0	X	X	X	X	X	X	All registers cleared
1	0	X	X	X	X	X	X	Shift registers cleared = 000 <sub>HEX</sub> , DAC registers = 800 <sub>HEX</sub>

Note: X = Don't Care. ↓ = Falling edge triggered.

**FUNCTIONAL BLOCK DIAGRAM, DAC4814 — Quad 12-bit DAC, Serial Port**





# DISCUSSION OF SPECIFICATIONS

## INPUT CODES

All digital inputs of the DAC4814 are TTL and 5V CMOS compatible. Input codes for the DAC4814 are either USB (Unipolar Straight Binary) or BOB (Bipolar Offset Binary) depending on the mode of operation. See Figure 3 for  $\pm 10V$  bipolar connection. See Figures 4 and 5 for 0 to 10V and 0 to  $-10V$  unipolar connections.

## UNIPOLAR AND BIPOLAR OUTPUTS FOR SELECTED INPUT

DIGITAL INPUT	UNIPOLAR (USB)	BIPOLAR (BOB)
FFF <sub>HEX</sub>	+Full scale	+Full scale
800 <sub>HEX</sub>	+1/2 Full scale	Zero
7FF <sub>HEX</sub>	+1/2 Full scale - 1 LSB	Zero - 1 LSB
000 <sub>HEX</sub>	Zero	-Full scale

## INTEGRAL OR RELATIVE LINEARITY

This term, also known as end point linearity, describes the transfer function of analog output to digital input code. Integral linearity error is the deviation of the analog output versus code transfer function from a straight line drawn through the end points.

## DIFFERENTIAL NONLINEARITY

Differential nonlinearity is the deviation from an ideal 1 LSB change in the output voltage when the input code changes by 1 LSB. A differential nonlinearity specification of  $\pm 1$  LSB maximum guarantees monotonicity.

## UNIPOLAR OFFSET ERROR

The output voltage for code 000<sub>HEX</sub> when the DAC is in unipolar mode of operation.

## BIPOLAR ZERO ERROR

The output voltage for code 800<sub>HEX</sub> when the DAC is in the bipolar mode of operation.

## GAIN ERROR

The deviation of the output voltage span ( $V_{MAX} - V_{MIN}$ ) from the ideal span of 10V - 1 LSB (unipolar mode) or 20V - 1 LSB (bipolar mode). The gain error is specified with and without the internal +10V reference error included.

## OUTPUT SETTLING TIME

The time required for the output voltage to settle within a percentage-of-full-scale error band for a full scale transition. Settling to  $\pm 0.012\%$  (1/2 LSB) is specified for the DAC4814.

## DIGITAL-TO-ANALOG GLITCH

Ideally, the DAC output would make a clean step change in response to an input code change. In reality, glitches occur during the transition. See Typical Performance Curves.

## DIGITAL CROSSTALK

Digital crosstalk is the glitch impulse measured at the output of one DAC due to a full scale transition on the other DAC—see Typical Performance Curves. It is dominated by digital coupling. Also, the integrated area of the glitch pulse is specified in nV-s. See table of electrical specifications.

## DIGITAL FEEDTHROUGH

Digital feedthrough is the noise at a DAC output due to activity on the digital inputs—see Typical Performance Curves.

## OPERATION

DACs can be updated simultaneously or independently as required. Data are transferred on falling clock edges into a 48-bit shift register. DAC D MSB is loaded first. Data are transferred to the DAC registers when the LATCH signals are brought low. The data are latched when the LATCH signals are brought high. All LATCH signals may be tied together to allow simultaneous update of the DACs if required. The output of the DAC shift register is provided to allow cascading of several DACs on the same bit stream. By using separate signals for LATCH A, LATCH B, LATCH C, and LATCH D it is possible to update one of the four DACs every 12 clock cycles.

When CLR is brought low, the input shift registers are cleared to 000<sub>HEX</sub> while the DAC registers = 800<sub>HEX</sub>. If LATCH is brought low after CLR, the DACs are updated with 000<sub>HEX</sub> resulting in  $-10V$  (bipolar) or 0V (unipolar) on the output.

