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ICM-20789

7-Axis, High Performance Integrated 6-Axis Inertial and Barometric Pressure Sensor

GENERAL DESCRIPTION

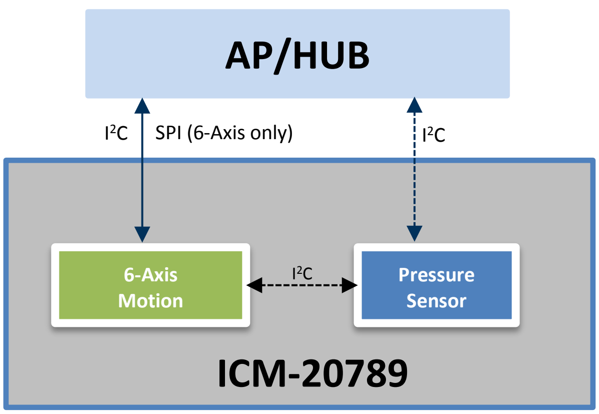
The 7-Axis ICM-20789 is an integrated 6-axis inertial device that combines a 3-axis gyroscope, 3-axis accelerometer, and an ultra-low noise MEMS capacitive pressure sensor in a 24-pin LGA package. This unique 7-Axis device offers performance of discrete components in a single small footprint for tracking rotational and linear motion as well as pressure differences with an accuracy of ±1 Pa, an accuracy enabling altitude measurement differentials as small as 8.5 cm.

The pressure sensor's MEMS capacitive architecture provides the industry's lowest noise at the lowest power, high sensor throughput, and temperature coefficient offset of ±0.5 Pa/°C. The pressure sensor's combination of high accuracy elevation measurements, low power, and temperature stability complemented by the motion tracking 6-axis inertial sensor in a small footprint, make it ideal for a wide range of motion tracking applications.

The embedded 6-axis MotionTracking device combines a 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor™ (DMP). An available large 4 kB FIFO reduces traffic on the serial bus interface, and power consumption through burst sensor data transmission. The Gyroscope has programmable FSR of ±250 dps, ±500 dps, ±1000 dps and ±2000 dps. The Accelerometer FSR is programmable to ±2g, ±4g, ±8g and ±16g

ICM-20789 has 16-bit ADC for the 6-axis inertial sensor and 24-bit ADC for the pressure Sensor, programmable digital filters, two temperature sensors – one each in 6-axis Inertial and Pressure sensor. The device features an operating voltage of 1.8V. Communication port includes I^2C at 400 kHz (6-axis and Pressure) and 8 MHz SPI (6-axis only). The package is 4x4x1.365 mm 24-pin to minimize board area requirements.

BLOCK DIAGRAM



APPLICATIONS

- Drones and Flying Toys
- Motion-based gaming controllers
- Virtual Reality headsets and controllers
- Indoor/Outdoor Navigation (dead-reckoning, floor/elevator/step detection)

FEATURES

- Pressure operating range: 30 to 110 kPa
- Noise and current consumption
  - 3.2 Pa @ 1.3 µA (LP mode)
  - 0.8 Pa @ 5.2 µA (LN mode)
  - 0.4 Pa @ 10.4 µA (ULN mode)
- Pressure Sensor Relative Accuracy: ±1 Pa for any 10 hPa change over 950 hPa-1050 hPa at 25°C
- Pressure Sensor Absolute Accuracy: ±1 hPa over 950 hPa-1050 hPa, 0°C to 65°C
- Pressure Sensor Temperature Coefficient Offset: ±0.5 Pa/°C over 25°C to 45°C at 100 kPa
- Gyroscope programmable FSR of ±250 dps, ±500 dps, ±1000 dps, and ±2000 dps
- Accelerometer with Programmable FSR of ±2*g*, ±4*g*, ±8*g*, and ±16*g*
- Large 4 kB FIFO reduces traffic on the serial bus interface
- EIS FSYNC support
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- Host interface: 400 kHz Fast Mode I^2C & 8 MHz SPI (see datasheet for ICM-20689)
- Digital-output temperature sensor (x2)
- Nominal VDD operation at 1.8V
- RoHS and Green compliant

ORDERING INFORMATION

PART	TEMP RANGE	PACKAGE
ICM-20789†	−40°C to +85°C	24-Pin LGA

†Denotes RoHS and Green-Compliant Package

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document is a product specification, providing a description, specifications, and design related information on the ICM-20789, a 6-axis inertial and pressure sensor device. The device is packaged in a 4 mm x 4 mm x 1.365 mm 24-pin LGA package.

1.2 PRODUCT OVERVIEW

The ICM-20789 is a 6-axis inertial sensor, 3-axis gyroscope and a 3-axis accelerometer, ultra-low noise MEMS capacitive barometric pressure sensor in a 4 mm x 4 mm x 1.365 mm (24-pin LGA) package. It features a 4 KB FIFO that can lower the traffic on the serial bus interface.

