



# QUAD, 16-BIT, LOW-POWER, VOLTAGE OUTPUT, I<sup>C</sup> INTERFACE DIGITAL-TO-ANALOG CONVERTER

# FEATURES

- Micropower Operation: 950 µA at 5 V V<sub>DD</sub>
- **Power-On Reset to Zero**
- +2.7-V to +5.5-V Analog Power Supply
- **16-Bit Monotonic**
- Settling Time: 10 $\mu s$  to  $\pm 0.003\%$  FSR
- I<sup>2</sup>C<sup>™</sup> Interface Up to 3.4 Mbps
- **Data Transmit Capability**
- **On-Chip Output Buffer Amplifier. Rail-to-Rail** Operation
- **Double-Buffered Input Register**
- Address Support for up to Sixteen DAC8574s
- Synchronous Update Support for up to 64 Channels
- Operation From –40°C to 105°C
- Small 16-Lead TSSOP Package

# APPLICATIONS

- Process Control
- **Data Acquisition Systems**
- **Closed-Loop Servo Control**
- **PC Peripherals**

A

Portable Instrumentation

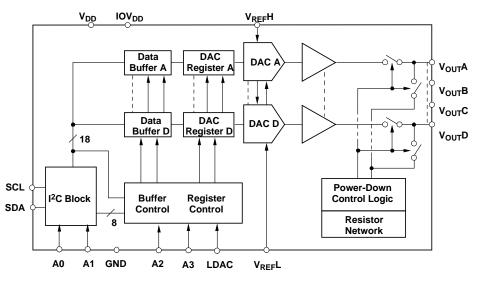
# DESCRIPTION

The DAC8574 is a low-power, quad channel, 16-bit buffered voltage output DAC. Its on-chip precision output amplifier allows rail-to-rail output swing to be achieved. The DAC8574 utilizes an I<sup>2</sup>C compatible two wire serial interface supporting high-speed interface mode with address support of up to sixteen DAC8574s for a total of 64 channels on the bus.

The DAC8574 requires an external reference voltage to set the output range of the DAC. The DAC8574 incorporates a power-on-reset circuit that ensures that the DAC output powers up at zero volts and remains there until a valid write takes place to the device. The DAC8574 contains a power-down feature, accessed via the internal control register, that reduces the current consumption of the device to 200 nA at 5 V.

The low power consumption of this part in normal operation makes it ideally suited to portable battery operated equipment. The power consumption is less than 5 mW at  $V_{DD} = 5$  V reducing to 1  $\mu$ W in power-down mode.

The DAC8574 is available in a 16-lead TSSOP package.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet. I<sup>2</sup>C is a trademark of Philips Corporation.



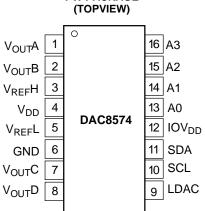


This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

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	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFICATION TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA
DAC8574	16-TSSOP	PW	–40°C TO +105°C	D8574I	DAC8574IPW	90 Piece Tube
					DAC8574IPWR	2000 Piece Tape and Reel



**PW PACKAGE** 

#### **PIN DESCRIPTIONS**

PIN	NAME	DESCRIPTION
1	V <sub>OUT</sub> A	Analog output voltage from DAC A
2	V <sub>OUT</sub> B	Analog output voltage from DAC B
3	V <sub>REF</sub> H	Positive reference voltage input
4	V <sub>DD</sub>	Analog voltage supply input
5	V <sub>REF</sub> L	Negative reference voltage input
6	GND	Ground reference point for all circuitry on the part
7	V <sub>OUT</sub> C	Analog output voltage from DAC C
8	V <sub>OUT</sub> D	Analog output voltage from DAC D
9	LDAC	H/W synchronous V <sub>OUT</sub> update
10	SCL	Serial clock input
11	SDA	Serial data input
12	IOV <sub>DD</sub>	I/O voltage supply input
13	A0	Device address select - I <sup>2</sup> C
14	A1	Device address select - I <sup>2</sup> C
15	A2	Device address select - Extended
16	A3	Device address select - Extended

# ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

V <sub>DD</sub> to GND		-0.3 V to +6 V
Digital input voltage to GND		-0.3 V to V <sub>DD</sub> + 0.3 V
V <sub>OUT</sub> to GND		0.3 V to V <sub>DD</sub> + 0.3 V
Operating temperature range		40°C to +105°C
Storage temperature range		65°C to +150°C
Junction temperature range (	T <sub>J</sub> max)	+150°C
Power dissipation:	Thermal impedance (OJA)	118°C/W
	Thermal impedance (OJC)	29°C/W
Lead temperature, soldering:	Vapor phase (60s)	215°C
	Infrared (15s)	220°C

(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.

# **ELECTRICAL CHARACTERISTICS**

 $V_{DD}$  = 2.7 V to 5.5 V,  $R_L$  = 2 k $\Omega$  to GND;  $C_L$  = 200 pF to GND; all specifications -40°C to +105°C, unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
STATIC PERFORMANCE <sup>(1)(2)</sup>					
Resolution		16			Bits
Relative accuracy				$\pm0.0987$	% of FSR
Differential nonlinearity	Specified monotonic by design			± 1	LSB
Zero-scale error			5	20	mV
Full-scale error			-0.15	±1.0	% of FSR
Gain error				± 1.0	% of FSR
Zero code error drift			±7		µV/∘C
Gain temperature coefficient			± 3		ppm of FSR/°C
PSRR	$V_{DD} = 5 V$		0.75		mV/V
OUTPUT CHARACTERISTICS <sup>(3)</sup>	·				
Output voltage range		0		V <sub>REF</sub> H	V
Output voltage settling time (full scale)	$R_L = 2 \text{ k}\Omega; 0 \text{ pF} < C_L < 200 \text{ pF}$		8	10	μs
	$R_{L} = 2 k\Omega; C_{L} = 500 pF$		12		μs
Slew rate			1		V/µs
DC crosstalk			0.25		LSB
AC crosstalk	1 kHz Sine Wave		-100	-96	dB
Capacitive load stability	R <sub>L</sub> = ∞		470		pF
	$R_L = 2 k\Omega$		1000		pF
Digital-to-analog glitch impulse	1 LSB change around major carry		20		nV-s
Digital feedthrough			0.5		nV-s
DC output impedance			1		Ω
Short-circuit current	V <sub>DD</sub> = 5 V		50		mA
	V <sub>DD</sub> = 3 V		20		mA
Power-up time	Coming out of power-down mode, V <sub>DD</sub> = +5 V		2.5		μs
	Coming out of power-down mode, $V_{DD}$ = +3 V		5		μs
REFERENCE INPUT					
V <sub>REF</sub> H Input range		0		$V_{DD}$	V
V <sub>REF</sub> L Input range	$V_{REF}L < V_{REF}H$	0	GND	$V_{DD}$	V
Reference input impedance			35		kΩ
Reference current	$V_{REF} = V_{DD} = +5 V$		135	180	μA
	V <sub>REF</sub> =V <sub>DD</sub> = +3 V		80	120	
LOGIC INPUTS <sup>(3)</sup>	·				
Input current				± 1	μA
V <sub>IN_L</sub> , Input low voltage				0.3xIOV <sub>DD</sub>	V
V <sub>IN_H</sub> , Input high voltage	V <sub>DD</sub> = 3 V	0.7xIOV <sub>DD</sub>			V
Pin Capacitance				3	pF
POWER REQUIREMENTS	·				-
V <sub>DD</sub> , IOV <sub>DD</sub>		2.7		5.5	V
I <sub>DD</sub> (normal operation)	Excluding load current				
I <sub>DD</sub> @ V <sub>DD</sub> =+3.6V to +5.5V	V <sub>IH</sub> = IOV <sub>DD</sub> and V <sub>IL</sub> =GND		950	1600	μA
I <sub>DD</sub> @ V <sub>DD</sub> =+2.7V to +3.6V	V <sub>IH</sub> = IOV <sub>DD</sub> and V <sub>IL</sub> =GND		900	1500	μA

Linearity tested using a reduced code range of 485 to 64714; output unloaded.
 V<sub>REF</sub>H = V<sub>DD</sub> - 0.1 V, V<sub>REF</sub>L = GND
 Specified by design and characterization, not production tested.

# **ELECTRICAL CHARACTERISTICS (continued)**

 $V_{DD}$  = 2.7 V to 5.5 V,  $R_L$  = 2 k $\Omega$  to GND;  $C_L$  = 200 pF to GND; all specifications -40°C to +105°C, unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I <sub>DD</sub> (all power-down modes)					
I <sub>DD</sub> @ V <sub>DD</sub> =+3.6V to +5.5V	V <sub>IH</sub> = IOV <sub>DD</sub> and IOV <sub>IL</sub> =GND		0.2	1	μA
I <sub>DD</sub> @ V <sub>DD</sub> =+2.7V to +3.6V	V <sub>IH</sub> = V <sub>DD</sub> and V <sub>IL</sub> =GND		0.05	1	μA
POWER EFFICIENCY		L.			
I <sub>OUT</sub> /I <sub>DD</sub>	$I_{LOAD}$ = 2 mA, $V_{DD}$ = +5 V		93%		
TEMPERATURE RANGE		L.			
Specified performance		-40		+105	°C

# TIMING CHARACTERISTICS

 $V_{DD}$  = 2.7 V to 5.5 V,  $R_L$  = 2 k $\Omega$  to GND; all specifications -40°C to +105°C, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP M	AX	UNITS
		Standard mode			100	kHz
,		Fast mode			400	kHz
f <sub>SCL</sub>	SCL clock frequency	High-Speed Mode, C <sub>B</sub> = 100 pF max			3.4	MHz
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$			1.7	MHz
+	Bus free time between a	Standard mode	4.7			μs
t <sub>BUF</sub>	STOP and START condition	Fast mode	1.3			μs
		Standard mode	4.0			μs
t <sub>HD</sub> ; t <sub>STA</sub>	Hold time (repeated) START condition	Fast mode	600			ns
	0011011	High-speed mode	160			ns
		Standard mode	4.7			μs
+	LOW pariad of the SCL alask	Fast mode	1.3			μs
t <sub>LOW</sub>	LOW period of the SCL clock	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	160			ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	320			ns
		Standard mode	4.0			μs
		Fast mode	600			ns
t <sub>HIGH</sub>	HIGH period of the SCL clock	High-Speed Mode, C <sub>B</sub> = 100 pF max	60			ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	120			ns
		Standard mode	4.7			μs
t <sub>SU</sub> ; t <sub>STA</sub>	Setup time for a repeated START condition	Fast mode	600			ns
		High-speed mode	160			ns
		Standard mode	250			ns
t <sub>SU</sub> ; t <sub>DAT</sub>	Data setup time	Fast mode	100			ns
		High-speed mode	10			ns
		Standard mode	0	3	.45	μs
4 . 4	Data hold time	Fast mode	0		0.9	μs
t <sub>HD</sub> ; t <sub>DAT</sub>	Data hold time	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	0		70	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	0		150	ns
		Standard mode		10	000	ns
+	Pigo time of SCL gigan	Fast mode	20 + 0.1C <sub>B</sub>	:	300	ns
t <sub>RCL</sub>	Rise time of SCL signal	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	10		40	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	20		80	ns

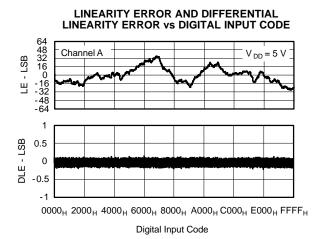
# TIMING CHARACTERISTICS (continued)

