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MMA65xx, Dual-Axis, SPI Inertial Sensor

MMA65xx, a SafeAssure solution, is a SPI-based, dual-axis, medium-*g*, over-damped lateral accelerometer designed for use in automotive airbag systems.

MMA65xx

Bottom view

Pb-free, 16-pin QFN
6 mm x 6 mm x 1.98 mm package

Features

- ±80 *g*, ±105 *g* or ±120 *g* full-scale range, independently specified for each axis
- 3.3 V or 5 V single supply operation
- SPI-compatible serial interface
- 12-bit digital signed or unsigned SPI data output
- Independent programmable arming functions for each axis
- Twelve low-pass filter options, ranging from 50 Hz to 1000 Hz
- Optional offset cancellation with > 6 s averaging period and < 0.25 LSB/s slew rate
- Pb-free, 16-pin QFN, 6 mm x 6 mm x 1.98 mm package

Referenced Documents

- AEC-Q100, Revision G, dated May 14, 2007 (http://www.aecouncil.com/)

Ordering information				
Device	**X-Axis Range**	**Y-Axis Range**	**Package**	**Shipping**
MMA6519KCW	±80 *g*	±80 *g*	98ASA00690D	Tubes
MMA6525KCW	±105 *g*	±105 *g*	98ASA00690D	Tubes
MMA6527KCW	±120 *g*	±120 *g*	98ASA00690D	Tubes
MMA6519KCWR2	±80 *g*	±80 *g*	98ASA00690D	Tape & Reel
MMA6525KCWR2	±105 *g*	±105 *g*	98ASA00690D	Tape & Reel
MMA6527KCWR2	±120 *g*	±120 *g*	98ASA00690D	Tape & Reel

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1 General Description

1.1 Application diagram

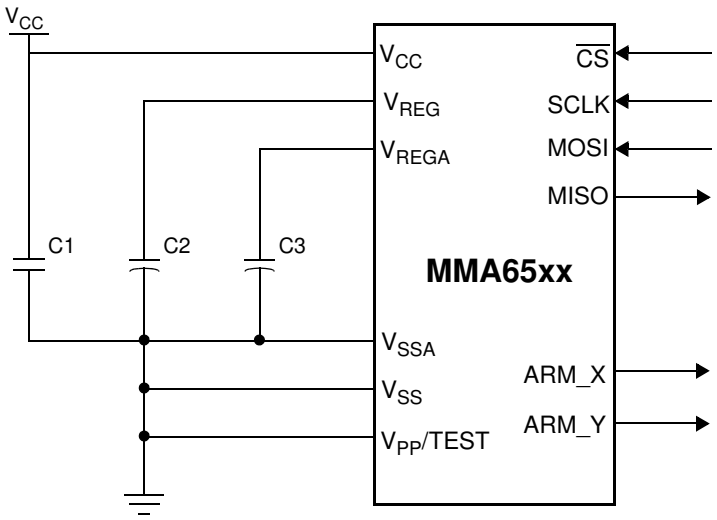

Figure 1. Application Diagram

Table 1. External Component Recommendations

Ref Des	Type	Description	Purpose
C1	Ceramic	0.1 µF, 10 %, 10 V Minimum, X7R	V_{CC} Power Supply Decoupling
C2	Ceramic	1 µF, 10 %, 10 V Minimum, X7R	Voltage Regulator Output Capacitor (C_{VREG})
C3	Ceramic	1 µF, 10 %, 10 V Minimum, X7R	Voltage Regulator Output Capacitor (C_{VREGA})

1.2 Internal block diagram

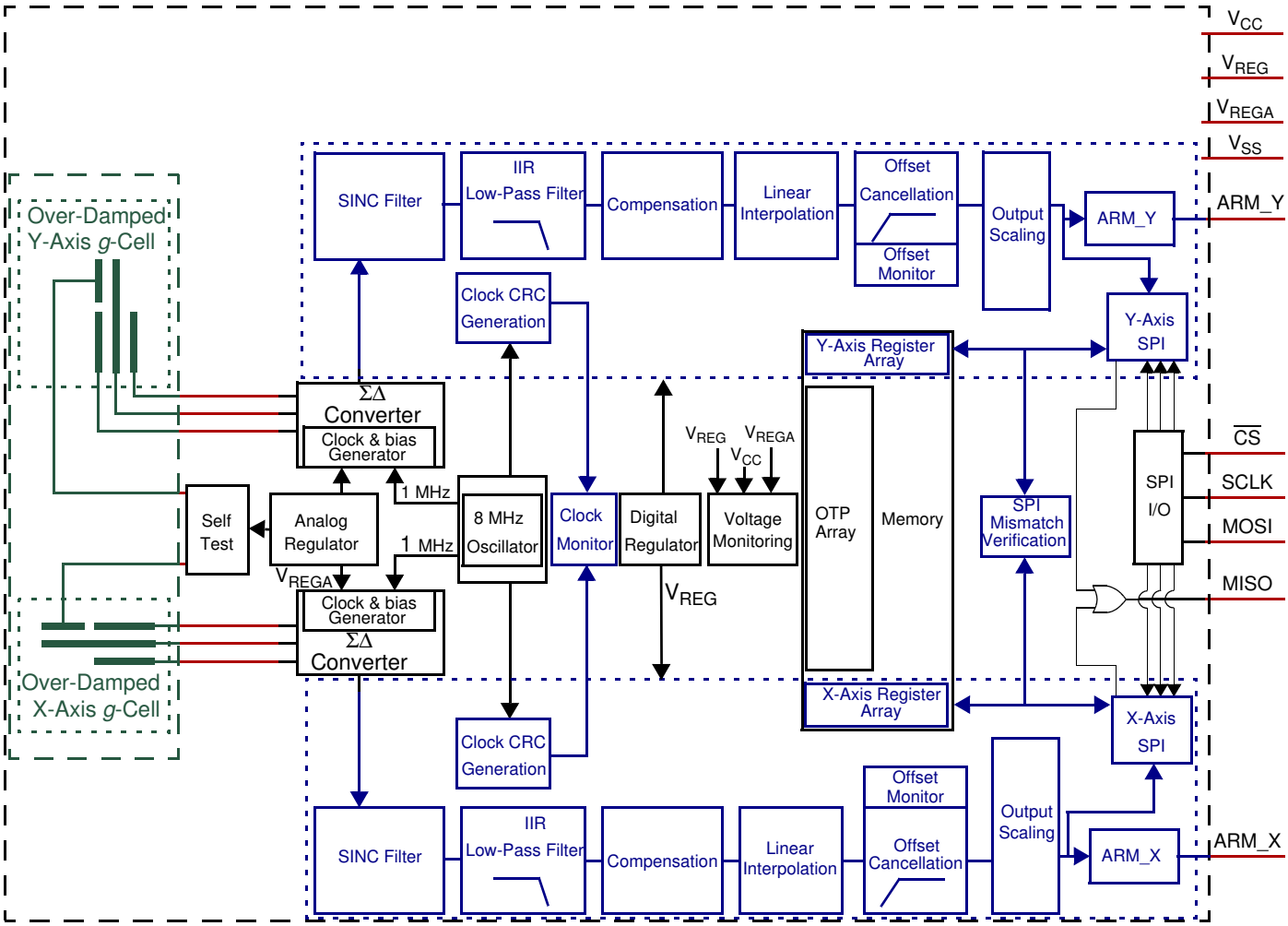

Figure 2. Internal Block Diagram

1.3 Device orientation and part marking

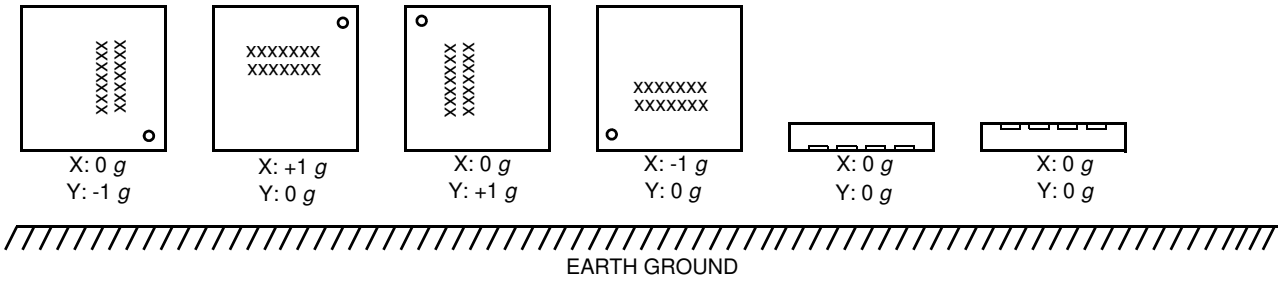

Figure 3. Device Orientation Diagram

Data Code Legend:
A: Assembly Location
WL: Wafer Lot Number (*g*-cell Lot Number)
Y: Year
WW: Work Week
Z: Assembly Lot Number

Figure 4. Part Marking

1.4 Pin Connections

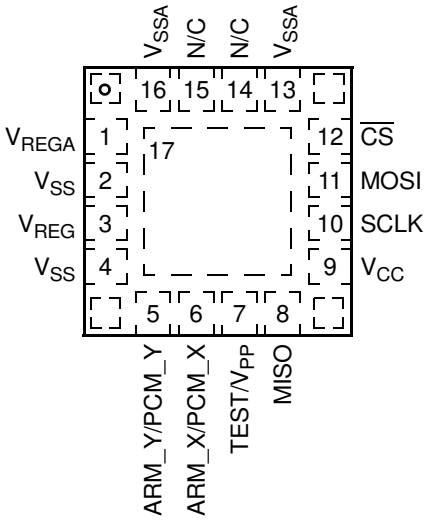

Figure 5. Top View, 16-Pin QFN Package

Table 2. Pin Descriptions

Pin	Pin Name	Formal Name	Definition
1	V_{REGA}	Analog Supply	This pin is connected to the power supply for the internal analog circuitry. An external capacitor must be connected between this pin and V_{SSA}. Reference Figure 1.
2	V_{SS}	Digital GND	This pin is the power supply return node for the digital circuitry.
3	V_{REG}	Digital Supply	This pin is connected to the power supply for the internal digital circuitry. An external capacitor must be connected between this pin and V_{SS}. Reference Figure 1.
4	V_{SS}	Digital GND	This pin is the power supply return node for the digital circuitry.
5	ARM_Y/ PCM_Y	Y-Axis Arm Output / PCM Output	The function of this pin is configurable via the DEVCFG register as described in Section 3.1.6.6. When the arming output is selected, ARM_Y can be configured as an open drain, active low output with a pullup current; or an open drain, active high output with a pulldown current. Alternatively, this pin can be configured as a digital output with PCM signal proportional to the Y axis acceleration data. Reference Section 3.8.10 and Section 3.8.11. If unused, this pin must be left unconnected.
6	ARM_X/ PCM_X	X-Axis Arm Output / PCM Output	The function of this pin is configurable via the DEVCFG register as described in Section 3.1.6.6. When the arming output is selected, ARM_X can be configured as an open drain, active low output with a pullup current; or an open drain, active high output with a pulldown current. Alternatively, this pin can be configured as a digital output with a PCM signal proportional to the X-axis acceleration data. Reference Section 3.8.10 and Section 3.8.11. If unused, this pin must be left unconnected.
7	TEST / V_{PP}	Programming Voltage	This pin provides the power for factory programming of the OTP registers. This pin must be connected to V_{SS} in the application.
8	MISO	SPI Data Out	This pin functions as the serial data output for the SPI port.
9	V_{CC}	Supply	This pin supplies power to the device. An external capacitor must be connected between this pin and V_{SS}. Reference Figure 1.
10	SCLK	SPI Clock	This input pin provides the serial clock to the SPI port. An internal pulldown device is connected to this pin.
11	MOSI	SPI Data In	This pin functions as the serial data input to the SPI port. An internal pulldown device is connected to this pin.
12	CS	Chip Select	This input pin provides the chip select for the SPI port. An internal pullup device is connected to this pin.
13	V_{SSA}	Analog GND	This pin is the power supply return node for analog circuitry.
14	N/C	No Connect	Not internally connected. This pin can be unconnected or connected to V_{SS} in the application.
15	N/C	No Connect	Not internally connected. This pin can be unconnected or connected to V_{SS} in the application.
16	V_{SSA}	Analog GND	This pin is the power supply return node for analog circuitry.
17	PAD	Die Attach Pad	This pin is the die attach flag, and is internally connected to V_{SS}. Reference Section 5 for die attach pad connection details.
Corner Pads			The corner pads are internally connected to V_{SS}.

