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InvenSense
Sensing Everything

ICM-20649

World's First Wide-Range 6-Axis MEMS MotionTracking™ Device for Sports and High Impact Applications

GENERAL DESCRIPTION

Many of today's wearable and sports solutions, which analyze the motion of a user's golf or tennis swings, soccer ball kicks, or basketball activities, require higher than currently available ±2000 dps (degrees per second) FSR for gyroscope and ±16*g* FSR for accelerometer to better insure that critical data is not lost at the point of high impact or high speed rotation. The ICM-20649 6-axis inertial sensor offers the smallest size, lowest profile and lowest power in conjunction with industry leading high FSR.

With an extended FSR range of ±4000 dps for gyroscope and ±30*g* for accelerometer, the ICM-20649 enables precise analysis of contact sports applications providing continuous motion sensor data before, during and after impact providing more accurate feedback

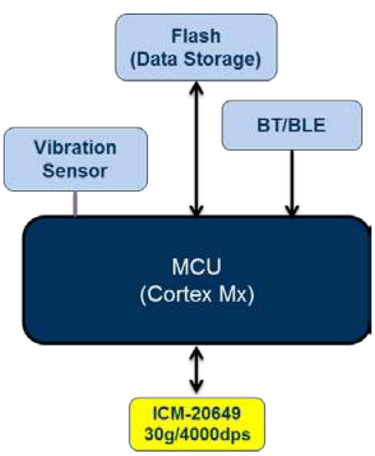
The ICM-20649 is the world's first wide-range 6-axis MotionTracking device for Sports and other High Impact applications. It is available in a 3x3x0.9 mm 24-pin QFN package.

ORDERING INFORMATION

PART	TEMP RANGE	PACKAGE
ICM-20649†	−40°C to +85°C	24-Pin QFN

†Denotes RoHS and Green-Compliant Package

BLOCK DIAGRAM



Motion Analysis Pod Architecture

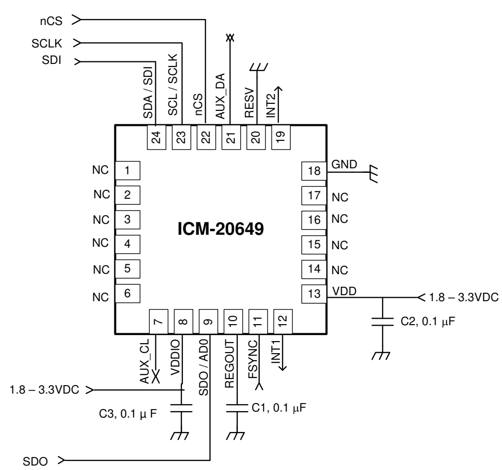
APPLICATIONS

- Sports
- Wearable Sensors
- High Impact Applications

FEATURES

- 3-Axis gyroscope with programmable FSR of ±500 dps, ±100 dps, ±2000 dps, and ±4000 dps
- 3-Axis accelerometer with programmable FSR of ±4*g*, ±8*g*, ±16*g*, and ±30*g*
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- 512-byte FIFO buffer enables the applications processor to read the data in bursts
- On-Chip 16-bit ADCs and Programmable Filters
- DMP Enabled:
  - SMD, Step Count, Step Detect, Activity Classifier, RV, GRV
  - Calibration of accel/gyro/compass
- Host interface: 7 MHz SPI or 400 kHz I^2C
- Digital-output temperature sensor
- VDD operating range of 1.71V to 3.6V
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

TYPICAL OPERATING CIRCUIT



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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document is a preliminary product specification, providing a description, specifications, and design related information on the ICM-20649 MotionTracking device.

Final specifications are available via our sales contacts. For references to register map and descriptions of individual registers, please refer to the ICM-20649 Register Map and Register Descriptions sections.

1.2 PRODUCT OVERVIEW

The ICM-20649 is a MotionTracking device that combines a 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor™ (DMP) all in a small 3.0x3.0x0.9mm QFN package. The device supports the following features:

- Android Lollipop support
- FIFO of size 512 bytes (FIFO size will vary depending on DMP feature-set)
- Runtime Calibration
- Enhanced FSYNC functionality to improve timing for applications like EIS

ICM-20649 devices, with their 6-axis integration, on-chip DMP, and run-time calibration firmware, enable manufacturers to eliminate the costly and complex selection, qualification, and system level integration of discrete devices, guaranteeing optimal motion performance for consumers.

The gyroscope has a programmable full-scale range up to ±4000 dps. The accelerometer has a user-programmable accelerometer full-scale range up to ±30*g*. Factory-calibrated initial sensitivity of both sensors reduces production-line calibration requirements.

Other key features include on-chip 16-bit ADCs, programmable digital filters, an embedded temperature sensor, and programmable interrupts. The device features I^2C and SPI serial interfaces, a VDD operating range of 1.71V to 3.6V, and a separate digital IO supply, VDDIO from 1.71V to 3.6V.

Communication with all registers of the device is performed using I^2C at up to 100 kHz (standard-mode) or up to 400 kHz (fast-mode), or SPI at up to 7 MHz.

By leveraging its patented and volume-proven CMOS-MEMS fabrication platform, which integrates MEMS wafers with companion CMOS electronics through wafer-level bonding, InvenSense has driven the package size down to a footprint and thickness of 3.0x3.0x0.9 mm (24-pin QFN), to provide a very small yet high-performance, low-cost package. The device provides high robustness by supporting 10,000*g* shock reliability.