$V_{DD}$ = 2.7 V to 5.5 V, R <sub>L</sub> = 2 k $\Omega$ to GND; all specifications -40°C to +105°C, unless other	wise specified.
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SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP M	٩X	UNITS
		Standard mode		10	00	ns
t- ou u	Rise time of SCL signal after a	Fast mode	20 + 0.1C <sub>B</sub>	3	00	ns
t <sub>RCL1</sub>	repeated START condition and after an acknowledge BIT	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	10		80	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	20	1	60	ns
		Standard mode		3	00	ns
	Foll time of SCL signal	Fast mode	20 + 0.1C <sub>B</sub>	3	00	ns
t <sub>FCL</sub>	Fall time of SCL signal	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	10		40	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	20		80	ns
		Standard mode		10	00	ns
	Diag time of SDA signal	Fast mode	20 + 0.1C <sub>B</sub>	3	00	ns
t <sub>RDA</sub>	Rise time of SDA signal	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	10		80	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	20	1	60	ns
		Standard mode		3	00	ns
+	Fall time of SDA signal	Fast mode	20 + 0.1C <sub>B</sub>	3	00	ns
t <sub>FDA</sub>	Fail time of SDA signal	High-speed mode, $C_B = 100 \text{ pF} \text{ max}$	10		80	ns
		High-speed mode, $C_B = 400 \text{ pF} \text{ max}$	20	1	60	ns
		Standard mode	4.0			μs
t <sub>SU</sub> ; t <sub>STO</sub>	Setup time for STOP condition	Fast mode	600			ns
		High-speed mode	160			ns
C <sub>B</sub>	Capacitive load for SDA and SCL			4	00	pF
+	Pulse width of spike sup-	Fast mode			50	ns
t <sub>SP</sub>	pressed	High-speed mode			10	ns
V <sub>NH</sub>	Noise margin at the HIGH	Standard mode				
	level for each connected de-	Fast mode	0.2 V <sub>DD</sub>			V
	vice (including hysteresis)	High-speed mode				
	Noise margin at the LOW level	Standard mode				
V <sub>NL</sub>	for each connected device	Fast mode	0.1 V <sub>DD</sub>			V
	(including hysteresis)	High-speed mode				

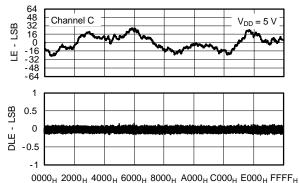
# TYPICAL CHARACTERISTICS

At  $T_A = +25^{\circ}C$ , unless otherwise noted.



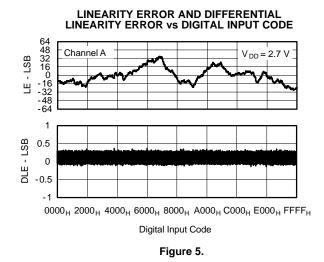
#### Figure 1.

# LINEARITY ERROR AND DIFFERENTIAL LINEARITY ERROR vs DIGITAL INPUT CODE

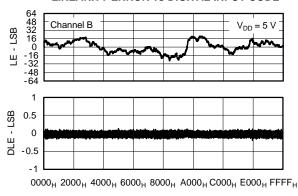


Digital Input Code

Figure 3.



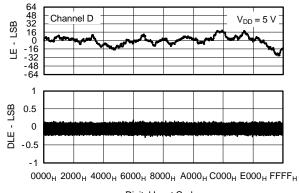
LINEARITY ERROR AND DIFFERENTIAL LINEARITY ERROR vs DIGITAL INPUT CODE



Digital Input Code

Figure 2.

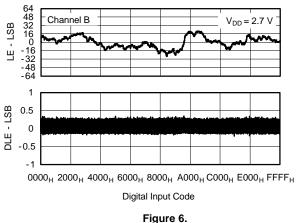
# LINEARITY ERROR AND DIFFERENTIAL LINEARITY ERROR vs DIGITAL INPUT CODE



Digital Input Code

Figure 4.

# LINEARITY ERROR AND DIFFERENTIAL LINEARITY ERROR vs DIGITAL INPUT CODE



# **TYPICAL CHARACTERISTICS (continued)**

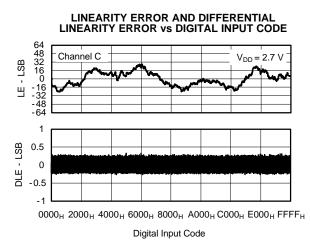
At  $T_A = +25^{\circ}C$ , unless otherwise noted.

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#### Figure 7.



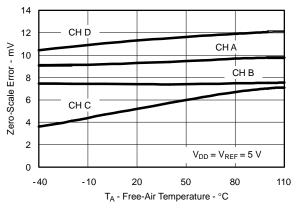
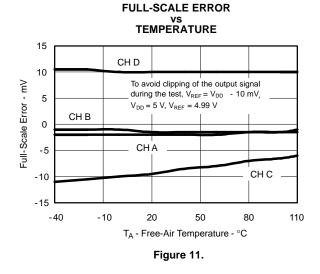
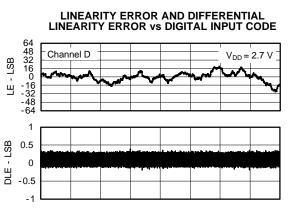


Figure 9.



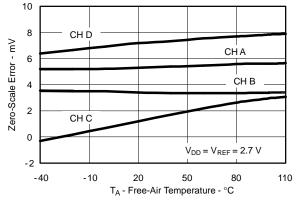


0000\_H 2000\_H 4000\_H 6000\_H 8000\_H A000\_H C000\_H E000\_H FFFF\_H

Digital Input Code

Figure 8.

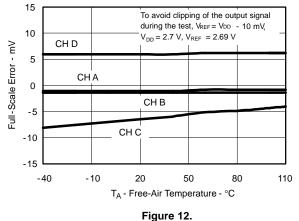






# FULL-SCALE ERROR

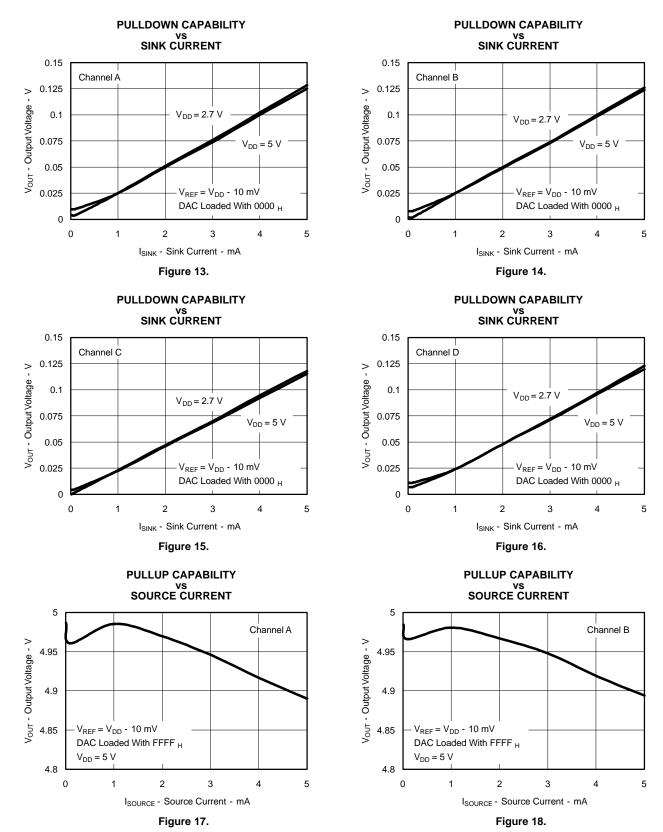
vs TEMPERATURE





# TYPICAL CHARACTERISTICS (continued)

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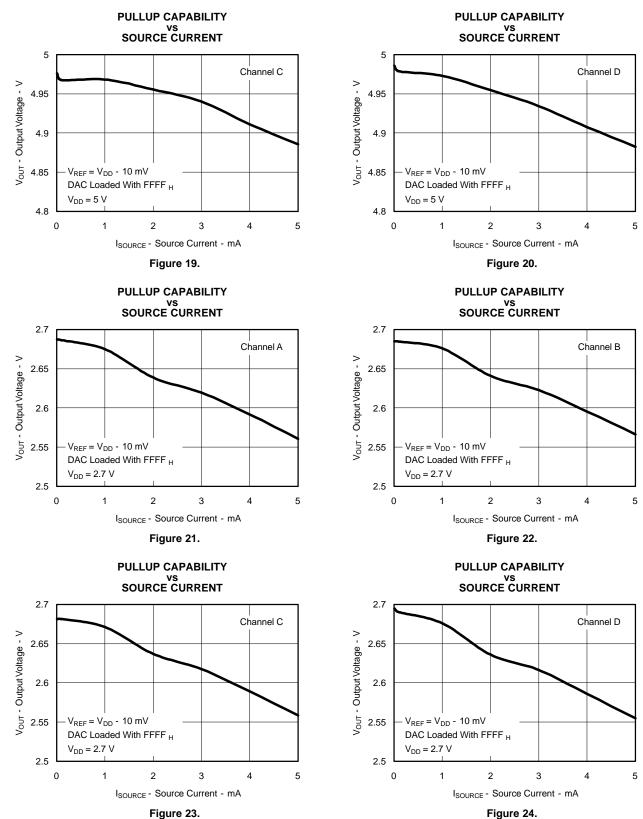




# **TYPICAL CHARACTERISTICS (continued)**

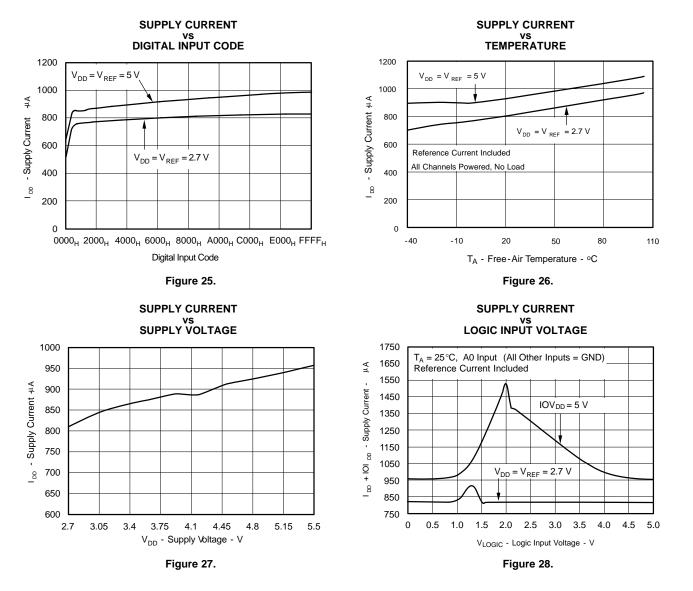
At  $T_A = +25^{\circ}C$ , unless otherwise noted.

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# **TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^{\circ}C$ , unless otherwise noted.

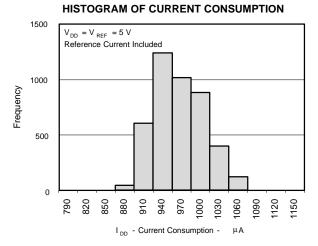


# **TYPICAL CHARACTERISTICS (continued)**

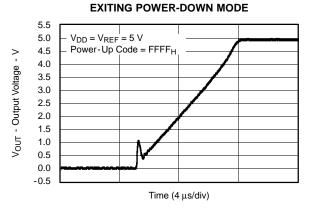
At  $T_A = +25^{\circ}C$ , unless otherwise noted.

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#### Figure 29.





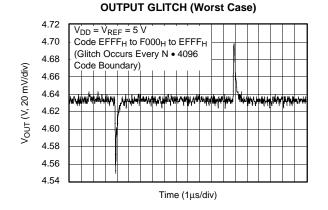
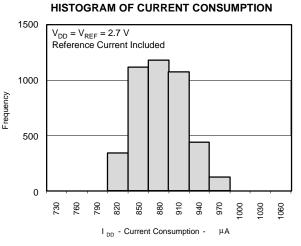


Figure 33.