2 Electrical Characteristics

2.1 Maximum Ratings

Maximum ratings are the extreme limits to which the device can be exposed without permanently damaging it.

#	Rating	Symbol	Value	Unit	
1	Supply Voltage	V_{CC}	-0.3 to +7.0	V	(3)
2	V_{REG}, V_{REGA}	V_{REG}	-0.3 to +3.0	V	(3)
3	SCLK, $\overline{CS}$, MOSI,V_{PP}/TEST	V_{IN}	-0.3 to V_{CC} + 0.3	V	(3)
4	ARM_X, ARM_Y	V_{IN}	-0.3 to V_{CC} + 0.3	V	(3)
5	MISO (high impedance state)	V_{IN}	-0.3 to V_{CC} + 0.3	V	(3)
6	Powered Shock (six sides, 0.5 ms duration)	g_{pms}	±1500	*g*	(5,18)
7	Unpowered Shock (six sides, 0.5 ms duration)	g_{shock}	±2000	*g*	(5,18)
8	Drop Shock (to concrete surface)	h_{DROP}	1.2	m	(5)
	Electrostatic Discharge				
9	Human Body Model (HBM)	V_{ESD}	±2000	V	(5)
10	Charge Device Model (CDM)	V_{ESD}	±750	V	(5)
11	Machine Model (MM)	V_{ESD}	±200	V	(5)
12	Storage Temperature Range	T_{stg}	-40 to +125	°C	(5)
13	Thermal Resistance - Junction to Case	q_{JC}	2.5	°C/W	(14)

2.2 Operating Range

The operating ratings are the limits normally expected in the application and define the range of operation.

#	Characteristic	Symbol	Min	Typ	Max	Units	
	Supply Voltage		V_L	V_{TYP}	V_H		
14	Standard Operating Voltage, 3.3 V	V_{CC}	+3.135	+3.3	+5.25	V	(15)
15	Standard Operating Voltage, 5.0 V			+5.0		V	(15)
	Operating Ambient Temperature Range		T_L		T_H		
16	Verified by 100% Final Test	T_A	-40	—	+105	C	(1)
17	Power-on Ramp Rate (V_{CC})	V_{CC_r}	0.000033	—	3300	V/µs	(19)

2.3 Electrical Characteristics - Power Supply and I/O

$V_L \le (V_{CC} - V_{SS}) \le V_H$, $T_L \le T_A \le T_H$, $|\Delta T_A| < 25$ K/min unless otherwise specified

#	Characteristic		Symbol	Min	Typ	Max	Units	
18	Supply Current	*	I_{DD}	4.0	—	8.0	mA	(1)
	Power Supply Monitor Thresholds (See Figure 9)							
19	V_{CC} Under Voltage (Falling)	*	$V_{CC_UV_f}$	2.74	—	3.02	V	(3,6)
20	V_{REG} Under Voltage (Falling)	*	$V_{REG_UV_f}$	2.10	—	2.25	V	(3,6)
21	V_{REG} Over Voltage (Rising)	*	$V_{REG_OV_r}$	2.65	—	2.85	V	(3,6)
22	V_{REGA} Under Voltage (Falling)	*	$V_{REGA_UV_f}$	2.20	—	2.35	V	(3,6)
23	V_{REGA} Over Voltage (Rising)	*	$V_{REGA_OV_r}$	2.65	—	2.85	V	(3,6)
	Power Supply Monitor Hysteresis							
24	V_{CC} Under Voltage		V_{HYST}	65	100	110	mV	(3)
25	V_{REG} Under Voltage, V_{REG} Over Voltage		V_{HYST}	20	100	210	mV	(3)
26	V_{REGA} Under Voltage, V_{REGA} Over Voltage		V_{HYST}	20	100	150	mV	(3)
	Power Supply RESET Thresholds (See Figure 6, and Figure 9)							
27	V_{REG} Under Voltage RESET (Falling)	*	$V_{REG_UVR_f}$	1.764	—	2.024	V	(3,6)
28	V_{REG} Under Voltage RESET (Rising)	*	$V_{REG_UVR_r}$	1.876	—	2.152	V	(3,6)
29	V_{REG} RESET Hysteresis		V_{HYST}	80	—	140	mV	(3)
	Internally Regulated Voltages							
30	V_{REG}	*	V_{REG}	2.42	2.50	2.58	V	(1,3)
31	V_{REGA}	*	V_{REGA}	2.42	2.50	2.58	V	(1,3)
	External Filter Capacitor (C_{VREG}, C_{VREGA})							
32	Value		C_{VREG}, C_{VREGA}	700	1000	1500	nF	(19)
33	ESR (including interconnect resistance)		ESR	—	—	400	mΩ	(19)
	Power Supply Coupling							
34	50 kHz ≤ f_n ≤ 20 MHz			—	—	0.004	LSB/mv	(3)
35	20 MHz ≤ f_n ≤ 100 MHz			—	—	0.004	LSB/mv	(19)
	Output High Voltage (MISO, PCM_X, PCM_Y)							
36	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (I_{Load} = -1 mA)	*	V_{OH_3}	V_{CC} - 0.2	—	—	V	(2,3)
37	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (I_{Load} = -1 mA)	*	V_{OH_5}	V_{CC} - 0.4	—	—	V	(2,3)
	Output Low Voltage (MISO, PCM_X, PCM_Y)							
38	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (I_{Load} = 1 mA)	*	V_{OL_3}	—	—	0.2	V	(2,3)
39	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (I_{Load} = 1 mA)	*	V_{OL_5}	—	—	0.4	V	(2,3)
	Open Drain Output High Voltage (ARM_X, ARM_Y)							
40	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (I_{ARM} = -1 mA)	*	V_{ODH_3}	V_{CC} - 0.2	—	—	V	(2,3)
41	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (I_{ARM} = -1 mA)	*	V_{ODH_5}	V_{CC} - 0.4	—	—	V	(2,3)
	Open Drain Output Pulldown Current (ARM_X, ARM_Y)							
42	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (V_{ARM} = 1.5 V)	*	I_{ODPD_3}	50	—	100	µA	(2,3)
43	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (V_{ARM} = 1.5 V)	*	I_{ODPD_5}	50	—	100	µA	(2,3)
	Open Drain Output Low Voltage (ARM_X, ARM_Y)							
44	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (I_{ARM} = 1 mA)	*	V_{ODH_3}	—	—	0.2	V	(2,3)
45	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (I_{ARM} = 1 mA)	*	V_{ODH_5}	—	—	0.4	V	(2,3)
	Open Drain Output Pullup Current (ARM_X, ARM_Y)							
46	3.15 V ≤ (V_{CC} - V_{SS}) ≤ 3.45 V (V_{ARM} = 1.5 V)	*	I_{ODPU_3}	-100	—	-50	µA	(2,3)
47	4.75 V ≤ (V_{CC} - V_{SS}) ≤ 5.25 V (V_{ARM} = 1.5 V)	*	I_{ODPU_5}	-100	—	-50	µA	(2,3)
48	Input High Voltage $\overline{CS}$, SCLK, MOSI	*	V_{IH}	2.0	—	—	V	(3,6)
49	Input Low Voltage $\overline{CS}$, SCLK, MOSI	*	V_{IL}	—	—	1.0	V	(3,6)
50	Input Voltage Hysteresis $\overline{CS}$, SCLK, MOSI	*	V_{I_HYST}	0.125	—	0.500	V	(19)
	Input Current							
51	High (at V_{IH}) (SCLK, MOSI)	*	I_{IH}	-70	-50	-30	µA	(2,3)
52	Low (at V_{IL}) ($\overline{CS}$)	*	I_{IL}	30	50	70	µA	(2,3)

2.4 Electrical Characteristics - Sensor and Signal Chain

$V_L \le (V_{CC} - V_{SS}) \le V_H$, $T_L \le T_A \le T_H$, $|\Delta T_A| < 25$ K/min unless otherwise specified.

#	Characteristic		Symbol	Min	Typ	Max	Units	
	Digital Sensitivity (SPI)							
53	80g (12-Bit Output)	*	SENS	—	24.0	—	LSB/g	(1,9)
54	105.5g (12-Bit Output)	*	SENS	—	18.2	—	LSB/g	(1,9)
55	120g (12-Bit Output)	*	SENS	—	16.0	—	LSB/g	(1,9)
	Sensitivity Error							
56	T_A = 25 °C	*	ΔSENS	-4	—	+4	%	(1)
57	-40 °C ≤ T_A ≤ 105 °C	*	ΔSENS	-5	—	+5	%	(1)
58	-40 °C ≤ T_A ≤ 105 °C, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		ΔSENS	-5	—	+5	%	(3)
	Offset at 0g (105.5g 120g Range, No Offset Cancellation)							
59a	12 bits, unsigned	*	OFFSET	1988	2048	2108	LSB	(1)
60a	12 bits, signed	*	OFFSET	-60	0	+60	LSB	(1)
61a	12 bits, unsigned, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	1988	—	1988	LSB	(3)
62a	12 bits, signed, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	-60	—	-60	LSB	(3)
	Offset at 0g (80g Range, No Offset Cancellation)							
63a	12 bits, unsigned	*	OFFSET	1968	2048	2128	LSB	(1)
64a	12 bits, signed	*	OFFSET	-80	0	+80	LSB	(1)
65a	12 bits, unsigned, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	1968	—	1968	LSB	(3)
66a	12 bits, signed, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	-80	—	-80	LSB	(3)
	Offset at 0g (With Offset Cancellation)							
67b	12 bits, unsigned	*	OFFSET	2047.75	2048	2048.25	LSB	(9,7)
68b	12 bits, signed	*	OFFSET	-0.25	0	+0.25	LSB	(9,7)
69b	12 bits, unsigned, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	2047.75	—	2048.25	LSB	(9)
70b	12 bits, signed, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		OFFSET	-0.25	—	+0.25	LSB	(9)
	Offset Monitor Thresholds							
71	Positive Threshold (12 bits signed)		$OFFTHR_{POS}$	—	100	—	LSB	(7)
72	Negative Threshold (12 bits signed)		$OFFTHR_{NEG}$	—	-100	—	LSB	(7)
	Range of Output (SPI, 12 bits, unsigned)							
73	Normal		RANGE	128	—	3968	LSB	(7)
74	Fault Response Code		FAULT	—	0	—	LSB	(7)
75	Unused Codes		UNUSED	1	—	127	LSB	(7)
76	Unused Codes		UNUSED	3969	—	4095	LSB	(7)
	Range of Output (SPI, 12 bits, signed)							
77	Normal		RANGE	-1920	—	1920	LSB	(7)
78	Unused Codes		UNUSED	-2047	—	-1921	LSB	(7)
79	Unused Codes		UNUSED	1921	—	2047	LSB	(7)
80	Nonlinearity	*	NL_{OUT}	-1	—	1	% FSR	(3)
	System Output Noise							
81	RMS (12 bits, All Ranges, 400 Hz, 3-pole LPF)		n_{RMS}	—	—	1	LSB	(3)
82	Peak to Peak (12 bits, All Ranges, 400 Hz, 3-pole LPF)		n_{P-P}	—	—	3	LSB	(3)
	Cross-Axis Sensitivity							
83	V_{ZX}	*	V_{ZX}	-4	—	+4	%	(3)
84	V_{YX}	*	V_{YX}	-4	—	+4	%	(3)
85	V_{ZY}	*	V_{ZY}	-4	—	+4	%	(3)
86	V_{XY}	*	V_{XY}	-4	—	+4	%	(3)

2.5 Self Test

$V_L \le (V_{CC} - V_{SS}) \le V_H$, $T_L \le T_A \le T_H$, $|\Delta T_A| < 25$ K/min unless otherwise specified.

