

## Dual-Channel, 10-/12-Bit, 500-MSPS Digital-to-Analog Converters (DACs)

Check for Samples: [DAC3152](#), [DAC3162](#)

### FEATURES

- **Low Power:** 270 mW at 500 MSPS
- **LVDS Input Data Bus**
  - Interleaved DDR Data Load
- **High DC Accuracy:**  $\pm 0.25$  LSB DNL (10-bit),  $\pm 0.5$  LSB INL (12-bit)
- **Low Latency:** 1.5 Clock Cycles
- **Simple Control:** No Software Required
- **Differential Scalable Output:** 2 mA to 20 mA
- **On-Chip 1.2-V Reference**
- **1.8-V and 3.3-V DC Supplies**
- **Space Saving Package:** 48-pin 7-mm x 7-mm QFN

### APPLICATIONS

- Cellular Base Stations
- Wideband Communications
- Medical Instrumentation
- Test and Measurement

### DESCRIPTION

The DAC3152/DAC3162 is a low-power, low-latency, high-dynamic-range, dual-channel, 10-/12-bit, pin-compatible family of digital-to-analog converters (DACs) with a sample rate as high as 500 MSPS.

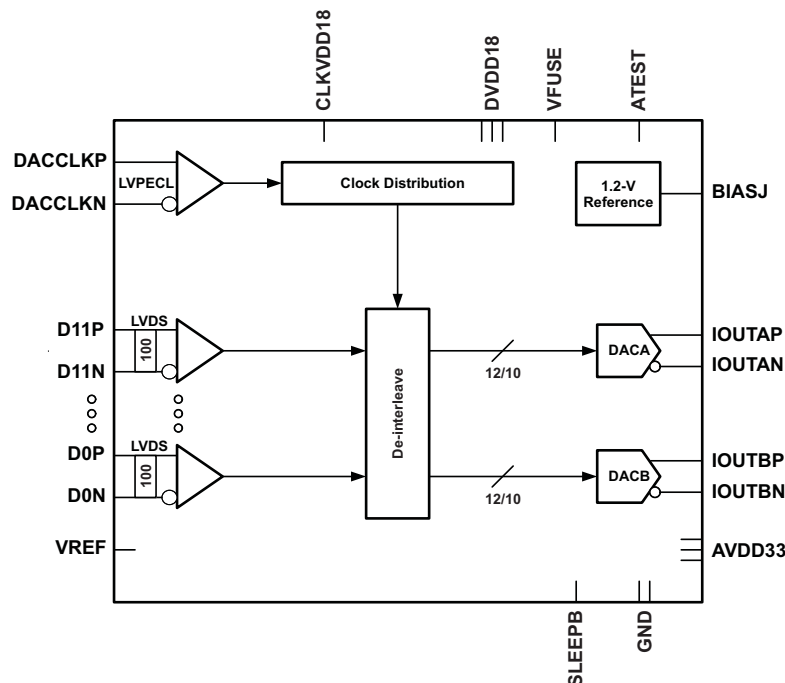
The device simplicity (no software required), low latency, and low power simplify the design of complex systems. The DACs interface seamlessly with the high-performance TRF370333 analog quadrature modulator for direct upconversion architectures.

Digital data for both DAC channels is interleaved through a single LVDS data bus with on-chip termination. The high input rate of the devices allows the processing of wide-bandwidth signals.

The devices are characterized for operation over the entire industrial temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and are available in a small 48-pin 7-mm x 7-mm QFN package.

The low power, small size, speed, superior crosstalk, simplicity, and low latency of the DAC3152/DAC3162 make them an attractive fit for a variety of applications.

### FUNCTIONAL BLOCK DIAGRAM

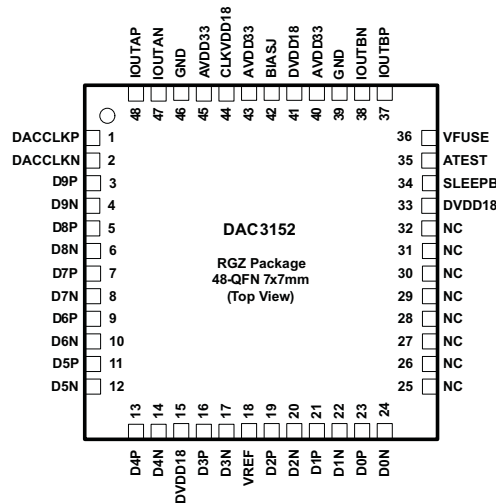


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

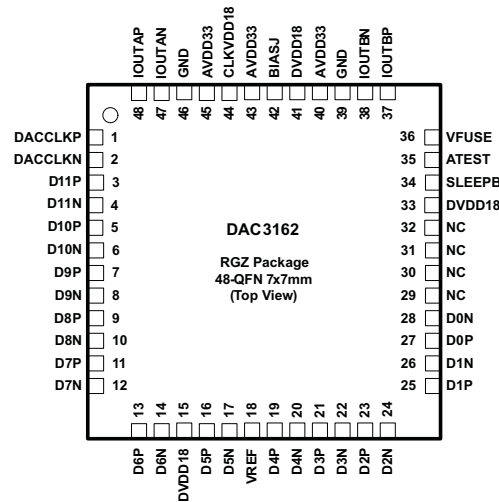
## DAC3152 PINOUT AND PIN FUNCTIONS



### PIN FUNCTIONS

PIN		I/O	DESCRIPTION
NAME	NO.		
ATEST	35	O	Factory use only. <b>Leave unconnected for normal operation.</b>
AVDD33	40, 43, 45	–	Analog supply voltage (3.3 V)
BIASJ	42	O	Full-scale output current bias. For 20-mA full-scale output current, connect a 960-Ω resistor to GND.
CLKVDD18	44	–	Internal clock buffer supply voltage (1.8 V) This supply can be shared with DIGVDD18.
D[9..0]P	3, 5, 7, 9, 11, 13, 16, 19, 21, 23	I	LVDS positive-input data bits 0 through 9. Each positive/negative LVDS pair has an internal 100-Ω termination resistor. Data format relative to DACCLKP/N clock is double data rate (DDR) with two data transfers per DACCLKP/N clock cycle. Dual-channel data is interleaved on this bus.  D9P is most-significant data bit (MSB) – pin 3 D0P is least-significant data bit (LSB) – pin 23
D[9..0]N	4, 6, 8, 10, 12, 14, 17, 20, 22, 24	I	LVDS negative-input data bits 0 through 9. (See D[9:0]P description)  D9N is most-significant data bit (MSB) – pin 4 D0N is least-significant data bit (LSB) – pin 24
DACCLKP	1	I	Positive external LVPECL clock input with a self-bias of approximately CLKVDD18/2. Input data is latched on both edges of DACCLKP/N (double data rate). The LVPECL clock signal should be AC coupled.
DACCLKN	2	I	Complementary external LVPECL clock input (see the DACCLKP description). The LVPECL clock signal should be AC coupled.
DVDD18	15, 33, 41	–	Digital supply voltage (1.8 V). This supply can be shared with CLKVDD18.
GND	39, 46, Thermal pad	–	Pins 39 and 46 and the thermal pad located on the bottom of the QFN package are ground for all supplies.
IOUTAP	48	O	A-channel DAC current output. An offset binary data pattern of 0x0000 at the DAC input results in a full-scale current sink and the least-positive voltage on the IOUTAP pin. Similarly, a 0x3FF data input results in a 0-mA current sink and the most-positive voltage on the IOUTAP pin.
IOUTAN	47	O	A-channel DAC complementary current output. IOUTAN has the opposite behavior of the IOUTAP described for IOUTAP. An input data value of 0x0000 results in a 0-mA sink and the most-positive voltage on the IOUTAN pin.
IOUTBP	37	O	B-channel DAC current output. See the IOUTAP description.
IOUTBN	38	O	B-channel DAC complementary current output. See the IOUTAN description.
NC	25–32	–	No connect. Leave unconnected for normal operation.
SLEEPB	34	I	Connect to GND to put the device in sleep mode or to AVDD for active mode. Internal pullup
VFUSE	36	–	Digital supply voltage (1.8 V). This supply pin is also used for factory fuse programming. <b>Connect to DVDD18 pins for normal operation.</b>
VREF	18	I/O	Factory use only. <b>Connect to a 0.1-μF decoupling capacitor to GND.</b>

## DAC3162 PINOUT AND PIN FUNCTIONS



### PIN FUNCTIONS

PIN		I/O	DESCRIPTION
NAME	NO.		
ATEST	35	O	Factory use only. <b>Leave unconnected for normal operation.</b>
AVDD33	40, 43, 45	–	Analog supply voltage (3.3 V)
BIASJ	42	O	Full-scale output current bias. For 20-mA full-scale output current, connect a 960-Ω resistor to GND.
CLKVDD18	44	–	Internal clock buffer supply voltage (1.8 V) This supply can be shared with DIGVDD18.
D[11..0]P	3, 5, 7, 9, 11, 13, 16, 19, 21, 23, 25, 27	I	LVDS positive-input data bits 0 through 11. Each positive/negative LVDS pair has an internal 100-Ω termination resistor. Data format relative to DACCLKP/N clock is double data rate (DDR) with two data transfers per DACCLKP/N clock cycle. Dual channel data is interleaved on this bus.  D11P is most-significant data bit (MSB) – pin 3 D0P is least-significant data bit (LSB) – pin 27
D[11..0]N	4, 6, 8, 10, 12, 14, 17, 20, 22, 24, 26, 28	I	LVDS negative-input data bits 0 through 11. (See D[11:0]P description)  D11N is most-significant data bit (MSB) – pin 4 D0N is least-significant data bit (LSB) – pin 28
DACCLKP	1	I	Positive external LVPECL clock input with a self-bias of approximately CLKVDD18/2. Input data is latched on both edges of DACCLKP/N (double data rate). The LVPECL clock signal should be AC coupled.
DACCLKN	2	I	Complementary external LVPECL clock input (see the DACCLKP description). The LVPECL clock signal should be AC coupled.
DVDD18	15, 33, 41	–	Digital supply voltage (1.8 V) This supply can be shared with CLKVDD18.
GND	39, 46, Thermal pad	–	Pins 39, 46 and the thermal pad located on the bottom of the QFN package are ground for all supplies.
IOUTAP	48	O	A-channel DAC current output. An offset binary data pattern of 0x0000 at the DAC input results in a full-scale current sink and the least-positive voltage on the IOUTAP pin. Similarly, a 0xFFFF data input results in a 0-mA current sink and the most-positive voltage on the IOUTAP pin.
IOUTAN	47	O	A-channel DAC complementary current output. IOUTAN has the opposite behavior of the IOUTAP described for IOUTAP. An input data value of 0x0000 results in a 0-mA sink and the most-positive voltage on the IOUTAN pin.
IOUTBP	37	O	B-channel DAC current output. See the IOUTAP description.
IOUTBN	38	O	B-channel DAC complementary current output. See the IOUTAN description.
NC	25–32	–	No connect. Leave unconnected for normal operation.
SLEEPB	34	I	Connect to GND to put the device in sleep mode or to AVDD for active mode. Internal pullup.
VFUSE	36	–	Digital supply voltage (1.8 V). This supply pin is also used for factory fuse programming. <b>Connect to DVDD18 pins for normal operation.</b>
VREF	18	I/O	Factory use only. <b>Connect to a 0.1-μF decoupling capacitor to GND.</b>

