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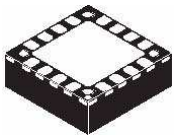
Document Number: MMA51xxL
Rev. 5.0, 01/2017

MMA51xxL, PSI5 Inertial Sensor

The MMA51xxL family, a SafeAssure solution, includes the AKLV27 and PSI5 Version 1.3 compatible overdamped Z-axis satellite accelerometers.

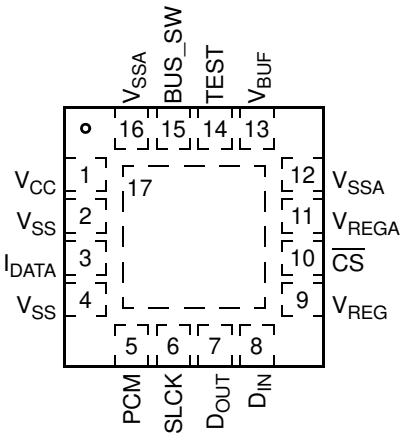
MMA51xxL

Bottom View



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

Top View



Pin connections

Features

- ±60 *g* to ±480 *g* Full-Scale Range
- Selectable 400 Hz, 3-Pole, or 4-pole Low-Pass Filter
- Single Pole High-Pass Filter with Fast Startup and Output Rate Limiting
- PSI5 Version 1.3 Compatible
  - PSI5-P10P-500/3L Compatible
  - Programmable Time Slots with 0.5 µs Resolution
  - Selectable Baud Rate: 125 kBaud or 190.5 kBaud
  - Selectable Data Length: 8 or 10 bits
  - Selectable Error Detection: Even Parity, or 3-bit CRC
  - Optional Daisy Chain with External Low-Side Switch
  - Two-Wire Programming Mode
- 16 µs Internal Sample Rate, with Interpolation to 1 µs
- Pb-free,16-pin QFN, 6 mm x 6 mm x 1.98 mm package

Typical Applications

- Airbag Front and Side Crash Detection

Referenced Documents

- Qualified AEC-Q100, Revision G, Grade 1 (-40 °C to +125 °C) (http://www.aecouncil.com/)

Ordering information

Device	Axis	Range	Package	Shipping
MMA5106LCW	Z	±60 *g*	98ASA00690D	Tubes
MMA5112LCW	Z	±120 *g*	98ASA00690D	Tubes
MMA5124LCW	Z	±240 *g*	98ASA00690D	Tubes
MMA5148LCW	Z	±480 *g*	98ASA00690D	Tubes
MMA5106LCWR2	Z	±60 *g*	98ASA00690D	Tape & Reel
MMA5112LCWR2	Z	±120 *g*	98ASA00690D	Tape & Reel
MMA5124LCWR2	Z	±240 *g*	98ASA00690D	Tape & Reel
MMA5148LCWR2	Z	±480 *g*	98ASA00690D	Tape & Reel

1 General Description

1.1 Application Diagram

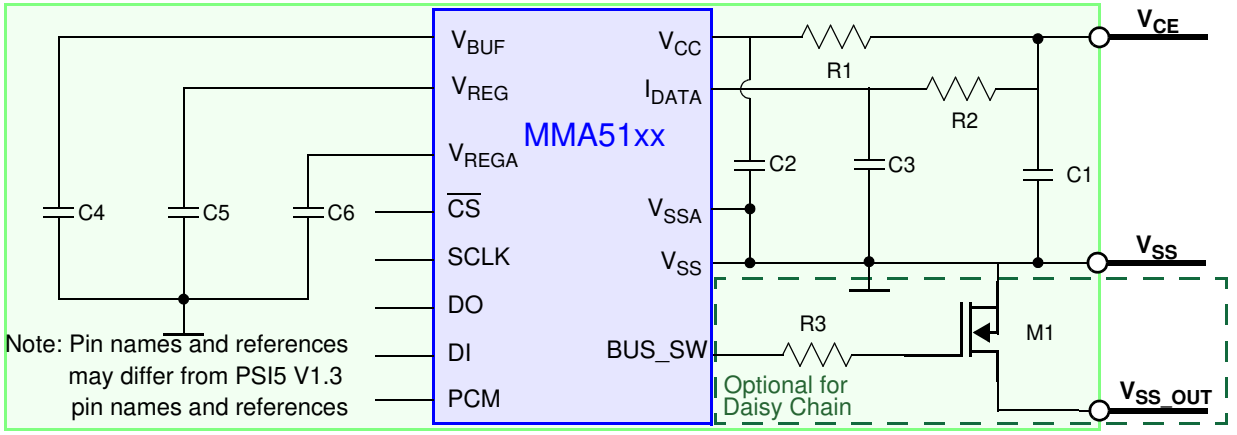


Figure 1. Application Diagram

Table 1. External Component Recommendations

Ref Des	Type	Description	Purpose
C1	Ceramic	2.2 nF, 10 %, 50 V minimum, X7R	V_{CC} Power Supply Decoupling and Signal Damping
C3	Ceramic	470 pF, 10 %, 50 V minimum, X7R	I_{DATA} Filtering and Signal Damping
C2	Ceramic	15 nF, 10 %, 50 V minimum, X7R	V_{CC} Power Supply Decoupling
C4, C5, C6	Ceramic	1 mF, 10 %, 10 V minimum, X7R	Voltage Regulator Output Capacitor(s)
R1	General Purpose	82 W, 5 %, 200 PPM	V_{CC} Filtering and Signal Damping
R2	General Purpose	27 W, 5 %, 200 PPM	I_{DATA} Filtering and Signal Damping
R3	General Purpose	20 kW, 5 %, 200 PPM	Gate Resistor for External Low-Side Daisy Chain FET
M1	N-Channel MOSFET	—	Low-Side Daisy Chain Transistor