## CIRCUIT DESCRIPTION

Each of the four DACs in the DAC4814 consists of a CMOS logic section, a CMOS DAC cell, and an output amplifier. One buried-zener +10.0V reference and a reference inverter (for a  $-10.0V$  reference) are shared by all DACs.

Figure 1 is a simplified circuit for a DAC cell. An R, 2R ladder network is driven by a voltage reference at  $V_{REF}$ . Current from the ladder is switched either to  $I_{OUT}$  or AGND by 12 single-pole double-throw CMOS switches. This maintains constant current in each leg of the ladder regardless of digital input code. This makes the resistance at  $V_{REF}$  constant (it can be driven by either a voltage or current reference). The reference can be either positive or negative polarity with a range of up to  $\pm 10V$ .

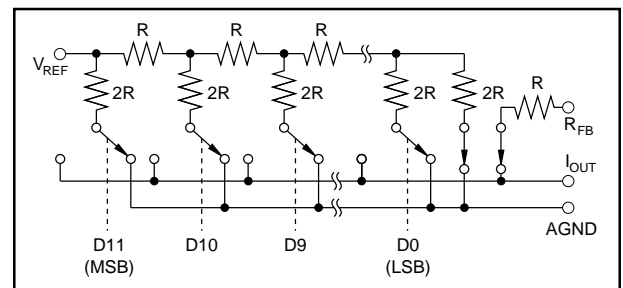


FIGURE 1. Simplified Circuit Diagram of DAC Cell.

CMOS switches included in series with the ladder terminating resistor and the feedback resistor,  $R_{FB}$ , compensate for the temperature drift of the ladder switch ON resistance.

The output op amps are connected as transimpedance amplifiers to convert the DAC-cell output current into an output voltage. They have been specially designed and compensated for precision and fast settling in this application.

### POWER SUPPLY CONNECTIONS

The DAC4814 is specified for operation with power supplies of  $V_L = +5V$  and  $V_S = \text{either } \pm 12V \text{ or } \pm 15V$ . Even with the  $V_S$  supplies at  $\pm 11.4V$  the DACs can swing a full  $\pm 10V$ . Power supply decoupling capacitors ( $1\mu F$  tantalum) should be located close to the DAC power supply connections.

Separate digital and analog ground pins are provided to permit separate current returns. They should be connected together at one point. Proper layout of the two current returns will prevent digital logic switching currents from degrading the analog output signal. The analog ground current is code dependent so the impedance to the system

reference ground must be kept to a minimum. Connect DACs as shown in Figure 2 or use a ground plane to keep ground impedance less than  $0.1\Omega$  for less than 0.1LSB error.

### -10V REFERENCE

An internal inverting amplifier (Gain =  $-1.0V/V$ ) is provided to invert the  $+10V$  reference. Connect  $+V_{REF}$  Out to Inv In for a  $-10V$  reference at Inv Out.

### OUTPUT RANGE CONNECTIONS

#### $\pm 10V$ Output Range

For a  $\pm 10V$  bipolar output connect the DAC4814 as shown in Figure 3. Connect the MODE to logic high ( $+5V$ ) for reset to bipolar zero. With MODE connected low (GND) reset will be to  $-Full-Scale$ .

#### 0 To $+10V$ Output Range

For 0 to  $+10V$  unipolar outputs connect the DAC4814 as shown in Figure 4. Connect the MODE to logic low (GND) for reset to unipolar zero.