## ABSOLUTE MAXIMUM RATINGS

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

		VALUE		UNIT
		MIN	MAX	
Supply-voltage range <sup>(2)</sup>	DVDD18, CLKVDD18	−0.5	2.3	V
	VFUSE	−0.5	2.3	V
	AVDD33	−0.5	4	V
Pin-voltage range <sup>(2)</sup>	D[11..0]P/N	−0.5	DVDD18 + 0.5	V
	DACCLKP/N	−0.5	CLKVDD18 + 0.5 V	V
	BIASJ, SLEEPB	−0.5	AVDD33 + 0.7 V	V
	IOUTAP/N, IOUTBP/N	−1	AVDD33 + 0.7 V	V
Peak input current (any input)			±20	mA
Peak total input current (all inputs)			±30	mA
Operating free-air temperature range, T <sub>A</sub>		−40	85	°C
Storage temperature range, T <sub>stg</sub>		−65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of 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 GND

## THERMAL INFORMATION

THERMAL METRIC <sup>(1)(2)</sup>		DAC3152 DAC3162	UNIT
		RGZ (48 PINS)	
θ <sub>JA</sub>	Junction-to-ambient thermal resistance	28.9	°C/W
θ <sub>JCTop</sub>	Junction-to-case (top) thermal resistance	14.9	
θ <sub>JB</sub>	Junction-to-board thermal resistance	5.62	
ψ <sub>JT</sub>	Junction-to-top characterization parameter	0.3	
ψ <sub>JB</sub>	Junction-to-board characterization parameter	5.6	
θ <sub>JCbot</sub>	Junction-to-case (bottom) thermal resistance	1.7	

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) For thermal estimates of this device based on PCB copper area, see the [TI PCB Thermal Calculator](#).

## ELECTRICAL CHARACTERISTICS – DC SPECIFICATION

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC}$  = 500 MSPS,  $f_{OUT}$  = 1 MHz over recommended operating free-air temperature range,  $I_{OUTFS}$  = 20 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS	DAC3152			DAC3162			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>Resolution</b>		10			12			Bits
<b>DC ACCURACY</b>								
DNL	Differential nonlinearity		±0.1			±0.4		LSB
INL	Integral nonlinearity		±0.15			±0.5		LSB
<b>ANALOG OUTPUT<sup>(1)</sup></b>								
	Gain error		±1.6			±1.6		%FSR
	Gain mismatch		±0.2			±0.2		%FSR
	Full-scale output current	2		20	2		20	mA
	Output compliance range	AVDD – 0.5		AVDD + 0.5	AVDD – 0.5		AVDD + 0.5	V
	Output resistance		300			300		kΩ
	Output capacitance		5			5		pF
<b>REFERENCE</b>								
$V_{REF}$	Internal reference voltage	1.14	1.2	1.26	1.14	1.2	1.26	V
<b>TEMPERATURE COEFFICIENTS</b>								
	Gain drift		±60			±60		ppm/°C
	Reference-voltage drift		±41			±41		ppm/°C
<b>POWER SUPPLY</b>								
	AVDD33	3	3.3	3.6	3	3.3	3.6	V
	CLKVDD18, DVDD18	1.7	1.8	1.9	1.7	1.8	1.9	V
PSRR	Power-supply rejection ratio	DC tested	±0.1		±0.1			%FSR/V
<b>POWER CONSUMPTION</b>								
$P_{DIS}$	Power dissipation	$f_{DAC}$ = 500 MSPS, $f_{OUT}$ = 10 MHz	270	310	278	320		mW
		Power-down mode: no clock, DAC on sleep mode, static data pattern	16	23	17	25		mW
$I_{(AVDD33)}$	Analog supply current		55	65	56	65		mA
$I_{(DVDD18)}$ $I_{(CLKVDD)}$	Digital and clock supply current		50	55	53	63		mA
	Operating range		–40	25	85	–40	25	85 °C

(1) Measured differentially across IOUTAP/N or IOUTBP/N with 25 Ω each to AVDD.

## ELECTRICAL CHARACTERISTICS – DIGITAL SPECIFICATIONS

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC}$  = 500 MSPS,  $f_{OUT}$  = 1 MHz over recommended operating free-air temperature range,  $I_{OUTFS}$  = 20 mA (unless otherwise noted)

PARAMETER		TEST CONDITIONS	DAC3152			DAC3162			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
LVDS INPUTS: DIGITAL INPUT DATA <sup>(1)</sup>									
V <sub>A,B+</sub>	Logic-high differential input voltage threshold		150	400		150	400		mV
V <sub>A,B−</sub>	Logic-low differential input voltage threshold			−400	−150		−400	−150	mV
V <sub>COM</sub>	Input common mode		0.9	1.2	1.5	0.9	1.2	1.5	V
Z <sub>T</sub>	Internal termination		85	110	135	85	110	135	Ω
C <sub>L</sub>	LVDS input capacitance			2			2		pF
f <sub>INTERL</sub>	Interleaved LVDS data rate				1000			1000	MSPS
f <sub>DATA</sub>	Input data rate (per DAC)				500			500	MSPS
CLOCK INPUT: DACCLKP/N									
	Duty cycle		40%		60%	40%		60%	
	Differential voltage		0.2	1		0.2	1		V
	Clock frequency				500			500	MHz
CMOS INTERFACE: SLEEPB									
V <sub>IH</sub>	High-level input voltage		2			2			V
V <sub>IL</sub>	Low-level input voltage				0.8			0.8	V
I <sub>IH</sub>	High-level input current		−40		40	−40		40	μA
I <sub>IL</sub>	Low-level input current		−40		40	−40		40	μA
C <sub>I</sub>	CMOS Input capacitance			2			2		pF
DIGITAL INPUT DATA TIMING SPECIFICATIONS: <i>DOUBLE EDGE</i> LATCHING									
t <sub>s(DATA)</sub>	Setup time, valid to either edge of DACCLKP/N		200			200			ps
t <sub>h(DATA)</sub>	Hold time, valid after either edge of DACCLKP/N		200			200			ps

(1) See LVDS INPUTS section for terminology.

## ELECTRICAL CHARACTERISTICS – AC SPECIFICATIONS

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz over recommended operating free-air temperature range,  $I_{OUTFS} = 20$  mA (unless otherwise noted)

PARAMETER		TEST CONDITIONS	DAC3152			DAC3162			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
ANALOG OUTPUT <sup>(1)</sup>									
f <sub>DAC</sub> Maximum DAC rate			500			500			MSPS
t <sub>s</sub> (DAC) Output settling time to 0.1%		Transition: Code 0x0000 to 0xFFFF	10			10			ns
t <sub>r</sub> (IOUT) Output rise time, 10% to 90%			220			220			ps
t <sub>f</sub> (IOUT) Output fall time, 90% to 10%			220			220			ps
Latency			1.5			1.5			DAC clock cycles
Power-up time	DAC wake-up time	IOUT current settling to 1% of IOUT <sub>FS</sub> .	2			2			μs
	DAC sleep time	IOUT current settling to less than 1% of IOUT <sub>FS</sub> .	2			2			μs
AC PERFORMANCE <sup>(2)</sup>									
SFDR	Spurious-free dynamic range, single tone at 0 dBFS	f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 10 MHz	78			79			dBc
		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 20 MHz	74			74			
		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 70 MHz	59			60			
IMD3	Third-order two-tone intermodulation distortion, each tone at –12 dBFS	f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 10 ± 0.5 MHz	91			93			dBc
		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 20 ± 0.5 MHz	85			86			
		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 70 ± 0.5 MHz	62			62			
NSD	Noise spectral density, single tone at 0 dBFS	f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 10 MHz	–145			–155			dBc/Hz
		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 70 MHz	–140			–140			
ACLR <sup>(3)</sup>	Adjacent-channel leakage ratio, single carrier	f <sub>DAC</sub> = 491.52 MSPS, f <sub>OUT</sub> = 30 MHz	68			76			dBc
		f <sub>DAC</sub> = 491.52 MSPS, f <sub>OUT</sub> = 70 MHz	67			70			
Channel isolation		f <sub>DAC</sub> = 500 MSPS, f <sub>OUT</sub> = 10 MHz	90			90			dBc

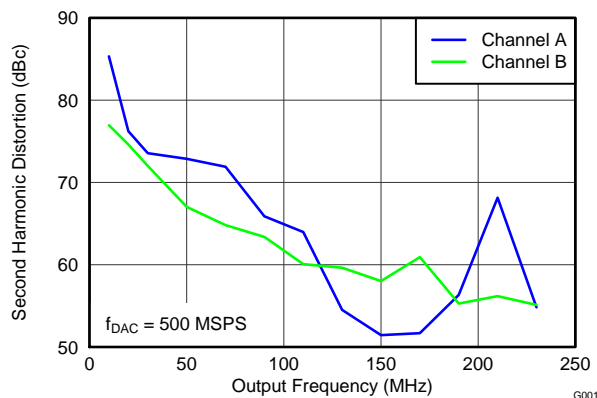
(1) Measured differentially across IOUTAP/N or IOUTBP/N with 25 Ω each to AVDD.

(2) 4:1 transformer output termination, 50-Ω doubly terminated load.

