

## 14-BIT 2.4-GSPS DIGITAL-TO-ANALOG CONVERTER

 Check for Samples: [DAC5670](#)

### FEATURES

- 14-Bit Resolution
- 2.4-GSPS Maximum Update Rate Digital to Analog Converter
- Dual Differential Input Ports
  - Even/Odd Demultiplexed Data
  - Maximum 1.2 GSPS Each Port, 2.4 GSPS Total
  - Dual 14-Bit Inputs + 1 Reference Bit
  - DDR Output Clock
  - DLL Optimized Clock Timing Synchronized to Reference Bit
  - LVDS and HyperTransport™ Voltage Level Compatible
  - Internal 100-Ω Terminations for Data and Reference Bit Inputs
- Selectable 2 Times Interpolation With Fs/2 Mixing
- Differential Scalable Current Outputs: 5 mA to 30 mA
- On-Chip 1.2-V Reference
- 3.3-V Analog Supply Operation
- Power Dissipation: 2 W
- 252-Ball GDJ Package

### APPLICATIONS

- Satellite Communications

### DESCRIPTION

The DAC5670 is a 14-bit 2.4-GSPS digital-to-analog converter (DAC) with dual demultiplexed differential input ports. The DAC5670 is clocked at the DAC sample rate and the two input ports run at a maximum of 1.2 GSPS. An additional reference bit input sequence is used to adjust the output clock delay to the data source, optimizing the internal data latching clock relative to this reference bit with a delay lock loop (DLL). Alternatively, the DLL may be bypassed and the timing interface managed by controlling DATA setup and hold timing to DLYCLK.

The DAC5670 also can accept data up to 1.2 GSPS on one input port the same clock configuration. In the single port mode, repeating the input sample (A\_ONLY mode), 2 times interpolation by zero stuff (A\_ONLY\_ZS mode), or 2 times interpolation by repeating and inverting the input sample (A\_ONLY\_INV) are used to double the input sample rate up to 2.4 GSPS.

The DAC5670 operates with a single 3-V to 3.6-V supply voltage. Power dissipation is 2 W at maximum operating conditions. The DAC5670 provides a nominal full-scale differential current-output of 20 mA, supporting both single-ended and differential applications. An on-chip 1.2-V temperature-compensated bandgap reference and control amplifier allows the user to adjust the full-scale output current from the nominal 20 mA to as low as 5 mA or as high as 30 mA. The output current can be directly fed to the load with no additional external output buffer required. The device has been specifically designed for a differential transformer coupled output with a 50-Ω doubly-terminated load.

The DAC5670 is available in a 252-ball GDJ package. The device is characterized for operation over the temperature range –40°C to 85°C .

### AVAILABLE OPTIONS<sup>(1)</sup>

TEMPERATURE	PACKAGE <sup>(2)</sup>	TOP SIDE SYMBOL
–40°C to 85°C	252-GDJ	DAC5670I

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

(2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).



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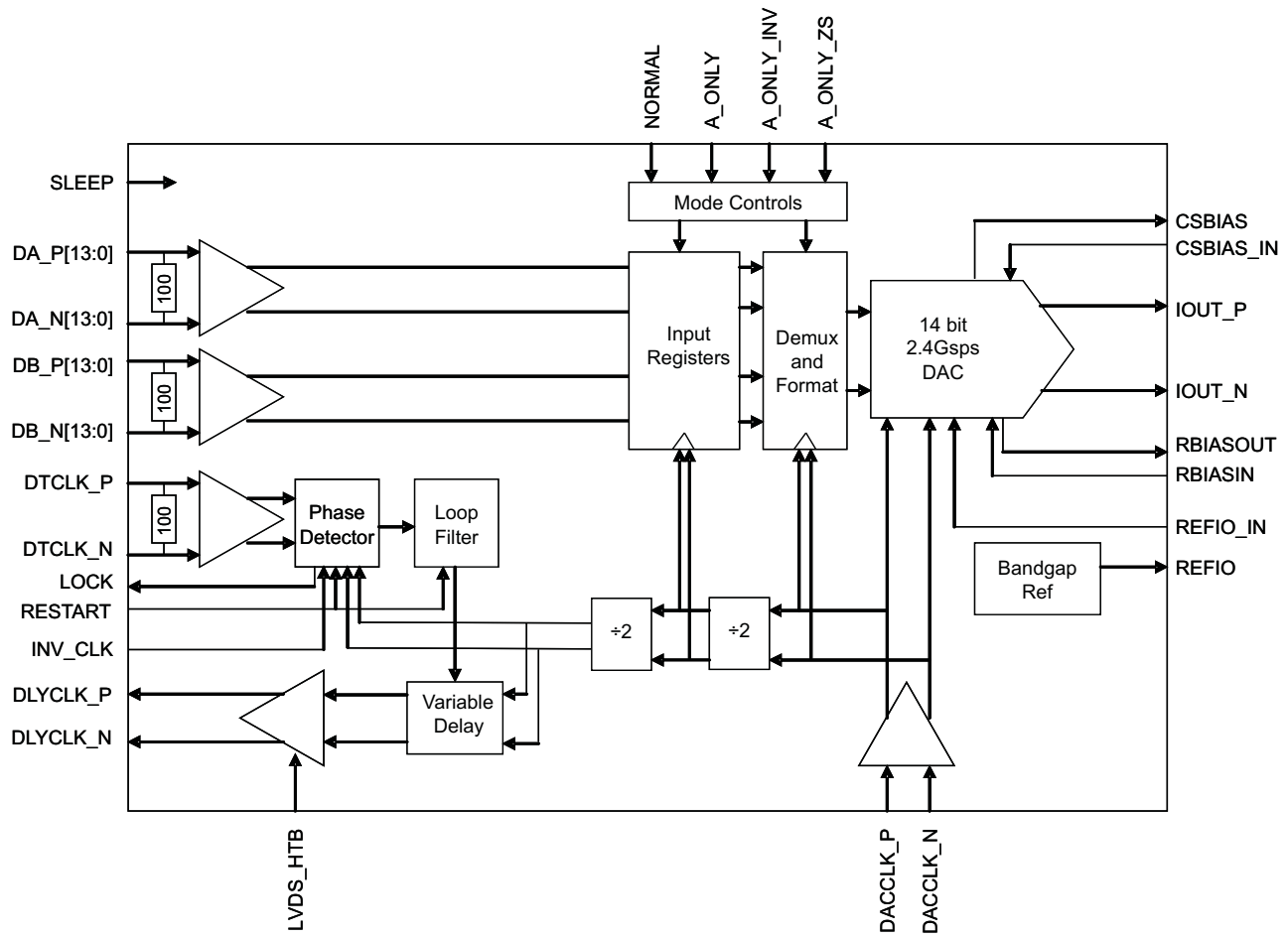


Figure 1. Functional Block Diagram DAC5670

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	GND	LOCK			GND	GND	IOUT_P	GND	GND	IOUT_N	GND	GND		RBIASOUT		GND
B		NORMAL	AVDD		GND	GND	IOUT_P	AVDD	AVDD	IOUT_N	GND			RBIASIN		REFIO
C	AVDD	RESTART	A_ONLY_ZS			GND	GND	GND	GND	GND	GND			GND		REFIO_IN
D	NIC	INV_CLK		A_ONLY_INV	SLEEP	LVDS_HTB	A_ONLY									CSCAP
E	GND	GND	GND		GND	AVDD	AVDD	AVDD	AVDD	AVDD	AVDD	GND				CSCAP_IN
F	DACCLK_P	DACCLK_N	GND	GND	AVDD	GND	GND	AVDD	AVDD	GND	GND	AVDD				
G	GND	GND	GND	GND	AVDD	GND	GND	GND	GND	GND	GND	AVDD				
H	GND				AVDD	AVDD	GND	/	/	GND	AVDD	AVDD		AVDD	DB_N(0)	GND
J	GND	DA_P(13)	DA_N(13)		AVDD	AVDD	GND	/	/	GND	AVDD	AVDD		AVDD	DB_N(1)	GND
K	DA_P(12)	DA_N(12)			AVDD	GND	GND	GND	GND	GND	GND	AVDD		DB_N(2)	DB_P(2)	DB_P(1)
L	DA_P(11)	DA_N(11)	DA_P(10)	DA_N(10)	AVDD	GND	GND	AVDD	AVDD	GND	GND	AVDD	DB_N(6)		DB_N(3)	DB_P(3)
M	DA_P(9)	DA_N(9)	DA_P(8)	DA_N(8)	GND	AVDD	AVDD	AVDD	AVDD	AVDD	AVDD	GND	DB_P(6)		DB_N(4)	DB_P(4)
N	DA_P(7)	DA_N(7)	DA_P(6)	DA_N(6)				DTCLK_P	DTCLK_N						DB_N(5)	DB_P(5)
P		DA_N(5)	GND					DLYCLK_P	DLYCLK_N	DB_N(13)			DB_N(9)	GND	DB_N(7)	DB_P(7)
R	DA_P(5)		DA_N(4)	DA_N(3)		DA_N(1)	DA_N(0)	AVDD	AVDD	DB_P(13)	DB_N(12)	DB_N(11)	DB_N(10)	DB_P(9)	DB_N(8)	DB_P(8)
T	GND	DA_P(4)	DA_P(3)	DA_P(2)	DA_N(2)	DA_P(1)	DA_P(0)	GND	GND			DB_P(12)	DB_P(11)	DB_P(10)		GND

**Figure 2. Ball Grid Array of the DAC5670**

### TERMINAL FUNCTIONS

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
DACCLK_P	F1	I	External clock input; sample clock for the DAC
DACCLK_N	F2	I	Complementary external clock input; sample clock for the DAC
DLYCLK_P	P8	O	DDR type data clock output to data source
DLYCLK_N	P9	O	DDR type data clock output to data source complementary signal
DTCLK_P	N8	I	Input data toggling reference bit
DTCLK_N	N9	I	Input data toggling reference bit complementary signal
DA_P[13]	J2	I	Port A data bit 13 (MSB)
DA_N[13]	J3	I	Port A data bit 13 complement (MSB)
DA_P[12]	K1	I	Port A data bit 12
DA_N[12]	K2	I	Port A data bit 12 complement
DA_P[11]	L1	I	Port A data bit 11
DA_N[11]	L2	I	Port A data bit 11 complement
DA_P[10]	L3	I	Port A data bit 10
DA_N[10]	L4	I	Port A data bit 10 complement
DA_P[9]	M1	I	Port A data bit 9
DA_N[9]	M2	I	Port A data bit 9 complement
DA_P[8]	M3	I	Port A data bit 8
DA_N[8]	M4	I	Port A data bit 8 complement
DA_P[7]	N1	I	Port A data bit 7
DA_N[7]	N2	I	Port A data bit 7 complement
DA_P[6]	N3	I	Port A data bit 6
DA_N[6]	N4	I	Port A data bit 6 complement
DA_P[5]	R1	I	Port A data bit 5
DA_N[5]	P2	I	Port A data bit 5 complement
DA_P[4]	T2	I	Port A data bit 4
DA_N[4]	R3	I	Port A data bit 4 complement
DA_P[3]	T3	I	Port A data bit 3
DA_N[3]	R4	I	Port A data bit 3 complement
DA_P[2]	T4	I	Port A data bit 2
DA_N[2]	T5	I	Port A data bit 2 complement
DA_P[1]	T6	I	Port A data bit 1
DA_N[1]	R6	I	Port A data bit 1 complement
DA_P[0]	T7	I	Port A data bit 0 (LSB)
DA_N[0]	R7	I	Port A data bit 0 complement (LSB)
DB_P[13]	R10		Port B data bit 13 (MSB)
DB_N[13]	P10	I	Port B data bit 13 complement (MSB)
DB_P[12]	T12	I	Port B data bit 12
DB_N[12]	R11	I	Port B data bit 12 complement
DB_P[11]	T13	I	Port B data bit 11
DB_N[11]	R12	I	Port B data bit 11 complement
DB_P[10]	T14	I	Port B data bit 10
DB_N[10]	R13	I	Port B data bit 10 complement
DB_P[9]	R14	I	Port B data bit 9
DB_N[9]	P13	I	Port B data bit 9 complement