#### Figure 30.

#### **OUTPUT GLITCH (Mid-Scale)**

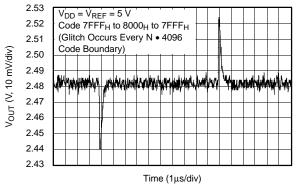
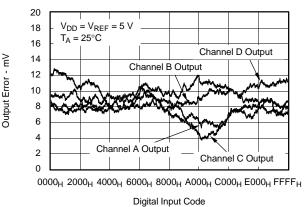


Figure 32.

#### ABSOLUTE ERROR

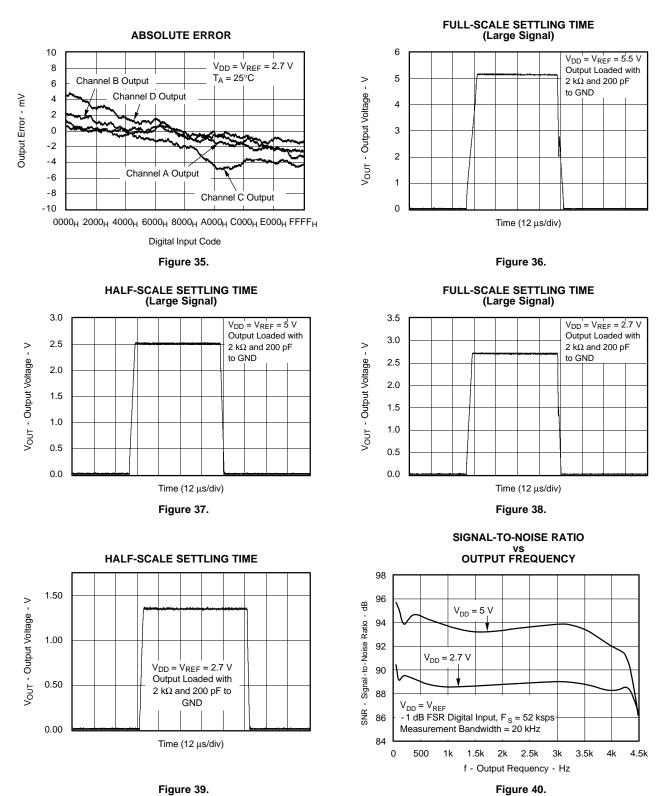






#### TYPICAL CHARACTERISTICS (continued)

At  $T_A = +25^{\circ}C$ , unless otherwise noted.





# **TYPICAL CHARACTERISTICS (continued)**

At  $T_A = +25^{\circ}C$ , unless otherwise noted.

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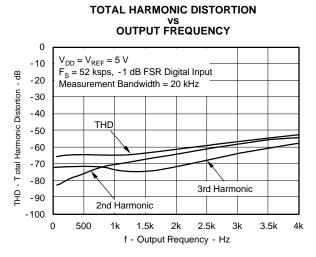


Figure 41.

FULL-SCALE SETTLING TIME (Small-Signal-Positive Going Step)

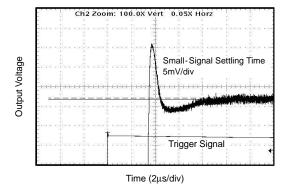


Figure 43.

VS OUTPUT FREQUENCY 0  $V_{DD} = V_{REF} = 2.7 V$ -10  $F_{S} = 52$  ksps, -1 dB FSR Digital Input THD - T otal Harmonic Distortion - dB -20 Measurement Bandwidth = 20 kHz -30 -40 THD -50 -60 -70 -80 -90 2nd Harmonic 3rd Harmonic -100 0 500 1k 1.5k 2k 2.5k 3k 3.5k 4k f - Output Frequency - Hz

TOTAL HARMONIC DISTORTION



FULL-SCALE SETTLING TIME (Small-Signal-Negative Going Step)

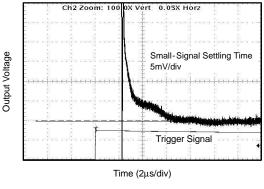


Figure 44.

# THEORY OF OPERATION

# **D/A SECTION**

The architecture of the DAC8574 consists of a string DAC followed by an output buffer amplifier. Figure 45 shows a generalized block diagram of the DAC architecture.

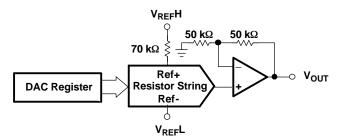


Figure 45. R-String DAC Architecture

The input coding to the DAC8574 is unsigned binary, which gives the ideal output voltage as:

 $V_{OUT} = V_{REF}L + (V_{REF}H - V_{REF}L) \times \frac{D}{65536}$ 

Where D = decimal equivalent of the binary code that is loaded to the DAC register; it can range from 0 to 65535.

# **RESISTOR STRING**

The resistor string section is shown in Figure 46. It is basically a divide-by-2 resistor, followed by a string of resistors, each of value R. The code loaded into the DAC register determines at which node on the string the voltage is tapped off to be fed into the output amplifier by closing one of the switches connecting the string to the amplifier. Because the architecture consists of a string of resistors, it is specified monotonic.

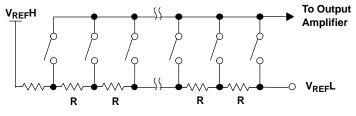


Figure 46. Typical Resistor String

# **Output Amplifier**

The output buffer is a gain-of-2 noninverting amplifiers, capable of generating rail-to-rail voltages on its output, which gives an output range of 0V to  $V_{DD}$ . It is capable of driving a load of 2 k $\Omega$  in parallel with 1000 pF to GND. The source and sink capabilities of the output amplifier can be seen in the typical curves. The slew rate is 1 V/µs with a half-scale settling time of 8 µs with the output unloaded.

# I<sup>2</sup>C Interface

I<sup>2</sup>C is a 2-wire serial interface developed by Philips Semiconductor (see I<sup>2</sup>C-Bus Specification, Version 2.1, January 2000). The bus consists of a data line (SDA) and a clock line (SCL) with pullup structures. When the bus is *idle*, both SDA and SCL lines are pulled high. All the I<sup>2</sup>C compatible devices connect to the I<sup>2</sup>C bus through open drain I/O pins, SDA and SCL. A *master* device, usually a microcontroller or a digital signal processor, controls the bus. The master is responsible for generating the SCL signal and device addresses. The master also generates specific conditions that indicate the START and STOP of data transfer. A *slave* device receives and/or transmits data on the bus under control of the master device.

# THEORY OF OPERATION (continued)

The DAC8574 works as a slave and supports the following data transfer *modes*, as defined in the I<sup>2</sup>C-Bus Specification: standard mode (100 kbps), fast mode (400 kbps), and high-speed mode (3.4 Mbps). The data transfer protocol for standard and fast modes is exactly the same, therefore they are referred to as F/S-mode in this document. The protocol for high-speed mode is different from the F/S-mode, and it is referred to as HS-mode. The DAC8574 supports 7-bit addressing; 10-bit addressing, and general call address are *not* supported.

# **F/S-Mode Protocol**

- The *master* initiates data transfer by generating a *start condition*. The *start condition* is when a high-to-low transition occurs on the SDA line while SCL is high, as shown in Figure 47. All I<sup>2</sup>C-compatible devices should recognize a *start condition*.
- The master then generates the SCL pulses, and transmits the 7-bit address and the *read/write direction bit* R/W on the SDA line. During all transmissions, the master ensures that data is *valid*. A *valid data* condition requires the SDA line to be stable during the entire high period of the clock pulse (see Figure 48). All devices recognize the address sent by the master and compare it to their internal fixed addresses. Only the slave device with a matching address generates an *acknowledge* (see Figure 49) by pulling the SDA line low during the entire high period of the 9th SCL cycle. Upon detecting this acknowledge, the master knows that communication link with a slave has been established.
- The master generates further SCL cycles to either *transmit* data to the slave (R/W bit 1) or *receive* data from the slave (R/W bit 0). In either case, the *receiver* needs to acknowledge the data sent by the *transmitter*. So acknowledge signal can either be generated by the master or by the slave, depending on which one is the receiver. 9-bit valid data sequences consisting of 8-bit data and 1-bit acknowledge can continue as long as necessary.
- To signal the end of the data transfer, the master generates a *stop condition* by pulling the SDA line from low to high while the SCL line is high (see Figure 47). This releases the bus and stops the communication link with the addressed slave. All I<sup>2</sup>C compatible devices must recognize the stop condition. Upon the receipt of a *stop condition*, all devices know that the bus is released, and they wait for a *start condition* followed by a matching address.

#### **H/S-Mode Protocol**

- When the bus is idle, both SDA and SCL lines are pulled high by the pullup devices.
- The master generates a start condition followed by a valid serial byte containing H/S master code 00001XXX. This transmission is made in F/S-mode at no more than 400 Kbps. No device is allowed to acknowledge the H/S master code, but all devices must recognize it and switch their internal setting to support 3.4 Mbps operation.
- The master then generates a *repeated start condition* (a repeated start condition has the same timing as the start condition). After this repeated start condition, the protocol is the same as F/S-mode, except that transmission speeds up to 3.4 Mbps are allowed. A stop condition ends the H/S-mode and switches all the internal settings of the slave devices to support the F/S-mode. Instead of using a stop condition, repeated start conditions should be used to secure the bus in H/S-mode.

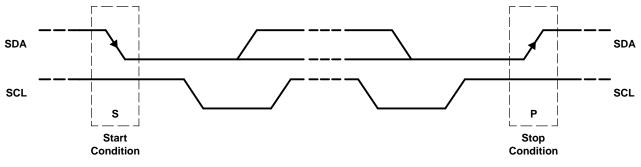


Figure 47. START and STOP Conditions

# **THEORY OF OPERATION (continued)**

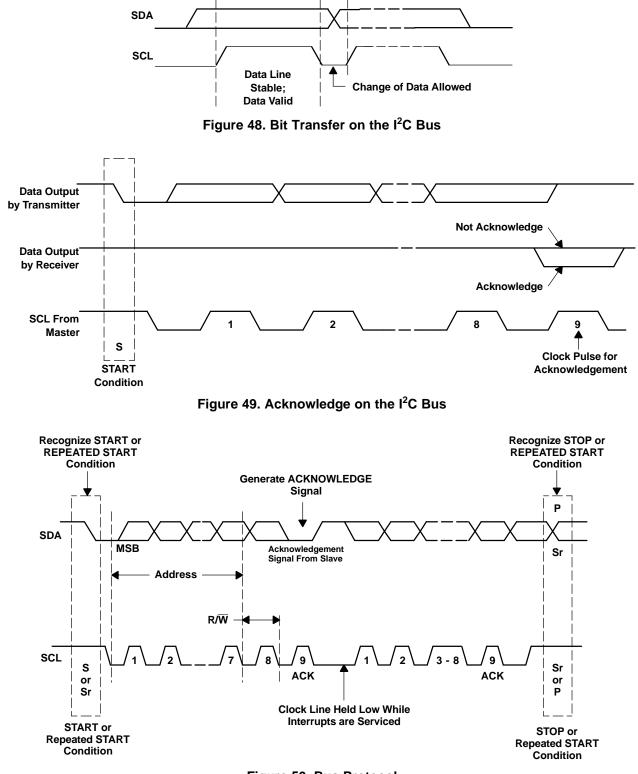


Figure 50. Bus Protocol

# DAC8574 I<sup>2</sup>C Update Sequence

The DAC8574 requires a start condition, a valid I<sup>2</sup>C address, a control byte, an MSB byte, and an LSB byte for a single update. After the receipt of each byte, DAC8574 acknowledges by pulling the SDA line low during the high period of a single clock pulse. A valid I<sup>2</sup>C address selects the DAC8574. The control byte sets the operational mode of the selected DAC8574. Once the operational mode is selected by the control byte, DAC8574 expects an MSB byte followed by an LSB byte for data update to occur. DAC8574 performs an update on the falling edge of the acknowledge signal that follows the LSB byte.

