

# 用于体重秤和人体成分测量的 AFE4300 低成本集成模拟前端

## 1 特性

- 体重秤前端:
  - 支持最多四路称重传感器输入
  - 通过片上称重传感器 1.7V 激励电压进行比例式测量
  - 68nVrms 输入参考噪声 (0.1Hz 至 2Hz)
  - 最佳线性: 满量程的 0.01%
  - 体重计测量: 540 $\mu$ A
- 主体组成部分前端:
  - 支持高达 3 个双向四电极波 (Tetra-Polar) 复杂阻抗测量
  - 6 位, 每秒1百万次采样 (1-MSPS) 正弦波生成数模转换器 (DAC)
  - 247.5 $\mu$ Arms、 $\pm$ 20% 激励源
  - 在 2Hz 带宽中具有 0.1 $\Omega$  测量 RMS 噪声
  - 人体成分测量: 970 $\mu$ A
- 模数转换器 (ADC):
  - 16 位、860SPS
  - 电源电流: 110 $\mu$ A

## 2 应用

可进行人体成分测量的体重秤

## 3 说明

AFE4300 是一款低成本模拟前端, 此模拟前端有两个独立的信号链: 一个信号链用于体重计 (WS) 测量, 而另外一个信号链用于体成分测量 (BCM) 分析。一个 16 位, 860SPS 模数转换器 (ADC) 在两个信号链间复用。体重测量信号链包括一个可由外部电阻器设定增益的仪器放大器 (INA), 后接一个用于偏移校正的 6 位数模转换器 (DAC), 和一个驱动外部桥/负载单元 (有一个用于比例式测量的 1.7V 固定电压) 的电路。

AFE4300 还可通过产生一个进入人体的正弦电流来测量人体成分。此正弦电流由一个内部模式生成器和一个 6 位, 1MSPS DAC 生成。一个电压电流转换器将这个正弦电流应用在两个端子之间的人体上。在这两个端子上生成的电压是由人体的阻抗生成的, 此电压由一个差分放大器测量, 再经过整流, 且其振幅由 16 位 ADC 提取并测量。

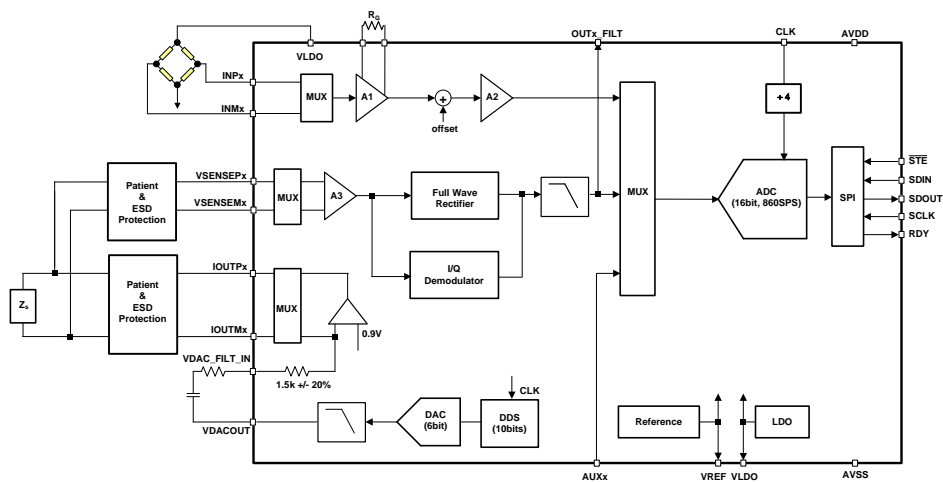
AFE4300 的工作电压范围为 2V 至 3.6V, 额定温度为 0°C 至 +70°C, 并采用 LQFP-80 封装。

### 器件信息(1)

器件型号	封装	封装尺寸 (标称值)
AFE4300	LQFP (80)	12.00mm x 12.00mm

(1) 如需了解所有可用封装, 请参阅数据表末尾的可订购产品附录。

### 功能框图



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## 4 修订历史

### Changes from Revision B (June 2013) to Revision C

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• 添加了器件信息表、ESD 额定值表、特性描述部分、器件功能模式部分、编程部分、应用和实施部分、电源建议部分、布局部分、器件和文档支持部分以及机械、封装和可订购信息部分 .....	1
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• 通篇将 TQFP 更改为 LQFP .....	1
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• Changed VSENSEN to VSENSEM in pins 41 and 42 in <i>Pin Functions</i> table .....	5
• Changed AVSS parameter name to <i>Ground</i> from <i>Supply voltage</i> in <i>Recommended Operating Conditions</i> table .....	6
• Changed symbol R1 to $R_{FB1}$ in <i>Electrical Characteristics: Front-End Amplification (Weight-Scale Signal Chain)</i> table .....	7
• Changed typical specification of <i>DAC full-scale voltage</i> parameter from 1 to 1.05 in <i>Electrical Characteristics: Body Composition Measurement Front-End</i> table .....	8
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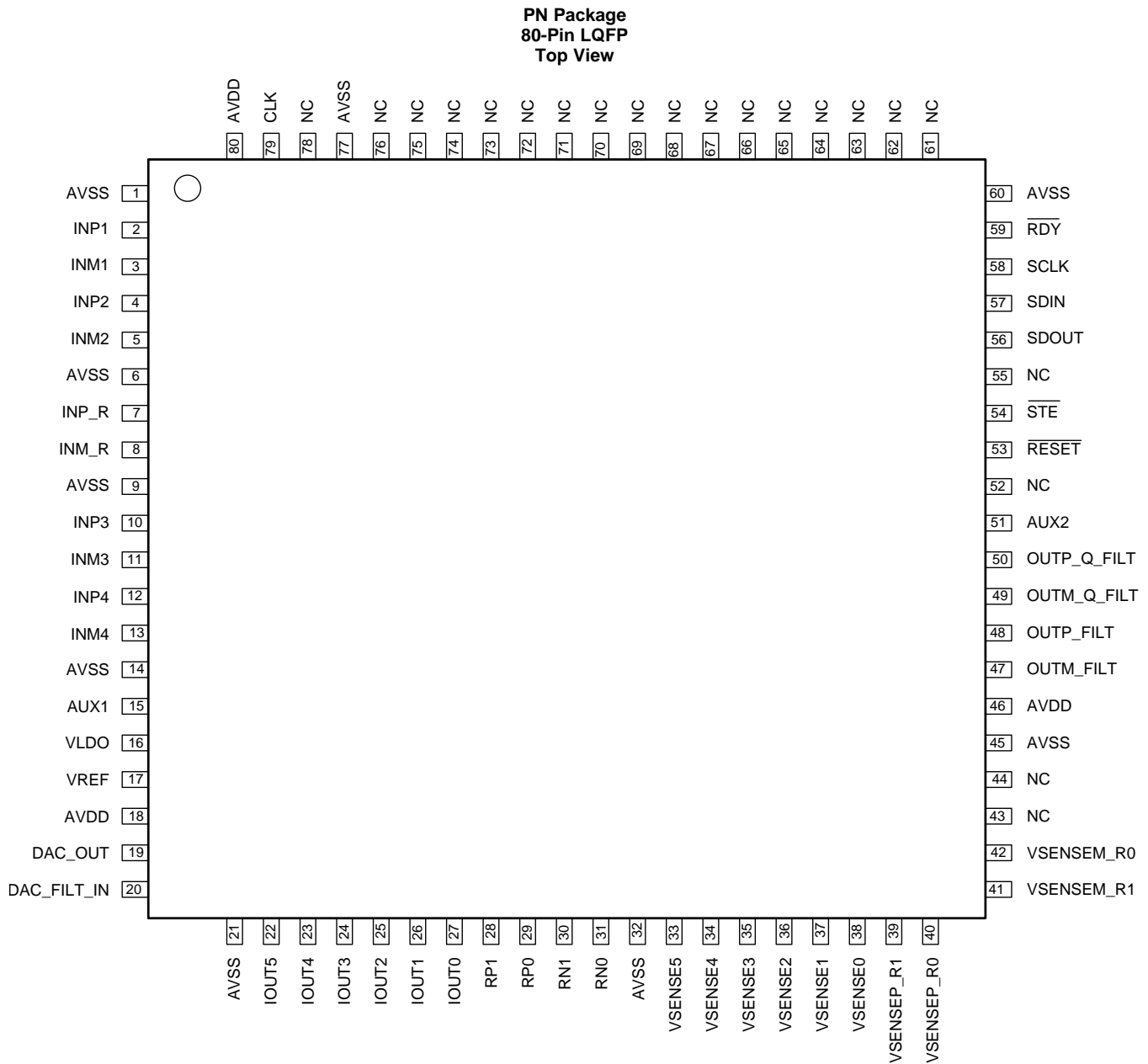
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## 5 Pin Configuration and Functions



### Pin Functions

PIN		I/O	DESCRIPTION
NAME	NUMBER		
AAUX1	15	I	Auxiliary input to the ADC
AAUX2	51	I	Auxiliary input to the ADC
AVDD	18, 46, 80	—	Supply (3.3 V)
AVSS	1, 6, 9, 14, 21, 32, 45, 60, 77	—	Ground
CLK	79	I	1-MHz clock
DAC_FILT_IN	20	I	Current generator input. Connect ac blocking capacitor between this pin and pin 19.
DACOUT	19	O	DAC output. Connect ac blocking capacitor between this pin and pin 20.

**Pin Functions (continued)**

PIN		I/O	DESCRIPTION
NAME	NUMBER		
INM1	3	I	Instrumentation amplifier differential inputs for each of the four weight-scale channels
INM2	5		
INM3	11		
INM4	13		
INP1	2		
INP2	4		
INP3	10		
INP4	12		
INM_R	8	—	Connection of gain setting resistor for the instrumentation amplifier
INP_R	7	—	
IOUT0	27	O	Current source output to electrodes
IOUT1	26		
IOUT2	25		
IOUT3	24		
IOUT4	23		
IOUT5	22		
NC	43, 44, 52, 55, 61-76, 78	—	Do not connect
OUTM_I_FILT	47	—	I channel demodulator low pass filter, connect 10 $\mu$ F between both pins
OUTP_I_FILT	48	—	
OUTM_Q_FILT	49	—	Q channel demodulator low pass filter, connect 10 $\mu$ F between both pins
OUTP_Q_FILT	50	—	
$\overline{\text{RDY}}$	59	O	Data ready
RN0	31	O	Current source output to calibration resistors
RN1	30		
RP0	29		
RP1	28		
$\overline{\text{RST}}$	53	I	Reset. 0: reset, 1: normal operation.
SCLK	58	I	Serial clock to latch input data (negative edge latch)
SDIN	57	I	Serial data input
SDOUT	56	O	Serial data output
$\overline{\text{STE}}$	54	I	SPI enable. 0: shift data in, 1: disable.
VLDO	16	O	LDO output to supply the bridges (~1.7 V), connect 470 nF to AVSS
VREF	17	O	Reference voltage (connect 470 nF to AVSS)
VSENSEM_R0	42	I	Input to differential amplifier from calibration resistors
VSENSEM_R1	41		
VSENSEP_R0	40		
VSENSEP_R1	39		
VSENSE0	38	I	Input to differential amplifier from electrode
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## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Voltage range	AVDD to AVSS	-0.3	4.1	V
	Any pin	-0.3	AVDD + 0.3	
Diode current at any device pin		±2		mA
Maximum operating junction temperature, T <sub>J</sub> max		105		°C
Storage humidity		10%	90%	Rh
Storage temperature, T <sub>stg</sub>		-25	85	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub> Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
AVDD	Supply voltage	2		3.6	V
AVSS	Ground		0		V
f <sub>CLK</sub>	External clock input frequency		1		MHz
T <sub>A</sub>	Ambient temperature range	0		70	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		AFE4300	UNIT
		PN (LQFP)	
		80 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	50.5	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	14.2	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	25.3	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	0.5	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	24.9	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 Electrical Characteristics: Front-End Amplification (Weight-Scale Signal Chain)

over operating free-air temperature range, AVDD – AVSS = 3 V, G1 = 183, and G2 = 1 (unless otherwise noted)

PARAMETER	TEST CONDITIONS	AFE4300			UNIT	
		MIN	TYP	MAX		
<b>BRIDGE SUPPLY</b>						
V <sub>(VLDO)</sub>	Output voltage (bridge supply voltage)		1.7		V	
I <sub>O</sub>	Output current	Current capability		20	mA	
		Short-circuit protection		100	mA	
t <sub>STBY</sub>	Enable, disable time	With 470-nF capacitor on the VLDO pin	1		ms	
<b>AMPLIFICATION CHAIN</b>						
	Offset error	With offset correction DAC disabled	80		μV	
	Offset drift vs temperature	With offset correction DAC disabled	0.25		μV/°C	
	Input bias current		±70		fA	
	Input offset current		±140		fA	
V <sub>n</sub>	Noise voltage, equivalent input	G1 = 183, 0.01 Hz < f < 2 Hz	68		nVrms	
I <sub>n</sub>	Noise current, equivalent input	f = 10 Hz	100		fA/√Hz	
Z <sub>id</sub>	Differential input impedance		100    4		GΩ    pF	
Z <sub>ic</sub>	Common-mode input impedance		100    8		GΩ    pF	
CMRR	Input common-mode rejection ratio	G1 = 183	95		dB	
INL <sub>WS</sub>	Gain nonlinearity	From input to digital output (including ADC)	0.01		% of FS <sup>(1)</sup>	
		First-stage gain equation	(1 + 2 × 100k / R <sub>G</sub> )		V/V	
t <sub>up</sub>	Power-up time	From power up to valid reading	1		ms	
R <sub>FB1</sub>	Internal feedback resistors		95	100	105	kΩ
Gain2	Second-stage gain settings		1, 2, 3, 4			
		Total gain error	±5%			
		Offset DAC number of bits	6		Bits	
I <sub>DAC</sub>	Full-scale offset DAC output current		±6.5		μA	

(1) FS = full-scale.