**TERMINAL FUNCTIONS (continued)**

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
DB_P[8]	R16	I	Port B data bit 8
DB_N[8]	R15	I	Port B data bit 8 complement
DB_P[7]	P16	I	Port B data bit 7
DB_N[7]	P15	I	Port B data bit 7 complement
DB_P[6]	M13	I	Port B data bit 6
DB_N[6]	L13	I	Port B data bit 6 complement
DB_P[5]	N16	I	Port B data bit 5
DB_N[5]	N15	I	Port B data bit 5 complement
DB_P[4]	M16	I	Port B data bit 4
DB_N[4]	M15	I	Port B data bit 4 complement
DB_P[3]	L16	I	Port B data bit 3
DB_N[3]	L15	I	Port B data bit 3 complement
DB_P[2]	K15	I	Port B data bit 2
DB_N[2]	K14	I	Port B data bit 2 complement
DB_P[1]	K16	I	Port B data bit 1
DB_N[1]	J15	I	Port B data bit 1 complement
DB_P[0]	J14	I	Port B data bit 0 (LSB)
DB_N[0]	H15	I	Port B data bit 0 complement (LSB)
IOUT_P	A7, B7	O	DAC current output. Full scale when all input bits are set 1.
IOUT_N	A10, B10	O	DAC complementary current output. Full scale when all input bits are 0.
RBIASOUT	A14	O	Rbias resistor current output
RBIASIN	B14	I	Rbias resistor sense input
CSCAP	D16	O	Current source bias voltage output
CSCAP_IN	E16	I	Current source bias voltage sense input
REFIO	B16	O	Bandgap reference output
REFIO_IN	C16	I	Bandgap reference sense input
RESTART	C2	I	Resets DLL when high. Low for DLL operation. High for using external setup/hold timing.
LVDS_HTB	D6	I	DLYCLK_P/N control; lvds mode when high, ht mode when low.
INV_CLK	D2	I	Inverts the DLL target clocking relationship when high. Low for normal DLL operation. See DLL usage section.
LOCK	A2	O	DLL lock indicator, constant high when locked. <sup>(1)</sup>
SLEEP	D5	I	Active high sleep.
NORMAL	B2	I	High for {a0,b0,a1,b1,a2,b2, ...} normal mode
A_ONLY	D7	I	High for {a0,a0,a1,a1,a2,a2, ...} A_only mode
A_ONLY_INV	D4	I	High for {a0,-a0, a1,-a1,a2,-a2, ...} A_only_inv mode
A_ONLY_ZS	C3	I	High for {a0,0,a1,0,a2,0, ...} A_only_zs mode

(1) The DLL LOCK indicator on the current version of the DAC5670 is only partially functional - the lock signal may indicate a DLL lock condition when no DACCLK signal or DTCLK signal is present.

TERMINAL		DESCRIPTION
NAME	NO.	
GND	A1, A6, A8, A9, A11, A16, B6, B11, C6, C7, C8, C9, C10, C11, C14, E1, E2, E3, E5, E12, F3, F4, F6, F7, F10, F11, G1, G2, G3, G4, G6, G7, G8, G9, G10, G11, H1, H7, H10, H16, J1, J7, J10, J16, K6, K7, K8, K9, K10, K11, L6, L7, L10, L11, M5, M12, P3, P14, T1, T8, T9, T16	Ground
AVDD	B3, B8, B9, C1, E6, E7, E8, E9, E10, E11, F5, F8, F9, F12, G5, G12, H5, H6, H11, H12, H14, J5, J6, J11, J12, K5, K12, L5, L8, L9, L12, M6, M7, M8, M9, M10, M11, R8, R9	3.3 V Analog power supply
No connect	A3, A4, A13, A15, B1, B4, B13, B15, C4, C12, C13, C15, D3, D8, D9, D10, D11, D12, D13, D14, D15, E4, E13, E14, E15, F13, F14, F15, F16, G13, G14, G15, G16, H2, H3, H4, H13, J4, J13, K3, K4, K13, L14, M14, N5, N6, N7, N10, N11, N12, N13, N14, P1, P4, P5, P6, P7, P11, P12, R2, R5, T10, T11, T15	No internal connection. These balls can be connected to GND (if desired), or left open.
No connect	B12, C5, D1	Factory use only, must be left unconnected.
Reserved	A5, A12, B5	Factory use only, must be connected to GND.

### Absolute Maximum Ratings<sup>(1)</sup>

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Supply voltage	AVDD to GND		5.0	V
DA_P[13..0], DA_N[13..0], DB_P[13..0], DB_N[13..0]	Measured with respect to GND	-0.3	AVDD + 0.3	V
NORMAL, A_ONLY, A_ONLY_INV, A_ONLY_ZS	Measured with respect to GND	-0.3	AVDD + 0.3	V
DTCLK_P, DTCLK_N, DACCLK_P, DACCLK_N	Measured with respect to GND	-0.3	AVDD + 0.3	V
LVDS_HTB, INV_CLK, RESTART	Measured with respect to GND	-0.3	AVDD + 0.3	V
IOUT_P, IOUT_N	Measured with respect to GND	AVDD – 0.5	AVDD + 1.5	V
CSCAP_IN, REFIO_IN, RBIAS_IN	Measured with respect to GND	-0.3	AVDD + 0.3	V
Peak input current (any input)			20	mA
Storage temperature range		-65	150	°C
Maximum Junction Temperature			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.

## DC Electrical Characteristics

$T_{C,MIN} = -40^{\circ}\text{C}$  to  $T_{C,MAX} = 85^{\circ}\text{C}$ , typical values at  $25^{\circ}\text{C}$ ,  $AV_{DD} = 3\text{ V}$  to  $3.6\text{ V}$ ,  $I_{outFS} = 20\text{ mA}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
<b>Resolution</b>			14			Bits
<b>DC Accuracy</b>						
INL	Integral nonlinearity	$T_{C,MIN}$ to $T_{C,MAX}$ , $f_{DAC} = 640\text{ MHz}$ , $f_{OUT} = 10\text{ MHz}$	-7.5	$\pm 1.5$	7.5	LSB
DNL	Differential nonlinearity		-0.98	$\pm 0.8$	1.75	
<b>Monotonicity</b>			14			Bits
<b>Analog Output</b>						
	Offset error	Mid code offset	-0.45	$\pm 0.09$	0.45	%FSR
	Gain error	With external reference	-6.0	$\pm 1.6$	6.0	%FSR
	Gain error	With internal reference	-6.0	$\pm 1.6$	6.0	%FSR
	Full-scale output current				30	mA
	Output compliance range	$I_{O(FS)} = 20\text{ mA}$ , $AV_{DD} = 3.15\text{ V}$ to $3.45\text{ V}$	$AV_{DD} - 0.5$		$AV_{DD} + 0.5$	V
	Output resistance			$300^{(2)}$		k $\Omega$
	Output capacitance	IOUT_P and IOUT_N single ended		$13.7^{(2)}$		pF
<b>Reference Output</b>						
	Reference voltage		1.14	1.2	1.26	V
	Reference output current			100		nA
<b>Reference Input</b>						
$V_{REFIO}$	Input voltage range		1.14	1.2	1.26	V
	Input resistance			$1^{(2)}$		M $\Omega$
	Small-signal bandwidth			1.4		MHz
	Input capacitance			$3.2^{(2)}$		pF
<b>Temperature Coefficients</b>						
	Offset drift			75		ppm of FSR/ $^{\circ}\text{C}$
	Gain drift	With external reference		75		ppm of FSR/ $^{\circ}\text{C}$
	Gain drift	With internal reference		75		ppm of FSR/ $^{\circ}\text{C}$
	Reference voltage drift			35		ppm/ $^{\circ}\text{C}$
<b>Power Supply</b>						
$AV_{DD}$	Analog supply voltage		3	3.3	3.6	V
$I_{AVDD}$	Analog supply current	$f_{DAC} = 2.4\text{ GHz}$ , NORMAL input mode		560	650	mA
$I_{AVDD}$	Sleep mode, $AV_{DD}$ supply current	Sleep mode (SLEEP pin high)		150	180	mA
P	Power dissipation	$f_{DAC} = 2.4\text{ GHz}$ , NORMAL input mode		1800	2350	mW
PSRR	Power-supply rejection ratio	$AV_{DD} = 3.15\text{ V}$ to $3.45\text{ V}$		0.4	1.3	%FSR/V

(1) Typicals are characterization values at  $25^{\circ}\text{C}$  and  $AV_{DD} = 3.3\text{ V}$ . These parameters are characterized but not production tested.

(2) Specified by design

## AC Electrical Characteristics

$T_{C,MIN} = -40^{\circ}\text{C}$  to  $T_{C,MAX} = 85^{\circ}\text{C}$ , typical values at  $25^{\circ}\text{C}$ ,  $AVDD = 3\text{ V}$  to  $3.6\text{ V}$ ,  $I_{outFS} = 20\text{ mA}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
<b>Analog Output</b>						
$f_{DAC}$	Output update rate				2.4	GSPS
$t_{s(DAC)}$	Output setting time to 0.1%	Mid-scale transition		3.5		ns
$t_{pd}$	Output propagation delay			7 DACCLK + 1.5 ns		
$t_{r(IOUT)}$	Output rise time, 10% to 90%			280		ps
$t_{f(IOUT)}$	Output fall time, 90% to 10%			280		ps
<b>AC Performance</b>						
SFDR	Spurious-free dynamic range	$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 100\text{ MHz}$ , Dual-port mode, 0 dBFS	47	55		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 200\text{ MHz}$ , Dual-port mode, 0 dBFS	38	51		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 300\text{ MHz}$ , Dual-port mode, 0 dBFS	37	41		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, 0 dBFS	44	50		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, -6 dBFS		47		
SNR	Signal-to-noise ratio	$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 100\text{ MHz}$ , Dual-port mode, 0 dBFS	63	70		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 200\text{ MHz}$ , Dual-port mode, 0 dBFS	62	70		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 300\text{ MHz}$ , Dual-port mode, 0 dBFS	57	62		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, 0 dBFS	53	60		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, -6 dBFS		52		
THD	Total harmonic distortion	$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 100\text{ MHz}$ , Dual-port mode, 0 dBFS	50	55		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 200\text{ MHz}$ , Dual-port mode, 0 dBFS	41	50		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 300\text{ MHz}$ , Dual-port mode, 0 dBFS	38	48		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, 0 dBFS	47	53		
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 500\text{ MHz}$ , Dual-port mode, -6 dBFS		44		
IMD3	Third-order two-tone intermodulation	$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 99\text{ MHz}$ and $102\text{ MHz}$ , Each tone at -6 dBFS, Dual-port mode.	65	70		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 200\text{ MHz}$ and $202\text{ MHz}$ , Each tone at -6 dBFS, Dual-port mode.	51	68		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 253\text{ MHz}$ and $257\text{ MHz}$ , Each tone at -6 dBFS, Dual-port mode.	47	57		dBc
		$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 299\text{ MHz}$ and $302\text{ MHz}$ , Each tone at -6 dBFS, Dual-port mode.	51	55		dBc
IMD	Four-tone intermodulation	$f_{DAC} = 2.4\text{ GSPS}$ , $f_{OUT} = 298\text{ MHz}$ , $299\text{ MHz}$ , $300\text{ MHz}$ , and $301\text{ MHz}$ , Each tone at -12 dBFS, Dual-port mode.	51	62.5		dBc

