Freescale Semiconductor
Technical Data

Document Number: MMA7455L
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±2g/±4g/±8g Three Axis Low-g Digital Output Accelerometer

The MMA7455L is a Digital Output (I^2C/SPI), low power, low profile capacitive micromachined accelerometer featuring signal conditioning, a low pass filter, temperature compensation, self-test, configurable to detect 0g through interrupt pins (INT1 or INT2), and pulse detect for quick motion detection. 0g offset and sensitivity are factory set and require no external devices. The 0g offset can be customer calibrated using assigned 0g registers and g-Select which allows for command selection for 3 acceleration ranges (2g/4g/8g). The MMA7455L includes a Standby Mode that makes it ideal for handheld battery powered electronics.

Features

- Digital Output (I^2C/SPI)
- 3mm x 5mm x 1mm LGA-14 Package
- Low Current Consumption: 400 μA
- Self-Test for Z-Axis
- Low Voltage Operation: 2.4 V – 3.6 V
- User Assigned Registers for Offset Calibration
- Programmable Threshold Interrupt Output
- Level Detection for Motion Recognition (Shock, Vibration, Freefall)
- Pulse Detection for Single or Double Pulse Recognition
- Sensitivity (64 LSB/g @ 2g and @ 8g in 10-Bit Mode)
- Selectable Sensitivity (±2g, ±4g, ±8g) for 8-bit Mode
- Robust Design, High Shocks Survivability (5,000g)
- RoHS Compliant
- Environmentally Preferred Product
- Low Cost

Typical Applications

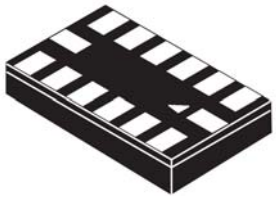
- Cell Phone/PMP/PDA: Image Stability, Text Scroll, Motion Dialing, Tap to Mute
- HDD: Freefall Detection
- Laptop PC: Freefall Detection, Anti-Theft
- Pedometer
- Motion Sensing, Event Recorder

ORDERING INFORMATION			
Part Number	**Temperature Range**	**Package**	**Shipping**
MMA7455LT	–40 to +85°C	LGA-14	Tray
MMA7455LR1	–40 to +85°C	LGA-14	7” Tape & Reel
MMA7455LR2	–40 to +85°C	LGA-14	13” Tape & Reel

MMA7455L

MMA7455L: XYZ-AXIS ACCELEROMETER ±2G/±4G/±8G

Bottom View



14 LEAD LGA CASE 1977-01

Top View

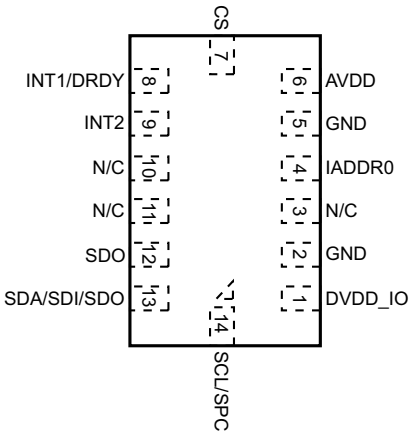


Figure 1. Pin Connections

This document contains certain information on a new product.
Specifications and information herein are subject to change without notice.

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Table 1. Pin Descriptions

Pin #	Pin Name	Description	Pin Status
1	DVDD_IO	Digital Power for I/O pads	Input
2	GND	Ground	Input
3	N/C	No internal connection. Leave unconnected or connect to Ground.	Input
4	IADDR0	I^2C Address Bit 0 (optional)*	Input
5	GND	Ground	Input
6	AVDD	Analog Power	Input
7	CS	SPI Enable (0), I^2C Enable (1)	Input
8	INT1/DRDY	Interrupt 1/ Data Ready	Output
9	INT2	Interrupt 2	Output
10	N/C	No internal connection. Leave unconnected or connect to Ground.	Input
11	N/C	Leave unconnected or connect to Ground.	Input
12	SDO	SPI Serial Data Output	Output
13	SDA/SDI/SDO	I^2C Serial Data (SDA), SPI Serial Data Input (SDI), 3-wire interface Serial Data Output (SDO)	Open Drain/Input/Output
14	SCL/SPC	I^2C Serial Clock (SCL), SPI Serial Clock (SPC)	Input

*This address selection capability is not enabled at the default state. If the user wants to use it, factory programming is required. If activated (pin4 on the device is active).