The digital output barometric pressure sensor is based on an ultra-low noise innovative MEMS capacitive technology that can measure pressure differences with an accuracy of ±1 Pa, an accuracy enabling altitude measurement differentials as small as 8.5 cm without the penalty of increased power consumption or reduced sensor throughput. The capacitive pressure sensor has a ±1 hPa absolute accuracy over its full range of 300 hPa -1100 hPa. The pressure sensor offers industry leading temperature stability of the pressure sensor with a temperature coefficient offset of ±0.5 Pa/°C, embedded temperature sensor and 400 kHz I^2C bus for communication.

The gyroscope has a programmable full-scale range of ±250 dps, ±500 dps, ±1000 dps, and ±2000 dps. The accelerometer has a user-programmable full-scale range of ±2*g*, ±4*g*, ±8*g*, and ±16*g*. Factory-calibrated initial sensitivity of both sensors reduces production-line calibration requirements. Other features include on-chip 16-bit ADCs, programmable digital filters, another embedded temperature sensor, and programmable interrupts. The device features I^2C serial interface to access its registers at 400 kHz as well as at 8 MHz SPI.

By leveraging its patented and volume-proven CMOS-MEMS fabrication platform, which integrates MEMS wafers with companion CMOS electronics through wafer-level bonding, TDK has driven the package size down to a footprint and thickness of 4 mm x 4 mm x 1.365 mm (24-pin LGA), to provide an integrated high-performance package. The device provides high robustness by supporting 10,000*g* shock reliability.

1.3 APPLICATIONS

- Drones and Flying Toys
- Motion-based gaming controllers
- Virtual Reality Headsets & Controllers
- Indoor/Outdoor Navigation (dead-reckoning, floor/elevation/step detection)

2 FEATURES

2.1 GYROSCOPE FEATURES

- Digital-output X-, Y-, and Z-axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250 dps, ±500 dps, ±1000 dps, and ±2000 dps and integrated 16-bit ADCs
- Digitally-programmable low-pass filter
- Low-power gyroscope operation
- Factory calibrated sensitivity scale factor
- Self-test

2.2 ACCELEROMETER FEATURES

- Digital-output X-, Y-, and Z-axis accelerometer with a programmable full scale range of ±2*g*, ±4*g*, ±8*g*, and ±16*g* and integrated 16-bit ADCs
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- Self-test

2.3 PRESSURE SENSOR FEATURES

- Pressure operating range: 30 kPa to 110 kPa
- 4 operating modes to optimize noise and power, 3 example modes:
  - 3.2 Pa @ 1.3 µA (LP mode)
  - 0.8 Pa @ 5.2 µA (LN mode)
  - 0.4 Pa @ 10.4 µA (ULN mode)
- Relative accuracy: ±1 Pa for any 10 hPa change over 950 hPa-1050 hPa at 25°C
- Absolute accuracy: ±1 hPa over 950 hPa-1050 hPa, 0°C to 65°C
- Temperature Coefficient Offset: ±0.5 Pa/°C over 25°C to 45°C at 100 kPa
- I^2C at 400 kHz
- Temperature sensor accuracy: ±0.4°C

2.4 ADDITIONAL FEATURES

- Minimal cross-axis sensitivity between the accelerometer and gyroscope axes
- 4 kB FIFO buffer enables the applications processor to read the data in bursts
- Digital-output temperature sensor
- User-programmable digital filters for gyroscope, accelerometer, and temp sensor
- 10,000*g* shock tolerant
- 400 kHz Fast Mode I^2C for communicating with all registers
- RoHS and Green compliant

2.5 MOTION PROCESSING

- Internal Digital Motion Processing™ (DMP™) engine supports advanced MotionProcessing and low power functions
- DMP operation is possible in low-power gyroscope and low-power accelerometer modes