2 FEATURES

2.1 GYROSCOPE FEATURES

The triple-axis MEMS gyroscope in the ICM-20649 includes the following features:

- Digital-output X-, Y-, and Z-axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±500 dps, ±1000 dps, ±2000 dps, and ±4000 dps and integrated 16-bit ADCs
- Digitally-programmable low-pass filter
- Factory calibrated sensitivity scale factor
- Self-test

2.2 ACCELEROMETER FEATURES

The triple-axis MEMS accelerometer in ICM-20649 includes the following features:

- Digital-output X-, Y-, and Z-axis accelerometer with a programmable full scale range of ±4*g*, ±8*g*, ±16*g*, and ±30*g* and integrated 16-bit ADCs
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- Self-test

2.3 DMP FEATURES

The DMP in ICM-20649 includes the following capabilities:

- Offloads computation of motion processing algorithms from the host processor. The DMP can be used to minimize power, simplify timing, simplify the software architecture, and save valuable MIPS on the host processor for use in applications.
- Optimized for Android Lollipop for low power features (AP suspended) including SMD, Step Count, Step Detect, Activity Classification, Rotation Vector, and Gaming Rotation Vector
- Optimized for Android Lollipop batching, both while the AP is active and suspended. The DMP will also batch data from externally connected sensors such as a compass, or pressure sensor.
- The DMP enables ultra-low power run-time and background calibration of the accelerometer, gyroscope, and compass, maintaining optimal performance of the sensor data for both physical and virtual sensors generated through sensor fusion. This enables the best user experience for all sensor enabled applications for the lifetime of the device.
- DMP features simplify the software architecture resulting in quicker time to market.
- DMP features are OS, Platform, and Architecture independent, supporting virtually any AP, MCU, or other embedded architecture.

2.4 ADDITIONAL FEATURES

The ICM-20649 includes the following additional features:

- I^2C at up to 100 kHz (standard-mode) or up to 400 kHz (fast-mode) or SPI at up to 7 MHz for communication with registers
- Auxiliary master I^2C bus for reading data from external sensors (e.g. magnetometer)
- Digital-output temperature sensor
- 10,000*g* shock tolerant
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

3 ELECTRICAL CHARACTERISTICS

3.1 GYROSCOPE SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

Note: All specifications apply to Standard (Duty-Cycled) Mode and Low-Noise Mode, unless noted otherwise.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
GYROSCOPE SENSITIVITY						
Full-Scale Range	GYRO_FS_SEL = 0		±500		dps	1
	GYRO_FS_SEL = 1		±1000		dps	1
	GYRO_FS_SEL = 2		±2000		dps	1
	GYRO_FS_SEL = 3		±4000		dps	1
Gyroscope ADC Word Length			16		bits	1
Sensitivity Scale Factor	GYRO_FS_SEL = 0		65.5		LSB/(dps)	1
	GYRO_FS_SEL = 1		32.8		LSB/(dps)	1
	GYRO_FS_SEL = 2		16.4		LSB/(dps)	1
	GYRO_FS_SEL = 3		8.2		LSB/(dps)	1
Sensitivity Scale Factor Tolerance	25°C		±0.5		%	3
Sensitivity Scale Factor Variation Over Temperature	-40°C to +85°C		±2		%	2
Nonlinearity	Best fit straight line; 25°C		±0.1		%	2, 4
Cross-Axis Sensitivity			±2		%	2, 4
ZERO-RATE OUTPUT (ZRO)						
Initial ZRO Tolerance	25°C (Component-level)		±5		dps	3
ZRO Variation Over Temperature	-40°C to +85°C		±0.05		dps/°C	2
GYROSCOPE NOISE PERFORMANCE (GYRO_FS_SEL=0)						
Noise Spectral Density	Based on Noise Bandwidth = 10 Hz		0.0175		dps/√Hz	3
GYROSCOPE MECHANICAL FREQUENCIES		25	27	29	kHz	3
LOW PASS FILTER RESPONSE	Programmable Range	5.7		197	Hz	1, 4
GYROSCOPE START-UP TIME	From Full-Chip Sleep mode		35		ms	2, 4
OUTPUT DATA RATE	Standard (duty-cycled) Mode	4.4		562.5	Hz	1
	Low-Noise Mode GYRO_FCHOICE = 1; GYRO_DLPFCFG = x	4.4		1.125k	Hz	
	Low-Noise Mode GYRO_FCHOICE = 0; GYRO_DLPFCFG = x			9k	Hz	

Table 1. Gyroscope Specifications

Notes:
1. Guaranteed by design.
2. Derived from validation or characterization of parts, not guaranteed in production.
3. Tested in production.
4. Low-noise mode specification.

3.2 ACCELEROMETER SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

Note: All specifications apply to Standard (Duty-Cycled) Mode and Low-Noise Mode, unless noted otherwise.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
ACCELEROMETER SENSITIVITY						
Full-Scale Range	ACCEL_FS = 0		±4		*g*	1
	ACCEL_FS = 1		±8		*g*	1
	ACCEL_FS = 2		±16		*g*	1
	ACCEL_FS = 3		±30		*g*	1
ADC Word Length	Output in two's complement format		16		bits	1
Sensitivity Scale Factor	ACCEL_FS = 0		8,192		LSB/*g*	1
	ACCEL_FS = 1		4,096		LSB/*g*	1
	ACCEL_FS = 2		2,048		LSB/*g*	1
	ACCEL_FS = 3		1,024		LSB/*g*	1
Initial Tolerance	Component-level		±0.5		%	3
Sensitivity Change vs. Temperature	-40°C to +85°C ACCEL_FS=0		±0.026		%/ºC	2
Nonlinearity	Best Fit Straight Line		±0.5		%	2, 4
Cross-Axis Sensitivity			±2		%	2, 4
Initial Tolerance	Component-level, all axes		±65		m*g*	3
Zero-G Level Change vs. Temperature	0°C to +85°C		±0.80		m*g*/°C	2
ACCELEROMETER NOISE PERFORMANCE						
Noise Spectral Density	Based on Noise Bandwidth = 10 Hz		285		µ*g*/√Hz	3
LOW PASS FILTER RESPONSE	Programmable Range	5.7		246	Hz	1, 4
INTELLIGENCE FUNCTION INCREMENT			32		m*g*/LSB	1
ACCELEROMETER STARTUP TIME	From Sleep mode		20		ms	2, 4
	From Cold Start, 1ms V_{DD} ramp		30		ms	2, 4
OUTPUT DATA RATE	Low-Power Mode	0.27		562.5	Hz	1
	Low-Noise Mode ACCEL_FCHOICE = 1; ACCEL_DLPFCFG = x	4.5		1.125k	Hz	
	Low-Noise Mode ACCEL_FCHOICE = 0; ACCEL_DLPFCFG = x			4.5k	Hz	

Table 2. Accelerometer Specifications

Notes:
1. Guaranteed by design.
2. Derived from validation or characterization of parts, not guaranteed in production.
3. Tested in production.
4. Low-noise mode specification.