(1) Typicals are characterization values at 25C and AVDD = 3.3V. These parameters are characterized but not production tested



## Digital Electrical Characteristics

$T_{C,MIN} = -40^{\circ}C$  to  $T_{C,MAX} = 85^{\circ}C$ , typical values at  $25^{\circ}C$ ,  $AVDD = 3\text{ V}$  to  $3.6\text{ V}$ ,  $I_{outFS} = 20\text{ mA}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP <sup>(1)</sup>	MAX	UNIT
<b>CMOS Interface (SLEEP, RESTART, INV_CLK, NORMAL, A_ONLY, A_ONLY_INV, A_ONLY_ZS)</b>						
$V_{IH}$	High-level input voltage		2	3		V
$V_{IL}$	Low-level input voltage		0	0	0.8	V
$I_{IH}$	High-level input current			0.2	10	$\mu A$
$I_{IL}$	Low-level input current		-10	-0.2		$\mu A$
	Input capacitance			2.5 <sup>(2)</sup>		pF
<b>Differential Data Interface (DA_P[13:0], DA_N[13:0], DB_P[13:0], DB_N[13:0], DTCLK_P, DTCLK_N)</b>						
$V_{ITH}$	Differential input threshold		-100		100	mV
$Z_T$	Internal termination impedance		80	100	125	$\Omega$
$V_{ICOM}$	Input common mode		0.6		1.4	V
$C_i$	Input capacitance			2.6 <sup>(2)</sup>		pF
<b>Differential Data Interface (DA_P[13:0], DA_N[13:0], DB_P[13:0], DB_N[13:0] External Timing With DLL in Restart) (See Figure 17)</b>						
$T_{setup}$	Data setup to DLYCLK <sup>(3)</sup>	RESTART = 1, DLYCLK 20-pf load. See Figure 17	2.45			ns
$T_{hold}$	Data hold to DLYCLK <sup>(3)</sup>	RESTART = 1, DLYCLK 20-pf load. See Figure 17	-1.2			ns
<b>Clock Inputs (DACCLK_P, DACCLK_N)</b>						
$ DACCLK_P - DACCLK_N $	Clock differential input voltage		200		1000	mV
	Clock duty cycle		40		60	%
$V_{CLKCM}$	Clock common mode		1.0		1.4	V
<b>DLL (See Figure 15)</b>						
$NegD$	DLL min negative delay	RESTART = 0	150			ps
$PosD$	DLL min positive delay	RESTART = 0	600			ps
$T_{valid}$	CLK/4 internal setup+hold width	See <sup>(3)</sup>		160		ps
$F_{dac}$		RESTART = 0	1		2.4	GHz

(1) Typicals are characterization values at 25C and  $AVDD = 3.3V$ . These parameters are characterized but not production tested.

(2) Specified by design.

(3) Tested using SNR as pass/fail criteria.

## THERMAL INFORMATION

THERMAL METRIC		DAC5670	UNITS
		GDJ	
		252 PINS	
$\theta_{JA}$	Junction-to-ambient thermal resistance <sup>(1)</sup>	22.5	$^{\circ}C/W$
$\theta_{JC}$	Junction-to-case thermal resistance <sup>(2)</sup>	7.6	

(1) Non-thermally enhanced JEDEC standard PCB, per JESD-51, 51-3.

(2) MIL-STD-883 test method 1012.

### TYPICAL CHARACTERISTICS

Single-Tone Spectrum Power  
vs  
Frequency

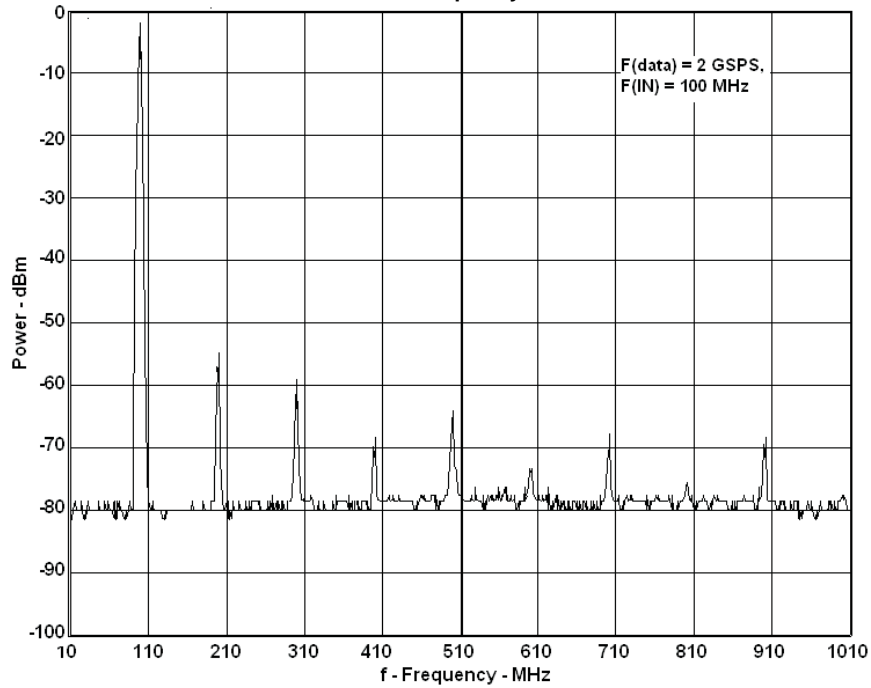


Figure 3.

Two-Tone IMD (Power)  
vs  
Frequency

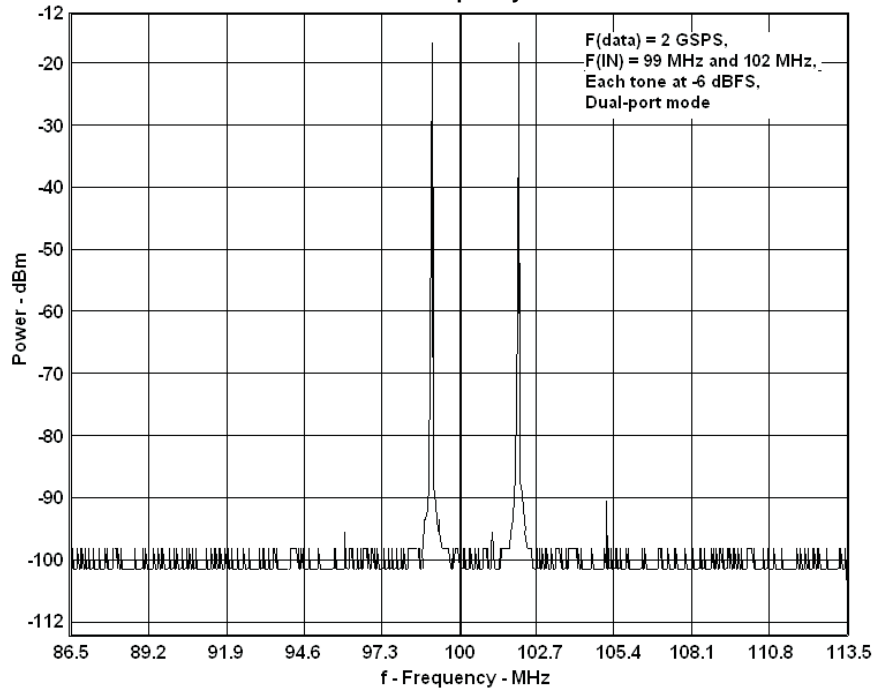


Figure 4.

**TYPICAL CHARACTERISTICS (continued)**

**W-CDMA TM1 Single Carrier Power vs Frequency**

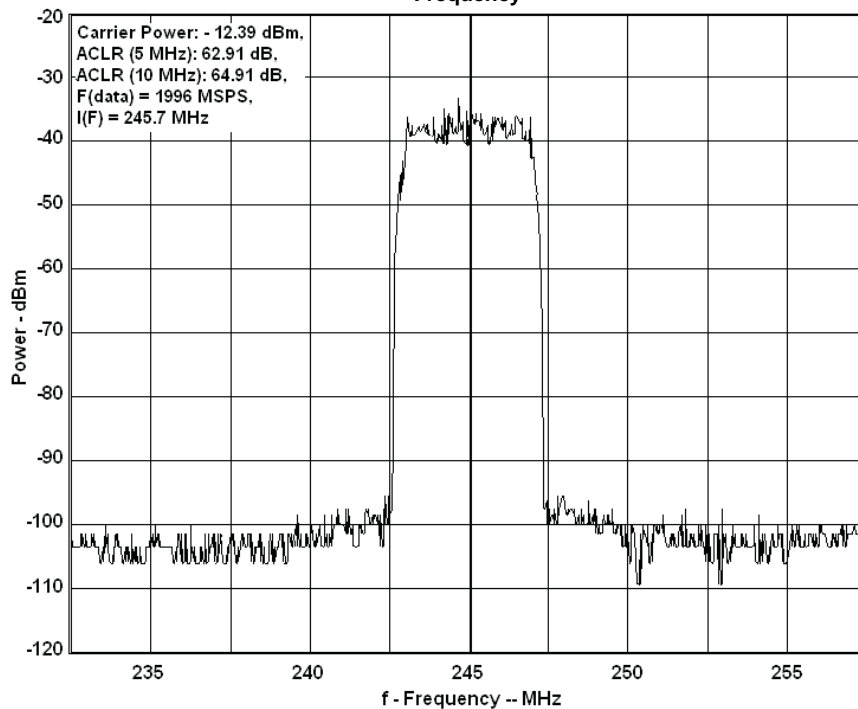


Figure 5.

**W-CDMA TM1 Single Carrier Power vs Frequency**

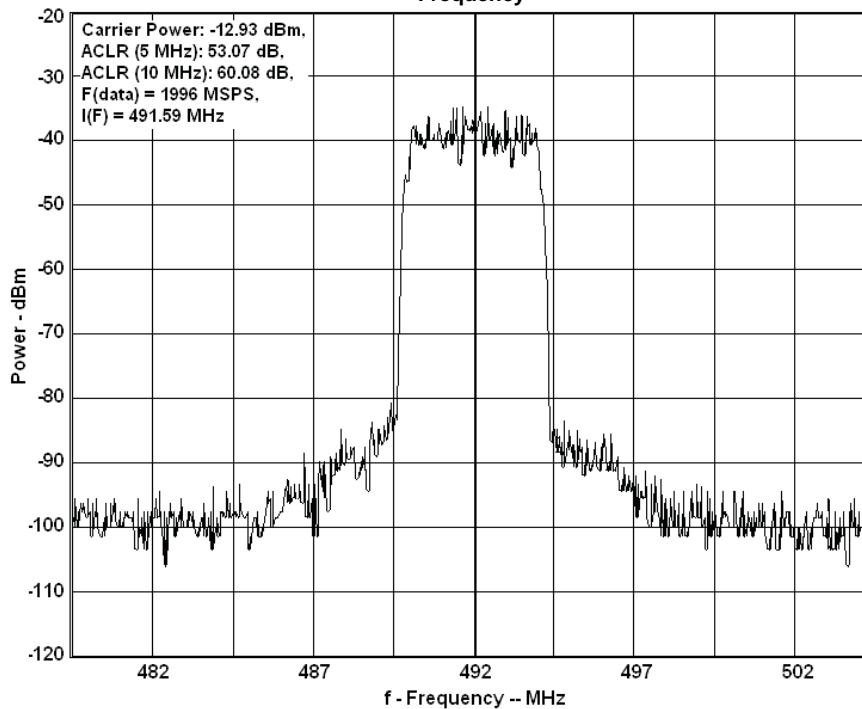


Figure 6.