<$1D= 0001 1101> bit 0 is V_{DD} on pin 4

<$1C=0001 1100> bit 0 is GND on pin 4. If the pin is programmed it cannot be left NC.

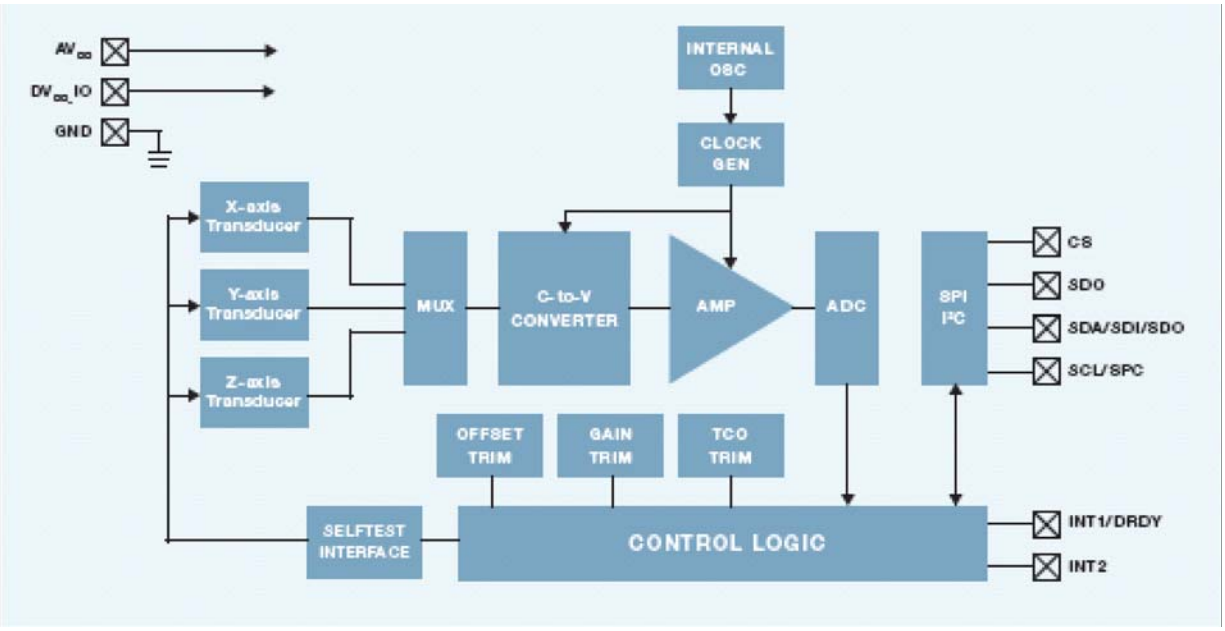

Figure 1. Simplified Accelerometer Functional Block Diagram

Table 2. Maximum Ratings
(Maximum ratings are the limits to which the device can be exposed without causing permanent damage.)

Rating	Symbol	Value	Unit
Maximum Acceleration (all axes)	g_{max}	5000	g
Analog Supply Voltage	AV_{DD}	-0.3 to +3.6	V
Digital I/O pins Supply Voltage	DV_{DD_IO}	-0.3 to +3.6	V
Drop Test	D_{drop}	1.8	m
Storage Temperature Range	T_{stg}	-40 to +125	°C

ELECTRO STATIC DISCHARGE (ESD)

WARNING: This device is sensitive to electrostatic discharge.

Although the Freescale accelerometer contains internal 2000V ESD protection circuitry, extra precaution must be taken by the user to protect the chip from ESD. A charge of over 2000 volts can accumulate on the human body or associated test equipment. A charge of this magnitude can alter the performance or cause failure of the chip. When handling the accelerometer, proper ESD precautions should be followed to avoid exposing the device to discharges which may be detrimental to its performance.