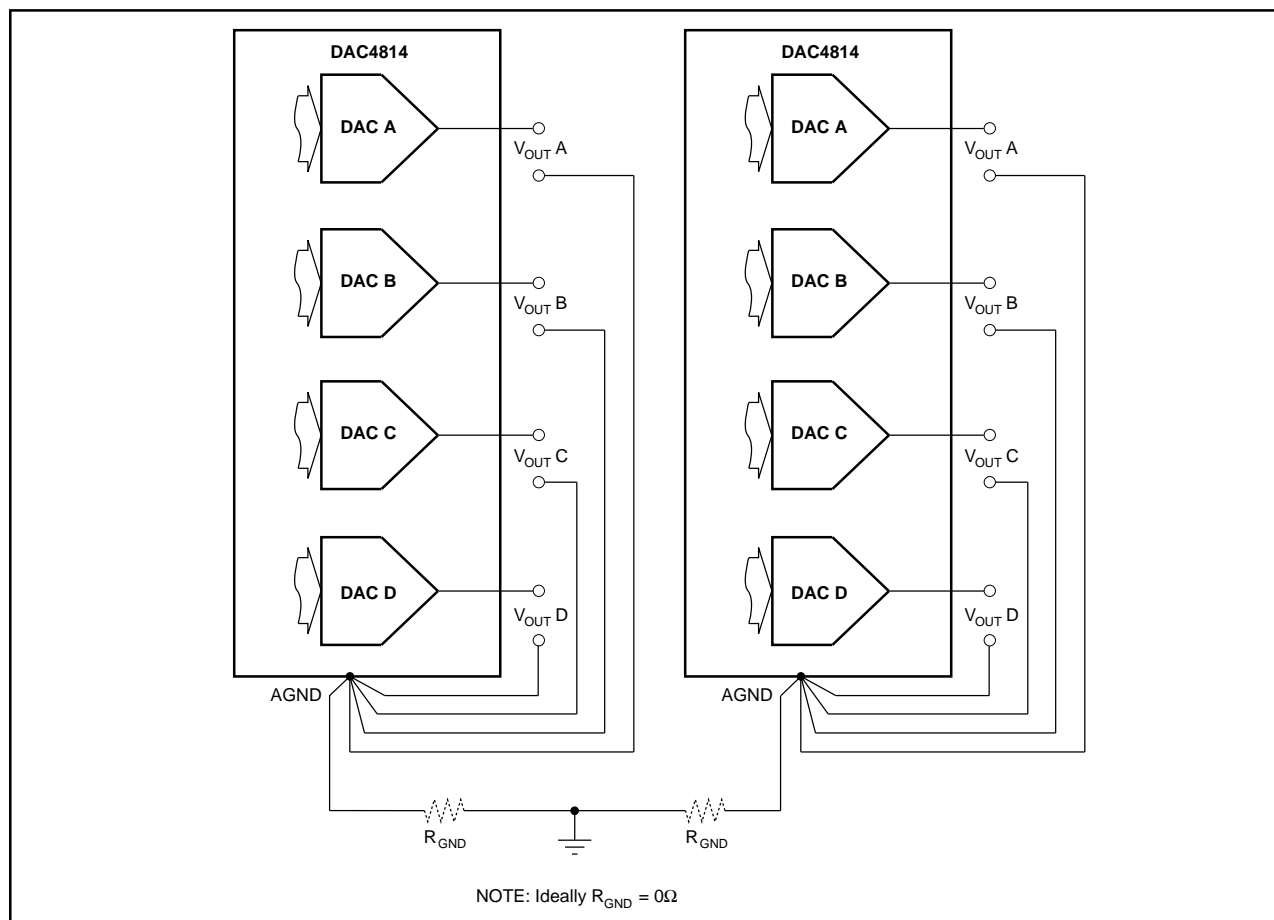


FIGURE 2. Recommended Ground Connections for Multiple DAC Packages.