### TYPICAL CHARACTERISTICS (continued)

W-CDMA TM1 Dual Carrier Power  
vs  
Frequency

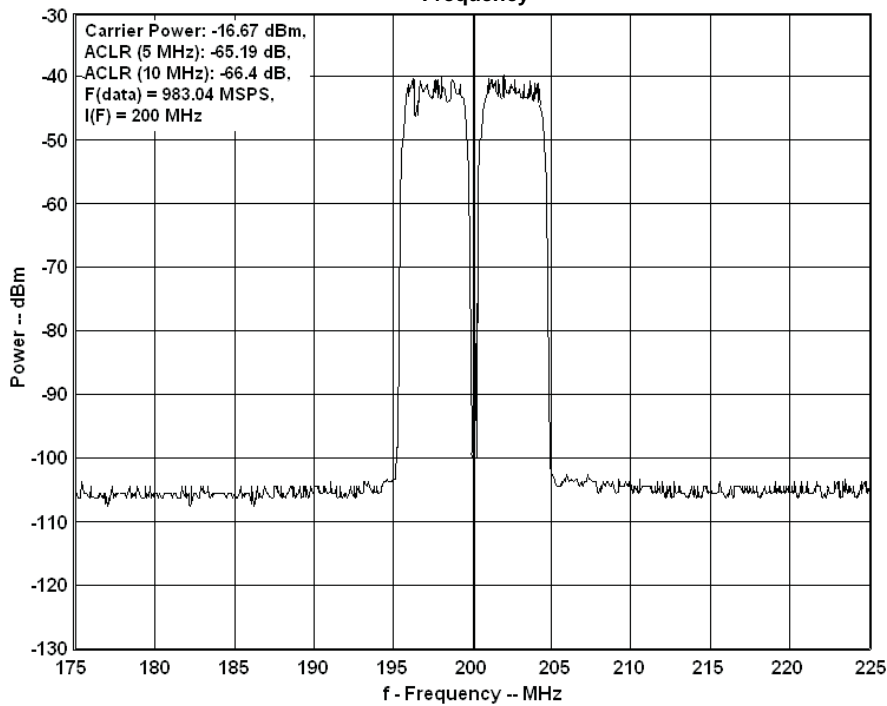


Figure 7.

W-CDMA TM1 Three Carrier Power  
vs  
Frequency

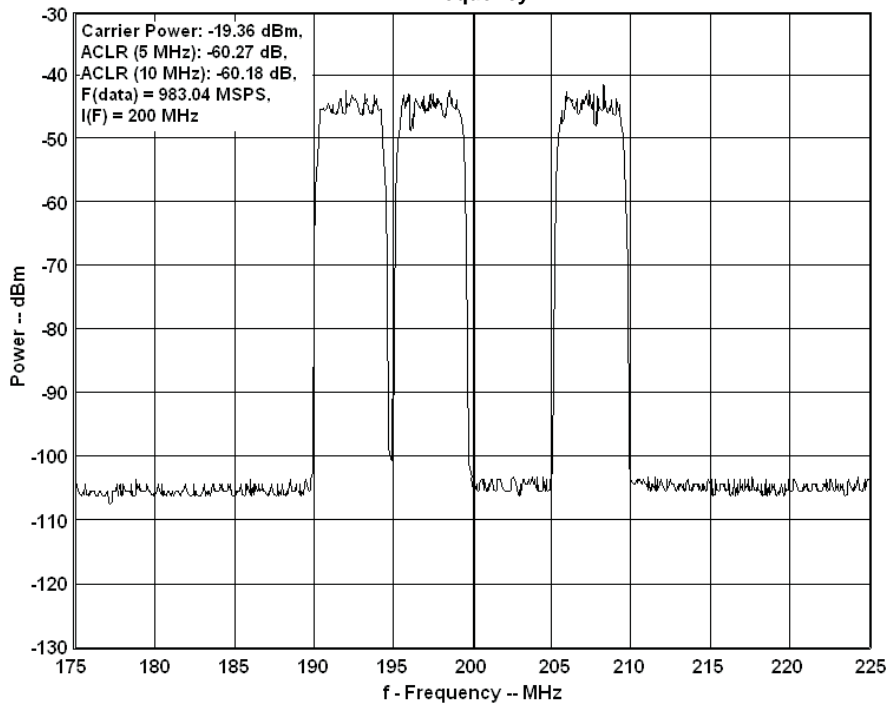


Figure 8.

**TYPICAL CHARACTERISTICS (continued)**

W-CDMA TM1 Four Carrier Power

vs

Frequency

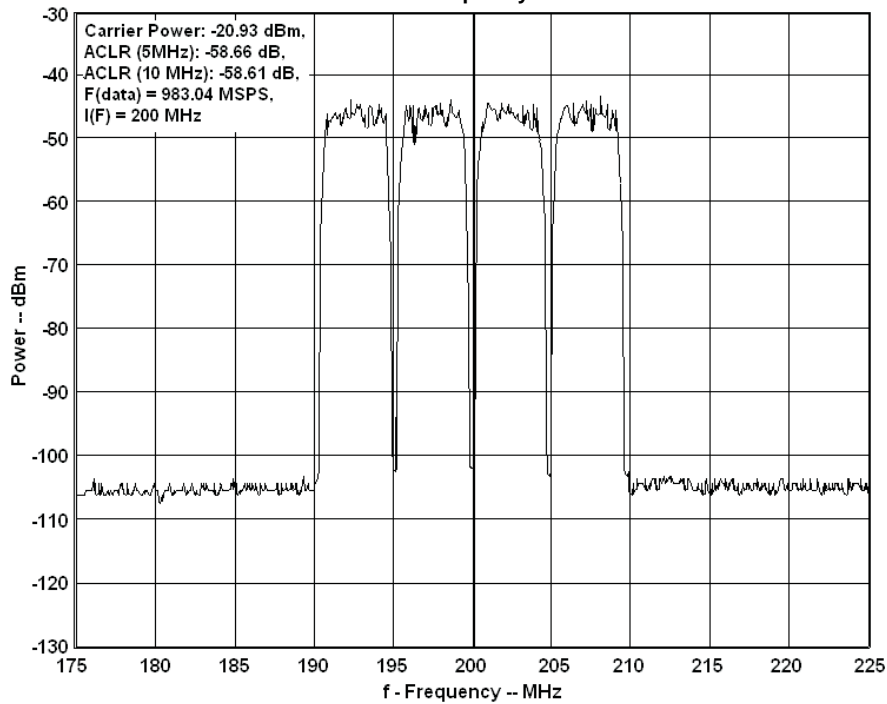


Figure 9.

## APPLICATION INFORMATION

### Detailed Description

Figure 10 shows a simplified block diagram of the current steering DAC5670. The DAC5670 consists of a segmented array of NPN-transistor current sinks, capable of delivering a full-scale output current up to 30mA. Differential current switches direct the current of each current sink to either one of the complementary output nodes IOUT\_P or IOUT\_N. The complementary current output enables differential operation, canceling out common-mode noise sources (digital feed-through, 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 (RBIAS) in combination with an on-chip bandgap voltage reference source (1.2V) and control amplifier. The current (IBIAS) through resistor RBIAS is mirrored internally to provide a full-scale output current equal to 32 times IBIAS. The full-scale current is adjustable from 30mA down to 5mA by using the appropriate bias resistor value.

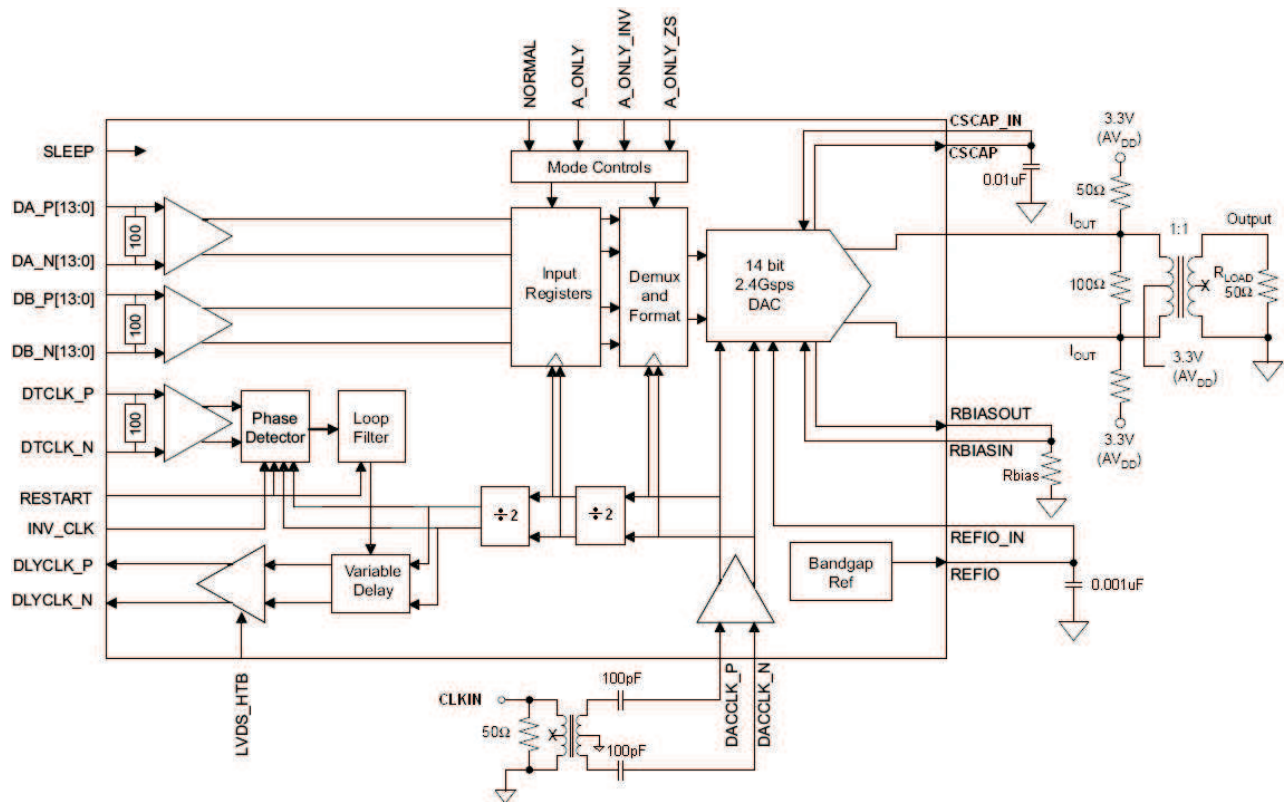


Figure 10. Current Steering DAC5670

### Digital Inputs

The DAC5670 differential digital inputs are compatible with LVDS and HyperTransport voltage levels.