## 6.6 Electrical Characteristics: Body Composition Measurement Front-End

over operating free-air temperature range, AVDD – AVSSS = 3 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	AFE4300			UNIT
		MIN	TYP	MAX	
<b>WAVEFORM GENERATOR</b>					
DAC resolution			6		Bits
DAC full-scale voltage	Common-mode voltage = 0.9 V		1.05		V <sub>(PP)</sub>
DAC sample rate			1		MSPS
BW <sub>LPF</sub>	–3 dB bandwidth of the 2nd-order low-pass filter		150 ±30		kHz
R1	Internal current-setting resistor		1.5 ±20%		kΩ
<b>DEMODULATION CHAIN</b>					
Input Impedance			50		kΩ
Gain	From impedance to dc output of demodulator, IQ mode and FWR mode		0.72		V/kΩ
Gain error (without calibration)	FWR mode and I/Q mode		2.5		% of FS
Offset error (without calibration)	FWR mode and I/Q mode		±5		mV
CMRR	Common-mode rejection ratio		75		dB
Nonlinearity	0-Ω to 1.25-kΩ range		0.15		% of FS
	0-Ω to 2.50-kΩ range		3		% of FS
BW <sub>DEM0D</sub>	Rectifier bandwidth	Internal resistor = 5 kΩ, external capacitor = 4.7 μF	3.5 ±20%		Hz
	Output noise at rectifier output	20-kHz waveform, noise integrated from 0.01 Hz to 2 Hz	15		μVrms

## 6.7 Electrical Characteristics: Analog-to-Digital Converter

over operating free-air temperature range, AVDD – AVSS = 3 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	AFE4300			UNIT
		MIN	TYP	MAX	
<b>ANALOG-TO-DIGITAL CONVERTER</b>					
	ADC input voltage range	At the input of the ADC (after PGA)			V
V <sub>IN</sub>	Full-scale input voltage	At the input of the PGA			V
V <sub>REF</sub>	Reference voltage				V
R <sub>ON(mux)</sub>	Input multiplexer on-resistance	0 V ≤ V <sub>AAUX</sub> ≤ AVDD			kΩ
	AAUX input impedance				MΩ
f <sub>DR</sub>	Output data rate	8		860	SPS
	Resolution	16			Bits
E <sub>I</sub>	Integral linearity error	Best fit, DR = 8 SPS			LSB
E <sub>O</sub>	Offset error	Differential inputs			LSB
		Single-ended inputs			LSB
E <sub>G</sub>	Gain error				
V <sub>BAT_MON</sub>	Battery monitor output	AVDD / 3			V
I <sub>BAT_MON</sub>	Battery monitor current consumption	1.5			μA
I <sub>BAT_MON_ACC</sub>	Battery monitor accuracy	±2%			
<b>POWER CONSUMPTION</b>					
Supply current	Power-down current	0.25			μA
	Sleep-mode current	100			μA
	Weight-scale chain measurements	540			μA
	Body-composition measurements	970			μA
	Auxillary-channel measurements	110			μA

## 6.8 Electrical Characteristics: Digital Input/Output

over operating free-air temperature range, AVDD – AVSS = 3 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V <sub>IH</sub>	High-level input voltage	0.75 × AVDD		AVDD	V
V <sub>IL</sub>	Low-level input voltage	AVSS		0.25 × AVDD	V
V <sub>OH</sub>	High-level output voltage	0.8 × AVDD			V
V <sub>OL</sub>	Low-level output voltage	GND		0.2 × AVDD	V
I <sub>IN</sub>	Input current		±30		μA

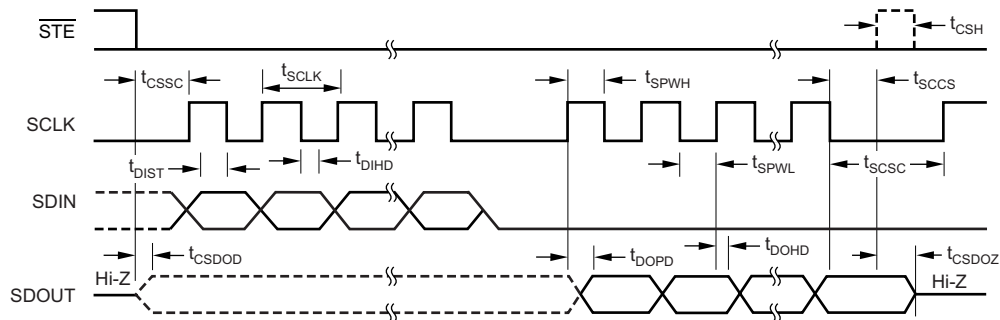
## 6.9 Timing Requirements: Serial Interface Timing

at  $T_A = 0^\circ\text{C}$  to  $+70^\circ\text{C}$  and  $V_{DD} = 2\text{ V}$  to  $3.6\text{ V}$  (unless otherwise noted)

		MIN	NOM	MAX	UNIT
$t_{\text{CSSC}}$	$\overline{\text{STE}}$ low to first SCLK setup time <sup>(1)</sup>	100			ns
$t_{\text{SCLK}}$	SCLK period	250			ns
$t_{\text{SPWH}}$	SCLK pulse duration high	100			ns
$t_{\text{SPWL}}$	SCLK pulse duration low	100			ns
$t_{\text{DIST}}$	Valid SDIN to SCLK falling edge setup time	50			ns
$t_{\text{DIHD}}$	Valid SDIN to SCLK falling edge hold time	50			ns
$t_{\text{DOPD}}$	SCLK rising edge to valid new SDOOUT propagation delay <sup>(2)</sup>			50	ns
$t_{\text{DOHD}}$	SCLK rising edge to DOUT invalid hold time	0			ns
$t_{\text{CSDOD}}$	$\overline{\text{STE}}$ low to SDOOUT driven propagation delay	100			ns
$t_{\text{CSDOZ}}$	$\overline{\text{STE}}$ high to SDOOUT Hi-Z propagation delay	100			ns
$t_{\text{CSH}}$	$\overline{\text{STE}}$ high pulse	200			ns
$t_{\text{SCCS}}$	Final SCLK falling edge to $\overline{\text{STE}}$ high	100			ns

(1)  $\overline{\text{STE}}$  can be tied low.

(2) DOUT load =  $20\text{ pF} \parallel 100\text{ k}\Omega$  to DGND.



**Figure 1. Serial Interface Timing**

### 6.10 Typical Characteristics

all measurements at room temperature with AVDD = 3 V (unless otherwise specified)

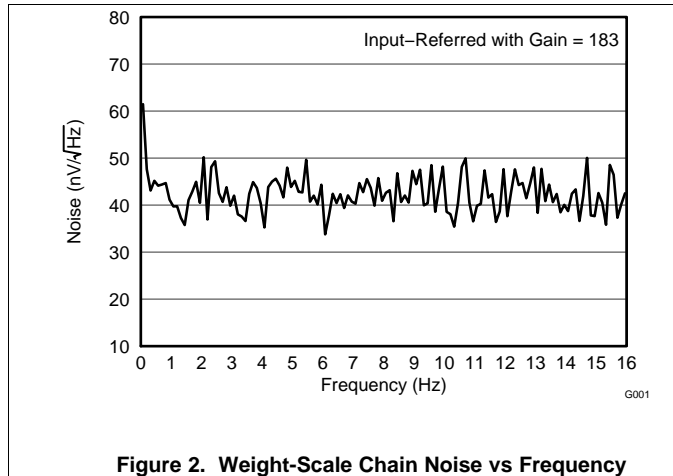


Figure 2. Weight-Scale Chain Noise vs Frequency

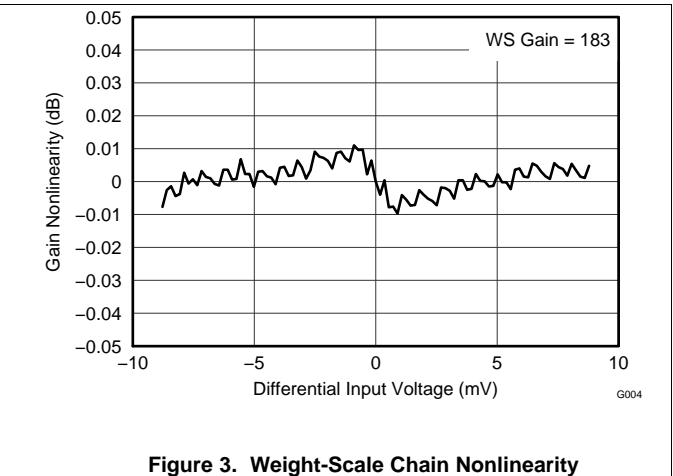


Figure 3. Weight-Scale Chain Nonlinearity

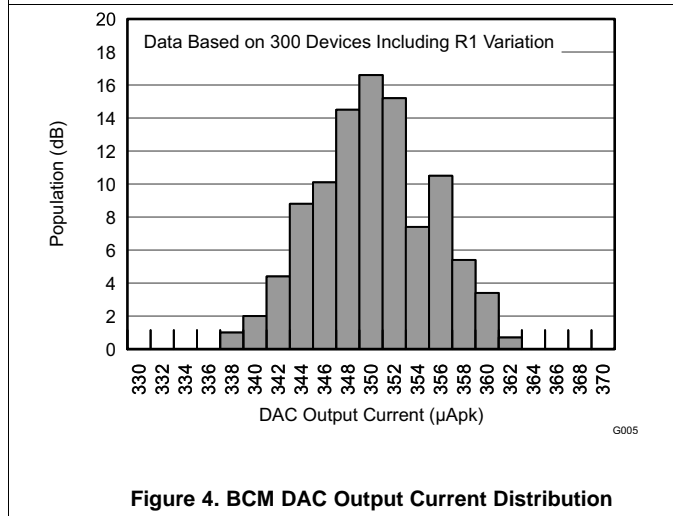


Figure 4. BCM DAC Output Current Distribution

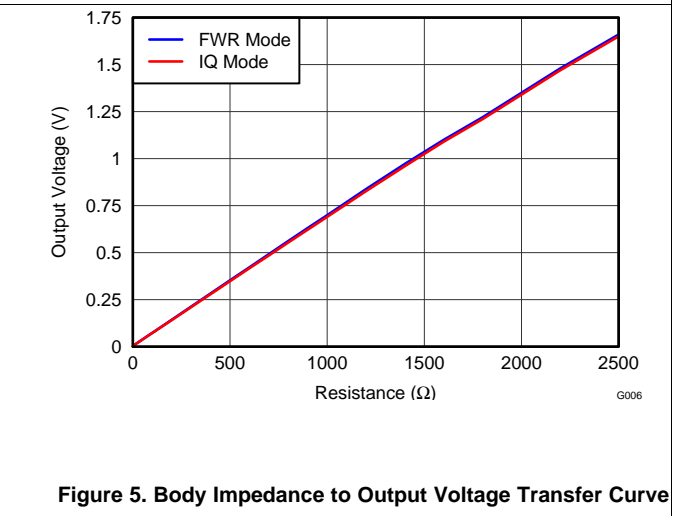


Figure 5. Body Impedance to Output Voltage Transfer Curve

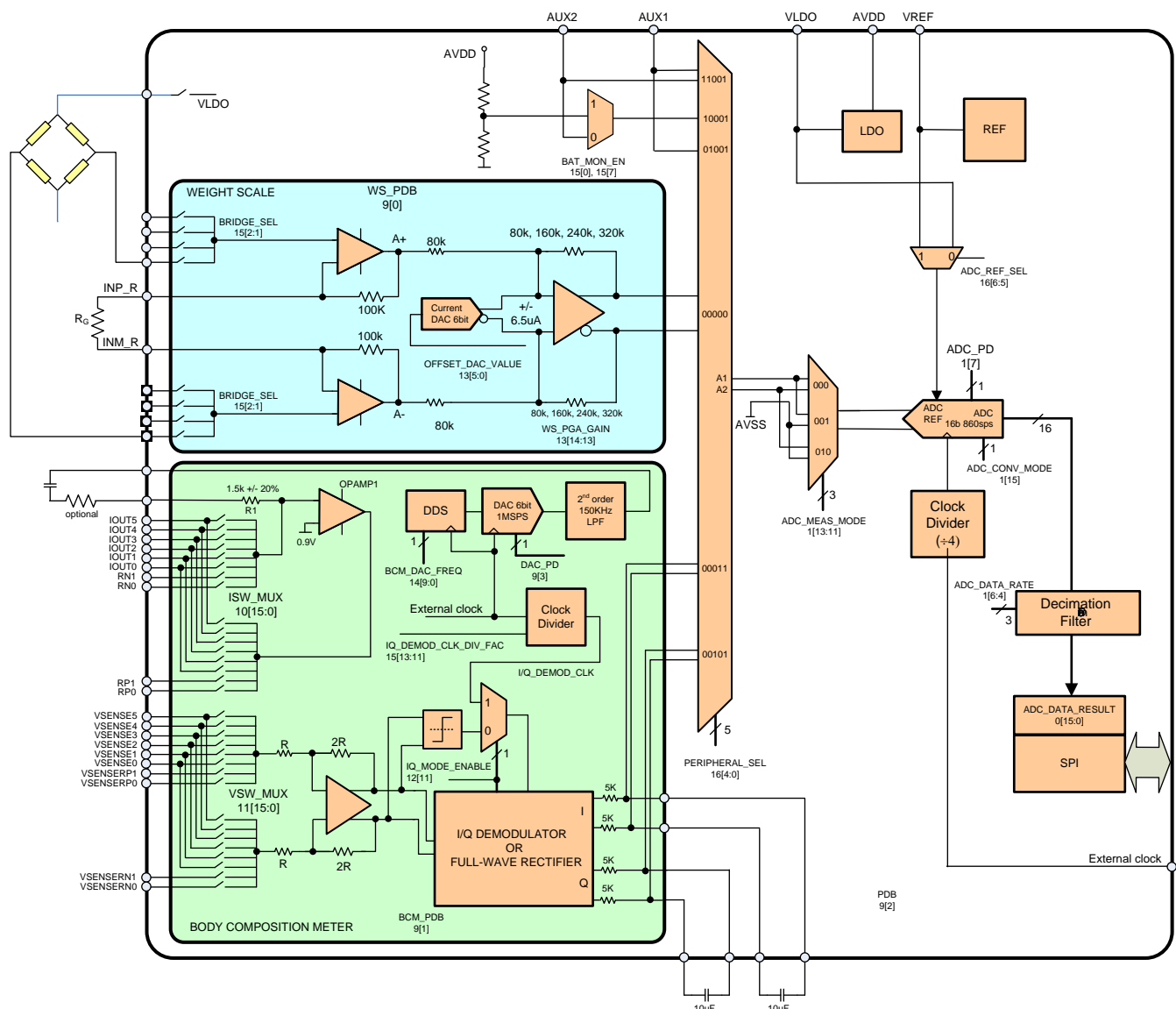
## 7 Detailed Description

### 7.1 Overview

The AFE4300 is a low-cost, integrated front-end designed for weight scales incorporating body-composition measurements. The AFE4300 integrates all the components typically used in a weight scale. The device has two signal chains: one for weight scale measurements and the other for body composition measurements. Both signal chains share a 16-bit, delta-sigma converter that operates at a data rate of up to 860 SPS. This device also integrates a reference and a low-dropout regulator (LDO) that generates a 1.7-V supply that can be used as the excitation source for the load cells, thus simplifying ratiometric measurements. Both the signal chains use a single digital-to-analog converter (DAC). The DAC is used to generate the dc signal for load-cell offset cancellation in the weight-scale chain. The same DAC is also used to generate the sine-wave modulation signal for the body-composition signal chain. Therefore, only one of the two signal chains can be activated at a time (using the appropriate register bits).

Two unique features of the AFE4300 are that the device provides an option for connecting up to four separate load cells, and supports tetrapolar measurements with I/Q measurements.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

This section describes the details of the AFE4300 internal functional elements. The analog blocks are reviewed first, followed by the digital interface. The theory behind the body-composition measurement using the full-wave rectification method and the I/Q demodulation method are also described. The analog front-end is divided in two signal chains: a weight-measurement chain and a body-composition measurement front-end chain; both use the same 16-bit ADC and 6-bit DAC.

