

## 14-Bit 400-MSPS Digital-to-Analog Converter

### FEATURES

- 400-MSPS Update Rate
- Controlled Baseline
  - One Assembly
  - One Test Site
  - One Fabrication Site
- Extended Temperature Performance of  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Enhanced Diminishing Manufacturing Sources (DMS) Support
- Enhanced Product-Change Notification
- LVDS-Compatible Input Interface
- Spurious-Free Dynamic Range (SFDR) to Nyquist
  - 69 dBc at 70 MHz IF, 400 MSPS
- W-CDMA Adjacent Channel Power Ratio (ACPR)
  - 73 dBc at 30.72-MHz IF, 122.88 MSPS
  - 71 dBc at 61.44-MHz IF, 245.76 MSPS
- Differential Scalable Current Outputs: 2 mA to 20 mA
- On-Chip 1.2-V Reference
- Single 3.3-V Supply Operation

- Power Dissipation: 660 mW at  $f_{\text{CLK}} = 400 \text{ MSPS}$ ,  $f_{\text{OUT}} = 20 \text{ MHz}$
- Package: 48-Pin PowerPAD™ Thermally-Enhanced Thin Quad Flat Pack (HTQFP)  $T_{\text{JA}} = 29.1^{\circ}\text{C/W}$

### APPLICATIONS

- Cellular Base Transceiver Station Transmit Channel:
  - CDMA: WCDMA, CDMA2000, IS-95
  - TDMA: GSM, IS-136, EDGE/GPRS
  - Supports Single-Carrier and Multicarrier Applications
- Test and Measurement: Arbitrary Waveform Generation
- Military Communications

### DESCRIPTION/ORDERING INFORMATION

The DAC5675 is a 14-bit resolution high-speed digital-to-analog converter (DAC). The DAC5675 is designed for high-speed digital data transmission in wired and wireless communication systems, high-frequency direct-digital synthesis (DDS), and waveform reconstruction in test and measurement applications. The DAC5675 has excellent spurious-free dynamic range (SFDR) at high intermediate frequencies, which makes it well-suited for multicarrier transmission in TDMA- and CDMA-based cellular base transceiver stations (BTSS).

The DAC5675 operates from a single-supply voltage of 3.3 V. Power dissipation is 660 mW at  $f_{\text{CLK}} = 400 \text{ MSPS}$ ,  $f_{\text{OUT}} = 20 \text{ MHz}$ . The DAC5675 provides a nominal full-scale differential current output of 20 mA, supporting both single-ended and differential applications. The output current can be directly fed to the load with no additional external output buffer required. The output is referred to the analog supply voltage  $AV_{\text{DD}}$ .

The DAC5675 comprises a low-voltage differential signaling (LVDS) interface for high-speed digital data input. LVDS features a low differential voltage swing with a low constant power consumption across frequency, allowing for high-speed data transmission with low noise levels; that is, with low electromagnetic interference (EMI). LVDS is typically implemented in low-voltage digital CMOS processes, making it the ideal technology for high-speed interfacing between the DAC5675 and high-speed low-voltage CMOS ASICs or FPGAs. The DAC5675 current-source-array architecture supports update rates of up to 400 MSPS. On-chip edge-triggered input latches provide for minimum setup and hold times, thereby relaxing interface timing.



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PowerPAD is a trademark of Texas Instruments.

The DAC5675 has been specifically designed for a differential transformer-coupled output with a 50- $\Omega$  doubly-terminated load. With the 20-mA full-scale output current, both a 4:1 impedance ratio (resulting in an output power of 4 dBm) and 1:1 impedance ratio transformer (–2 dBm) is supported. The last configuration is preferred for optimum performance at high output frequencies and update rates. The outputs are terminated to AVDD and have voltage compliance ranges from  $AV_{DD} - 1$  to  $AV_{DD} + 0.3$  V.

An accurate on-chip 1.2-V temperature-compensated bandgap reference and control amplifier allows the user to adjust this output current from 20 mA down to 2 mA. This provides 20-dB gain range control capabilities. Alternatively, an external reference voltage may be applied. The DAC5675 features a SLEEP mode, which reduces the standby power to approximately 18 mW.

The DAC5675 is available in a 48-pin PowerPAD™ thermally-enhanced thin quad flat pack (HTQFP). This package increases thermal efficiency in a standard size IC package. The device is specified for operation over the military temperature range of –55°C to 125°C.



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.

### ORDERING INFORMATION<sup>(1)</sup>

PRODUCT	PACKAGE LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
DAC5675-EP	48 HTQFP	PHP	DAC5675-EP	DAC5675MHPREP	Tape and reel, 1000
				DAC5675MPHPEP	Tray, 250

(1) For the most current package and ordering information, see the *Package Option Addendum* located at the end of this data sheet.

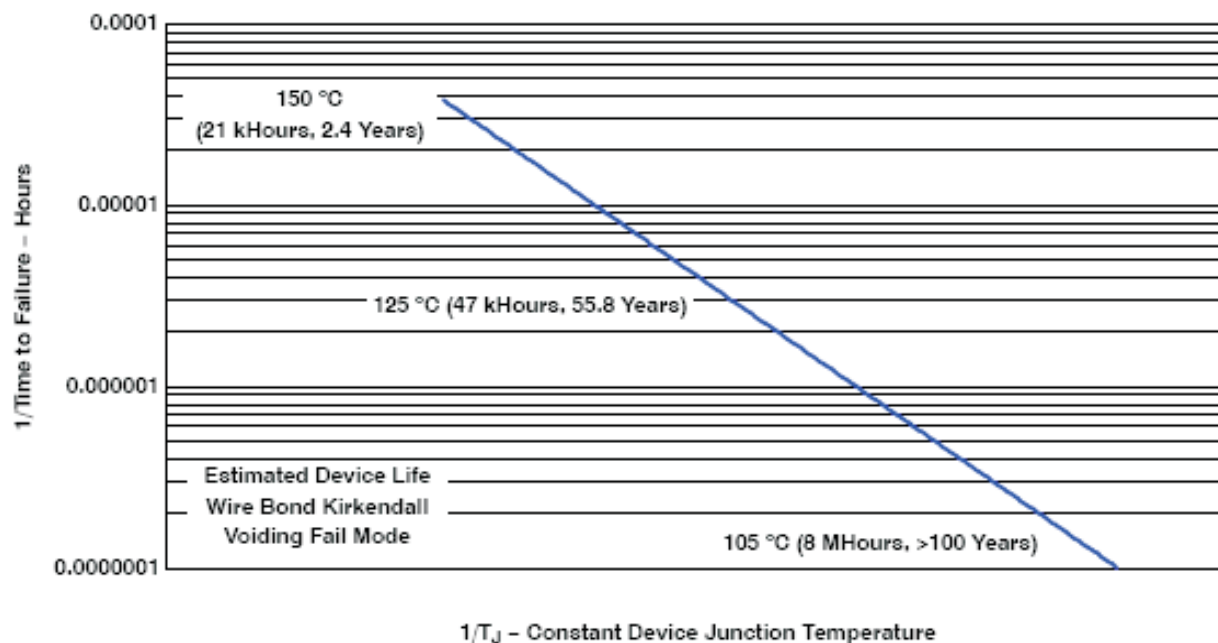
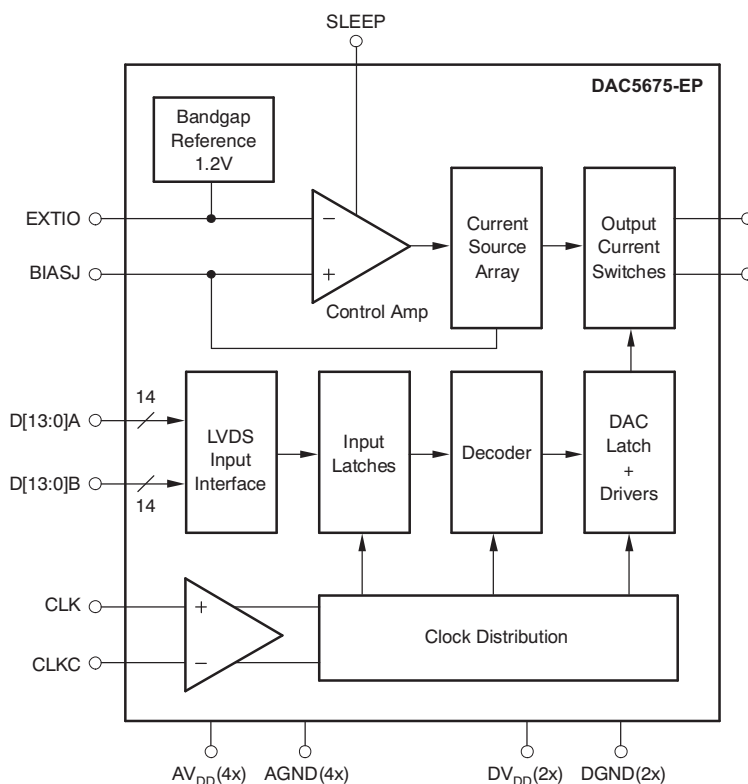
### TQFP-48 PACKAGE THERMAL CHARACTERISTICS

PARAMETER	SAME PACKAGE FORM WITHOUT PowerPAD	PowerPAD CONNECTED TO PCB THERMAL PLANE <sup>(1)</sup>
$R_{\theta JA}$ Thermal resistance, junction to ambient <sup>(1)(2)</sup>	108.71°C/W	29.11°C/W
$R_{\theta JC}$ Thermal resistance, junction to case <sup>(1)(2)</sup>	18.18°C/W	1.14°C/W

(1) Airflow is at 0 LFM (no airflow).