1.2 Device Orientation and Part Marking

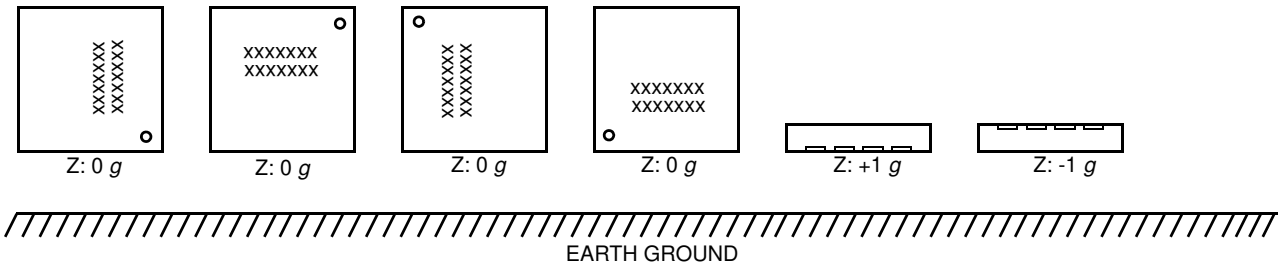


Figure 2. Device Orientation Diagram

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

Figure 3. Part Marking

1.3 Internal Block Diagram

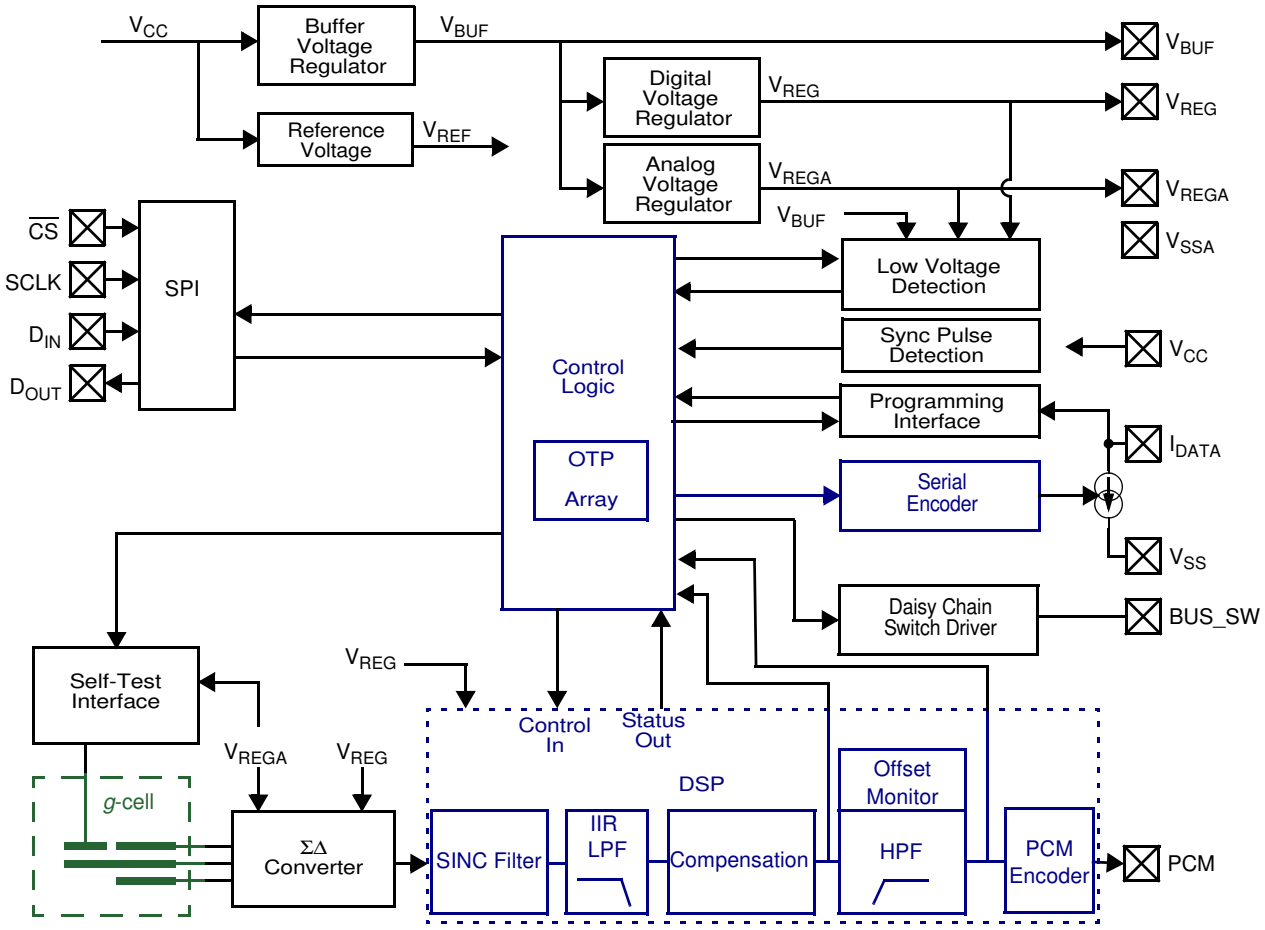


Figure 4. Internal Block Diagram

1.4 Pin Connections

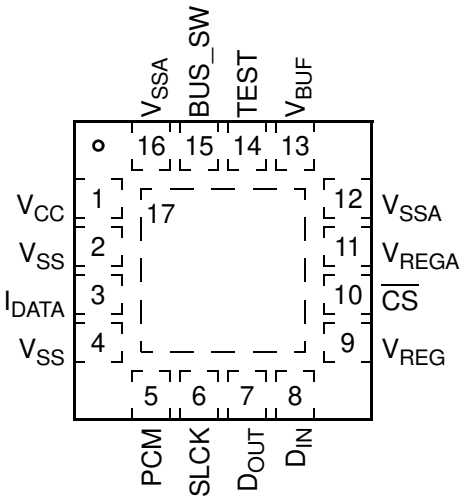


Figure 5. Top View, 16-Pin QFN Package

Table 2. Pin Description

Pin	Pin Name	Formal Name	Definition
1	V_{CC}	Supply	This pin is connected to the PSI5 power and data line through a resistor and supplies power to the device. An external capacitor must be connected between this pin and V_{SS}. Reference Figure 1.
2	V_{SS}	Digital GND	This pin is the power supply return node for the digital circuitry.
3	I_{DATA}	Response Current	This pin is connected to the PSI5 power and data line through a resistor and modulates the response current for PSI5 communication. Reference Figure 1.
4	V_{SS}	Digital GND	This pin is the power supply return node for the digital circuitry.
5	PCM	PCM Output	This pin provides a 4 MHz PCM signal proportional to the acceleration data for test purposes. The output can be enabled via OTP. Reference Section 3.5.3.7. If unused, this pin must be left unconnected.
6	SCLK	SPI Clock	This input pin provides the serial clock to the SPI port for test purposes. An internal pulldown device is connected to this pin. This pin must be grounded or left unconnected in the application.
7	D_{OUT}	SPI Data Out	This pin functions as the serial data output from the SPI port for test purposes. This pin must be left unconnected in the application.
8	D_{IN}	SPI Data In	This pin functions as the serial data input to the SPI port for test purposes. An internal pulldown device is connected to this pin. This pin must be grounded or left unconnected in the application.
9	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.
10	CS	Chip Select	This input pin provides the chip select to the SPI port for test purposes. An internal pullup device is connected to this pin.This pin must be left unconnected in the application.
11	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.
12	VSSA	Analog GND	This pin is the power supply return node for the analog circuitry.
13	V_{BUF}	Power Supply	This pin is connected to a buffer regulator for the internal circuitry. The buffer regulator supplies both the analog (V_{REGA}) and digital (V_{REG}) supplies to provide immunity from EMC and supply dropouts on V_{CC}. An external capacitor must be connected between this pin and V_{SS}. Reference Figure 1.
14	TEST	Test Pin	This pin is must be grounded or left unconnected in the application.
15	BUS_SW	Bus Switch Gate Drive	This pin is the drive for a low-side daisy chain switch. When daisy chain mode is enabled, this pin is connected to the gate of an n-channel FET which connects V_{SS} to V_{SS_OUT}. Reference Figure 1. If unused, this pin must be left unconnected.
16	VSSA	Analog GND	This pin is the power supply return node for the analog circuitry.
17	PAD	Die Attach Pad	This pin is the die attach flag, and is internally connected to VSS. Reference Section 7 for die attach pad connection details.
	Corner Pads	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	
	Supply Voltage (V_{CC}, I_{DATA})				
1	Reverse Current ≤ 160 mA, t ≤ 80 ms	V_{CC_REV}	-0.7	V	(3)
2	Continuous	V_{CC_MAX}	+20.0	V	(3)
3	Transient (< 10 µs)	V_{CC_TRANS}	+25.0	V	(9)
4	$V_{BUF,}$ Test, BUS_SW		-0.3 to +4.2	V	(3)
5	V_{REG}, $V_{REGA,}$ SCLK, $\overline{CS}$, D_{IN}, D_{OUT}, PCM		-0.3 to +3.0	V	(3)
6	Powered Shock (six sides, 0.5 ms duration)	g_{pms}	±2000	*g*	(3)
7	Unpowered Shock (six sides, 0.5 ms duration)	g_{shock}	±2500	*g*	(3)
8	Drop Shock (to concrete, tile or steel surface, 10 drops, any orientation)	h_{DROP}	1.2	m	(5)
	Electrostatic Discharge (per AEC-Q100)				
9	External Pins (V_{CC}, I_{DATA}, V_{SS}, V_{SSA}), HBM (100 pF, 1.5 kΩ)	V_{ESD}	±4000	V	(5)
10	HBM (100 pF, 1.5 kΩ)	V_{ESD}	±2000	V	(5)
11	CDM (R = 0 Ω)	V_{ESD}	±1500	V	(5)
12	MM (200 pF, 0 Ω)	V_{ESD}	±200	V	(5)
	Temperature Range				
13	Storage	T_{stg}	-40 to +125	°C	(3)
14	Junction	T_J	-40 to +150	°C	(9)
15	Thermal Resistance	θ_{JC}	2.5	°C/W	(9,14)

2.2 Operating Range

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

#	Characteristic	Symbol	Min	Typ	Max	Units	
	Supply Voltage		V_L		V_H		
16		V_{CC}	4.2	—	17.0	V	(1)
17		V_{CC_UV}	$V_{VCC\_UV\_F}$	—	V_L	V	(9)
18	Programming Voltage (I_{DATA} ≤ 85 mA) Applied to $I_{DATA,}$ V_{CC}	V_{PP}	14.0	—	—	V	(3)
	Operating Temperature Range		T_L		T_H		
19		T_A	-40	—	+105	°C	(1)
20		T_A	-40	—	+125	°C	(3)

2.3 Electrical Characteristics - Supply and I/O

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

#	Characteristic		Symbol	Min	Typ	Max	Units	
21	Quiescent Supply Current	*	I_{IDLE}	4.0	—	8.0	mA	(1)
22	Modulation Supply Current	*	I_{MOD}	I_{IDLE}+ 22.0	I_{IDLE}+ 26.0	I_{IDLE}+ 30.0	mA	(1)
23	Inrush Current (Power On until V_{BUF}, V_{REG}, V_{REGA} Stable)		I_{INRUSH}	—	—	30	mA	(3)
	Internally Regulated Voltages							
24	V_{BUF}	*	V_{BUF}	3.60	3.80	4.00	V	(1)
25	V_{REG}	*	V_{REG}	2.425	2.50	2.575	V	(1)
26	V_{REGA}	*	V_{REGA}	2.425	2.50	2.575	V	(1)
27	Low Voltage Detection Threshold							
28	V_{CC} Falling		$V_{VCC\_UV\_F}$	3.40	3.70	4.0	V	(3, 6)
29	V_{BUF} Falling		$V_{BUF\_UV\_F}$	2.95	3.15	3.35	V	(3, 6)
30	V_{REG} Falling		$V_{REG\_UV\_F}$	2.15	2.25	2.35	V	(3, 6)
	V_{REGA} Falling		$V_{REGA\_UV\_F}$	2.15	2.25	2.35	V	(3, 6)
	Hysteresis							
31	V_{CC}		V_{CC_HYST}	0.10	0.25	0.40	V	(3)
32	V_{BUF}		V_{BUF_HYST}	0.05	0.10	0.15	V	(3)
33	V_{REG}		V_{REG_HYST}	0.05	0.10	0.15	V	(3)
34	V_{REGA}		V_{REGA_HYST}	0.05	0.10	0.15	V	(3)
	External Capacitor (V_{BUF}, V_{REG}, V_{REGA})							
35	Capacitance			500	1000	1500	nF	(9)
36	ESR (including interconnect resistance)		ESR	0	—	200	mΩ	(9)
	Synchronization Pulse (See Figure 6)							
37	V_{IDLE} Voltage Range	*	V_{IDLE}	—	—	15.4	V	(3, 11)
38	DC Sync Pulse Detection Threshold	*	ΔV_{SYNC}	V_{IDLE}+1.4	V_{IDLE}+2.0	V_{IDLE}+2.6	V	(3, 6)
39	Sync Pulse Pulldown Current		I_{SYNC_PD}	—	I_{MOD} - I_{IDLE}	—	mA	(3)
	Output High Voltage (DO)							
40	I_{Load} = 100 µA		V_{OH}	V_{REG} - 0.1	—	—	V	(9)
	Output Low Voltage (DO)							
41	I_{Load} = 100 µA		V_{OL}	—	—	0.1	V	(9)
	Input High Voltage							
42	$\overline{CS}$, SCLK, DI		V_{IH}	0.7 * V_{REG}	—	—	V	(9)
	Input Low Voltage							
43	$\overline{CS}$, SCLK, DI		V_{IL}	—	—	0.3 * V_{REG}	V	(9)
	Input Current							
44	High (at V_{IH}) ($\overline{DI}$)		I_{IH}	-100	—	-10	µA	(9)
45	Low (at V_{IL}) ($\overline{CS}$)		I_{IL}	10	—	100	µA	(9)
46	Pulldown Resistance (SCLK)		R_{PD}	20	—	100	kΩ	(9)
	BUS_SW Output High Voltage (BUS_SW)							
47	I_{Load} = 100 µA		$V_{BUS\_SW\_OH}$	3.15	—	V_{BUF}	V	(9)
	Output Low Voltage (BUS_SW)							
48	I_{Load} = 100 µA		$V_{BUS\_SW\_OL}$	0.0	—	0.45	V	(9)
49	Daisy Chain Addressing Mode Sync Pulse Period			—	$t_{S\text{-}S\_PM\_L}$	—	s	(7)
	Bus Switch Output Activation Time (C = 50 pF)							
50	From last bit of “SetAdr” Response to 80% of $V_{BUS\_SW\_OH}$		t_{BUS_SW}	—	—	300	µs	(7)
	Sync Pulse Blanking Time after “SetAdr” Command Received							
51	From last bit of “SetAdr” Response		$t_{DC\_BLANKING}$		200000 / f_{OSC}		s	(7)

2.4 Electrical Characteristics - Sensor and Signal Chain

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

#	Characteristic		Symbol	Min	Typ	Max	Units	
	Sensitivity (10-bit output @ 100 Hz, referenced to 0 Hz)							
52	±60 *g* Range	*	SENS	—	8	—	LSB/g	(1)
53	±120 *g* Range	*	SENS	—	4	—	LSB/g	(1)
54	±240 *g* Range	*	SENS	—	2	—	LSB/g	(1)
55	±480 *g* Range	*	SENS	—	1	—	LSB/g	(1)
	Total Sensitivity Error (including non-linearity)							
56	T_A = 25 °C, ≤ ±240 *g*	*	ΔSENS_240	-5	—	+5	%	(1)
57	$T_L \le T_A \le T_H$, ≤ ±240 *g*	*	ΔSENS_240	-7	—	+7	%	(1)
58	$T_L \le T_A \le T_H$, ≤ ±240 *g*, $V_{VCC\_UV\_F} \le V_{CC} \le V_L$		ΔSENS_240	-7	—	+7	%	(9)
59	T_A = 25°C, > ±240 *g*	*	ΔSENS_480	-5	—	+5	%	(1)
60	$T_L \le T_A \le T_H$, > ±240 *g*	*	ΔSENS_480	-7	—	+7	%	(1)
61	$T_L \le T_A \le T_H$, > ±240 *g*, $V_{VCC\_UV\_F} \le V_{CC} \le V_L$		ΔSENS_480	-7	—	+7	%	(9)
	Digital Offset Before Offset Cancellation							
62	10-bit	*	OFF_{10Bit}	-52	0	+52	LSB	(1)
63	10-bit, $T_L \le T_A \le T_H$, $V_{VCC\_UV\_F} \le V_{CC} \le V_L$		OFF_{10Bit}	-52	0	+52	LSB	(9)
	Digital Offset After Offset Cancellation							
64	10-bit, 0.3 Hz HPF or 0.1 Hz HPF	*	OFF_{10Bit}	-1	0	+1	LSB	(1)
65	10-bit, 0.04 Hz HPF	*	OFF_{10Bit}	-2	0	+2	LSB	(9)
	Continuous Offset Monitor Limit							
66	10-bit output, before compensation		OFF_{MON}	-66	—	+66	LSB	(3)
	Range of Output (10-Bit Mode)							
67	Acceleration		RANGE	-480	—	+480	LSB	(3)
	Cross-Axis Sensitivity							
68	X-axis to Z-Axis	*	V_{XZ}	-5	—	+5	%	(3)
69	Y-axis to Z-Axis	*	V_{YZ}	-5	—	+5	%	(3)
70	System Output Noise Peak (10-bit Mode, 1 Hz - 1 kHz, All Ranges)	*	n_{Peak}	-4	—	+4	LSB	(3)
71	System Output Noise RMS (10-bit mode, 1 Hz - 1 kHz, All Ranges)	*	n_{RMS}	—	—	+1.0	LSB	(3)
	Non-linearity							
72	10-bit output, ≤ ±240 *g*		NL_{OUT_240g}	-2	—	+2	%	(3)
73	10-bit output, > ±240 *g*		NL_{OUT_480g}	-2	—	+2	%	(3)