#	Characteristic		Symbol	Min	Typ	Max	Units	
	Self Test Output Change (Ref Section 3.6)			ΔST_{MIN}	ΔST_{NOM}	ΔST_{MAX}		
87	80g, T_A = 25 °C	*	ΔST_{80_25}	582	727	872	LSB	(1)
88	80g, -40 °C ≤ T_A ≤ 105 °C	*	$\Delta ST_{80_\Delta T}$	545	727	909	LSB	(1)
89	80g, -40 °C ≤ T_A ≤ 105 °C, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		$\Delta ST_{80_\Delta T\Delta V}$	545	727	909	LSB	(3)
90	105.5 *g*, T_A = 25 °C	*	ΔST_{105_25}	442	553	663	LSB	(1)
91	105.5 g, -40 °C ≤ T_A ≤ 105 °C	*	$\Delta ST_{105_\Delta T}$	414	553	690	LSB	(1)
92	105.5 g, -40 °C ≤ T_A ≤ 105 °C, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		$\Delta ST_{105_\Delta T\Delta V}$	414	553	690	LSB	(3)
93	120g, T_A = 25 °C	*	ΔST_{120_25}	387	484	581	LSB	(1)
94	120g, -40 °C ≤ T_A ≤ 105 °C	*	$\Delta ST_{120_\Delta T}$	363	484	605	LSB	(1)
95	120g, -40 °C ≤ T_A ≤ 105 °C, $V_{CC_UV_f} \le V_{CC} - V_{SS} \le V_L$		$\Delta ST_{120_\Delta T\Delta V}$	363	484	605	LSB	(3)
	Self Test Cross-Axis Output							
96	Y-Axis Output with X-Axis Self Test		ΔSTCrossAxis	-10	—	+10	LSB	(1)
97	X-Axis Output with Y-Axis Self Test		ΔSTCrossAxis	-10	—	+10	LSB	(1)
	Self Test Output Accuracy							
98	Δ from Stored Value, including Sensitivity Error	*						
99	-40 °C ≤ T_A ≤ 105 °C (Ref Section 3.6)		ΔSTACC	-10	—	+10	%	(3)
	Sigma Delta Modulator Range							
100	X/Y-Axis, Any Range Positive/Negative		g_{ADCI_Clip}	375	400	450	g	(19)
	Acceleration (without hitting internal *g*-cell stops)							
101	X/Y-Axis, Any Range Positive/Negative		$g_{g\text{-}cell_Clip}$	500	560	600	g	(19)

2.6 Dynamic Electrical Characteristics - Signal Chain

$V_L \le (V_{CC} - V_{SS}) \le V_H$, $T_L \le T_A \le T_H$, $|\Delta T_A| < 25$ K/min unless otherwise specified.

#	Characteristic		Symbol	Min	Typ	Max	Units	
102	DSP Sample Rate (LPF 0,1,2,3,4,5)		t_S	—	$64/f_{OSC}$	—	s	(7)
103	DSP Sample Rate (LPF 8,9,10,11,12,13)		t_S	—	$128/f_{OSC}$	—	s	(7)
104	Interpolation Sample Rate		t_{INTERP}	—	$t_S/2$	—	s	(7)
	Data Path Latency (excluding *g*-cell and Low-pass Filter)							
105	$T_S = 64/f_{OSC}$	*	$t_{DataPath_8}$	33.0	34.8	36.5	µs	(7,16)
106	$T_S = 128/f_{OSC}$	*	$t_{DataPath_16}$	51.9	54.6	57.4	µs	(7,16)
	Low-Pass Filter (t_s = 8µs)							
107	Cutoff frequency 0: 100 Hz, 4-pole	*	$f_{C0(LPF)}$	95	100	105	Hz	(3,7,17)
108	Cutoff frequency 1: 300 Hz, 4-pole	*	$f_{C1(LPF)}$	285	300	315	Hz	(3,7,17)
109	Cutoff frequency 2: 400 Hz, 4-pole	*	$f_{C2(LPF)}$	380	400	420	Hz	(3,7,17)
110	Cutoff frequency 3: 800 Hz, 4-pole	*	$f_{C3(LPF)}$	760	800	840	Hz	(3,7,17)
111	Cutoff frequency 4: 1000 Hz, 4-pole	*	$f_{C4(LPF)}$	950	1000	1050	Hz	(3,7,17)
112	Cutoff frequency 5: 400 Hz, 3-pole	*	$f_{C5(LPF)}$	380	400	420	Hz	(3,7,17)
	Low-Pass Filter (t_s = 16µs)							
113	Cutoff frequency 8: 50 Hz, 4-pole	*	$f_{C8(LPF)}$	47.5	50	52.5	Hz	(3,7,17)
114	Cutoff frequency 9: 150 Hz, 4-pole	*	$f_{C9(LPF)}$	142.5	150	157.5	Hz	(3,7,17)
115	Cutoff frequency 10: 200 Hz, 4-pole	*	$f_{C10(LPF)}$	190	200	210	Hz	(3,7,17)
116	Cutoff frequency 11: 400 Hz, 4-pole	*	$f_{C11(LPF)}$	380	400	420	Hz	(3,7,17)
117	Cutoff frequency 12: 500 Hz, 4-pole	*	$f_{C12(LPF)}$	475	500	525	Hz	(3,7,17)
118	Cutoff frequency 13: 200 Hz, 3-pole	*	$f_{C13(LPF)}$	190	200	210	Hz	(3,7,17)
	Offset Cancellation (Normal Mode, 12-Bit Output)							
119	Offset Averaging Period	*	OFF_{AVEPER}	—	6.29146	—	s	(3,7)
120	Offset Slew Rate	*	OFF_{SLEW}	—	0.2384	—	LSB/s	(3,7)
121	Offset Update Rate	*	OFF_{RATE}	—	1049	—	ms	(3,7)
122	Offset Correction Value per Update Positive	*	OFF_{CORRP}	—	0.25	—	LSB	(3,7)
123	Offset Correction Value per Update Negative	*	OFF_{CORRN}	—	-0.25	—	LSB	(3,7)
124	Offset Correction Threshold Positive	*	OFF_{THP}	—	0.125	—	LSB	(3,7)
125	Offset Correction Threshold Negative	*	OFF_{THN}	—	0.125	—	LSB	(3,7)
	Self Test Activation Time ($\overline{CS}$ rising edge to 90% of ST Final Value)							
126	Cutoff frequency 0: 100 Hz, 4-pole		ST_ACT_{100}	—	—	7.00	ms	(19)
127	Cutoff frequency 1: 300 Hz, 4-pole		ST_ACT_{300}	—	—	3.00	ms	(19)
128	Cutoff frequency 2: 400 Hz, 4-pole		ST_ACT_{400}	—	—	2.50	ms	(19)
129	Cutoff frequency 3: 800 Hz, 4-pole		ST_ACT_{800}	—	—	1.70	ms	(19)
130	Cutoff frequency 4: 1000 Hz, 4-pole		ST_ACT_{1000}	—	—	1.60	ms	(19)
131	Cutoff frequency 5: 400 Hz, 3-pole		$ST_ACT_{400_3}$	—	—	2.40	ms	(19)
132	Offset Monitor Bypass Time after Self Test Deactivation		t_{ST_OMB}	—	320	—	t_S	(3,7)
133	Time Between Acceleration Data Requests (Same Axis)		t_{ACC_REQ}	15	—	—	µs	(3,7,20)
	Arming Output Activation Time (ARM_X, ARM_Y, I_{ARM} = 200µA)							
134	Moving Average and Count Arming Modes (2,3,4,5)		t_{ARM}	0	—	1.51	µs	(3,12)
135	Unfiltered Mode Activation Delay (Reference Figure 30)		$t_{ARM_UF_DLY}$	0	—	1.51	µs	(3,12)
136	Unfiltered Mode Arm Assertion Time (Reference Figure 30)		$t_{ARM_UF_ASSERT}$	5.00	—	6.579	µs	(3)
137	Sensing Element Natural Frequency		f_{gcell}	10791	13464	15879	Hz	(19)
138	Sensing Element Cutoff Frequency (-3 dB ref. to 0 Hz)		f_{gcell}	0.851	1.58	2.29	kHz	(19)
139	Sensing Element Damping Ratio		ζ_{gcell}	2.46	4.31	9.36	—	(19)
140	Sensing Element Delay (@100 Hz)		f_{gcell_delay}	70	101	187	µs	(19)
141	Sensing Element Step Response (0% - 90%)		t_{Step_gcell}	—	—	200	µs	(19)
142	Package Resonance Frequency		$f_{Package}$	100	—	—	kHz	(19)
143	Package Quality Factor		$q_{Package}$	1	—	5	—	(19)

2.7 Dynamic Electrical Characteristics - Supply and SPI

$V_L \le (V_{CC} - V_{SS}) \le V_H$, $T_L \le T_A \le T_H$, $|\Delta T_A| < 25$ K/min unless otherwise specified