Control byte needs not to be resent until a change in operational mode is required. The bits of the control byte continuously determine the type of update performed. Thus, for the first update, DAC8574 requires a start condition, a valid I<sup>2</sup>C address, a control byte, an MSB byte and an LSB byte. For all consecutive updates, DAC8574 needs an MSB byte and an LSB byte as long as the control command remains the same.

Using the I<sup>2</sup>C high-speed mode ( $f_{scl}$ = 3.4 MHz), the clock running at 3.4 MHz, each 16-bit DAC update other than the first update can be done within 18 clock cycles (MSB byte, acknowledge signal, LSB byte, acknowledge signal), at 188.88 KSPS. Using the fast mode ( $f_{scl}$ = 400 kHz), clock running at 400 kHz, maximum DAC update rate is limited to 22.22 KSPS. Once a stop condition is received DAC8574 releases the I<sup>2</sup>C bus and awaits a new start condition.

#### Address Byte

MSB							LSB
1	0	0	1	1	A1	A0	R/W

The address byte is the first byte received following the START condition from the master device. The first five bits (MSBs) of the address are factory preset to 10011. The next two bits of the address are the device select bits A1 and A0. The A1, A0 address inputs can be connected to  $V_{DD}$  or digital GND, or can be actively driven by TTL/CMOS logic levels. The device address is set by the state of these pins during the power-up sequence of the DAC8574. Up to 16 devices (DAC8574) can still be connected to the same I<sup>2</sup>C-Bus.

#### **Broadcast Address Byte**

MSB							LSB
1	0	0	1	0	0	0	0

Broadcast addressing is also supported by DAC8574. Broadcast addressing can be used for synchronously updating or powering down multiple DAC8574 devices. DAC8574 is designed to work with other members of the DAC857x and DAC757x families to support multichannel synchronous update. Using the broadcast address, DAC8574 responds regardless of the states of the address pins. Broadcast is supported only in write mode (Master writes to DAC8574).

#### Control Byte

MSB							LSB
A3	A2	L1	L0	Х	Sel1	Sel0	PD0

Bit Name	e Bit Number/Description				
A3	Extended Addr	ess Bit	The state of these bits must match the state of pins A3 and A2 in order for a		
A2	Extended Addr	ress Bit	proper DAC8574 data update, except in broadcast update mode.		
L1	Load1 (Mode S	Select) Bit	Are used for selecting the update mode.		
L2	Load0 (Mode Select) Bit		Are used for selecting the update mode.		
	00		ents of MS-BYTE and LS-BYTE (or power down information) are stored in the elected channel. This mode does not change the DAC output of the selected		
	01	LS-BYTE (or power dowr	th I <sup>2</sup> C data. Most commonly utilized mode. The contents of MS-BYTE and information) are stored in the temporary register and in the DAC register of is mode changes the DAC output of the selected channel with the new data.		
	10	are stored in the tempora	update. The contents of MS-BYTE and LS-BYTE (or power down information) rry register and in the DAC register of the selected channel. Simultaneously, get updated with previously stored data from the temporary register. This annels together.		
	regardless of local add		This mode has two functions. In broadcast mode, DAC8574 responds ss matching, and channel selection becomes irrelevant as all channels update. enable up to 64 channels simultaneous update, if used with the I <sup>2</sup> C broadcast		
		If Sel1=0	All four channels are updated with the contents of their temporary register data.		
		If Sel1=1	All four channels are updated with the MS-BYTE and LS-BYTE data or powerdown.		
Sel1	Buff Sel1 Bit				
Sel0	Buff Sel0 Bit		Channel Select Bits		
	00	Channel A			
	01	Channel B			
	10	Channel C			
	11	Channel D			
PD0	Power Down F	lag			
	0	Normal operation			
	1	Power-down flag (MSB7	and MSB6 indicate a power-down operation, as shown in Table 2).		

#### **Table 1. Control Register Bit Descriptions**

					Та	able 2. Co	ontrol E	Byte				
C7	C6	C5	C4	C3	C2	C1	C0	MSB7	MSB6	MSB5		
A3	A2	Load1	Load0	Don't Care	Ch Sel 1	Ch Sel 0	PD0	MSB (PD1)			DESCRIPTION	
	ess Sel- ct)											
should spond	nd A2 I corre- to the	0	0	х	0	0	0		Data		Write to temporary register A (TRA) with data	
dress pins A	ge ad- set via \3 and 2.)	0	0	х	0	1	0		Data		Write to temporary register B (TRB) with data	
		0	0	х	1	0	0		Data		Write to temporary register C (TRC) with data	
		0	0	х	1	1	0	Data		Data		Write to temporary register D (TRD) with data
			0	х	(00, 01, 10, or 11)		1	see Table 8		0	Write to TRx (selected by C2 &C1 w/Powerdown Com- mand	
		0	1	х	(00, 01, 10, or 11)		0		Data		Write to TRx (selected by C2 &C1 and load DACx w/data	
		0	1	х	(00, 01, 10, or 11)		1	see T	see Table 8 0		Power-down DACx (selected by C2 and C1)	
		1	0	х	(00, 01, 10	), or 11)	0		Data		Write to TRx (selected by C2 &C1 w/ data and load all DACs	
		1	0	х	(00, 01, 10	), or 11)	1	see T	able 8	0	Power-down DACx (selected by C2 and C1) & load all DACs	
		Br	oadcast Mo	odes (con	trols up to 4	4 devices o	n a sing	le serial b	us)			
х	х	1	1	х	0	х	Х		х		Update all DACs, all devices with previously stored TRx data	
х	Х	1	1	х	1	Х	0		Data		Update all DACs, all devices with MSB[7:0] and LSB[7:0] data	
х	Х	1	1	х	1	Х	1	see T	able 8	0	Power-down all DACs, all devices	

# Most Significant Byte

Most Significant Byte MSB[7:0] consists of eight most significant bits of 16-bit unsigned binary D/A conversion data. C0=1, MSB[7], MSB[6] indicate a powerdown operation as shown in Table 8.

### Least Significant Byte

Least Significant Byte LSB[7:0] consists of the 8 least significant bits of the 16bit unsigned binary D/A conversion data. DAC8574 updates at the falling edge of the acknowledge signal that follows the LSB[0] bit.

#### Default Readback Condition

If the user initiates a readback of a specified channel without first writing data to that specified channel, the default readback is all zeros, since the readback register is initialized to 0 during the power on reset phase.

# LDAC Functionality

Depending on the control byte, DACs are synchronously updated on the falling edge of the acknowledge signal that follows LS byte. The LDAC pin is required only when an external timing signal is used to update all the channels of the DAC asynchronously. LDAC is a positive edge triggered asynchronous input that allows four DAC output voltages to be updated simultaneously with temporary register data. The LDAC trigger should only be used after the buffers temporary registers are properly updated through software.

#### DAC8574 Registers

Register	Description
CTRL[7:0]	Stores 8-bit wide control byte sent by the master
MSB[7:0]	Stores the 8 most significant bits of unsigned binary data sent by the master. Can also store 2-bit power-down data.
LSB[7:0]	Stores the 8 least significant bits of unsigned binary data sent by the master.
TRA[17:0], TRB[17:0], TRC[17:0], TRD[17:0]	18-bit temporary storage registers assigned to each channel. Two MSBs store power-down information, 16 LSBs store data.
DRA[17:0], DRB[17:0], DRC[17:0], DRD[17:0]	18-bit DAC registers for each channel. Two MSBs store power-down information, 16 LSBs store DAC data. An update of this register means a DAC update with data or power-down.

#### Table 3. DAC8574 Architecture Register Descriptions

# DAC8574 as a Slave Receiver - Standard and Fast Mode

Figure 51 shows the standard and fast mode master transmitter addressing a DAC8574 *Slave Receiver* with a 7-bit address.

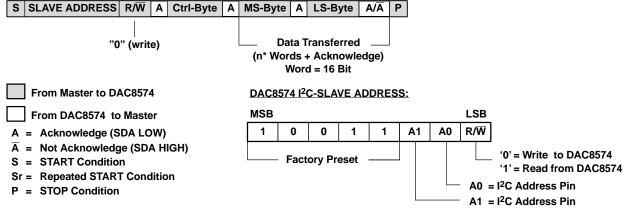


Figure 51. Standard and Fast Mode: Slave Receiver

# DAC8574 as a Slave Receiver - High-Speed Mode

Figure 52 shows the high-speed mode master transmitter addressing a DAC8574 *Slave Receiver* with a 7-bit address.

-	— F/S	-Mode			•						HS-Mod	le —						-	— F/S-Mode
S	HS-Ma	ster C	ode	Ā	Sr	Slave	e Addres	s	R/W	Α	Ctrl-Byt	e A	MS-B	yte	Α	LS-Byte	A/A	Ρ	
<u>HS-I</u>	Mode M	aster (	Code:					"0"	 ' (wri	te)			(n*	Word	s +	ansferre Acknow = 16 Bit	-		Mode Continues
MSE	3						L	SB											
0	0	0	0	1	I	Х	X R	/x			Contro	ol Byt	<u>e:</u>						
											MSB							LSB	_
MS-	Byte:										A3	A2	L1	L0	)	K Sel1	Sel2	PD0	]
MSE	3						L	SB			A3		tende						
D15	5 D14	D13	D12	D	11   1	D10	D9 D	8			A2 L1		(tende) ad1 (N			s Bit ect) Bit			
LS-E	Byte:										L0	= Lo	oad0 (N	lode	Sele	ect) Bit el) Selec	t Bit		
MSE	3						L	SB			Sel0	= B	uff Sel	) (Cha	anne	el) Selec	t Bit		
D7	D6	D5	D4	D	3	D2	D1 D	0			PD0	= Po	ower D	own I	Flag				
D15	- D0 = [	Data Bi	its								х	= Do	n't Ca	re					

Figure 52. High-Speed Mode: Slave Receiver

### Master Transmitter Writing to a Slave Receiver (DAC8574) in Standard/Fast Modes

All write access sequences begin with the device address (with R/W = 0) followed by the control byte. This control byte specifies the operation mode of DAC8574 and determines which channel of DAC8574 is being accessed in the subsequent read/write operation. The LSB of the control byte (PD0-Bit) determines if the following data is power-down data or regular data.

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With (PD0-Bit = 0) the DAC8574 expects to receive data in the following sequence HIGH-BYTE - LOW-BYTE - HIGH-BYTE - LOW-BYTE..., until a STOP Condition or REPEATED START Condition on the I<sup>2</sup>C-Bus is recognized (refer to the DATA INPUT MODE section of Table 4).

With (PD0-Bit = 1) the DAC8574 expects to receive 2 Bytes of power-down data (refer to the POWER DOWN MODE section of Table 4).