3.3 ELECTRICAL SPECIFICATIONS

3.3.1 D.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SUPPLY VOLTAGES						
VDD		1.71	1.8	3.6	V	1
VDDIO		1.71	1.8	3.6	V	1
SUPPLY CURRENTS						
Gyroscope Only (DMP & Accelerometer disabled)	Low-Noise Mode		2.67		mA	2
Accelerometer Only (DMP & Gyroscope disabled)	Low-Noise Mode		760		µA	2
Gyroscope + Accelerometer (DMP disabled)	Low-Noise Mode		3.21		mA	2
Gyroscope Only (DMP & Accelerometer disabled)	Low-Power Mode, 102.3 Hz update rate, 1x averaging filter		1.23		mA	2, 3
Accelerometer Only (DMP & Gyroscope disabled)	Low-Power Mode, 102.3 Hz update rate, 1x averaging filter		68.9		µA	2, 3
Gyroscope + Accelerometer (DMP disabled)	Low-Power Mode, 102.3 Hz update rate, 1x averaging filter		1.27		mA	2, 3
Full-Chip Sleep Mode			8		µA	2
TEMPERATURE RANGE						
Specified Temperature Range	Performance parameters are not applicable beyond Specified Temperature Range	-40		+85	°C	1

Table 3. D.C. Electrical Characteristics

Notes:

1. Guaranteed by design.
2. Derived from validation or characterization of parts, not guaranteed in production.
3. The 102.3 Hz ODR value shown here is an example; please see the section below for the full list of ODRs supported and corresponding current values.

3.3.2 A.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SUPPLIES						
Supply Ramp Time (T_{RAMP})	Monotonic ramp. Ramp rate is 10% to 90% of the final value.	0.01	20	100	ms	1
TEMPERATURE SENSOR						
Operating Range	Ambient	-40		85	°C	1
Sensitivity	Untrimmed		333.87		LSB/°C	
Room Temp Offset	21°C		0		LSB	
Power-On RESET						
Supply Ramp Time (T_{RAMP})	Valid power-on RESET	0.01	20	100	ms	1
Start-up time for register read/write	From power-up		11	100	ms	1
I²C ADDRESS	AD0 = 0 AD0 = 1		1101000 1101001			
DIGITAL INPUTS (FSYNC, AD0, SCLK, SDI, CS)						
V_{IH}, High Level Input Voltage		0.7*VDDIO			V	1
V_{IL}, Low Level Input Voltage				0.3*VDDIO	V	
C_I, Input Capacitance			< 10		pF	
DIGITAL OUTPUT (SDO, INT)						
V_{OH}, High Level Output Voltage	R_{LOAD} = 1 MΩ;	0.9*VDDIO			V	1
V_{OL1}, LOW-Level Output Voltage	R_{LOAD} = 1 MΩ;			0.1*VDDIO	V	
$V_{OL.INT1}$, INT Low-Level Output Voltage	OPEN = 1, 0.3 mA sink Current			0.1	V	
Output Leakage Current	OPEN = 1		100		nA	
t_{INT}, INT Pulse Width	LATCH_INT_EN = 0		50		µs	
I²C I/O (SCL, SDA)						
V_{IL}, LOW Level Input Voltage		-0.5 V		0.3*VDDIO	V	1
V_{IH}, HIGH-Level Input Voltage		0.7*VDDIO		VDDIO + 0.5 V	V	
V_{hys}, Hysteresis			0.1*VDDIO		V	
V_{OL}, LOW-Level Output Voltage	3 mA sink current	0		0.4	V	
I_{OL}, LOW-Level Output Current	V_{OL} = 0.4 V V_{OL} = 0.6 V		3 6		mA mA	
Output Leakage Current			100		nA	
t_{of}, Output Fall Time from V_{IHmax} to V_{ILmax}	C_b bus capacitance in pf	20+0.1 C_b		250	ns	
AUXILLIARY I/O (AUX_CL, AUX_DA)						
V_{IL}, LOW-Level Input Voltage		-0.5 V		0.3*VDDIO	V	1
V_{IH}, HIGH-Level Input Voltage		0.7* VDDIO		VDDIO + 0.5 V	V	
V_{hys}, Hysteresis			0.1* VDDIO		V	
V_{OL1}, LOW-Level Output Voltage	VDDIO > 2 V; 1 mA sink current	0		0.4	V	
V_{OL3}, LOW-Level Output Voltage	VDDIO < 2 V; 1 mA sink current	0		0.2* VDDIO	V	
I_{OL}, LOW-Level Output Current	V_{OL} = 0.4 V V_{OL} = 0.6 V		3 6		mA mA	
Output Leakage Current			100		nA	
t_{of}, Output Fall Time from V_{IHmax} to V_{ILmax}	C_b bus capacitance in pF	20+0.1C_b		250	ns	
INTERNAL CLOCK SOURCE						
Clock Frequency Initial Tolerance	Accelerometer Only Mode	-5		+5	%	1
	Gyroscope or 6-Axis Mode WITHOUT Timebase Correction	-9		+9	%	1
	Gyroscope or 6-Axis Mode WITH Timebase Correction	-1		+1		

