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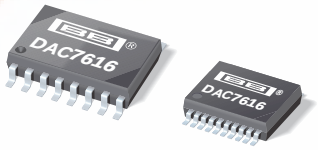
DAC7616



Quad, Serial Input, 12-Bit, Voltage Output DIGITAL-TO-ANALOG CONVERTER

FEATURES

- LOW POWER: 3mW
- SETTLING TIME: 10μs to 0.012%
- 12-BIT LINEARITY AND MONOTONICITY: –40°C to +85°C
- USER SELECTABLE RESET TO MID-SCALE OR ZERO-SCALE
- SECOND-SOURCE for DAC8420
- SO-16 or SSOP-20 PACKAGES
- SINGLE SUPPLY +3V OPERATION

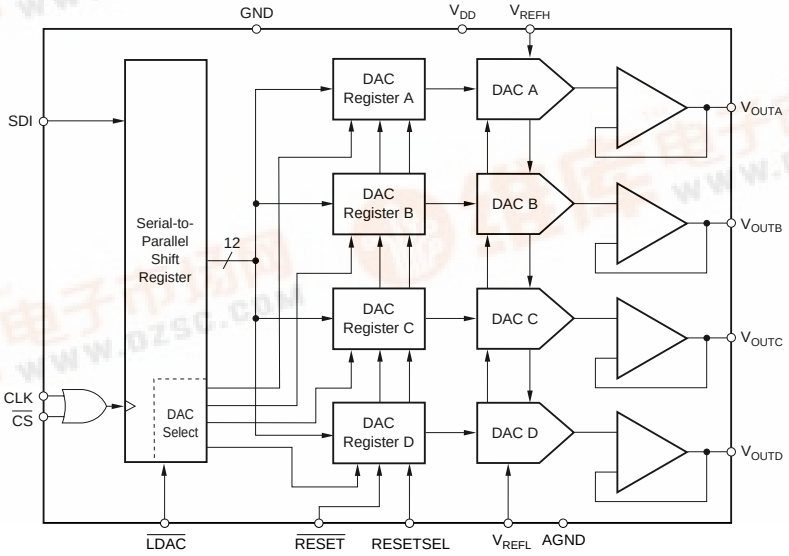
APPLICATIONS

- ATE PIN ELECTRONICS
- PROCESS CONTROL
- CLOSED-LOOP SERVO-CONTROL
- MOTOR CONTROL
- DATA ACQUISITION SYSTEMS
- DAC-PER-PIN PROGRAMMERS

DESCRIPTION

The DAC7616 is a quad, serial input, 12-bit, voltage output Digital-to-Analog Converter (DAC) with guaranteed 12-bit monotonic performance over the –40°C to +85°C temperature range. An asynchronous reset clears all registers to either mid-scale (800_H) or zero-scale (000_H), selectable via the RESETSEL pin. The device is powered from a single +3V supply.

Low power and small size makes the DAC7616 ideal for process control, data acquisition systems, and closed-loop servo-control. The device is available in SO-16 or SSOP-20 packages, and is guaranteed over the –40°C to +85°C temperature range.



TEXAS INSTRUMENTS

SPECIFICATIONS

At T_A = –40°C to +85°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, unless otherwise noted.

PARAMETER	CONDITIONS	DAC7616E, U			DAC7616EB, UB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
ACCURACY								
Linearity Error[1]				±2			±1	LSB[2]
Linearity Matching[3]				±2			±1	LSB
Differential Linearity Error				±1			±1	LSB
Monotonicity		12			*			Bits
Zero-Scale Error	Code = $00A_H$			±2.4			*	mV
Zero-Scale Drift			5	10		*	*	ppm/°C
Zero-Scale Matching[3]			±1	±2		*	±1.2	mV
Full-Scale Error	Code = FFF_H			±2.4			*	mV
Full-Scale Matching[3]			±1	±2		*	±1.2	mV
Power Supply Rejection			30			*		ppm/V
ANALOG OUTPUT								
Voltage Output[4]		V_{REFL}		V_{REFH}	*		*	V
Output Current		–625		+625	*		*	µA
Load Capacitance	No Oscillation		100			*		pF
Short-Circuit Current			+8, –2			*		mA
Short-Circuit Duration			Indefinite			*		
REFERENCE INPUT								
V_{REFH} Input Range		0		+1.25	*		*	V
V_{REFL} Input Range		0			*			V
DYNAMIC PERFORMANCE								
Settling Time	To ±0.012%		5	10		*	*	µs
Channel-to-Channel Crosstalk	Full-Scale Step On Any Other DAC		0.1			*		LSB
Output Noise Voltage	Bandwidth: 0Hz to 1MHz		65			*		$nV/\sqrt{Hz}$
DIGITAL INPUT/OUTPUT								
Logic Family			CMOS			*		
Logic Levels								
V_{IH}	$\lvert I_{IH} \rvert \leq 10\mu A$	V_{DD} • 0.7		V_{DD}	*		*	V
V_{IL}	$\lvert I_{IL} \rvert \leq 10\mu A$	–0.3		V_{DD} • 0.3	*		*	V
Data Format			Straight Binary			*		
POWER SUPPLY REQUIREMENTS								
V_{DD}		3.0	3.3	3.6	*	*	*	V
I_{DD}			0.8	1		*	*	mA
Power Dissipation			2.4	3		*	*	mW
TEMPERATURE RANGE								
Specified Performance		–40		+85	*		*	°C

* Specification same as DAC7616E, U.

NOTES: (1) Specification applies at code $00A_H$ and above. (2) LSB means Least Significant Bit, with V_{REFH} equal to +1.25V and V_{REFL} equal to 0V, one LSB is 0.305mV. (3) All DAC outputs will match within the specified error band. (4) Ideal output voltage does not take into account zero or full-scale error.