2.5 Electrical Characteristics - Self-Test and Overload

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

#	Characteristic	Symbol	Min	Typ	Max	Units	
	10-Bit Output During Active Self-Test ($T_L \leq T_A \leq T_H$)						
74	±60 *g* Range *	g_{ST10_60Z}	120	—	280	LSB	(3)
75	±120 *g* Range *	g_{ST10_120Z}	40	—	160	LSB	(3)
76	±240 *g* Range *	g_{ST10_240Z}	35	—	153	LSB	(3)
77	±480 *g* Range *	g_{ST10_480Z}	12	—	94	LSB	(3)
	Acceleration (without hitting internal *g*-cell stops)						
78	±60 *g* Range Positive	$g_{g\text{-}cell\_Clip60ZP}$	425	642	980	*g*	(9)
79	±60 *g* Range Negative	$g_{g\text{-}cell\_Clip60ZN}$	-1205	-720	-512	*g*	(9)
	Acceleration (without hitting internal *g*-cell stops)						
80	±120 *g* Range Positive	$g_{g\text{-}cell\_Clip120ZP}$	425	642	980	*g*	(9)
81	±120 *g* Range Negative	$g_{g\text{-}cell\_Clip120ZN}$	-1205	-720	-512	*g*	(9)
	Acceleration (without hitting internal *g*-cell stops)						
82	±240 *g* Range Positive	$g_{g\text{-}cell\_Clip240ZP}$	1450	2180	2800	*g*	(9)
83	±240 *g* Range Negative	$g_{g\text{-}cell\_Clip240ZN}$	-3100	-2210	-1800	*g*	(9)
	Acceleration (without hitting internal *g*-cell stops)						
84	±480 *g* Range Positive	$g_{g\text{-}cell\_Clip480ZP}$	2200	2800	3300	*g*	(9)
85	±480 *g* Range Negative	$g_{g\text{-}cell\_Clip480ZN}$	-3700	-3220	-2780	*g*	(9)
	ΣΔ and Sinc Filter Clipping Limit						
86	±60 *g* Range Positive	$g_{ADC\_Clip60ZP}$	159	238	336	*g*	(9)
87	±60 *g* Range Negative	$g_{ADC\_Clip60ZN}$	-334	-274	-216	*g*	(9)
	ΣΔ and Sinc Filter Clipping Limit						
88	±120 *g* Range Positive	$g_{ADC\_Clip120ZP}$	305	433	577	*g*	(9)
89	±120 *g* Range Negative	$g_{ADC\_Clip120ZN}$	-693	-544	-414	*g*	(9)
	ΣΔ and Sinc Filter Clipping Limit						
90	±240 *g* Range Positive	$g_{ADC\_Clip240ZP}$	836	1178	1599	*g*	(9)
91	±240 *g* Range Negative	$g_{ADC\_Clip240ZN}$	-1909	-1566	-1245	*g*	(9)
	ΣΔ and Sinc Filter Clipping Limit						
92	±480 *g* Range Positive	$g_{ADC\_Clip480ZP}$	1591	2014	2478	*g*	(9)
93	±480gZ Range Negative	$g_{ADC\_Clip480ZN}$	-3217	-2856	-2524	*g*	(9)

2.6 Dynamic Electrical Characteristics - PSI5

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

#	Characteristic		Symbol	Min	Typ	Max	Units	
	Initialization Timing							
94	Phase 1		t_{PSI5_INIT1}	—	532000 / f_{OSC}	—	s	(7)
95	Phase 2 (10-Bit, Synchronous Mode, k = 4)		$t_{PSI5\_INIT2\_10s}$	—	256 * t_{S-S}	—	s	(7)
96	Phase 2 (8-Bit, Synchronous Mode, k = 8)		$t_{PSI5\_INIT2\_8s}$	—	288 * t_{S-S}	—	s	(7)
97	Phase 2 (10-Bit, Asynchronous Mode 0, k = 8)		$t_{PSI5\_INIT2\_10a0}$	—	512 * t_{ASYNC}	—	s	(7)
98	Phase 2 (8-Bit, Asynchronous Mode 0, k = 16)		$t_{PSI5\_INIT2\_8a0}$	—	576 * t_{ASYNC}	—	s	(7)
99	Phase 3 (10-Bit, Synchronous Mode, ST_RPT = 0)		$t_{PSI5\_INIT3\_10s}$	—	2 * t_{S-S}	—	s	(7, 12)
100	Phase 3 (8-Bit, Synchronous Mode, ST_RPT = 0)		$t_{PSI5\_INIT3\_8s}$	—	2 * t_{S-S}	—	s	(7, 12)
101	Phase 3 (10-Bit, Asynchronous Mode 0, ST_RPT = 0)		$t_{PSI5\_INIT3\_10a0}$	—	19 * t_{ASYNC}	—	s	(7, 12)
102	Phase 3 (8-Bit, Asynchronous Mode 0, ST_RPT = 0)		$t_{PSI5\_INIT3\_8a0}$	—	2 * t_{ASYNC}	—	s	(7, 12)
103	Offset Cancellation Stage 1 Operating Time		t_{OC1}	—	320000 / f_{OSC}	—	s	(7)
104	Offset Cancellation Stage 2 Operating Time		t_{OC2}	—	280000 / f_{OSC}	—	s	(7)
105	Self-Test Stage 1 Operating Time		t_{ST1}	—	128000 / f_{OSC}	—	s	(7)
106	Self-Test Stage 2 Operating Time		t_{ST2}	—	128000 / f_{OSC}	—	s	(7)
107	Self-Test Stage 3 Operating Time		t_{ST3}	—	128000 / f_{OSC}	—	s	(7)
108	Self-Test Repetitions		ST_RPT	0	—	5		(7, 12)
109	Programming Mode Entry Window		t_{PME}	—	300000 / f_{OSC}	—	s	(7)
	Synchronization Pulse (Figure 6, Figure 29 and Figure 33)							
110	Reset to first sync pulse (Program Mode Entry)		t_{RS_PM}	58	—	—	ms	(7)
111	Reset to first sync pulse (Normal Mode)		t_{RS}	t_{PSI5_INIT1}	—	—	s	(7)
112	Sync Pulse Period		t_{S-S}	t_{SYNC_OFF}	—	—	µs	(7)
113	Sync Pulse Width		t_{SYNC}	9	—	—	µs	(7)
114	Sync Pulse Reference LPF time constant		t_{SYNC_LPF}	120	280	—	µs	(9)
115	Sync Pulse Reference Discharge Start Time		$t_{SYNC\_LPF\_RST\_ST}$	—	66 / f_{OSC}	—	s	(7)
116	Sync Pulse Reference Discharge Activation Time		$t_{SYNC\_LPF\_RST}$	—	616 / f_{OSC}	—	s	(7)
117	Sync Pulse Detection Disable Time (BLANKTIME = 0)		$t_{SYNC\_OFF\_500}$	—	1810 / f_{OSC}	—	s	(7)
118	Analog Delay of Sync Pulse Detection		$t_{A\_SYNC\_DLY}$	50	—	600	ns	(9)
119	Sync Pulse Pulldown Function Delay Time		t_{PD_DLY}	—	74 / f_{OSC}	—	s	(7)
120	Sync Pulse Pulldown Function Activate Time		t_{PD_ON}	—	64 / f_{OSC}	—	s	(7)
121	Sync Pulse Detection Jitter		t_{SYNC_JIT}	0	—	2 / f_{OSC}	s	(7)
122	Data Transmission Single Bit Time (PSI5 Low Bit Rate)	*	t_{BIT_LOW}	7.6000	8.0000	8.4000	µs	(7)
123	Data Transmission Single Bit Time (PSI5 High Bit Rate)	*	t_{BIT_HI}	4.9875	5.2500	5.5125	µs	(7)
	Modulation Current (20% to 80% of I_{MOD} - I_{IDLE})							
124	Rise Time		t_{RISE}	324	463	602	ns	(3)
125	Fall Time		t_{FALL}	324	463	602	ns	(3)
126	Position of bit transition (PSI5 Low Baud Rate)	*	$t_{Bittrans\_LowBaud}$	49	50	51	%	(7)
127	Position of bit transition (PSI5 High Baud Rate)	*	$t_{Bittrans\_HighBaud}$	47	—	53	%	(7)
128	Asynchronous Response Time	*	t_{ASYNC}	—	912 / f_{OSC}	—	s	(7)
	Time Slots							
129	Minimum Programmed Time Slot (TIMESLOTx = 0x001)		$t_{TIMESLOTx\_MIN}$	—	2 / f_{OSC}	—	s	(7, 9)
130	Maximum Programmed Time Slot (TIMESLOTx = 0x3FF)		$t_{TIMESLOTx\_MAX}$	—	2046 / f_{OSC}	—	s	(3, 7)
131	Default Time Slot (TIMESLOTx = 0x000)		$t_{TIMESLOT\_DFLT}$	—	186 / f_{OSC}	—	s	(3, 7)
132	Time Plot Resolution	*	$t_{TIMESLOTx\_RES}$	—	2 / f_{OSC}	—	s/LSB	(7)
133	Sync Pulse to Daisy Chain Default Time Slot 1		$t_{TIMESLOT\_DC1}$	—	186 / f_{OSC}	—	s	(7)
134	Sync Pulse to Daisy Chain Default Time Slot 2		$t_{TIMESLOT\_DC2}$	—	768 / f_{OSC}	—	s	(7)
135	Sync Pulse to Daisy Chain Default Time Slot 3		$t_{TIMESLOT\_DC3}$	—	1400 / f_{OSC}	—	s	(7)
136	Sync Pulse to Daisy Chain Programming Time Slot		$t_{TIMESLOT\_DCP}$	—	186 / f_{OSC}	—	s	(7)
137	Data Interpolation Latency (Figure 36, Figure 37)		t_{LAT_INTERP}	64 / f_{OSC}	—	65 / f_{OSC}	s	(7)
138	Data Setup Time - Synchronous Mode (Figure 37)		$t_{DATASETUP\_synch}$	48 / f_{OSC}	—	56 / f_{OSC}	s	(7)
139	Data Setup Time - Double Sample Rate Mode (Figure 38)		$t_{DATASETUP\_double}$	48 / f_{OSC}	—	60 / f_{OSC}	s	(7)
140	Data Setup Time - 16 Bit Resolution Mode (Figure 40)		$t_{DATASETUP\_16}$	48 / f_{OSC}	—	60 / f_{OSC}	s	(7)
	Programming Mode Timing							
141	Programming Mode Sync Pulse Period		$t_{S-S\_PM\_L}$	495	500	505	µs	(7)
142	Programming Mode Command Timeout		$t_{PM\_TIMEOUT}$	—	4 * t_{S-S_PM}	—	µs	(7)
143	OTP Write Command to $V_{CC} = V_{PP}$		t_{PROG_HOLD}	—	—	20	µs	(7)
144	OTP Write CMD Response to OTP programming start		t_{PROG_DELAY}	—	—	40	ms	(7)
145	Time to program the OTP User Array		t_{PROG_ARRAY}	70	—	—	ms	(7)