DATA INPUT M	IODE								
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master			I		Start		1		Begin sequence
Master	1	0	0	1	1	A1	A0	R/W	Write addressing (R/W=0)
DAC8574				DAC8574	Acknowle	edges			
Master	A3	A2	Load 1	Load 0	x	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0=0)
DAC8574				DAC8574	Acknowle	edges			
Master	D15	D14	D13	D12	D11	D10	D9	D8	Writing data word, high byte
DAC8574				DAC8574	Acknowle	edges			
Master	D7	D6	D5	D4	D3	D2	D1	D0	Writing data word, low byte
DAC8574				DAC8574	Acknowle	edges			
Master			Dat	a or Stop o	r Repeat	ed Start <sup>(1)</sup>			Data or done <sup>(2)</sup>
POWER DOWN	MODE								
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master				ę	Start				Begin sequence
Master	1	0	0	1	1	A1	A0	R/W	Write addressing (R/W=0)
DAC8574				DAC8574	Acknowle	edges			
Master	A3	A2	Load 1	Load 0	х	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0 = 1)
DAC8574				DAC8574	Acknowle	edges			
Master	PD1	PD2	0	0	0	0	0	0	Writing data word, high byte
DAC8574				DAC8574	Acknowle	edges			
Master	0	0	0	0	0	0	0	0	Writing data word, low byte
DAC8574			•	DAC8574	Acknowle	edges			
Master				Stop or Re	peated S	Start <sup>(1)</sup>			Done

#### Table 4. Write Sequence in F/S Mode

(1) Use repeated START to secure bus operation and loop back to the stage of write addressing for next Write.

(2) Once DAC8574 is properly addressed and control byte is sent, HIGH–BYTE–LOW–BYTE sequences can repeat until a STOP condition or repeated START condition is received.

#### Master Transmitter Writing to a Slave Receiver (DAC8574) in HS Mode

When writing data to the DAC8574 in HS-mode, the master begins to transmit what is called the *HS-Master Code* (0000 1XXX) in F/S-mode. No device is allowed to acknowledge the *HS-Master Code*, so the *HS-Master Code* is followed by a NOT acknowledge.

The master then *switches* to HS-mode and issues a *repeated start* condition, followed by the address byte (with R/W = 0) after which the DAC8574 acknowledges by pulling SDA low. This address byte is usually followed by the control byte, which is also acknowledged by the DAC8574. The LSB of the control byte (PD0-Bit) determines if the following data is *power-down data* or regular data.

With (PD0-Bit = 0) the DAC8574 expects to receive data in the following sequence HIGH-BYTE – LOW-BYTE – HIGH-BYTE – LOW-BYTE..., until a STOP condition or *repeated start* condition on the  $I^2$ C-Bus is recognized (refer to Table 5 HS-MODE WRITE SEQUENCE - DATA).

With (PD0-Bit = 1) the DAC8574 expects to receive 2 bytes of power-down data (refer to Table 5 HS-MODE WRITE SEQUENCE - POWER DOWN).

HS MODE WRIT	TE SEQUEI	NCE - D	ATA						
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master				ç	Start				Begin sequence
Master	0	0	0	0	1	Х	Х	Х	HS Mode Master Code
NONE				Not Ac	knowled	ge			No device may acknowledge HS master code
Master				Repea	ated Sta	rt			
Master	1	0	0	1	1	A1	A0	R/W	Write addressing (R/W=0)
DAC8574				DAC8574	Acknowl	edges			
Master	0	0	Load 1	Load 0	0	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0=0)
DAC8574				DAC8574	Acknowl	edges			
Master	D15	D14	D13	D12	D11	D10	D9	D8	Writing data word, MSB
DAC8574				DAC8574	Acknowl	edges			
Master	D7	D6	D5	D4	D3	D2	D1	D0	Writing data word, LSB
DAC8574				DAC8574	Acknowl	edges			
Master			Dat	a or Stop o	r Repeat	ed Start <sup>(1)</sup>			Data or done <sup>(2)</sup>
HS MODE WRIT	TE SEQUEI	NCE - P	OWER DO	WN					
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master				Ś	Start				Begin sequence
Master	0	0	0	0	1	Х	Х	Х	HS Mode Master Code
NONE				Not Ac	knowled	ge			No device may acknowledge HS master code
Master				Repea	ated Sta	rt			
Master	1	0	0	1	1	A1	A0	R/W	Write addressing $(\mathbf{R}/\mathbf{\overline{W}} = 0)$
DAC8574				DAC8574	Acknowl	edges			
Master	0	0	Load 1	Load 2	0	Buff Sel 1	Buff Sel 0	PD0	Control Byte (PD0=1)
DAC8574				DAC8574	Acknowl	edges			
Master	PD1	PD2	0	0	0	0	0	0	Writing data word, high byte
DAC8574				DAC8574	Acknowl	edges			
Master	0	0	0	0	0	0	0	0	Writing data word, low byte
DAC8574				DAC8574	Acknowl	edges			
Master				Stop or re	peated s	tart <sup>(1)</sup>			Done

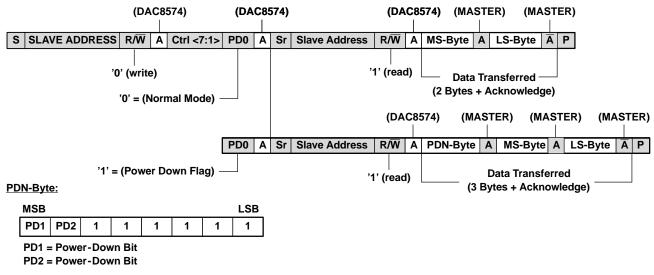
Table 5. Master Transmitter Writes to Slave Receiver (DAC8574) in HS-Mode

(1) Use repeated start to secure bus operation and loop back to the stage of write addressing for next Write.

(2) Once DAC8574 is properly addressed and control byte is sent, high-byte-low-byte sequences can repeat until a stop or repeated start condition is received.

# DAC8574 as a Slave Transmitter - Standard and Fast Mode

Figure 53 shows the standard and fast mode master transmitter addressing a DAC8574 *Slave Transmitter* with a 7-bit address.





# DAC8574 as a Slave Transmitter - High-Speed Mode

Figure 54 shows an  $I^2$ C-Master addressing DAC8574 in high-speed mode (with a 7-bit address), as a *Slave Transmitter*.

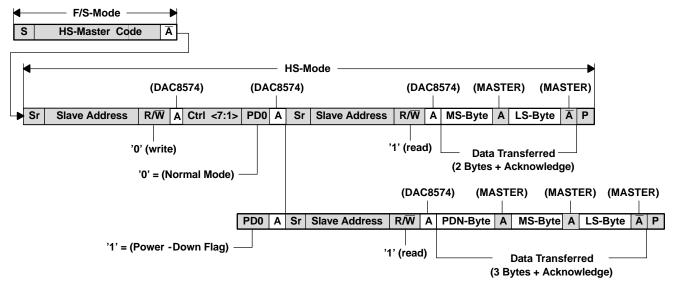


Figure 54. High-Speed Mode: Slave Transmitter

#### Master Receiver Reading From a Slave Transmitter (DAC8574) in Standard/Fast Modes

When reading data back from the DAC8574, the user begins with an address byte (with R/W = 0) after which the DAC8574 will acknowledge by pulling SDA low. This address byte is usually followed by the Control Byte, which is also acknowledged by the DAC8574. Following this there is a REPEATED START condition by the Master and the address is resent with (R/W = 1). This is acknowledged by the DAC8574, indicating that it is prepared to transmit data. Two or three bytes of data are then read back from the DAC8574, depending on the (PD0-Bit). The value of *Buff-Sel1* and *Buff-Sel0* determines, which channel data is read back. A STOP Condition follows.

With the (PD0-Bit = 0) the DAC8574 transmits 2 bytes of data, *HIGH-BYTE* followed by the *LOW-BYTE* (refer to Table 2. Data Readback Mode - 2 bytes).

With the (PD0-Bit = 1) the DAC8574 transmits 3 bytes of data, POWER-DOWN-BYTE followed by the HIGH-BYTE followed by the LOW-BYTE (refer to Table 2. Data Readback Mode - 3 bytes).

DATA READ	ВАСК МО	DE - 2 B	YTES						
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master					Start				Begin sequence
Master	1	0	0	1	1	A1	A0	R/W	Write addressing (R/W=0)
DAC8574				DAC8574	4 Acknowle	edges			
Master	A3	A2	Load 1	Load 0	х	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0=0)
DAC8574				DAC8574	4 Acknowle	edges			
Master	Repeated Start								
Master	1	0	0	1	1	A1	A0	R/W	Read addressing ( <b>R/W = 1</b> )
DAC8574				DAC8574	4 Acknowle	edges			
DAC8574	D15	D14	D13	D12	D11	D10	D9	D8	Reading data word, high byte
Master				Master	Acknowled	lges			
DAC8574	D7	D6	D5	D4	D3	D2	D1	D0	Reading data word, low byte
Master				Master No	ot Acknowl	edges			Master signal end of read
Master	Stop or Repeated Start <sup>(1)</sup>								Done
DATA READI	ВАСК МО	DE - 3 B	YTES						
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master					Start				Begin sequence
Master	1	0	0	1	1	A1	A0	R/W	Write addressing (R/W=0)
DAC8574				DAC8574	4 Acknowle	edges			
Master	A3	A2	Load 1	Load 0	х	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0=1)
DAC8574				DAC8574	4 Acknowle	edges			
Master				Rep	eated Star	t			
Master	1	0	0	1	1	A1	A0	R/W	Read addressing ( <b>R/W = 1</b> )
DAC8574				DAC8574	4 Acknowle	edges			
DAC8574	PD1	PD2	1	1	1	1	1	1	Read power down byte
Master				Master	Acknowled	lges			
DAC8574	D15	D14	D13	D12	D11	D10	D9	D8	Reading data word, high byte
Master				Master	Acknowled	lges	<u> </u>		
DAC8574	D7	D6	D5	D4	D3	D2	D1	D0	Reading data word, low byte
Master				Master No	ot Acknowl	edges	<u> </u>		Master signal end of read
Master				Stop or R	Repeated S	tart <sup>(1)</sup>			Done

#### Table 6. Read Sequence in F/S Mode

(1) Use repeated start to secure bus operation and loop back to the stage of write addressing for next Write.

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### Master Receiver Reading From a Slave Transmitter (DAC8574) in HS-Mode

When reading data to the DAC8574 in HS-MODE, the master begins to transmit, what is called the *HS-Master Code* (0000 1XXX) in F/S-mode. No device is allowed to acknowledge the *HS-Master Code*, so the *HS-Master Code* is followed by a NOT acknowledge.

The Master then *switches* to HS-mode and issues a REPEATED START condition, followed by the address byte (with R/W = 0) after which the DAC8574 acknowledges by pulling SDA low. This address byte is usually followed by the control byte, which is also acknowledged by the DAC8574.

Then there is a REPEATED START condition initiated by the master and the address is resent with (R/W = 1). This is acknowledged by the DAC8574, indicating that it is prepared to transmit data. Two or Three bytes of data are then read back from the DAC8574, depending on the (PD0-Bit). The value of *Buff-Sel1* and *Buff-Sel0* determines, which channel data is read back. A STOP condition follows.

With the (PD0-Bit = 0) the DAC8574 transmits 2 bytes of data, *HIGH-BYTE* followed by *LOW-BYTE* (refer to Table 7 HS-Mode Readback Sequence).

With the (PD0-Bit = 1) the DAC8574 transmits 3 bytes of data, *POWER-DOWN-BYTE* followed by the *HIGH-BYTE* followed by the *LOW-BYTE* (refer to Table 7 HS-Mode Readback Sequence).