ABSOLUTE MAXIMUM RATINGS[1]

V_{DD} to GND	–0.3V to +5.5V
V_{REFL} to GND	–0.3V to (V_{DD} + 0.3V)
V_{DD} to V_{REFH}	–0.3V to V_{DD}
V_{REFH} to V_{REFL}	–0.3V to V_{DD}
Digital Input Voltage to GND	–0.3V to V_{DD} + 0.3V
Maximum Junction Temperature	+150°C
Operating Temperature Range	–40°C to +85°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (soldering, 10s)	+300°C

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

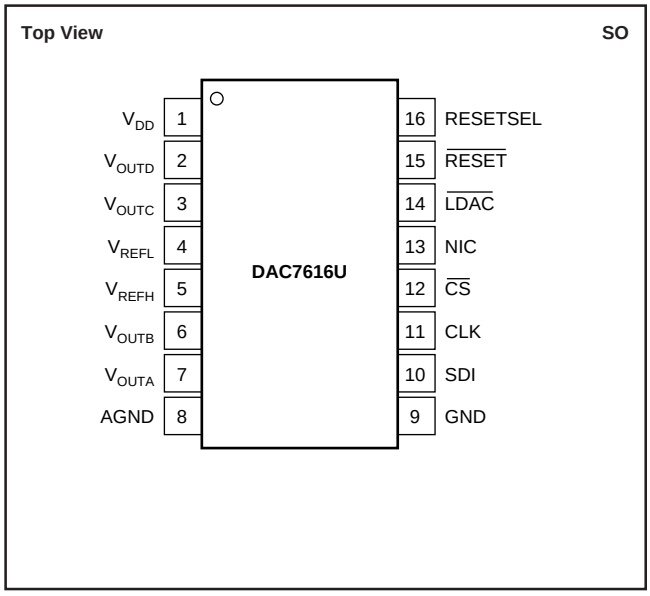
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

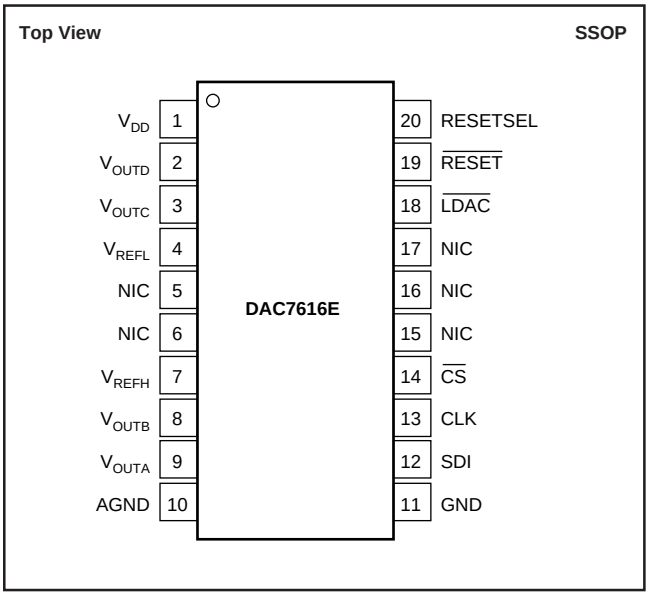
PRODUCT	MAXIMUM LINEARITY ERROR (LSB)	MAXIMUM DIFFERENTIAL LINEARITY (LSB)	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFICATION TEMPERATURE RANGE	ORDERING NUMBER[1]	TRANSPORT MEDIA
DAC7616U	±2	±1	SO-16	211	–40°C to +85°C	DAC7616U	Rails
"	"	"	"	"	"	DAC7616U/1K	Tape and Reel
DAC7616UB	±1	±1	SO-16	211	–40°C to +85°C	DAC7616UB	Rails
"	"	"	"	"	"	DAC7616UB/1K	Tape and Reel
DAC7616E	±2	±1	SSOP-20	334	–40°C to +85°C	DAC7616E	Rails
"	"	"	"	"	"	DAC7616E/1K	Tape and Reel
DAC7616EB	±1	±1	SSOP-20	334	–40°C to +85°C	DAC7616EB	Rails
"	"	"	"	"	"	DAC7616EB/1K	Tape and Reel

NOTES: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /1K indicates 1000 devices per reel). Ordering 1000 pieces of "DAC7616EB/1K" will get a single 1000-piece Tape and Reel.

PIN CONFIGURATION—U Package



PIN CONFIGURATION—E Package



PIN DESCRIPTIONS—U Package

PIN	LABEL	DESCRIPTION
1	V_{DD}	Positive Analog Supply Voltage, +3V nominal.
2	V_{OUTD}	DAC D Voltage Output
3	V_{OUTC}	DAC C Voltage Output
4	V_{REFL}	Reference Input Voltage Low. Sets minimum output voltage for all DACs.
5	V_{REFH}	Reference Input Voltage High. Sets maximum output voltage for all DACs.
6	V_{OUTB}	DAC B Voltage Output
7	V_{OUTA}	DAC A Voltage Output
8	AGND	Analog Ground
9	GND	Ground
10	SDI	Serial Data Input
11	CLK	Serial Data Clock
12	$\overline{CS}$	Chip Select Input
13	NIC	Not Internally Connected.
14	$\overline{LDAC}$	The selected DAC register becomes transparent when $\overline{LDAC}$ is LOW. It is in the latched state when $\overline{LDAC}$ is HIGH.
15	$\overline{RESET}$	Asynchronous Reset Input. Sets all DAC registers to either zero-scale (000_H) or mid-scale (800_H) when LOW. RESETSEL determines which code is active.
16	RESETSEL	When LOW, a LOW on $\overline{RESET}$ will cause all DAC registers to be set to code 000_H. When RESETSEL is HIGH, a LOW on $\overline{RESET}$ will set the registers to code 800_H.

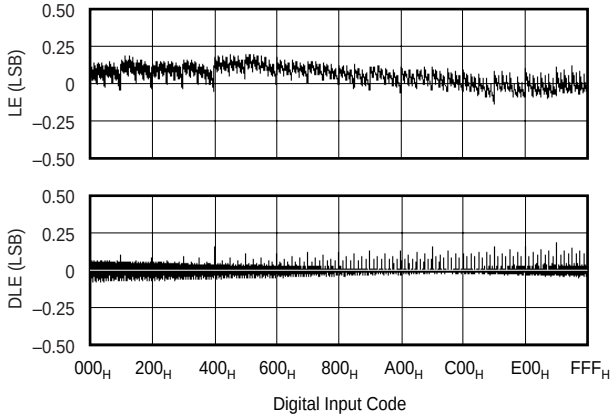
PIN DESCRIPTIONS—E Package

PIN	LABEL	DESCRIPTION
1	V_{DD}	Positive Analog Supply Voltage, +3V nominal.
2	V_{OUTD}	DAC D Voltage Output
3	V_{OUTC}	DAC C Voltage Output
4	V_{REFL}	Reference Input Voltage Low. Sets minimum output voltage for all DACs.
5	NIC	Not Internally Connected.
6	NIC	Not Internally Connected.
7	V_{REFH}	Reference Input Voltage High. Sets maximum output voltage for all DACs.
8	V_{OUTB}	DAC B Voltage Output.
9	V_{OUTA}	DAC A Voltage Output.
10	AGND	Analog Ground
11	GND	Ground
12	SDI	Serial Data Input
13	CLK	Serial Data Clock
14	$\overline{CS}$	Chip Select Input
15	NIC	Not Internally Connected.
16	NIC	Not Internally Connected.
17	NIC	Not Internally Connected.
18	$\overline{LDAC}$	The selected DAC register becomes transparent when $\overline{LDAC}$ is LOW. It is in the latched state when $\overline{LDAC}$ is HIGH.
19	$\overline{RESET}$	Asynchronous Reset Input. Sets all DAC registers to either zero-scale (000_H) or mid-scale (800_H) when LOW. RESETSEL determines which code is active.
20	RESETSEL	When LOW, a LOW on $\overline{RESET}$ will cause all DAC registers to be set to code 000_H. When RESETSEL is HIGH, a LOW on $\overline{RESET}$ will set the registers to code 800_H.