Throughout this document:

- $f_{CLK}$  denotes the frequency of the signal at the CLK pin.
- $t_{CLK}$  denotes the period of the signal at the CLK pin.
- $f_{DR}$  denotes the output data rate of the ADC.
- $t_{DR}$  denotes the time period of the output data.
- $f_{MOD}$  denotes the frequency at which the modulator samples the input.

#### 7.3.1 Weight-Scale Analog Front-End

Figure 6 shows a top-level view of the front-end section devoted to weight-scale measurement. The weight-scale front-end has two stages of gain, with an offset correction DAC in the second gain stage. The first-stage gain is set by the external resistor and the second-stage gain is set by programming the internal registers. For access and programming information, see the [Register Maps](#) section.

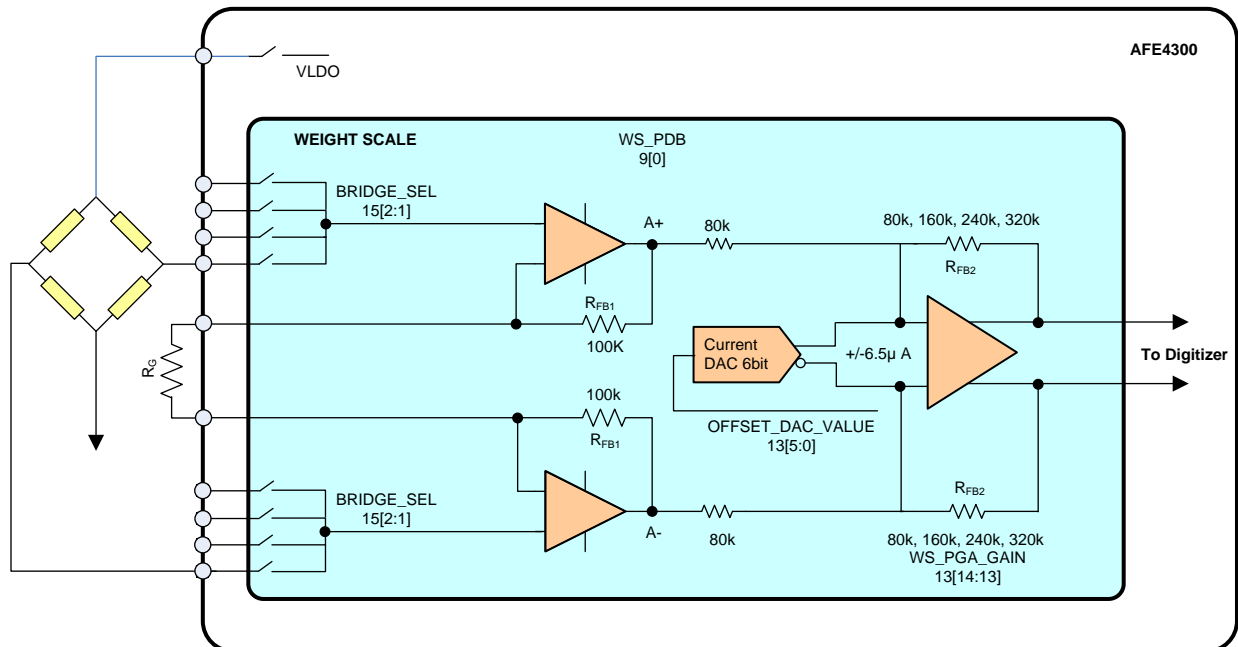


Figure 6. Weight-Scale Front-End

Though not shown in the diagram, an antialiasing network is required in front of the INA to filter out electromagnetic interference (EMI) signals or any other anticipated interference signals. A simple RC network is sufficient, combined with the attenuation provided by the on-chip decimation filter.

An internal reference source provides a constant voltage of 1.7 V at the VLDO output to drive the external bridge. The output of the bridge is connected to an INA (first stage). The first-stage gain ( $A_1$ ) is set by the external resistor ( $R_G$ ) and the 100-k $\Omega$  ( $\pm 5\%$ ) internal feedback resistors ( $R_{FB1}$ ) as shown in [Equation 1](#):

$$A_1 = (1 + 2 \times 100k / R_G) \quad (1)$$

The second-stage gain ( $A_2$ ) is controlled by feedback resistors  $R_{FB2}$ , which have four possible values: 80 k $\Omega$ , 160 k $\Omega$ , 240 k $\Omega$ , and 320 k $\Omega$ . Because the gain is  $R_F / 80$  k $\Omega$ , the gain setting can be 1, 2, 3, or 4. See the [Register Maps](#) section for details on setting the appropriate register bits.

## Feature Description (continued)

### 7.3.1.1 Input Common Mode Range

The usable input common mode range of the weight-scale front-end depends on various parameters, including the maximum differential input signal, supply voltage, and gain. The output of the first-stage amplifier must be within 250 mV of the power supply rails for linear operation. The allowed common-mode range is determined by Equation 2:

$$AVDD - 0.25 - \frac{GAIN \times V_{MAX\_DIFF}}{2} > CM > AVSS + 0.25 + \frac{GAIN \times V_{MAX\_DIFF}}{2}$$

Where:

- $V_{MAX\_DIFF}$  = maximum differential input signal at the input of the first gain stage,
- CM = Common-mode range. (2)

For example, If  $AVDD = 2\text{ V}$ , the first stage gain = 183, and  $V_{MAX\_DIFF} = 7.5\text{ mV}$  (dc + signal), then:

$$1.06\text{ V} > CM > 0.936\text{ V}$$

### 7.3.1.2 Input Differential Dynamic Range

The max differential (INP – INN) signal depends on the analog supply, reference used in the system. This range is shown in Equation 3:

$$\text{MAX}(\text{INP} - \text{INN}) < \frac{V_{REF}}{GAIN}; \text{ Full-Scale Range} = 2 \times \frac{V_{REF}}{GAIN} \quad (3)$$

The gain in Equation 3 is the product of the gains of the INA and the second-stage gain. The full-scale input from the bridge signal typically consists of a differential dc offset from the load cell plus the actual weight signal. Having a high gain in the first stage helps minimize the effect of the noise addition from the subsequent stages. However, make sure to choose a gain that does not saturate the first stage with the full-scale signal. Also, the common-mode of the signal must fall within the range, as per Equation 2.

### 7.3.1.3 Offset Correction DAC

One way to increase the dynamic range of the signal chain is by calibrating the inherent offset of the load cell during the initial calibration cycle. The offset correction is implemented in the second stage with a 6-bit differential DAC, where each output is a mirror of the other and can source or sink up to 6.5  $\mu\text{A}$ . The effect at the output of the second stage is an addition of up to  $\pm 6.5\ \mu\text{A} \times 2 \times R_{FB2}$ . This effect is equivalent to a voltage at the input of the second stage (A+ / A–) of up to  $\pm 6.5\ \mu\text{A} \times 2 \times 80\ \text{k}\Omega = \pm 1\ \text{V}$ , when  $R_{FB2} = 80\ \text{k}\Omega$ . The first-stage saturation cannot be avoided using this DAC. Because the offset correction DAC is a 6-bit DAC, the offset compensation step is  $2\ \text{V} / 2^6 = 31.2\ \text{mV}$  when referred to the input of the second stage.

#### 7.3.1.3.1 Offset Correction Example

As an example, use a bridge powered from 1.7 V with 1.5 mV/V sensitivity and a potential offset between –4 mV and 4 mV. Worst case, the maximum signal is 4 mV of offset plus  $1.7 \times 1.5\ \text{mV/V} = 2.55\ \text{mV}$  of signal, for a total of 6.55 mV. The bridge common-mode voltage is –0.85 V. The maximum excursion is  $0.85\ \text{V} - 0.25\ \text{V} = 0.6\ \text{V}$  (bottom rail) single-ended, on each output (A+ or A–). Therefore,  $\pm 1.2\ \text{V}$  differentially at the output of the first stage prevents saturation. This result means that the first stage can have up to a gain of  $1.2\ \text{V} / 6.55\ \text{mV} = 183$ .

Using this same example, the swing at the output of the first stage corresponding only to the potential offset range is  $183 \times \pm 4\ \text{mV} = \pm 0.732\ \text{V}$ . This swing can be completely removed at the output of the second stage by the offset correction (because the offset correction DAC has a  $\pm 1\text{-V}$  range) except for a maximum error of 31.2 mV.

**Feature Description (continued)**

**7.3.2 Body Composition Measurement Analog Front-End**

Body composition is traditionally obtained by measuring the impedance across several points on the body and matching the result in a table linking both the impedance measured and the body composition. This table is created by each manufacturer and is usually based on age group, sex, weight, and other parameters.

The body impedance that we want to measure,  $Z(f)$ , is a function of the excitation frequency, and can be represented by polar or cartesian notations:

$$Z(f) = |Z(f)| \cdot e^{j\theta(f)} = R(f) + jX(f)$$

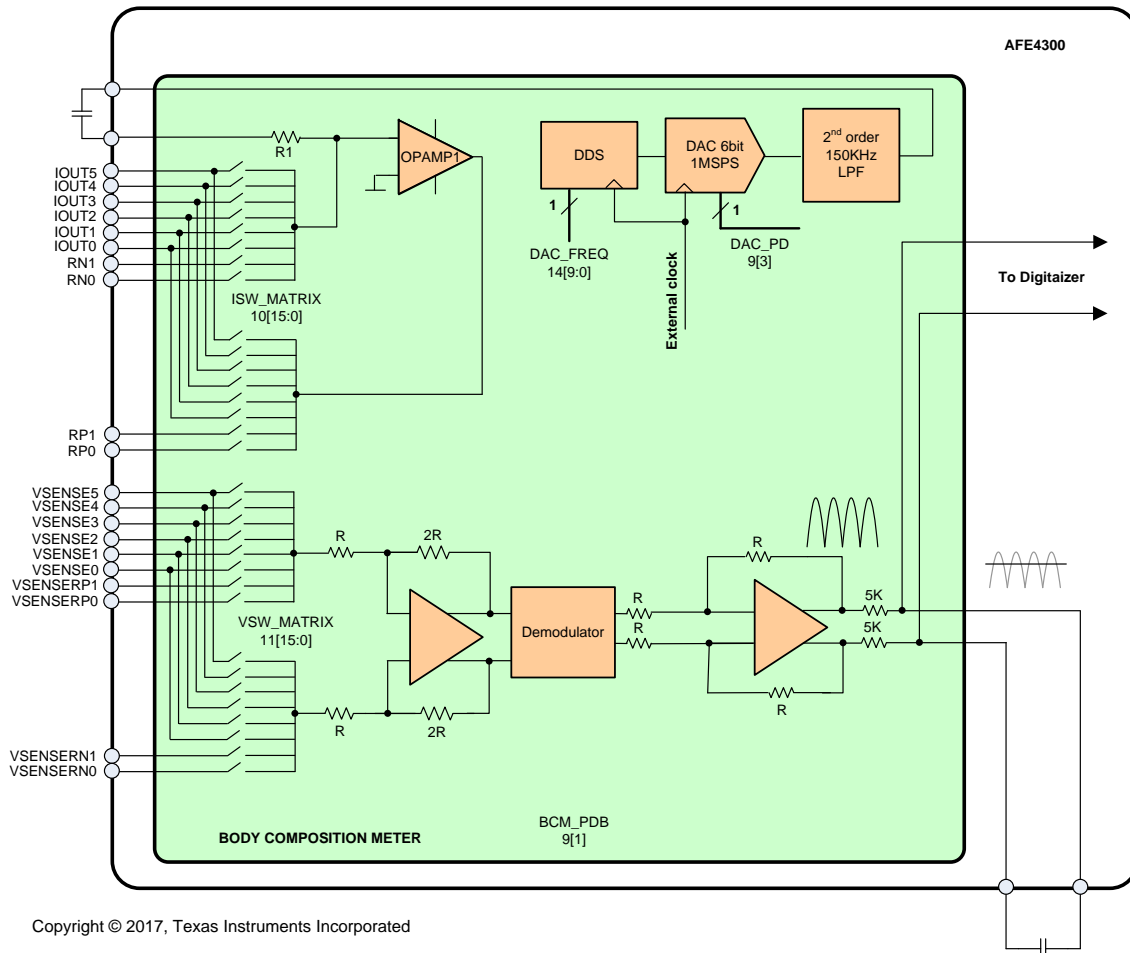
where:

- $|Z| = \text{sqrt}(R^2 + X^2)$
  - $\theta = \text{arctg}(X/R)$
- (4)

The AFE4300 provides two options for body impedance measurement: ac rectification and I/Q demodulation. Both options work by injecting a sinusoidal current into the body and measuring the voltage across the body. The portion of the circuit injecting the current into the body is the same for each of those options. The difference, however, lies in how the measured voltage across the impedance is processed to obtain the final result.

**7.3.2.1 AC Rectification**

Figure 7 shows the portion of the AFE4300 devoted to body composition measurement in the RMS detector mode.



**Figure 7. BCM in AC Rectifier Mode**

## Feature Description (continued)

The top portion of [Figure 7](#) represents the current-injection circuit. A direct digital synthesizer (DDS) generates a sinusoidal digital pattern with a frequency obtained by dividing a 1-MHz clock with a 10-bit counter. The digital pattern drives a 6-bit, 1-MSPS DAC. The output of the DAC is filtered by a 150-kHz, second-order filter to remove the high-frequency images, followed by a series external capacitor to block the dc current and avoid any dc current injection into the body. The output of the filter (after the dc blocking capacitor) drives a resistor setting the amplitude of the current to be injected in the body, as shown in [Equation 5](#):

$$I(t) = V_{DACOUT} / R1 = A \sin(\omega_0 t) \quad (5)$$

The nominal DACOUT voltage ( $V_{DACOUT}$ ) is  $1.05 V_{PP}$  ( $371.23 \mu V_{rms}$ ). The nominal value of  $R1$  is  $1.5 k\Omega$ . So the nominal excitation current is  $247.5 \mu A_{rms}$ .  $R1$  can have a  $\pm 20\%$  device-to-device variation, so the highest current is close to  $300 \mu A_{rms}$  ( $850 \mu A_{PP}$ ). The maximum voltage swing for the excitation electrodes (IOUT1-IOUT0) is  $1 V_{PP}$ . This swing limits the recommended total impedance in feedback to approximately  $1175 \Omega$ . To reduce the excitation current, place an external resistor,  $R_{DAC}$ , (between DACOUT and DAC\_FILT\_IN) in series with  $R1$ . For example, with a  $1.5-k\Omega$  external resistor, the currents roughly reduce by 2X, thereby extending the range of the measured impedance.

Current flows into the body through an output analog multiplexer (mux) that allows the selection of up to six different contact points on the body. The same mux allows the connection of four external impedances for calibration. The current crosses the body impedance and a second mux selects the return path (contact) on the body, closing the loop to the output of the amplifier.

At the same time that the current is injected, a second set of multiplexers connects a differential amplifier across the same body impedance in order to measure the voltage drop created by the injected current, shown by [Equation 6](#):

$$v(t) = A |Z| \sin(\omega_0 t + \theta)$$

where  $Z$  and  $\theta$  are the module and phase of the impedance at  $\omega_0$ , respectively. (6)

The output of the amplifier is routed to a pair of switches that implement the demodulation at the same frequency as the excitation current source in order to drive the control of those switches. This circuit performs a full-wave rectification of the differential amplifier output and a low-pass filter at the output, recovers the dc level, and finally routes the amplifier output to the same 16-bit digitizer used in the weight-scale chain.