HS MODE RE		<b>SEQU</b>	ENCE						
Transmitter	MSB	6	5	4	3	2	1	LSB	Comment
Master					Start				Begin sequence
Master	0	0	0	0	1	Х	Х	Х	HS Mode Master Code
NONE				Not	Acknowl	edge			No device may acknowledge HS master code
Master				Re	peated S	Start			
Master	1	0	0	1	1	A1	A0	R/W	Write addressing ( <b>R/W</b> = <b>0</b> )
DAC8574				DAC85	74 Ackno	wledges			
Master	A3	A2	Load 1	Load 0	Х	Buff Sel 1	Buff Sel 0	PD0	Control byte (PD0 = 1)
DAC8574		DAC8574 Acknowledges							
Master				Re	peated S	Start			
Master	1	0	0	1	1	A1	A0	R/W	Read addressing ( <b>R/W=1</b> )
DAC8574				DAC85	74 Ackno	wledges			
DAC8574	PD1	PD2	1	1	1	1	1	1	Power-down byte
Master				Maste	r Acknow	vledges			
DAC8574	D15	D14	D13	D12	D11	D10	D9	D8	Reading data word, high byte
Master				Maste	r Acknow	vledges			
DAC8574	D7	D6	D5	D4	D3	D2	D1	D0	Reading data word, low byte
Master				Master N	Not Ackn	owledges			Master signal end of read
Master				Stop o	r Repeat	ed Start			Done

#### Table 7. Master Receiver Reading Slave Transmitter (DAC8574) in HS-Mode

# **Power-On Reset**

The DAC8574 contains a power-on-reset circuit that controls the output voltage during power up. On power up, the DAC register is filled with zeros and the output voltage is 0 V; it remains there until a valid write sequence is made to the DAC. This is useful in applications where it is important to know the state of the output of the DAC while it is in the process of powering up. No device pin should be brought high before supply is applied.

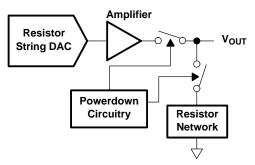
# **Power-Down Modes**

The DAC8574 contains four separate power-down modes of operation. The modes are programmable via two most significant bits of the MSB byte, while (CTRL[0] = PD0 = 1). Table 8 shows how the state of these bits correspond to the mode of operation of the device.

CTRL[0]	MSB[7]	MSB[6]	OPERATING MODE
1	0	0	High Impedance Output
1	0	1	1 kΩ to GND
1	1	0	100 kΩ to GND
1	1	1	High Impedance

Table 8.	<b>Power-Down</b>	Modes o	f Operation	for the	DAC8574
		moucs o			

When (CTRL[0] = PD0 = 0), the device works normally with its normal power consumption of 250  $\mu$ A at 5 V per channel. However, for the three power-down modes, the supply current falls to 200 nA at 5 V (50 nA at 3 V). Not only does the supply current fall but also the output stage is also internally switched from the output of the amplifier to a resistor network of known values. This has the advantage that the output impedance of the device is known while in power-down mode. There are three different options: The output is connected internally to GND through a 1-k $\Omega$  resistor, a 100 k $\Omega$  resistor or left open-circuit (high impedance). The output stage is illustrated in Figure 55.





All linear circuitry is shut down when the power-down mode is activated. However, the contents of the DAC register are unaffected when in power-down. The time to exit power down is typically 2.5  $\mu$ s for V<sub>DD</sub> = 5 V and 5  $\mu$ s for V<sub>DD</sub> = 3 V. (See the Typical Curves section for additional information.)

The DAC8574 offers a flexible power-down interface based on channel register operation. A channel consists of a single 16-bit DAC with power-down circuitry, a temporary storage register (TR) and a DAC register (DR). TR and DR are both 18 bits wide. Two MSBs represent the power-down condition and the 16 LSBs represent data for TR and DR. By using bits 17 and 18 of TR and DR, a power-down condition can be temporarily stored and used just like data. Internal circuits ensure that MSB[7] and MSB[6] get transferred to TR[17] and TR[16] (DR[17] and DR[16]) when the power-down flag (CTRL[0] = PD0) is set. Therefore, DAC8574 treats power-down conditions like data and all the operational modes are still valid for power down. It is possible to broadcast a power-down condition to all the DAC8574s in the system, or it is possible to simultaneously power down a channel while updating data on other channels.



### **CURRENT CONSUMPTION**

The DAC8574 typically consumes 225  $\mu$ A at V<sub>DD</sub> = 5 V and 200  $\mu$ A at V<sub>DD</sub> = 3 V for each active channel, including reference current consumption. Additional current consumption can occur at the digital inputs if V<sub>IH</sub> << V<sub>DD</sub>. For most efficient power operation, CMOS logic levels are recommended at the digital inputs to the DAC. In power-down mode, typical current consumption is 200 nA. A delay time of 10 to 20 ms after a power-down command is issued to the DAC is typically sufficient for the power-down current to drop below 10  $\mu$ A.

# DRIVING RESISTIVE AND CAPACITIVE LOADS

The DAC8574 output stage is capable of driving loads of up to 1000 pF while remaining stable. Within the offset and gain error margins, the DAC8574 can operate rail-to-rail when driving a capacitive load. Resistive loads of 2 k $\Omega$  can be driven by the DAC8574 while achieving very good load regulation. Load regulation error increases as the output voltage approaches each rail. When the outputs of the DAC are driven to the positive rail under resistive loading, the PMOS transistor of each Class-AB output stage can enter into the linear region. When this occurs, the added IR voltage drop deteriorates the linearity performance of the DAC. This only occurs within approximately the top 20 mV of the DAC's digital input-to-voltage output transfer characteristic. The reference voltage applied to the DAC8574 may be reduced below the supply voltage applied to V<sub>DD</sub> in order to eliminate this condition if good linearity is a requirement at full scale (under resistive loading conditions).

# CROSSTALK AND AC PERFORMANCE

The DAC8574 architecture uses separate resistor strings for each DAC channel in order to achieve ultra-low crosstalk performance. DC crosstalk seen at one channel during a full-scale change on the neighboring channel is typically less than 0.5 LSBs. The ac crosstalk measured (for a full-scale, 1 kHz sine wave output generated at one channel, and measured at the remaining output channel) is typically under –100 dB. In addition, the DAC8574 can achieve typical ac performance of 96 dB signal-to-noise ratio (SNR) and 65 dB total harmonic distortion (THD), making the DAC8574 a solid choice for applications requiring high SNR at output frequencies at or below 4 kHz.

# **OUTPUT VOLTAGE STABILITY**

The DAC8574 exhibits excellent temperature stability of  $\pm 3$  ppm/°C typical output voltage drift over the specified temperature range of the device. This enables the output voltage of each channel to stay within a  $\pm 25 \ \mu$ V window for a  $\pm 1^{\circ}$ C ambient temperature change. Good power-supply rejection ratio (PSRR) performance reduces supply noise present on V<sub>DD</sub> from appearing at the outputs to well below 10  $\mu$ V-s. Combined with good dc noise performance and true 16-bit differential linearity, the DAC8574 becomes a perfect choice for closed-loop control applications.

# SETTLING TIME AND OUTPUT GLITCH PERFORMANCE

Settling time to within the 16-bit accurate range of the DAC8574 is achievable within 10  $\mu$ s for a full-scale code change at the input. Worst case settling times between consecutive code changes is typically less than 2  $\mu$ s. The high-speed serial interface of the DAC8574 is designed in order to support up to 188ksps update rate. For full-scale output swings, the output stage of each DAC8574 channel typically exhibits less than 100 mV of overshoot and undershoot when driving a 200 pF capacitive load. Code-to-code change glitches are extremely low (~10  $\mu$ V) given that the code-to-code transition does not cross an Nx4096 code boundary. Due to internal segmentation of the DAC8574, code-to-code glitches occur at each crossing of an Nx4096 code boundary. These glitches can approach 100mVs for N = 15, but settle out within ~2  $\mu$ s.

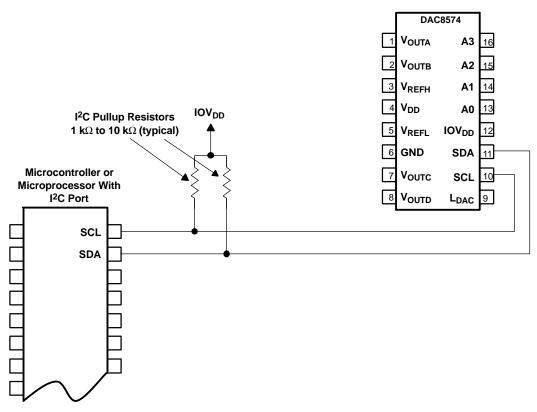
# **APPLICATION INFORMATION**

The following sections give example circuits and tips for using the DAC8574 in various applications. For more information, contact your local TI representative, or visit the Texas Instruments website at http://www.ti.com.

#### **BASIC CONNNECTIONS**

For many applications, connecting the DAC8574 is extremely simple. A basic connection diagram for the DAC8574 is shown in Figure 56. The 0.1  $\mu$ F bypass capacitors help provide the momentary bursts of extra current needed from the supplies.

#### **APPLICATION INFORMATION (continued)**



NOTE: DAC8574 power and input/output connections are omitted for clarity, except I<sup>2</sup>C Inputs.

#### Figure 56. Typical DAC8574 Connections

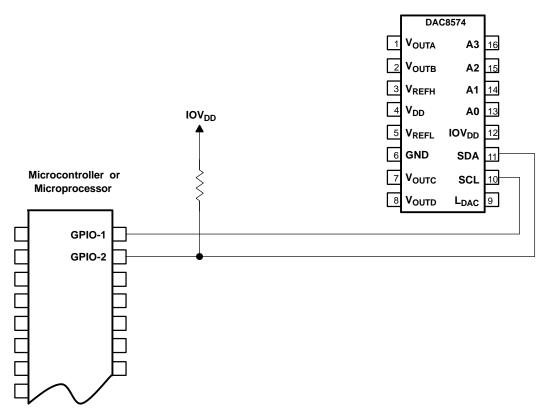
The DAC8574 interfaces directly to standard mode, fast mode and high-speed mode  $I^2C$  controllers. Any microcontroller's  $I^2C$  peripheral, including master-only and non-multiple-master  $I^2C$  peripherals, work with the DAC8574. The DAC8574 does not perform clock-stretching (i.e., it never pulls the clock line low), so it is not necessary to provide for this unless other devices are on the same  $I^2C$  bus.

Pullup resistors are necessary on both the SDA and SCL lines because I<sup>2</sup>C bus drivers are open-drain. The size of the these resistors depend on the bus operating speed and capacitance on the bus lines. Higher-value resistors consume less power, but increase the transition times on the bus, limiting the bus speed. Lower-value resistors allow higher speed at the expense of higher power consumption. Long bus lines have higher capacitance and require smaller pullup resistors to compensate. If the pullup resistors are too small the bus drivers may not be able to pull the bus line low.

#### USING GPIO PORTS FOR I<sup>2</sup>C

Most microcontrollers have programmable input/output pins that can be set in software to act as inputs or outputs. If an  $l^2C$  controller is not available, the DAC8574 can be connected to GPIO pins, and the  $l^2C$  bus protocol simulated, or bit-banged, in software. An example of this for a single DAC8574 is shown in Figure 57.

# **APPLICATION INFORMATION (continued)**



NOTE: DAC8574 power and input/output connections are omitted for clarity, except I<sup>2</sup>C Inputs.

#### Figure 57. Using GPIO With a Single DAC8574

Bit-banging I<sup>2</sup>C with GPIO pins can be done by setting the GPIO line to zero and toggling it between input and output modes to apply the proper bus states. To drive the line low, the pin is set to output a zero; to let the line go high, the pin is set to input. When the pin is set to input, the state of the pin can be read; if another device is pulling the line low, this reads as a zero in the port's input register.

Note that no pullup resistor is shown on the SCL line. In this simple case the resistor is not needed. The microcontroller can simply leave the line on output, and set it to one or zero as appropriate. It can do this because the DAC8574 never drives its clock line low. This technique can also be used with multiple devices, and has the advantage of lower current consumption due to the absence of a resistive pullup.

If there are any devices on the bus that may drive their clock lines low, the above method should not be used. The SCL line should be high-Z or zero, and a pullup resistor provided as usual. Note also that this cannot be done on the SDA line in any case, because the DAC8574 drives the SDA line low from time to time, as all  $I^2C$  devices do.

Some microcontrollers have selectable strong pullup circuits built in to their GPIO ports. In some cases, these can be switched on and used in place of an external pullup resistor. Weak pullups are also provided on some microcontrollers, but usually these are too weak for I<sup>2</sup>C communication. Test any circuit before committing it to production.