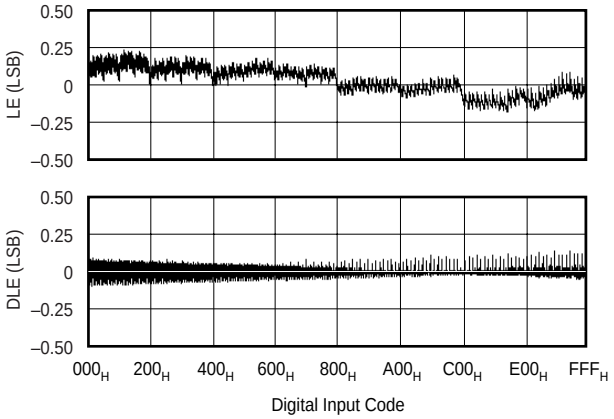
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, representative unit, unless otherwise specified.

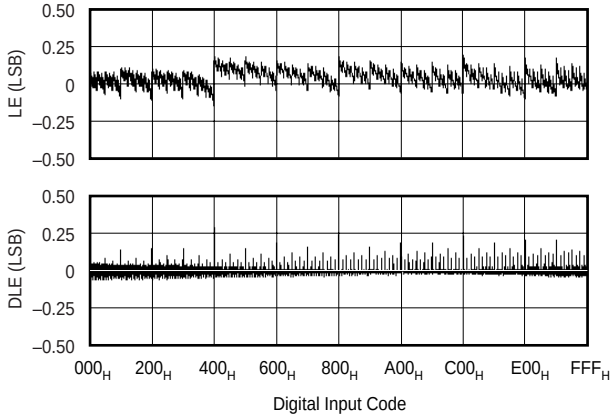
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, +25°C)



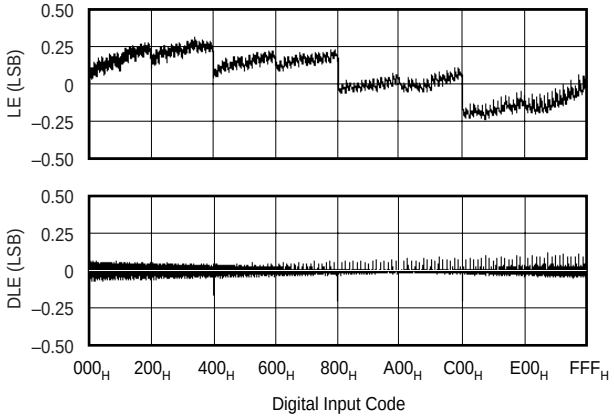
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, +85°C)



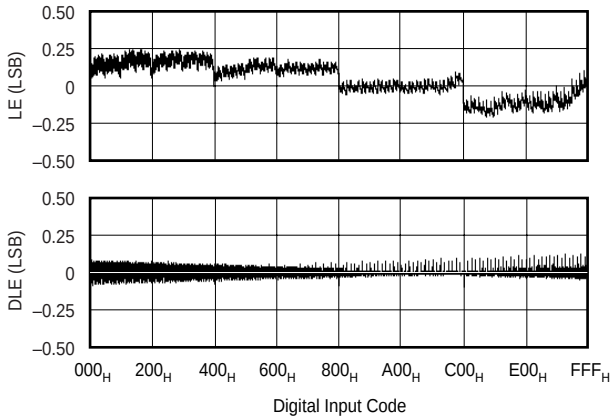
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC A, –40°C)



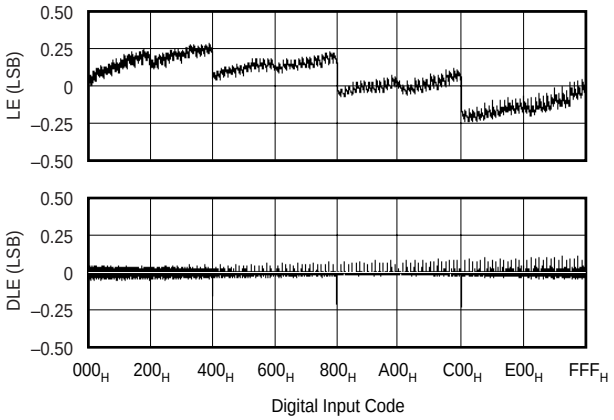
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, +25°C)



LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, +85°C)



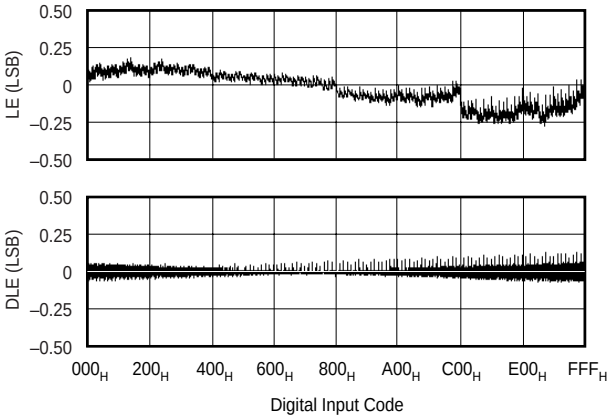
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC B, –40°C)



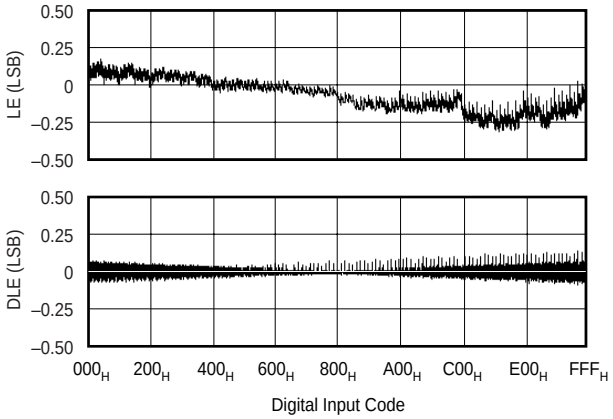
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, representative unit, unless otherwise specified.