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
Frequency Variation over Temperature	Accelerometer Only Mode	-10		+10	%	1
	Gyroscope or 6-Axis Mode		±1		%	1

Table 4. A.C. Electrical Characteristics

Notes:

1. Derived from validation or characterization of parts, not guaranteed in production.

3.3.3 Other Electrical Specifications

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	Units	Notes
SERIAL INTERFACE						
SPI Operating Frequency, All Registers Read/Write	Low Speed Characterization		100 ±10%		kHz	
	High Speed Characterization		7 ±10%		MHz	
I^2C Operating Frequency	All registers, Fast-mode			400	kHz	
	All registers, Standard-mode			100	kHz	

Table 5. Other Electrical Specifications

3.4 I²C TIMING CHARACTERIZATION

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

PARAMETERS	CONDITIONS	MIN	TYPICAL	MAX	UNITS	NOTES
I²C TIMING	I²C FAST-MODE					
f_{SCL}, SCL Clock Frequency				400	kHz	1, 2
$t_{HD.STA}$, (Repeated) START Condition Hold Time		0.6			µs	1, 2
t_{LOW}, SCL Low Period		1.3			µs	1, 2
t_{HIGH}, SCL High Period		0.6			µs	1, 2
$t_{SU.STA}$, Repeated START Condition Setup Time		0.6			µs	1, 2
$t_{HD.DAT}$, SDA Data Hold Time		0			µs	1, 2
$t_{SU.DAT}$, SDA Data Setup Time		100			ns	1, 2
t_r, SDA and SCL Rise Time	C_b bus cap. from 10 to 400 pF	20+0.1C_b		300	ns	1, 2
t_f, SDA and SCL Fall Time	C_b bus cap. from 10 to 400 pF	20+0.1C_b		300	ns	1, 2
$t_{SU.STO}$, STOP Condition Setup Time		0.6			µs	1, 2
t_{BUF}, Bus Free Time Between STOP and START Condition		1.3			µs	1, 2
C_b, Capacitive Load for each Bus Line			< 400		pF	1, 2
$t_{VD.DAT}$, Data Valid Time				0.9	µs	1, 2
$t_{VD.ACK}$, Data Valid Acknowledge Time				0.9	µs	1, 2

Table 6. I²C Timing Characteristics

Notes:

1. Timing Characteristics apply to both Primary and Auxiliary I²C Bus.
2. Based on characterization of 5 parts over temperature and voltage as mounted on evaluation board or in sockets.

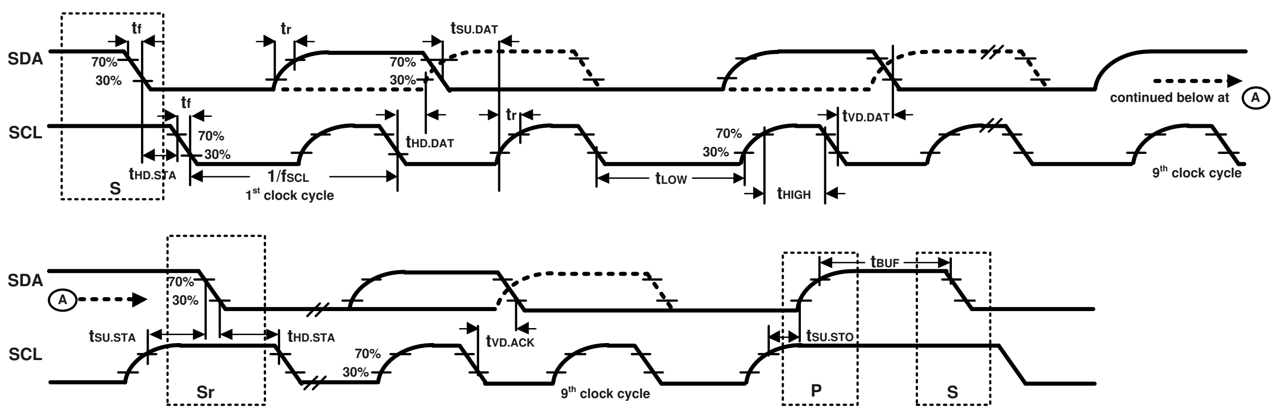

Figure 1. I²C Bus Timing Diagram

3.5 SPI TIMING CHARACTERIZATION

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T_A = 25°C, unless otherwise noted.

Parameters	Conditions	Min	Typical	Max	Units	Notes
SPI TIMING						
f_{SCLK}, SCLK Clock Frequency				7	MHz	
t_{LOW}, SCLK Low Period		64			ns	
t_{HIGH}, SCLK High Period		64			ns	
$t_{SU.CS}$, CS Setup Time		8			ns	
$t_{HD.CS}$, CS Hold Time		500			ns	
$t_{SU.SDI}$, SDI Setup Time		5			ns	
$t_{HD.SDI}$, SDI Hold Time		7			ns	
$t_{VD.SDO}$, SDO Valid Time	C_{load} = 20 pF			59	ns	
$t_{HD.SDO}$, SDO Hold Time	C_{load} = 20 pF	6			ns	
$t_{DIS.SDO}$, SDO Output Disable Time				50	ns	

Table 7. SPI Timing Characteristics (7 MHz)

Note:
1. Based on characterization of 5 parts over temperature and voltage as mounted on evaluation board or in sockets.