Table 3. Operating Characteristics

Unless otherwise noted: –40°C ≤ T_A ≤ 85°C, 2.4 V ≤ AV_{DD} ≤ 3.6 V, Acceleration = 0g, Loaded output.

Characteristic	Symbol	Min	Typ	Max	Unit
Analog Supply Voltage					
Standby/Operation Mode	AV_{DD}	2.4	2.8	3.6	V
Enable Bus Mode	AV_{DD}		0		V
Digital I/O Pins Supply Voltage					
Standby/Operation Mode	DV_{DD_IO}	1.71	1.8	AV_{DD}	V
Enable Bus Mode	DV_{DD_IO}	1.71	1.8	3.6	V
Supply Current Drain					
Operation Mode	I_{DD}	—	400	490	μA
Pulse Detect Function Mode	I_{DD}	—	400	490	μA
Standby Mode (except data loading and I^2C/SPI communication period)	I_{DD}	—	2.5	10	μA
Operating Temperature Range	T_A	-40	25	85	°C
0g Output Signal (T_A=25°C, AV_{DD} = 2.8 V					
±2g range (25°C) 8bit GLVL[1:0]= 0 1		-21	0	21	count
±4g range (25°C) 8bit GLVL[1:0]= 1 0		—	0	—	count
±8g range (25°C) 8bit GLVL[1:0]= 0 0		—	0	—	count
±8g range (25°C) 10bit		-21	0	21	count
Sensitivity (T_A=25°C, AV_{DD} = 2.8 V)					
±2g range (25°C) 8bit		58	64	70	count/g
±4g range (25°C) 8bit		—	32	—	count/g
±8g range (25°C) 8bit		—	16	—	count/g
±8g range (25°C) 10bit		58	64	70	count/g
Self-Test Output Response					
Zout	ΔST_Z	+48	+64	+80	count
Input High Voltage	V_{IH}	0.7 x DVDD	—	—	V
Input Low Voltage	V_{IL}	—	—	0.35 x DVDD	V
Internal Clock Frequency (T_A = 25°C, AV_{DD} = 2.8 V)	t_{CLK}	140	150	160	kHz
SPI Frequency					
DV_{DD_IO} < 2.4 V		—	4	—	MHz
DV_{DD_IO} > 2.4 V		—	8	—	MHz
Bandwidth for Data Measurement (User Selectable)					
DFBW 0		—	62.5	—	Hz
DFBW 1		—	125	—	Hz
Output Data Rate					
Output Data Rate is 125 Hz when 62.5 bandwidth is selected.		—	125	—	Hz
Output Data rate is 250 Hz when 125Hz bandwidth is selected.		—	250	—	Hz
Control Timing					
Wait Time for I^2C/SPI ready after power on	t_{su}	—	1	—	ms
Turn On Response Time (Standby to Normal Mode)	t_{ru}	—	—	20	ms
Turn Off Response Time (Normal to Standby Mode)	t_{rd}	—	—	20	ms
Self-Test Response Time	t_{st}	—	—	20	ms
Sensing Element Resonant Frequency					
XY	$f_{GCELLXY}$	—	6.0	—	kHz
Z	f_{GCELLZ}	—	3.4	—	kHz
Nonlinearity (2 g range)		-1	—	+1	%FS
Cross Axis Sensitivity		-5	—	+5	%

Table 4. Function Parameters for Detection

–40°C ≤ T_A ≤ 85°C, 2.4 V ≤ AV_{DD} ≤ 3.6 V, unless otherwise specified

Characteristic	Symbol	Min	Typ	Max	Unit
Level Detection					
Detection Threshold Range		0	—	FS	g
Pulse Detection					
Pulse detection range (Adjustable range)		0.5	—	127	ms
Time step for pulse detection		—	0.5	—	ms
Threshold range for pulses		0	—	FS	g
Detection levels for threshold		—	127	—	Counts
Latency timer (Adjustable range)		1	—	150	ms
Time Window (Adjustable range)		1	—	250	ms
Bandwidth for detecting interrupt*		—	600	—	Hz
Time step for latency timer and time window		—	1	—	ms

Note: The response time is between 10% of full scale V_{DD} input voltage and 90% of the final operating output voltage.