(2) Specified with the PowerPAD bond pad on the backside of the package soldered to a 2-oz CU plate PCB thermal plane

## FUNCTIONAL BLOCK DIAGRAM



## Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		DAC5675-EP	UNIT
Supply voltage range	$AV_{DD}^{(2)}$	–0.3 to 3.6	V
	$DV_{DD}^{(3)}$	–0.3 to 3.6	
	$AV_{DD}$ to $DV_{DD}$	–3.6 to 3.6	
Voltage between AGND and DGND		–0.3 to 0.5	V
CLK, CLKC <sup>(2)</sup>		–0.3 to $AV_{DD} + 0.3$	V
Digital input D[13:0]A, D[13:0]B <sup>(3)</sup> , SLEEP, DLLOFF		–0.3 to $DV_{DD} + 0.3$	V
IOUT1, IOUT2 <sup>(2)</sup>		–1 to $AV_{DD} + 0.3$	V
EXTIO, BIASJ <sup>(2)</sup>		–1 to $AV_{DD} + 0.3$	V
Peak input current (any input)		20	mA
Peak total input current (all inputs)		–30	mA
Operating free-air temperature range, $T_A$		–55 to 125	°C
Storage temperature range		–65 to 150	°C
Lead temperature 1,6 mm (1/16 in) from the case for 10 s		260	°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 degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) Measured with respect to AGND

(3) Measured with respect to DGND

## DC Electrical Characteristics

over operating free-air temperature range, typical values at 25°C,  $AV_{DD} = 3.3$  V,  $DV_{DD} = 3.3$  V,  $I_{O(FS)} = 20$  mA (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Resolution			14			Bit
DC Accuracy <sup>(1)</sup>						
INL	Integral nonlinearity	T <sub>MIN</sub> to T <sub>MAX</sub>	−4	±1.5	4.6	LSB
DNL	Differential nonlinearity		−2	±0.6	2.2	LSB
Monotonicity			Monotonic 12b Level			
Analog Output						
I <sub>O(FS)</sub>	Full-scale output current		2		20	mA
	Output compliance range	AV <sub>DD</sub> = 3.15 V to 3.45 V, I <sub>O(FS)</sub> = 20 mA	AV <sub>DD</sub> − 1		AV <sub>DD</sub> + 0.3	V
	Offset error		0.01			%FSR
	Gain error	Without internal reference	−10	5	10	%FSR
		With internal reference	−10	2.5	10	
	Output resistance		300			kΩ
	Output capacitance		5			pF
Reference Output						
V <sub>(EXTIO)</sub>	Reference voltage		1.17	1.23	1.29	V
	Reference output current <sup>(2)</sup>		100			nA
Reference Input						
V <sub>(EXTIO)</sub>	Input reference voltage		0.6	1.2	1.25	V
	Input resistance		1			MΩ
	Small-signal bandwidth		1.4			MHz
	Input capacitance		100			pF
Temperature Coefficients						
	Offset drift		12			ppm of FSR/°C
ΔV <sub>(EXTIO)</sub>	Reference voltage drift		±50			ppm/°C
Power Supply						
AV <sub>DD</sub>	Analog supply voltage		3.15	3.3	3.6	V
DV <sub>DD</sub>	Digital supply voltage		3.15	3.3	3.6	V
I <sub>(AVDD)</sub>	Analog supply current <sup>(3)</sup>		115			mA
I <sub>(DVDD)</sub>	Digital supply current <sup>(3)</sup>		85			mA
P <sub>D</sub>	Power dissipation	Sleep mode	18			mW
		AV <sub>DD</sub> = 3.3 V, DV <sub>DD</sub> = 3.3 V	660 900			
APSRR	Analog and digital power-supply rejection ratio	AV <sub>DD</sub> = 3.15 V to 3.45 V	−0.9	±0.1	0.9	%FSR/V
DPSRR			−0.9	±0.1	0.9	

(1) Measured differential at  $I_{OUT1}$  and  $I_{OUT2}$ : 25 Ω to  $AV_{DD}$

(2) Use an external buffer amplifier with high impedance input to drive any external load.

(3) Measured at  $f_{CLK} = 400$  MSPS and  $f_{OUT} = 70$  MHz

## AC Electrical Characteristics

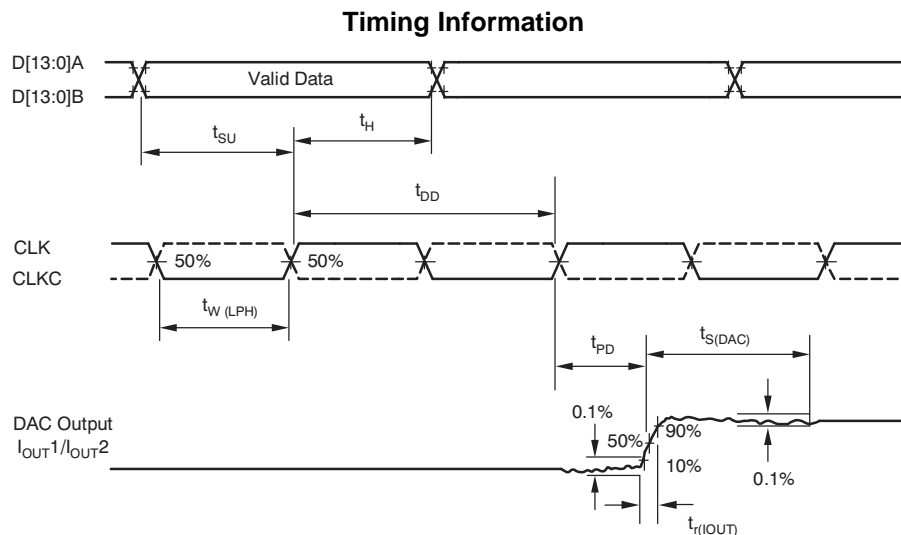
over operating free-air temperature range, typical values at 25°C,  $AV_{DD} = 3.3\text{ V}$ ,  $DV_{DD} = 3.3\text{ V}$ ,  $I_{O(FS)} = 20\text{ mA}$ , differential transformer-coupled output, 50- $\Omega$  doubly-terminated load (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Analog Output						
f <sub>CLK</sub>	Output update rate			400		MSPS
t <sub>s(DAC)</sub>	Output setting time to 0.1%	Transition: code x2000 to x23 <sub>FF</sub>		12		ns
t <sub>PD</sub>	Output propagation delay			1		ns
t <sub>r(IOUT)</sub>	Output rise time, 10% to 90%			2		ns
t <sub>f(IOUT)</sub>	Output fall time, 90% to 10%			2		ns
Output noise		IOUT <sub>FS</sub> = 20 mA		55		pA/√Hz
		IOUT <sub>FS</sub> = 2 mA		30		
AC Linearity						
THD	Total harmonic distortion	f <sub>CLK</sub> = 100 MSPS, f <sub>OUT</sub> = 19.9 MHz		73		dBc
		f <sub>CLK</sub> = 160 MSPS, f <sub>OUT</sub> = 41 MHz		72		
		f <sub>CLK</sub> = 200 MSPS, f <sub>OUT</sub> = 70 MHz		68		
		f <sub>CLK</sub> = 400 MSPS	f <sub>OUT</sub> = 20.1 MHz	72		
			f <sub>OUT</sub> = 70 MHz	71		
			f <sub>OUT</sub> = 140 MHz	58		
SFDR	Spurious-free dynamic range to Nyquist	f <sub>CLK</sub> = 100 MSPS, f <sub>OUT</sub> = 19.9 MHz		73		dBc
		f <sub>CLK</sub> = 160 MSPS, f <sub>OUT</sub> = 41 MHz		73		
		f <sub>CLK</sub> = 200 MSPS, f <sub>OUT</sub> = 70 MHz		70		
		f <sub>CLK</sub> = 400 MSPS	f <sub>OUT</sub> = 20.1 MHz	73		
			f <sub>OUT</sub> = 70 MHz	74		
			f <sub>OUT</sub> = 140 MHz	60		
SFDR	Spurious-free dynamic range within a window, 5-MHz span	f <sub>CLK</sub> = 100 MSPS, f <sub>OUT</sub> = 19.9 MHz		88		dBc
		f <sub>CLK</sub> = 160 MSPS, f <sub>OUT</sub> = 41 MHz		87		
		f <sub>CLK</sub> = 200 MSPS, f <sub>OUT</sub> = 70 MHz		82		
		f <sub>CLK</sub> = 400 MSPS	f <sub>OUT</sub> = 20.1 MHz	87		
			f <sub>OUT</sub> = 70 MHz	82		
			f <sub>OUT</sub> = 140 MHz	75		
ACPR	Adjacent channel power ratio WCDM A with 3.84 MHz BW, 5-MHz channel spacing	f <sub>CLK</sub> = 122.88 MSPS, IF = 30.72 MHz, See <a href="#">Figure 9</a>		73		dB
		f <sub>CLK</sub> = 245.76 MSPS, IF = 61.44 MHz, See <a href="#">Figure 10</a>		71		
		f <sub>CLK</sub> = 399.32 MSPS, IF = 153.36 MHz, See <a href="#">Figure 12</a>		65		
IMD	Two-tone intermodulation to Nyquist (each tone at –6 dBfs)	f <sub>CLK</sub> = 400 MSPS, f <sub>OUT1</sub> = 70 MHz, f <sub>OUT2</sub> = 71 MHz		73		dBc
		f <sub>CLK</sub> = 400 MSPS, f <sub>OUT1</sub> = 140 MHz, f <sub>OUT2</sub> = 141 MHz		62		
	Four-tone intermodulation, 15-MHz span, missing center tone (each tone at –16 dBfs)	f <sub>CLK</sub> = 156 MSPS, f <sub>OUT</sub> = 15.6, 15.8, 16.2, 16.4 MHz		82		
		f <sub>CLK</sub> = 400 MSPS, f <sub>OUT</sub> = 68.1, 69.3, 71.2, 72 MHz		74		