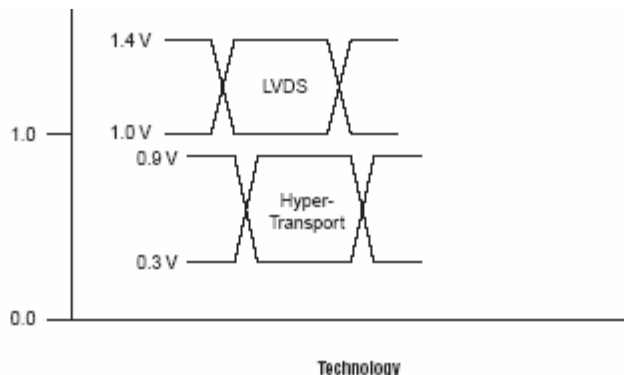


Figure 11. Digital Input Voltage Options

The DAC5670 uses low voltage differential signaling (LVDS and Hyper-Transport) for the bus input interface. The LVDS and Hyper-Transport input modes feature a low differential voltage swing. The differential characteristic of LVDS and Hyper-Transport modes allow for high-speed data transmission with low electromagnetic interference (EMI) levels. Figure 12 shows the equivalent complementary digital input interface for the DAC5670, valid for pins DA\_P[13:0], DA\_N[13:0], DB\_P[13:0], and DB\_N[13:0].

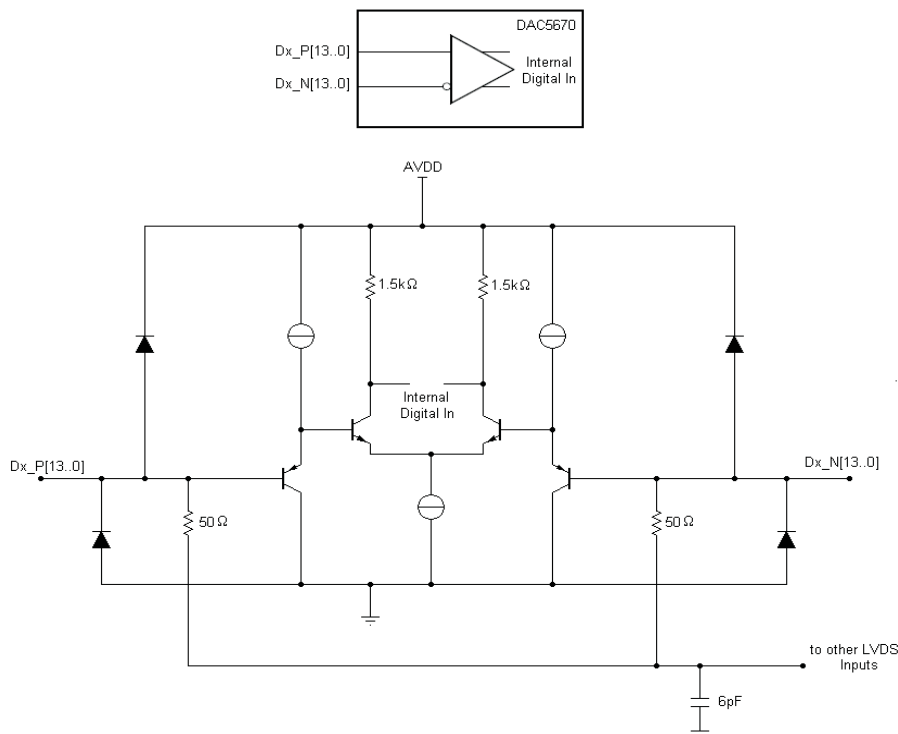


Figure 12.

Figure 13 shows a schematic of the equivalent CMOS/TTL-compatible digital inputs of the DAC5670, valid for the following pins: RESTART, LVDS\_HTB, INV\_CLK, SLEEP, NORMAL, A\_ONLY, A\_ONLY\_INV, and A\_ONLY\_ZS.

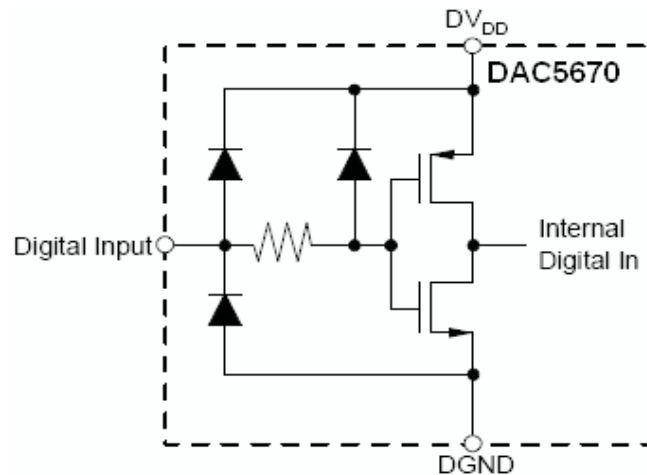


Figure 13.

### DLL Usage

The DAC5670 is clocked at the DAC sample rate. Each input port runs at a maximum of 1.2 GSPS. The DAC5670 provides an output clock (DLYCLK) at one-half the input port data rate (DACCLK/4), and monitors an additional reference bit (DTCLK). DTCLK is used as feedback clock to adjust interface timing. To accomplish this, the DAC5670 implements a delay locked loop (DLL) to help manage the timing interface from external data source. As with all DLLs, there are limitations on the capability of the DLL with respect to the delay chain length, implementation of the phase detector, and the bandwidth of the control loop. The DAC5670 implements a quadrature based phase detector. This scheme allows for the DLL to provide maximum setup/hold delay margins when quadrature can be reached. Quadrature is reached when the internal CLK/4 is 90° out of phase with DTCLK. Additionally, as the frequency of operation decreases, the delay line's fixed length limits its ability to change the delay path enough to reach quadrature. See Figure 15. It is also worth noting that the delay line has asymmetric attributes. The NegD range is smaller than the PosD range. From its nominal (restart) position, it can delay more than it can subtract.

Figure 15 represents the behavior of the phase detector and the delay line with respect to initial positions of the rising edge of DTCLK. There are 4 distinct quadrants that define the behavior. Each quadrant represents the period of the DDR clock rate (600 Mhz in the 2.4 GSPS case) divided by 4. The ideal location has the initial delays of DTCLK (and hence data bits) in quadrant 1. The stable lock point of DLL is at T/4, between Q1 and Q2. If DTCLK's initial delay is in quadrants 3 or 4, the INV\_CLK pin can be asserted to improve ability of DLL to obtain quadrature. This will move the stable quadrature point to the center of 3T/4 vs T/4 as shown in Figure 15. Essentially the zones that add delay become zones that subtract delay and vice-versa. The clock phase of CLK/4 would also invert.

In cases where it is not appropriate to use the DLL to manage the timing interface, it is possible to utilize fixed setup and hold values for DA and DB signals relative to the generated DLYCLK output when the DLL is held in restart. This is accomplished by asserting RESTART to logic high and using the timing input conditions for external timing interface with DLL in restart in the recommended operating conditions table. See Figure 17.