3 ELECTRICAL CHARACTERISTICS

3.1 GYROSCOPE SPECIFICATIONS

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, T_A=25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
GYROSCOPE SENSITIVITY						
Full-Scale Range	FS_SEL=0		±250		dps	3
	FS_SEL=1		±500		dps	3
	FS_SEL=2		±1000		dps	3
	FS_SEL=3		±2000		dps	3
Gyroscope ADC Word Length			16		bits	3
Sensitivity Scale Factor	FS_SEL=0		131		LSB/(dps)	3
	FS_SEL=1		65.5		LSB/(dps)	3
	FS_SEL=2		32.8		LSB/(dps)	3
	FS_SEL=3		16.4		LSB/(dps)	3
Sensitivity Scale Factor Tolerance	Component-Level, 25°C		±2		%	2
Sensitivity Scale Factor Variation Over Temperature	-40°C to +85°C		±1.5		%	1
Nonlinearity	Best fit straight line; 25°C		±0.1		%	1
Cross-Axis Sensitivity			±2		%	1
ZERO-RATE OUTPUT (ZRO)						
Initial ZRO Tolerance	Component-Level, 25°C		±5		dps	2
ZRO Variation Over Temperature	-40°C to +85°C		±0.05		dps/°C	1
GYROSCOPE NOISE PERFORMANCE (FS_SEL=0)						
Noise Spectral Density			0.006		dps/√Hz	1
Gyroscope Mechanical Frequencies		25	27	29	kHz	2
Low Pass Filter Response	Programmable Range	5		250	Hz	3
Gyroscope Start-Up Time	From Sleep mode		35		ms	1
Output Data Rate	Standard (duty-cycled) mode	3.91		500	Hz	1
	Low-Noise (active) mode	4		8000	Hz	1

Table 1. Gyroscope Specifications

Notes:

1. Derived from validation or characterization of parts, not guaranteed in production.
2. Tested in production.
3. Guaranteed by design.

3.2 ACCELEROMETER SPECIFICATIONS

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, T_A=25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
ACCELEROMETER SENSITIVITY						
Full-Scale Range	AFS_SEL=0		±2		*g*	3
	AFS_SEL=1		±4		*g*	3
	AFS_SEL=2		±8		*g*	3
	AFS_SEL=3		±16		*g*	3
ADC Word Length	Output in two's complement format		16		bits	3
Sensitivity Scale Factor	AFS_SEL=0		16,384		LSB/*g*	3
	AFS_SEL=1		8,192		LSB/*g*	3
	AFS_SEL=2		4,096		LSB/*g*	3
	AFS_SEL=3		2,048		LSB/*g*	3
Sensitivity Initial Tolerance	Component-Level, 25°C		±2		%	2
Sensitivity Change vs. Temperature	-40°C to +85°C		±1		%	1
Nonlinearity	Best Fit Straight Line		±0.5		%	1
Cross-Axis Sensitivity			±2		%	1
ZERO-G OUTPUT						
Offset Initial Tolerance	Component-Level, 25°C		±80		m*g*	2
Zero-G Level Change vs. Temperature	-5°C to +85°C		±0.75		m*g*/°C	1
NOISE PERFORMANCE						
Noise Spectral Density			150		µ*g*/√Hz	1
Low Pass Filter Response	Programmable Range	5		218	Hz	3
Intelligence Function Increment			4		m*g*/LSB	3
Accelerometer Startup Time	From Sleep mode		20		ms	1
	From Cold Start, 1 ms V_{DD} ramp		30		ms	1
Output Data Rate	Standard (duty-cycled) mode	0.24		500	Hz	1
	Low-Noise (active) mode	4		4000	Hz	

Table 2. Accelerometer Specifications

Notes:
1. Derived from validation or characterization of parts, not guaranteed in production.
2. Tested in production.
3. Guaranteed by design.

3.3 PRESSURE SENSOR SPECIFICATIONS

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, TA=25°C, unless otherwise noted.

OPERATION RANGE	PRESSURE (kPa)	TEMPERATURE (°C)
Normal	70 to 110	0 to 65
Extended	30 to 110	0 to 65
Maximum	25 to 115	-40 to 85

Table 3. Operation Ranges

PRESSURE PARAMETER	CONDITIONS	Sensor Mode	TYP	MAX	UNITS	NOTES
Conversion Time	Time between sending last bit of measurement command, and sensor data ready for measurement	Low Power (LP)	1.6	1.8	ms	1
		Normal (N)	5.6	6.3		1
		Low Noise (LN)	20.8	23.8		1
		Ultra Low Noise (ULN)	83.2	94.5		1
Current Consumption	1 Hz ODR	Low Power (LP)	1.3		µA	
		Normal (N)	2.6			
		Low Noise (LN)	5.2			
		Ultra Low Noise (ULN)	10.4			
Pressure RMS Noise	Valid for P = 100 kPa, T = 25°C, and U = 1.8V	Low Power (LP)	3.2		Pa	
		Normal	1.6			
		Low Noise (LN)	0.8			
		Ultra Low Noise (ULN)	0.4			

Table 4. Operation Modes

Notes:
1. Guaranteed by design.