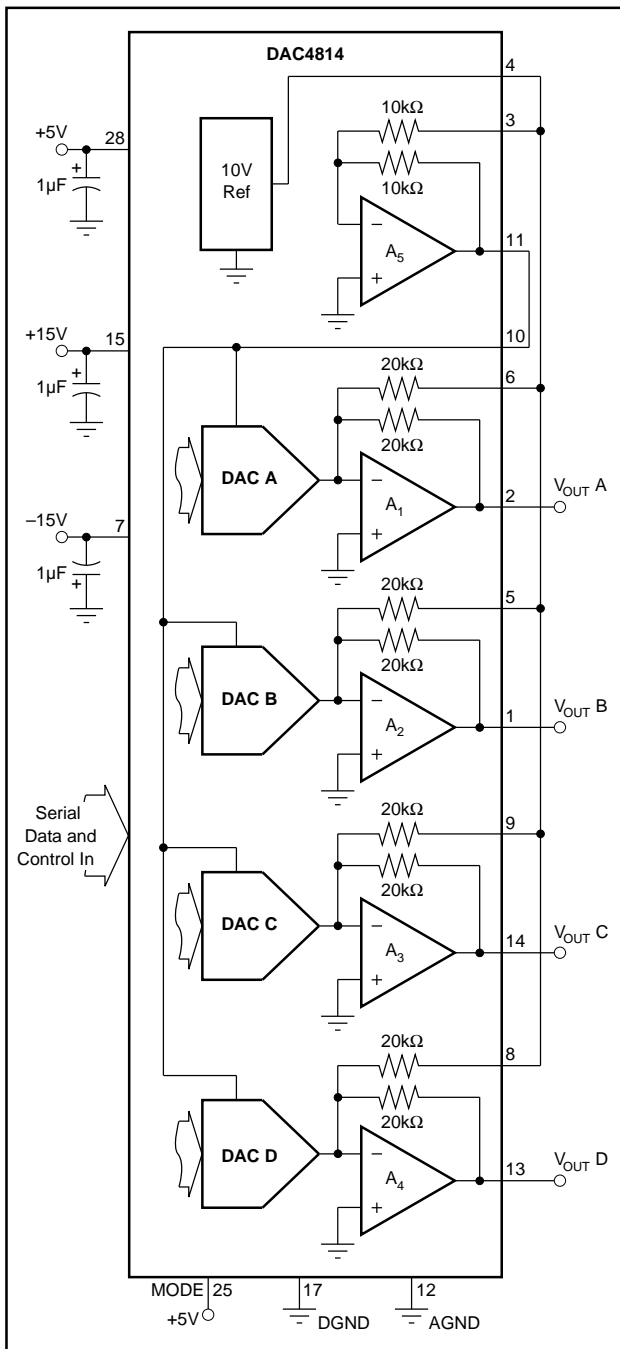


FIGURE 3. Analog Connections for  $\pm 10\text{V}$  DAC Output.

### 0 To $-10\text{V}$ Output Range

For 0 to  $-10\text{V}$  unipolar outputs connect the DAC4814 as shown in Figure 5. Connect the MODE to logic low (GND) for reset to unipolar zero.

### CONNECTION TO DIGITAL BUS

#### Cascaded Bus Connection

Multiple DAC4814s can be connected to the same  $\overline{\text{CLK}}$  and DATA input lines in two ways. Since the output of the DAC shift register is available, any number of DAC4814s can be