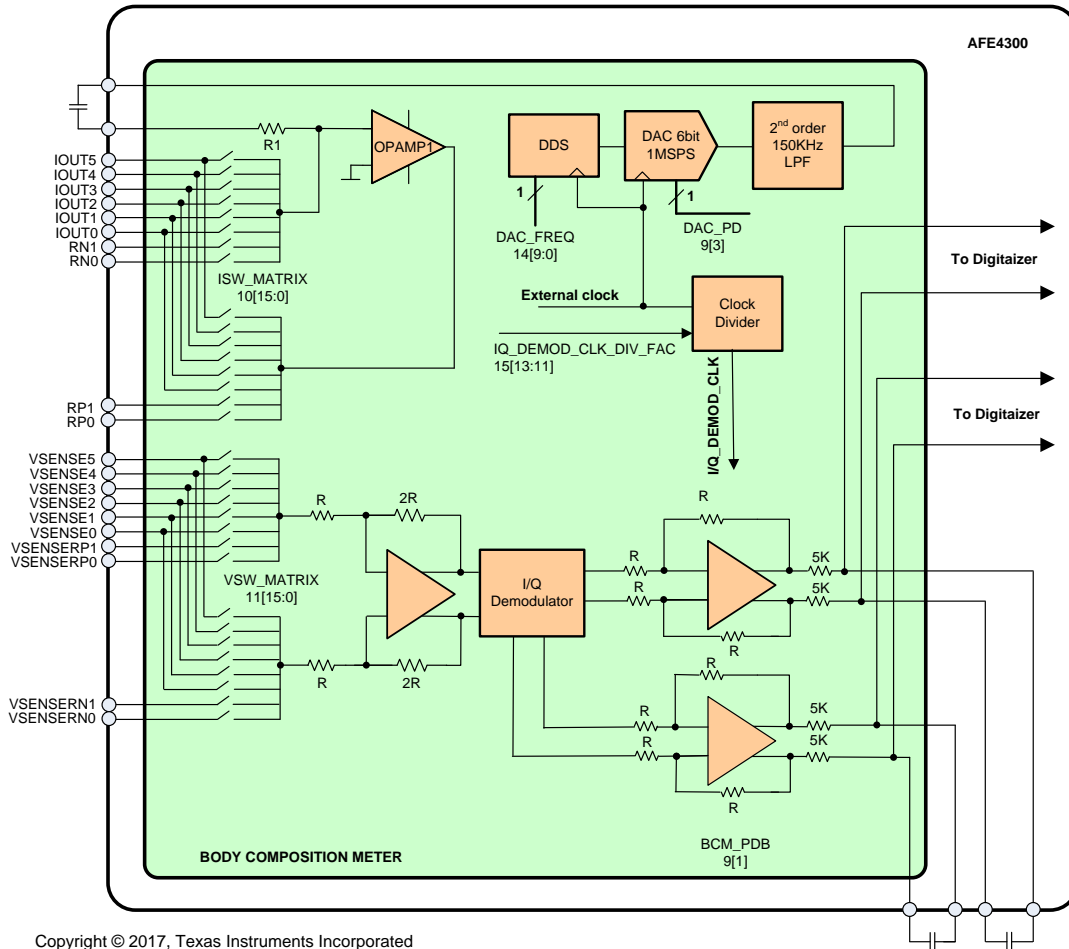
$$DC = \frac{2}{T} \int_{T/2} A |Z| \sin(\omega_0 t + \theta) dt = \frac{2A |Z|}{\pi} \quad (7)$$

Ultimately, the dc output is proportional to the module of the impedance. The proportionality factor can be obtained through calibration with the four external impedances. Although, with one single frequency or measurement, only the module of the impedance can be obtained; two different frequencies could be used to obtain both the real and the imaginary parts.

## Feature Description (continued)

### 7.3.2.2 I/Q Demodulation

The AFE4300 includes a second circuit that with a single frequency measurement, obtains both the real and the imaginary portions, as shown in Figure 8. As explained previously, the portion of the circuit injecting the current into the body is the same for both configurations. Therefore, the circuit is the same in Figure 7 and Figure 8. The difference between them is that an I/Q demodulator is used in this second approach, as shown in Figure 8.



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Figure 8. BCM in I/Q Demodulator Mode

As with the case of the RMS detector, a differential amplifier measures the voltage drop across the impedance, as shown in Equation 8:

$$v(t) = A|Z|\sin(\omega_0 t + \theta)$$

where:

- $Z$  = the module of the impedance at  $\omega_0$
- $\theta$  = phase of the impedance at  $\omega_0$

(8)

The I/Q demodulator takes the  $v(t)$  signal and outputs two dc values. These two values are used to extract the impedance module and phase with a single frequency measurement. Figure 8 shows the block diagram of the implementation. Using the I/Q demodulator helps reduce power consumption and still yields excellent performance. The local oscillator (LO) signals for the mixers are generated from the same clock driving the DDS/DAC and are of the same phase and frequency as the sinusoidal  $i(t)$  (see Equation 5). The LO signals directly control the switches on the in-phase (I) path, and after a delay of 90° degrees, control the switches on the quadrature (Q) path. This switching results in multiplying the  $v(t)$  signal by a square signal swinging from -1 to 1.

## Feature Description (continued)

Breaking down the LO signal into Fourier terms results in [Equation 9](#):

$$LO_1(t) = \frac{4}{\pi}(\sin(\omega_0 t) + \frac{1}{3}\sin(3\omega_0 t) + \frac{1}{5}\sin(5\omega_0 t) + \dots) \quad (9)$$

Therefore, the output voltage of the mixer is as shown in [Equation 10](#):

$$I(t) = A|Z|\frac{4}{\pi}(\sin(\omega_0 t + \theta)\sin(\omega_0 t) + \frac{1}{3}\sin(\omega_0 t + \theta)\sin(3\omega_0 t) + \frac{1}{5}\sin(\omega_0 t + \theta)\sin(5\omega_0 t) + \dots)$$

Where  $I(t)$  = in-phase output (not to be confused with  $i(t)$ , the current injected in the impedance). (10)

Applying fundamental trigonometry gives [Equation 11](#):

$$\sin a \sin b = -\frac{1}{2}\cos(a + b) + \frac{1}{2}\cos(a - b) \quad (11)$$

Each product of sinusoids can be broken up in an addition of two sinusoids. [Equation 12](#) shows the first term:

$$\sin(\omega_0 t + \theta)\sin(\omega_0 t) = \frac{1}{2}\cos(\omega_0 t + \theta - \omega_0 t) - \frac{1}{2}\cos(\omega_0 t + \omega_0 t + \theta) = \frac{1}{2}\cos(\theta) - \frac{1}{2}\cos(2\omega_0 t + \theta) \quad (12)$$

[Equation 13](#) shows the 2nd product:

$$\sin(\omega_0 t + \theta)\sin(3\omega_0 t) = \frac{1}{2}\cos(\omega_0 t + \theta - 3\omega_0 t) - \frac{1}{2}\cos(3\omega_0 t + \omega_0 t + \theta) = \frac{1}{2}\cos(-2\omega_0 t + \theta) - \frac{1}{2}\cos(4\omega_0 t + \theta) \quad (13)$$

And so on. Performing the same analysis on the Q side, the output voltage of the mixer is shown in [Equation 14](#):

$$Q(t) = A|Z|\frac{4}{\pi}(\sin(\omega_0 t + \theta)\cos(\omega_0 t) + \frac{1}{3}\sin(\omega_0 t + \theta)\cos(3\omega_0 t) + \frac{1}{5}\sin(\omega_0 t + \theta)\cos(5\omega_0 t) + \dots) \quad (14)$$

Again, applying fundamental trigonometry gives [Equation 15](#):

$$\sin a \cos b = \frac{1}{2}\sin(a + b) + \frac{1}{2}\sin(a - b) \quad (15)$$

Each of the products can be broken up into sums. Starting with the first product, as shown in [Equation 16](#):

$$\sin(\omega_0 t + \theta)\cos(\omega_0 t) = \frac{1}{2}\sin(2\omega_0 t + \theta) + \frac{1}{2}\sin(\theta) \quad (16)$$

And so on. Note that on  $I(t)$  as well as on  $Q(t)$ , all the terms beyond the cutoff frequency of the low-pass filter at the output of the mixers (setup by the two  $1\text{-k}\Omega$  resistors and an external capacitor) are removed, leaving only the dc terms, giving [Equation 17](#) for  $I_{DC}$  and [Equation 18](#) for  $Q_{DC}$ :

$$I_{DC} = \frac{2A|Z|}{\pi}\cos(\theta) = K|Z|\cos(\theta) \quad (17)$$

$$Q_{DC} = \frac{2A|Z|}{\pi}\sin(\theta) = K|Z|\sin(\theta) \quad (18)$$

In reality, the LO amplitude is not known (likely, not  $\pm 1$ ) and affects the value of  $K$  in [Equation 17](#) and [Equation 18](#). Solving these two equations gives [Equation 19](#):

$$\theta = \arctan \frac{Q_{DC}}{I_{DC}}$$

$$Z = \frac{1}{K} \sqrt{I_{DC}^2 + Q_{DC}^2} \quad (19)$$

In order to account for all the nonidealities in the system, the AFE4300 also offers four extra terminals on the driving side (two to drive, and two for the currents to return) and four extra terminals on the receive/differential-amplifier side. As with RMS mode, these spare terminals allow for connection of up to four external calibration impedances, and they also compute  $K$ .

## Feature Description (continued)

### 7.3.3 Digitizer

The digitizer block includes an analog mux and a 16-bit sigma-delta ADC.

#### 7.3.3.1 Multiplexer

There are two levels of analog mux. The first level selects from among the outputs of the weight scale, the body composition function, two auxiliary inputs, and the battery monitor. A second mux is used to obtain the measurement of the outputs coming from the first mux, either differentially or with respect to ground (single-ended). Note that when measuring single-ended inputs, the negative range of the output codes are not used. For battery or AVDD monitoring, an internal 1/3 resistor divider is included that enables the measurement using only one reference setting for any battery voltage, thus simplifying the monitoring routine.

#### 7.3.3.2 Analog-to-Digital Converter

The 16-bit, delta-sigma, ADC operates at a modulator frequency of 250 kHz with an  $f_{CLK}$  of 1 MHz. The full-scale voltage of the ADC is set by the voltage at the reference ( $V_{REF}$ ). The reference can be either the LDO output (1.7 V) for the weight-scale front-end or the internally-generated reference signal (1.7 V) for the BCM front-end.

The decimation filter at the output of the modulator is a single-order sinc filter. The decimation rate can be programmed to provide data rates from 8 SPS to 860 SPS with an  $f_{CLK}$  of 1 MHz. Refer to the ADC\_CONTROL\_REGISTER1 register in the [Register Maps](#) section for details on programming the data rates. [Figure 9](#) shows the frequency response of the digital filter for a data rate of 8 SPS. Note that the modulator has pass band around integer multiples of the modulator sampling frequency of 250 kSPS. Set the corner frequency of the antialiasing network before the INA so that there is adequate attenuation at the first multiple of the modulator frequency.

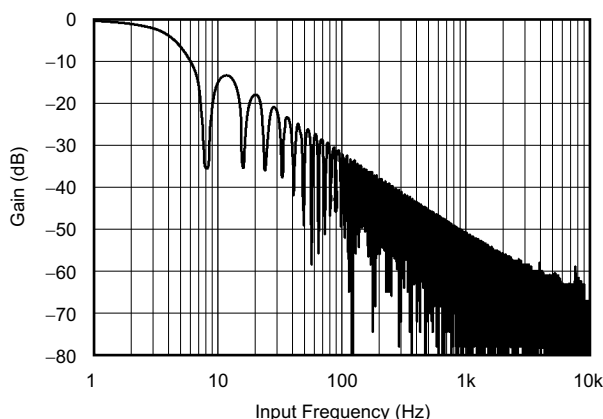


Figure 9. Frequency Response

The output format of the ADC is twos complement binary. [Table 1](#) describes the output code versus the input signal, where full-scale (FS) is equal to the  $V_{REF}$  value.

Table 1. Input Signal Versus Ideal Output Code

INPUT SIGNAL, $V_{IN}$ ( $A_{INP} - A_{INN}$ )	IDEAL OUTPUT CODE
$\geq FS (2^{15} - 1)/2^{15}$	7FFFh
$+FS/2^{15}$	0001h
0	0
$-FS/2^{15}$	FFFFh
$\leq -FS$	8000h

### 7.3.4 Reset and Power-Up

After power up, the device needs to be reset to get all the internal registers to their default state. Resetting the device is done by applying a zero pulse in the  $\overline{\text{RST}}$  line for more than 20 ns after the power is stable for 5 ms. After 30 ns, the first access can be initiated (first falling edge of  $\overline{\text{STE}}$ ). As part of the reset process, the AFE4300 sets all of the register bits to the respective default settings. Some of the register bits must be written after reset and power up for proper operation. Refer to the [Register Maps](#) section for more details. By default, the AFE4300 enters into a power-down state at start-up. The device interface and digital are active, but no conversion occurs until the ADC\_PD bit is written to. The initial power-down state of the AFE4300 is intended to relieve systems with tight power-supply requirements from encountering a surge during power-up.

### 7.3.5 Duty Cycling for Low Power

For many applications, improved performance at low data rates may not be required. For these applications, the AFE4300 supports duty cycling that can yield significant power savings by periodically requesting high data-rate readings at an effectively lower data rate. For example, an AFE4300 in power-down mode with a data rate set to 860 SPS could be operated by a microcontroller that instructs a single-shot conversion every 125 ms (8 SPS). Because a conversion at 860 SPS only requires approximately 1.2 ms, the AFE4300 automatically enters power-down mode for the remaining 123.8 ms. In this configuration, the digitizer consumes about 1/100th the power of the digitizer when operated in Continuous-Conversion mode. The rate of duty cycling is completely arbitrary and is defined by the master controller.

## 7.4 Device Functional Modes

### 7.4.1 Operating Modes

The ADC operates in one of two conversion modes: Continuous-Conversion or Single-Shot conversion. The conversion mode is set using the ADC\_CONV\_MODE bit. In Continuous-Conversion mode, the ADC continuously performs conversions when the ADC\_PD bit is set to 0. When a conversion completes, the ADC places the result in a register, issues an interrupt on the RDY pin, and immediately begins another conversion. In this mode, if ADC\_PD is set to 1, then the ADC goes into a power-down state.

To get a Single-Shot conversion, the ADC\_PD bit is to be first set to 1. When the ADC\_CONV\_MODE is subsequently set to 1, then the Single-Shot conversion is enabled. When enabled, the ADC does a single conversion and gives an interrupt on the RDY pin. To do one more Single-Shot conversion, the ADC\_CONV\_MODE bit must be set to 0 and then 1 again (with the ADC\_PD bit at 1).