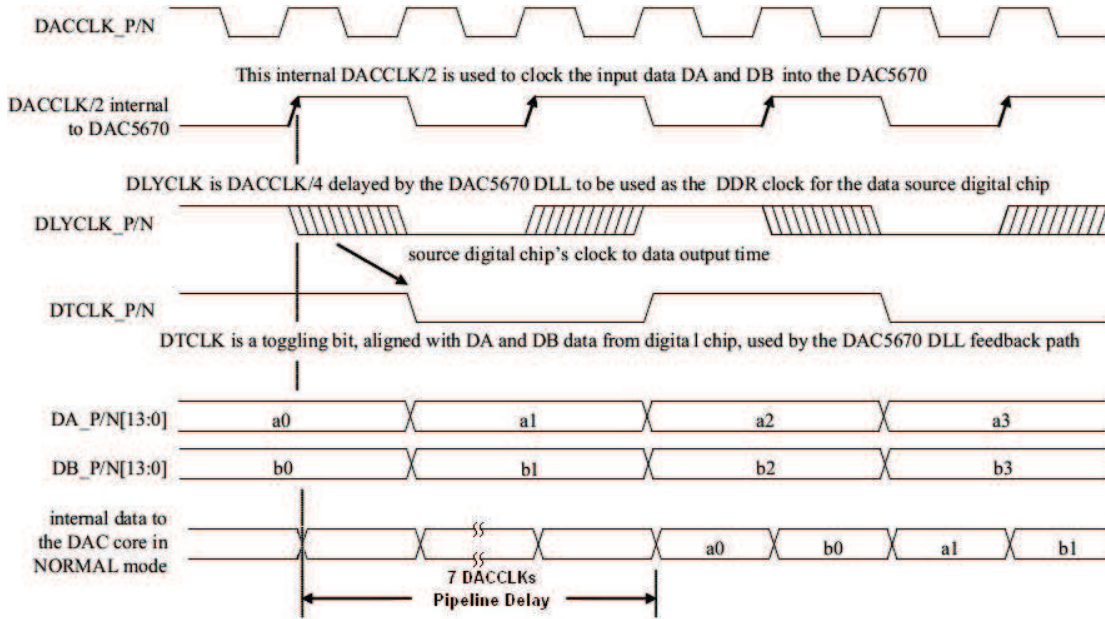


Figure 16. DLL Input Loop Functional Timing

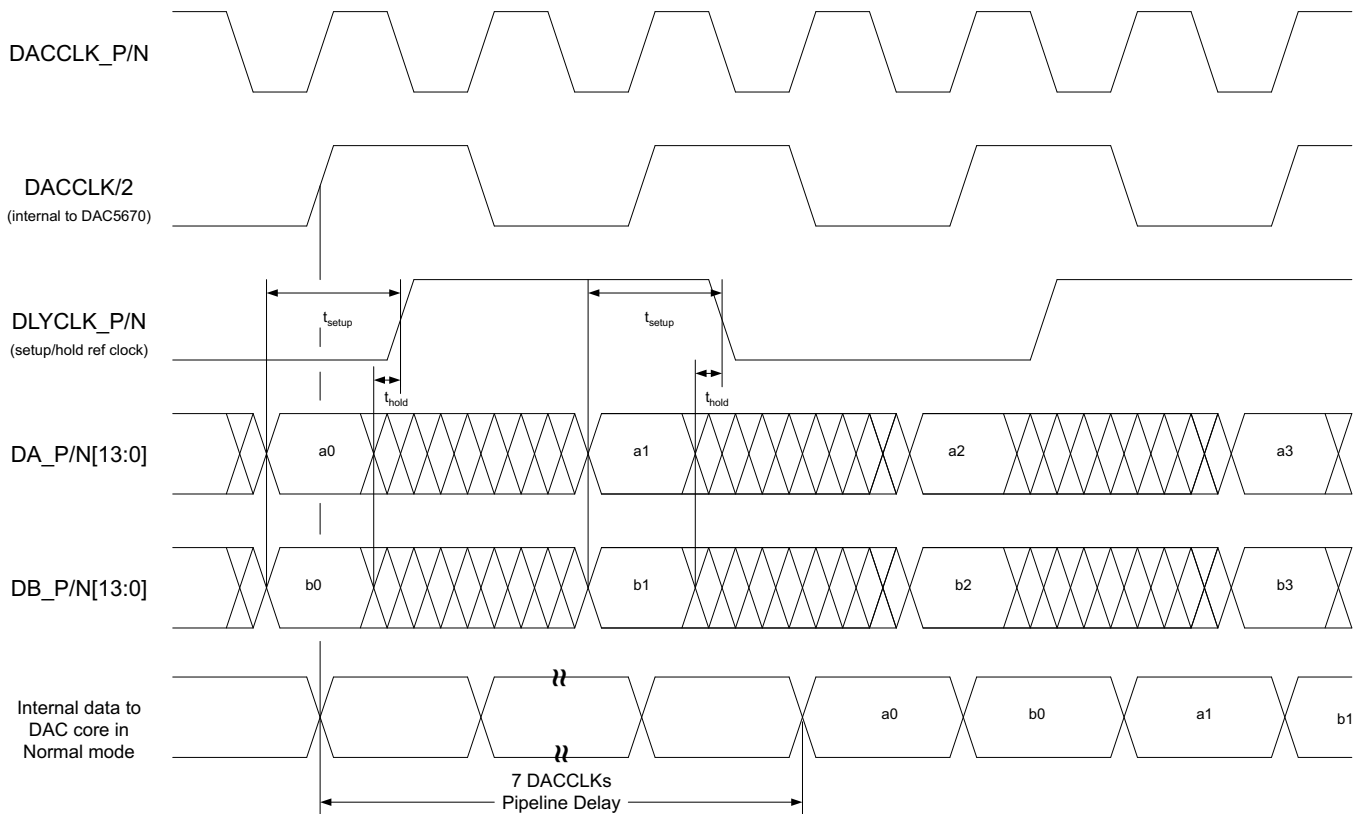


Figure 17. External Interface Timing With DLL in Restart

### Input Format

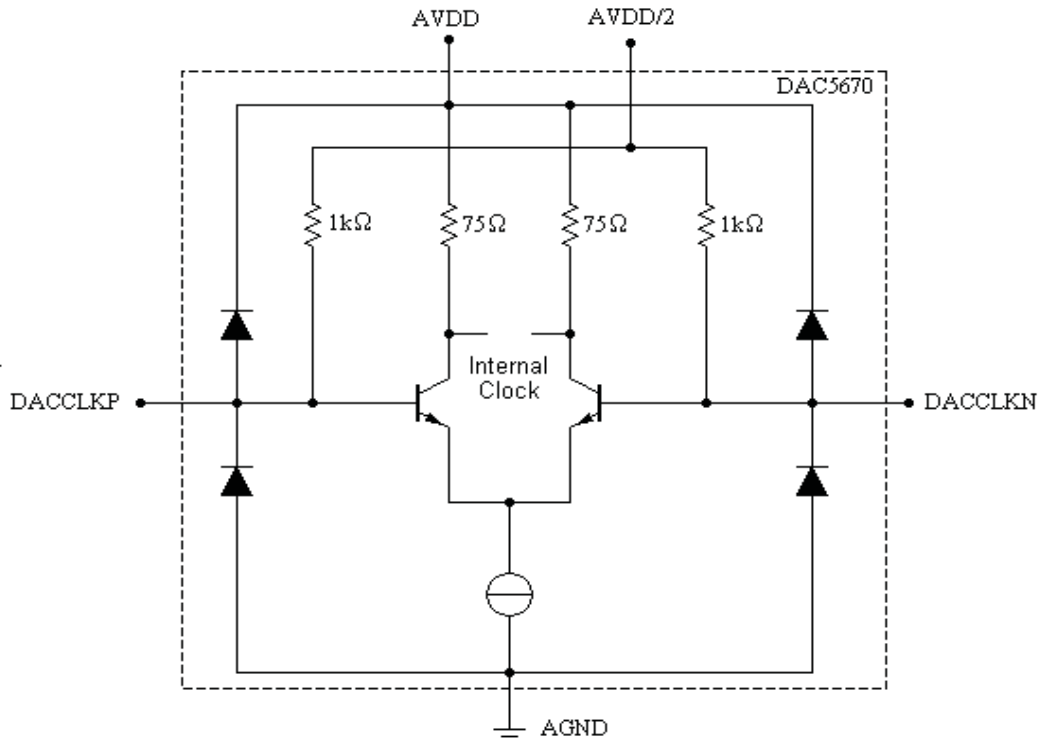
The DAC5670 has four input modes selected by the four mutually exclusive configuration pins: NORMAL, A\_ONLY, A\_ONLY\_INV, and A\_ONLY\_ZS. [Table 1](#) lists the input modes, the input sample rates, the maximum DAC sample rate (CLK input) and resulting DAC output sequence for each configuration. For all configurations, the DLYCLK\_P/N outputs and DTCLK\_P/N inputs are DACCLK\_P/N frequency divided by four.

**Table 1. DAC5670 Input Formats**

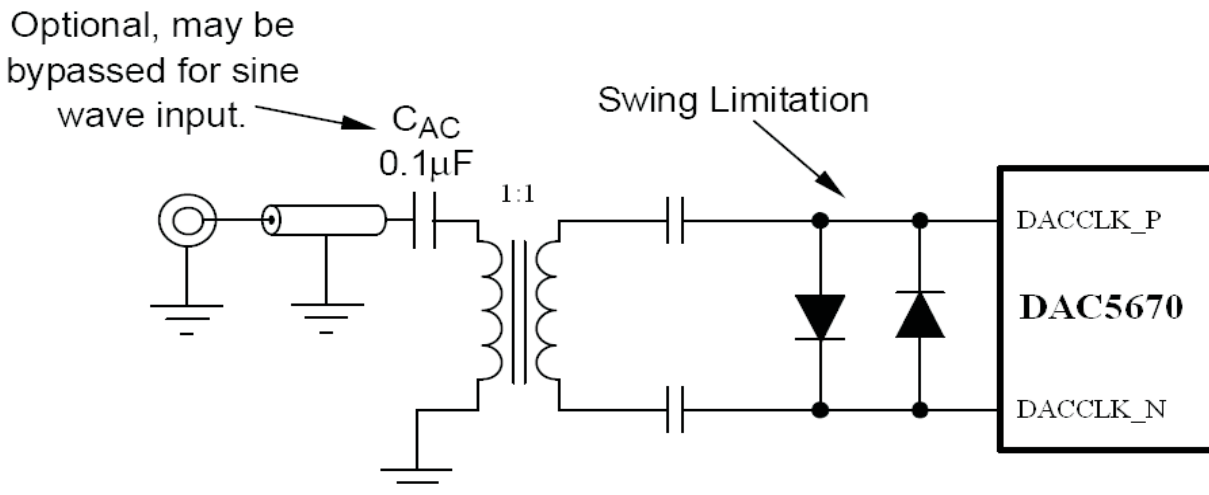
NORMAL	A_ONLY	A_ONLY_INV	A_ONLY_ZS	FinA/Fdac	FinB/Fdac	f <sub>DAC</sub> MAX (MHz)	DLYCLK_P/N AND DTCLK_P/N FREQ (MHz)	DAC OUTPUT SEQUENCE
1	0	0	0	1/2	1/2	2400	Fdac/4	A0, B0, A1, B1, A2, B2, . . .
0	1	0	0	1/2	Off	2400	Fdac/4	A0, A0, A1, A1, A2, A2, . . .
0	0	1	0	1/2	Off	2400	Fdac/4	A0, –A0, A1, –A1, A2, –A2, . . .
0	0	0	1	1/2	Off	2400	Fdac/4	A0, 0, A1, 0, A2, 0, . . .

**Clock Input**

The DAC5670 features differential, LVPECL compatible clock inputs (DACCLK\_P, DACCLK\_N). Figure 18 shows the equivalent schematic of the clock input buffer. The internal biasing resistors set the input common-mode voltage to AVDD/2, while the input resistance is typically 1 kΩ. A variety of clock sources can be ac-coupled to the device, including a sine wave source (see Figure 19).



**Figure 18. Clock Equivalent Input**



**Figure 19. Driving the DAC5670 with a Single-Ended Clock Source Using a Transformer**

To obtain best ac performance the DAC5670 clock input should be driven with a differential LVPECL or sine wave source as shown in Figure 20 and Figure 21. Here, the potential of VTT should be set to the termination voltage required by the driver along with the proper termination resistors (RT). The DAC5670 clock input can also be driven single-ended for slower clock rates using TTL/CMOS levels; this is shown in Figure 22.

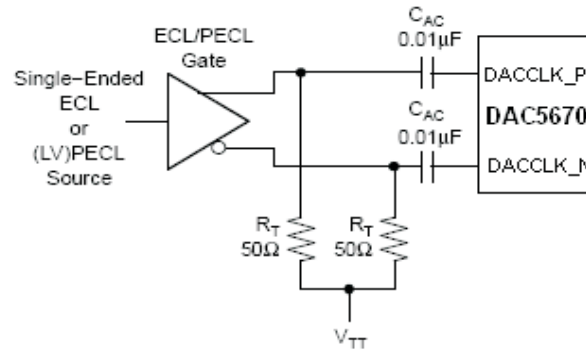


Figure 20. Driving the DAC5670 with a Single-Ended ECL/PECL Clock Source

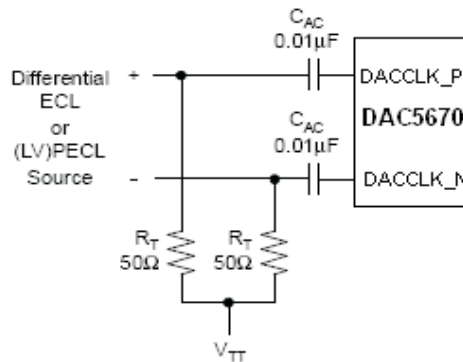


Figure 21. Driving the DAC5670 with a Differential ECL/PECL Clock Source

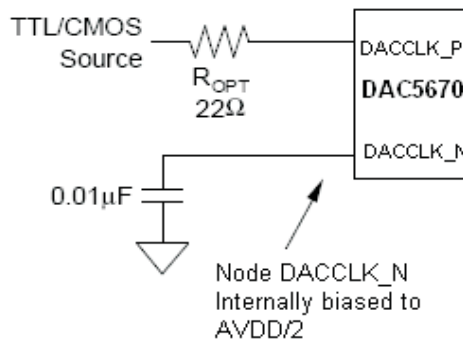


Figure 22. Driving the DAC5670 with a Single-Ended TTL/CMOS Clock Source

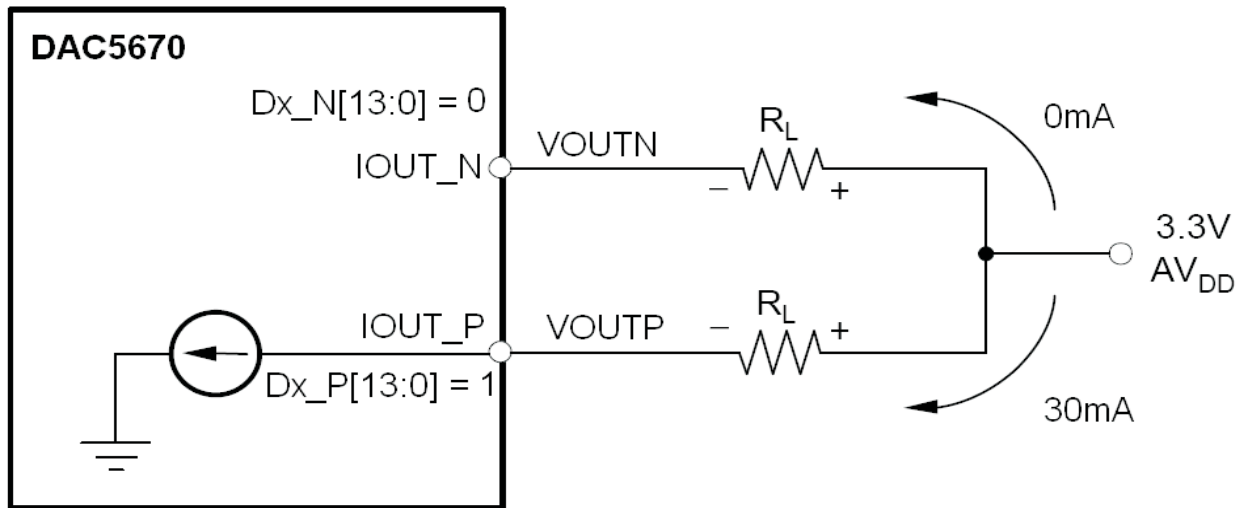
**DAC Transfer Function**

The DAC5670 has a current sink output. The current flow through IOUT\_P and IOUT\_N is controlled by Dx\_P[13:0] and Dx\_N[13:0]. For ease of use, we denote D[13:0] as the logical bit equivalent of Dx\_P[13:0] and its complement Dx\_N[13:0]. The DAC5670 supports straight binary coding with D13 being the MSB and D0 the LSB. Full-scale current flows through IOUTP when all D[13:0] inputs are set high and through IOUTN when all D[13:0] inputs are set low. The relationship between IOUT\_P and IOUT\_N can be expressed as [Equation 1](#):

$$IOUT\_N = IO_{(FS)} - IOUT\_P \tag{1}$$

$IO_{(FS)}$  is the full-scale output current sink (5 mA to 30 mA). Since the output stage is a current sink, the current can only flow from AVDD through the load resistors  $R_L$  into the IOUT\_N and IOUT\_P pins.