*The bandwidth for detecting interrupts in level and pulse is 600Hz which is changed from measurement mode.

PRINCIPLE OF OPERATION

The Freescale accelerometer is a surface-micromachined integrated-circuit accelerometer. The device consists of a surface micromachined capacitive sensing cell (g-cell) and a signal conditioning ASIC contained in a single package. The sensing element is sealed hermetically at the wafer level using a bulk micromachined cap wafer. The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as a set of beams attached to a movable central mass that move between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to an acceleration (Figure 2).

As the beams attached to the central mass move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The change in distance is a measure of acceleration. The g-cell beams form two back-to-back capacitors (Figure 2). As the center beam moves with acceleration, the distance between the beams changes and each capacitor's value will change, ($C = A\varepsilon/D$). Where A is the area of the beam, ε is the dielectric constant, and D is the distance between the beams.

The ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors. The ASIC also signal conditions and filters (switched capacitor) the signal, providing a digital output that is proportional to acceleration.

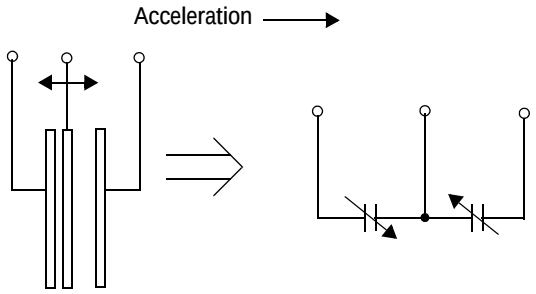

Figure 2. Simplified Transducer Physical Model

FEATURES

Self-Test

The sensor provides a self-test feature that allows the verification of the mechanical and electrical integrity of the accelerometer at any time before or after installation. This feature is critical in applications such as hard disk drive protection where system integrity must be ensured over the life of the product. When the self-test function is initiated through the mode control register ($16), accessing the “self-test” bit, an electrostatic force is applied to each axis to cause it to deflect. The Z-axis is trimmed to deflect 1g. This procedure assures that both the mechanical (g-cell) and electronic sections of the accelerometer are functioning.

g-Select

The g-Select feature enables the selection between 3 acceleration ranges for measurement. Depending on the values in the Mode control register ($16), the MMA7455L's internal gain will be changed allowing it to function with a 2g, 4g or 8g measurement sensitivity. This feature is ideal when a product has applications requiring two or more acceleration ranges for optimum performance and for enabling multiple functions. The sensitivity can be changed during the operation by modifying the two GLVL bits located in the mode control register.

$16: Mode Control Register (Read/Write)

D7	D6	D5	D4	D3	D2	D1	D0	Bit
--	DRPD	SPI3W	STON	GLVL[1]	GLVL[0]	MODE[1]	MODE[0]	Function
0	0	0	0	0	0	0	0	Default

Table 5. Configuring the g-Select for 8-bit output using Register $16 with GLVL[1:0] bits.

GLVL [1:0]	g-Range	Sensitivity
00	8g	16 LSB/g
01	2g	64 LSB/g
10	4g	32 LSB/g

Standby Mode

This digital output 3-axis accelerometer provides a standby mode that is ideal for battery operated products. When standby mode is active, the device outputs are turned off, providing significant reduction of operating current. When the device is in standby mode the current will be reduced to 2.5 µA typical. In standby mode the device can read and write to the registers with the I^2C/SPI available, but no new measurements can be taken in this mode as all current consuming parts are off. The mode of the device is controlled through the mode control register by accessing the two mode bits as shown in Table 6.

Table 6. Configuring the Mode using Register $16 with MODE[1:0] bits.

MODE [1:0]	Function
00	Standby Mode
01	Measurement Mode
10	Level Detection Mode
11	Pulse Detection Mode

Measurement Mode

During measurement mode, continuous measurements on all three axes enabled. The g-range for 2g, 4g, or 8g are selectable with 8-bit data and the g-range of 8g is selectable with 10-bit data. The sample rate during measurement mode is 125 Hz with 62.5 BW filter selected. The sample rate is 250 Hz with the 125 Hz filter selected. Therefore, when a conversion is complete (signaled by the DRDY flag), the next measurement will be ready.