## 7.5 Programming

### 7.5.1 Serial Interface

The SPI™-compatible serial interface consists of either four signals ( $\overline{ST\bar{E}}$ , SCLK, SDIN, and SDOUT) or three signals (in which case,  $\overline{ST\bar{E}}$  can be tied low). The interface is used to read conversion data, read from and write to registers, and control AFE4300 operation. The data packet (between falling and rising edge of  $\overline{ST\bar{E}}$ ) is 24 bits long and is serially shifted into SDIN with the MSB first. The first eight bits (MSB) represent the address of the register being accessed and last 16 bits (LSB) represent the data to be stored or read from that address. For the eight bits address, the lower five bits [20:16] are the real address bits. Bit 21 is the read and write bit.

- '0' in bit 21 defines a write operation of the 16 data bits [15:0] into the register defined by the address bits [20:16].
- '1' in bit 21 triggers a read operation of the register defined by the address bits [20:16]. The data are output into SDOUT with every rising edge of SCLK, starting at the ninth rising edge. At the same time, data in SDIN are shifted inside the 16 data bits of that given register. Note that every time a register is read, the register must be rewritten except when reading the data output register.

#### 7.5.1.1 SPI Enable ( $\overline{ST\bar{E}}$ )

The  $\overline{ST\bar{E}}$  pin selects the AFE4300 for SPI communication. This feature is useful when multiple devices share the serial bus.  $\overline{ST\bar{E}}$  must remain low for the duration of the serial communication. When  $\overline{ST\bar{E}}$  is taken high, the serial interface is reset, and SCLK is ignored.

#### 7.5.1.2 Serial Clock (SCLK)

The SCLK pin features a Schmitt-triggered input and is used to clock data on the DIN and  $\overline{RD\bar{Y}}$  pins into and out of the AFE4300. Even though the input has hysteresis, SCLK is recommended to be kept as clean as possible to prevent glitches from accidentally shifting the data. When the serial interface is idle, hold SCLK low.

#### 7.5.1.3 Data Input (SDIN)

The data input pin (SDIN) is used along with SCLK to send data to the AFE4300 (opcode commands and register data). The device latches data on SDIN on the falling edge of SCLK. The AFE4300 never drives the SDIN pin. Note that every time a register is read, the register must be rewritten, except when reading the data output register.

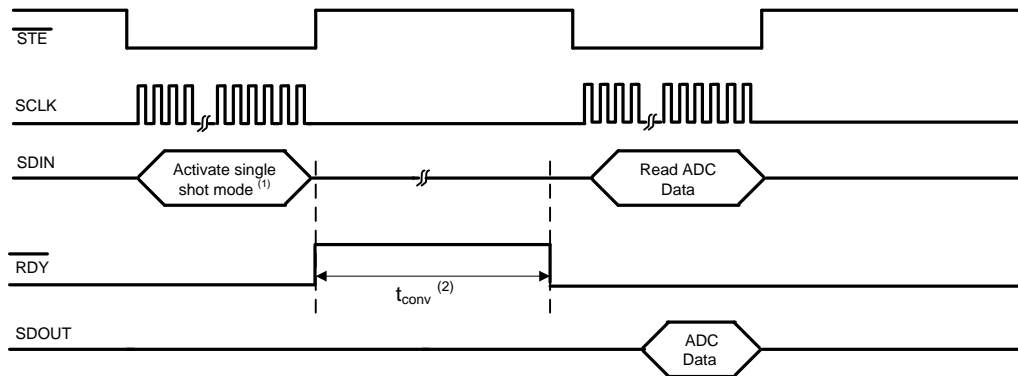
#### 7.5.1.4 Data Output (SDOUT)

The data output and data ready pin ( $\overline{RD\bar{Y}}$ ) are used with SCLK to read conversion and register data from the AFE4300. In Read Data Continuous mode,  $\overline{RD\bar{Y}}$  goes low when conversion data are ready, and goes high 8  $\mu$ s before the data ready signal. Data on  $\overline{RD\bar{Y}}$  are shifted out on the rising edge of SCLK. If the AFE4300 does not share the serial bus with another device,  $\overline{ST\bar{E}}$  may be tied low. Note that every time a register is read, the register must be rewritten, except when reading the data output register.

**Programming (continued)**

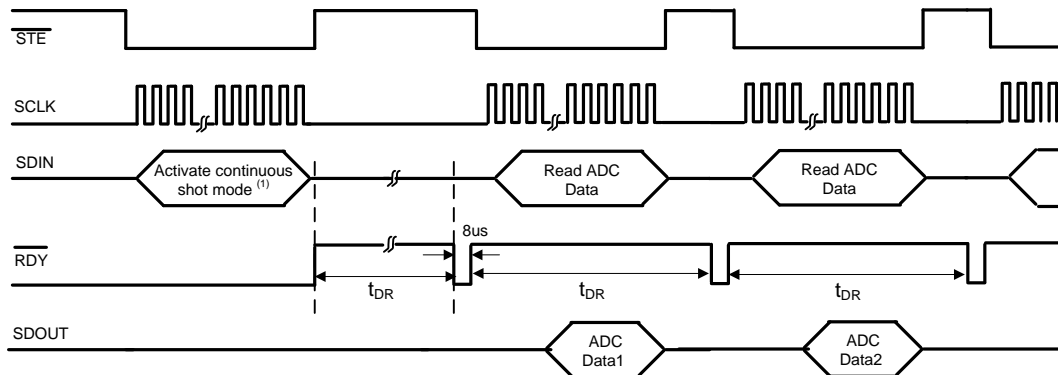
**7.5.1.5 Data Ready ( $\overline{RDY}$ )**

$\overline{RDY}$  acts as a conversion ready pin in both Continuous-Conversion mode and Single-Shot mode. When in Continuous-Conversion mode, the AFE4300 provides a brief (~8  $\mu$ s) pulse on the  $\overline{RDY}$  pin at the end of each conversion. In Single-Shot mode, the  $\overline{RDY}$  pin asserts low at the end of a conversion. Figure 10 and Figure 11 show the timing diagram for these two modes.



Note 1 : Write ADC\_CONTROL\_REGISTER[7] = 1, ADC\_CONTROL\_REGISTER1[15] = 1,  
 Note 2 :  $t_{conv}$  = Time to internally set ADC\_CONTROL\_REGISTER[15] to logic '0', ADC power up, single conversion, ADC power down, ADC\_CONTROL\_REGISTER1[15] internally set to logic '1'

**Figure 10. Timing for Single-Shot Mode**



Note 1 : Write ADC\_CONTROL\_REGISTER[7] = 0

**Figure 11. Timing for Continuous Mode**

## 7.6 Register Maps

### 7.6.1 Register Map

Table 2 describes the registers of the AFE4300.

**Table 2. Register Map**

REGISTER NAME	CONTROL	ADDRESS	DESCRIPTION	DEFAULT
<b>DEVICE CONTROLS</b>				
DEVICE_CONTROL1	(See Description)	0x09[14:13]	Write '11' after power up and/or reset	00b
	DAC_PD	0x09[3]	Enable DAC for WS, BC measurements	0b
	PDB	0x09[2]	Chip power down	0b
	BCM_PDB	0x09[1]	Body composition measurement front-end power down	0b
	WS_PDB	0x09[0]	Weight-scale front-end power down	0b
DEVICE_CONTROL2	BAT_MON_EN1	0x0F[7]	Enables battery monitoring along with bit[0]	0b
	BAT_MON_EN2	0x0F[0]	Enables battery monitoring along with bit[7]	0b
<b>ADC CONTROLS</b>				
ADC_DATA_RESULT	(See Description)	0x00[15:0]	ADC data result, read only register	
ADC_CONTROL_REGISTER1	ADC_CONV_MODE	0x01[15]	Continuous-Conversion or Single-Shot mode	0b
	ADC_MEAS_MODE	0x01[13:11]	Single-Ended or Differential mode	000b
	ADC_PD	0x01[7]	ADC power down	1b
	ADC_DATA_RATE	0x01[6:4]	ADC data-rate control bits	100b
ADC_CONTROL_REGISTER2	ADC_REF_SEL	0x10[6:5]	Reference selection bits	00b
	PERIPHERAL_SEL	0x10[4:0]	Peripheral selection bits	00000b
<b>WEIGHT-SCALE MODES</b>				
DEVICE_CONTROL2	BRIDGE_SEL	0x0F[2:1]	Selects one of the four bridge inputs	00b
WEIGHT_SCALE_CONTROL	WS_PGA_GAIN	0x0D[14:13]	PGA gain of weight-scale front-end	00b
	OFFSET_DAC_VALUE	0x0D[5:0]	Offset DAC setting for weight-scale front-end	000000b
<b>BCM CONTROLS</b>				
ISW_MUX	ISW_MUXP	0x0A[15:8]	Control for switches IOU TP and RP	0x00
	ISW_MUXM	0x0A[7:0]	Control for switches IOU TN and RN	0x00
VSENSE_MUX	VSENSE_MUXP	0x0B[15:8]	Control for switches VSENSE P and VSENSE P_R	0x00
	VSENSE_MUXM	0x0B[7:0]	Control for switches VSENSE N and VSENSE N_R	0x00
BCM_DAC_FREQ	DAC_FREQ	0x0E[9:0]	Sets the frequency of BCM excitation current source	0x00
IQ_MODE_ENABLE	IQ_MODE_ENABLE	0x0C[11]	Enable IQ demodulator	0b
DEVICE_CONTROL2	IQ_DEMOD_CLK_DIV_FAC	0x0F[13:11]	IQ Demodulator clock frequency	000b
<b>MISCELLANEOUS REGISTERS</b>				
MISC_REGISTER1	(See Description)	0x02[15:0]	Write 0x0000 after power up and/or reset	0x8000
MISC_REGISTER2	(See Description)	0x03[15:0]	Write 0xFFFF after power up and/or reset	0x7FFF
MISC_REGISTER3	(See Description)	0x1A[15:0]	Write 0x0030 after power up and/or reset	0x0000

**7.6.1.1 ADC\_DATA\_RESULT (Address 0x00, Default 0x0000)**

This register stores the most recent conversion data in twos complement format with the MSB in bit 15 and the LSB in bit 0.

**7.6.1.2 ADC\_CONTROL\_REGISTER1 (Address 0x01, Default 0x01C3)**

This register is used in conjunction with ADC\_PD (bit 7). Refer to the description of the ADC\_PD bit for more details.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADC_CONV_MODE	1		ADC_MEAS_MODE	0	0	1	ADC_PD		ADC_DATA_RATE	0	0	0	0			

**Bit 15**

**ADC\_CONV\_MODE:** ADC conversion mode/ADC single-shot conversion start.

This bit determines the operational status of the device. This bit can only be written when in the ADC power-down mode. When read, this bit gives the status report of the conversion.

For a write status:

0 : No effect (default)

1 : Single-shot conversion mode

For a read status:

0 : Device currently performing a conversion

1 : Device not currently performing a conversion

**Bit 14**

**Always write '1'.**

**Bits[13:11]**

**ADC\_MEAS\_MODE:** ADC measurement mode selection.

These bits set the ADC measurements to be either single-ended or differential.

ADC_MEAS_MODE	ADC AINP, AINM
000 (default)	A1, A2 = differential (default)
001	A1, AVSS = single-ended
010	A2, AVSS = single-ended

**Bits[10:8]**

Always write '001'

**Bit 7**

**ADC\_PD:** ADC Powerdown

This bit powers down the ADC\_PGA and the ADC. By default, the ADC is powered down (ADC\_PDN = '1').

For continuous conversion mode, this bit must be set to '0'.

For single-shot mode, this bit must be set to '1' along with bit 15. During single-shot conversion mode, the device automatically powers up the ADC, triggers one ADC conversion, and then powers down the ADC.

ADC_CONV_MODE (Bit 15)	ADC_PDN (Bit 7)	MODE
X	0	Continuous conversion
0	1 (default)	ADC PD
1	1 (default)	Single-shot

**Bits[6:4]**

**ADC\_DATA\_RATE:** Conversion rate select bits.

These bits select one of eight different ADC conversion rates. The data rates shown assume a master clock of 1 MHz.

000: 8 SPS

001: 16 SPS

010: 32 SPS

011: 64 SPS

100: 128 SPS (default)

101: 250 SPS

110: 475 SPS

111: 860 SPS

**Bits[3:0]**

**Always write '0000'.** At power up, these bits are set as '0011'.

**7.6.1.3 MISC\_REGISTER1 (Address 0x02, Default 0x8000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

**Bit 15** Always write '0'. At power up, this bit is set as '1'.

**Bits[14:0]** Not used, always write '0'. At power up, these bits are set as '0'.

**7.6.1.4 MISC\_REGISTER2 (Address 0x03, Default 0x7FFF)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

**Bit 15** Always write '1'. At power up, this bit is set as '0'.

**Bits[14:0]** Always write '1'. At power up, these bits are set as '1'.

**7.6.1.5 DEVICE\_CONTROL1 (Address 0x09, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	1	0	0	0	0	0	0	0	0	0	DAC_PDB	PDB	BCM_PDB	WS_PDB

**Bits[15]** Not used. Always write '0'.

**Bits[14:13]** Not used. Always write '1'.

**Bits[12:4]** Not used. Always write '0'.

**Bit 3** **DAC\_PDB:** Power down DAC.

This bit powers down the weight-scale front-end offset correction DAC and the BCM front-end current source DAC.

0: Power up DAC (default)

1: Power down DAC

**Bit 2** **PDB:** Power down device.

This bit in conjunction with the other power-down bits determines the power state of the device.

0: Power down (default)

1: Power up of front-end

**Bit 1** **BCM\_PDB:** Body composition measurement front-end power-down bit.

0: Power down body composition measurement front-end (default)

1: Power up body composition measurement front-end. Power down the weight scale when powering up the BCM.

**Bit 0** **WS\_PDB:** Weight-scale front-end power-down bit.

0: Power down weight-scale front-end (default)

1: Power up weight-scale front-end. Power down BCM when powering up the weight scale.

Table 3 shows the available power-down modes.

**Table 3. Power-Down Modes**

DAC_PDB (Bit 3)	PDB (Bit 2)	BCM_PDB (Bit 1)	WS_PDB (Bit 0)	ADC_PD (Bit 7, ADC Control Register)	MODE
X	0	0	0	1	Full device power down
1	1	0	0	1	Sleep mode
0	1	1	0	0	Weight-scale power down, body composition measurement
0	1	0	1	0	Body composition measurement power down, weight-scale measurement
0	1	0	0	0	Weight-scale and body composition measurement power down (aux/battery measurement)

**7.6.1.6 ISW\_MUX (Address 0x0A, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IOUTP5	IOUTP4	IOUTP3	IOUTP2	IOUTP1	IOUTP0	RP1	RP0	IOUTN5	IOUTN4	IOUTN3	IOUTN2	IOUTN1	IOUTN0	RN1	RN0

**Bits[15:10] IOUTP[5:0]**

These bits close the switches routing IOUTPx to the output of OPAMP1.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[9:8] RP[1:0]**

These bits close the switches routing the calibration signal to the output of OPAMP1.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[7:2] IOUTN[5:0]**

These bits close the switches routing IOUTNx to the negative input of OPAMP1.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[1:0] RN[1:0]**

These bits close the switches routing the calibration signal to the negative input of OPAMP1.