The output current flow in each pin driving a resistive load can be expressed as shown in [Figure 23](#), as well as in [Equation 2](#) and [Equation 3](#).



**Figure 23. Relationship between D[13:0], IOUT\_N and IOUT\_P**

$$IOUT\_N = (IOUT_{(FS)} \times (16383 - CODE)) / 16384 \tag{2}$$

$$IOUT\_P = (IOUT_{(FS)} \times CODE) / 16384 \tag{3}$$

where CODE is the decimal representation of the DAC input word. This would translate into single-ended voltages at IOUT\_N and IOUT\_P, as shown in [Equation 4](#) and [Equation 5](#):

$$VOUTN = AVDD - IOUT\_N \times R_L \tag{4}$$

$$VOUTP = AVDD - IOUT\_P \times R_L \tag{5}$$

For example, assuming that D[13:0] = 1 and that  $R_L$  is 50  $\Omega$ , the differential voltage between pins IOUT\_N and IOUT\_P can be expressed as shown in [Equation 6](#) through [Equation 8](#) where  $IO_{(FS)} = 20$  mA:

$$VOUTN = 3.3 \text{ V} - 0 \text{ mA} \times 50 \ \Omega = 3.3 \text{ V} \tag{6}$$

$$VOUTP = 3.3 \text{ V} - 20 \text{ mA} \times 50 \ \Omega = 2.3 \text{ V} \tag{7}$$

$$VDIFF = VOUTN - VOUTP = 1 \text{ V} \tag{8}$$

If D[13:0] = 0, then IOUT\_P = 0 mA and IOUT\_N = 20 mA and the differential voltage  $VDIFF = -1$  V.

The output currents and voltages in IOUT\_N and IOUT\_P are complementary. The voltage, when measured differentially, will be doubled compared to measuring each output individually. Care must be taken not to exceed the compliance voltages at the IOUT\_N and IOUT\_P pins in order to keep signal distortion low.

Reference Operation

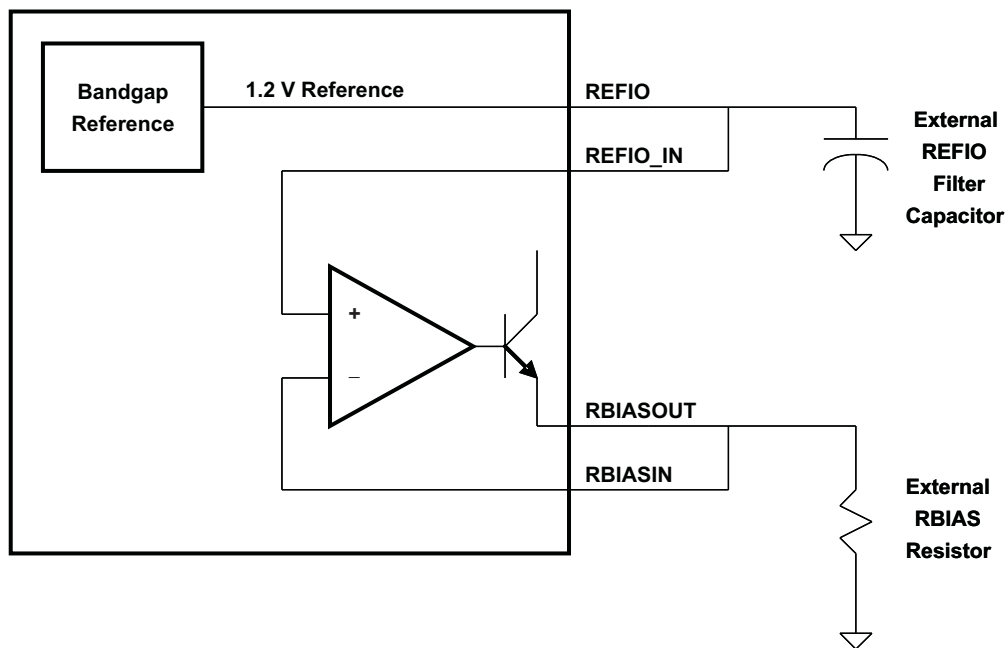


Figure 24. Reference Circuit

The DAC5670 comprises 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  $R_{BIAS}$  to pins RBIASOUT and RBIASIN. 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 32 times this bias current. The full-scale output current  $I_{OUT_{FS}}$  can thus be expressed as:

$$I_{OUT_{FS}} = 32 \times I_{BIAS} = 32 \times V_{REFIO}/R_{BIAS} \tag{9}$$

Where:

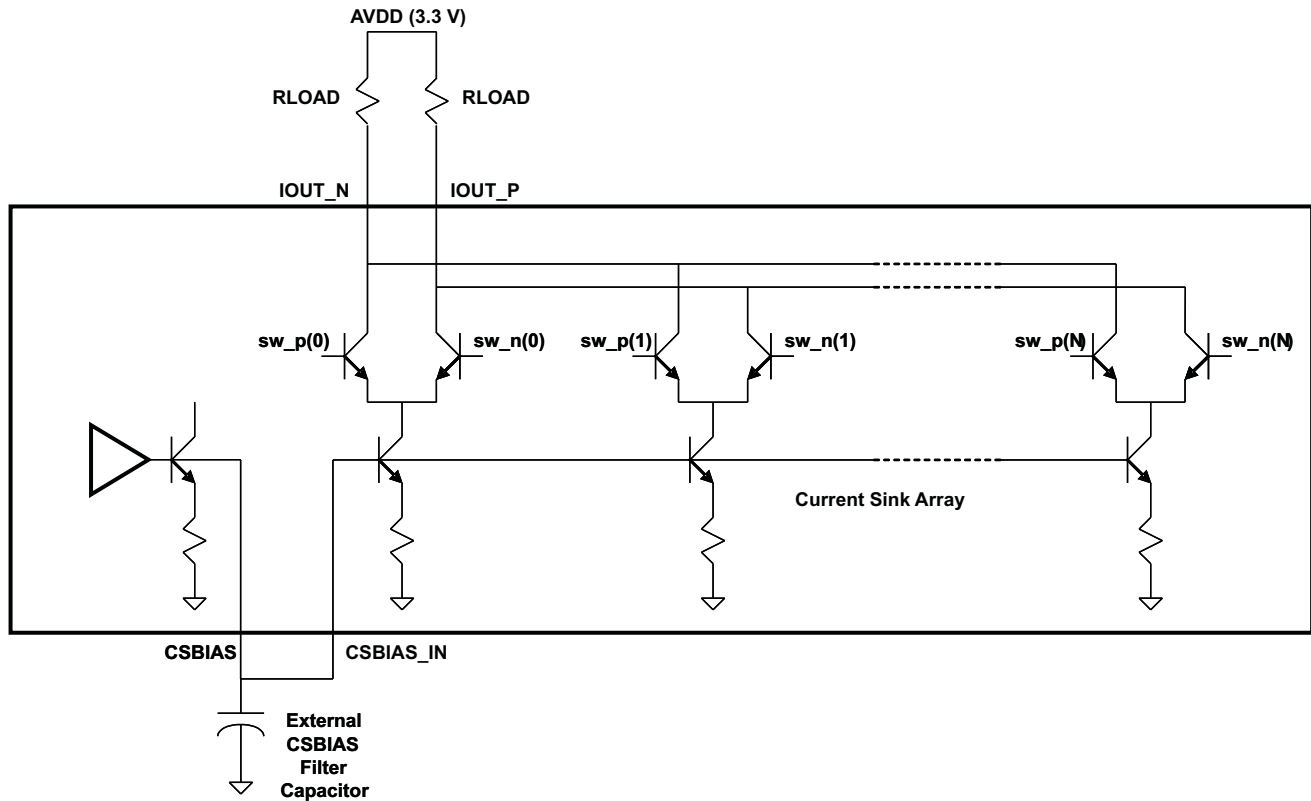
$V_{REFIO}$  Voltage at terminals REFIO and REFIO\_IN

The bandgap reference voltage delivers an accurate voltage of 1.2 V. An external REFIO filter capacitor of 0.1  $\mu$ F should be connected externally to the terminals REFIO and REFIO\_IN for compensation.

The full-scale output current can be adjusted from 30 mA down to 5 mA by varying external resistor  $R_{BIAS}$ .

## Analog Current Outputs

Figure 25 is a simplified schematic of the current sink array output with corresponding switches. Differential NPN switches direct the current of each individual NPN current sink to either the positive output node IOOUT\_P or its complementary negative output node IOOUT\_N. The input data presented at the DA\_P[13:0], DA\_N[13:0], DB\_P[13:0] and DB\_N[13:0] is decoded to control the sw\_p(N) and sw\_n(N) current switches.



**Figure 25. Current Sink Array**

The external output resistors  $R_{LOAD}$  are connected to the positive supply, AVDD.

The DAC5670 can easily be configured to drive a doubly-terminated 50  $\Omega$  cable using a properly selected transformer. Figure 26 and Figure 27 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 AVDD, enabling a dc current flow for both IOOUT\_N and IOOUT\_P.