#	Characteristic		Symbol	Min	Typ	Max	Units	
144	Power-On Recovery Time (VCC = VCCMIN to first SPI access)		t_{OP}	—	—	10	ms	(3)
145	Power-On Recovery Time (Internal POR to first SPI access)		t_{OP}	—	—	840	µs	(3,7)
146	SPI Reset Activation Time (CS high to Reset)		t_{SPI_RESET}	—	—	300	ns	(7)
147	Internal Oscillator Frequency	*	f_{OSC}	7.6	8	8.4	MHz	(7)
148	Test Frequency - Divided from Internal Oscillator		f_{OSCTST}	0.95	1	1.05	MHz	(1)
	Serial Interface Timing (See Figure 7, $C_{MISO} \le 80$pF, $R_{MISO} \ge 10$kW)							
149	Clock (SCLK) period (10% of V_{CC} to 10% of V_{CC})	*	t_{SCLK}	120	—	—	ns	(3)
150	Clock (SCLK) high time (90% of V_{CC} to 90% of V_{CC})	*	t_{SCLKH}	40	—	—	ns	(3)
151	Clock (SCLK) low time (10% of V_{CC} to 10% of V_{CC})	*	t_{SCLKL}	40	—	—	ns	(3)
152	Clock (SCLK) rise time (10% of V_{CC} to 90% of V_{CC})		t_{SCLKR}	—	15	40	ns	(19)
153	Clock (SCLK) fall time (90% of V_{CC} to 10% of V_{CC})		t_{SCLKF}	—	15	28	ns	(19)
154	$\overline{CS}$ asserted to SCLK high ($\overline{CS}$ = 10% of V_{CC} to SCLK = 10% of V_{CC})		t_{LEAD}	60	—	—	ns	(3)
155	$\overline{CS}$ asserted to MISO valid ($\overline{CS}$ = 10% of V_{CC} to MISO = 10/90% of V_{CC})		t_{ACCESS}	—	—	60	ns	(3)
156	Data setup time (MOSI = 10/90% of V_{CC} to SCLK = 10% of V_{CC})	*	t_{SETUP}	20	—	—	ns	(3)
157	MOSI Data hold time (SCLK = 90% of V_{CC} to MOSI = 10/90% of V_{CC})	*	t_{HOLD_IN}	10	—	—	ns	(3)
158	MISO Data hold time (SCLK = 90% of V_{CC} to MISO = 10/90% of V_{CC})	*	t_{HOLD_OUT}	0	—	—	ns	(3)
159	SCLK low to data valid (SCLK = 10% of V_{CC} to MISO = 10/90% of V_{CC})	*	t_{VALID}	—	—	35	ns	(3)
160	SCLK low to $\overline{CS}$ high (SCLK = 10% of V_{CC} to $\overline{CS}$ = 90% of V_{CC})	*	t_{LAG}	60	—	—	ns	(3)
161	$\overline{CS}$ high to MISO disable ($\overline{CS}$ = 90% of V_{CC} to MISO = Hi Z)	*	$t_{DISABLE}$	—	—	60	ns	(3)
162	$\overline{CS}$ high to $\overline{CS}$ low ($\overline{CS}$ = 90% of V_{CC} to $\overline{CS}$ = 90% of V_{CC})	*	t_{CSN}	526	—	—	ns	(3)
163	SCLK low to $\overline{CS}$ low (SCLK = 10% of V_{CC} to $\overline{CS}$ = 90% of V_{CC})	*	t_{CLKCS}	50	—	—	ns	(3)
164	$\overline{CS}$ high to SCLK high ($\overline{CS}$ = 90% of V_{CC} to SCLK = 90% of V_{CC})		t_{CSCLK}	50	—	—	ns	(19)

1. Parameters tested 100% at final test.
2. Parameters tested 100% at wafer probe.
3. Parameters verified by characterization
4. (*) Indicates a critical characteristic.
5. Verified by qualification testing.
6. Parameters verified by pass/fail testing in production.
7. Functionality verified 100% via scan. Timing characteristic is directly determined by internal oscillator frequency.
8. N/A.
9. Devices are trimmed at 100 Hz with 1000 Hz low-pass filter option selected. Response is corrected to 0 Hz response.
10. Low-pass filter cutoff frequencies shown are -3 dB referenced to 0 Hz response.
11. Power supply ripple at frequencies greater than 900 kHz should be minimized to the greatest extent possible.
12. Time from falling edge of $\overline{CS}$ to ARM_X, ARM_Y output valid
13. N/A.
14. Thermal resistance between the die junction and the exposed pad; cold plate is attached to the exposed pad.
15. Device characterized at all values of V_L and V_H. Production test is conducted at all typical voltages (V_{TYP}) unless otherwise noted.
16. Data Path Latency is the signal latency from *g*-cell to SPI output disregarding filter group delays.
17. Filter characteristics are specified independently, and do not include *g*-cell frequency response.
18. Electrostatic Deflection Test completed during wafer probe.
19. Verified by Simulation.
20. Acceleration Data Request timing constraint only applies for proper operation of the Arming Function.

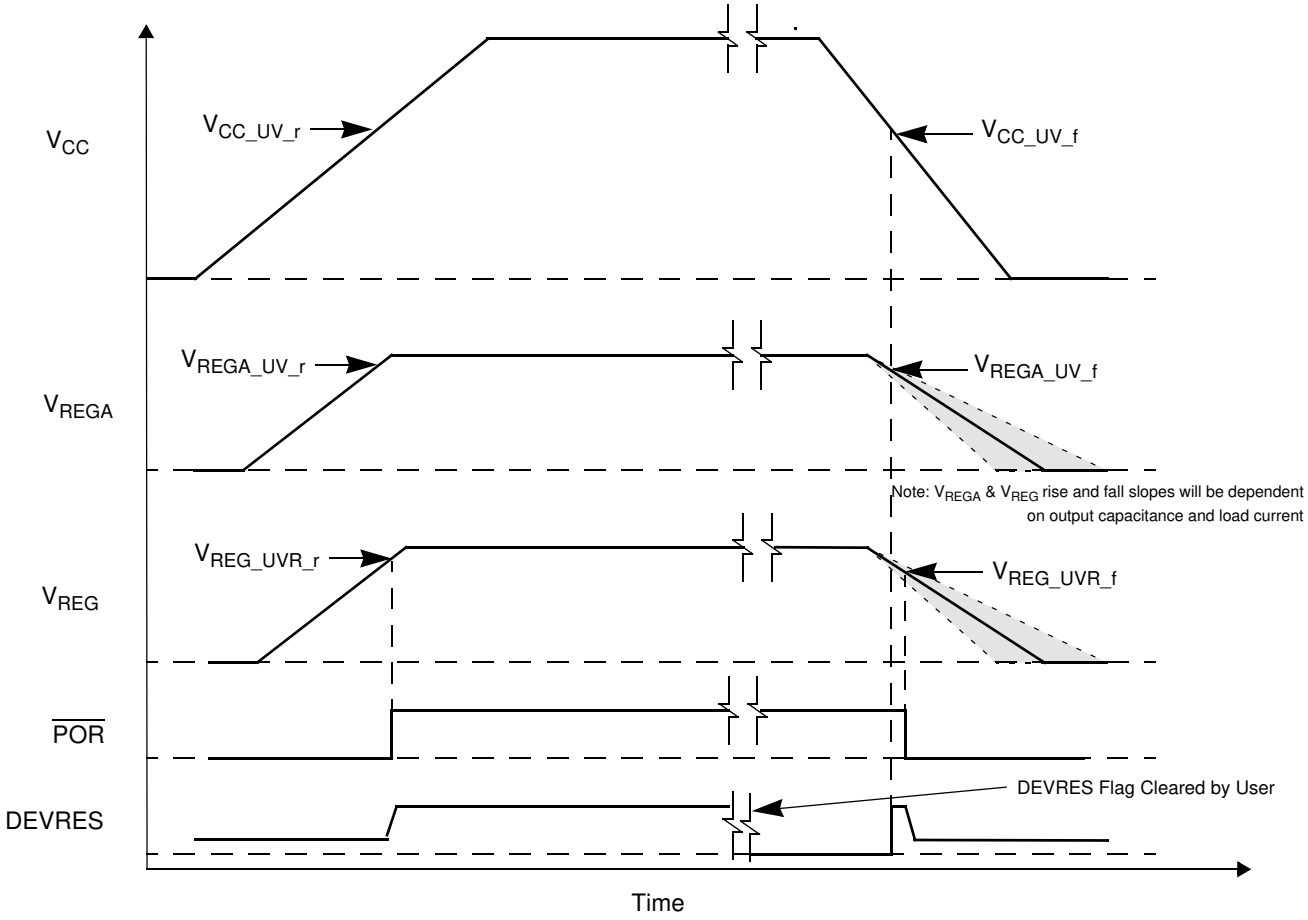

Figure 6. Power-Up Timing

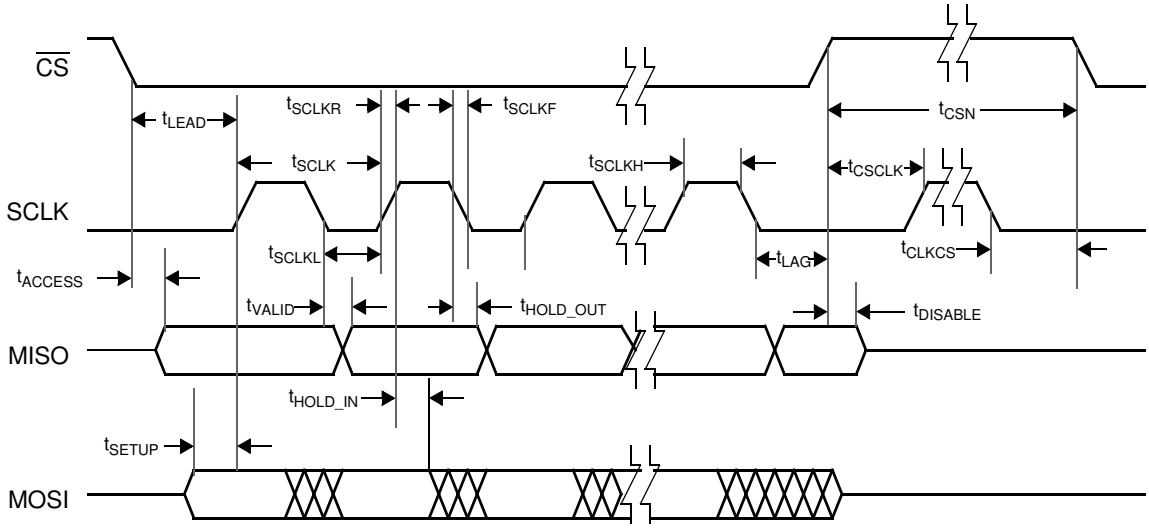

Figure 7. Serial Interface Timing

3 Functional Description

3.1 Customer Accessible Data Array

A customer accessible data array allows for each device to be customized. The array consists of an OTP factory programmable block and read/write registers for device programmability and status. The OTP and writable register blocks incorporate independent CRC circuitry for fault detection (reference Section 3.2). The writable register block includes a locking mechanism to prevent unintended changes during normal operation. Portions of the array are reserved for factory-programmed trim values. The customer accessible data is shown in the table below.