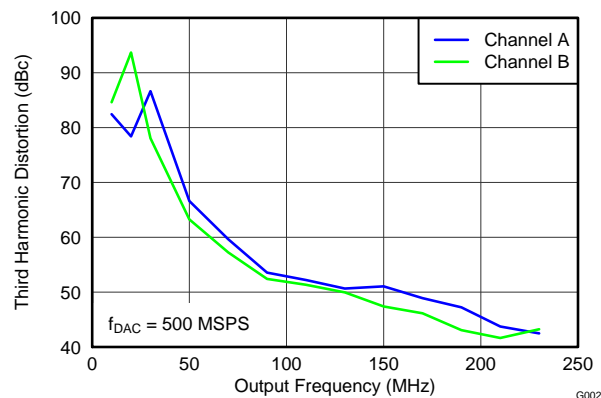
(3) Single carrier, W-CDMA with 3.84 MHz BW, 5-MHz spacing, centered at IF, PAR = 12 dB. TESTMODEL 1, 10 ms

## Typical Characteristics

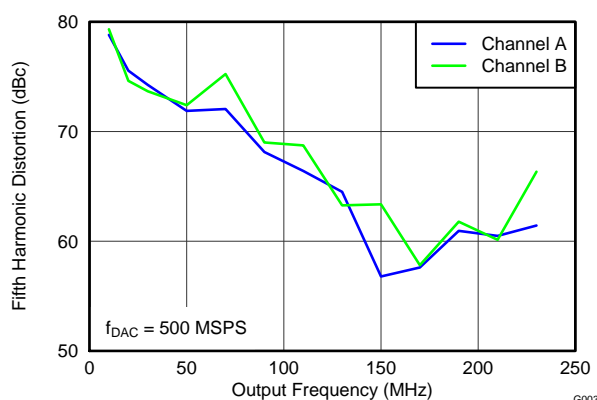
DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)



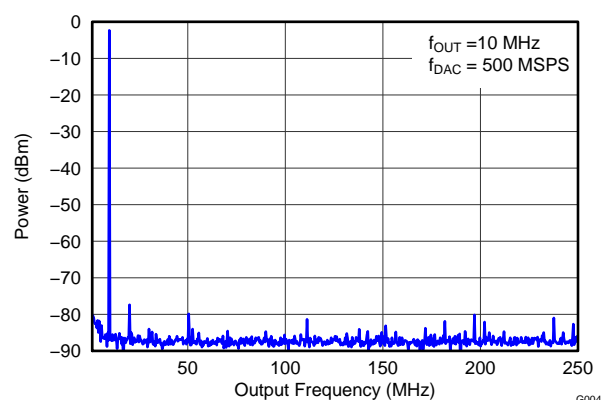
**Figure 1. DAC3152 Second-Harmonic Distortion vs Frequency**



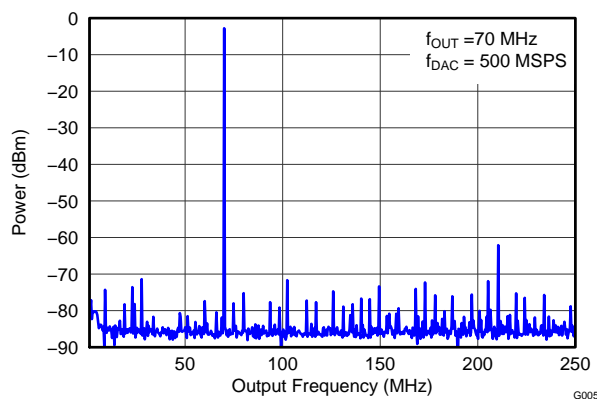
**Figure 2. DAC3152 Third-Harmonic Distortion vs Frequency**



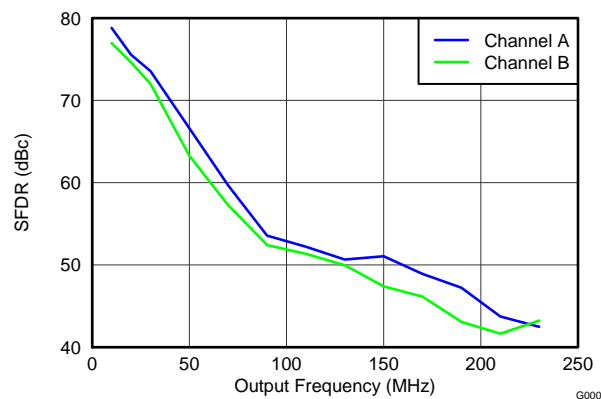
**Figure 3. DAC3152 Fifth-Harmonic Distortion vs Frequency**



**Figure 4. DAC3152 10-MHz Spectrum vs Frequency**



**Figure 5. DAC3152 70-MHz Spectrum vs Frequency**



**Figure 6. DAC3152 Spurious-Free Dynamic Range vs Frequency**



## Typical Characteristics (continued)

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)

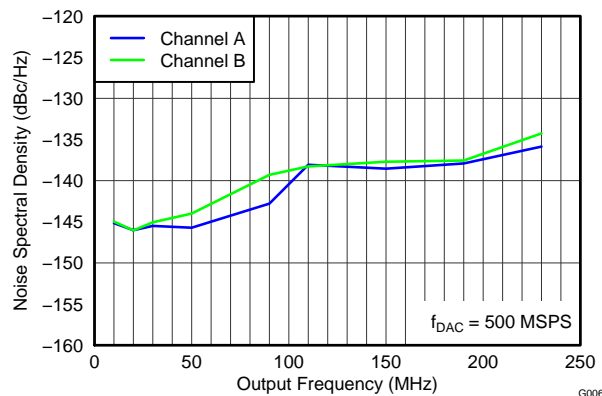


Figure 7. DAC3152 Noise Spectral Density vs Frequency

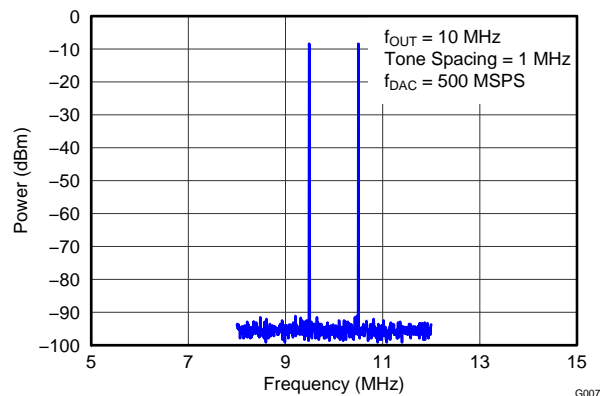


Figure 8. DAC3152 10-MHz Two-Tone Spectrum vs Frequency

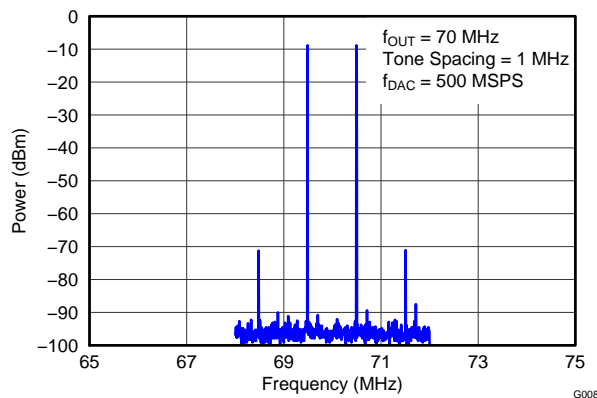


Figure 9. DAC3152 70-MHz Two-Tone Spectrum vs Frequency

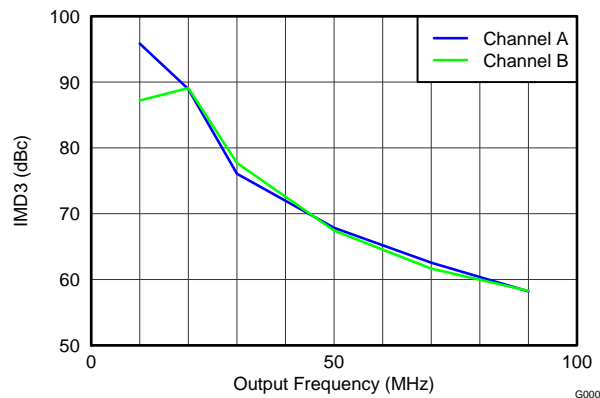


Figure 10. DAC3152 Intermodulation Distortion vs Frequency

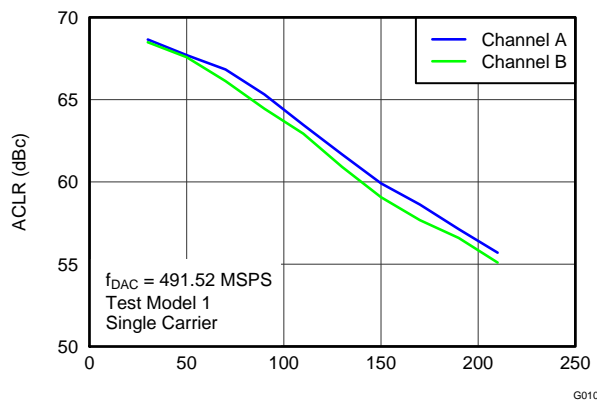


Figure 11. DAC3152 Alternate Channel vs Frequency

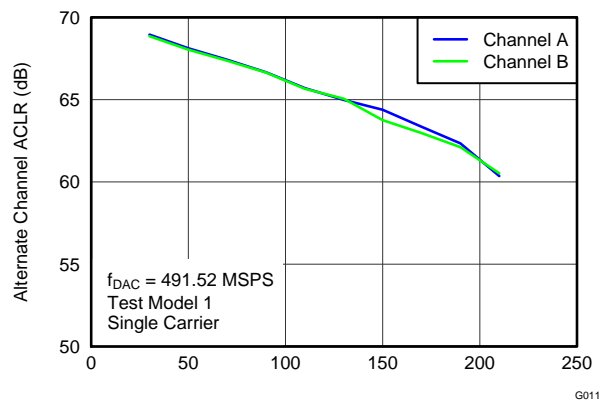
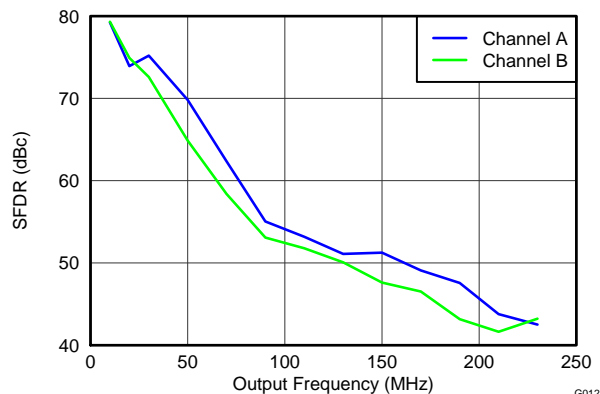