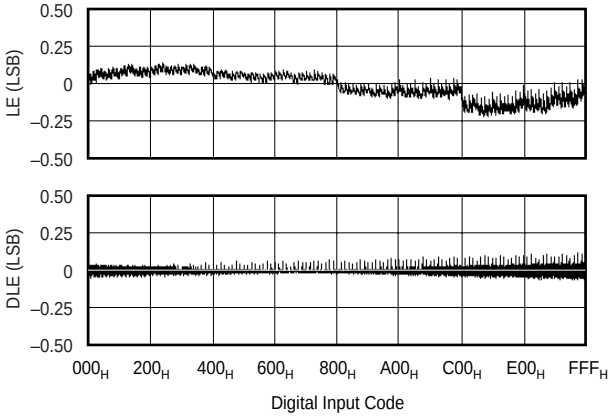
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC C, +25°C)



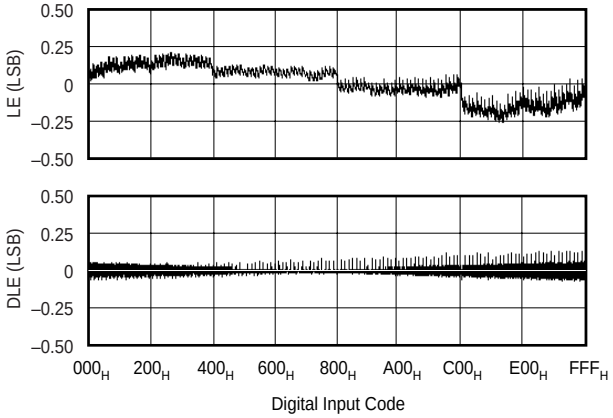
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC C, +85°C)



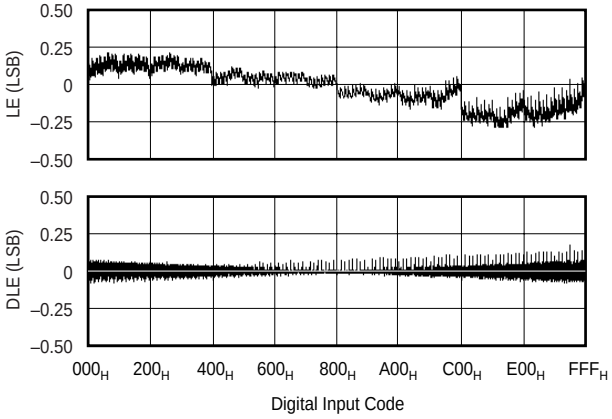
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC C, –40°C)



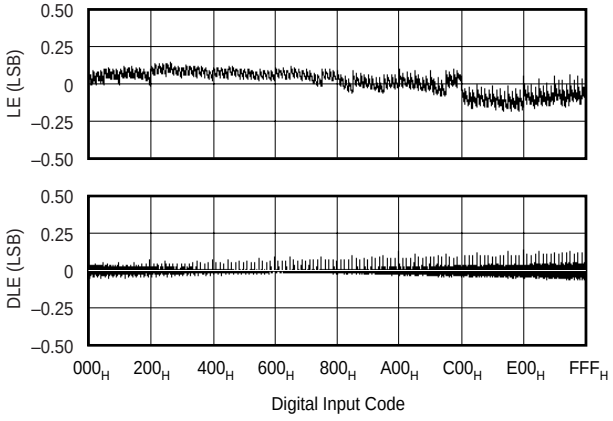
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC D, +25°C)



LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC D, +85°C)



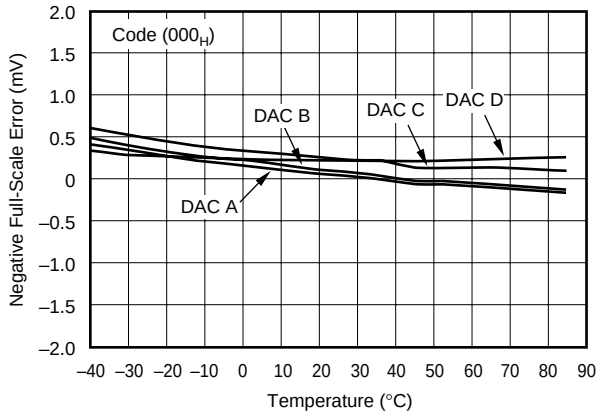
LINEARITY ERROR AND
DIFFERENTIAL LINEARITY ERROR vs CODE
(DAC D, –40°C)



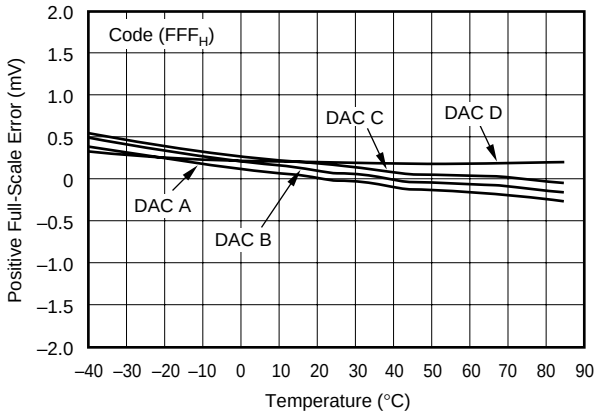
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, representative unit, unless otherwise specified.

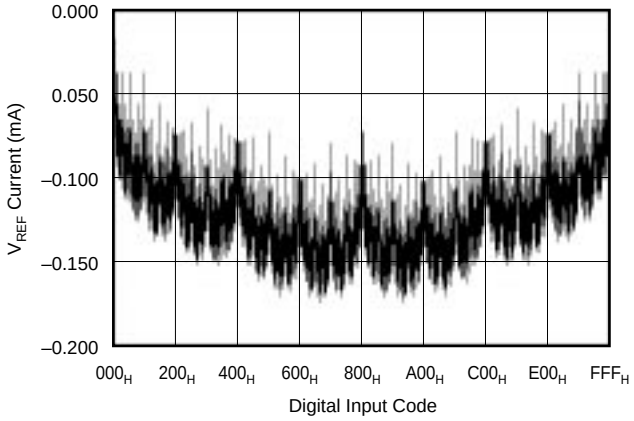
NEGATIVE FULL-SCALE ERROR vs TEMPERATURE