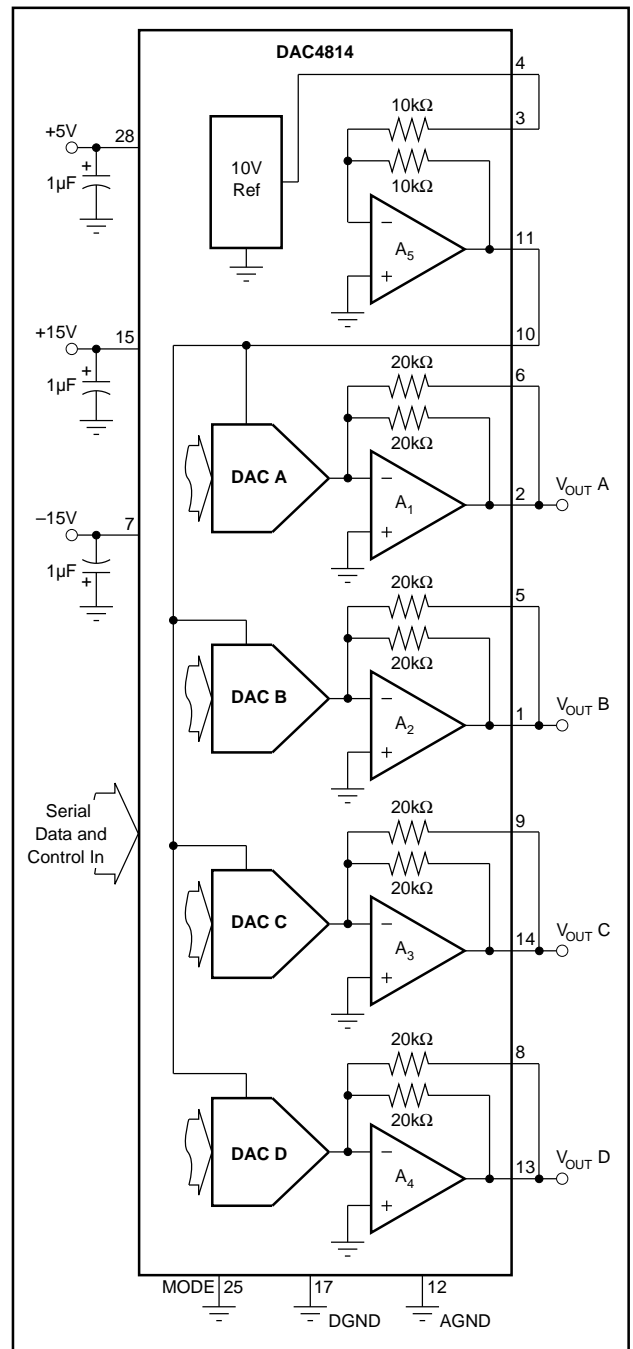


FIGURE 4. Analog Connections for 0 to  $+10\text{V}$  DAC Output.

cascaded on the same input bit stream as shown in Figure 6. This arrangement allows all DACs in the system to be updated simultaneously and requires a minimum number of control signal inputs. However, up to  $48N$   $\overline{\text{CLK}}$  cycles may be required to update any given DAC, where  $N$  = number of DAC4814s.

#### Parallel Bus Connection

Several DAC4814s can also have their DATA inputs connected in parallel as shown in Figure 7. This allows any DAC in the system to be updated in a maximum of  $48$   $\overline{\text{CLK}}$  cycles.