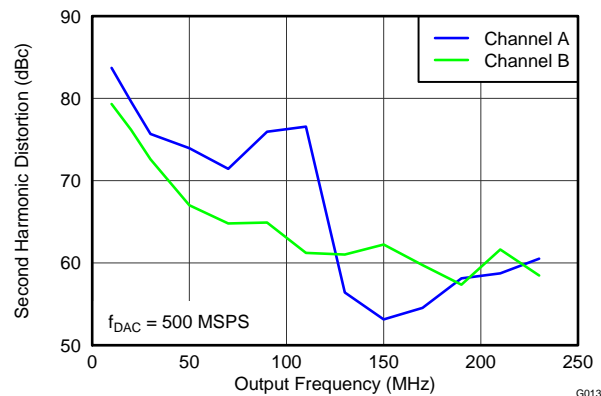
Figure 12. DAC3152 Alternate Channel vs Frequency

## Typical Characteristics (continued)

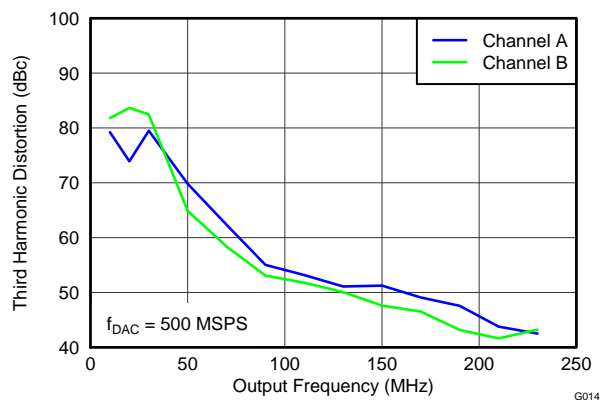
DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)



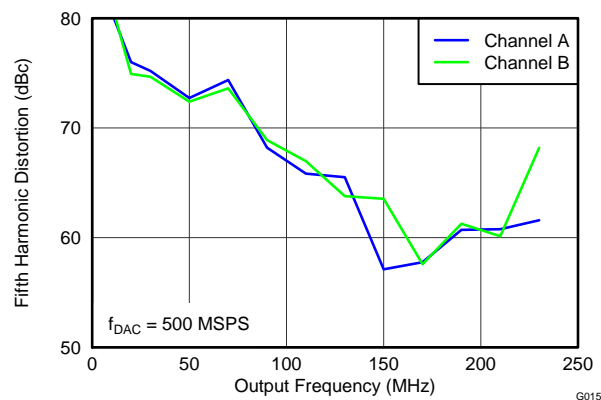
**Figure 13. DAC3162 Spurious-Free Dynamic Range vs Frequency**



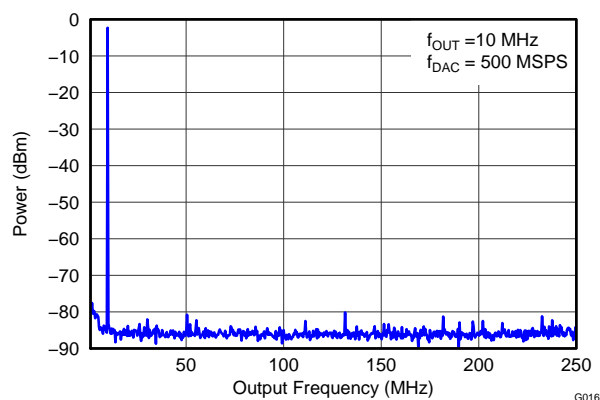
**Figure 14. DAC3162 Second-Harmonic Distortion vs Frequency**



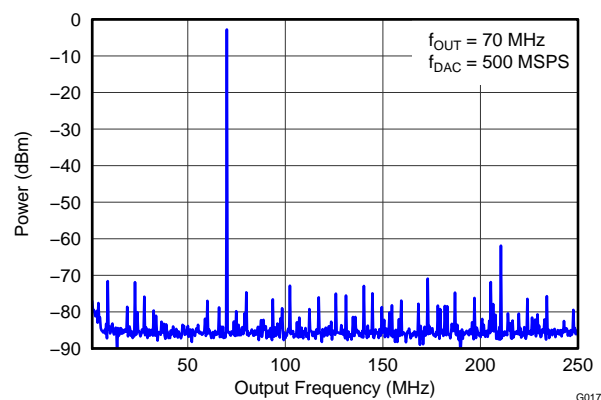
**Figure 15. DAC3162 Third-Harmonic Distortion vs Frequency**



**Figure 16. DAC3162 Fifth-Harmonic Distortion vs Frequency**



**Figure 17. DAC3162 10-MHz Spectrum vs Frequency**



**Figure 18. DAC3162 70-MHz Spectrum vs Frequency**

## Typical Characteristics (continued)

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)

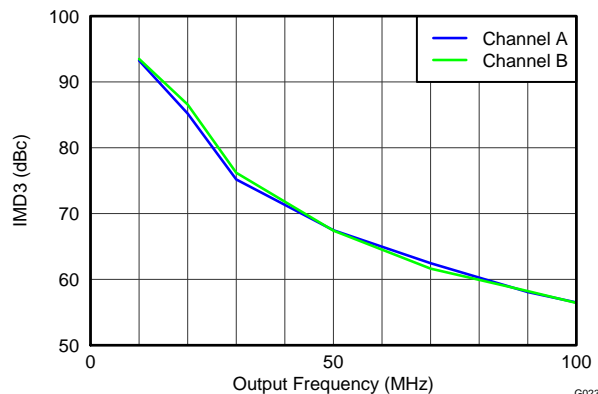


Figure 19. DAC3152 Intermodulation Distortion vs Frequency

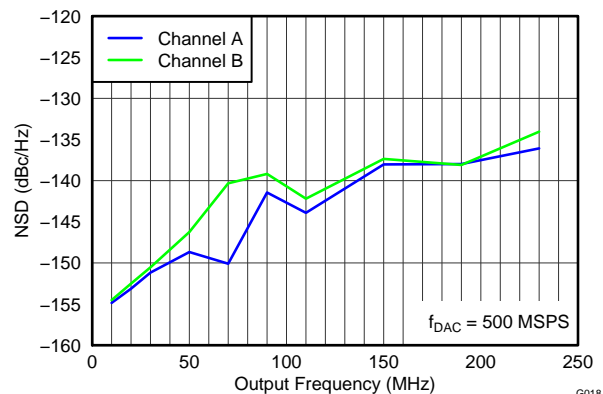


Figure 20. DAC3162 Noise Spectral Density vs Frequency

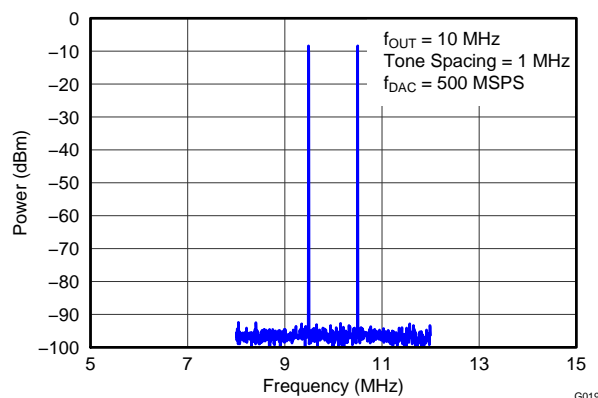


Figure 21. DAC3162 10-MHz Two-Tone Spectrum vs Frequency

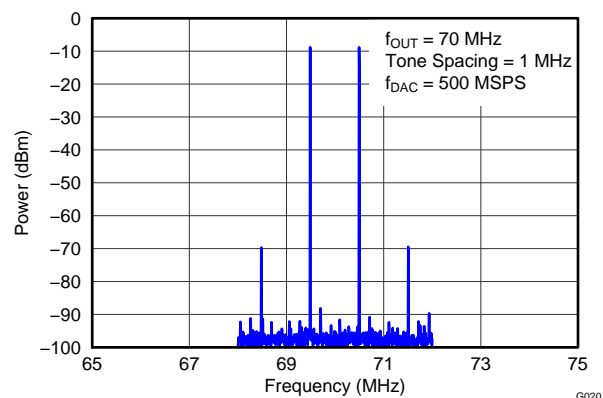


Figure 22. DAC3162 70-MHz Two-Tone Spectrum vs Frequency

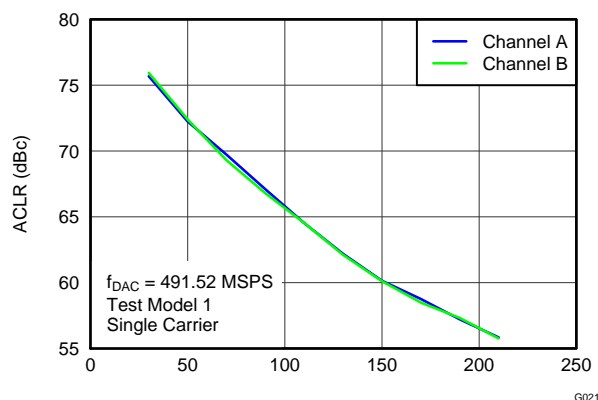


Figure 23. DAC3162 Alternate Channel vs Frequency

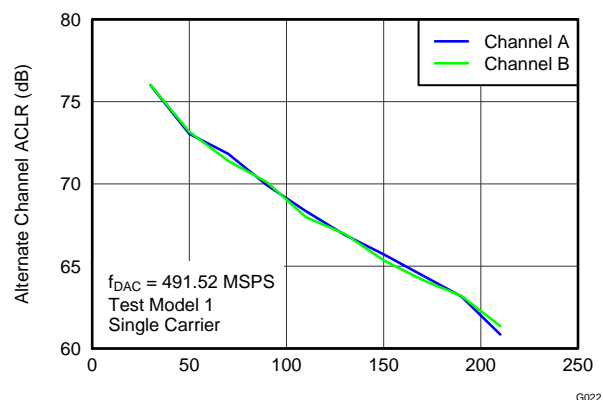


Figure 24. DAC3162 Alternate Channel vs Frequency

## Typical Characteristics (continued)

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)