# **APPLICATION INFORMATION (continued)**

# **USING REF02 AS A POWER SUPPLY FOR DAC8574**

Due to the extremely low supply current required by the DAC8574, a possible configuration is to use a REF02 +5 V precision voltage reference to supply the required voltage to the DAC8574's supply input as well as the reference input, as shown in Figure 58. This is especially useful if the power supply is quite noisy or if the system supply voltages are at some value other than 5 V. The REF02 outputs a steady supply voltage for the DAC8574. If the REF02 is used, the current it needs to supply to the DAC8574 is 950  $\mu$ A typical and 1600  $\mu$ A max for V<sub>DD</sub> = 5 V. When a DAC output is loaded, the REF02 also needs to supply the current to the load. The total typical current required (with a 5-k $\Omega$  load on a single DAC output) is:

#### 950 $\mu$ A + (5 V / 5 k $\Omega$ ) = 1.950 mA

The load regulation of the REF02 is typically 0.005%/mA, which results in an error of 488µV for 1.950-mA of current drawn from it. This corresponds to a 6.4 LSB error for a 0-V to 5-V output range.

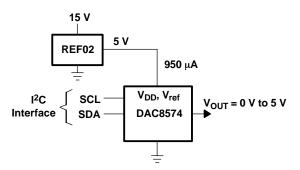


Figure 58. REF02 Power Supply

REF3040 can also be used to generate a 4.096-V reference from a 5-V supply.



# GENERATING $\pm$ 5-V, $\pm$ 10-V, and $\pm$ 12-V OUTPUTS FOR PRECISION INDUSTRIAL CONTROL

Industrial control applications can require multiple feedback loops consisting of sensors, ADCs, MCUs, DACs, and actuators. Loop accuracy and loop speed are the two important parameters of such control loops.

#### Loop Accuracy:

In a control loop, the ADC has to be accurate. Offset, gain, and the integral linearity errors of the DAC are not factors in determining the accuracy of the loop. As long as a voltage exists in the transfer curve of a monotonic DAC, the loop can find it and settle to it. On the other hand, DAC resolution and differential linearity do determine the loop accuracy, because each DAC step determines the minimum incremental change the loop can generate. A DNL error less than -1 LSB (non-monotonicity) can create loop instability. A DNL error greater than +1 LSB implies unnecessarily large voltage steps, and missed voltage targets. With high DNL errors, the loop looses its stability, resolution, and accuracy. Offering 16-bit assured monotonicity and  $\pm$  0.25 LSB typical DNL error, 85XX DACs are great choices for precision control loops.

#### Loop Speed:

Many factors determine control loop speed. Typically, the ADC's conversion time, and the MCU's computation time are the two major factors that dominate the time contstant of the loop. DAC settling time is rarely a dominant factor because ADC conversion times usually exceed DAC conversion times. DAC offset, gain, and linearity errors can slow the loop down only during the start-up. Once the loop reaches its steady-state operation, these errors do not affect loop speed any further. Depending on the ringing characteristics of the loop's transfer function, DAC glitches can also slow the loop down. With its 188 ksps maximum data update rate, DAC8574 can support high-speed control loops.

#### Generating Industrial Voltage Ranges:

For control loop applications, DAC gain and offset errors are not important parameters. This could be exploited to lower trim and calibration costs in a high-voltage control circuit design. Using a quad op amp (OPA4130), a voltage reference (REF3040) and a quad 12-bit DAC (DAC7574), the DAC8574 can generate the wide voltage swings required by the control loop.

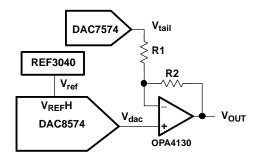


Figure 59. Low-cost, Wide-swing Voltage Generator for Control Loop Applications

The output voltage of the configuration is given by:

$$V_{out} = V_{ref} \left( \frac{R2}{R1} + 1 \right) \frac{Din}{65536} - V_{tail} \frac{R2}{R1}$$

Fixed R1 and R2 resistors can be used to coarsely set the gain required in the first term of the equation. Once R2 an R1 set the gain properly, a DAC7574 could be used to set the required offset voltages. Residual errors are not an issue for loop accuracy because offset and gain errors could be tolerated.

For ±5-V operation: R1=10 k $\Omega$ , R2 = 15 k $\Omega$ , Vtail = 3.33 V, Vref = 4.096 V

For ±10-V operation: R1=10 k $\Omega$ , R2 = 39 k $\Omega$ , Vtail = 2.56 V, Vref = 4.096 V

For ±12-V operation: R1=10 k $\Omega$ , R2 = 49 k $\Omega$ , Vtail = 2.45 V, Vref = 4.096 V

# **Digital Correction of DAC Errors**

For open-loop applications requiring improved accuracy, offset and gain errors of the DAC8574 can be measured and digitally corrected. To avoid waveform clipping, it is recommended to make the offset and gain error measurements at codes 1024 and 64512 respectively. The total error of DAC8574 is dominated by gain and offset errors, and it can be improved by an order of magnitude using the following digital correction:

 $DIN = DDIN - OE - (FSE - OE) \times (DDIN - 1024) \div 64512$ 

where:

DIN = Digital input code to the DAC after offset and gain correction

DDIN = Digital input code to the DAC before offset and gain correction

OE = measured DAC error at code 1024 (in LSBs)

FSE = measured DAC error at code 64512 (in LSBs)

If division operation is not feasible, FSE measurement can be done at code 32768 instead of code 64512. Division by 32768 implies a 15-bit arithmetic right shift. Improvements to the transfer curve are still significant.

DAC8574 integral linearity error is well within  $\pm 5$  mV, therefore it only has a secondary effect on total DAC error. Using piece-wise linear approximation, and non-volatile memory, integral linearity errors of DAC8574 can also be digitally corrected. Consult TI applications engineering for details.

# 64 Channel Operation

DAC8574 is designed to facilitate high channel count operation. DAC8574 supports multichannel simultaneous synchronous update up to 16 DAC8574 devices for up to 64 channels on a single l<sup>2</sup>C bus. Working with multiple DAC8574s, single channel DAC8571s can be used on the same bus to obtain odd channel counts, or quad channel DAC7574s can be used if some channels only need 12 bits of resolution.

Data or power down can be loaded to temporary registers of each channel serially and a single broadcast operation can be used to update all channels of all devices simultaneously with previously stored data or power-down condition. Another feature useful for system start-up or system shut-down is to broadcast the same data (or power-down condition) to all channels with a single broadcast command.

All multichannel system updates are performed at the falling edge of the acknowledge signal that follows the least significant byte.

The 64-channel operation requires 6-bit address decoding. 4-bit address decoding is used to support 16 DAC8574 devices on the same bus and 2-bit address decoding is used to select one out of four channels of a DAC8574. 4-bit address decoding that selects one out of 16 DAC8574 devices is done as follows: To save  $I^2C$  address space, 2-bits (A0 and A1) are used for  $I^2C$  address decoding, and two additional bits (A2 and A3) are used for local address decoding. Up to 4 DAC8574 devices using the same  $I^2C$  address can be connected on the same  $I^2C$  bus. These four devices with the same  $I^2C$  address can be locally decoded using A2 and A3 pins. If multiple devices use the same  $I^2C$  address, multiple devices acknowledge at the same time. However, in order for a particular device to respond to a command, the states of the first two bits of the control word C7 and C6 must match the states of A3 and A2 pins. Four devices per  $I^2C$  address and four distinct  $I^2C$  addresses enable 16 devices on the same bus.

The four address pins should be set at power-up, and address bits must be set to match a particular device's address pins. To decode up to 16 DAC8574 devices, the logic states of A3, A2, A1, A0 address pins and C7, C6, A1, A0 address bits should be set as shown in Table 9.

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DEV #	A3 PIN	C7 BIT	A2 PIN	C6 BIT	A1 PIN	A1 BIT	A0 PIN	A0 BIT
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	1	1
3	0	0	0	0	1	1	0	0
4	0	0	0	0	1	1	1	1
5	0	0	1	1	0	0	0	0
6	0	0	1	1	0	0	1	1
7	0	0	1	1	1	1	0	0
8	0	0	1	1	1	1	1	1
9	1	1	0	0	0	0	0	0
10	1	1	0	0	0	0	1	1
11	1	1	0	0	1	1	0	0
12	1	1	0	0	1	1	1	1
13	1	1	1	1	0	0	0	0
14	1	1	1	1	0	0	1	1
15	1	1	1	1	1	1	0	0
16	1	1	1	1	1	1	1	1

# Table 9. 64 Channel Address Decoding

Once a DAC8574 device is selected, channel select bits C2 and C1 can select a particular channel. Overall, I<sup>2</sup>C address bits A1, A0, control bits C7, C6, C2 and C1 form the 6-bit address required to select one channel out of 64 possibilities.

Broadcast operation is supported for both  $I^2C$  addressing and for extended addressing. A broadcast address (10010000) makes all DAC8574 devices listen, regardless of the states of A0 and A1 pins. Also, a broadcast command (C5 = C4 = 1) makes all devices listen, regardless of the states of A2 and A3 pins. The same broadcast command (C5 = C4 = 1) also selects all channels for a given device, regardless of the states of channel select bits. Thus, a global broadcast message that simultaneously updates up to 64 channels uses 10010000 as  $I^2C$  address and has (C5 = C4 = 1) in the control word.

# Examples

#### I<sup>2</sup>C Standard and Fast Mode Examples (A0, A1, A2, A3 and LDAC pins tied to GND):

			•		•				
EXAMPLE 1	: WRITE 1/4 SCALE	TO CHAN	NEL A						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0000	ACK	0100 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utA output voltage is	valid						VoutA =	1.25 V
EXAMPLE 2	: WRITE 1/2 SCALE	TO CHAN	NEL B						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0010	ACK	1000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utB output voltage is	valid						VoutB =	2.50 V
EXAMPLE 3	: WRITE 3/4 SCALE	TO CHAN	NEL C						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0100	ACK	1100 0000	ACK	0000 0000	ACK	STOP
Previous VoutC output voltage is valid									3.75 V

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EXAMPLE	1: WRITE 4/4 SCALE	TO CHAN	NEL D						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0110	ACK	1111 1111	ACK	1111 1111	ACK	STOP
Previous Vo	utD output voltage is	valid	- <b>!</b>		<u> </u>		-	VoutB =	5.0 V
EXAMPLE	5: Power-Down Chai	nnel A, Witl	h Hi-Z Output						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0001	ACK	0000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utA output voltage is	valid			•		L.	VoutA =	Hi-Z
EXAMPLE	3: Power-Down Chai	nnel B, Witl	h Hi-Z Output						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0011	ACK	0000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utB output voltage is	valid						VoutB =	Hi-Z
EXAMPLE	7: Power-Down Chai	nnel C, Witl	h Hi-Z Output						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0101	ACK	0000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utC output voltage is	valid						VoutC =	Hi-Z
EXAMPLE	3: Power-Down Chai	nnel D, Witl	h Hi-Z Output						
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0111	ACK	0000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utD output voltage is	valid						VoutD =	Hi-Z
EXAMPLE	: Power-Down Chai	nnel D, Witl	h 1 kΩ Outpu	t Impedance t	o Ground				
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0111	ACK	0100 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utA output voltage is	valid						VoutD =	0 V
EXAMPLE '	10: Power-Down Cha	annel D, Wi	th 100 k $\Omega$ Ou	tput Impedan	ce to Ground				
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0001 0111	ACK	1000 0000	ACK	0000 0000	ACK	STOP
Previous Vo	utD output voltage is	valid						VoutD =	0 V