2.7 Dynamic Electrical Characteristics - Signal Chain

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

#	Characteristic		Symbol	Min	Typ	Max	Units	
146	Internal Oscillator Frequency	*	f_{OSC}	3.80	4	4.20	MHz	(1)
	DSP Low-Pass Filter (Note15)							
147	Cutoff frequency LPF0 (referenced to 0 Hz)	*	f_{C_LPF0}	—	400	—	Hz	(7)
148	Filter Order LPF0	*	O_{LPF0}	—	3	—	1	(7)
149	Cutoff frequency LPF1 (referenced to 0 Hz)	*	f_{C_LPF1}	—	400	—	Hz	(7)
150	Filter Order LPF1	*	O_{LPF1}	—	4	—	1	(7)
	DSP Offset Cancellation Low-Pass Filter (Note15)							
151	Offset Cancellation Low-Pass Filter Input Sample Rate		$t_{OC\_SampleRate}$	—	256	—	µs	(7)
152	Stage 1 Cutoff frequency, Startup Phase 1		f_{C_OC10}	—	10.0	—	Hz	(7)
153	Stage 1 Filter Order, Startup Phase 1		O_{OC10}	—	1	—	1	(7)
154	Stage 2 Cutoff frequency, Startup Phase 1		f_{C_OC03}	—	0.300	—	Hz	(7)
155	Stage 2 Filter Order, Startup Phase 1		O_{OC03}	—	1	—	1	(7)
156	Cutoff frequency, Option 0		f_{C_OC0}	—	0.100	—	Hz	(7)
157	Filter Order, Option 0		O_{OC0}	—	1	—	1	(7)
158	Offset Cancellation Output Update Rate (8-Bit Mode)		$t_{OffRate\_8}$	—	f_{OSC} / 2e6	—	s	(7)
159	Offset Cancellation Output Step Size (8-Bit Mode)		OFF_{Step_8}	—	0.125	—	LSB	(7)
160	Offset Cancellation Output Update Rate (10-Bit Mode)		$t_{OffRate\_10}$	—	f_{OSC} / 2e6	—	s	(7)
161	Offset Cancellation Output Step Size (10-Bit Mode)		OFF_{Step_10}	—	0.5	—	LSB	(7)
162	Offset Monitor Update Frequency		$OFFMON_{OSC}$	—	f_{OSC} / 2000	—	Hz	(7)
163	Offset Monitor Count Limit		$OFFMON_{CNTLIMIT}$	—	4096	—	1	(7)
164	Offset Monitor Counter Size		$OFFMON_{CNTSIZE}$	—	8192	—	1	(7)
	Sensing Element Natural Frequency							
165	±60 *g*		f_{gcell_Z60}	7000	—	8000	Hz	(9)
166	±120 *g*		f_{gcell_Z120}	7000	—	8000	Hz	(9)
167	±240 *g*		f_{gcell_Z240}	13600	—	15100	Hz	(9)
168	±480 *g*		f_{gcell_Z480}	16289	—	17996	Hz	(9)
	Sensing Element Roll-off Frequency (-3 db)							
169	±60 *g*		f_{gcell_Z60}	798	—	2211	Hz	(9)
170	±120 *g*		f_{gcell_Z120}	798	—	2211	Hz	(9)
171	±240 *g*		f_{gcell_Z240}	2000	—	4700	Hz	(9)
172	±480 *g*		f_{gcell_Z480}	2250	—	6350	Hz	(9)
	Sensing Element Damping Ratio							
173	±60 *g*		ζ_{gcell_Z60}	1.870	—	4.610	—	(9)
174	±120 *g*		ζ_{gcell_Z120}	1.870	—	4.610	—	(9)
175	±240 *g*		ζ_{gcell_Z240}	1.750	—	3.500	—	(9)
176	±480 *g*		ζ_{gcell_Z480}	1.250	—	3.000	—	(9)
	Sensing Element Delay (@100 Hz)							
177	±60 *g*		$f_{gcell\_delay\_Z60}$	77	—	200	µs	(9)
178	±120 *g*		$f_{gcell\_delay\_Z120}$	77	—	200	µs	(9)
179	±240 *g*		$f_{gcell\_delay\_Z240}$	40	—	86	µs	(9)
180	±480 *g*		$f_{gcell\_delay\_Z480}$	21	—	60	µs	(9)
181	Package Resonance Frequency		$f_{Package}$	100	—	—	kHz	(9)

2.8 Dynamic Electrical Characteristics - Supply and SPI

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

#	Characteristic	Symbol	Min	Typ	Max	Units	
182	Quiescent Current Settling Time (Power Applied to Iq = I_{IDLE} ± 2 mA)	t_{SET}	—	—	5	ms	(3)
183	Reset Recovery Internal Delay (After internal POR)	t_{INT_INIT}	—	16000 / f_{OSC}	—	s	(7)
	V_{CC} Micro-cut (C_{BUF}=C_{REG}=C_{REGA}=1 µF)						
184	Survival Time (V_{CC} disconnect without Reset, C_{BUF}=C_{REG}=C_{REGA}=700 nF)	$t_{VCC\_MICROCUTmin}$	30	—	—	µs	(3)
185	Survival Time (V_{CC} disconnect without Reset, C_{BUF}=C_{REG}=C_{REGA}=1 µF)	$t_{VCC\_MICROCUT}$	50	—	—	µs	(3)
186	Reset Time (V_{CC} disconnect above which Reset is guaranteed)	t_{VCC_RESET}	—	—	1000	µs	(3)
	V_{BUF}, Capacitor Monitor Disconnect Time (Figure 11)						
187	POR to first Capacitor Test Disconnect	$t_{POR\_CAPTEST}$	—	12000 / f_{OSC}	—	s	(7)
188	Disconnect Time (Figure 11)	$t_{CAPTEST\_TIME}$	—	1.5	5.0	µs	(7)
189	Disconnect Delay, Asynchronous Mode (Figure 11)	$t_{CAPTEST\_ADLY}$	—	688 / f_{OSC}	—	s	(7)
190	Disconnect Delay, Synchronous Mode (Figure 12)	$t_{CAPTEST\_SDLY}$	—	72 / f_{OSC}	—	s	(7)
	V_{REG}, V_{REGA} Capacitor Monitor						
191	POR to first Capacitor Test Disconnect	$t_{POR\_CAPTEST}$	—	12000 / f_{OSC}	—	s	(7)
192	Disconnect Time	$t_{CAPTEST\_TIME}$	—	6 / f_{OSC}	—	s	(7)
193	Disconnect Rate	$t_{CAPTEST\_RATE}$	—	256 / f_{OSC}	—	s	(7)
	Serial Interface Timing (See Figure 8, C_{DOUT} ≤ 80 pF, R_{DOUT} ≥ 10 kΩ)						
194	Clock (SCLK) period (10% of V_{CC} to 10% of V_{CC})	t_{SCLK}	320	—	—	ns	(9)
195	Clock (SCLK) high time (90% of V_{CC} to 90% of V_{CC})	t_{SCLKH}	120	—	—	ns	(9)
196	Clock (SCLK) low time (10% of V_{CC} to 10% of V_{CC})	t_{SCLKL}	120	—	—	ns	(9)
197	Clock (SCLK) rise time (10% of V_{CC} to 90% of V_{CC})	t_{SCLKR}	—	15	40	ns	(9)
198	Clock (SCLK) fall time (90% of V_{CC} to 10% of V_{CC})	t_{SCLKF}	—	15	28	ns	(9)
199	$\overline{CS}$ asserted to SCLK high ($\overline{CS}$ = 10% of V_{CC} to SCLK = 10% of V_{CC})	t_{LEAD}	60	—	—	ns	(9)
200	$\overline{CS}$ asserted to D_{OUT} valid ($\overline{CS}$ = 10% of V_{CC} to D_{OUT} = 10/90% of V_{CC})	t_{ACCESS}	—	—	60	ns	(9)
201	Data setup time (D_{IN} = 10/90% of V_{CC} to SCLK = 10% of V_{CC})	t_{SETUP}	20	—	—	ns	(9)
202	D_{IN} Data hold time (SCLK = 90% of V_{CC} to D_{IN} = 10/90% of V_{CC})	t_{HOLD_IN}	10	—	—	ns	(9)
203	D_{OUT} Data hold time (SCLK = 90% of V_{CC} to D_{OUT} = 10/90% of V_{CC})	t_{HOLD_OUT}	0	—	—	ns	(9)
204	SCLK low to data valid (SCLK = 10% of V_{CC} to D_{OUT} = 10/90% of V_{CC})	t_{VALID}	—	—	50	ns	(9)
205	SCLK low to $\overline{CS}$ high (SCLK = 10% of V_{CC} to $\overline{CS}$ = 90% of V_{CC})	t_{LAG}	60	—	—	ns	(9)
206	$\overline{CS}$ high to D_{OUT} disable ($\overline{CS}$ = 90% of V_{CC} to D_{OUT} = Hi Z)	$t_{DISABLE}$	—	—	60	ns	(9)
207	CS high to CS low ($\overline{CS}$ = 90% of V_{CC} to $\overline{CS}$ = 90% of V_{CC})	t_{CSN}	1000	—	—	ns	(9)

1. Parameters tested 100% at final test.
2. Parameters tested 100% at wafer probe.
3. Verified by characterization.
4. * Indicates critical characteristic.
5. Verified by qualification testing.
6. Parameters verified by pass/fail testing in production.
7. Functionality guaranteed by modeling, simulation and/or design verification. Circuit integrity assured through IDDQ and scan testing. Timing is determined by internal system clock frequency.
8. N/A.
9. Verified by simulation.
10. N/A.
11. Measured at V_{CC} pin; V_{SYNC} guaranteed across full V_{IDLE} range.
12. Self-Test repeats on failure up to a ST_RPT_{MAX} times before transmitting Sensor Error Message.
13. N/A.
14. Thermal resistance between the die junction and the exposed pad; cold plate is attached to the exposed pad.
15. Filter cutoff frequencies are directly dependent upon the internal oscillator frequency.