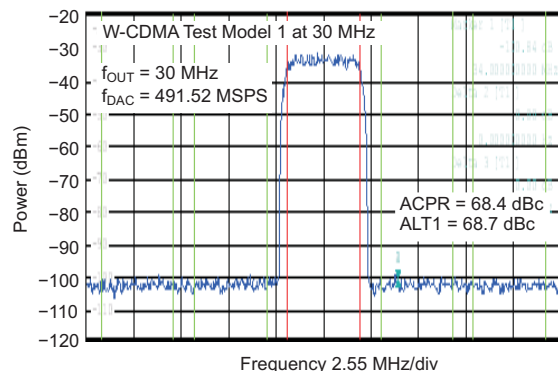


Figure 25. DAC3152 30-MHz WCDMA vs Frequency

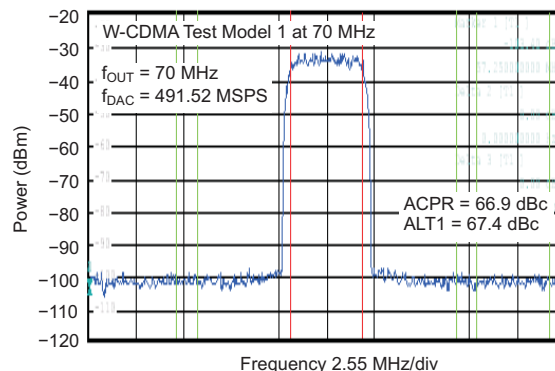


Figure 26. DAC3152 70-MHz WCDMA vs Frequency

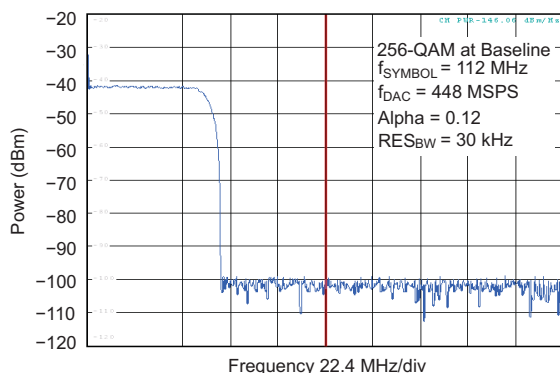


Figure 27. DAC3152 QAM vs Frequency

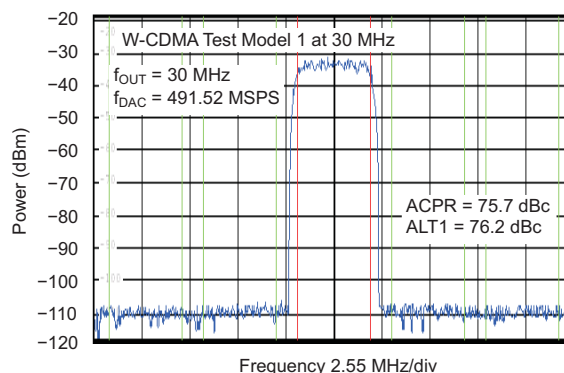


Figure 28. DAC3162 30-MHz WCDMA vs Frequency

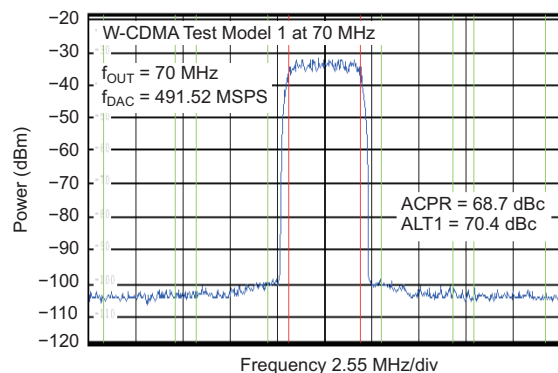


Figure 29. DAC3162 70-MHz WCDMA vs Frequency

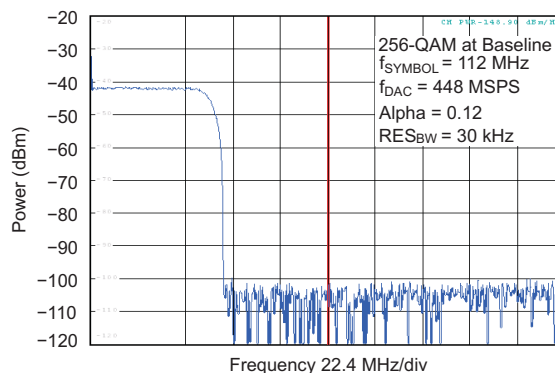
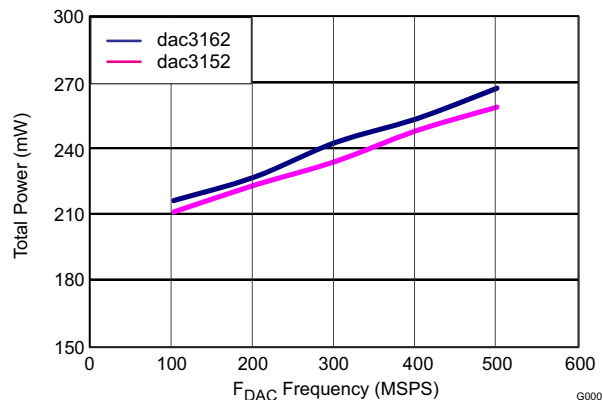


Figure 30. DAC3162 QAM vs Frequency

### Typical Characteristics (continued)

DVDD18 = CLKVDD18 = 1.8 V, AVDD33 = 3.3 V,  $f_{DAC} = 500$  MSPS,  $f_{OUT} = 1$  MHz,  $I_{OUTfs} = 20$  mA (unless otherwise noted)



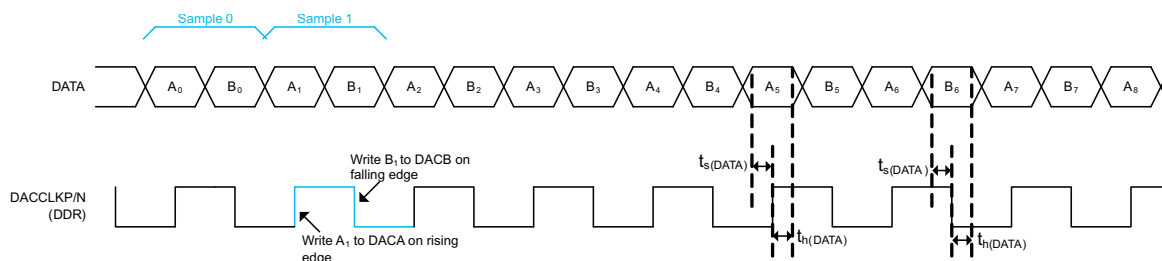
**Figure 31. POWER vs Frequency**

## APPLICATION INFORMATION

### DATA INTERFACE

The parallel-port data interface to the device consists of a single LVDS bus that accepts interleaved A and B data with up to 12-bit resolution. Data is sampled by the LVPECL double-data-rate (DDR) clock DACCLK. DACCLK is additionally used for the data conversion process, and hence a low-jitter source is recommended. Setup and hold requirements must be met for proper sampling.

The interleaved data for channels A and B is interleaved in the form A0, B0, A1, B1... into the data bus. Data into the device is formatted according to the diagram shown in [Figure 32](#).



**Figure 32. Data Transmission Format**

## CLOCK INPUT

The DAC clock (DACCLKP/N) is an internally biased differential input that for optimal performance should be driven by a low-jitter clock source. The DACCLK signal is used for both data latching (in DDR format) and as the data conversion clock. Figure 33 shows an equivalent circuit for the DAC input clock.

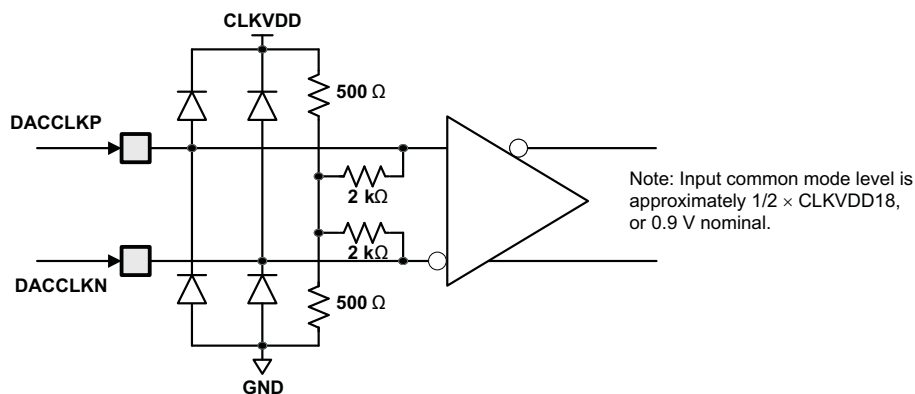


Figure 33. DACCLKP/N Equivalent Input Circuit

The preferred configuration for driving the DACCLK input consists of a differential ECL/PECL source as shown in Figure 34. Although not optimal due to the limited signal swing, an LVDS source can also be used to drive the clock input with the preferred configuration shown in Figure 35.

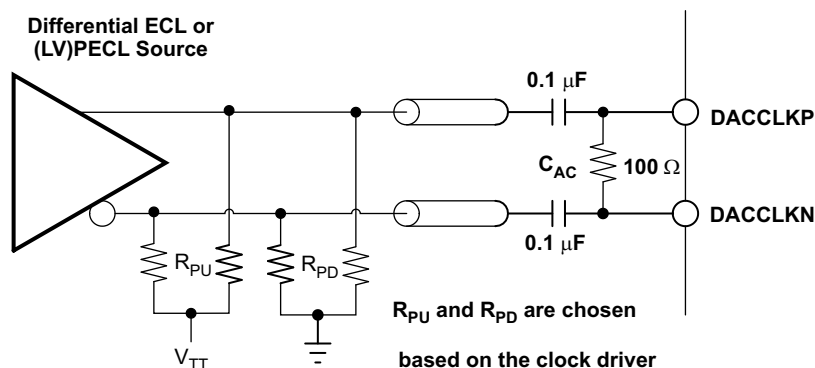


Figure 34. Clock Input Configuration LVPECL

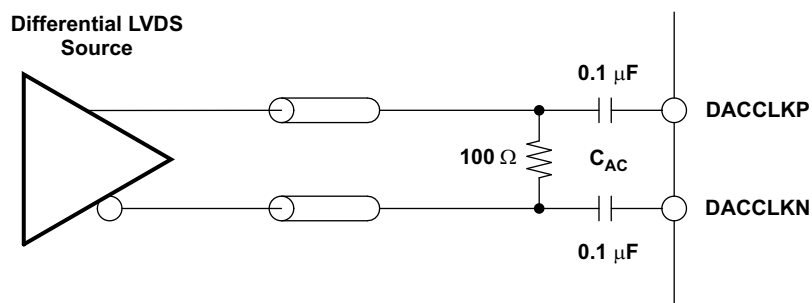


Figure 35. Clock Input Configuration LVDS

A single-ended clock, such as a clean sinusoid or a 1.8 V LVCMOS signal (for low-rate operation), can also be used to drive the clock if configured as in the input circuits of [Figure 36](#) and [Figure 37](#).