EXAMPLE 11: Simultaneous Update of All Channels

EXAMPLE 1	1: Simultaneous Up	date of All	Channels						
Write 4/4 So DACs Simu	ale, 4/3 Scale, 2/4 S Itaneously	cale, and 1/	4 Scale Data	to Temporary	Registers of (	Channels A, B	, C, D Serially,	and Upc	late all
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0000 0000	ACK	1111 1111	ACK	1111 1111	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels						
START	1001 1000	ACK	0000 0010	ACK	1100 0000	ACK	0000 0000	ACK	
Previous DA	C output voltages are	e valid for all	channels						
START	1001 1000	ACK	0000 0100	ACK	1000 0000	ACK	0000 0000	ACK	
Previous DA	C output voltages are	e valid for all	channels		<u> </u>				
START	1001 1000	ACK	0010 0110	ACK	0100 0000	ACK	0000 0000	ACK	
Previous DA	C output voltages are	e valid for all	channels		<u> </u>			New dat	a is valid
EXAMPLE 1	2: Simultaneous Up	date Chann	els A, B, C a	nd Power-Do	wn of Channel	D at The End	of The Fourth	Cycle	
	ale, 3/4 Scale, 2/4 S ultaneously	cale, and Po	ower-Down (	Hi-Z) Data to 1	Cemporary Reg	jisters of Char	nnels A, B, C, I	D Serially	/, and
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0000 0000	ACK	1111 1111	ACK	1111 1111	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels						1
START	1001 1000	ACK	0000 0010	ACK	1100 0000	ACK	0000 0000	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels		<u> </u>				
START	1001 1000	ACK	0000 0100	ACK	1000 0000	ACK	0000 0000	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels						
START	1001 1000	ACK	0010 0111	ACK	0000 0000	ACK	0000 0000	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels					New dat	a is valid
EXAMPLE 1 B, C, D)	3: Store data and w	ait for upda	te command	(Write codes	128, 256, 512,	and 1024 to te	emporary regis	ters of c	hannels
Write 4/4 So DACs Simu	ale, 3/4 Scale, 2/4 S Itaneously	cale, and 1/	4 Scale Data	to Temporary	Registers of (	Channels A, B	, C, D Serially,	and Upc	late all
	ADDRESS [70]		C [70]		M [70]		L [70]		
START	1001 1000	ACK	0000 0000	ACK	0000 0000	ACK	1000 0000	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels						
START	1001 1000	ACK	0000 0010	ACK	0000 0001	ACK	0000 0000	ACK	STOP
Previous DA	C output voltages are	e valid for all	channels		·				
START	1001 1000	ACK	0000 0100	ACK	0000 0010	ACK	0000 0000	ACK	STOP
	i								
Previous DA	C output voltages are	e valid for all	channels						
Previous DA START	C output voltages are 1001 1000	e valid for all ACK	channels 0010 0110	ACK	0100 0100	ACK	0000 0000	ACK	STOP

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EXAMPL	EXAMPLE 14: Broadcast update command. All channels of all DAC8574s update with previously stored temporary register data.											
	ADDRESS [70]		C [7	′0]		M []	70]			L [70]		
START	1001 0000	ACK	0011	0000	АСК	XXXX	XXXX	ACK	X	XXX XXXX	ACK	STOP
Previous	DAC output voltages	are valid f	for all cl	hannels, al	DAC85	74s					New data is	valid
EXAMPL	E 15: Broadcast Da	ta. All cha	nnels o	of all DAC	8574s g	et set to	code 7.					
	ADDRESS [7	0]		C [70]			M [70]			L [70]		
START	1001 0000	Α	ск	0011 0000	A	СК	0000 0000	A	СК	0000 0111	АСК	STOP
Previous	DAC output voltages	are valid l	for all cl	hannels, al	DAC85	74s					All Vouts µV	= 7 x 76
EXAMPLE 16: Broadcast Power-Down. All channels of all DAC8574s get powered down with output impedance of 1 kΩ to ground.												
	ADDRESS [7	0]		C [70]			M [70]			L [70]		
START	START         1001 0000         ACK         0011 0001         ACK         0100 0000         ACK         0000 0000         ACK         STOP											
Previous DAC output voltages are valid for all channels, all DAC8574s All Vouts = G									= GND			

# I<sup>2</sup>C Read-back Examples (A0, A1, A2, A3 and LDAC pins tied to GND):

EXAMPLE 17: I	Read back channe	ΙАрс	wer-down	bits and	16-bit cl	hannel A d	data. V	denotes valid logi		
	ADDRESS [7	0]		C [7	'0]			REPEATED	ADDRESS	
START	1001 1000		ACK	0001	0001	ACK		START	1001 1001	ACK
PWD [70]	MASTER	Μ	ISB [70]	MAST	ER	LSB [7.	0]	MASTER		
VV11 1111	ACK	٧٧٧	/V VVVV	ACK		VVVV V	VVV	NOT ACK		
EXAMPLE 18: I	Read back channe	I B po	wer-down	bits and	16-bit cl	hannel B o	data. V	denotes valid logic		
	ADDRESS [7	0]		C [7	0]			REPEATED	ADDRESS	
START	1001 1000		ACK	0001	0011	ACK		START	1001 1001	ACK
PWD [70]	MASTER	Μ	SB [70]	MASTE	ĒR	LSB [7	0]	MASTER		
VV11 1111	ACK	VV	/V VVVV	ACK		VVVV V	'VVV	NOT ACK		
EXAMPLE 19: I	Read back channe	I C po	wer-down	bits and	16-bit cl	hannel C o	data. V	denotes valid logic	<b>.</b>	
	ADDRESS [7	0]		C [7	0]			REPEATED	ADDRESS	
START	1001 1000		ACK	0001	0101	ACK		START	1001 1001	ACK
PWD [70]	MASTER	M	SB [70]	MASTE	ER	LSB [7	0]	MASTER		
VV11 1111	ACK	VV	/V VVVV	ACK		VVVV V	'VVV	NOT ACK		
EXAMPLE 20: I	Read back channe	l D po	wer-down	bits and	16-bit cl	hannel D o	data. V	denotes valid logic	<b>.</b>	
	ADDRESS [7	0]		C [7	0]			REPEATED	ADDRESS	
START	1001 1000		ACK	0001	0111	ACK		START	1001 1001	ACK
PWD [70]	MASTER	Μ	SB [70]	MASTE	ĒR	LSB [7	0]	MASTER		
VV11 1111	ACK	VV	/V VVVV	ACK		VVVV V	'VVV	NOT ACK		
EXAMPLE 21: I	Read back 16-bit c	hanne	el D data or	nly. V de	notes va	lid logic.				
	ADDRESS [7	.0]		С	[70]			REPEATED	ADDRESS	
START	1001 1000		ACK	000	1 0110	ACK		START	1001 1001	ACK
MSB [70]	MASTER		LSB [70	)]		MASTER				
VVVV VVVV	ACK			/V		NOT ACK	(			

#### I<sup>2</sup>C High Speed Examples (A0, A1, A2, A3 and LDAC pins tied to GND):

		HS Master Code	e NOT	REPEATED	ADDRESS		C [7 0]	
STAR	Г	0000 1000	ACK	START	10011 0000	ACK	0001 0110	ACK
Previous Vou	tD volta	ge valid						
MSB [70]		LSB [70]		MSB [7	0]		LSB [70]	
0000 0000	ACK	0000 0000	ACK	0000 00	000	ACK	0000 0001	ACK
Previous Vou	tD volta	ge valid	VoutD = 0 V					VoutD = 76 µV
MSB [70]]		LSB [70]		MSB 7.	0]		LSB [70]	
0000 0000	ACK	0000 0010	ACK	0000 00	000	ACK	0000 0011	ACK
VoutD = 76 µ	V		VoutD = 2 x 76	μV				VoutD = 3 x 76 µV
MSB [70]		LSB [70]		MSB [7	0]		LSB [70]	
0000 0000	ACK	0000 0100	ACK	0000 0	000	ACK	0000 0101	ACK
VoutD = 3 x 7	76 μV		VoutD = 4 x 76	μV				VoutD = 5 x 76 µV
MSB [70]		LSB [70]		MSB [7	0]		LSB [70]	
0000 0000	ACK	0000 0110	ACK	0000 0	000	ACK	0000 0111	ACK
VoutD = 5 x 7	76 μV		VoutD = 6 x 76	μV				VoutD = 7 x 76 µV

# LAYOUT

A precision analog component requires careful layout, adequate bypassing, and clean, well-regulated power supplies.

The power applied to  $V_{DD}$  should be well-regulated and low noise. Switching power supplies and dc/dc converters 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 positive 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, a 1  $\mu$ F to 10  $\mu$ F capacitor in parallel with a 0.1  $\mu$ F bypass capacitor is strongly recommended. In some situations, additional bypassing may be required, such as a 100  $\mu$ F electrolytic capacitor or even a Pi filter made up of inductors and capacitors—all designed to essentially low-pass filter the –5 V supply, removing the high-frequency noise.

### PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	e Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
DAC8574IPW	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
DAC8574IPWG4	ACTIVE	TSSOP	PW	16	90	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
DAC8574IPWR	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
DAC8574IPWRG4	ACTIVE	TSSOP	PW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

<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), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<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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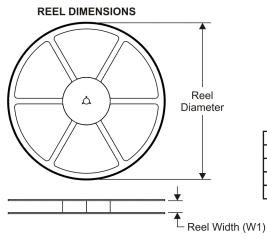
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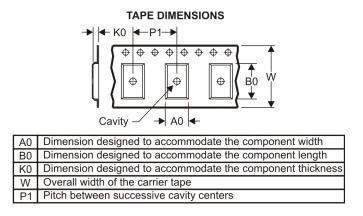
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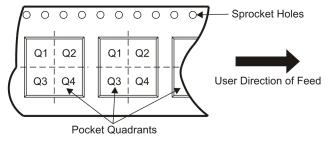
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# TAPE AND REEL INFORMATION





# QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dim	ensions are	e nominal	

Device	-	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
DAC8574IPWR	TSSOP	PW	16	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

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# PACKAGE MATERIALS INFORMATION

25-Sep-2009



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DAC8574IPWR	TSSOP	PW	16	2000	346.0	346.0	29.0

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



NOTES:

A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.  $\beta$ . This drawing is subject to change without notice.

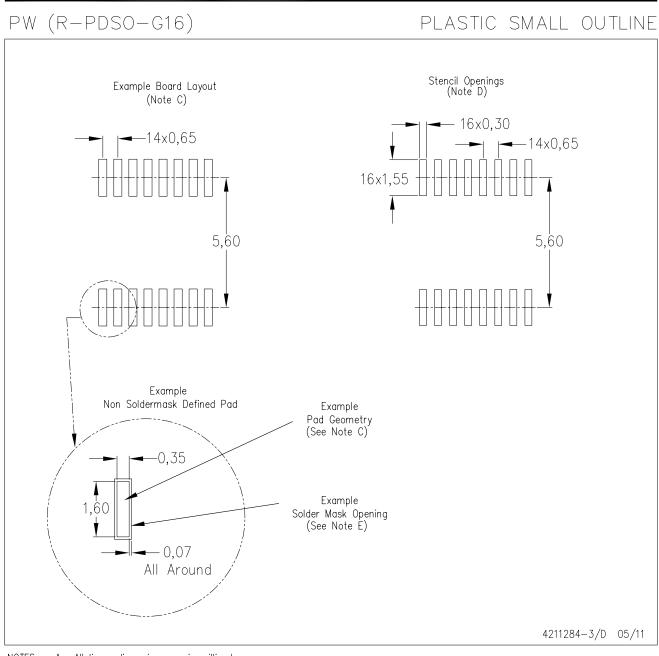
Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.

Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.

E. Falls within JEDEC MO-153



# LAND PATTERN DATA



NOTES: A. All linear dimensions are in millimeters.

- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
- E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.



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