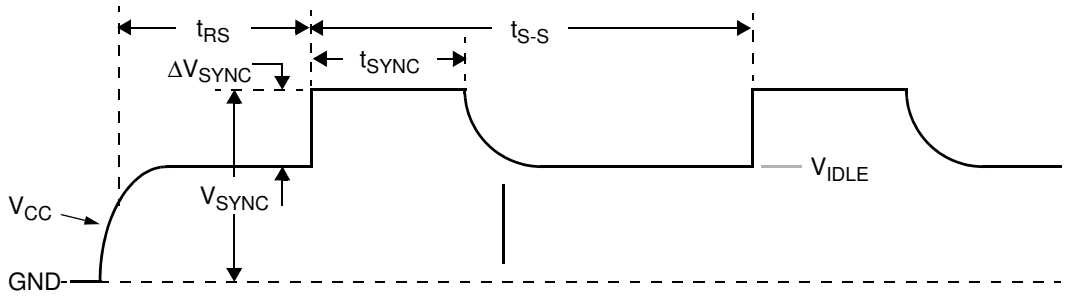


Figure 6. Sync Pulse Characteristics

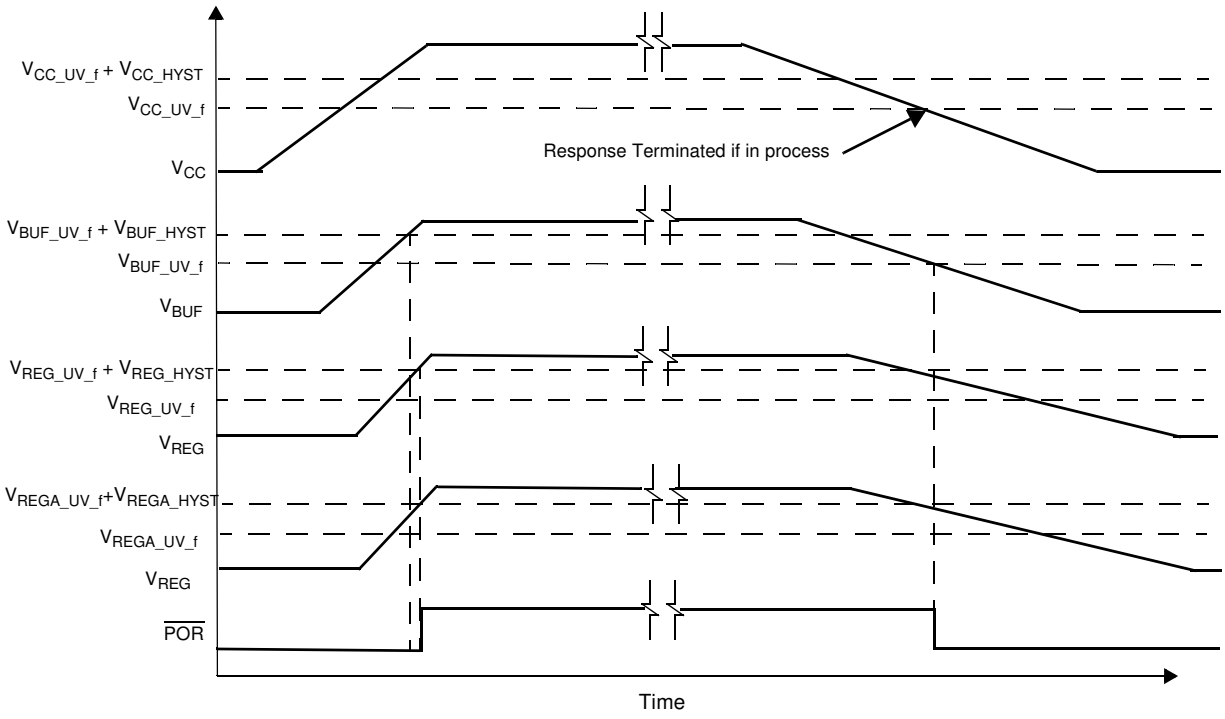


Figure 7. Powerup Timing

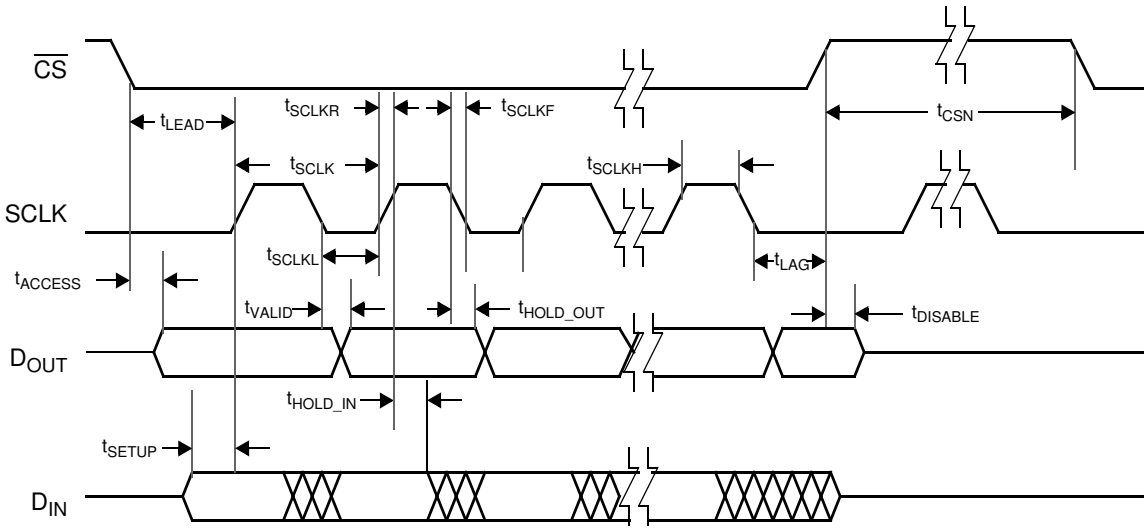


Figure 8. Serial Interface Timing

3 Functional Description

3.1 User Accessible Data Array

A user accessible data array allows for each device to be customized. The array consists of an OTP factory programmable block, an OTP user programmable block, and read only registers for device status. The OTP blocks incorporate independent error detection circuitry for fault detection (reference Section 3.2). Portions of the factory programmable array are reserved for factory-programmed trim values. The user accessible data is shown in Table 3.

Table 3. User Accessible Data

Byte Addr (XLong Msg)	Register	Nibble Addr (Long Msg)	Bit Function				Nibble Addr (Long Msg)	Bit Function				Type
			7	6	5	4		3	2	1	0	
$00	SN0	$01	SN[7]	SN[6]	SN[5]	SN[4]	$00	SN[3]	SN[2]	SN[1]	SN[0]	
$01	SN1	$03	SN[15]	SN[14]	SN[13]	SN[12]	$02	SN[11]	SN[10]	SN[9]	SN[8]	
$02	SN2	$05	SN[23]	SN[22]	SN[21]	SN[20]	$04	SN[19]	SN[18]	SN[17]	SN[16]	F, R
$03	SN3	$07	SN[31]	SN[30]	SN[29]	SN[28]	$06	SN[27]	SN[26]	SN[25]	SN[24]	
$04	DEVCFG1	$09	0	0	1	0	$08	AXIS	RNG[2]	RNG[1]	RNG[0]	
$05	DEVCFG2	$0B	LOCK_U	PCM	SYNC_PD	LATENCY	$0A	DATASIZE	BLANKTIME	P_CRC	BAUD	
$06	DEVCFG3	$0D	TRANS_MD[1]	TRANS_MD[0]	LPF[1]	LPF[0]	$0C	TIMESLOTB[9]	TIMESLOTB[8]	TIMESLOTA[9]	TIMESLOTA[8]	
$07	DEVCFG4	$0F	TIMESLOTA[7]	TIMESLOTA[6]	TIMESLOTA[5]	TIMESLOTA[4]	$0E	TIMESLOTA[3]	TIMESLOTA[2]	TIMESLOTA[1]	TIMESLOTA[0]	
$08	DEVCFG5	$11	TIMESLOTB[7]	TIMESLOTB[6]	TIMESLOTB[5]	TIMESLOTB[4]	$10	TIMESLOTB[3]	TIMESLOTB[2]	TIMESLOTB[1]	TIMESLOTB[0]	U, R
$09	DEVCFG6	$13	INIT2_EXT	ASYNC	U_DIR[1]	U_DIR[0]	$12	U_REV[3]	U_REV[2]	U_REV[1]	U_REV[0]	
$0A	DEVCFG7	$15	MONTH[3]	MONTH[2]	MONTH[1]	MONTH[0]	$14	YEAR[3]	YEAR[2]	YEAR[1]	YEAR[0]	
$0B	DEVCFG8	$17	UD[2]	UD[1]	UD[0]	DAY[4]	$16	DAY[3]	DAY[2]	DAY[1]	DAY[0]	
$0C	SC	$19	0	TM_B	RESERVED	IDEN_B	$18	OC_INIT_B	IDEF_B	OFF_B	1	R
$0D	MFG_ID	$1B	MFG_ID[7]	MFG_ID[6]	MFG_ID[5]	MFG_ID[4]	$1A	MFG_ID[3]	MFG_ID[2]	MFG_ID[1]	MFG_ID[0]	U, R

Type codes

F: NXP programmed OTP location

U: User programmable OTP location via PSI5

R: Readable register via PSI5

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
SN[12:0]	Serial Number
SN[31:13]	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 factory programmed OTP 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 Factory Configuration Register (DEVCFG1)

The factory configuration register is a factory programmed, read only register which contains user specific device configuration information. The factory configuration register is included in the factory programmed OTP CRC verification.

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	2	**1**	**0**
$04	DEVCFG1	0	0	1	0	AXIS	RNG[2]	RNG[1]	RNG[0]
Factory Default		0	0	1	0	1	0	0	0

3.1.2.1 Axis Indication Bit (AXIS)

The axis indication bit indicates the axes of sensitivity as shown below. This bit is factory programmed.

AXIS	Sensitivity Axis
0	X
1	Z

3.1.2.2 Range Indication Bits (RNG[2:0])

The range indication bits are factory programmed and indicate the full-scale range of the device as shown below.

RNG[2]	RNG[1]	RNG[0]	Full-Scale Acceleration Range	*g*-Cell Design	PSI5 Init Data Transmission (D9) Reference Table 13
0	0	0	Reserved	N/A	0001
0	0	1	±60 *g*	Medium-*g*	0111
0	1	0	Reserved	N/A	0010
0	1	1	±120 *g*	Medium-*g*	1000
1	0	0	Reserved	N/A	0011
1	0	1	±240 *g*	High-*g*	1001
1	1	0	Reserved	N/A	0100
1	1	1	±480 *g*	High-*g*	1010

3.1.3 Device Configuration 2 Register (DEVCFG2)

Device configuration register 2 is a user programmable OTP register that contains device configuration information.

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$05	DEVCFG2	LOCK_U	PCM	SYNC_PD	LATENCY	DATASIZE	BLANKTIME	P_CRC	BAUD
Factory Default		0	0	0	0	0	0	0	0

3.1.3.1 User Configuration Lock Bit (LOCK_U)

The LOCK_U bit allows the user to prevent writes to the user configuration array once programming is completed.