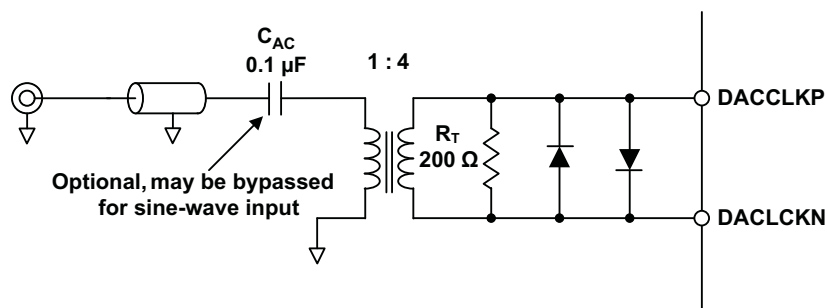


Figure 36. Clock Input Configuration Using 50-Ω Cable Input

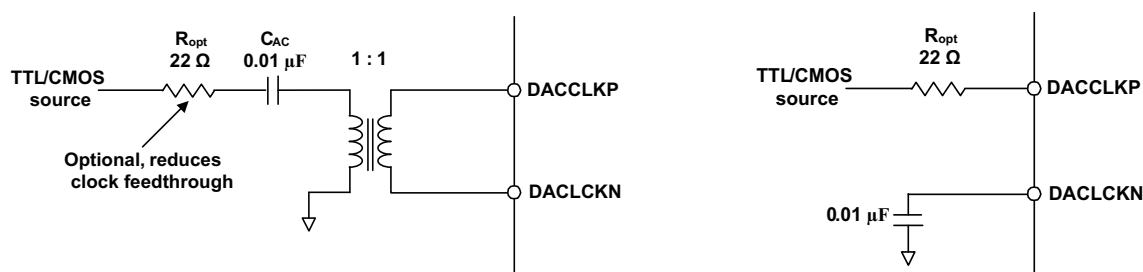


Figure 37. Clock Input Configuration With a Single-Ended TTL/CMOS Clock



## DATA INPUTS

The input data LVDS pairs (D[11:0]P/N) have the input configuration shown in Figure 38. Figure 39 shows the typical input levels and common-mode voltage used to drive these inputs.

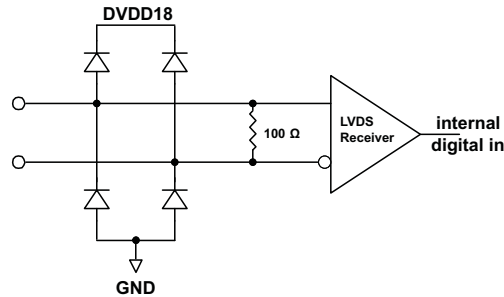


Figure 38. D[13:0]P/N LVDS Input Configuration

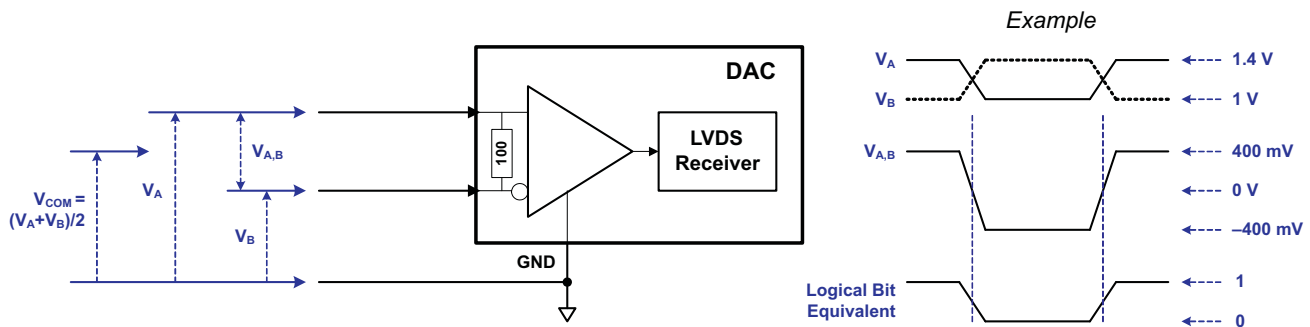


Figure 39. LVDS Data Input Levels

Table 1.

Applied Voltages		Resulting Differential Voltage	Resulting Common-Mode Voltage	Logical Bit Binary Equivalent
$V_A$	$V_B$	$V_{A,B}$	$V_{COM}$	
1.4 V	1 V	400 mV	1.2 V	1
1 V	1.4 V	-400 mV		0
1.2 V	0.8 V	400 mV	1 V	1
0.8 V	1.2 V	-400 mV		0

## CMOS INPUT

Figure 40 shows a schematic of the SLEEPB equivalent CMOS digital inputs. See the specification table for logic thresholds. The pullup circuitry is approximately equivalent to 100 kΩ.

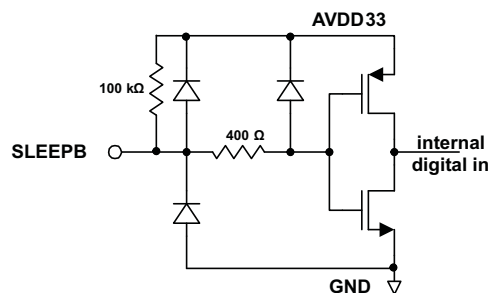


Figure 40. SLEEPB Digital Equivalent Input

## REFERENCE OPERATION

The DAC3152/DAC3162 uses a band-gap 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 pin BIASJ. The bias current  $I_{BIAS}$  through resistor  $R_{BIAS}$  is defined by the on-chip band-gap reference voltage and control amplifier. The default full-scale output current equals 16 times this bias current and can thus be expressed as:

$$IOUT_{FS} = 16 \times I_{BIAS} = 16 \times V_{BG} / R_{BIAS}$$

The band-gap reference voltage delivers an accurate voltage of 1.2 V. The full-scale output current can be adjusted from 20 mA down to 2 mA by varying resistor  $R_{BIAS}$ . The internal control amplifier has a wide input range, supporting the full-scale output current range of 20 dB. The recommended value for  $R_{BIAS}$  is 960  $\Omega$ , which results in a full-scale output current of 20 mA.

## DAC TRANSFER FUNCTION

The DAC outputs of the DAC3152/DAC3162 consist of a segmented array of NMOS current sinks, capable of sinking a full-scale output current up to 20 mA. Differential current switches direct the current to either one of the complementary output nodes IOUTP or IOUTN. Complementary output currents enable differential operation, thus canceling out common-mode noise sources (digital feed-through, on-chip and PCB noise), dc offsets, and even-order distortion components, and increasing signal output power by a factor of four.

The full-scale output current is set using external resistor  $R_{BIAS}$  in combination with an on-chip band-gap voltage reference source (1.2 V) and control amplifier. Current  $I_{BIAS}$  through resistor  $R_{BIAS}$  is mirrored internally to provide a maximum full-scale output current equal to 16 times  $I_{BIAS}$ .

The relation between IOUTP and IOUTN can be expressed as:

$$IOUT_{FS} = IOUTP + IOUTN$$

Current flowing into a node is denoted as – current, and current flowing out of a node as + current. Because the output stage is a current sink, the current flows from AVDD33 into the IOUTP and IOUTN pins. The output current flow in each pin driving a resistive load can be expressed as:

$$IOUTP = IOUT_{FS} \times ((2^N - 1) - CODE) / 2^N$$

$$IOUTN = IOUT_{FS} \times CODE / 2^N$$

where CODE is the decimal representation of the DAC data input word and N is the DAC bit resolution.

For the case where IOUTP and IOUTN drive resistor loads  $R_L$  directly, this translates into single-ended voltages at IOUTP and IOUTN:

$$VOUTP = AVDD - |IOUTP| \times R_L$$

$$VOUTN = AVDD - |IOUTN| \times R_L$$

Assuming that the data is full scale ( $2^N - 1$  in offset binary notation) and the  $R_L$  is 25  $\Omega$ , the differential voltage between pins IOUTP and IOUTN can be expressed as:

$$VOUTP = AVDD - |-0 \text{ mA}| \times 25 \Omega = 3.3 \text{ V}$$

$$VOUTN = AVDD - |-20 \text{ mA}| \times 25 \Omega = 2.8 \text{ V}$$

$$V_{DIFF} = VOUTP - VOUTN = 0.5 \text{ V}$$

Note that care should be taken not to exceed the compliance voltages at nodes IOUTP and IOUTN, which would lead to increased signal distortion.

## ANALOG CURRENT OUTPUTS

The DAC outputs can be easily configured to drive a doubly terminated 50-Ω cable using a properly selected RF transformer. Figure 41 and Figure 42 show the 50-Ω doubly terminated transformer configuration with 1:1 and 4:1 impedance ratios, respectively. Note that the center tap of the primary input of the transformer must be connected to AVDD to enable a dc current flow. Applying a 20-mA full-scale output current leads to a 0.5-V<sub>pp</sub> output for a 1:1 transformer and a 1-V<sub>pp</sub> output for a 4:1 transformer. The low dc impedance between IOUTP or IOUTN and the transformer center tap sets the center of the ac signal to AVDD, so the 1-V<sub>pp</sub> output for the 4:1 transformer results in an output between AVDD – 0.5 V and AVDD + 0.5 V.