## Digital Specifications

over operating free-air temperature range, typical values at 25°C,  $AV_{DD} = 3.3\text{ V}$ ,  $DV_{DD} = 3.3\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
LVDS Interface: Nodes D[13:0]A, D[13:0]B						
V <sub>ITH+</sub>	Positive-going differential input voltage threshold	See LVDS Min/Max Threshold Voltages table	100			mV
V <sub>ITH−</sub>	Negative-going differential input voltage threshold		−100			mV
Z <sub>T</sub>	Internal termination impedance		90	110	132	Ω
C <sub>I</sub>	Input capacitance		2			pF
CMOS Interface (SLEEP)						
V <sub>IH</sub>	High-level input voltage		2	3.3		V
V <sub>IL</sub>	Low-level input voltage			0	0.8	V
I <sub>IH</sub>	High-level input current		−100		100	μA
I <sub>IL</sub>	Low-level input current		−10		10	μA
	Input capacitance		2			pF
Clock Interface (CLK, CLKC)						
CLK-CLKC	Clock differential input voltage		0.4		0.8	V <sub>PP</sub>
t <sub>w(H)</sub>	Clock pulse width high		1.25			ns
t <sub>w(L)</sub>	Clock pulse width low		1.25			ns
	Clock duty cycle		40%		60%	
V <sub>CM</sub>	Common-mode voltage range		2 ± 20%			V
	Input resistance	Node CLK, CLKC	670			Ω
	Input capacitance	Node CLK, CLKC	2			pF
	Input resistance	Differential	1.3			kΩ
	Input capacitance	Differential	1			pF
Timing						
t <sub>SU</sub>	Input setup time		1.5			ns
t <sub>H</sub>	Input hold time		0.25			ns
t <sub>LPH</sub>	Input latch pulse high time		2			ns
t <sub>DD</sub>	Digital delay time	DLL disabled, DLLOFF = 1	3			clk



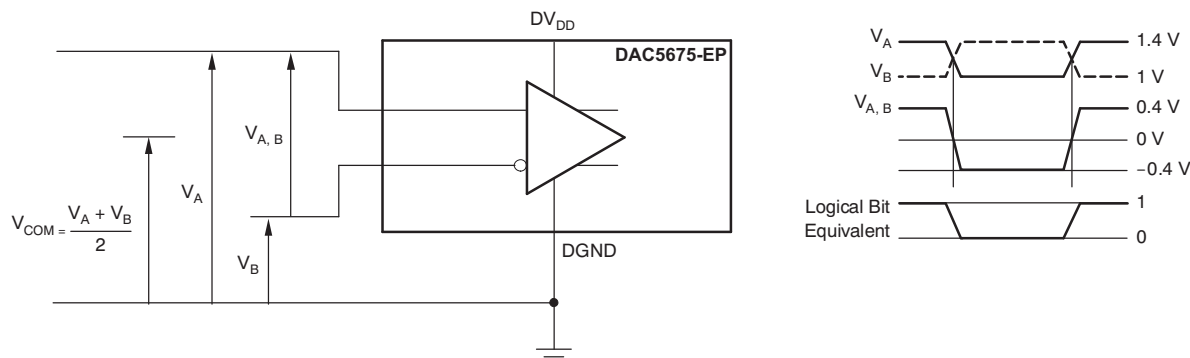
**Figure 1. Timing Diagram**

### Electrical Characteristics<sup>(1)</sup>

over operating free-air temperature range, AV<sub>DD</sub> = 3.3 V, DV<sub>DD</sub> = 3.3 V, I<sub>O(FS)</sub> = 20 mA (unless otherwise noted)

APPLIED VOLTAGES		RESULTING DIFFERENTIAL INPUT VOLTAGE	RESULTING COMMON-MODE INPUT VOLTAGE	LOGICAL BIT BINARY EQUIVALENT	COMMENT
V <sub>A</sub> (V)	V <sub>B</sub> (V)	V <sub>A,B</sub> (mV)	V <sub>COM</sub> (V)		
1.25	1.15	100	1.2	1	Operation with minimum differential voltage (±100 mV) applied to the complementary inputs versus common-mode range
1.15	1.25	–100	1.2	0	
2.4	2.3	100	2.35	1	
2.3	2.4	–100	2.35	0	
0.1	0	100	0.05	1	
0	0.1	–100	0.05	0	
1.5	0.9	600	1.2	1	Operation with maximum differential voltage (±600 mV) applied to the complementary inputs versus common-mode range
0.9	1.5	–600	1.2	0	
2.4	1.8	600	2.1	1	
1.8	2.4	–600	2.1	0	
0.6	0	600	0.3	1	
0	0.6	–600	0.3	0	

(1) Specifications subject to change.

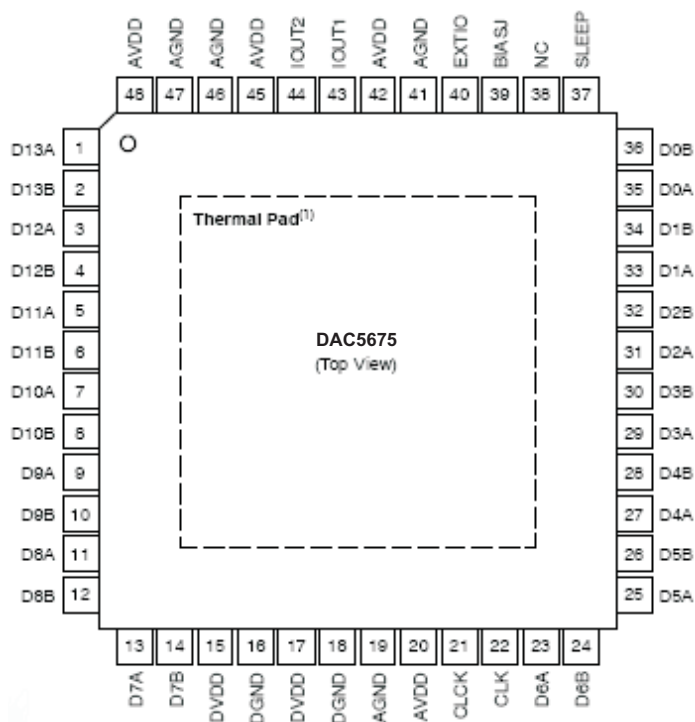


**Figure 2. LVDS Timing Test Circuit and Input Test Levels**



## DEVICE INFORMATION

### PHP PACKAGE (TOP VIEW)



- A. Thermal pad size: 4,5mm × 4,5mm (min), 5,5mm × 5,5mm (max)

## DEVICE INFORMATION (continued)

### TERMINAL FUNCTIONS

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
AGND	19, 41, 46, 47	I	Analog negative supply voltage (ground). Pin 47 is internally connected to the heat slug.
AV <sub>DD</sub>	20, 42, 45, 48	I	Analog positive supply voltage
BIASJ	39	O	Full-scale output current bias
CLK	22	I	External clock input
CLKC	21	I	Complementary external clock
D[13:0]A	1, 3, 5, 7, 9, 11, 13, 23, 25, 27, 29, 31, 33, 35	I	LVDS positive input, data bits 13–0. D13A is the most significant data bit (MSB). D0A is the least significant data bit (LSB).
D[13:0]B	2, 4, 6, 8, 10, 12, 14, 24, 26, 28, 30, 32, 34, 36	I	LVDS negative input, data bits 13–0.. D13B is the most significant data bit (MSB). D0B is the least significant data bit (LSB).
DGND	16, 18	I	Digital negative supply voltage (ground)
DV <sub>DD</sub>	15, 17	I	Digital positive supply voltage
EXTIO	40	I/O	Internal reference output or external reference input. Requires a 0.1-μF decoupling capacitor to AGND when used as reference output.
IOUT1	43	O	DAC current output. Full-scale when all input bits are set 1. Connect the reference side of the DAC load resistors to AV <sub>DD</sub> .
IOUT2	44	O	DAC complementary current output. Full-scale when all input bits are 0. Connect the reference side of the DAC load resistors to AV <sub>DD</sub> .
NC	38		Not connected in chip. Can be high or low.
SLEEP	37	I	Asynchronous hardware power-down input. Active high. Internal pulldown.