- 0: Switch is open (default)
- 1: Switch is closed

**7.6.1.7 VSENSE\_MUX (Address 0x0B, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
VSENSEP5	VSENSEP4	VSENSEP3	VSENSEP2	VSENSEP1	VSENSEP0	VSENSEP_R1	VSENSEP_R0	VSENSEN5	VSENSEN4	VSENSEN3	VSENSEN2	VSENSEN1	VSENSEN0	VSENSEM_R1	VSENSEM_R0

**Bits[15:10] VSENSEPx[5:0]**

These bits close the switches routing VSENSEPx to the positive input of the receive amplifier.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[9:8] VSENSEP\_Rx[1:0]**

These bits close the switches routing the calibration signal to the positive input of the receive amplifier.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[7:2] VSENSENx[5:0]**

These bits close the switches routing VSENSENx to the negative input of the receive amplifier.

- 0: Switch is open (default)
- 1: Switch is closed

**Bits[1:0] VSENSEM\_Rx[1:0]**

These bits close the switches routing the calibration signal to the negative input of the receive amplifier.

- 0: Switch is open (default)
- 1: Switch is closed

**7.6.1.8 IQ\_MODE\_ENABLE (Address 0x0C, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	IQ_MODE_ENABLE	0	0	0	0	0	0	0	0	0	0	0

**Bits[15:12]** Not used. Always write '0'.

**Bit 11** **IQ\_MODE\_ENABLE:** Enable the I/Q demodulator.

This bit sets the impedance measurement mode to either full-wave rectifier mode or I/Q demodulator mode. For I/Q Demodulator mode, the DAC\_FREQ bits of the BCM\_DAC\_FREQ register and the IQ\_DEMOD\_CLK\_DIV\_FAC bits of the DEVICE\_CONTROL2 register must be set appropriately. Refer to the respective register section for more details.

0: Full-Wave Rectifier mode (default)

1: I/Q Demodulator mode

**Bits[10:0]** Not used. Always write '0'.

**7.6.1.9 WEIGHT\_SCALE\_CONTROL (Address 0x0D, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	WS_PGA_GAIN	0	0	0	0	0	0	0	0	OFFSET_DAC_VALUE					

**Bit 15** Not used. Always write '0'.

**Bits[14:13]** **WS\_PGA\_GAIN:** Sets the second-stage gain of the weight-scale front-end.

00: Gain = 1 (default)

01: Gain = 2

10: Gain = 3

11: Gain = 4

**Bits[12:6]** Not used. Always write '0'.

**Bit[5:0]** **OFFSET\_DAC\_VALUE:** Offset correction DAC setting.

These bits set the value for the DAC used to correct the input offset of the weight-scale front-end. The correction is made at the second stage. The offset correction at the output of the first stage is given by OFFSET\_DAC\_VALUE × 31.2 mV. Note that OFFSET\_DAC\_VALUE is a number from –32 to 31, in twos complement; default is '000000'.

**7.6.1.10 BCM\_DAC\_FREQ (Address 0x0E, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	DAC9	DAC8	DAC7	DAC6	DAC5	DAC4	DAC3	DAC2	DAC1	DAC0

**Bits[15:9:10]** Not used. Always write '0'.

**Bits[9:0]** **DAC[9:0]:** Sets the frequency of the BCM excitation current source.

The DAC output frequency is given by  $DAC[9:0] \times f_{CLK} / 1024$ , where  $f_{CLK}$  is the frequency of the device input clock (pin 79). All combinations of the DAC frequency can be used for the full-wave rectifier mode. However, only certain combinations of the DAC frequency can be used for the I/Q demodulator mode. Refer to the description of the DEVICE\_CONTROL2 register for more details.

For example, with  $f_{CLK} = 1.024$  MHz:

DAC = 0x00FF → 255 kHz

DAC = 0x0001 → 1 kHz

**7.6.1.11 DEVICE\_CONTROL2 (Address 0x0F, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	IQ_DEMOD_CLK_DIV_FAC			0	0	0	BAT_MON_EN1	0	0	0	0	BRIDGE_SEL	BAT_MON_EN0	

**Bits[15:14]** Not used. Always write '0'.

**Bits[13:11]** **IQ\_DEMOD\_CLK\_DIV\_FAC:** 1/Q demodulator clock frequency.

The clock for the IQ demodulator (IQ\_DEMOD\_CLK signal) is internally generated from the device input clock ( $f_{CLK}$ ) by a divider controlled by this register. Note that the IQ\_DEMOD\_CLK must be four times the BCM\_DAC\_FREQ so that the phases for the mixers can be generated (that is,  $IQ\_DEMOD\_CLK = f_{CLK} / (IQ\_DEMOD\_CLK\_DIV\_FAC) = BCM\_DAC\_FREQ \times 4$ )

- 000: Divide by 1 (default)
- 001: Divide by 2
- 010: Divide by 4
- 011: Divide by 8
- 100: Divide by 16
- Others: Divide by 32

**Bit 7** **BAT\_MON\_EN1:** This bit (along with BAT\_MON\_EN0, bit 0) enables battery monitoring.

When disabled, the battery monitoring block is powered down to save power. See the description of BAT\_MON\_EN0, bit 0.

**Bits[6:3]** Not used. Always write '0'.

**Bits[2:1]** **BRIDGE\_SEL:** Selects one of the four input pairs to be routed to the weight-scale front-end.

- 00: Bridge 1 (INP1, INM1) connected to the weight-scale front-end (default)
- 01: Bridge 2 (INP2, INM2) connected to the weight-scale front-end
- 10: Bridge 3 (INP3, INM3) connected to the weight-scale front-end
- 11: Bridge 4 (INP4, INM4) connected to the weight-scale front-end.

**Bit 0** **BAT\_MON\_EN0:** This bit along with BAT\_MON\_EN1 (Bit[7]) enables battery monitoring.

- 00: Monitor disabled (default)
- 11: Monitor enabled (AVDD / 3)

**NOTE:** The PERIPHERAL\_SEL bits of the ADC\_CONTROL\_REGISTER2 must be set to '10001' in order to route the battery monitor output to the ADC.

**7.6.1.12 ADC\_CONTROL\_REGISTER2 (Address 0x10, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	ADC_REF_SEL	PERIPHERAL_SEL					

**Bits[15:7]** Not used. Always write '0'.

**Bits[6:5]** **ADC\_REF\_SEL[1:0]:** Selects the reference for the ADC.

- 00: ADCREF connected to VLDO. Used for ratiometric weight-scale measurement (default).
- 01, 10: Do not use
- 11: ADCREF connected to VREF (internal voltage reference generator). Used for impedance measurement.

**Bits[4:0]** **PERIPHERAL\_SEL[4:0]:** Selects the signals that are connected to the ADC.

- 00000: Output of the weight-scale front-end (default)
- 00011: Output of the body composition measurement front-end (OUTP\_FILTER/OUTM\_FILTER)
- 00101: Output of the body composition measurement front-end (OUTP\_Q\_FILTER/OUTM\_Q\_FILTER)
- 01001: AUX1 signal for single-ended measurement. Also set bit[13:11] of the ADC\_CONTROL\_REGISTER1 to '001'.
- 10001: AUX2 signal for single-ended measurement. Also set bit[13:11] of the ADC\_CONTROL\_REGISTER1 to '010'.
- 11001: AUX2 and AUX1 signal for differential measurement (AUX2-AUX1). Also set bit[13:11] of the ADC\_CONTROL\_REGISTER1 to 000.

**NOTE:** All other bit combinations are invalid.

**7.6.1.13 MISC\_REGISTER3 (Address 0x1A, Default 0x0000)**

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0

**Bits[15:6]**            **Not used. Always write '0'.**

**Bits[5:4]**            **Always write '1'.**

**Bits[3:0]**            **Not used. Always write '0'.**

## 8 Application and Implementation

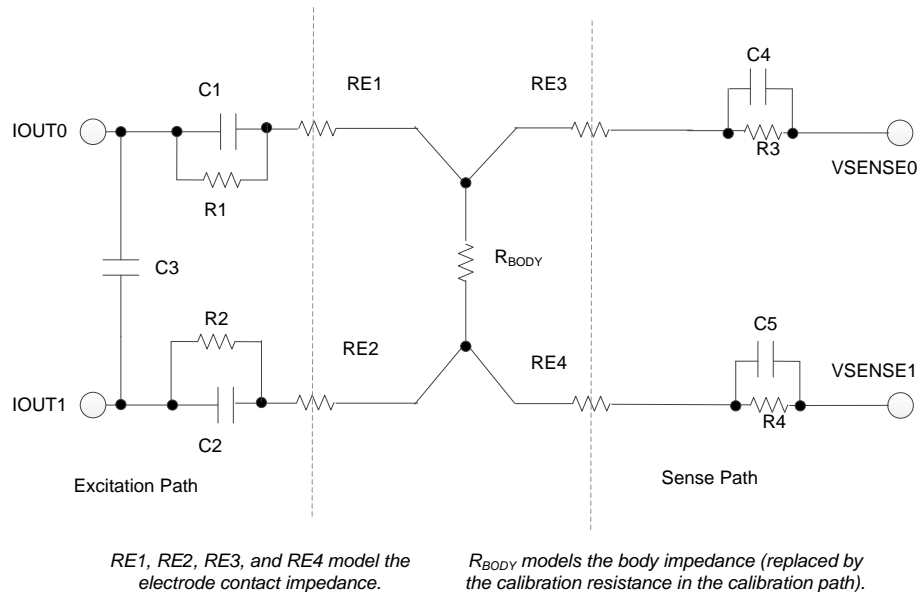
### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

#### 8.1.1 BCM Channel Connections

The suggested connections of the BCM excitation and sense electrodes to the device pins are shown in [Figure 12](#). The circuit shows an electrical model of the body impedance being measured ( $R_{\text{BODY}}$ ) along with models for the electrode contact impedances. The components connecting the electrodes to the IOUTx and VSENSEx pins are meant to be replicated in the path of the calibration impedances as well. Suggestions for the component values are shown in [Table 4](#).



**Figure 12. Connection of BCM Pins to Electrodes**

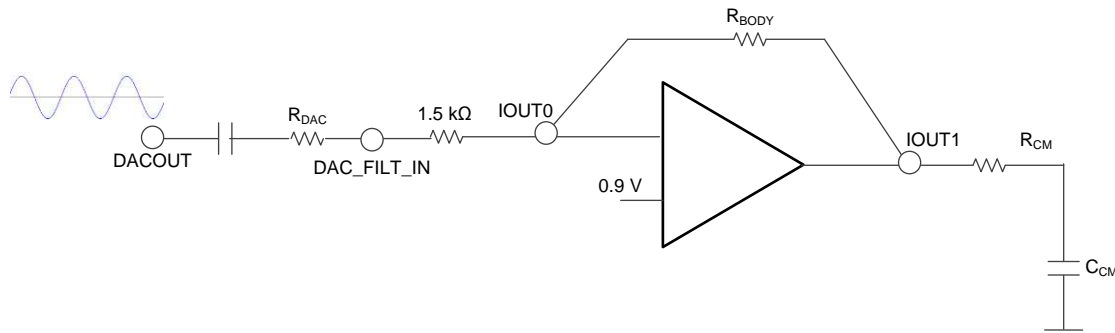
**Table 4. Component Values Corresponding to [Figure 12](#)<sup>(1)</sup>**

COMPONENT	ILLUSTRATIVE VALUE	COMMENTS
R1, R2	10 kΩ	Provides a dc feedback for the excitation op amp.
C1, C2	1 μF	Low-impedance path for the 50-kHz excitation, high impedance for dc currents.
C3	47 pF	Optional shunt capacitor across the excitation op amp to improve stability.
R3, R4	10 kΩ	Sets the dc voltage at the VSENSEx pins.
C4, C5	1 μF	Low-impedance path for the 50-kHz excitation, high impedance for dc currents (patient safety).

(1) The indicated component values are only for illustration. The actual choice of circuit configuration and component values in a product can be governed by other considerations (such as patient safety and so forth).

### 8.1.2 Handling Oscillation of the Excitation Amplifier

The phase margin of the excitation amplifier can degrade if there is high capacitance at the input and output terminals. High capacitances can result from the capacitances from the electrodes, from protection diodes (for instance, ESD diodes), as well as the capacitance presented by the human body. Degradation of phase margin resulting from high capacitances can result in oscillations leading to reduced measurement accuracy. One way to improve the phase margin of the excitation amplifier is to introduce a series R-C at the output of the excitation amplifier in every measurement. This process is done using the components  $R_{CM} = 1\text{ k}\Omega$  and  $C_{CM} = 1\text{ nF}$  in the simplistic model shown in Figure 13. This illustration is for a case where IOOUT0 and IOOUT1 are switched to the input and output of the excitation amplifier, respectively.



**Figure 13. Oscillation Fix of the Excitation Amplifier**

Such a scheme can be implemented in one of two methods:

1. A separate  $R_{CM}$ - $C_{CM}$  for every IOOUTx and RPx pin that gets switched to the excitation amplifier output.
2. A single  $R_{CM}$ - $C_{CM}$  on one of the RPx pins that gets switched to the excitation amplifier output during calibration. When not using this RPx pin, still switch the same RPx pin to the output of the excitation amplifier (in addition to whichever other pin is switched to the output) so that the  $R_{CM}$ - $C_{CM}$  still gets connected to the output of the excitation amplifier.

Method 2 is preferable because this method involves only one  $R_{CM}$  and one  $C_{CM}$ .

### 8.1.3 Achieving Deterministic Phase in the IQ Mode

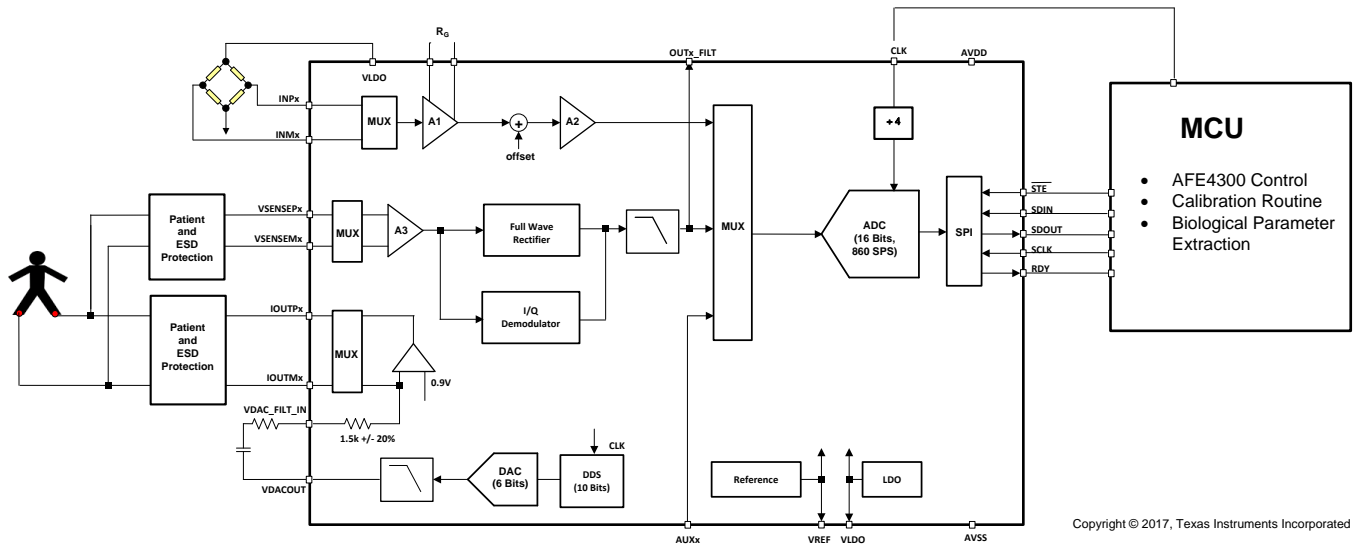
The DAC frequency generator (DDS) is initialized on the register update of the DAC frequency register. The IQ demod clock divider is updated on the divider register value. Because the registers are written through the SPI interface (that is, asynchronous to the device clock), every time either of these registers are written, the phase relation between the DAC output and the I-Q demod clock can get altered. This alteration in phase relation can cause the phase of the I-Q measurement to be non-deterministic.