Table 3. Customer Accessible Data

Location		Bit Function								Type
Addr	Register	7	6	5	4	3	2	1	0	
$00	SN0	SN[7]	SN[6]	SN[5]	SN[4]	SN[3]	SN[2]	SN[1]	SN[0]	F
$01	SN1	SN[15]	SN[14]	SN[13]	SN[12]	SN[11]	SN[10]	SN[9]	SN[8]	
$02	SN2	SN[23]	SN[22]	SN[21]	SN[20]	SN[19]	SN[18]	SN[17]	SN[16]	
$03	SN3	SN[31]	SN[30]	SN[29]	SN[28]	SN[27]	SN[26]	SN[25]	SN[24]	
$04	STDEFL_X	STDEFL_X[7]	STDEFL_X[6]	STDEFL_X[5]	STDEFL_X[4]	STDEFL_X[3]	STDEFL_X[2]	STDEFL_X[1]	STDEFL_X[0]	
$05	STDEFL_Y	STDEFL_Y[7]	STDEFL_Y[6]	STDEFL_Y[5]	STDEFL_Y[4]	STDEFL_Y[3]	STDEFL_Y[2]	STDEFL_Y[1]	STDEFL_Y[0]	
$06	FCTCFG_X	1	0	0	0	0	0	0	1	
$07	FCTCFG_Y	1	0	0	0	0	0	0	1	
$08	PN	PN[7]	PN[6]	PN[5]	PN[4]	PN[3]	PN[2]	PN[1]	PN[0]	
$09	Invalid Address: “Invalid Register Request”									
$0A	DEVCTL	RES_1	RES_0	OCPHASE[1]	OCPHASE[0]	OFFCFG_EN	Reserved	Reserved	Reserved	R/W
$0B	DEVCFG	$\overline{OC}$	Reserved	ENDINIT	$\overline{SD}$	OFMON	A_CFG[2]	A_CFG[1]	A_CFG[0]	
$0C	DEVCFG_X	ST_X	Reserved	Reserved	Reserved	LPF_X[3]	LPF_X[2]	LPF_X[1]	LPF_X[0]	
$0D	DEVCFG_Y	ST_Y	Reserved	Reserved	Reserved	LPF_Y[3]	LPF_Y[2]	LPF_Y[1]	LPF_Y[0]	
$0E	ARMCFGX	Reserved	Reserved	APS_X[1]	APS_X[0]	AWS_XN[1]	AWS_XN[0]	AWS_XP[1]	AWS_XP[0]	
$0F	ARMCFGY	Reserved	Reserved	APS_Y[1]	APS_Y[0]	AWS_YN[1]	AWS_YN[0]	AWS_YP[1]	AWS_YP[0]	
$10	ARMT_XP	AT_XP[7]	AT_XP[6]	AT_XP[5]	AT_XP[4]	AT_XP[3]	AT_XP[2]	AT_XP[1]	AT_XP[0]	
$11	ARMT_YP	AT_YP[7]	AT_YP[6]	AT_YP[5]	AT_YP[4]	AT_YP[3]	AT_YP[2]	AT_YP[1]	AT_YP[0]	
$12	ARMT_XN	AT_XN[7]	AT_XN[6]	AT_XN[5]	AT_XN[4]	AT_XN[3]	AT_XN[2]	AT_XN[1]	AT_XN[0]	
$13	ARMT_YN	AT_YN[7]	AT_YN[6]	AT_YN[5]	AT_YN[4]	AT_YN[3]	AT_YN[2]	AT_YN[1]	AT_YN[0]	
$14	DEVSTAT	UNUSED	IDE	UNUSED	DEVINIT	MISOERR	OFF_Y	OFF_X	DEVRES	R
$15	COUNT	COUNT[7]	COUNT[6]	COUNT[5]	COUNT[4]	COUNT[3]	COUNT[2]	COUNT[1]	COUNT[0]	
$16	OFFCORR_X	OFFCORR_X[7]	OFFCORR_X[6]	OFFCORR_X[5]	OFFCORR_X[4]	OFFCORR_X[3]	OFFCORR_X[2]	OFFCORR_X[1]	OFFCORR_X[0]	
$17	OFFCORR_Y	OFFCORR_Y[7]	OFFCORR_Y[6]	OFFCORR_Y[5]	OFFCORR_Y[4]	OFFCORR_Y[3]	OFFCORR_Y[2]	OFFCORR_Y[1]	OFFCORR_Y[0]	
$1C	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	
$1D	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	

Type codes

F: Factory programmed OTP locationR/W:Read/write register

R: Read-only registerN/A:Not applicable

3.1.1 Device Serial Number Registers

A unique serial number is programmed into the serial number registers of each device during manufacturing. The serial number is composed of the following information:

Bit Range	Content
S12 - S0	Serial Number
S31 - S13	Lot Number

Serial numbers begin at 1 for all produced devices in each lot, and are sequentially assigned. Lot numbers begin at 1 and are sequentially assigned. No lot will contain more devices than can be uniquely identified by the 13-bit serial number. Depending on lot size and quantities, all possible lot numbers and serial numbers may not be assigned.

The serial number registers are included in the OTP shadow register array CRC verification. Reference Section 3.2.1 for details regarding the CRC verification. Beyond this, the contents of the serial number registers have no impact on device operation or performance, and are only used for traceability purposes.

3.1.2 Self Test Deflection Registers (STDEFL_X, STDEFL_Y)

These read-only registers provide the nominal self test deflection values for each axis at ambient temperature. The self test value is a positive deflection value, measured at the factory, and factory programmed for each device. The minimum stored value ($00) equates to the minimum deflection specified in Section 2.4 (ΔST_{MIN}), and the maximum stored value ($FF) equates to the maximum deflection specified in Section 2.4 (ΔST_{MAX}).

Table 4. Self Test Deflection Registers

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$04	STDEFL_X	STDEFL_X[7]	STDEFL_X[6]	STDEFL_X[5]	STDEFL_X[4]	STDEFL_X[3]	STDEFL_X[2]	STDEFL_X[1]	STDEFL_X[0]
$05	STDEFL_Y	STDEFL_Y[7]	STDEFL_Y[6]	STDEFL_Y[5]	STDEFL_Y[4]	STDEFL_Y[3]	STDEFL_Y[2]	STDEFL_Y[1]	STDEFL_Y[0]

When self test is activated, the acceleration reading can be compared to the value in this register. The difference from the measured deflection value, and the nominal deflection value stored in the register shall not fall outside the self test accuracy limits specified in Section 2.4 (ΔST_{ACC}). Reference Section 3.6 for more details on calculating the self test limits.

3.1.3 Factory Configuration Registers

The factory configuration registers are one time programmable, read only registers which contain customer specific device configuration information that is programmed by NXP.

Table 5. Factory Configuration Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$06	FCTCFG_X	1	0	0	0	0	0	0	1
$07	FCTCFG_Y	1	0	0	0	0	0	0	1

3.1.4 Part Number Register (PN)

The part number register is a one time programmable, read only register which contains two digits of the device part number to identify the axis and range information. The contents of this register have no impact on device operation or performance.

Table 6. Part Number Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$08	PN	PN[7]	PN[6]	PN[5]	PN[4]	PN[3]	PN[2]	PN[1]	PN[0]

PN Register Value		X-Axis Range Section 2.4	Y-Axis Range Section 2.4
Decimal	**HEX**		
219	$DB	80	80
225	$E1	105	105
227	$E3	120	120

3.1.5 Device Control Register (DEVCTL

The device control register is a read-write register which contains device control operations. The upper 2 bits of this register can be written during both initialization and normal operation. Bits 5 through 0 can be programmed during initialization and then are ignored once the ENDINIT bit is set.

Table 7. Device Control Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0A	DEVCTL	RES_1	RES_0	OCPHASE[1]	OCPHASE[0]	OFFCFG_EN	Reserved	Reserved	Reserved
Reset Value		0	0	0	0	0	0	0	0

3.1.5.1 Reset Control (RES_1, RES_0)

A series of three consecutive register write operations to the reset control bits in the DEVCTL register will cause a device reset. To reset the internal digital circuitry, the following register write operations must be performed in the order shown below. The register write operations must be consecutive SPI commands in the order shown or the device will not be reset.

Register Write to DEVCTL	RES_1	RES_0	Effect
SPI Register Write 1	0	0	No Effect
SPI Register Write 2	1	1	No Effect
SPI Register Write 3	0	1	Device RESET

The response to the Register Write returns ‘0’ for RES_1 and RES_0, and the existing register value bits 5 through 0. A Register Read of RES_1 and RES_0 returns ‘0’ and terminates the reset sequence. If ENDINIT is cleared, the bits 2 through 0 in the DEVCTL register are modified as described in Section 4.4. If ENDINIT is set, a Register Write will not modify bits 2 through 0 and the response to a Register Read or Write will include the last successful written values for these bits.

3.1.5.2 Offset Cancellation Phase Control Bits (OCPHASE[1:0])

The offset cancellation phase control bits control the offset cancellation start up phase. These bits can be written at any time ENDINIT is '0' if the OFFCFG_EN bit is set.

OFFCFG_EN	OCPHASE[1]	OCPHASE[0]	Writes to OCPHASE[1:0]	Offset Cancellation Phase
0	Don't Care	Don't Care	Ignored	Continues from the previously written phase (OCPHASE[1:0]) as specified in Section 3.8.4.
1	0	0	Accepted	Remains in Start 1 until OFFCFG_EN is cleared or ENDINIT is set
1	0	1	Accepted	Remains in Start 2 until OFFCFG_EN is cleared or ENDINIT is set
1	1	0	Accepted	Remains in Start 3 until OFFCFG_EN is cleared or ENDINIT is set
1	1	1	Accepted	Remains in Normal Mode until OFFCFG_EN is cleared or ENDINIT is set

When ENDINIT is set, the OCPHASE[1:0] bits in a write command are ignored and the offset cancellation phase is set to "Normal". This can only be changed by a device reset. The response to a register read or write of the DEVCTL register once ENDINIT is set will return the last successfully written values of OCPHASE[1:0].

3.1.5.3 Offset Cancellation Configuration Enable Bit (OFFCFG_EN)

The offset cancellation phase configuration enable bit enables modification of the offset cancellation phase control bits (OCPHASE[1:0]) as shown in Section 3.1.5.2

When ENDINIT is set, the OFFCFG_EN bit in a write command is ignored, and the offset cancellation phase is set to "Normal". This can only be changed by a device reset. The response to a register read or write of the DEVCTL register once ENDINIT is set will return the last successfully written value of OFFCFG_EN.

3.1.5.4 Reserved Bits (DEVCTL[2:0])

Bits 2 through 0 of the DEVCTL register are reserved. A write to the reserved bits must always be logic '0' for normal device operation and performance.

3.1.6 Device Configuration Register (DEVCFG)

The device configuration register is a read/write register which contains data for general device configuration. The register can be written during initialization but is locked once the ENDINIT bit is set. This register is included in the writable register CRC check. Refer to Section 3.2.2 for details.

Table 8. Device Configuration Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0B	DEVCFG	$\overline{OC}$	Reserved	ENDINIT	$\overline{SD}$	OFMON	A_CFG[2]	A_CFG[1]	A_CFG[0]
Reset Value		0	0	0	0	0	0	0	0

3.1.6.1 Offset Cancelled Data Selection Bits ($\overline{OC}$)

The Offset Cancelled Data Selection Bit determines whether the SPI transmitted data is raw data or offset cancelled data.

$\overline{OC}$	SPI Data
0	Offset Cancelled
1	Raw Data

If the $\overline{OC}$ bit is cleared (Offset Cancelled Data), then the Offset Monitor is automatically enabled (OFMON = '1') regardless of the value written to DEVCFG[3].

3.1.6.2 Reserved Bit (Reserved)

Bits 6 of the DEVCFG register is reserved. A write to the reserved bit must always be logic '0' for normal device operation and performance.

3.1.6.3 End of Initialization Bit (ENDINIT)

The ENDINIT bit is a control bit used to indicate that the user has completed all device and system level initialization tests, and that the device will operate in normal mode. Once the ENDINIT bit is set, writes to all writable register bits are inhibited except for the DEVCTL register. Once written, the ENDINIT bit can only be cleared by a device reset. The writable register CRC check (reference Section 3.2.2) is only enabled when the ENDINIT bit is set.