When measurements on all three axes are completed, a logic high level is output to the DRDY pin, indicating "measurement data is ready." The DRDY status can be monitored by the DRDY bit in Status Register (Address: $09). The DRDY pin is kept high until one of the three Output Value Registers are read. If the next measurement data is written before the previous data is read, the DOVR bit in the Status Register will be set. Also note that in measurement mode, level detection mode and pulse detection mode are not available.

By default all three axes are enabled. X and/or Y and/or Z can be disabled. There is a choice between detecting an absolute signal or a positive or negative only signal on the enabled axes. There is also a choice between doing a detection for motion where X or Y or Z > Threshold vs. doing a detection for freefall where X & Y & Z < Threshold.

LEVEL DETECTION

When in Level or Pulse detection mode, it is not advisable to read the XYZ measurements because this can conflict with timing. The interrupts for level and pulse detection are at 600 Hz, while measurement mode is at 125 Hz. It is best to exit the pulse/level mode before taking a measurement on the XYZ.

Both the Level Detection and Pulse Detection modes can trigger an interrupt. Typically one interrupt is assigned to either pulse detection or level detection. To detect both at the same time 2 interrupts are required. The level detection mechanism has no timers associated with it. Once a set acceleration level is reached the interrupt pin will go high and remain high until the interrupt pin is cleared (See Assigning, Clearing & Detecting Interrupts).

By default all three axes are enabled and the detection range is 8g only. X and/or Y and/or Z can be disabled. There is a choice between detecting an Absolute signal or a Positive or Negative only signal on the enabled axes. There is also a choice between doing a detection for Motion where X or Y or Z > Threshold vs. doing a detection for Freefall where X& Y & Z < Threshold.

$18: Control 1 (Read/Write) Setting the Detection Axes for X, Y and Z

This allows the user to define how many axes to use for detection. All axes are enabled by default. To disable write 1.

XDA: Disable X

YDA: Disable Y

ZDA: Disable Z

D7	D6	D5	D4	D3	D2	D1	D0	Reg $18
DFBW	THOPT	ZDA	YDA	XDA	INTREG[1]	INTREG[0]	INTPIN	Function
0	0	0	0	0	0	0	0	Default

$19: Control 2 (Read/Write) Motion Detection (OR Condition) or Freefall Detection (AND Condition)

LDPL = 0: Level detection polarity is positive and detecting condition is **OR** for all 3 axes.

X or Y or Z > Threshold

||X|| or ||Y|| or ||Z|| > Threshold

LDPL = 1: Level detection polarity is negative detecting condition is **AND** for all 3 axes.

X and Y and Z < Threshold

||X|| and ||Y|| and ||Z|| < Threshold

D7	D6	D5	D4	D3	D2	D1	D0	Reg $19
--	--	--	--	--	DRVO	PDPL	LDPL	Function
0	0	0	0	0	0	0	0	Default

$18: Control 1 (Read/Write): Setting the threshold to be an integer value or an absolute value

This allows the user to set the threshold to be absolute, or to be based on the threshold value as positive or negative.

THOPT = 0 Absolute; THOPT = 1 Positive Negative

D7	D6	D5	D4	D3	D2	D1	D0	Reg $18
DFBW	THOPT	ZDA	YDA	XDA	INTREG[1]	INTREG[0]	INTPIN	Function
0	0	0	0	0	0	0	0	Default

$1A: **Level Detection Threshold Limit Value (Read/Write)**

When an event is detected the interrupt pin (either INT1 or INT2) will go high. The interrupt pin assignment is set up in Register $18, discussed in the Assigning, Clearing & Detecting Interrupts section. The detection status is monitored by the Detection Source Register $0A.

D7	D6	D5	D4	D3	D2	D1	D0	Reg $1A
LDTH[7]	LDTH[6]	LDTH[5]	LDTH[4]	LDTH[3]	LDTH[2]	LDTH[1]	LDTH[0]	Function
0	0	0	0	0	0	0	0	Default

LDTH[7:0]: Level detection threshold value. If THOPT bit in Detection Control Register is “0”, it is unsigned 7 bits value and LDTH[7] should be “0”. If THOPT bit is “1”, it is signed 8 bits value.