Two ways of circumventing this issue are:

1. Do a fresh calibration (measuring all the calibration impedances) each time the registers are reprogrammed for a new excitation frequency
2. Use an SPI clock synchronous with the device clock and follow the sequence below whenever the DACOUT frequency is to be changed:
  1. Write 0 to register 15 (set the IQ divider to 1)
  2. Write 0 to register 14 (DACOUT frequency is cleared)
  3. Write the required DAC frequency to register 14
  4. Write the required IQ\_DEMOD\_CLK\_DIV to register 15

## 8.2 Typical Application

A typical application of the AFE4300 is a weight scale, as shown in Figure 14, that includes a weight measurement as well as a body impedance measurement with the architecture.



**Figure 14. Weight Scale Application**

The weight applied on a load-cell generates the differential voltage that is converted by the weight scale signal chain of the AFE. For the body impedance measurement, a sinusoidal current (most commonly at a frequency of 50 kHz) is injected into a pair of electrodes that make contact with the human body. Two more electrodes serve as sense electrodes and the differential voltage developed across the sense electrodes is measured and digitized by the AFE. The whole system is clocked using an external clock source.

### 8.2.1 Design Requirements

Table 5 shows the typical requirements of a weight scale design using the AFE.

**Table 5. Weight Scale Design Requirements**

PARAMETER	EXAMPLE VALUE	COMMENTS
AVDD	3.3 V	Have enough margin for the dc inaccuracy and minimize ripple. For the battery-operated device, an LDO can be used to derive AVDD. Place decoupling capacitors close to the AFE.
Load-cell excitation voltage	1.7 V	$V_{LDO}$ is generated by the AFE and must be used as the load-cell excitation source. Because $V_{LDO}$ is used as the reference for the ADC in the weight scale signal chain, using $V_{LDO}$ as the excitation voltage for the load-cell makes the measurement ratio-metric and compensates errors resulting from variation in $V_{LDO}$ .
External clock frequency	1.024 MHz	—
BCM excitation frequency	50 kHz (set by programming the AFE)	For single-frequency body impedance analysis, the most commonly used frequency is 50 kHz.
Skin-electrode contact impedance	A few 100 $\Omega$ or lower	The electrodes must have a big enough contact area with the body in order to minimize the electrode-skin contact impedance (ac value at the excitation frequency).

### 8.2.2 Detailed Design Procedure

A body impedance measurement is usually performed using four electrodes: a pair of excitation electrodes and a pair of sense electrodes. Body contact to each electrode involves a series impedance resulting from the skin-electrode interface. On the excitation side, this contact impedances come in series with the body impedance and cause the voltage swing on the excitation terminals of the AFE to increase. Excessive contact impedances on the excitation electrodes can therefore cause the excitation amplifier to saturate even while measuring normal ranges of body impedance. On the sense electrodes, the input impedance of the receiver is 50 kΩ. As a result, the contact impedances on the sense electrodes cause a small attenuation in the effective signal input to the receiver. For these reasons, the ac contact impedance at the excitation frequency must be minimized on both the excitation and sense electrodes.

To deduce an accurate impedance value from the AFE output in the body impedance measurement requires calibration relative to known impedances. Calibration is usually performed by measuring two or more known impedances and by constructing a piece-wise linear curve between the AFE output and the impedance.

To conserve power when not used, the AFE can be put in a sleep mode in which all signal chains are powered down. This mode reduces the average power consumption significantly. When the user issues a power-up interrupt (pressing a button or so forth) to the system, the AFE can be programmed to come out of sleep mode, perform the measurement, and go back to sleep again. To account for drifts with time, TI recommends that calibration be done every time the AFE is woken up. For the BCM measurement, TI recommends measuring the calibration impedances before every fresh measurement of body impedance. For the weight scale measurement, TI recommends measuring the channel offset (the AFE output without any load) before the measurement of the load. Also after every wake-up, provide sufficient time for the signal chain to settle before doing any measurements.

To meet product-level ESD requirements, additional external ESD protection diodes may need to be used to protect the AFE pins that interface with the electrodes.

### 8.2.3 Application Curve

Figure 15 shows the linearity of the BCM up to 2.5 kΩ. As seen the figure, the maximum impedance that can be measured for the default configuration using the AFE4300 is typically 2.5 kΩ. However for better performance, TI suggests limiting the impedance to 1175 Ω. If higher impedance must be measured, the excitation current can be reduced by placing an external resistor of 1.5 kΩ (between DACOUT and DAC\_FILT\_IN), which increases the range by roughly 2x.

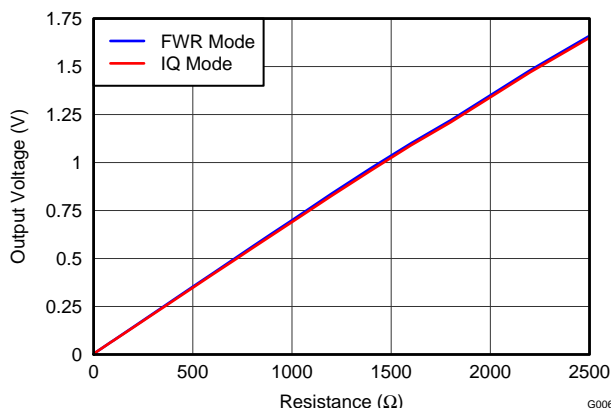


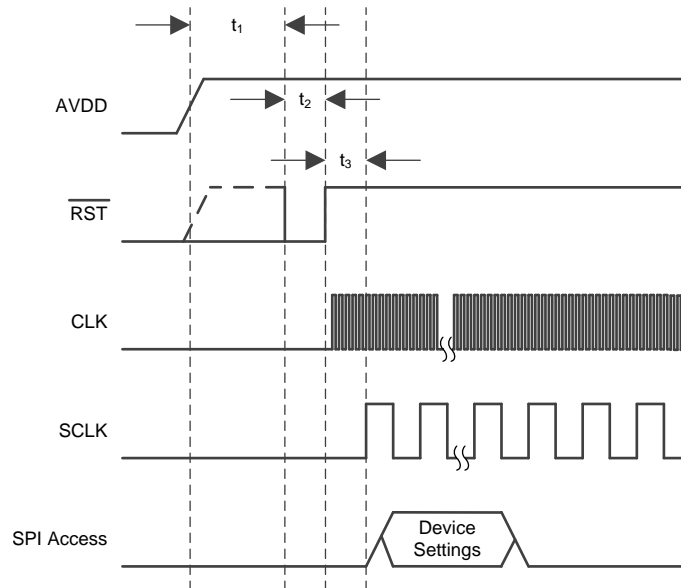
Figure 15. Body Impedance to Output Voltage Transfer Curve

## 9 Power Supply Recommendations

### 9.1 Power-Supply Recommendation and Initialization

The device has an analog supply (AVDD). Drive these pins with a clean supply and connect bypass capacitors close to the pins. After power up, the device must be reset to set all internal registers to their default state. Resetting the device is done by applying an active low pulse on the  $\overline{\text{RST}}$  pin after the power supplies stabilize. As part of the reset process, the AFE4300 sets all register bits to the respective default settings.

Some register bits must be written to values different from their default values after reset for proper operation. By default, the AFE4300 enters into a power-down state at start-up. The startup and initialization for the device is shown in Figure 16 and Table 6 lists the recommended timing values.



**Figure 16. Power-Up and Initialization**

**Table 6. Timing Parameters for Figure 16**

		<b>NOM</b>	<b>UNIT</b>
$t_1$	Time between supplies turning on and an active $\overline{\text{RST}}$	> 10	ms
$t_2$	Active $\overline{\text{RST}}$ duration	> 50	$\mu\text{s}$
$t_3$	Time between $\overline{\text{RST}}$ and register writes	> 1	ms

## 10 Layout

### 10.1 Layout Guidelines

The following points must be considered during layout:

- All input signals (INPx, INMx, VSENSEx, IOUTs) must be routed differentially with equal length
- Input signals must be isolated from high-frequency signals using a ground plane or a ground trace
- Special care (such as avoiding vias, test points, and so forth) must be given to minimize the parasitic capacitances in the input circuit of the BCM

### 10.2 Layout Example

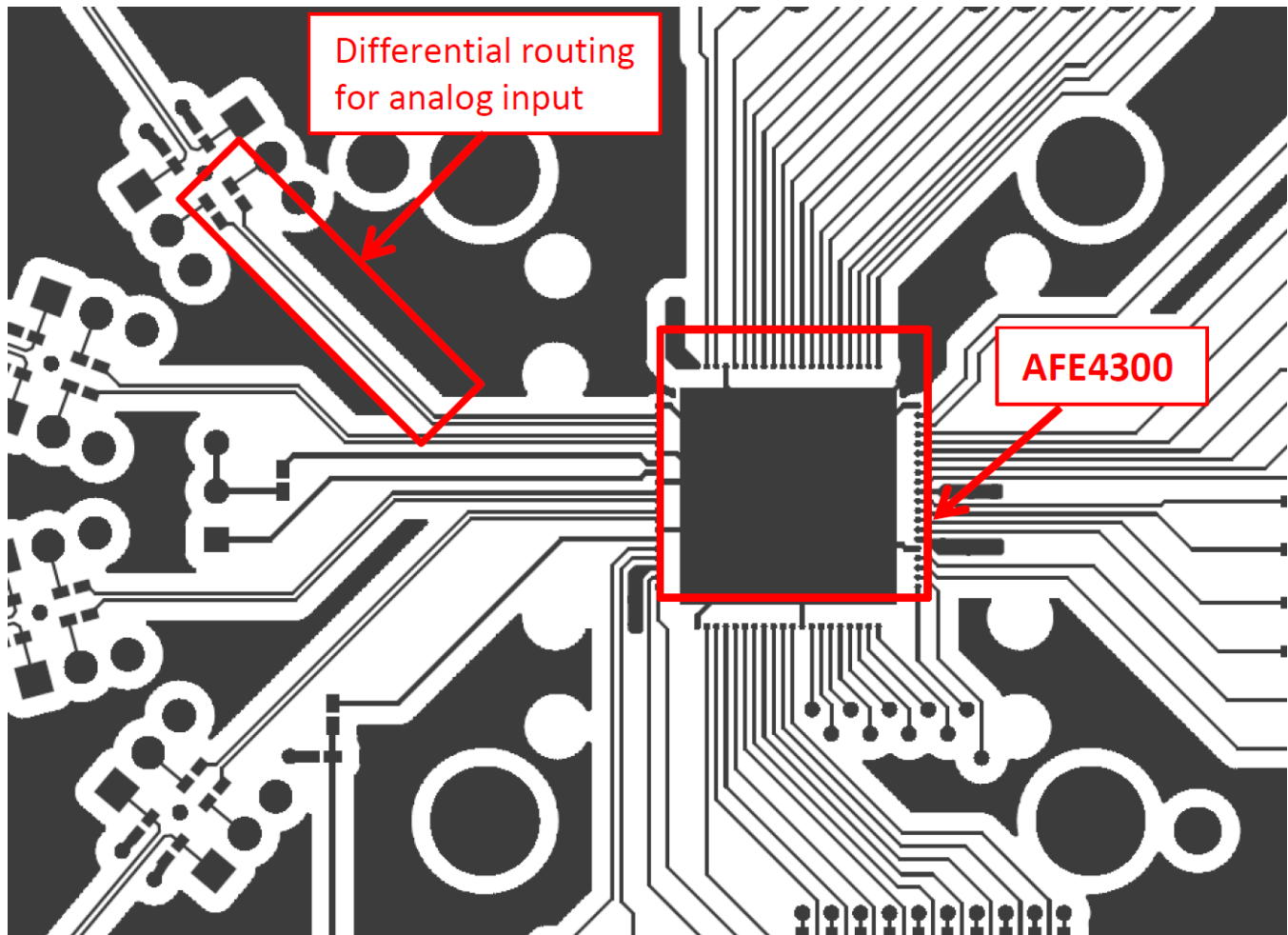


Figure 17. Example Layout

## 11 器件和文档支持

### 11.1 接收文档更新通知

要接收文档更新通知，请导航至 TI.com 上的器件产品文件夹。单击右上角的 [通知我](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

### 11.2 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 [《使用条款》](#)。

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### 11.3 商标

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### 11.4 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。这些数据如有变更，恕不另行通知和修订此文档。如欲获取此数据表的浏览器版本，请参阅左侧的导航。

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">AFE4300PN</a>	Active	Production	LQFP (PN)   80	119   JEDEC TRAY (5+1)	Yes	NIPDAU	Level-3-260C-168 HR	0 to 70	AFE4300
AFE4300PN.A	Active	Production	LQFP (PN)   80	119   JEDEC TRAY (5+1)	Yes	NIPDAU	Level-3-260C-168 HR	0 to 70	AFE4300
<a href="#">AFE4300PNR</a>	Active	Production	LQFP (PN)   80	1000   LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	0 to 70	AFE4300
AFE4300PNR.A	Active	Production	LQFP (PN)   80	1000   LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	0 to 70	AFE4300

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

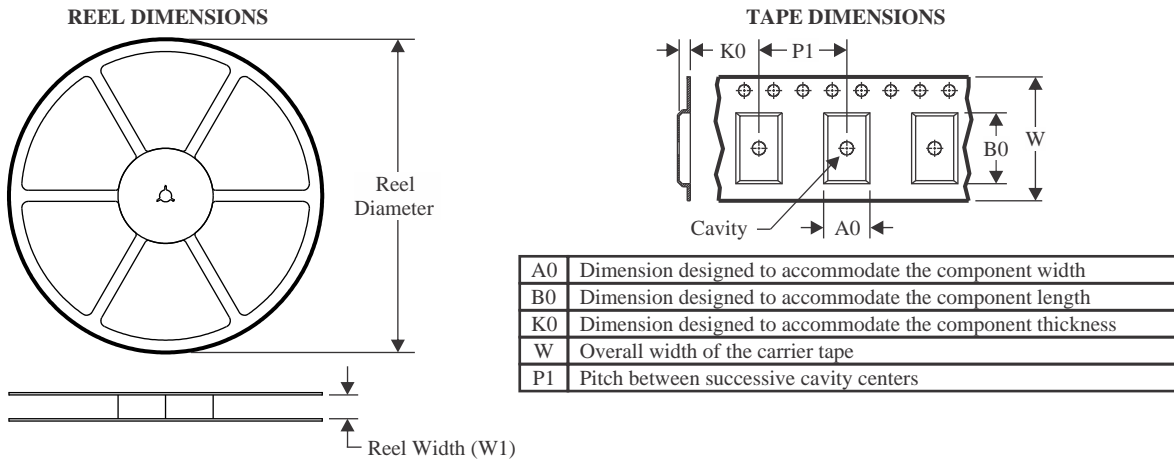
(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