When ENDINIT is set, the following occurs:

- Offset Cancellation is forced to normal mode. OCPHASE[1:0], and OFFCFG_EN remain in their previously set states.
- X-Axis Self Test is disabled. ST_X remains in its previously set states.
- Y-Axis Self Test is disabled. ST_Y remains in its previously set states.

3.1.6.4 $\overline{\text{SD}}$ Bit

The $\overline{\text{SD}}$ bit determines the format of acceleration data results. If the $\overline{\text{SD}}$ bit is set to a logic '1', unsigned results are transmitted, with the zero-g level represented by a nominal value of 512. If the $\overline{\text{SD}}$ bit is cleared, signed results are transmitted, with the zero-*g* level represented by a nominal value of 0.

$\overline{\text{SD}}$	Operating Mode
1	Unsigned Data Output
0	Signed Data Output

3.1.6.5 OFMON Bit

The OFMON bit determines if the offset monitor circuit is enabled. If the OFMON bit is set to a logic '1', the offset monitor is enabled. Reference Section 3.8.5. If the OFMON bit is cleared, the offset monitor is disabled.

OFMON	Operating Mode
1	Offset Monitor Circuit Enabled
0	Offset Monitor Circuit Disabled

If the $\overline{\text{OC}}$ bit in the DEVCFG register is cleared (Offset Cancelled Data), then the Offset Monitor is automatically enabled (OFMON = '1') regardless of the value written to DEVCFG[3].

3.1.6.6 ARM Configuration Bits (A_CFG[2:0])

The ARM Configuration Bits (A_CFG[2:0]) select the mode of operation for the ARM_X/PCM_X, ARM_Y/PCM_Y pins.

Table 9. Arming Output Configuration

A_CFG[2]	A_CFG[1]	A-CFG[0]	Operating Mode	Output Type	Reference
0	0	0	Arm Output Disabled	Hi Impedance	
0	0	1	PCM Output	Digital Output	Section 3.8.11
0	1	0	Moving Average Mode	Active High with Pulldown Current	Section 3.8.10.1
0	1	1	Moving Average Mode	Active Low with Pullup Current	Section 3.8.10.1
1	0	0	Count Mode	Active High with Pulldown Current	Section 3.8.10.2
1	0	1	Count Mode	Active Low with Pullup Current	Section 3.8.10.2
1	1	0	Unfiltered Mode	Active High with Pulldown Current	Section 3.8.10.3
1	1	1	Unfiltered Mode	Active Low with Pullup Current	Section 3.8.10.3

3.1.7 Axis Configuration Registers (DEVCFG_X, DEVCFG_Y)

The Axis configuration registers are read/write registers which contain axis specific configuration information. These registers can be written during initialization, but are locked once the ENDINIT bit is set. These registers are included in the writable register CRC check. Refer to Section 3.2.2 for details.

Table 10. Axis Configuration Registers

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0C	DEVCFG_X	ST_X	Reserved	Reserved	Reserved	LPF_X[3]	LPF_X[2]	LPF_X[1]	LPF_X[0]
$0D	DEVCFG_Y	ST_Y	Reserved	Reserved	Reserved	LPF_Y[3]	LPF_Y[2]	LPF_Y[1]	LPF_Y[0]
Reset Value		0	0	0	0	0	0	0	0

3.1.7.1 Self Test Control (ST_X, ST_Y)

The ST_X and ST_Y bits enable and disable the self test circuitry for their respective axes. Self test circuitry is enabled if a logic '1' is written to ST_X, or ST_Y and the ENDINIT bit has not been set. Enabling the self test circuitry results in a positive acceleration value on the enabled axis. Self test deflection values are specified in Section 2.4. ST_X and ST_Y are always cleared following internal reset.

When the self test circuitry is active, the offset cancellation block and the offset monitor status are suspended, and the status bits in the Acceleration Data Request Response will indicate "Self Test Active". Reference Section 3.8.4 and Section 4.2 for details. When the self test circuitry is disabled by clearing the ST_X or ST_Y bit, the offset monitor remains disabled until the time t_{ST_OMB} specified in Section 2.6 expires. However, the status bits in the Acceleration Data Request Response will immediately indicate that self test is deactivated.

When ENDINIT is set, self test is disabled. This can only be changed by a reset. A Register Write will not modify the ST_X and ST_Y bits and the response to a Register Read or Write will include the last successful written values for these bits.

3.1.7.2 Reserved Bits (Reserved)

Bits 6 through 4 of the DEVCFG_X and DEVCFG_Y registers are reserved. A write to the reserved bits must always be logic '0' for normal device operation and performance.

3.1.7.3 Low-Pass Filter Selection Bits (LPF_X[3:0], LPF_Y[3:0])

The Low-pass Filter selection bits independently select a low-pass filter for each axis as shown in Table 11. Refer to Section 3.8.3 for details regarding filter configurations.

Table 11. Low-pass Filter Selection Bits

LPF_X[3] / LPF_Y[3]	LPF_X[2] / LPF_Y[2]	LPF_X[1] / LPF_Y[1]	LPF_X[0] / LPF_Y[0]	Low-pass Filter Selected	Nominal Sample Rate (µs)
0	0	0	0	100 Hz, 4-pole	8
0	0	0	1	300 Hz, 4-pole	8
0	0	1	0	400 Hz, 4-pole	8
0	0	1	1	800 Hz, 4-pole	8
0	1	0	0	1000 Hz, 4-pole	8
0	1	0	1	400 Hz, 3-pole	8
0	1	1	0	Reserved	Reserved
0	1	1	1	Reserved	Reserved
1	0	0	0	50 Hz, 4-pole	16
1	0	0	1	150 Hz, 4-pole	16
1	0	1	0	200 Hz, 4-pole	16
1	0	1	1	400 Hz, 4-pole	16
1	1	0	0	500 Hz, 4-pole	16
1	1	0	1	200 Hz, 3-pole	16
1	1	1	0	Reserved	Reserved
1	1	1	1	Reserved	Reserved

Note: Filter characteristics do not include *g*-cell frequency response.

3.1.8 Arming Configuration Registers (ARMCFGX, ARMCFGY)

The arming configuration registers contain configuration information for the arming function. The values in these registers are only relevant if the arming function is operating in moving average mode, or count mode.

These registers can be written during initialization but are locked once the ENDINIT bit is set. Refer to Section 3.1.6.3. These registers are included in the writable register CRC check. Refer to Section 3.2.2 for details.

Table 12. Arming Configuration Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0E	ARMCFGX	Reserved	Reserved	APS_X[1]	APS_X[0]	AWS_XN[1]	AWS_XN[0]	AWS_XP[1]	AWS_XP[0]
$0F	ARMCFGY	Reserved	Reserved	APS_Y[1]	APS_Y[0]	AWS_YN[1]	AWS_YN[0]	AWS_YP[1]	AWS_YP[0]
Reset Value		0	0	0	0	1	1	1	1

3.1.9 Reserved Bits (Reserved)

Bits 7 through 6 of the ARMCFGX and ARMCFGY registers are reserved. A write to the reserved bits must always be logic ‘0’ for normal device operation and performance.

3.1.9.1 Arming Pulse Stretch (APS_X[1:0], APS_Y[1:0])

The APS_X[1:0] and APS_Y[1:0] bits set the programmable pulse stretch time for the arming outputs. Refer to Section 3.8.10 for more details regarding the arming function. Pulse stretch times are derived from the internal oscillator, so the tolerance on this oscillator applies.

Table 13. Arming Pulse Stretch Definitions

APS_X[1], APS_Y[1]	APS_X[0], APS_Y[0]	Pulse Stretch Time (Typical Oscillator)
0	0	0 mS
0	1	16.256 ms - 16.384 ms
1	0	65.408ms - 65.536 ms
1	1	261.888ms - 262.016 ms

3.1.9.2 Arming Window Size (AWS_Xx[1:0], AWS_Yx[1:0])

The AWS_Xx[1:0] & AWS_Yx[1:0] bits have different functions depending on the state of the A_CFG bits in the DEVCFG register. If the arming function is set to moving average mode, the AWS bits set the number of acceleration samples used for the arming function moving average. The number of samples is set independently for each axis and polarity. If the arming function is set to count mode, the AWS bits set the sample count limit for the arming function. The sample count limit is set independently for each axis. Refer to Section 3.8.10 for more details regarding the arming function.

Table 14. X-Axis Positive Arming Window Size Definitions (Moving Average Mode)

AWS_XP[1]	AWS_XP[0]	X-Axis Positive Window Size
0	0	2
0	1	4
1	0	8
1	1	16

Table 15. X-Axis Negative Arming Window Size Definitions (Moving Average Mode)

AWS_XN[1]	AWS_XN[0]	X-Axis Negative Window Size
0	0	2
0	1	4
1	0	8
1	1	16

Table 16. Y-Axis Positive Arming Window Size Definitions (Moving Average Mode)

AWS_YP[1]	AWS_YP[0]	Y-Axis Positive Window Size
0	0	2
0	1	4
1	0	8
1	1	16

Table 17. Y-Axis Negative Arming Window Size Definitions (Moving Average Mode)

AWS_YN[1]	AWS_YN[0]	Y-Axis Negative Window Size
0	0	2
0	1	4
1	0	8
1	1	16

Table 18. Arming Count Limit Definitions (Count Mode)

AWS_XN[1]	AWS_XN[0]	AWS_XP[1]	AWS_XP[0]	X-Axis Sample Count Limit
Don't Care	Don't Care	0	0	1
Don't Care	Don't Care	0	1	3
Don't Care	Don't Care	1	0	7
Don't Care	Don't Care	1	1	15

Table 19. Arming Count Limit Definitions (Count Mode)

AWS_YN[1]	AWS_YN[0]	AWS_YP[1]	AWS_YP[0]	Y-Axis Sample Count Limit
Don't Care	Don't Care	0	0	1
Don't Care	Don't Care	0	1	3
Don't Care	Don't Care	1	0	7
Don't Care	Don't Care	1	1	15

3.1.10 Arming Threshold Registers (ARMT_XP, ARMT_XN, ARMT_YP, ARMT_YN)

The arming threshold registers contain the X-axis and Y-axis positive and negative thresholds to be used by the arming function. Refer to Section 3.8.10 for more details regarding the arming function.

The arming threshold registers can be written during initialization but are locked once the ENDINIT bit is set. Refer to Section 3.1.6.3. The arming threshold registers are included in the writable register CRC check. Refer to Section 3.2.2 for details.

Table 20. Arming Threshold Registers

Location		Bit							
Address	Register	7	6	5	4	3	2	1	0
$10	ARMT_XP	AT_XP[7]	AT_XP[6]	AT_XP[5]	AT_XP[4]	AT_XP[3]	AT_XP[2]	AT_XP[1]	AT_XP[0]
$11	ARMT_YP	AT_YP[7]	AT_YP[6]	AT_YP[5]	AT_YP[4]	AT_YP[3]	AT_YP[2]	AT_YP[1]	AT_YP[0]
$12	ARMT_XN	AT_XN[7]	AT_XN[6]	AT_XN[5]	AT_XN[4]	AT_XN[3]	AT_XN[2]	AT_XN[1]	AT_XN[0]
$13	ARMT_YN	AT_YN[7]	AT_YN[6]	AT_YN[5]	AT_YN[4]	AT_YN[3]	AT_YN[2]	AT_YN[1]	AT_YN[0]
Reset Value		0	0	0	0	0	0	0	0

The values programmed into the threshold registers are the threshold values used for the arming function as described in Section 3.8.10. The threshold registers hold independent unsigned 8-bit values for each axis and polarity. Each threshold increment is equivalent to one output LSB. Table 21 shows examples of some threshold register values and the corresponding threshold.