## TYPICAL CHARACTERISTICS

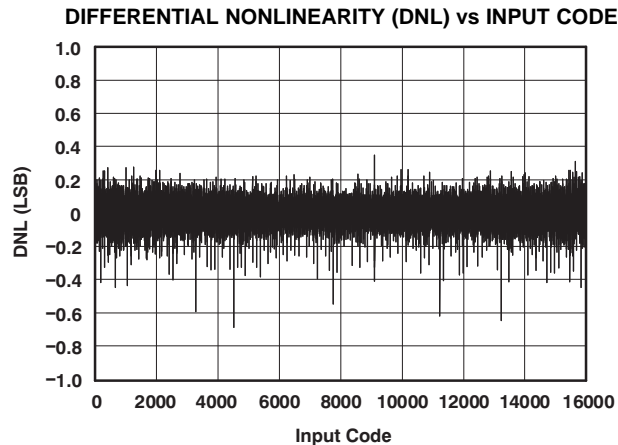


Figure 3.

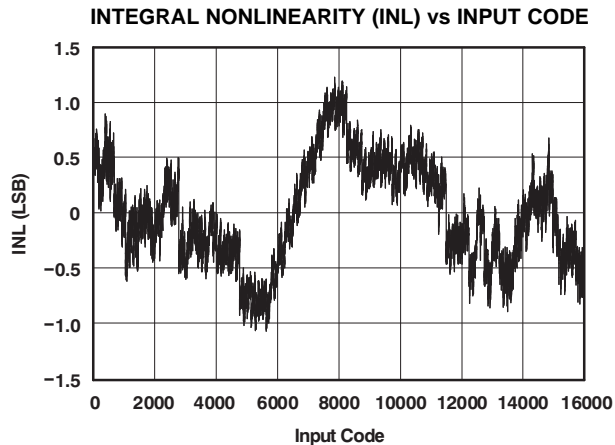


Figure 4.

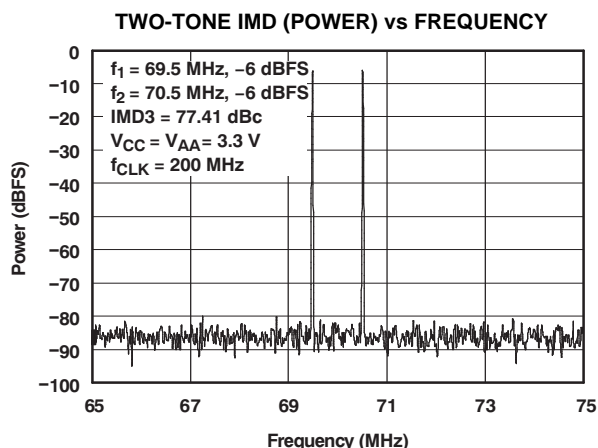


Figure 5.

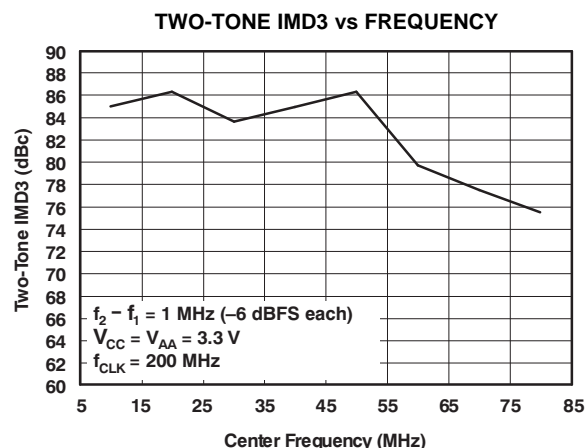


Figure 6.

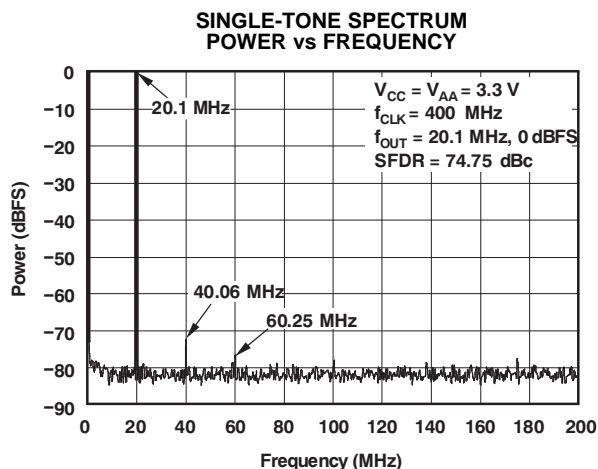


Figure 7.

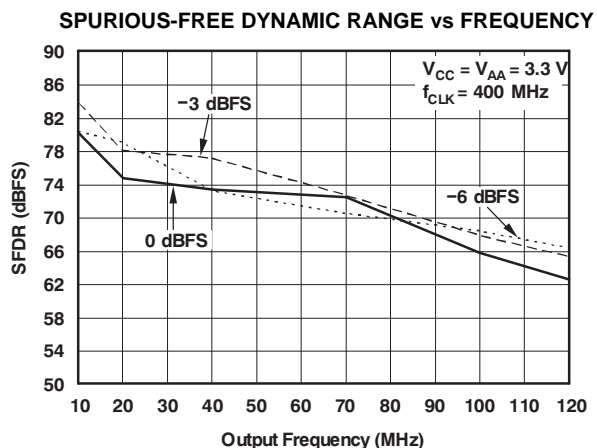


Figure 8.

## TYPICAL CHARACTERISTICS (continued)

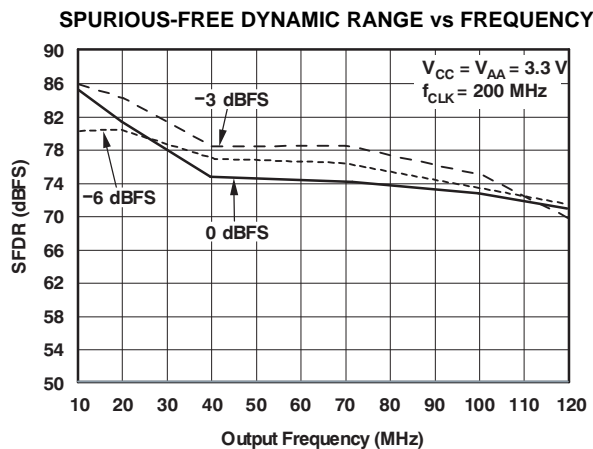


Figure 9.

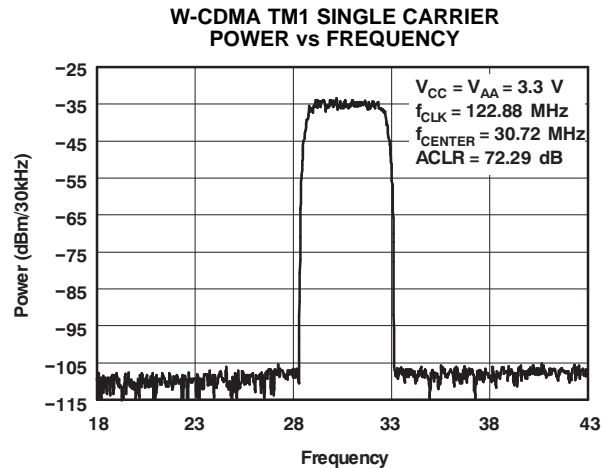


Figure 10.

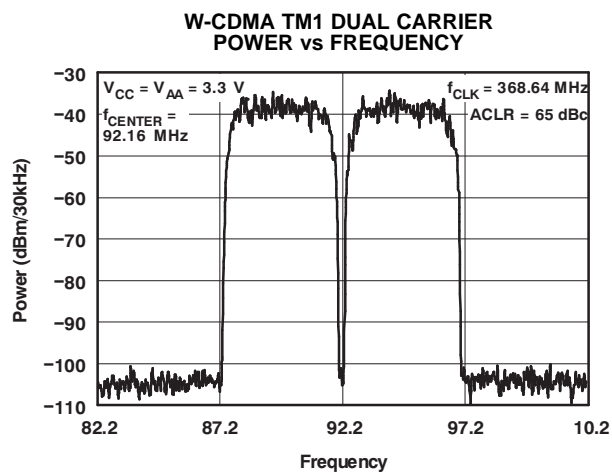


Figure 11.