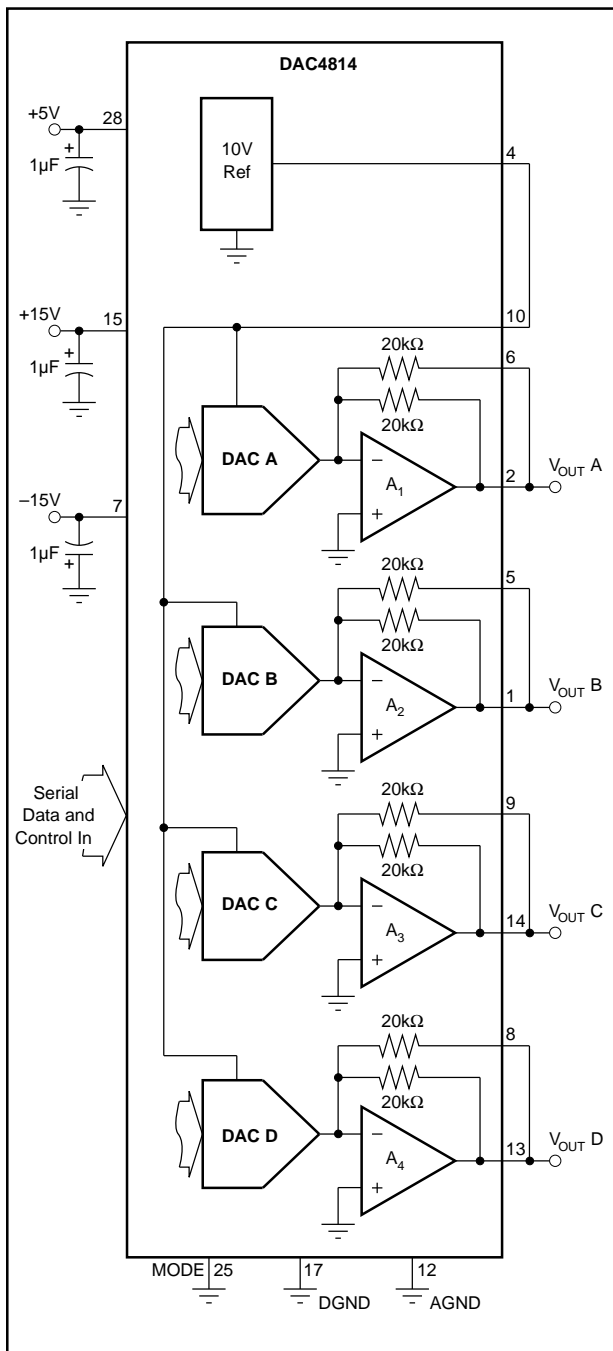


FIGURE 5. Analog Connections for 0 to -10V DAC Output.

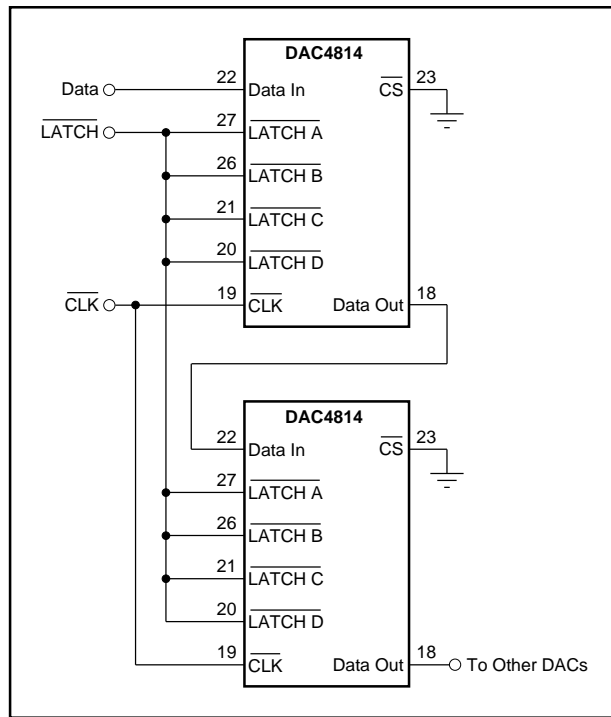


FIGURE 6. Cascaded Serial Bus Connection for Multiple DAC Packages.

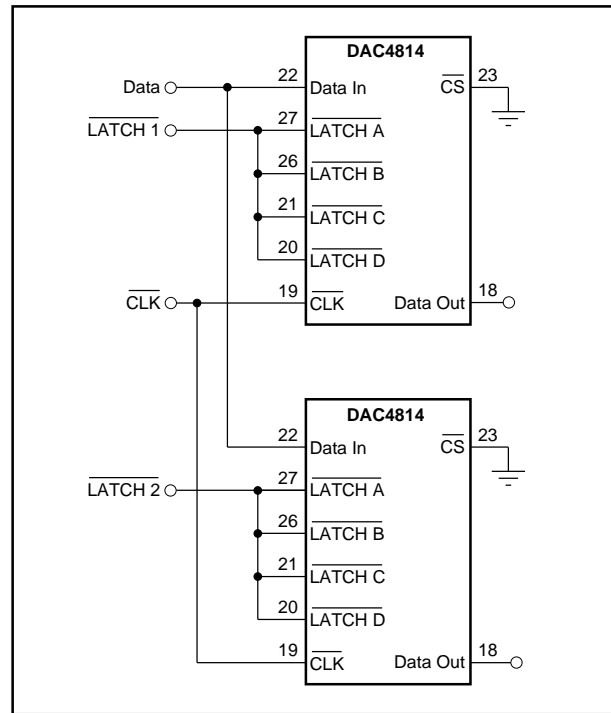


FIGURE 7. Parallel Bus Connection for Multiple DAC Packages.

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
DAC4814AP	OBSOLETE	PDIP	NTD	28		TBD	Call TI	Call TI
DAC4814BP	OBSOLETE	PDIP	NTD	28		TBD	Call TI	Call TI

<sup>(1)</sup> 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.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS) 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.

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**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)

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

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