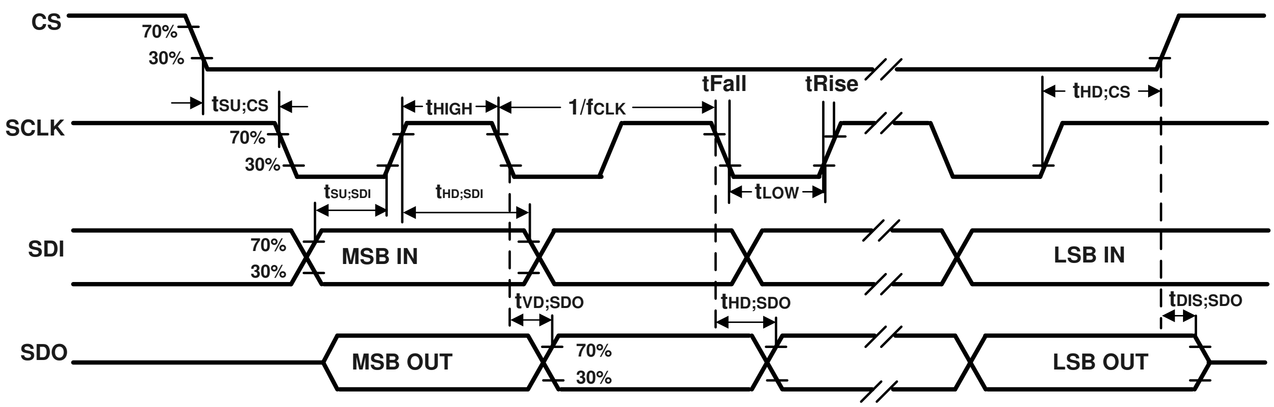

Figure 2. SPI Bus Timing Diagram

3.6 ABSOLUTE MAXIMUM RATINGS

Stress above those listed as "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to the absolute maximum ratings conditions for extended periods may affect device reliability.

Parameter	Rating
Supply Voltage, VDD	-0.5V to 4V
Supply Voltage, VDDIO	-0.5V to 4V
REGOUT	-0.5V to 2V
Input Voltage Level (AUX_DA, AD0, FSYNC, INT, SCL, SDA)	-0.5V to VDD + 0.5V
Acceleration (Any Axis, unpowered)	10,000*g* for 0.2 ms
Operating Temperature Range	-40°C to +105°C
Storage Temperature Range	-40°C to +125°C
Electrostatic Discharge (ESD) Protection	2 kV (HBM); 200V (MM)
Latch-up	JEDEC Class II (2),125°C ±100 mA

Table 8. Absolute Maximum Ratings

4 APPLICATIONS INFORMATION

4.1 PIN OUT DIAGRAM AND SIGNAL DESCRIPTION

PIN NUMBER	PIN NAME	PIN DESCRIPTION
7	AUX_CL	I^2C Master serial clock, for connecting to external sensors.
8	VDDIO	Digital I/O supply voltage.
9	AD0 / SDO	I^2C Slave Address LSB (AD0); SPI serial data output (SDO).
10	REGOUT	Regulator filter capacitor connection.
11	FSYNC	Frame synchronization digital input. Connect to GND if unused.
12	INT1	Interrupt 1.
13	VDD	Power supply voltage.
18	GND	Power supply ground.
19	INT2	Interrupt 2.
20	RESV	Reserved. Connect to GND.
21	AUX_DA	I^2C master serial data, for connecting to external sensors.
22	nCS	Chip select (SPI mode only).
23	SCL / SCLK	I^2C serial clock (SCL); SPI serial clock (SCLK).
24	SDA / SDI	I^2C serial data (SDA); SPI serial data input (SDI).
1 – 6, 14 - 17	NC	No Connect pins. Do not connect.