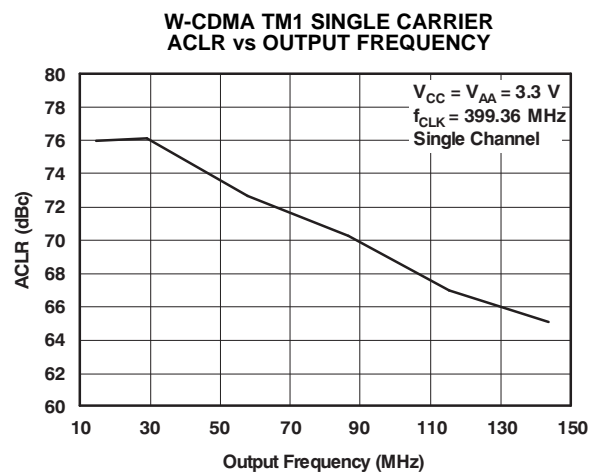


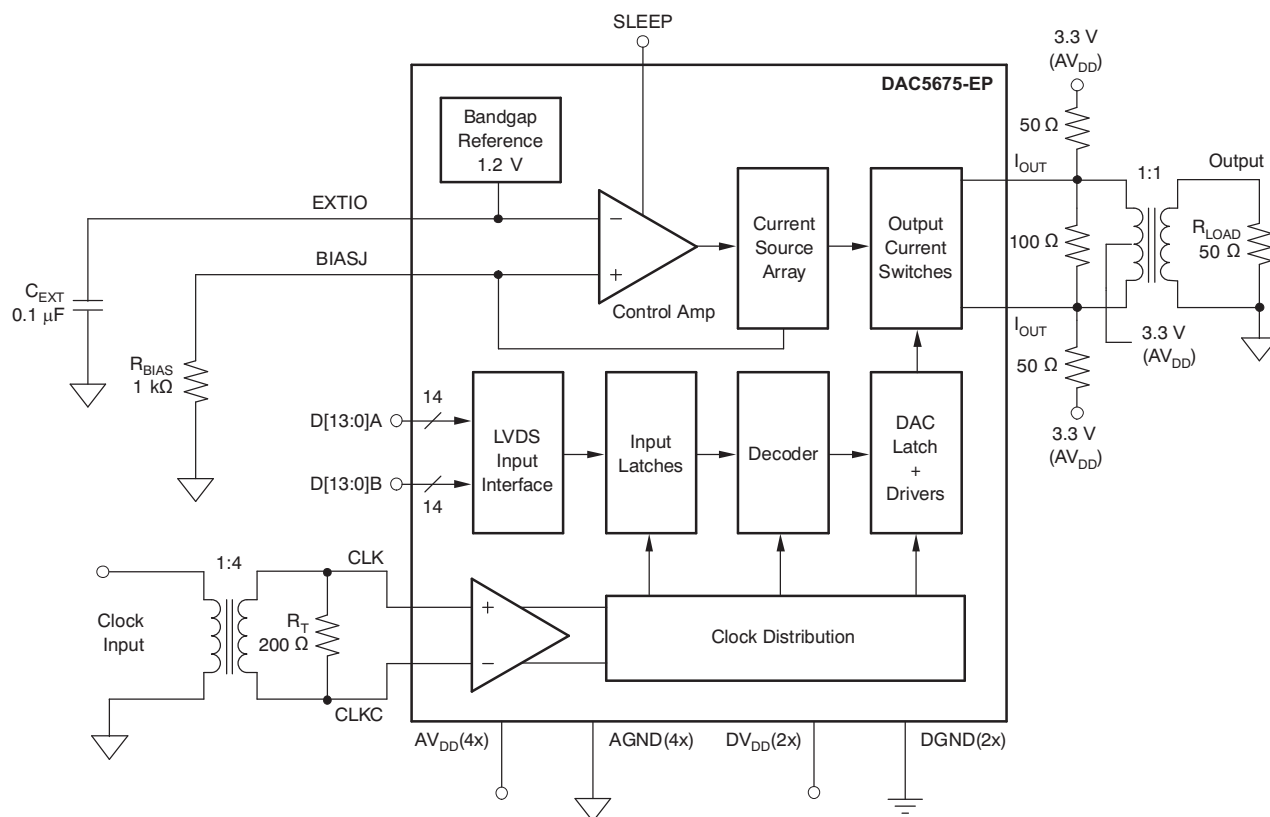
Figure 12.

## APPLICATION INFORMATION

### Detailed Description

**Figure 13** shows a simplified block diagram of the current steering DAC5675. The DAC5675 consists of a segmented array of NPN-transistor current sources, capable of delivering a full-scale output current up to 20 mA. Differential current switches direct the current of each current source to either one of the complementary output nodes IOUT1 or IOUT2. The complementary current output enables differential operation, canceling out common-mode noise sources (digital feedthrough, on-chip, and PCB noise), dc offsets, and even-order distortion components, and doubling signal output power.

The full-scale output current is set using an external resistor ( $R_{BIAS}$ ) in combination with an on-chip bandgap voltage reference source (1.2 V) and control amplifier. The current ( $I_{BIAS}$ ) through resistor  $R_{BIAS}$  is mirrored internally to provide a full-scale output current equal to 16 times  $I_{BIAS}$ . The full-scale current is adjustable from 20 mA down to 2 mA by using the appropriate bias resistor value.



### Figure 13. Application Schematic

## APPLICATION INFORMATION (continued)

## Digital Inputs

The DAC5675 uses a low-voltage differential signaling (LVDS) bus input interface. The LVDS features a low differential voltage swing with low constant power consumption (4 mA per complementary data input) across frequency. The differential characteristic of LVDS allows for high-speed data transmission with low electromagnetic interference (EMI) levels. The LVDS input minimum and maximum input threshold table lists the LVDS input levels. [Figure 14](#) shows the equivalent complementary digital input interface for the DAC5675, valid for pins D[13:0]A and D[13:0]B. Note that the LVDS interface features internal 110-Ω resistors for proper termination. [Figure 2](#) shows the LVDS input timing measurement circuit and waveforms. A common-mode level of 1.2 V and a differential input swing of 0.8 V<sub>PP</sub> is applied to the inputs.

[Figure 15](#) shows a schematic of the equivalent CMOS/TTL-compatible digital inputs of the DAC5675, valid for the SLEEP pin.

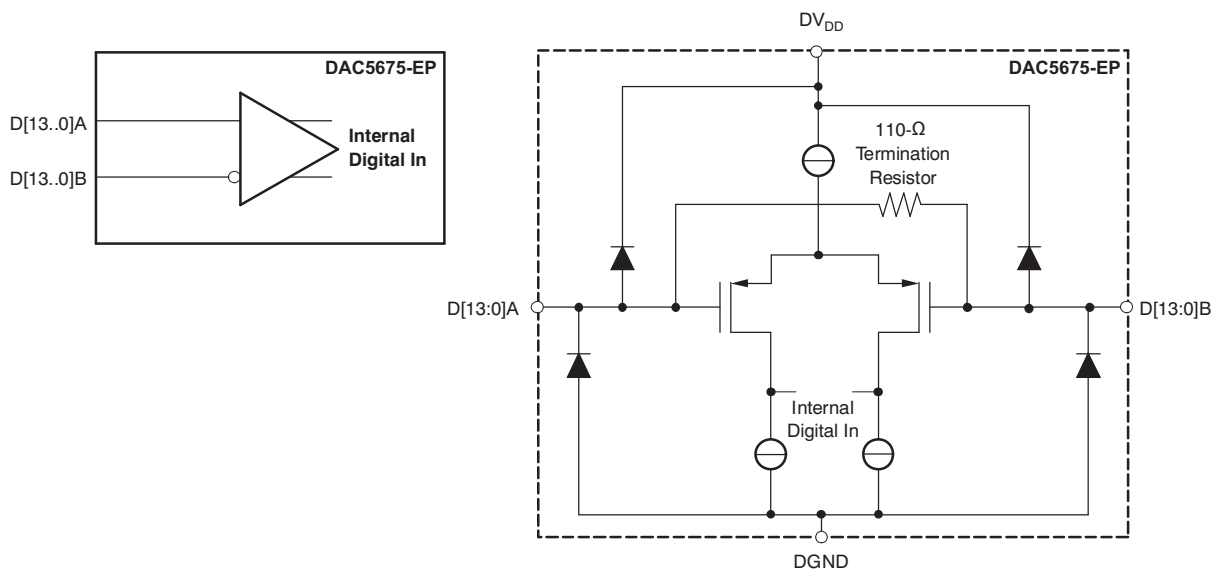


Figure 14. LVDS Digital Equivalent Input

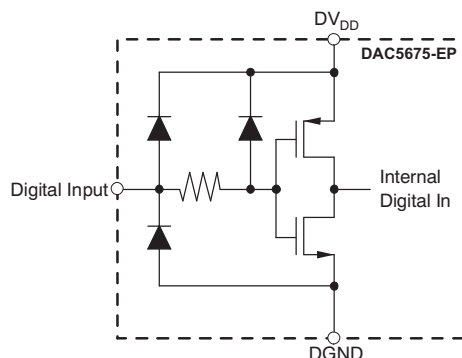


Figure 15. CMOS/TTL Digital Equivalent Input

## Clock Input

The DAC5675 features differential LVPECL-compatible clock inputs (CLK, CLKC). [Figure 16](#) shows the equivalent schematic of the clock input buffer. The internal biasing resistors set the input common-mode voltage to approximately 2 V, while the input resistance is typically 670 Ω. A variety of clock sources can be ac-coupled to the device, including a sine-wave source (see [Figure 17](#)).