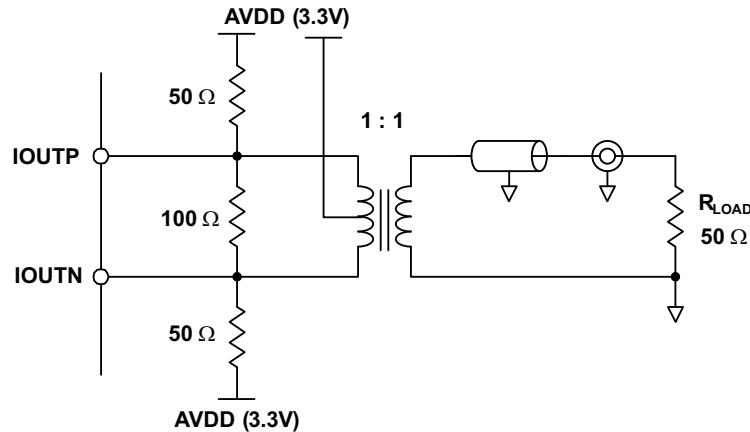


Figure 41. Driving a Doubly Terminated 50-Ω Cable Using a 1:1 Impedance-Ratio Transformer

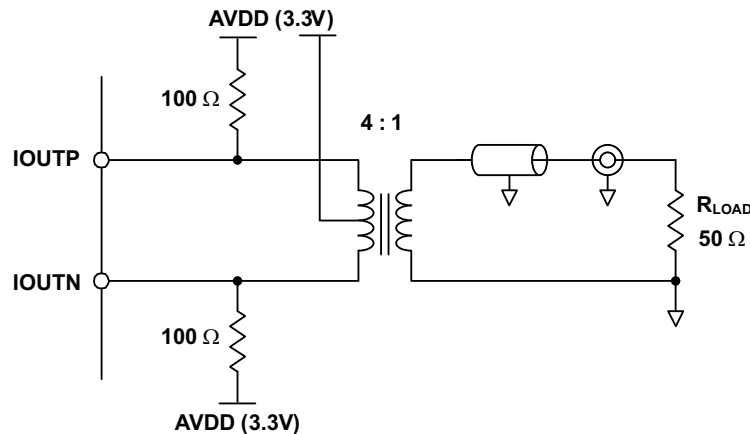
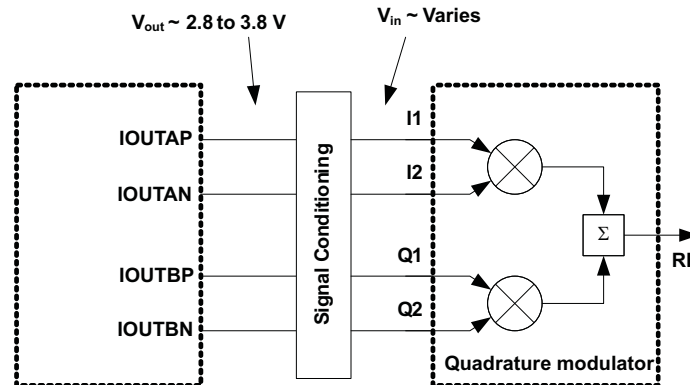


Figure 42. Driving a Doubly Terminated 50-Ω Cable Using a 4:1 Impedance-Ratio Transformer

## PASSIVE INTERFACE TO ANALOG QUADRATURE MODULATORS

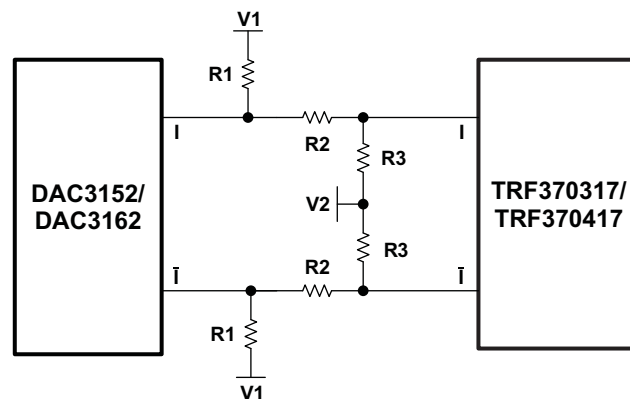
A common application in communication systems is to interface the DAC to an IQ modulator like the TRF3703 family of modulators from Texas Instruments. The input of the modulator is generally of high impedance and requires a specific common-mode voltage. A simple resistive network can be used to maintain 50-Ω load impedance for the DAC3152/DAC3162 and also provide the necessary common-mode voltages for both the DAC and the modulator.



**Figure 43. DAC3152/DAC3162 to Analog Quadrature Modulator Interface**

The DAC3152/DAC3162 has a maximum 20-mA full-scale output and a voltage compliance range of  $AV_{DD} \pm 0.5$  V. The TRF3703 IQ modulator family has three common-mode voltage options: 1.5 V, 1.7 V, and 3.3 V, and the TRF370417 IQ modulator has a 1.7-V common mode.

Figure 44 shows the recommended passive network to interface the DAC to the TRF370317, which has a common-mode voltage of 1.7 V. The network generates the 3.3-V common mode required by the DAC output and 1.7 V at the modulator input, while still maintaining a 50-Ω load for the DAC.



**Figure 44. DAC3152/DAC3162 to TRF370317 or TRF370417 Interface**

If  $V_1$  is set to 5 V and  $V_2$  is set to -5 V, the corresponding resistor values are  $R_1 = 57 \Omega$ ,  $R_2 = 80 \Omega$ , and  $R_3 = 336 \Omega$ . The loss developed through  $R_2$  is about -1.86 dB. When there is no -5-V supply available and  $V_2$  is set to 0 V, the resistor values are  $R_1 = 66 \Omega$ ,  $R_2 = 101 \Omega$ , and  $R_3 = 107 \Omega$ . The loss with these values is -5.76 dB.

Figure 45 shows the recommended network for interfacing with the TRF370333, which requires a common mode of 3.3 V. This is the simplest interface, as there is no voltage shift. With  $V_1 = 5$  V and  $V_2 = 0$  V, the resistor values are  $R_1 = 66 \Omega$  and  $R_3 = 208 \Omega$ .

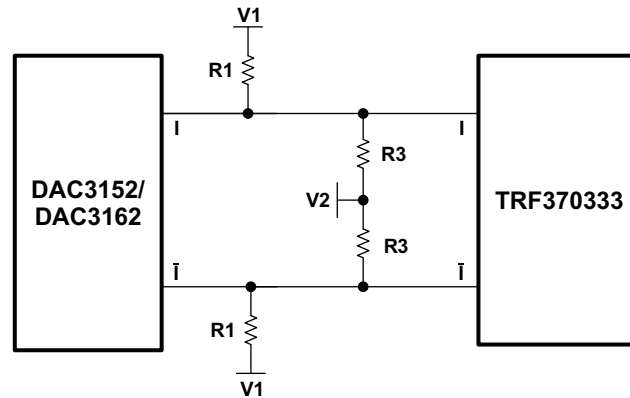


Figure 45. DAC3152/DAC3162 to TRF370333 Interface

In most applications, a baseband filter is required between the DAC and the modulator to eliminate the DAC images. This filter can be placed after the common-mode biasing network. For the DAC-to-modulator network shown in Figure 46, R2 and the filter load R4 must be considered into the DAC impedance. The filter must be designed for the source impedance created by the resistor combination of  $R3 \parallel (R2 + R1)$ . The effective impedance seen by the DAC is affected by the filter termination resistor, resulting in  $R1 \parallel (R2 + R3 \parallel (R4/2))$ .

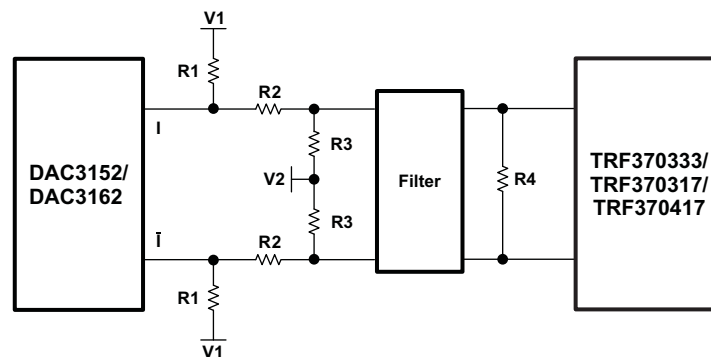


Figure 46. DAC to Modulator Interface With Filter

Factoring in R4 into the DAC load, a typical interface to the TRF370317 with  $V1 = 5\text{ V}$  and  $V2 = 0\text{ V}$  results in the following values:  $R1 = 72\ \Omega$ ,  $R2 = 116\ \Omega$ ,  $R3 = 124\ \Omega$  and  $R4 = 150\ \Omega$ . This implies that the filter must be designed for 75- $\Omega$  input and output impedance (single-ended impedance). The common-mode levels for the DAC and modulator are maintained at 3.3 V and 1.7 V, and the DAC load is 50  $\Omega$ . The added load of the filter termination causes the signal to be attenuated by -10.8 dB.

A filter can be implemented in a similar manner to interface with the TRF370333. In this case, it is much simpler to balance the loads and common-mode voltages, due to the absence of R2. An added benefit is that there is no loss in this network. With  $V1 = 5\text{ V}$  and  $V2 = 0\text{ V}$ , the network can be designed such that  $R1 = 115\ \Omega$ ,  $R3 = 681\ \Omega$ , and  $R4 = 200\ \Omega$ . This results in a filter impedance of  $R1 \parallel R2 = 100\ \Omega$ , and a DAC load of  $R1 \parallel R3 \parallel (R4/2)$ , which is equal to 50  $\Omega$ . R4 is a differential resistor and does not affect the common-mode level created by R1 and R3. The common-mode voltage is set at 3.3 V for a full-scale current of 20 mA.

For more information on how to interface the DAC3152/DAC3162 to an analog quadrature modulator, see the application reports *Passive Terminations for Current Output DACs* (SLAA399) and *Design of Differential Filters for High-Speed Signal Chains* (SLWA053).

## POWER-UP SEQUENCE

The following start-up sequence is recommended to power up the DAC3152/DAC3162:

- Supply 1.8 V to DVDD18 and CLKVDD18 simultaneously, and 3.3 V to AVDD33. Within AVDD33, the multiple AVDD33 pins should be powered up simultaneously. The 1.8-V and 3.3-V supplies can be powered up simultaneously or in any order.  
There are no specific requirements on the ramp rate for the supplies.
- Provide the DAC clock to the DACCLKP/N inputs.
- Toggle the SLEEPB pin for a minimum 25-ns low pulse duration.
- Provide the LVDS data inputs.

## DEFINITION OF SPECIFICATIONS

**Adjacent-Carrier Leakage Ratio (ACLR):** 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.

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

**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 ambient (25°C) to values over the full operating temperature range.

**Gain Error:** Defined as the percentage error (in FSR%) for the ratio between the measured full-scale output current and the ideal full-scale output current.

**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):** The two-tone IMD3 is defined as the ratio (in dBc) of the third-order 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 ambient (25°C) to values over the full operating temperature range.

**Offset Error:** Defined as the percentage error (in FSR%) for the ratio between the measured mid-scale output current and the ideal mid-scale output current.

**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.

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

**Noise Spectral Density (NSD):** Defined as the difference of power (in dBc) between the output tone signal power and the noise floor of 1 Hz bandwidth within the first Nyquist zone, excluding harmonics.