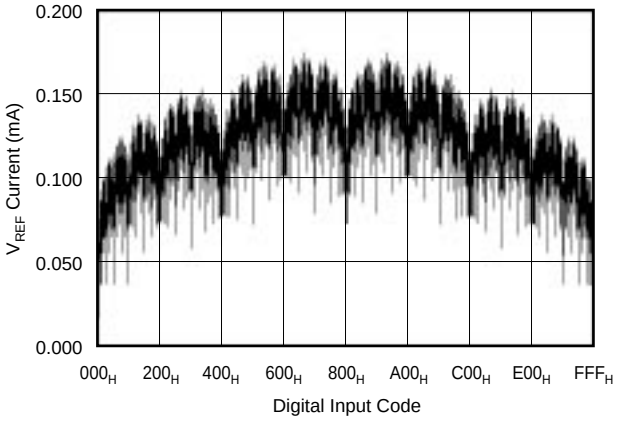
POSITIVE FULL-SCALE ERROR vs TEMPERATURE



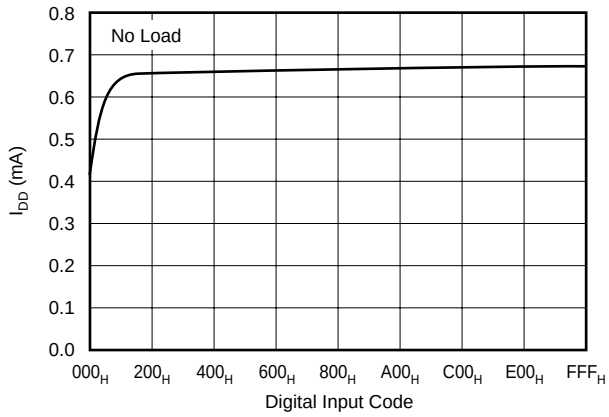
V_{REFL} CURRENT vs CODE



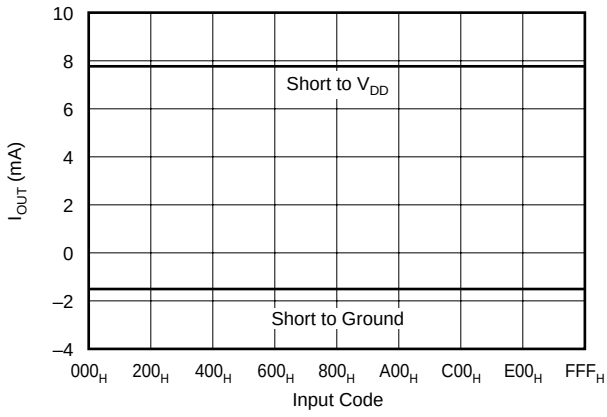
V_{REFH} CURRENT vs CODE



SUPPLY CURRENT vs DIGITAL INPUT CODE



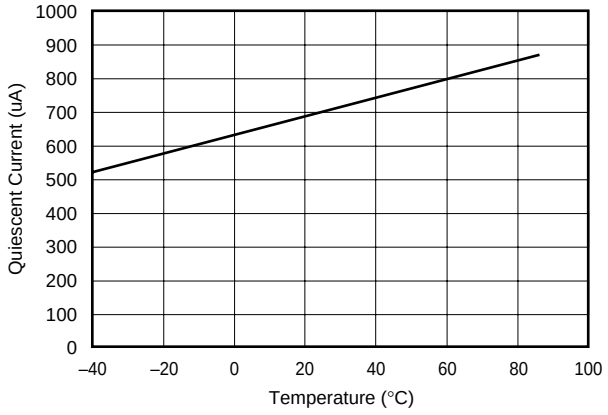
SUPPLY CURRENT LIMIT vs INPUT CODE



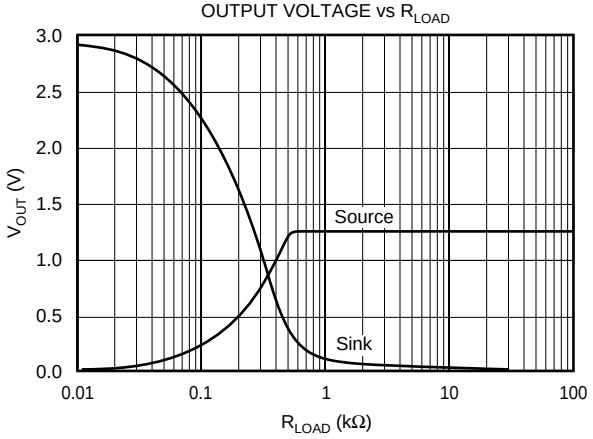
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, representative unit, unless otherwise specified.

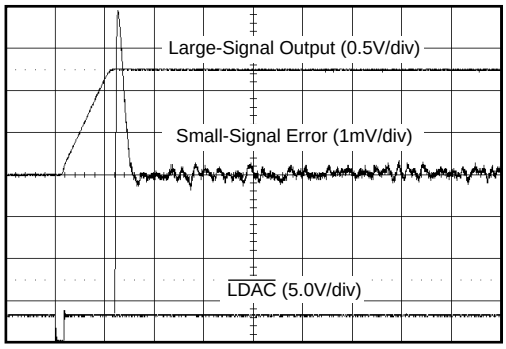
POWER SUPPLY CURRENT vs TEMPERATURE



OUTPUT VOLTAGE vs R_{LOAD}

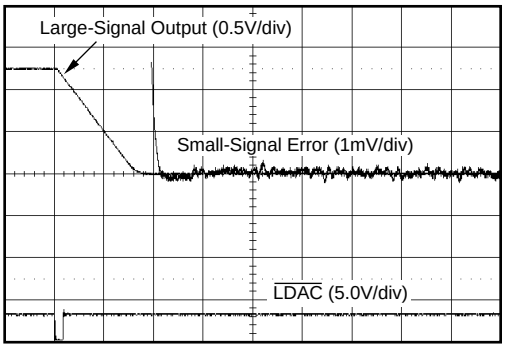


OUTPUT VOLTAGE vs SETTLING TIME
(0V to +1.25V)



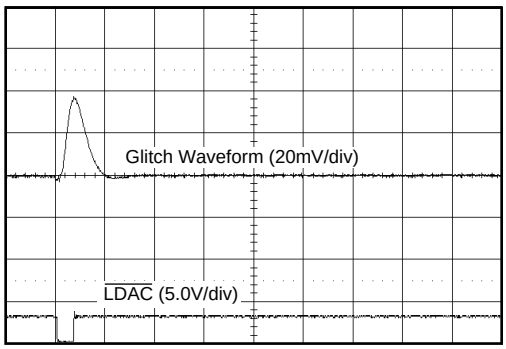
Time (2µs/div)