## APPLICATION INFORMATION (continued)

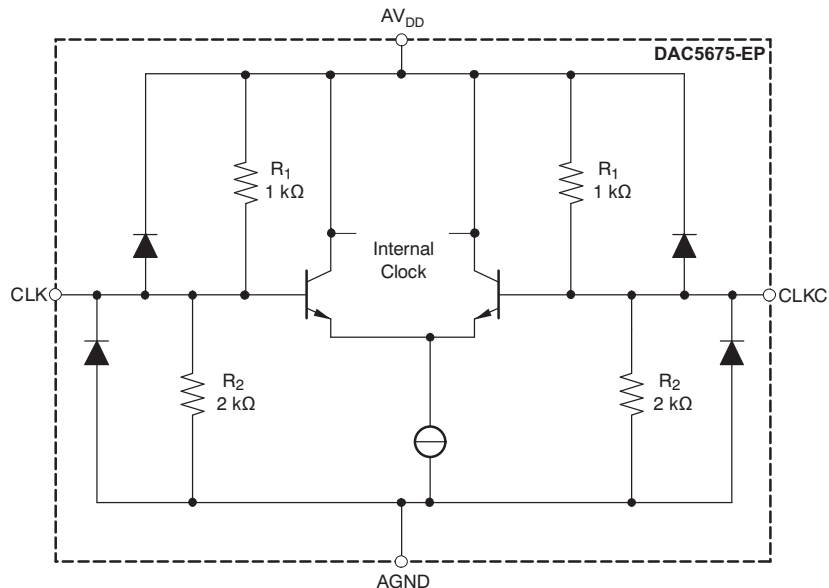


Figure 16. Clock Equivalent Input

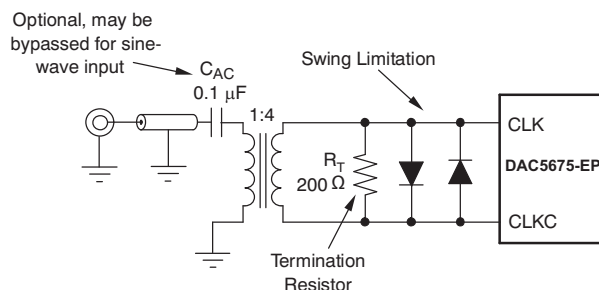


Figure 17. Driving the DAC5675 With a Single-Ended Clock Source Using a Transformer

To obtain best ac performance, the DAC5675 clock input should be driven with a differential LVPECL or sine-wave source as shown in [Figure 18](#) and [Figure 19](#). Here, the potential of  $V_{TT}$  should be set to the termination voltage required by the driver along with the proper termination resistors ( $R_T$ ). The DAC5675 clock input can also be driven single ended; this is shown in [Figure 20](#).

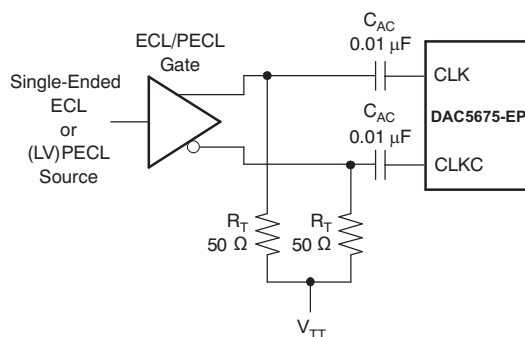


Figure 18. Driving the DAC5675 With a Single-Ended ECL/PECL Clock Source

## APPLICATION INFORMATION (continued)

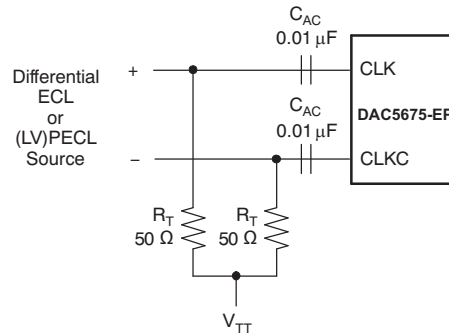


Figure 19. Driving the DAC5675 With a Differential ECL/PECL Clock Source

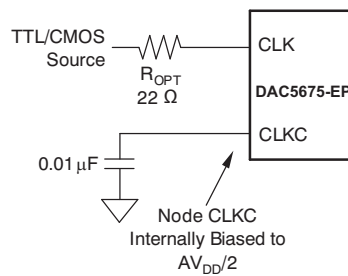


Figure 20. Driving the DAC5675 With a Single-Ended TTL/CMOS Clock Source

## Supply Inputs

The DAC5675 comprises separate analog and digital supplies, that is  $AV_{DD}$  and  $DV_{DD}$ , respectively. These supply inputs can be set independently from 3.6 V down to 3.15 V.

## DAC Transfer Function

The DAC5675 delivers complementary output currents  $I_{OUT1}$  and  $I_{OUT2}$ . The DAC supports straight binary coding, with D13 being the MSB and D0 the LSB. (For ease of notation, we denote D13–D0 as the logical bit equivalent of the complementary LVDS inputs D[13:0]A and D[13:0]B). Output current  $I_{OUT1}$  equals the approximate full-scale output current when all input bits are set high, when the binary input word has the decimal representation 16383. Full-scale output current flows through terminal  $I_{OUT2}$  when all input bits are set low (mode 0, straight binary input). The relation between  $I_{OUT1}$  and  $I_{OUT2}$  can thus be expressed as:

$$I_{OUT1} = I_{O(FS)} - I_{OUT2} \quad (1)$$

where  $I_{O(FS)}$  is the full-scale output current. The output currents can be expressed as:

$$I_{OUT1} = \frac{I_{O(FS)} \times \text{CODE}}{16384} \quad (2)$$

$$I_{OUT2} = \frac{I_{O(FS)} \times (16383 - \text{CODE})}{16384} \quad (3)$$

where CODE is the decimal representation of the DAC data input word. Output currents  $I_{OUT1}$  and  $I_{OUT2}$  drive a load  $R_L$ .  $R_L$  is the combined impedance for the termination resistance and/or transformer load resistance,  $R_{LOAD}$  (see Figure 22 and Figure 23). This would translate into single-ended voltages  $V_{OUT1}$  and  $V_{OUT2}$  at terminal  $I_{OUT1}$  and  $I_{OUT2}$ , respectively, of Equation 4 and Equation 5:



## APPLICATION INFORMATION (continued)

$$V_{OUT1} = I_{OUT1} \times R_L = \frac{(\text{CODE} \times I_{O(FS)} \times R_L)}{16384} \quad (4)$$

$$V_{OUT2} = I_{OUT2} \times R_L = \frac{(16383 - \text{CODE}) \times I_{O(FS)} \times R_L}{16384} \quad (5)$$

Thus, the differential output voltage  $V_{OUT(DIFF)}$  can be expressed as:

$$V_{OUT(DIFF)} = V_{OUT1} - V_{OUT2} = \frac{(2\text{CODE} - 16383) \times I_{O(FS)} \times R_L}{16384} \quad (6)$$

Equation 6 shows that applying the differential output results in doubling the signal power delivered to the load. Since the output currents  $I_{OUT1}$  and  $I_{OUT2}$  are complementary, they become additive when processed differentially. Care should be taken not to exceed the compliance voltages at nodes  $I_{OUT1}$  and  $I_{OUT2}$ , which leads to increased signal distortion.