If the LOCK_U bit is written to ‘1’ when a PSI5 “Execute Programming of NVM” command is executed, the LOCK_U OTP bit will be programmed. Upon completion of the OTP programming, an OTP readout will be executed, locking the array from future OTP writes. The User Programmable OTP Array Error Detection is also activated (Reference Section 3.2.2).

3.1.3.2 PCM Enable Bit (PCM)

The PCM bit enables the PCM output pin. When the PCM bit is set, the PCM output pin is active and outputs a Pulse Code Modulated signal proportional to the acceleration response. Reference Section 3.5.3.7 for more information regarding the PCM output. When the PCM bit is cleared, the PCM output pin is actively pulled low.

PCM	PCM Output
0	Actively Pulled Low
1	PCM Signal Enabled

3.1.3.3 Sync Pulse Pulldown Enable Bit (SYNC_PD)

The sync pulse pulldown enable bit selects if the sync pulse pulldown is enabled once a sync pulse is detected. Reference Section 4.2.1.2 for more information regarding the sync pulse pulldown.

SYNC_PD	Sync Pulse Pulldown
0	Disabled
1	Enabled

If Daisy Chain Mode is enabled, the Sync Pulse Pulldown is enabled as listed below:

SYNC_PD	Daisy Chain Address Programmed	"Run Mode" Command Received	Daisy Chain Address = '001'	Sync Pulse Pulldown
0	x	x	x	Disabled
1	No	x	x	Enabled
1	Yes	No	x	Disabled
1	Yes	Yes	No	Disabled
1	Yes	Yes	Yes	Enabled

3.1.3.4 Latency Selection Bit (LATENCY)

The latency selection bit selects between one of two data latency methods to accommodate synchronized sampling or simultaneous sampling. Reference Section 4.5 for more information regarding latency and data synchronization.

Latency	Data Latency
0	Simultaneous Sampling Mode (Latency relative to Sync Pulse)
1	Synchronous Sampling Mode (Latency relative to Time Slot)

3.1.3.5 Data Size Selection Bit (DATASIZE)

The data size selection bit selects one of two data lengths for the PSI5 response message as shown below.

DATASIZE	Data Length
0	10 Bits
1	8 Bits

3.1.3.6 PSI5 Sync Pulse Blanking Time Selection Bit (BLANKTIME)

The PSI5 sync pulse blanking time selection bit selects the timing for ignoring sync pulses after successful reception of a sync pulse. Reference Section 4.2.1.1 for details regarding sync pulse detection and blanking.

BLANKTIME	Blanking Time Method
0	Maximum of $t_{SYNC\_OFF\_500}$ or Response Transmission Complete
1	Blanking Time determined by end of response transmission for programmed time slot

3.1.3.7 PSI5 Response Message Error Detection Selection Bit (P_CRC)

The PSI5 response message error detection selection bit selects either even parity, or a 3-Bit CRC for error detection of the PSI5 response message. Reference Section 4.3.3 for details regarding response message error detection.

P_CRC	Parity or CRC
0	Parity
1	CRC

Note: The PSI5 specification recommends parity for data lengths of 10 bits or less.

3.1.3.8 Baud Rate Selection Bit (BAUD)

The baud rate selection bit selects one of two PSI5 baud rates as shown below. Reference Section 2.6 for baud rate timing specifications.

BAUD	Baud Rate
0	Low Baud Rate (125 kBaud)
1	High Baud Rate (190.5 kBaud)

3.1.4 Device Configuration Registers (DEVCFG3, DEVCFG4, DEVCFG5)

Device configuration registers 3, 4, and 5 are user programmable OTP registers which contain device configuration information.

Location		Bit							
Address	Register	7	6	5	4	3	2	1	0
$06	DEVCFG3	TRANS_MD[1]	TRANS_MD[0]	LPF[1]	LPF[0]	TIMESLOTB[9]	TIMESLOTB[8]	TIMESLOTA[9]	TIMESLOTA[8]
$07	DEVCFG4	TIMESLOTA[7]	TIMESLOTA[6]	TIMESLOTA[5]	TIMESLOTA[4]	TIMESLOTA[3]	TIMESLOTA[2]	TIMESLOTA[1]	TIMESLOTA[0]
$08	DEVCFG5	TIMESLOTB[7]	TIMESLOTB[6]	TIMESLOTB[5]	TIMESLOTB[4]	TIMESLOTB[3]	TIMESLOTB[2]	TIMESLOTB[1]	TIMESLOTB[0]
Factory Default		0	0	0	0	0	0	0	0

3.1.4.1 PSI5 Transmission Mode Selection Bits (TRANS_MD[1:0])

The PSI5 transmission mode selection bits select the PSI5 transmission mode as shown below.

TRANS_MD[1]	TRANS_MD[0]	Operating Mode	Reference
0	0	Normal Mode (Asynchronous or Parallel, Synchronous)	Section 4.5.1
0	1	Synchronous Double Sample Rate Mode	Section 4.5.2
1	0	16-bit Resolution Mode (Two 10-bit Responses)	Section 4.5.3
1	1	Daisy Chain Mode	Section 4.5.4

3.1.4.2 Low-Pass Filter Selection Bit (LPF[1:0])

The low-pass filter selection bits select the low-pass filter for the acceleration signal as described below:

LPF[1]	LPF[0]	Low-Pass Filter Selected
0	0	400 Hz, 3-Pole
0	1	400 Hz, 4-Pole
1	0	Reserved
1	1	Reserved

3.1.4.3 TimeSlot Selection Bits (TIMESLOTx[9:0])

The timeslot selection bits select the time slot(s) to be used for data transmission. Reference Section 4.5 for details regarding PSI5 transmission modes and time slots. Accepted time slot values are 0.5 µs to 511.5 µs in 0.5 µs increments. Care must be taken to prevent from programming time slots which violate the PSI5 Version 1.3 specification, or time slots which will cause data contention.

TIMESLOTx[9:0]	ASYNC Bit	Time Slot	Reference
00 0000 0000	0	Default Time Slot ($t_{TIMESLOT\_DFLT}$) from start of Sync Pulse (t_{TRIG})	Section 4.5
	1	Asynchronous Mode	Section 4.5.1.1
Non-Zero	N/A	TimeSlot Definition from start of Sync Pulse (t_{TRIG}) in 0.5µs Increments	Section 4.5

Note: TIMESLOTB is only used for Synchronous Double Sample Rate Mode and 16-Bit Resolution Mode.

3.1.5 Device Configuration Registers 6, 7, and 8 (DEVCFG6, DEVCFG7, DEVCFG8)

Device configuration registers 6, 7 and 8 are user programmable OTP registers which contain device configuration and user specific manufacturing information. The user specific manufacturing information bits have no impact on the performance, but are transmitted during the PSI5 initialization phase 2 in 10-bit mode.

Location		Bit							
Address	Register	7	6	5	4	3	2	1	0
$09	DEVCFG6	INIT2_EXT	ASYNC	U_DIR[1]	U_DIR[0]	U_REV[3]	U_REV[2]	U_REV[1]	U_REV[0]
$0A	DEVCFG7	MONTH[3]	MONTH[2]	MONTH[1]	MONTH[0]	YEAR[3]	YEAR[2]	YEAR[1]	YEAR[0]
$0B	DEVCFG8	UD[2]	UD[1]	UD[0]	DAY[4]	DAY[3]	DAY[2]	DAY[1]	DAY[0]
Factory Default		0	0	0	0	0	0	0	0

3.1.5.1 Initialization Phase 2 Data Extension Bit (INIT2_EXT)

The initialization phase 2 data extension bit enables or disables data transmission in data fields D27 through D32 of PSI5 Initialization Phase 2 as shown below.

INIT2_EXT	Description
0	D27 through D32 are set to “0000”
1	D27 through D32 are transmitted as defined in Section 4.4.2.1

3.1.5.2 Asynchronous Mode Bit (ASYNC)

The asynchronous mode bit enables asynchronous data transmission as described in Section 3.1.4.3.

3.1.5.3 User Sensing Direction (U_DIR[1:0])

The user sensing direction registers are user programmable OTP registers which contain the module level sensing direction. This data is transmitted to the main ECU during PSI5 initialization phase 2 in 10-bit mode, as described in Section 4.4.2.1.

U_DIR[1]	U_DIR[0]	Module Sensing Direction As Defined in AKLV27	PSI5 Init Data Transmission (D8) Reference Table 13
0	0	Connector Direction (β)	0000
0	1	Bushing Direction (α)	0100
1	0	Perpendicular to α and β (γ)	1000
1	1	Not used	1100

3.1.5.4 User Product Revision (U_REV[3:0])

The user product revision registers are user programmable OTP registers which contain the module production revision. The device supports up to 16 product revisions. This data is transmitted to the main ECU during PSI5 initialization phase 2 in 10-bit mode, as described in Section 4.4.2.1.

3.1.5.5 User Production Date Information (YEAR[3:0], MONTH[3:0], DAY[4:0)

The user production date information registers are user programmable OTP registers which contain the module production date. The table below shows the relationship between the stored values and the production date.

Programmed Value	Decoded Value	Julian Date Value
YEAR[3:0]	Year	JY[6:0]
0000	2009	0001001
• • •	• • •	• • •
1111	2024	0011000
MONTH[3:0]	Month	JM[3:0]
0000	N/A	0000
0001	January	0001
• • •	• • •	• • •
1100	December	1100
• • •	• • •	• • •
1111	N/A	N/A
DAY[4:0]	Day	JD[4:0]
00000	N/A	00000
00001	Day 1	00001
• • •	• • •	• • •
11111	Day 31	11111

The Julian date value is transmitted to the main ECU during PSI5 initialization phase 2 in 10-bit mode, as described in Section 4.4.2.1.

3.1.5.6 User Specific Data (UD[2:0])

The user specific data bits are user programmable OTP bits. These bits have no impact on device operation or performance.

3.1.6 Status Check Register (SC)

The status check register is a read-only register containing device status information.

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0C	SC	0	TM_B	RESERVED	IDEN_B	OC_INIT_B	IDEF_B	OFF_B	1

3.1.6.1 Test Mode Flag (TM_B)

The test mode bit is cleared if the device is in test mode.

TM_B	Operating Mode
0	Test Mode is active
1	Test Mode is not active

3.1.6.2 Internal Data Error Flag (IDEN_B)

The internal data error bit is cleared if a register data error detection mismatch is detected in the user accessible OTP array. A device reset is required to clear the error.

IDEN_B	Error Condition
0	Error detection mismatch in user programmable OTP array
1	No error detected

3.1.6.3 Offset Cancellation Init Status Flag (OC_INIT_B)

The offset cancellation initialization status bit is set once the offset cancellation initialization process is complete, and the filter has switched to normal mode.

OC_INIT_B	Error Condition
0	Offset Cancellation in initialization
1	Offset Cancellation initialization complete (t_{OC1} and t_{OC2} expired)

3.1.6.4 Internal Factory Data Error Flag (IDEF_B)

The internal factory data error bit is cleared if a register data CRC fault is detected in the factory programmable OTP array. A device reset is required to clear the error.

IDEF_B	Error Condition
0	CRC error in factory programmable OTP array
1	No error detected

3.1.6.5 Offset Error Flag (OFF_B)

The offset error flag is cleared if the acceleration signal reaches the offset limit.