Table 9. Signal Descriptions

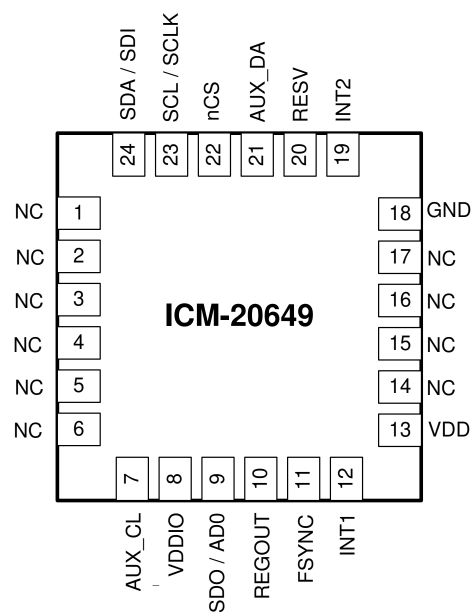

Figure 3. Pin out Diagram for ICM-20649 3.0x3.0x0.9 mm QFN

4.2 TYPICAL OPERATING CIRCUIT

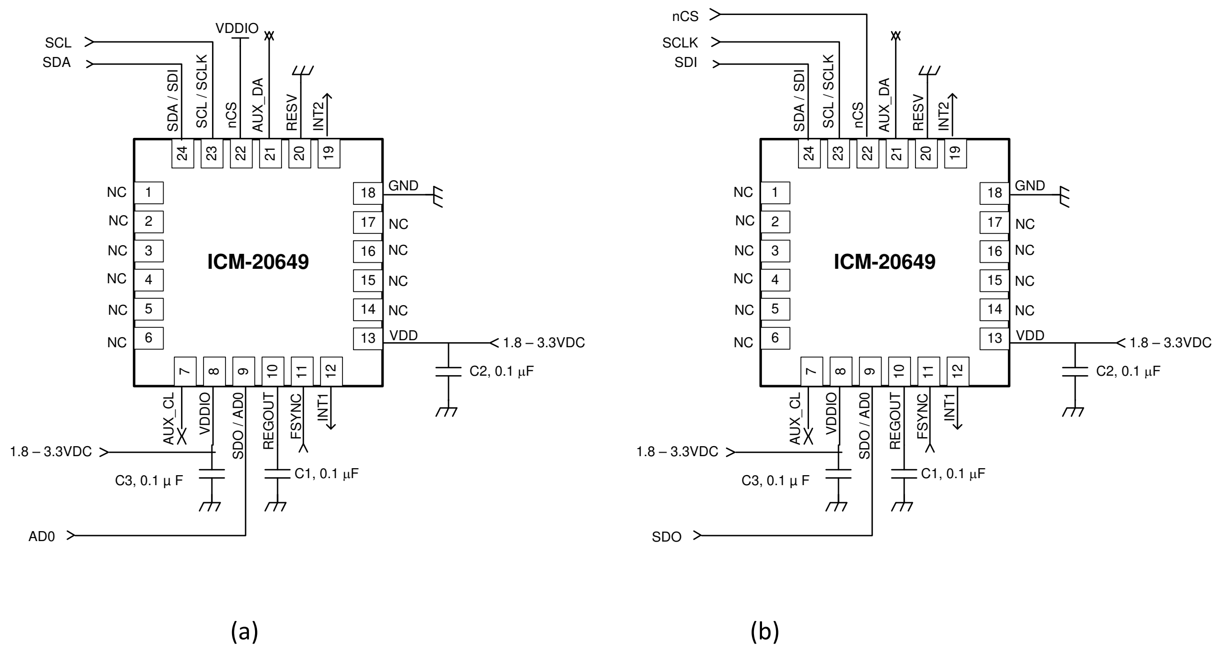

Figure 4. ICM-20649 Application Schematic (a) I²C operation (b) SPI operation

4.3 BILL OF MATERIALS FOR EXTERNAL COMPONENTS

Component	Label	Specification	Quantity
Regulator Filter Capacitor	C1	Ceramic, X7R, 0.1 µF ±10%	1
VDD Bypass Capacitor	C2	Ceramic, X7R, 0.1 µF ±10%	1
VDDIO Bypass Capacitor	C3	Ceramic, X7R, 0.1 µF ±10%	1

Table 10. Bill of Materials

4.4 BLOCK DIAGRAM

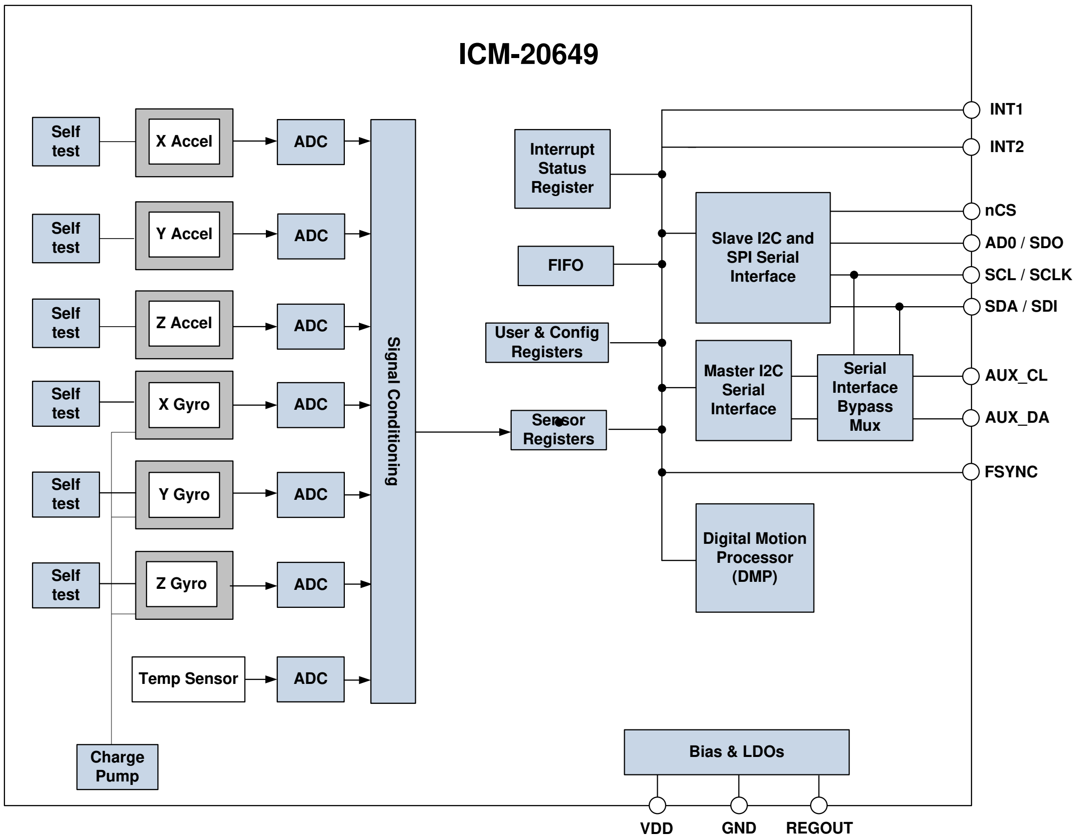

Figure 5. ICM-20649 Block Diagram

4.5 OVERVIEW

The ICM-20649 is comprised of the following key blocks and functions:

- Three-axis MEMS rate gyroscope sensor with 16-bit ADCs and signal conditioning
- Three-axis MEMS accelerometer sensor with 16-bit ADCs and signal conditioning
- Digital Motion Processor (DMP) engine
- Primary I^{2}C and SPI serial communications interfaces
- Auxiliary I^{2}C serial interface
- Self-Test
- Clocking
- Sensor Data Registers
- FIFO
- FSYNC
- Interrupts
- Digital-Output Temperature Sensor
- Bias and LDOs
- Charge Pump
- Power Modes

4.6 THREE-AXIS MEMS GYROSCOPE WITH 16-BIT ADCS AND SIGNAL CONDITIONING

The ICM-20649 consists of three independent vibratory MEMS rate gyroscopes, which detect rotation about the X-, Y-, and Z- Axes. When the gyros are rotated about any of the sense axes, the Coriolis Effect causes a vibration that is detected by a capacitive pickoff. The resulting signal is amplified, demodulated, and filtered to produce a voltage that is proportional to the angular rate. This voltage is digitized using individual on-chip 16-bit Analog-to-Digital Converters (ADCs) to sample each axis. The full-scale range of the gyro sensors may be digitally programmed to ±500, ±1000, ±2000, or ±4000 degrees per second (dps).