## Reference Operation

The DAC5675 has a bandgap reference and control amplifier for biasing the full-scale output current. The full-scale output current is set by applying an external resistor  $R_{BIAS}$ . The bias current  $I_{BIAS}$  through resistor  $R_{BIAS}$  is defined by the on-chip bandgap reference voltage and control amplifier. The full-scale output current equals 16 times this bias current. The full-scale output current  $I_{O(FS)}$  is thus expressed as [Equation 7](#):

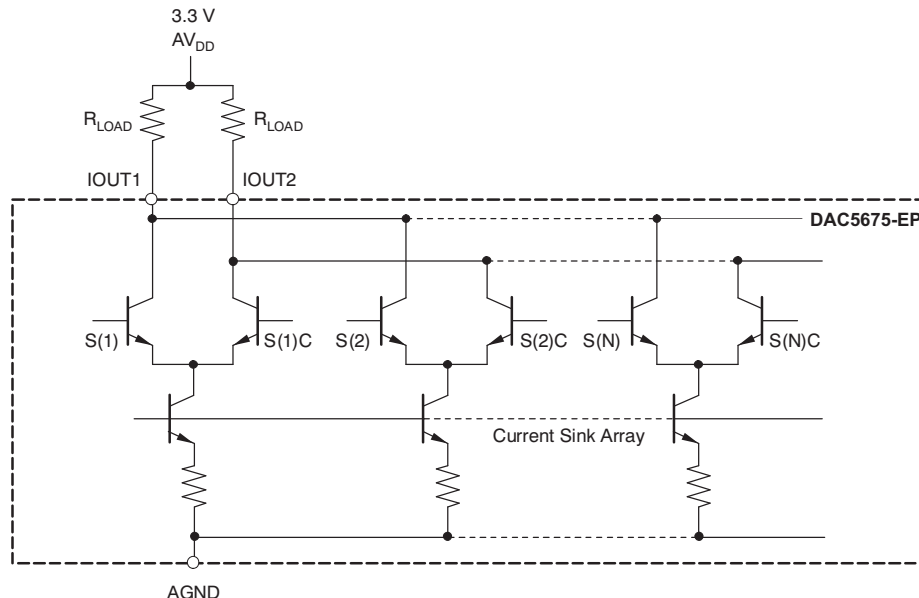
$$I_{O(FS)} = 16 \times I_{BIAS} = \frac{16 \times V_{EXTIO}}{R_{BIAS}} \quad (7)$$

where  $V_{EXTIO}$  is the voltage at terminal  $EXTIO$ . The bandgap reference voltage delivers a stable voltage of 1.2 V. This reference can be overridden by applying an external voltage to terminal  $EXTIO$ . The bandgap reference can additionally be used for external reference operation. In such a case, an external buffer amplifier with high impedance input should be selected in order to limit the bandgap load current to less than 100 nA. The capacitor  $C_{EXT}$  may be omitted. Terminal  $EXTIO$  serves as either an input or output node. The full-scale output current is adjustable from 20 mA down to 2 mA by varying resistor  $R_{BIAS}$ .

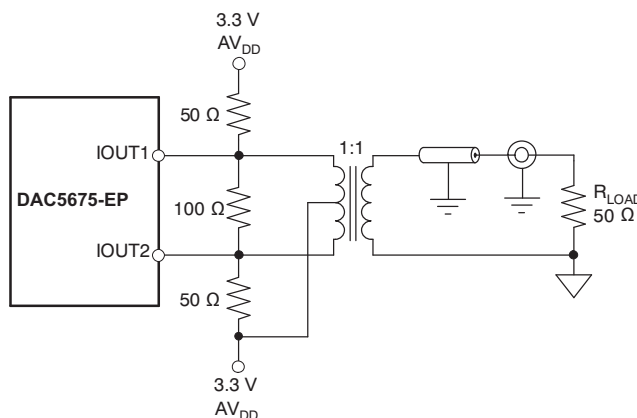
## Analog Current Outputs

[Figure 21](#) shows a simplified schematic of the current source array output with corresponding switches. Differential NPN switches direct the current of each individual NPN current source to either the positive output node  $I_{OUT1}$  or its complementary negative output node  $I_{OUT2}$ . The output impedance is determined by the stack of the current sources and differential switches and is  $>300 \text{ k}\Omega$  in parallel with an output capacitance of 5 pF.

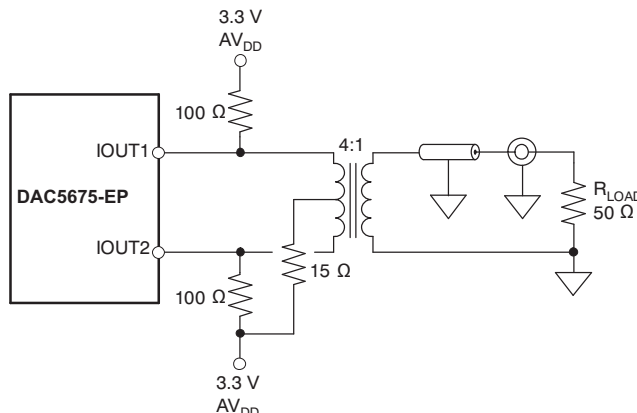
The external output resistors are referred to the positive supply  $AV_{DD}$ .

**APPLICATION INFORMATION (continued)****Figure 21. Equivalent Analog Current Output**

The DAC5675 can easily be configured to drive a doubly-terminated 50-Ω cable using a properly selected transformer. [Figure 22](#) and [Figure 23](#) show the 1:1 and 4:1 impedance ratio configuration, respectively. These configurations provide maximum rejection of common-mode noise sources and even-order distortion components, thereby doubling the power of the DAC to the output. The center tap on the primary side of the transformer is terminated to  $AV_{DD}$ , enabling a dc-current flow for both IOUT1 and IOUT2. Note that the ac performance of the DAC5675 is optimum and specified using a 1:1 differential transformer-coupled output.

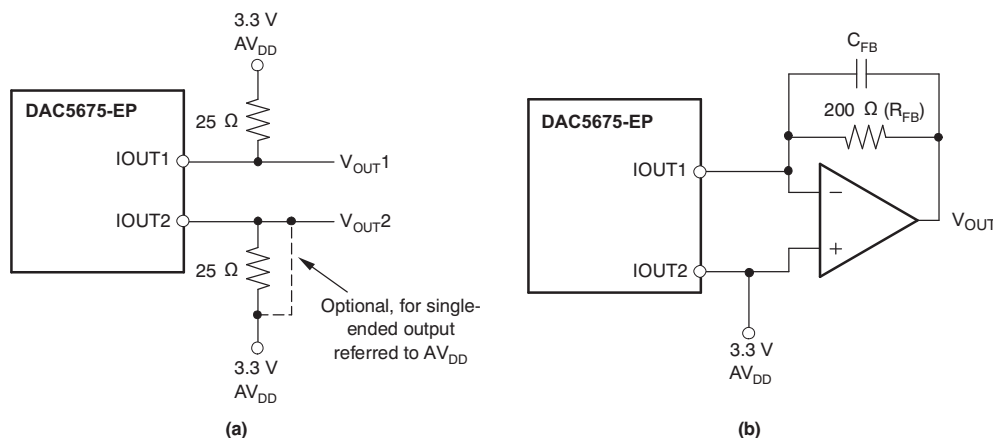
**Figure 22. Driving a Doubly-Terminated 50-Ω Cable Using a 1:1 Impedance Ratio Transformer**

## APPLICATION INFORMATION (continued)



**Figure 23. Driving a Doubly-Terminated 50-Ω Cable Using a 4:1 Impedance Ratio Transformer**

Figure 24(a) shows the typical differential output configuration with two external matched resistor loads. The nominal resistor load of 25 Ω gives a differential output swing of 1 V<sub>PP</sub> (0.5 V<sub>PP</sub> single ended) when applying a 20-mA full-scale output current. The output impedance of the DAC5675 slightly depends on the output voltage at nodes IOUT1 and IOUT2. Consequently, for optimum dc-integral nonlinearity, the configuration of Figure 24(b) should be chosen. In this current/voltage (I-V) configuration, terminal IOUT1 is kept at AV<sub>DD</sub> by the inverting operational amplifier. The complementary output should be connected to AV<sub>DD</sub> to provide a dc-current path for the current sources switched to IOUT1. The amplifier maximum output swing and the full-scale output current of the DAC determine the value of the feedback resistor R<sub>FB</sub>. The capacitor C<sub>FB</sub> filters the steep edges of the DAC5675 current output, thereby reducing the operational amplifier slew-rate requirements. In this configuration, the operational amplifier should operate at a supply voltage higher than the resistor output reference voltage AV<sub>DD</sub> as a result of its positive and negative output swing around AV<sub>DD</sub>. Node IOUT1 should be selected if a single-ended unipolar output is desired.



**Figure 24. Output Configurations**

## Sleep Mode

The DAC5675 features a power-down mode that turns off the output current and reduces the supply current to approximately 6 mA. The power-down mode is activated by applying a logic level one to the SLEEP pin, pulled down internally.

## DEFINITIONS

### Definitions of Specifications and Terminology

**Gain error** is defined as the percentage error in the ratio between the measured full-scale output current and the value of  $16 \times V_{(\text{EXTIO})}/R_{\text{BIAS}}$ . A  $V_{(\text{EXTIO})}$  of 1.25 V is used to measure the gain error with an external reference voltage applied. With an internal reference, this error includes the deviation of  $V_{(\text{EXTIO})}$  (internal bandgap reference voltage) from the typical value of 1.25 V.

**Offset error** is defined as the percentage error in the ratio of the differential output current (IOUT1-IOUT2) and the half of the full-scale output current for input code 8192.

**THD** is the ratio of the rms sum of the first six harmonic components to the rms value of the fundamental output signal.

**SNR** is the ratio of the rms value of the fundamental output signal to the rms sum of all other spectral components below the Nyquist frequency, including noise, but excluding the first six harmonics and dc.

**SINAD** is the ratio of the rms value of the fundamental output signal to the rms sum of all other spectral components below the Nyquist frequency, including noise and harmonics, but excluding dc.