OFF_B	Error Condition
0	Offset error detected
1	No error detected

3.1.7 Manufacturer ID (MFG_ID)

The manufacturer ID register is a user programmable OTP register that contains the PSI5 manufacturer ID. The manufacturer ID register has no impact on the performance, but is transmitted during the PSI5 initialization phase 2 in 10-bit mode.

Location		Bit							
Address	**Register**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
$0D	MFG_ID	MFG_ID[7]	MFG_ID[6]	MFG_ID[5]	MFG_ID[5]	MFG_ID[3]	MFG_ID[2]	MFG_ID[1]	MFG_ID[0]
Factory Default		0	0	0	0	0	0	0	0

3.2 OTP Array CRC Verification

3.2.1 Factory Programmed OTP Array CRC Verification

The Factory programmed OTP array is verified for errors with a 3-bit CRC. The CRC verification is enabled only when the factory programmed array is locked. The CRC verification uses a generator polynomial of $g(x) = X^3 + X + 1$, with a seed value = '111'.

Once the CRC verification is enabled, the CRC is continuously calculated on all bits in registers $00, $01, $02, $03, and $04 and on the factory programmable device configuration bits with the exception of the factory lock bit. Bits are fed in from right to left (LSB first), and top to bottom (lower addresses first) in the register map. The calculated CRC is then compared against the stored 3 bit CRC. If a CRC error is detected in the OTP array, the IDEF_B bit is cleared in the SC register.

The CRC verification is completed on the memory registers which hold a copy of the fuse array values, not the fuse array values.

3.2.2 User Programmable OTP Array Error Detection

The user programmable OTP array is independently verified for errors. The Error Detection is enabled only when the LOCK_U bit in the user data register array is set.

When a PSI5 Programming Mode "Execute Programming of NVM" command is received and the LOCK_U bit is set, the device calculates the error detection code and writes the code to NVM, enabling the Error Detection.

Once the error detection is enabled, the error detection code is continuously calculated on all bits in registers $05, $06, $07, $08, $09, $0A, $0B and $0D with the exception of the LOCK_U bit. The calculated code is then compared against the stored error code. If a mismatch is detected, the IDEN_B bit is cleared in the SC register.

The error detection is completed on the memory registers which hold a copy of the fuse array values, not the fuse array values.

3.3 Voltage Regulators

The device derives its internal supply voltage from the V_{CC} and V_{SS} pins. Separate internal voltage regulators are used for the analog (V_{REGA}) and digital circuitry (V_{REG}). The analog and digital regulators are supplied by a buffer regulator (V_{BUF}) to provide immunity from EMC and supply dropouts on V_{CC}. External filter capacitors are required, as shown in Figure 1.

The voltage regulator module includes voltage monitoring circuitry which holds the device in reset following power-on until the internal voltages have increased above the under-voltage detection thresholds. The voltage monitor asserts internal reset when the external supply or internally regulated voltages fall below the under-voltage detection thresholds. A reference generator provides a reference voltage for the ΣΔ converter.

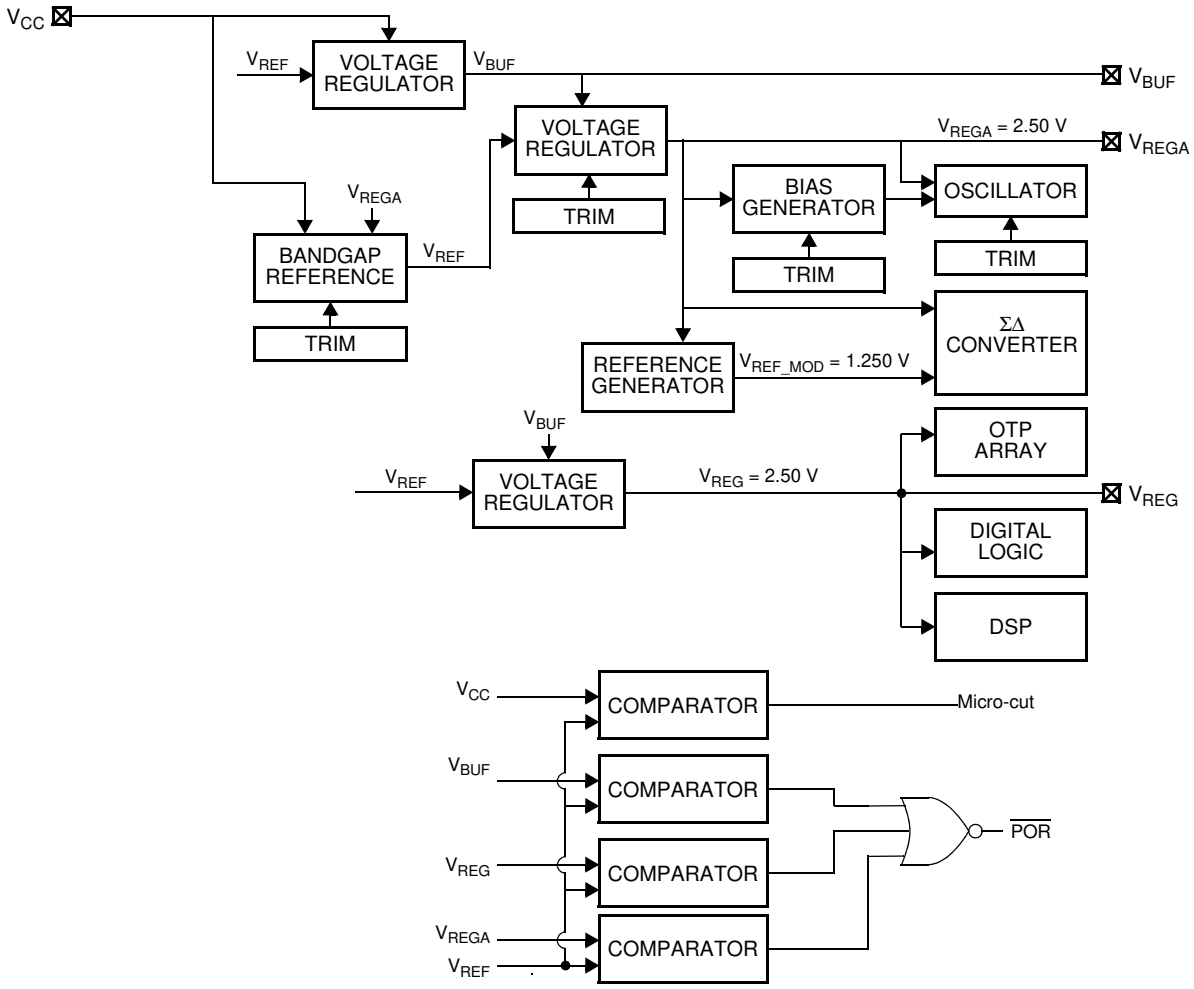


Figure 9. Voltage Regulation and Monitoring

3.3.1 V_{BUF}, V_{REG}, and V_{REGA} Regulator Capacitor

The internal regulators require an external capacitor between each of the regulator pins (V_{BUF}, V_{REG}, or V_{REGA}) and the associated the V_{SS} / V_{SSA} pin for stability. Figure 1 shows the recommended types and values for each of these capacitors.

3.3.2 V_{CC}, V_{BUF}, V_{REG}, and V_{REGA} Under-Voltage Monitor

A circuit is incorporated to monitor the supply voltage (V_{CC}) and all internally regulated voltages (V_{BUF}, V_{REG}, and V_{REGA}). If any of internal regulator voltages fall below the specified under-voltage thresholds in Section 2, the device will be reset. If V_{CC} falls below the specified threshold, PSI5 transmissions are terminated for the present response. Once the supply returns above the threshold, the device will respond to the next detected sync pulse. Reference Figure 10.

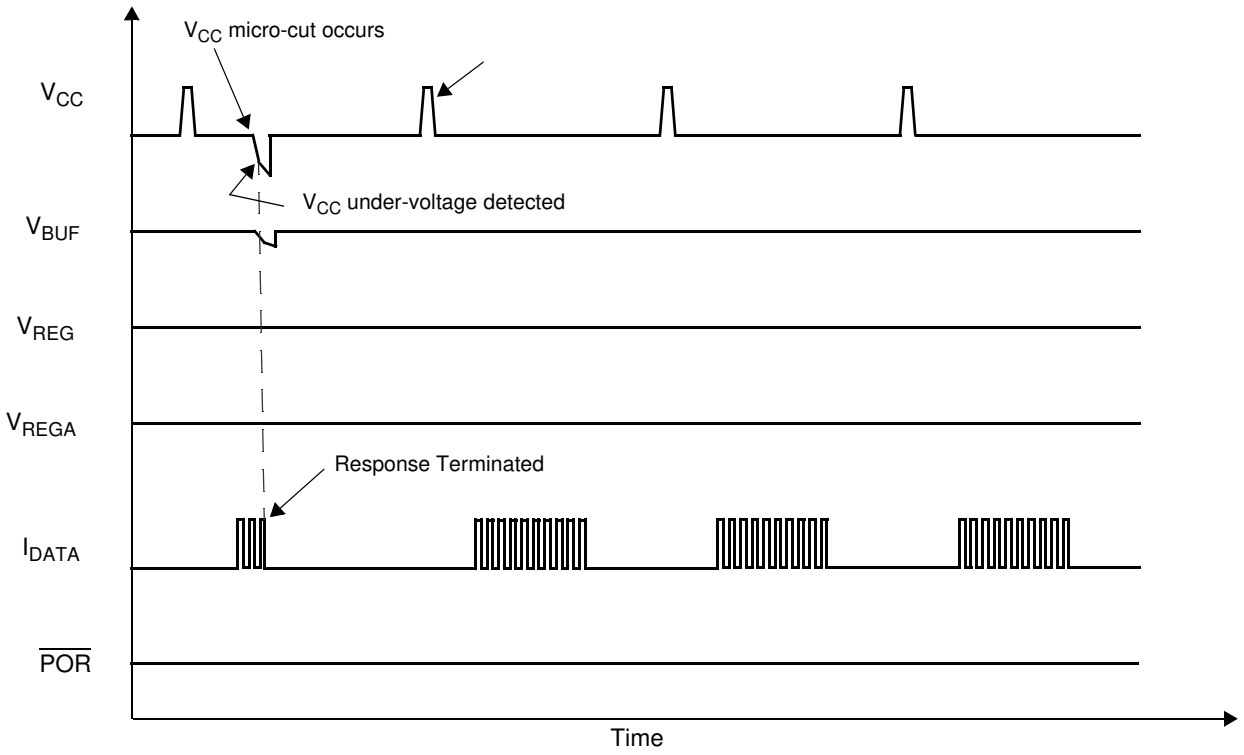


Figure 10. V_{CC} Micro-Cut Response

3.3.3 V_{BUF}, V_{REG}, and V_{REGA} Capacitance Monitor

A monitor circuit is incorporated to ensure predictable operation if the connection to the external V_{BUF}, V_{REG}, or V_{REGA}, capacitor becomes open.

In asynchronous mode, the V_{BUF} regulator is disabled $t_{CAPTEST\_ADLY}$ seconds after each data transmission for a duration of $t_{CAPTEST\_TIME}$ seconds. If the external capacitor is not present, the regulator voltage will fall below the internal reset threshold, forcing a device reset.