4.7 THREE-AXIS MEMS ACCELEROMETER WITH 16-BIT ADCS AND SIGNAL CONDITIONING

The ICM-20649's 3-Axis accelerometer uses separate proof masses for each axis. Acceleration along a particular axis induces displacement on the corresponding proof mass, and capacitive sensors detect the displacement differentially. The ICM-20649's architecture reduces the accelerometers' susceptibility to fabrication variations as well as to thermal drift. When the device is placed on a flat surface, it will measure 0*g* on the X- and Y-axes and +1*g* on the Z-axis. The accelerometers' scale factor is calibrated at the factory and is nominally independent of supply voltage. Each sensor has a dedicated sigma-delta ADC for providing digital outputs. The full scale range of the digital output can be adjusted to ±4*g*, ±8*g*, ±16*g*, or ±30*g*.

4.8 DIGITAL MOTION PROCESSOR

The embedded Digital Motion Processor (DMP) within the ICM-20649 offloads computation of motion processing algorithms from the host processor. The DMP acquires data from accelerometers, gyroscopes, and additional third party sensors such as magnetometers, and processes the data. The resulting data can be read from the FIFO. The DMP has access to the external pins, which can be used for generating interrupts.

The purpose of the DMP is to offload both timing requirements and processing power from the host processor. Typically, motion processing algorithms should be run at a high rate, often around 200 Hz, in order to provide accurate results with low latency. This is required even if the application updates at a much lower rate; for example, a low power user interface may update as slowly as 5 Hz, but the motion processing should still run at 200 Hz. The DMP can be used to minimize power, simplify timing, simplify the software architecture, and save valuable MIPS on the host processor for use in applications.

The DMP is optimized for Android Lollipop support.

4.9 PRIMARY I^2C AND SPI SERIAL COMMUNICATIONS INTERFACES

The ICM-20649 communicates to a system processor using either a SPI or an I^2C serial interface. The ICM-20649 always acts as a slave when communicating to the system processor. The LSB of the of the I^2C slave address is set by pin 1 (AD0).

4.9.1 ICM-20649 Solution Using I^2C Interface

In Figure 6, the system processor is an I^2C master to the ICM-20649. In addition, the ICM-20649 is an I^2C master to the optional external compass sensor. The ICM-20649 has limited capabilities as an I^2C Master, and depends on the system processor to manage the initial configuration of any auxiliary sensors. The ICM-20649 has an interface bypass multiplexer, which connects the system processor I^2C bus pins 23 and 24 (SCL and SDA) directly to the auxiliary sensor I^2C bus pins 7 and 21 (AUX_CL and AUX_DA).

Once the auxiliary sensors have been configured by the system processor, the interface bypass multiplexer should be disabled so that the ICM-20649 auxiliary I^2C master can take control of the sensor I^2C bus and gather data from the auxiliary sensors.