**ACPR** or adjacent channel power ratio is defined for a 3.84-Mcps 3GPP W-CDMA input signal measured in a 3.84-MHz bandwidth at a 5-MHz offset from the carrier with a 12-dB peak-to-average ratio.

**APSSR** or analog power supply ratio is the percentage variation of full-scale output current versus a 5% variation of the analog power supply  $AV_{\text{DD}}$  from the nominal. This is a dc measurement.

**DPSSR** or digital power supply ratio is the percentage variation of full-scale output current versus a 5% variation of the digital power supply  $DV_{\text{DD}}$  from the nominal. This is a dc measurement.

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
DAC5675MPHPEP	ACTIVE	HTQFP	PHP	48	250	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-55 to 125	DC5675MEP	<a href="#">Samples</a>
DAC5675MPHPREP	ACTIVE	HTQFP	PHP	48	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-55 to 125	DC5675MEP	<a href="#">Samples</a>
V62/05619-01XE	ACTIVE	HTQFP	PHP	48	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-55 to 125	DC5675MEP	<a href="#">Samples</a>
V62/05619-02XE	ACTIVE	HTQFP	PHP	48	250	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-55 to 125	DC5675MEP	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

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

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

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

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

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

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

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

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**OTHER QUALIFIED VERSIONS OF DAC5675-EP :**

- Catalog: [DAC5675](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
DAC5675MPHPREP	HTQFP	PHP	48	1000	330.0	16.4	9.6	9.6	1.5	12.0	16.0	Q2

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DAC5675MPHPREP	HTQFP	PHP	48	1000	350.0	350.0	43.0



## GENERIC PACKAGE VIEW

**PHP 48**

**TQFP - 1.2 mm max height**

7 x 7, 0.5 mm pitch

QUAD FLATPACK

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4226443/A

PHP (S-PQFP-G48)

PowerPAD™ PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Falls within JEDEC MS-026

PowerPAD is a trademark of Texas Instruments.

## THERMAL PAD MECHANICAL DATA

PHP (S-PQFP-G48)

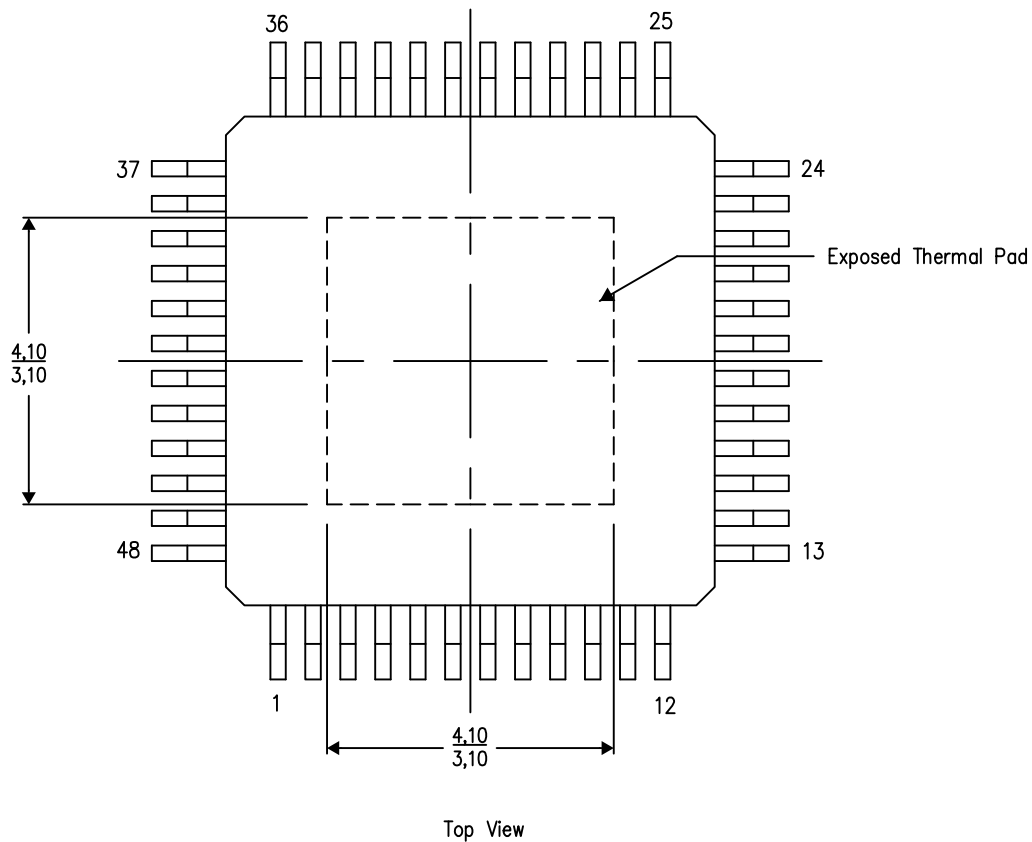
PowerPAD™ PLASTIC QUAD FLATPACK

### THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.

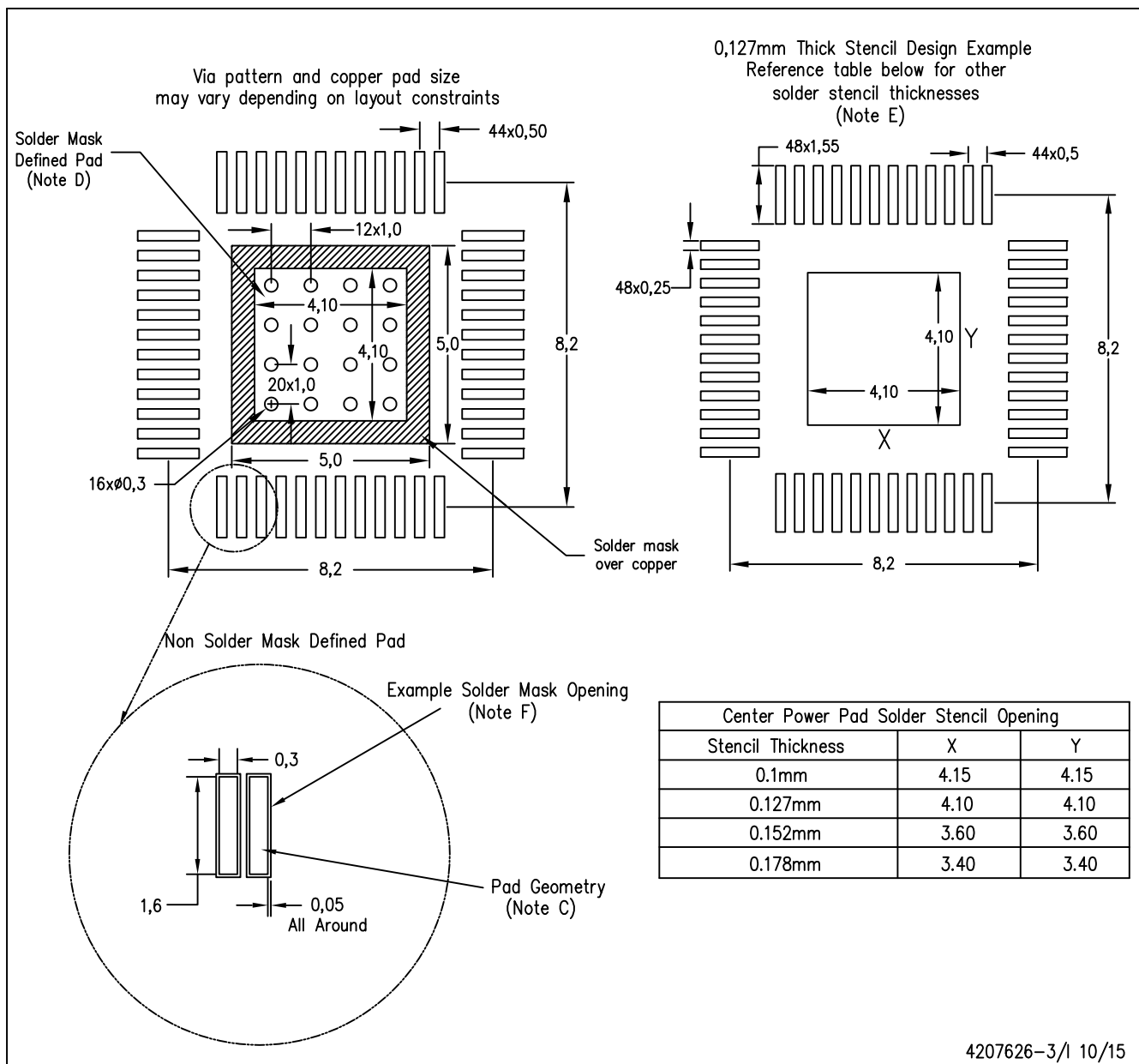


Exposed Thermal Pad Dimensions

4206329-3/P 03/15

NOTE: A. All linear dimensions are in millimeters

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- 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. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. 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 stencil design considerations.
  - F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting options for vias placed in the thermal pad.

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