In synchronous mode, the V_{BUF} regulator is disabled $t_{CAPTEST\_SDLY}$ seconds after each sync pulse for a duration of $t_{CAPTEST\_TIME}$ seconds. If the external capacitor is not present, the regulator voltage will fall below the internal reset threshold, forcing a device reset.

The V_{REG} and V_{REGA} regulators are disabled at a continuous rate ($t_{CAPTEST\_RATE}$), for a duration of $t_{CAPTEST\_TIME}$ seconds. If either external capacitor is not present, the associated regulator voltage will fall below the internal reset threshold, forcing a device reset.

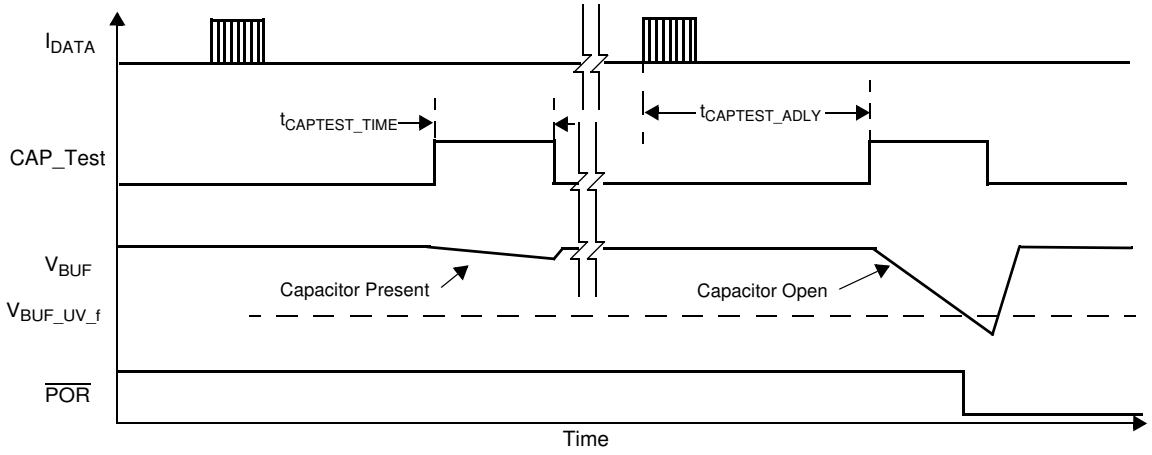


Figure 11. V_{BUF} Capacitor Monitor - Asynchronous Mode

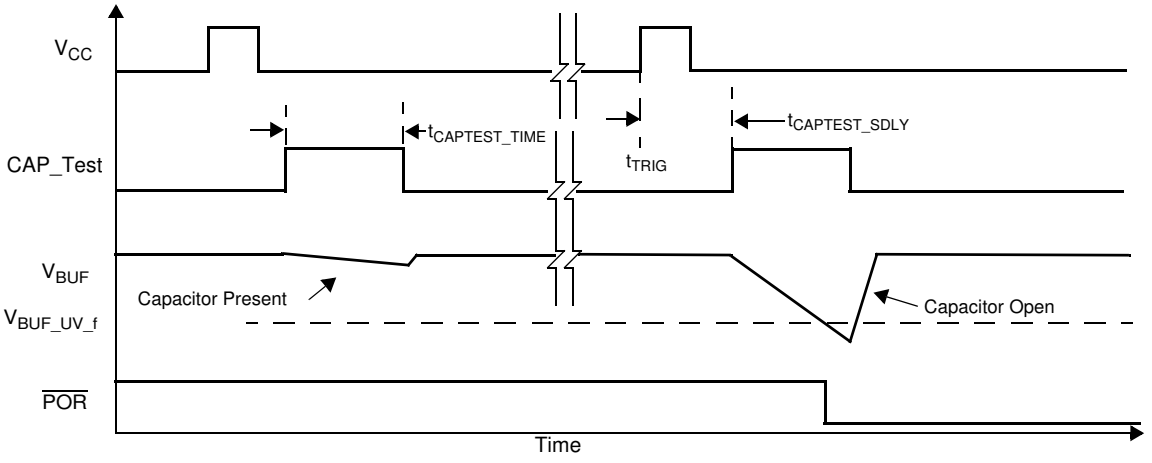


Figure 12. V_{BUF} Capacitor Monitor - Synchronous Mode

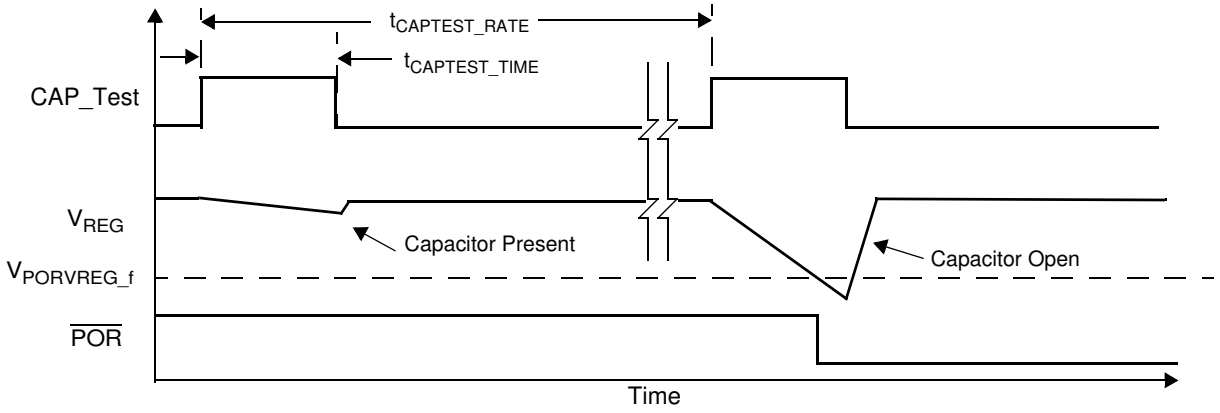


Figure 13. V_{REG} Capacitor Monitor

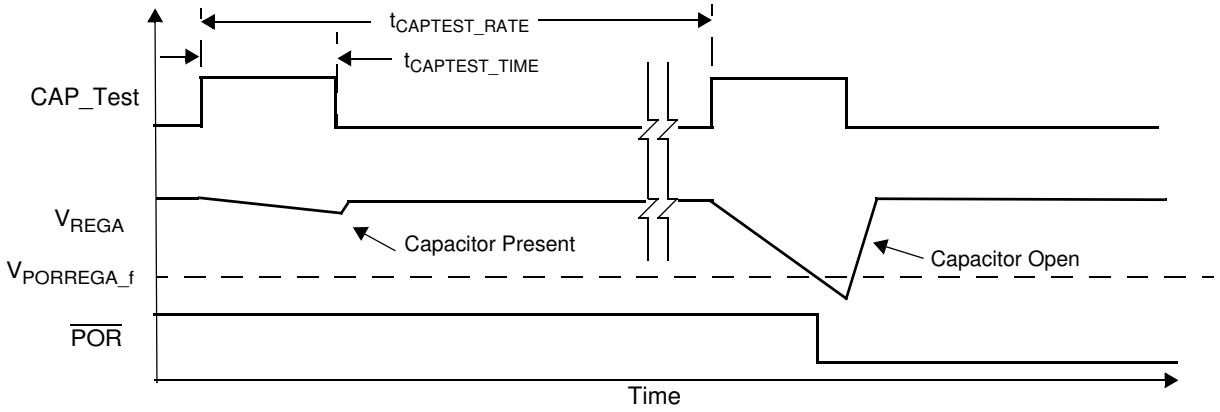


Figure 14. V_{REGA} Capacitor Monitor

3.4 Internal Oscillator

A factory trimmed oscillator is included as specified in Section 2.

3.5 Acceleration Signal Path

3.5.1 Transducer

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

where:

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

ζ = Damping Ratio

ω_n = Natural Frequency = $2 * \Pi * f_n$

Reference Section 2.7 for transducer parameters.

3.5.2 ΣΔ Converter

A sigma delta modulator converts the differential capacitance of the transducer to a 1 MHz data stream that is input to the DSP block.

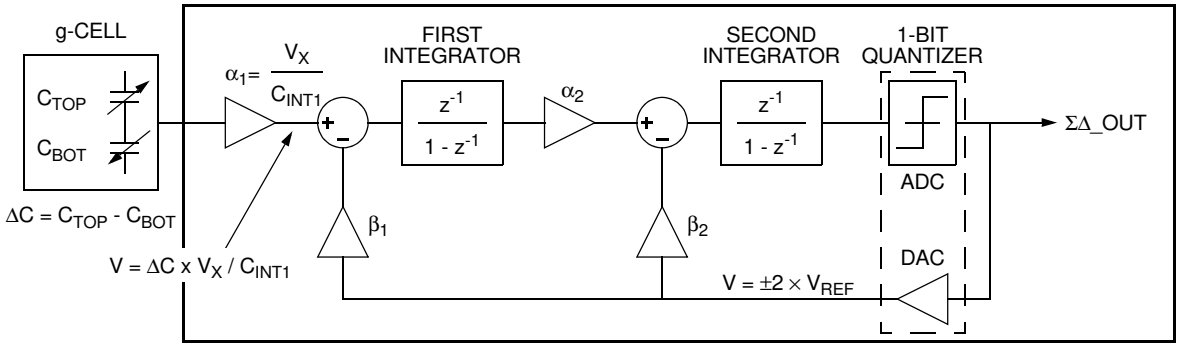


Figure 15. ΣΔ Converter Block Diagram

3.5.3 Digital Signal Processing Block

A Digital Signal Processing (DSP) block is used to perform signal filtering and compensation. A diagram illustrating the signal processing flow within the DSP block is shown in Figure 16.

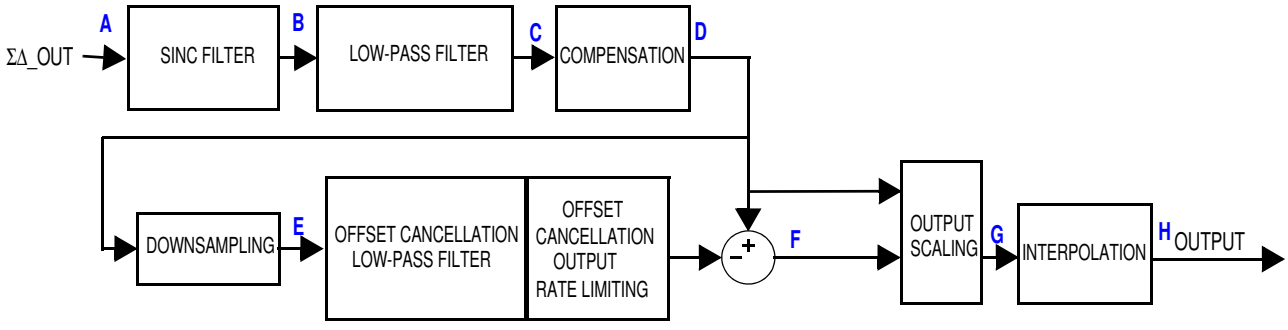


Figure 16. Signal Chain Diagram