OUTPUT VOLTAGE vs SETTLING TIME
(+1.25V to 0V)



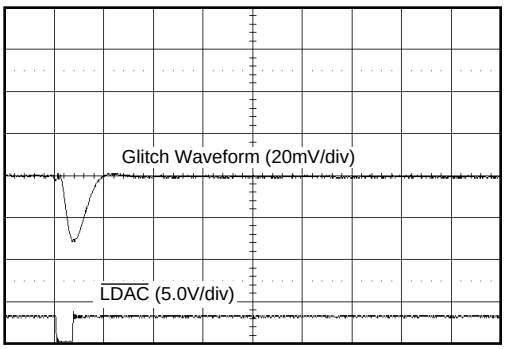
Time (2µs/div)

MID-SCALE GLITCH PERFORMANCE
(CODE $7FF_H$ to 800_H)



Time (1µs/div)

MID-SCALE GLITCH PERFORMANCE
(CODE 800_H to $7FF_H$)

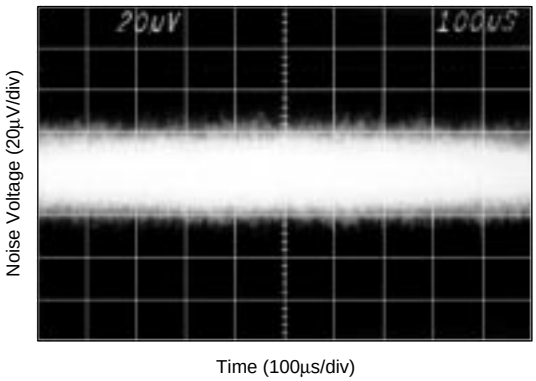


Time (1µs/div)

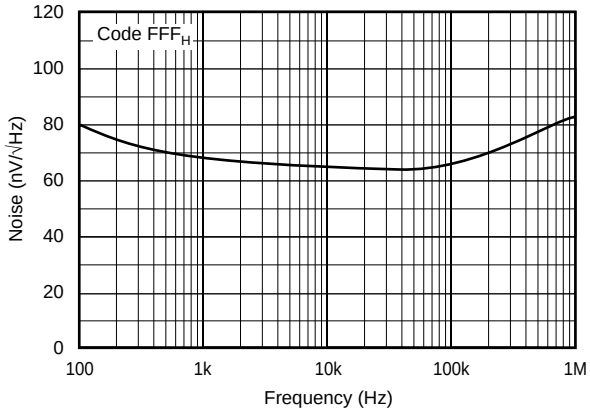
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, V_{DD} = +3V, V_{REFH} = +1.25V, and V_{REFL} = 0V, representative unit, unless otherwise specified.

WIDEBAND NOISE
(Bandwidth = 10kHz)



OUTPUT NOISE VOLTAGE vs FREQUENCY



THEORY OF OPERATION

The DAC7616 is a quad, serial input, 12-bit, voltage output DAC. The architecture is a classic R-2R ladder configuration followed by an operational amplifier that serves as a buffer. Each DAC has its own R-2R ladder network and output op amp, but all share the reference voltage inputs. The minimum voltage output ("zero-scale") and maximum voltage output ("full-scale") are set by external voltage references (V_{REFL} and V_{REFH}, respectively). The digital input is a 16-bit serial word that contains the 12-bit DAC code and a 2-bit address code that selects one of the four DACs (the two remaining bits are unused). The converter can be powered from a single +3V supply. Each device offers a reset function which immediately sets all DAC output voltages and internal registers to either zero-scale (code 000_H) or mid-scale (code 800_H). The reset code is selected by the state of the RESETSEL pin (LOW = 000_H, HIGH = 800_H). See Figure 1 for the basic operation of the DAC7616.

ANALOG OUTPUTS

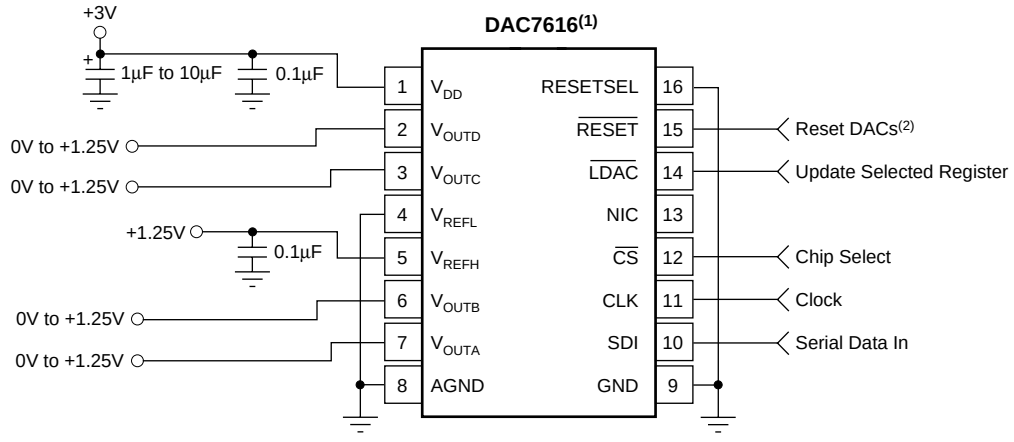
The output of the DAC7616 can swing to ground. Note that the settling time of the output op amp will be longer with voltages very near ground. Also, care must be taken when measuring the zero-scale error. If the output amplifier has a negative offset, the output voltage may not change for the first few digital input codes (000_H, 001_H, 002_H, etc.) since the output voltage cannot swing below ground.

The behavior of the output amplifier can be critical in some applications. Under short-circuit conditions (DAC output shorted to V_{DD}), the output amplifier can sink more current than it can source. See the Specifications table for more details concerning short-circuit current.

REFERENCE INPUTS

The minimum output of each DAC is equal to V_{REFL} plus a small offset voltage (essentially, the offset of the output op amp). The maximum output is equal to V_{REFH} – 1LSB plus a similar offset voltage.

The current into the reference inputs depends on the DAC output voltages and can vary from a few microamps to approximately 0.4 milliamp. Bypassing the reference voltage or voltages with a 0.1µF capacitor placed as close as possible to the DAC7616 package is strongly recommended.



NOTES: (1) U package pin configuration shown. (2) As configured, $\overline{\text{RESET}}$ LOW sets all internal registers to code 000_H (0V). If RESETSEL is HIGH, $\overline{\text{RESET}}$ LOW sets all internal registers to code 800_H (1.25V).