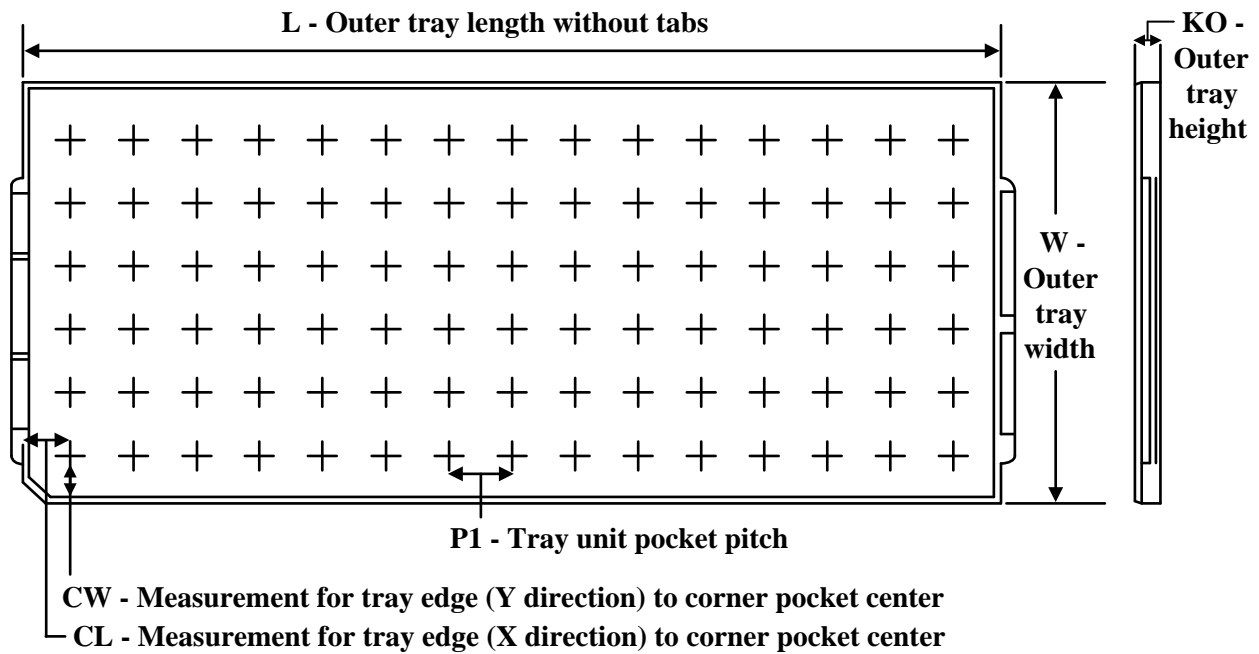

\*All dimensions are nominal

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
AFE4300PNR	LQFP	PN	80	1000	330.0	24.4	16.0	16.0	2.0	24.0	24.0	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
AFE4300PNR	LQFP	PN	80	1000	367.0	367.0	55.0

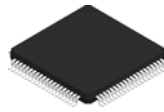
**TRAY**


Chamfer on Tray corner indicates Pin 1 orientation of packed units.

\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	K0 (µm)	P1 (mm)	CL (mm)	CW (mm)
AFE4300PN	PN	LQFP	80	119	7 X 17	150	315	135.9	7620	17.9	14.3	13.95
AFE4300PN.A	PN	LQFP	80	119	7 X 17	150	315	135.9	7620	17.9	14.3	13.95

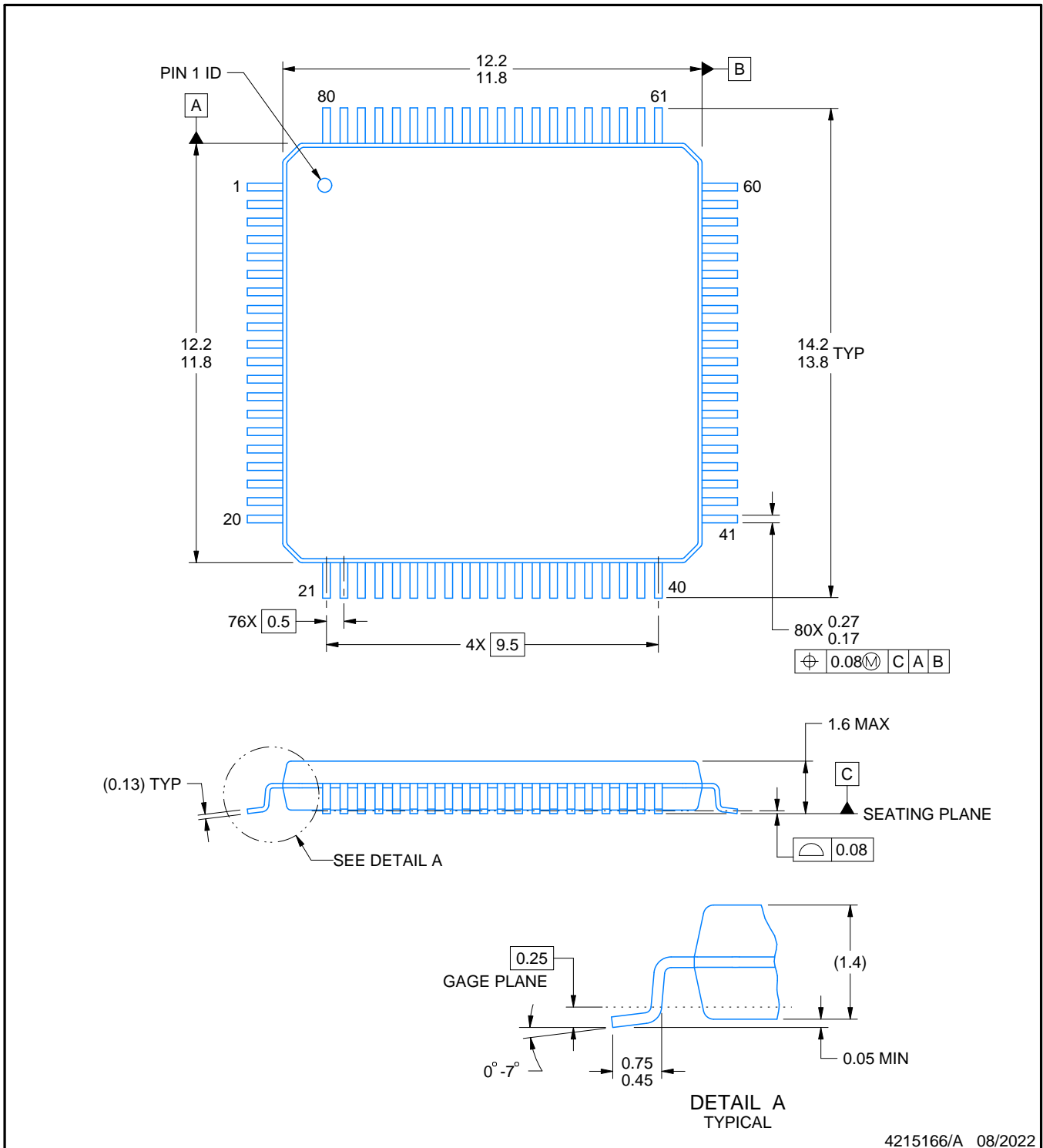
PN0080A



# PACKAGE OUTLINE

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



NOTES:

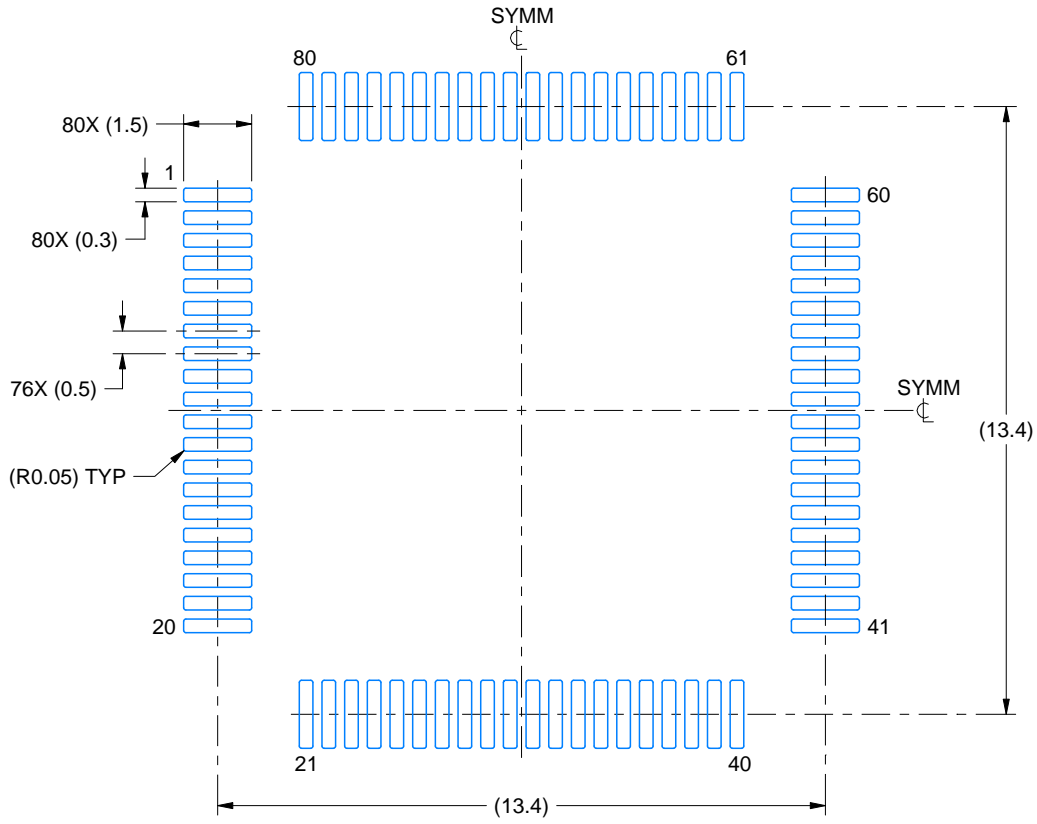
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration MS-026.

# EXAMPLE BOARD LAYOUT

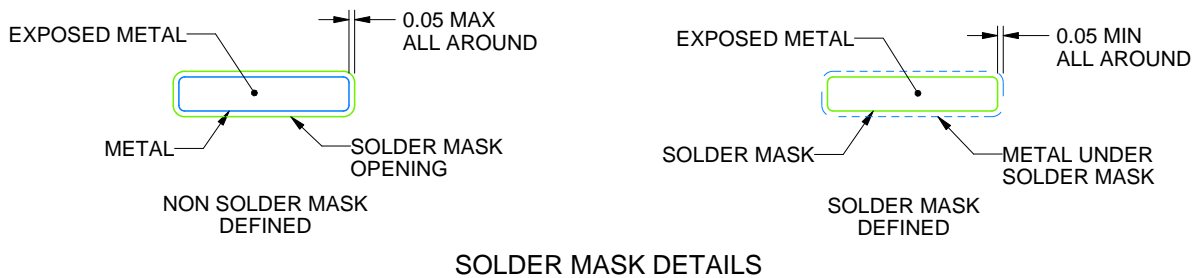
PN0080A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:6X



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NOTES: (continued)

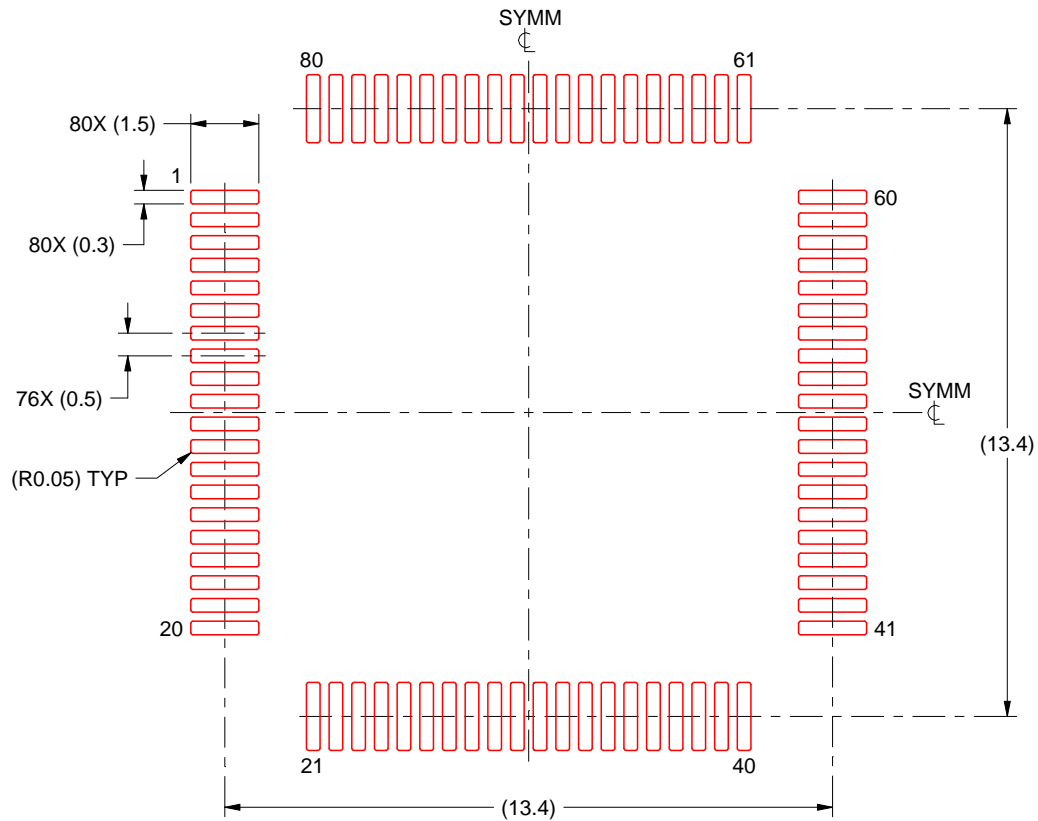
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
6. For more information, see Texas Instruments literature number SLMA004 ([www.ti.com/lit/slma004](http://www.ti.com/lit/slma004)).

# EXAMPLE STENCIL DESIGN

PN0080A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:6X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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