**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.

## REVISION HISTORY

### Changes from Original (November 2010) to Revision A Page

- Deleted the DAC3172 device ..... 1

### Changes from Revision A (November 2010) to Revision B Page

- Changed Feature bullet From: High DC Accuracy:  $\pm 1$  LSB DNL,  $\pm 2$  LSB INL To: High DC Accuracy:  $\pm 0.25$  LSB DNL (10-bit),  $\pm 0.5$  LSB INL (12-bit) ..... 1
- Added text "The LVPECL clock signal should be AC coupled" to Pin DACCLKP and DACCLKN descriptions. .... 2
- Added text "The LVPECL clock signal should be AC coupled" to Pin DACCLKP and DACCLKN descriptions. .... 3
- Added values to the Thermal Information table ..... 4
- Changed the ELECTRICAL CHARACTERISTICS – DC SPECIFICATION table ..... 5
- Added Min and Max values to  $V_{COM}$  - Internal common mode ..... 6
- Added Min and Max values to  $Z_T$  - Internal termination ..... 6
- Changed the AC Performance Typical values for DAC3152 and DAC3162 ..... 7
- Added the Typical Characteristics section ..... 8
- Replaced Signal to Noise Ratio (SNR) with Noise Spectral Density (NSD) ..... 22

### Changes from Revision B (December 2011) to Revision C Page

- Changed the CLOCK INPUT: DACCLKP/N - Differential voltage MIN value From: 0.4V To: 0.2V for both devices ..... 6
- Deleted Note 2 From the DIGITAL SPECIFICATIONS table- Driving the clock input with a differential voltage lower than 1 V results in degraded performance. .... 6

### Changes from Revision C (February 2012) to Revision D Page

- Added [Figure 31](#) ..... 12
- Changed [Figure 34](#) ..... 15
- Added [Figure 35](#) ..... 15
- Moved the DEFINITION OF SPECIFICATIONS to the end of the data sheet ..... 22

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
DAC3152IRGZR	ACTIVE	VQFN	RGZ	48	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	DAC3152I	<a href="#">Samples</a>
DAC3152IRGZT	ACTIVE	VQFN	RGZ	48	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	DAC3152I	<a href="#">Samples</a>
DAC3162IRGZR	ACTIVE	VQFN	RGZ	48	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	DAC3162I	<a href="#">Samples</a>
DAC3162IRGZT	ACTIVE	VQFN	RGZ	48	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-40 to 85	DAC3162I	<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.

**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.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side 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 Top-Side Marking for that device.

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**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
DAC3152IRGZR	VQFN	RGZ	48	2500	330.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2
DAC3152IRGZT	VQFN	RGZ	48	250	180.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2
DAC3162IRGZR	VQFN	RGZ	48	2500	330.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2
DAC3162IRGZT	VQFN	RGZ	48	250	180.0	16.4	7.3	7.3	1.5	12.0	16.0	Q2

## TAPE AND REEL BOX DIMENSIONS

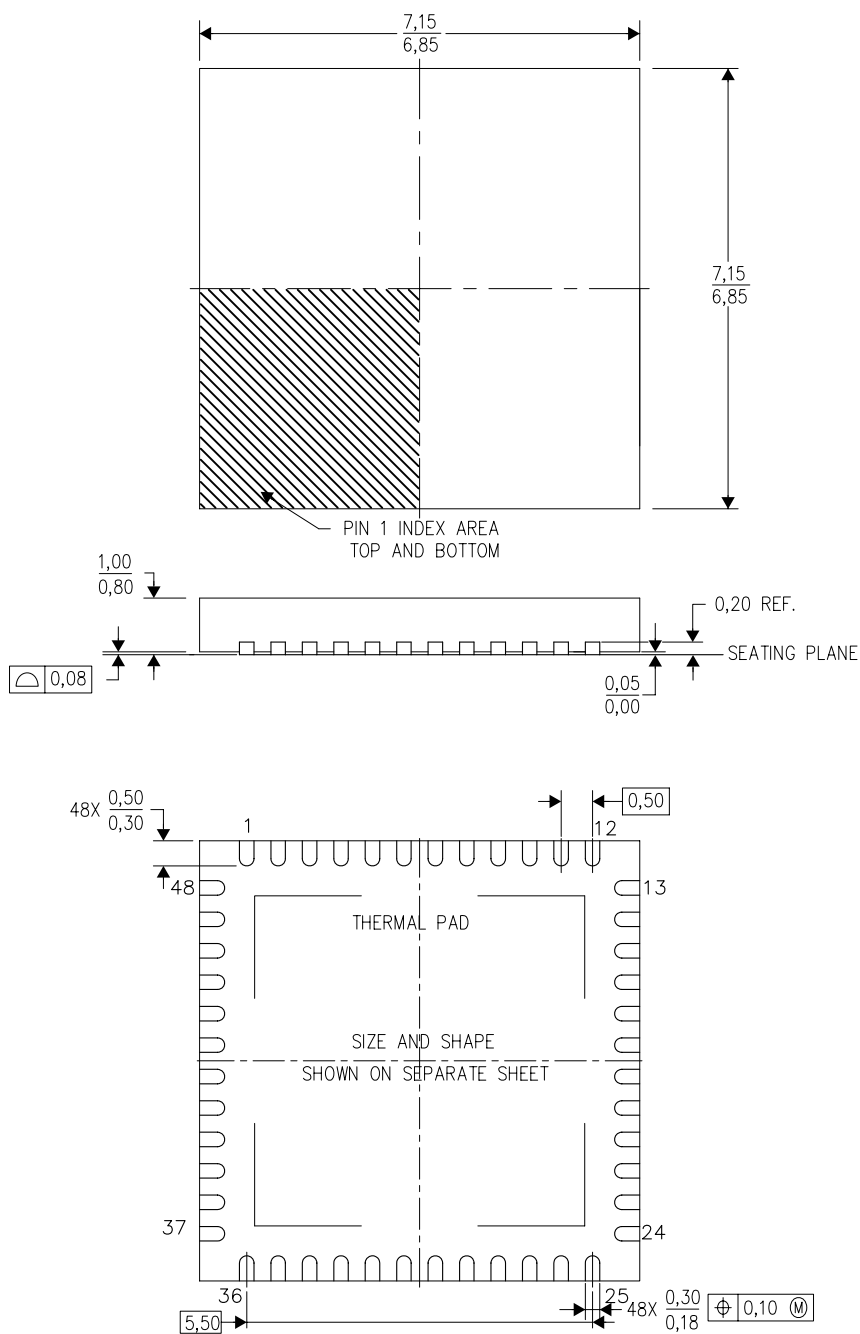


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DAC3152IRGZR	VQFN	RGZ	48	2500	336.6	336.6	28.6
DAC3152IRGZT	VQFN	RGZ	48	250	213.0	191.0	55.0
DAC3162IRGZR	VQFN	RGZ	48	2500	336.6	336.6	28.6
DAC3162IRGZT	VQFN	RGZ	48	250	213.0	191.0	55.0

RGZ (S-PVQFN-N48)

PLASTIC QUAD FLATPACK NO-LEAD



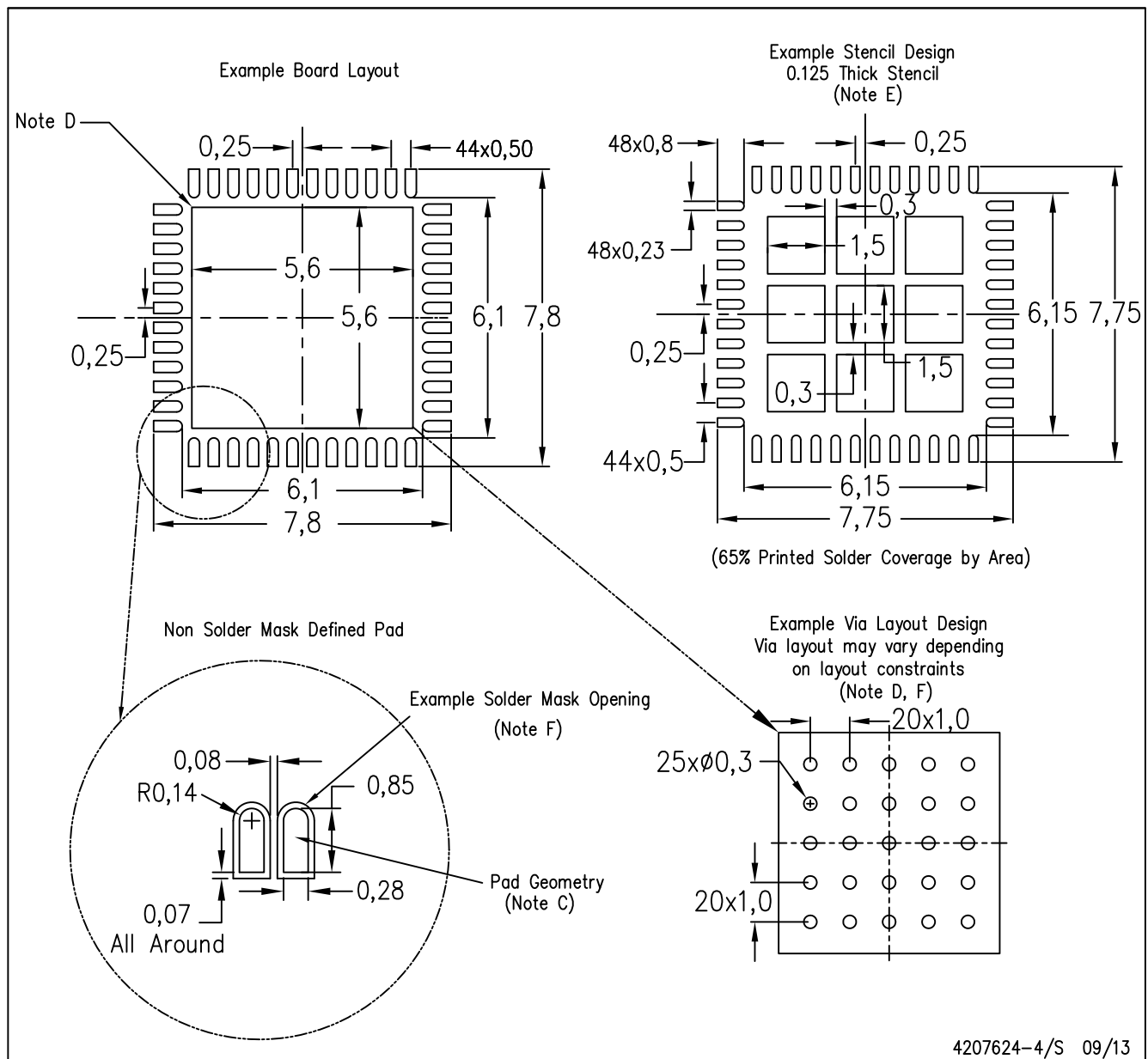
4204101/F 06/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Quad Flatpack, No-leads (QFN) package configuration.
  - D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
  - F. Falls within JEDEC MO-220.



RGZ (S-PVQFN-N48)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, 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>>.
  - 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.
  - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

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