FIGURE 1. Basic Single-Supply Operation of the DAC7616.

DIGITAL INTERFACE

Figure 2 and Table I provide the basic timing for the DAC7616. The interface consists of a serial clock (CLK), serial data (SDI), and a load DAC signal ($\overline{\text{LDAC}}$). In addition, a chip select ($\overline{\text{CS}}$) input is available to enable serial communication when there are multiple serial devices. An asynchronous reset input ($\overline{\text{RESET}}$) is provided to simplify start-up conditions, periodic resets, or emergency resets to a known state.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
t_{DS}	Data Valid to CLK Rising	25			ns
t_{DH}	Data Held Valid after CLK Rises	20			ns
t_{CH}	CLK HIGH	30			ns
t_{CL}	CLK LOW	50			ns
t_{CSS}	$\overline{\text{CS}}$ LOW to CLK Rising	55			ns
t_{CSH}	CLK HIGH to $\overline{\text{CS}}$ Rising	15			ns
t_{LD1}	$\overline{\text{LDAC}}$ HIGH to CLK Rising	40			ns
t_{LD2}	CLK Rising to $\overline{\text{LDAC}}$ LOW	15			ns
t_{LDDW}	$\overline{\text{LDAC}}$ LOW Time	45			ns
t_{RSSH}	RESETSEL Valid to $\overline{\text{RESET}}$ LOW	25			ns
t_{RSTW}	$\overline{\text{RESET}}$ LOW Time	70			ns
t_S	Settling Time	10			µs

TABLE I. Timing Specifications (T_A = –40°C to +85°C).

The DAC code and address are provided via a 16-bit serial interface as shown in Figure 2. The first two bits select the DAC register that will be updated when $\overline{\text{LDAC}}$ goes LOW (see Table II). The next two bits are not used. The last 12 bits is the DAC code which is provided, most significant bit first.

Note that $\overline{\text{CS}}$ and CLK are combined with an OR gate, whose output controls the serial-to-parallel shift register internal to the DAC7616 (see the block diagram on the front of this data sheet). These two inputs are completely interchangeable. In addition, care must be taken with the state of CLK when $\overline{\text{CS}}$ rises at the end of a serial transfer. If CLK is LOW when $\overline{\text{CS}}$ rises, the OR gate will provide a rising edge to the shift register, shifting the internal data one additional bit. The result will be incorrect data and possible selection of the wrong DAC.

A1	A0	$\overline{\text{LDAC}}$	$\overline{\text{RESET}}$	SELECTED DAC REGISTER	STATE OF SELECTED DAC REGISTER
L(1)	L	L	H	A	Transparent
L	H	L	H	B	Transparent
H	L	L	H	C	Transparent
H	H	L	H	D	Transparent
X(2)	X	H	H	NONE	(All Latched)
X	X	X	L	ALL	Reset(3)

NOTES: (1) L = Logic LOW. (2) X = Don't Care. (3) Resets to either 000H or 800_H, per the RESETSEL state (LOW = 000_H, HIGH = 800_H). When $\overline{\text{RESET}}$ rises, all registers that are in their latched state retain the reset value.

TABLE II. Control Logic Truth Table.

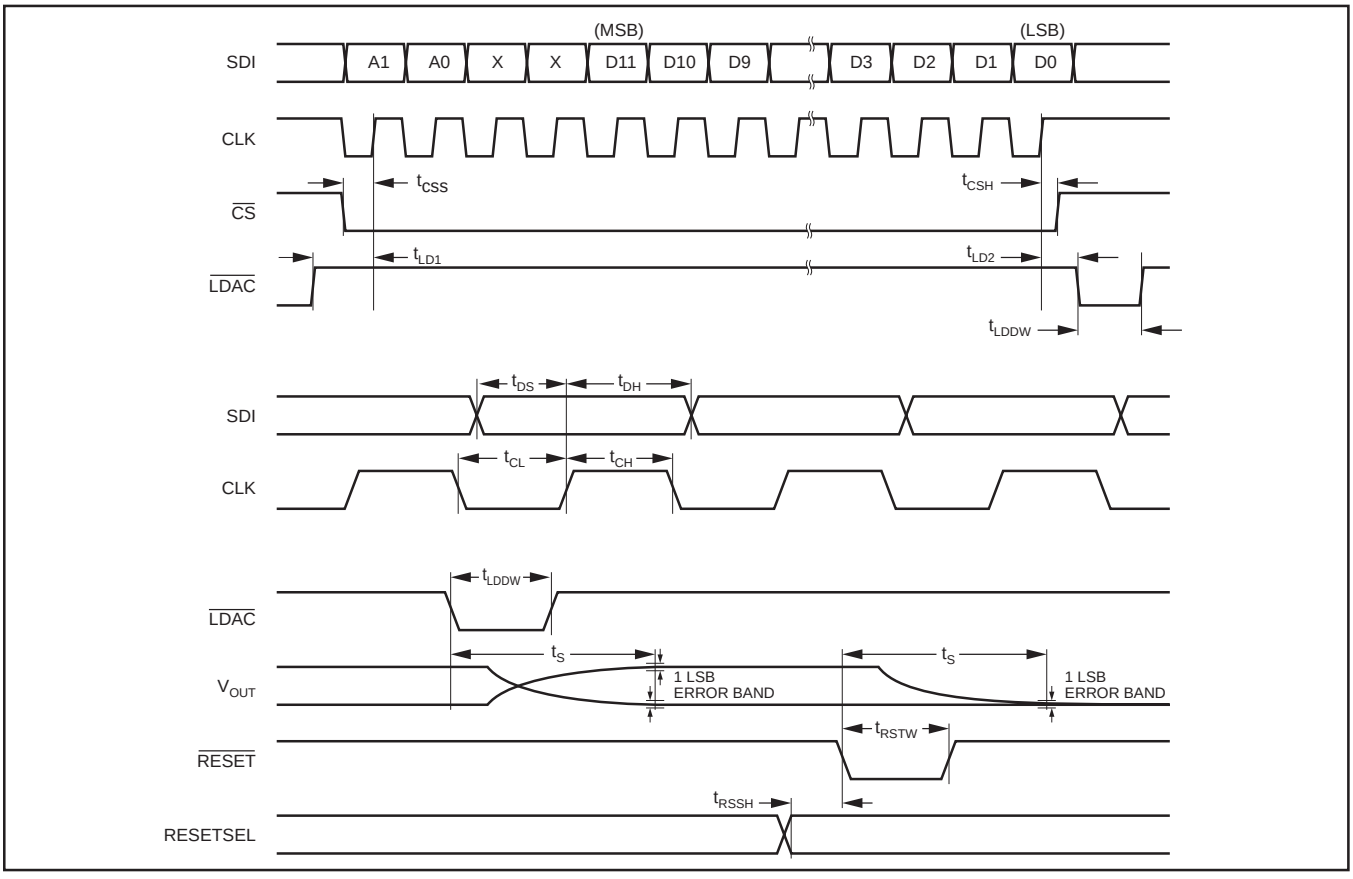


FIGURE 2. DAC7616 Timing.