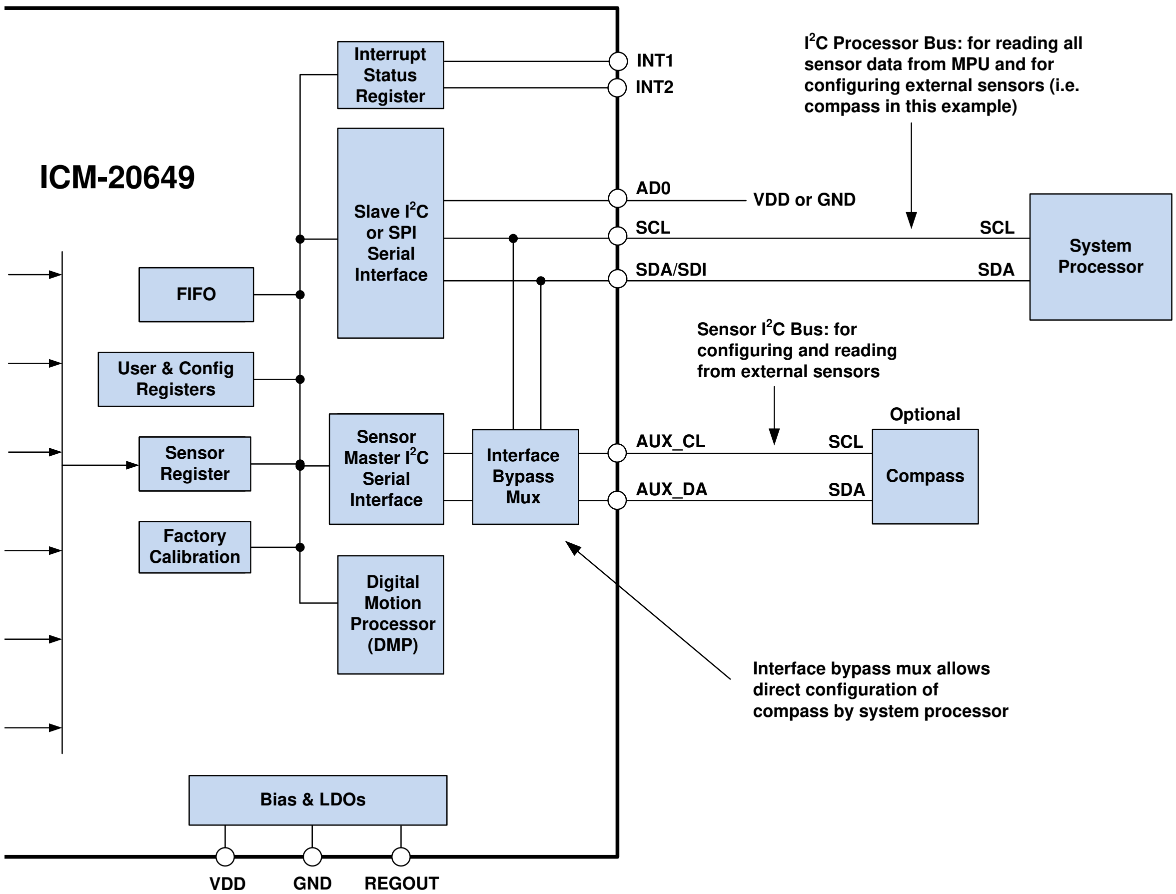

Figure 6. ICM-20649 Solution Using I²C Interface

4.9.2 ICM-20649 Solution Using SPI Interface

In Figure 7, the system processor is an SPI master to the ICM-20649. Pins 9, 22, 23, and 24 are used to support the SDO, nCS, SCLK, and SDI signals for SPI communications. Because these SPI pins are shared with the I^2C slave pins (9, 23 and 24), the system processor cannot access the auxiliary I^2C bus through the interface bypass multiplexer, which connects the processor I^2C interface pins to the sensor I^2C interface pins. Since the ICM-20649 has limited capabilities as an I^2C Master, and depends on the system processor to manage the initial configuration of any auxiliary sensors, another method must be used for programming the sensors on the auxiliary sensor I^2C bus pins 7 and 21 (AUX_CL and AUX_DA).

When using SPI communications between the ICM-20649 and the system processor, configuration of devices on the auxiliary I^2C sensor bus can be achieved by using I^2C Slaves 0-4 to perform read and write transactions on any device and register on the auxiliary I^2C bus. The I^2C Slave 4 interface can be used to perform only single byte read and write transactions. Once the external sensors have been configured, the ICM-20649 can perform single or multi-byte reads using the sensor I^2C bus. The read results from the Slave 0-3 controllers can be written to the FIFO buffer as well as to the external sensor registers.

For more information regarding the control of the ICM-20649's auxiliary I^2C interface, please refer to the ICM-20649 Register Map and Register Descriptions sections.

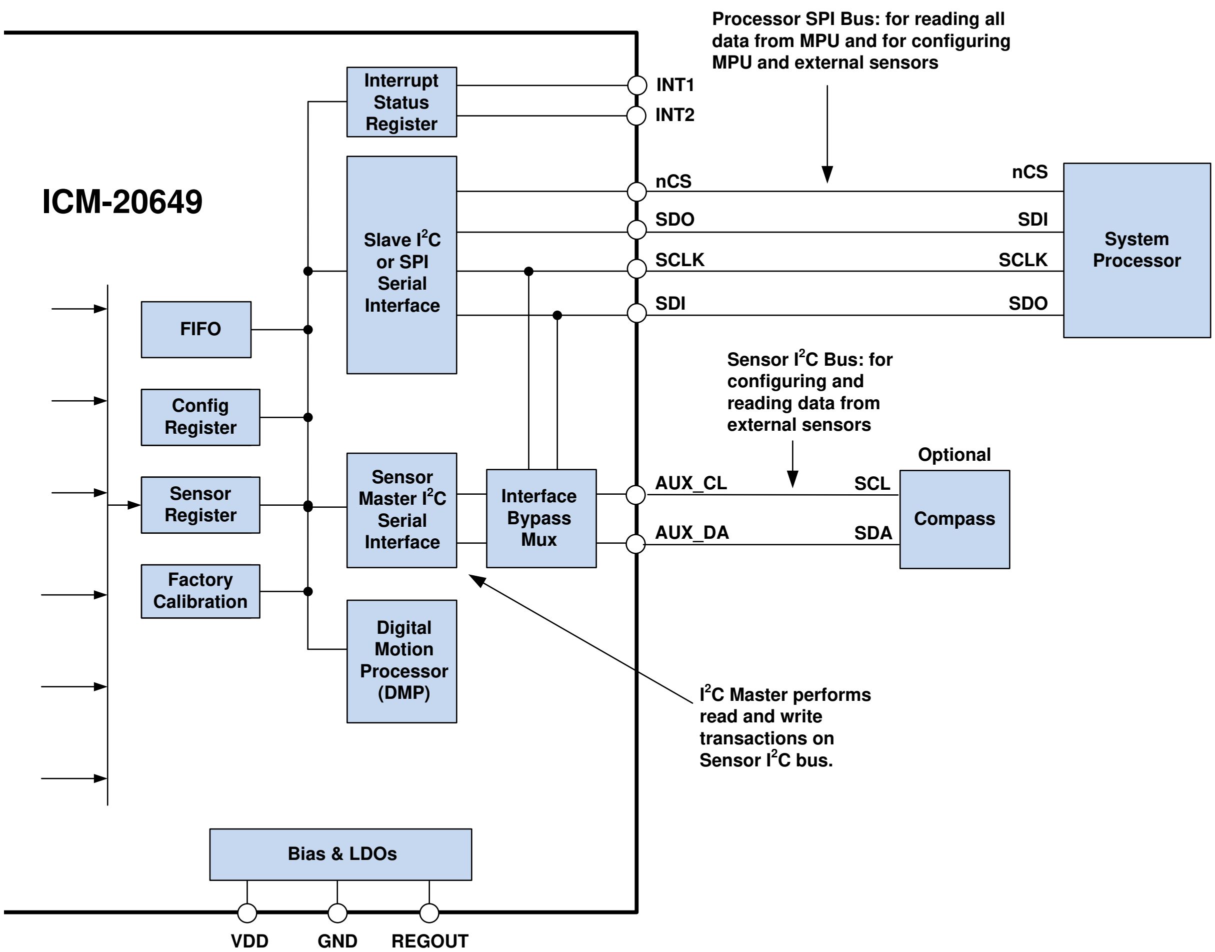

Figure 7. ICM-20649 Solution Using SPI Interface