Table 21. Threshold Register Value Examples

Axis Type		Programmed Thresholds		Positive Threshold (g)	Negative Threshold (g)
Range (g)	Sensitivity (LSB/g)	Positive (Decimal)	Negative (Decimal)		
80	24	100	50	4.17	-2.08
80	24	255	0	10.625	Disabled
80	24	50	20	2.08	-0.83
80	24	150	75	6.25	-3.125
105.5	18.2	100	50	5.50	-2.75
105.5	18.2	255	0	14.0	Disabled
105.5	18.2	50	20	2.75	-1.10
105.5	18.2	150	75	8.24	-4.12

If either the positive or negative threshold for one axis is programmed to $00, comparisons are disabled for only that polarity. The arming function still operates for the opposite polarity. If both the positive and negative arming thresholds for one axis are programmed to $00, the Arming function for the associated axis is disabled, and the associated output pin is disabled, regardless of the value of the A_CFG bits in the DEVCFG register.

3.1.11 Device Status Register (DEVSTAT)

The device status register is a read-only register. A read of this register clears the status flags affected by transient conditions. Reference Section 4.5 for details on the response for each status condition.

Table 22. Device Status Register

Location		Bit							
Address	Register	7	6	5	4	3	2	1	0
$14	DEVSTAT	UNUSED	IDE	UNUSED	DEVINIT	MISOERR	OFF_Y	OFF_X	DEVRES

3.1.11.1 Unused Bits (UNUSED)

The unused bits have no impact on operation or performance. When read these bits may be ‘1’ or ‘0’.

3.1.11.2 Internal Data Error Flag (IDE)

The internal data error flag is set if a customer or OTP register data CRC fault or other internal fault is detected as defined in Section 4.5.5. The internal data error flag is cleared by a read of the DEVSTAT register. If the error is associated with a CRC fault in the writable register array, the fault will be re-asserted and will require a device reset to clear. If the error is associated with the data stored in the fuse array, the fault will be re-asserted even after a device reset.

3.1.11.3 Device Initialization Flag (DEVINIT)

The device initialization flag is set during the interval between negation of internal reset and completion of internal device initialization. DEVINIT is cleared automatically. The device initialization flag is not affected by a read of the DEVSTAT register.

3.1.11.4 SPI MISO Data Mismatch Error Flag (MISOERR)

The MISO data mismatch flag is set when a MISO Data mismatch fault occurs as specified in Section 4.5.2. The MISOERR flag is cleared by a read of the DEVSTAT register.

3.1.11.5 Offset Monitor Error Flags (OFF_X, OFFSET_Y)

The offset monitor error flags are set if the acceleration signal of the associated axis reaches the specified offset limit. The offset monitor error flags are cleared by a read of the DEVSTAT register.

3.1.11.6 Device Reset Flag (DEVRES)

The device reset flag is set during device initialization following a device reset. The device reset flag is cleared by a read of the DEVSTAT register.

3.1.12 Count Register (COUNT)

The count register is a read-only register which provides the current value of a free-running 8-bit counter derived from the primary oscillator. A 10-bit pre-scaler divides the primary oscillator frequency by 1024. Thus, the value in the register increases by one count every 128 µs and the counter rolls over every 32.768 ms.

Table 23. Count Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$15	COUNT	COUNT[7]	COUNT[6]	COUNT[5]	COUNT[4]	COUNT[3]	COUNT[2]	COUNT[1]	COUNT[0]
Reset Value		0	0	0	0	0	0	0	0

3.1.13 Offset Correction Value Registers (OFFCORR_X, OFFCORR_Y)

The offset correction value registers are read-only registers which contain the most recent offset correction increment / decrement value from the offset cancellation circuit. The values stored in these registers indicate the amount of offset correction being applied to the SPI output data. The values have a resolution of 1 LSB.

Table 24. Offset Correction Value Register

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$16	OFFCORR_X	OFFCORR_X[7]	OFFCORR_X[6]	OFFCORR_X[5]	OFFCORR_X[4]	OFFCORR_X[3]	OFFCORR_X[2]	OFFCORR_X[1]	OFFCORR_X[0]
$17	OFFCORR_Y	OFFCORR_Y[7]	OFFCORR_Y[6]	OFFCORR_Y[5]	OFFCORR_Y[4]	OFFCORR_Y[3]	OFFCORR_Y[2]	OFFCORR_Y[1]	OFFCORR_Y[0]
Reset Value		0	0	0	0	0	0	0	0

3.1.14 Reserved Registers (Reserved)

Registers $1C and $1D are reserved. A write to the reserved bits must always be logic ‘0’ for normal device operation and performance.

Table 25. Reserved Registers

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$1C	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
$1D	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
Reset Value		0	0	0	0	0	0	0	0

3.2 Customer Accessible Data Array CRC Verification

3.2.1 OTP Shadow Register Array CRC Verification

The OTP shadow register array is verified for errors using a 3-bit CRC. The CRC verification uses a generator polynomial of g(x) = X^3 + X + 1, with a seed value = ‘111’. If a CRC error is detected in the OTP array, the IDE bit is set in the DEVSTAT register.

3.2.2 Writable Register CRC Verification

The writable registers in the data array are verified for errors using a 3-bit CRC. The CRC verification is enabled only when the ENDINIT bit is set in the DEVCFG register. The CRC verification uses a generator polynomial of g(x) = X^3+X+1, with a seed value = ‘111’. If a CRC error is detected in the writable register array, the IDE bit is set in the DEVSTAT register.

3.3 Voltage Regulators

Separate internal voltage regulators supply the analog and digital circuitry. External filter capacitors are required, as shown in Figure 1. The voltage regulator module includes voltage monitoring circuitry which indicates a device reset until the external supply and all internal regulated voltages are within predetermined limits. A reference generator provides a stable voltage which is used by the ΣΔ converters.

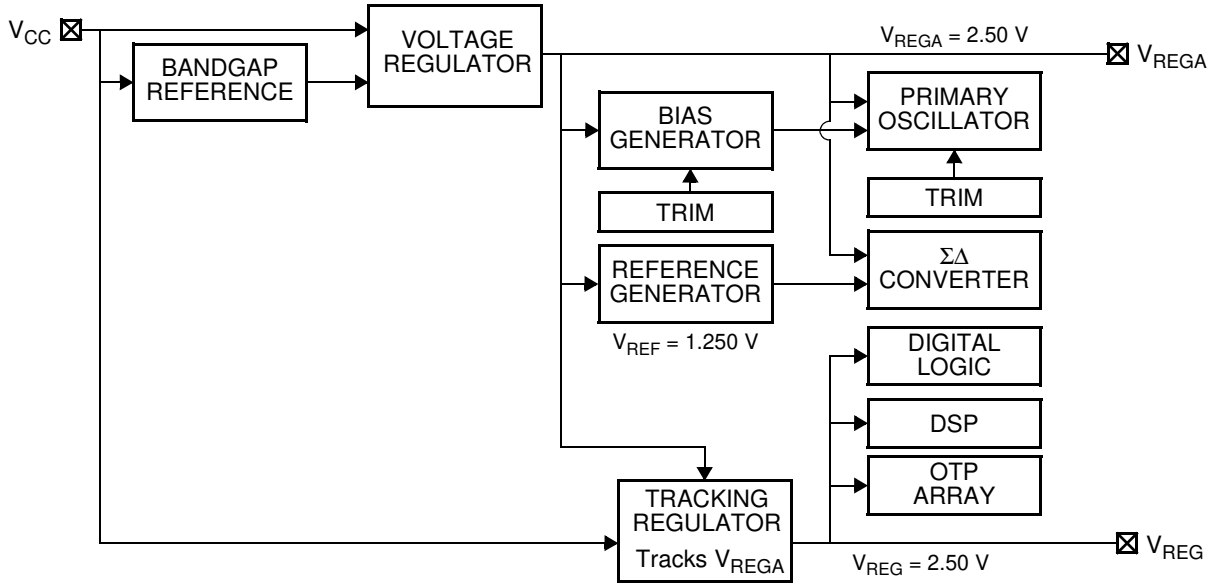

Figure 8. Power Supply Block Diagram

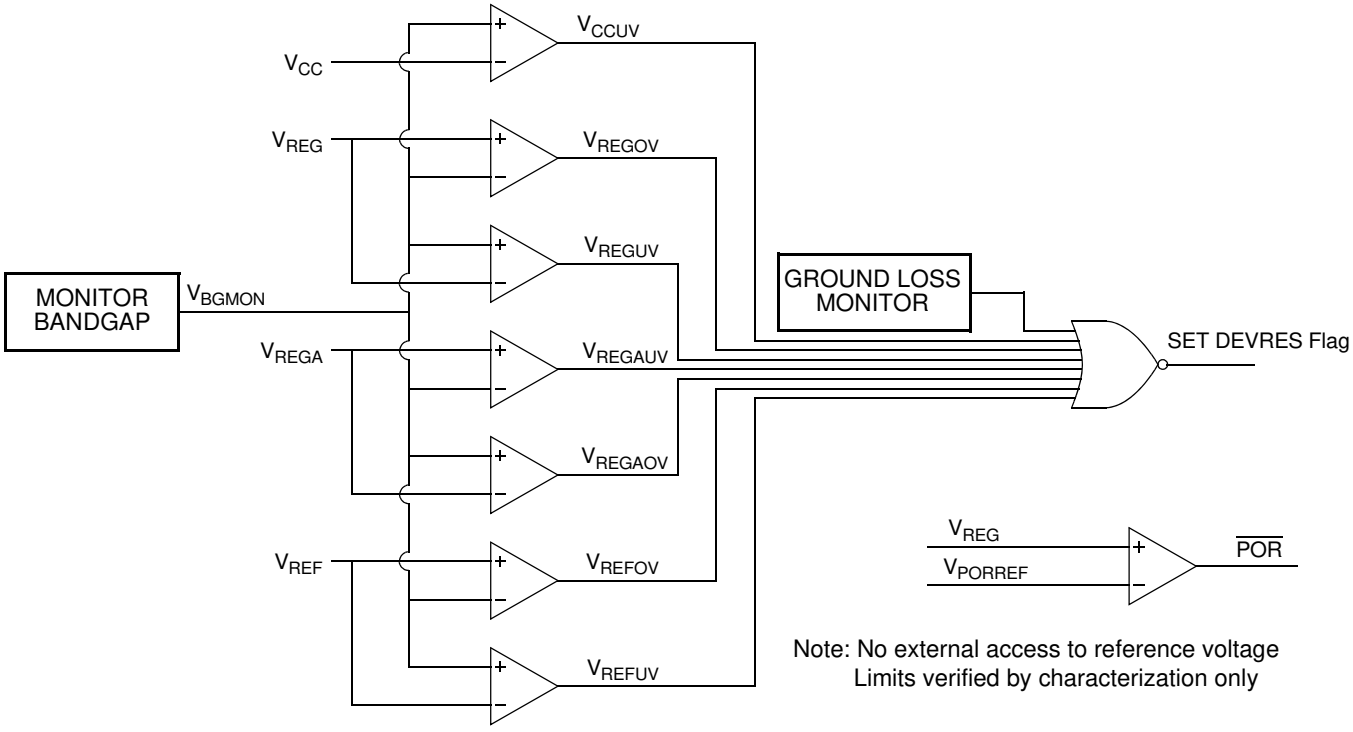

Figure 9. Voltage Monitoring

3.3.1 C_{VREG} Failure Detection

The digital supply voltage regulator is designed to be unstable with low capacitance. If the connection to the V_{REG} capacitor becomes open, the digital supply voltage will oscillate and cause either an under voltage, or over voltage failure within one internal sample time. This failure will result in one of the following:

1. The DEVRES flag in the DEVSTAT register will be set. The device will respond to SPI acceleration requests as defined in Table 30.
2. The device will be held in RESET and be non-responsive to SPI requests.