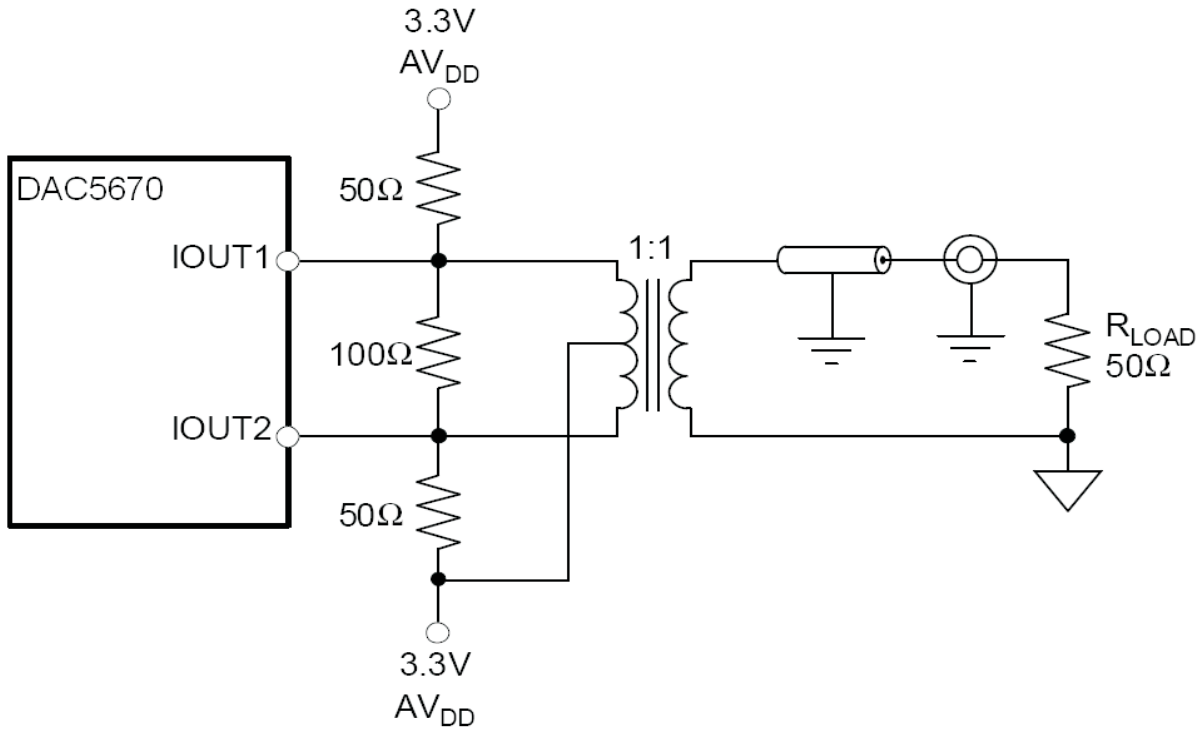


Figure 26.

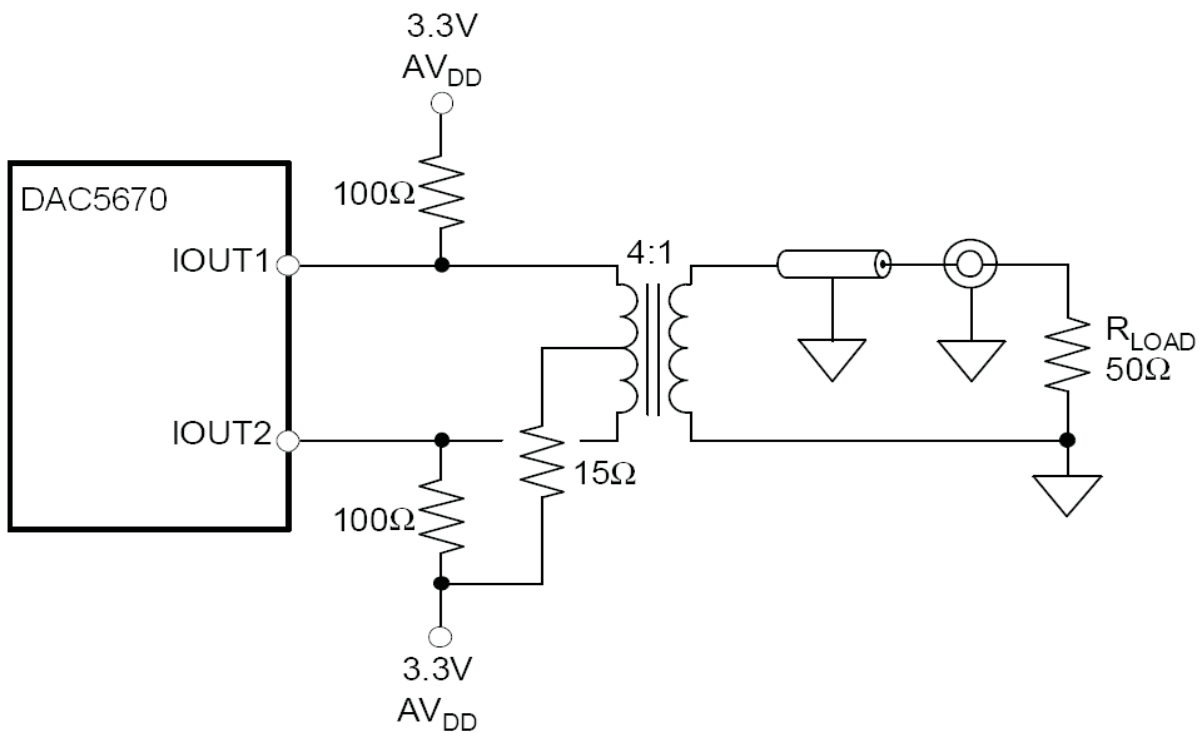


Figure 27.

**Sleep Mode**

When the SLEEP pin is asserted (high), the DAC5670 enters a lower-power mode.

## Definitions of Specifications and Terminology

**Differential Nonlinearity (DNL):** Defined as the variation in analog output associated with an ideal 1 LSB change in the digital input code.

**Gain Drift:** Defined as the maximum change in gain, in terms of ppm of full-scale range (FSR) per °C, from the value at 25°C to values over the full operating temperature range.

**Gain Error:** Defined as the percentage error in the ratio between the measured full-scale output current and the value of the ideal full-scale output ( $32 \times V_{REFIO}/R_{BIAS}$ ). A  $V_{REFIO}$  of 1.2V is used to measure the gain error with an external reference voltage applied. With an internal reference, this error includes the deviation of  $V_{REFIO}$  (internal bandgap reference voltage) from the typical value of 1.2V.

**Integral Nonlinearity (INL):** Defined as the maximum deviation of the actual analog output from the ideal output, determined by a straight line drawn from zero scale to full scale.

**Intermodulation Distortion (IMD3, IMD):** The two-tone IMD3 or four-tone IMD is defined as the ratio (in dBc) of the worst 3rd-order (or higher) intermodulation distortion product to either fundamental output tone.

**Offset Drift:** Defined as the maximum change in DC offset, in terms of ppm of full-scale range (FSR) per °C, from the value at 25°C to values over the full operating temperature range.

**Offset Error:** Defined as the percentage error in the ratio of the differential output current ( $I_{OUT\_P} - I_{OUT\_N}$ ) to half of the full-scale output current for input code 8192.

**Output Compliance Range:** Defined as the minimum and maximum allowable voltage at the output of the current-output DAC. Exceeding this limit may result in reduced reliability of the device or adversely affecting distortion performance.

**Power Supply Rejection Ratio (PSSR):** Defined as the percentage error in the ratio of the delta IOUT and delta supply voltage normalized with respect to the ideal IOUT current.

**Reference Voltage Drift:** Defined as the maximum change of the reference voltage in ppm per degree Celsius from value at ambient (25°C) to values over the full operating temperature range.

**Spurious Free Dynamic Range (SFDR):** Defined as the difference (in dBc) between the peak amplitude of the output signal and the peak spurious signal.

**Signal to Noise Ratio (SNR):** Defined as 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.

**Total Harmonic Distortion (THD):** Defined as the ratio of the rms sum of the first six harmonic components to the rms value of the fundamental output signal.

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
DAC5670IGDJ	ACTIVE	BGA	GDJ	252	90	Green (RoHS & no Sb/Br)	Call TI	Level-4-260C-72 HR	

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

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

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

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

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

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

(2) 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)

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

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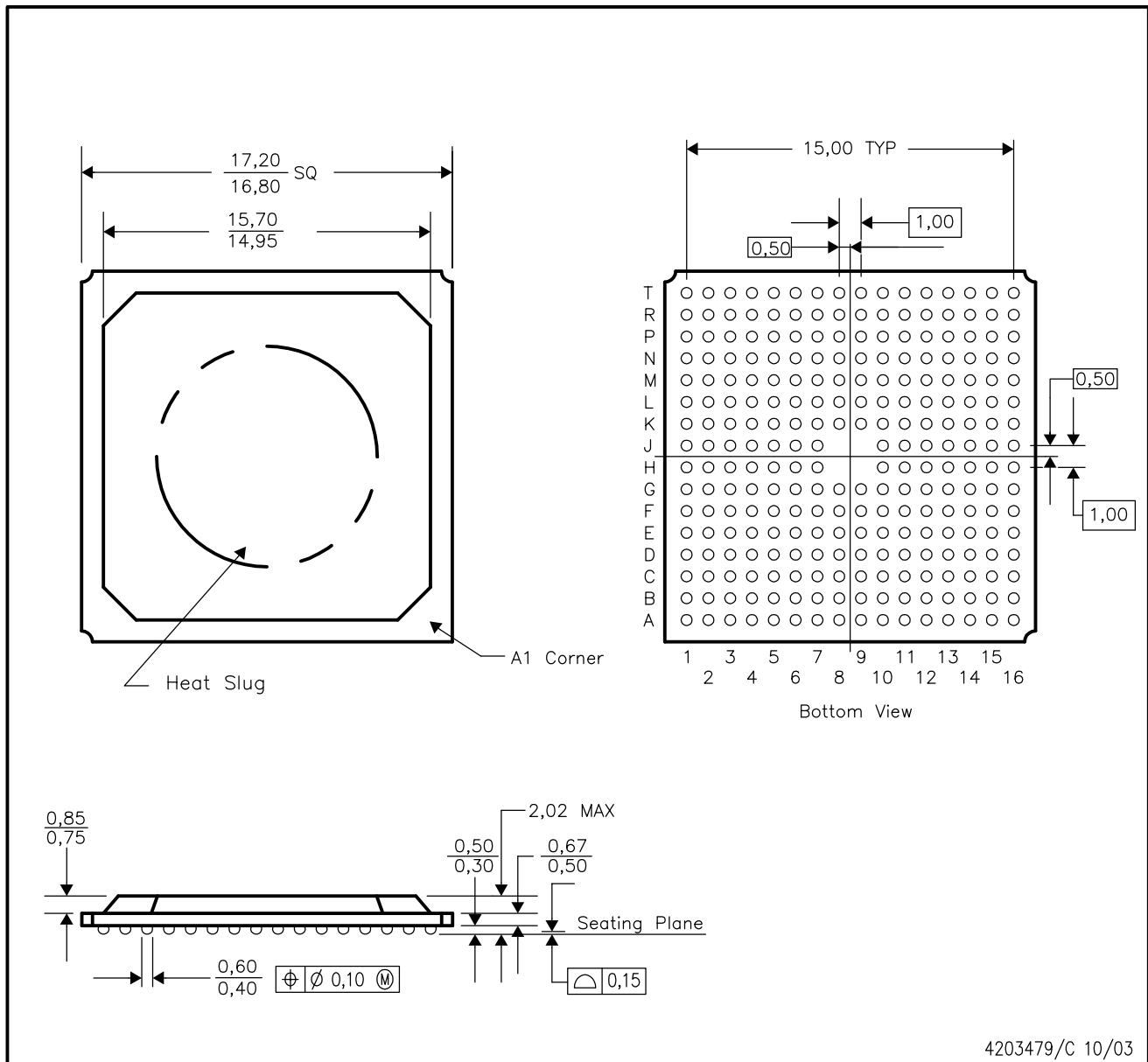
- Space: [DAC5670-SP](#)

NOTE: Qualified Version Definitions:

- Space - Radiation tolerant, ceramic packaging and qualified for use in Space-based application

GDJ (S-PBGA-N252)

PLASTIC BALL GRID ARRAY



4203479/C 10/03

- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Thermally enhanced plastic package with heat slug (HSL).

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