If both $\overline{CS}$ and CLK are used, then $\overline{CS}$ should rise only when CLK is HIGH. If not, then either $\overline{CS}$ or CLK can be used to operate the shift register. See Table III for more information.

$\overline{CS}$[1]	CLK[1]	$\overline{LDAC}$	$\overline{RESET}$	SERIAL SHIFT REGISTER
H[2]	X[3]	H	H	No Change
L[4]	L	H	H	No Change
L	↑[5]	H	H	Advanced One Bit
↑	L	H	H	Advanced One Bit
H[6]	X	L[7]	H	No Change
H[6]	X	H	L[8]	No Change

NOTES: (1) $\overline{CS}$ and CLK are interchangeable. (2) H = Logic HIGH. (3) X = Don't Care. (4) L = Logic LOW (5) = Positive Logic Transition. (6) A HIGH value is suggested in order to avoid a "false clock" from advancing the shift register and changing the shift register. (7) If data is clocked into the serial register while $\overline{LDAC}$ is LOW, the selected DAC register will change as the shift register bits "flow" through A1 and A0. This will corrupt the data in each DAC register that has been erroneously selected. (8) $\overline{RESET}$ LOW causes no change in the contents of the serial shift register.

TABLE III. Serial Shift Register Truth Table.

Digital Input Coding

The DAC7616 input data is in Straight Binary format. The output voltage is given by the following equation:

$$V_{OUT} = V_{REFL} + \frac{(V_{REFH} - V_{REFL}) \bullet N}{4096}$$

where N is the digital input code (in decimal). This equation does not include the effects of offset (zero-scale) or gain (full-scale) errors.

LAYOUT

A precision analog component requires careful layout, adequate bypassing, and clean, well-regulated power supplies. As the DAC7616 offers single-supply operation, it will often be used in close proximity with digital logic, microcontrollers, microprocessors, and digital signal processors. The more digital logic present in the design and the higher the switching speed, the more difficult it will be to keep digital noise from appearing at the converter output.

Because the DAC7616 has a single ground pin, all return currents, including digital and analog return currents, must flow through the GND pin. Ideally, GND should be connected directly to an analog ground plane. This plane should be separate from the ground connection for the digital components until they were connected at the power entry point of the system (see Figure 3).

The power applied to V_{DD} should be well regulated and low noise. Switching power supplies and DC/DC converters will often have high-frequency glitches or spikes riding on the output voltage. In addition, digital components can create similar high-frequency spikes as their internal logic switches states. This noise can easily couple into the DAC output voltage through various paths between the power connections and analog output.

As with the GND connection, V_{DD} should be connected to a +3V power supply plane or trace that is separate from the connection for digital logic until they are connected at the power entry point. In addition, the 1µF to 10µF and 0.1µF capacitors shown in Figure 4 are strongly recommended. In some situations, additional bypassing may be required, such as a 100µF electrolytic capacitor or even a "Pi" filter made up of inductors and capacitors—all designed to essentially lowpass filter the +3V supply, removing the high frequency noise (see Figure 3).

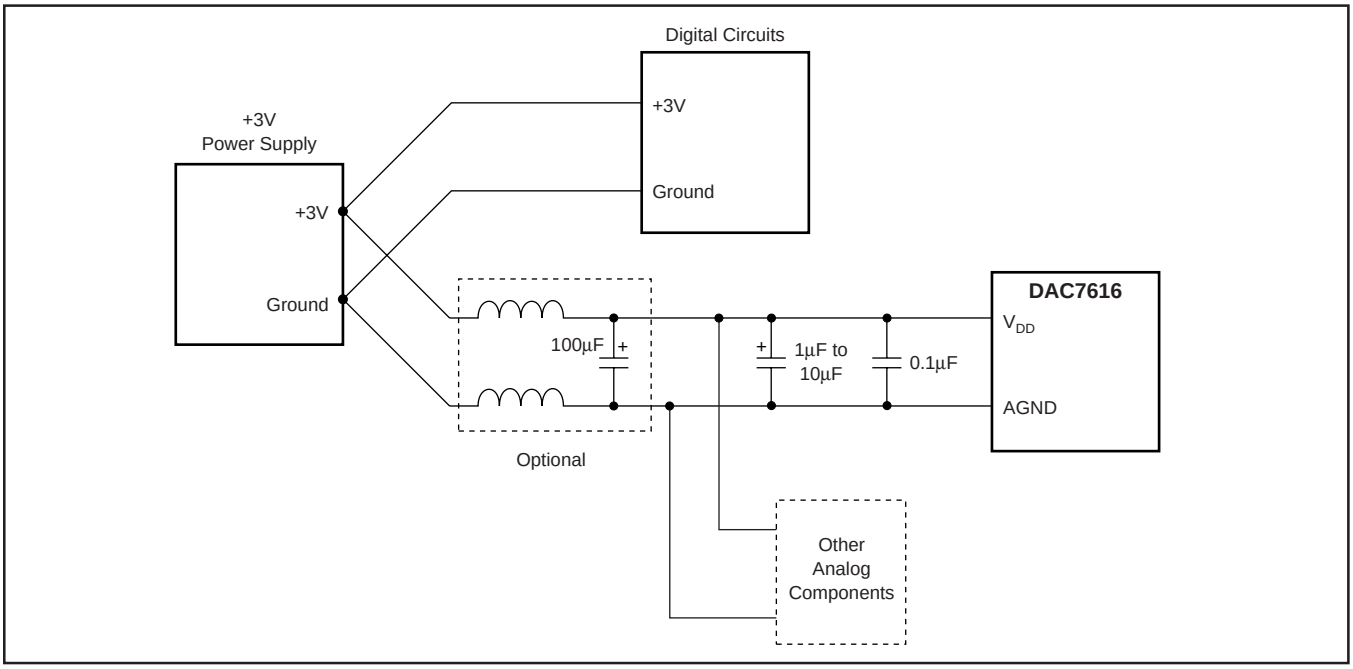


FIGURE 3. Suggested Power and Ground Connections for a DAC7616 Sharing a +3V Supply with a Digital System.

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Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265