3.3.2 C_{VREGA} Failure Detection

The analog supply voltage regulator is designed to be unstable with low capacitance. If the connection to the V_{REGA} capacitor becomes open, the analog supply voltage will oscillate and cause either an under voltage, or over voltage failure within one internal sample time. The DEVRES flag in the DEVSTAT register will be set. The device will respond to SPI acceleration requests as defined in Table 30.

3.3.3 V_{SS} and V_{SSA} Ground Loss Monitor

The device detects the loss of ground connection to either V_{SS} or V_{SSA}. A loss of ground connection to V_{SS} will result in a V_{REG} overvoltage failure. A loss of ground connection to V_{SSA} will result in a V_{REG} undervoltage failure. Both failures result in a device reset.

3.3.4 SPI Initiated Reset

In addition to voltage monitoring, a device reset can be initiated by a specific series of three write operations involving the RES_1 and RES_0 bits in the DEVCTL register. Reference Section 3.1.5.1. for details regarding the SPI initiated reset.

3.4 Internal Oscillator

The device includes a factory trimmed oscillator as specified in Section 2.7.

3.4.1 Oscillator Monitor

The COUNT register in the customer accessible array is a read-only register which provides the current value of a free-running 8-bit counter derived from the primary oscillator. A 10-bit pre-scaler divides the primary oscillator by 1024. Thus, the value in the COUNT register increases by one count every 128 µs, and the register rolls over every 32.768 ms. The SPI master can periodically read the COUNT register, and verify the difference between subsequent register reads against the system time base.

1. The SPI access rates and deviations must be taken into account for this oscillator verification method.

3.4.2 CRC Based Clock Monitor

The device includes unique DSP cores for the X-Axis and Y-Axis. Each DSP core uses multiple frequencies derived from the oscillator, ranging from the base oscillator frequency to the base oscillator frequency divided by 256. In order to guarantee that the clocks for the two DSP cores are synchronized, a clock CRC monitor is employed. The CRC monitor is updated every cycle of the base oscillator.

3.5 Transducer

The transducer is an overdamped mass-spring-damper system described by the following transfer function:

$$H(s) = \frac{\omega_n^2}{s^2 + 2 \cdot \xi \cdot \omega_n \cdot s + \omega_n^2}$$

where:

ζ= Damping Ratio
ω_n= Natural Frequency = $2 * \Pi * f_n$

Reference Section 2.4 for transducer parameters.

3.6 Self Test Interface

When self test is enabled, the self test interface applies a voltage to the *g*-cell, causing a deflection of the proof mass. Once enabled, offset cancellation is suspended and the deflection results in an acceleration which is superimposed upon the input acceleration.

The resulting acceleration readings can be compared either against absolute limits, or the values stored in the Self Test Deflection Registers (Reference Section 3.1.2). The self test interface is controlled through SPI write operations to the DEVCFG_X and DEVCFG_Y registers described in Section 3.1.7 only if the ENDINIT bit in the DEVCFG register is cleared. A diagram of the self test interface is shown in Figure 10.

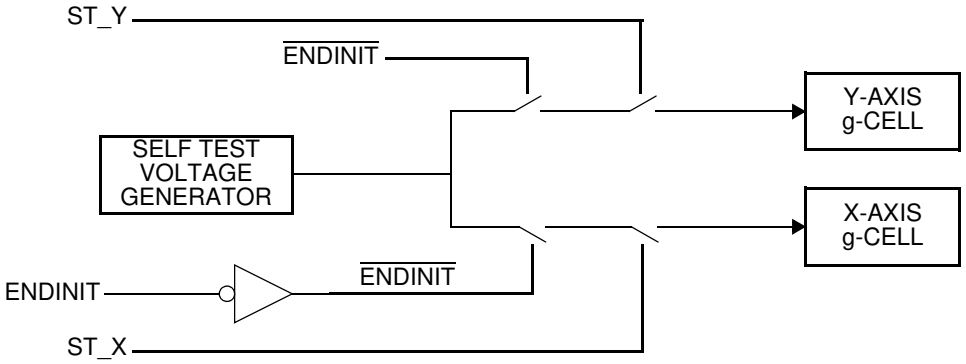

Figure 10. Self Test Interface

3.6.1 Raw Self Test Deflection Verification

The raw self test deflection can be directly verified against raw self test limits listed in Section 2.4.

3.6.2 Delta Self Test Deflection Verification

The raw self test deflection can be verified against the ambient temperature self test deflection value recorded at the time the device was produced. The production self test deflection is stored in the STDEFL_X and STDDEFL_Y registers such that the minimum stored value (0x00) is equivalent to ΔST_{MIN}, and the maximum stored value (0xFF) is equivalent to ΔST_{MAX}. The Delta Self Test Deflection limits can then be determined by the following equations:

$$\Delta ST_{ACCMINLIMIT} = FLOOR \cdot \left[\left(\Delta ST_{MIN} + \left[\frac{\Delta STDEFLx_{CNTS}}{255}\right] \times [\Delta ST_{MAX} - \Delta ST_{MIN}]\right) \times (1 - \Delta ST_{ACC})\right]$$

$$\Delta ST_{ACCMAXLIMIT} = CEIL \cdot \left[\left(\Delta ST_{MIN} + \left[\frac{\Delta STDEFLx_{CNTS}}{255}\right] \times [\Delta ST_{MAX} - \Delta ST_{MIN}]\right) \times (1 + \Delta ST_{ACC})\right]$$

where:

ΔST_{ACC}	The accuracy of the self test deflection relative to the stored deflection as specified in Section 2.4.
$\Delta STDEFLx_{CNTS}$	The value stored in the STDEFL_X or STDEFL_Y register.
ΔST_{MIN}	The minimum self test deflection at 25C as specified in Section 2.4.
ΔST_{MAX}	The maximum self test deflection at 25C as specified in Section 2.4.

3.7 ΣΔ Converter

A sigma delta converter provides the interface between the transducer and the DSP. The output of the ΣΔ converter is a data stream at a nominal frequency of 1 MHz.

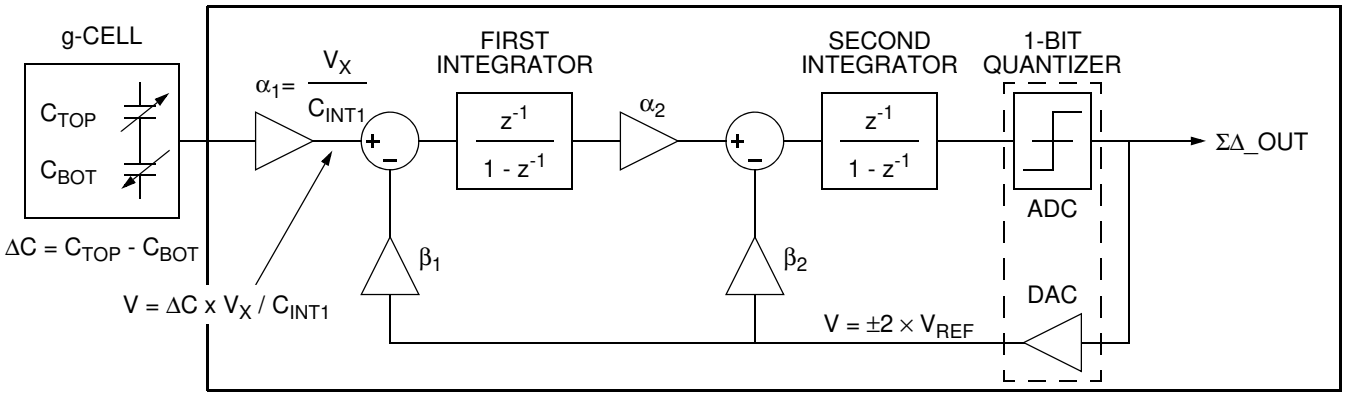

Figure 11. ΣΔ Converter Block Diagram

3.8 Digital Signal Processing Block

A digital signal processing (DSP) block is used to perform signal filtering and compensation operations. A diagram illustrating the signal processing flow is shown in Figure 12.

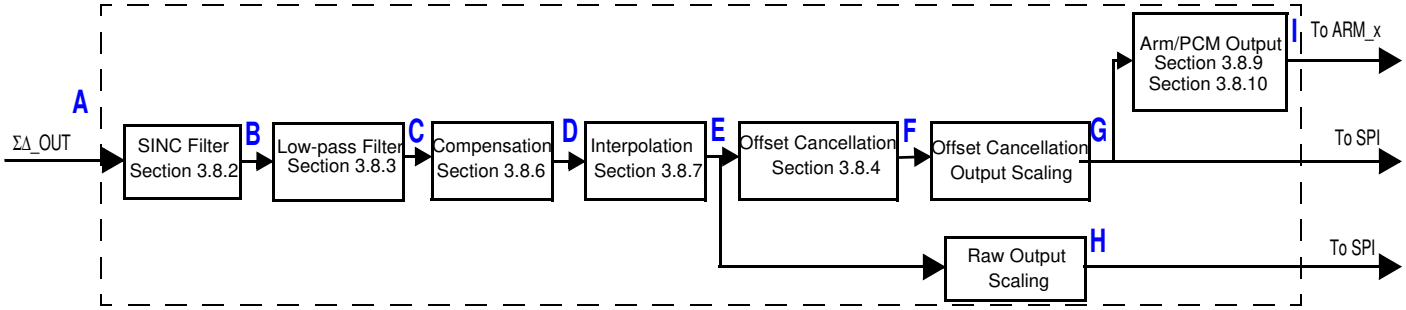

Figure 12. Signal Chain Diagram

Table 26. Signal Chain Characteristics

	Description	Sample Time (μs)	Data Width Bits	Over Range Bits	Effective Bits	Rounding Resolution Bits	Typical Block Latency	Reference
A	ΣΔ	1	1		1		3.2μs	Section 3.7
B	SINC Filter	8	14		13		11.2μs	Section 3.8.2
C	Low-pass Filter	8/16	20	4	12	4	Reference Section 3.8.3	Section 3.8.3
D	Compensation	8/16	20	4	12	4	7.875μs	Section 3.8.6
E	Interpolation	4/8	20	4	12	4	t_s / 2	Section 3.8.8
F	Offset Cancellation	256	20	4	12	4	N/A	Section 3.8.4
GH	SPI Output	4/8	—	—	12	—	t_s / 2	
I	PCM Output	4/8	—	—	9	—		Section 3.8.11