PARAMETER	CONDITIONS	TYP	UNITS	NOTES
Absolute Accuracy	Normal range Extended range	±1 ±1.5	hPa	1
Relative Accuracy	Any step ≤ 1 kPa, 25 °C Any step ≤ 10 kPa, 25 °C	±1 ±3	Pa	
Long-term drift During 1 year	Extended range	±1	hPa/y	
Solder drift		1.5	hPa	1, 2
Temperature coefficient offset	P = 100 kPa 25°C … 45°C	±0.5	Pa/°C	
Resolution	Maximum range	0.01	Pa	

Table 5. Pressure Sensor Specifications

Notes:
1. Absolute accuracy may be improved through One Point Calibration
2. Sensor accuracy post Solder reflow may be improved through One Point Calibration

Temperature PARAMETER	CONDITIONS	TYP	MAX	UNITS	NOTES
Absolute Accuracy	Extended range	±0.4		°C	
Repeatability	Extended range	±0.1		°C	
Resolution	Maximum range	0.01		°C	
Long-term drift	Normal range	<0.04		°C/y	

Table 6. Temperature Sensor Specifications

3.4 ELECTRICAL SPECIFICATIONS

D.C. Electrical Characteristics

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, T_A=25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SUPPLY VOLTAGES						
VDD (For 6-axis MEMS)		1.71	1.8	3.45	V	1
VDDIO (Pressure Sensor VDD and Chip I/O)		1.71	1.8	1.98	V	1
SUPPLY CURRENTS & BOOT TIME						
Normal Mode	7-axis Gyroscope + Accelerometer + Pressure		3.0		mA	1
	3-axis Gyroscope		2.6		mA	1
	3-axis Accelerometer, 4 kHz ODR		390		µA	1
	Pressure Sensor		1.1		µA	1
Accelerometer Low -Power Mode	100 Hz ODR, 1x averaging		57		µA	2
Gyroscope Low-Power Mode	100 Hz ODR, 1x averaging		1.6		mA	2
6-Axis Low-Power Mode (Gyroscope Low-Power Mode; Accelerometer Low-Noise Mode)	100 Hz ODR, 1x averaging		1.9		mA	2
Full-Chip Sleep Mode			6		µA	1
TEMPERATURE RANGE						
Specified Temperature Range	Performance parameters are not applicable beyond Specified Temperature Range	-40		+85	°C	1

Table 7. D.C. Electrical Characteristics

Notes:

1. Derived from validation or characterization of parts, not guaranteed in production.
2. Based on simulation.

A.C. Electrical Characteristics

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, 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		100	ms	1
TEMPERATURE SENSOR						
Operating Range	Ambient	-40		85	°C	1
Room Temperature Offset	25°C		0		°C	1
Sensitivity	Untrimmed		0.003		°C/LSB	1
POWER-ON RESET						
Supply Ramp Time (T_{RAMP}) (6-Axis)	Valid power-on RESET	0.01		100	ms	1
Start-up time for register read/write (6-Axis)	From power-up		11	100	ms	1
	From sleep			5	ms	1
Power-up time (pressure sensor)	After hard reset (Vdd>Vpor		170		µs	1
Soft reset time (Pressure sensor)	After soft reset		170		µs	a
I²C ADDRESS	AD0 = 0 AD0 = 1		1101000 1101001			
DIGITAL INPUTS (FSYNC, AD0)						
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 (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	
$V_{OL.INT}$, 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	$20+0.1C_b$		300	ns	

Table 8. A.C. Electrical Characteristics (6-Axis)

Notes:

1. Guaranteed by design

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	COMMENTS
Supply voltage	V_{DD}		1.71	1.8	1.89	V	
Power-up/down level	V_{POR}	Static power supply	1.0	1.25	1.5	V	
Supply current	I_{DD}	Idle state	-	1.0	2.5	µA	
		Measurement	-	210	300	µA	Current consumption while sensor is measuring.
		Average	-	1.3	-	µA	Current consumption in continuous operation @ 1 Hz ODR in LP Mode
			-	5.2	-	µA	Current consumption in continuous operation @1 Hz ODR in LN Mode
Low level input voltage	V_{IL}		0	-	0.3 V_{DD}	V	
High level input voltage	V_{IH}		0.7 V_{DD}	-	V_{DD}	V	
Low level output voltage	V_{OL}	0 < IOL < 3 mA	-	-	0.2 V_{DD}	V	
Output Sink Current	I_{OL}	V_{OL} = 0.4V	3.1	4.1	-	mA	
		V_{OL} = 0.6V	3.5	4.5	-	mA	

Table 9. Electrical Characteristics (Pressure sensor)

Other Electrical Specifications

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, T_A=25°C, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
SERIAL INTERFACE						
I²C Operating Frequency	All registers, Fast-mode			400	kHz	1
	All registers, Standard-mode			100	kHz	1

Table 10. Other Electrical Specifications

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

3.5 I²C TIMING CHARACTERIZATION

Typical Operating Circuit Figure 3, VDD = 1.8V, VDDIO = 1.8V, T_A=25°C, unless otherwise noted.

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

PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS	NOTES
I²C TIMING	**I²C FAST-MODE**					
$t_{VD.DAT}$, Data Valid Time				0.9	µs	1
$t_{VD.ACK}$, Data Valid Acknowledge Time				0.9	µs	1

Table 11. I²C Timing Characteristics

Notes:

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

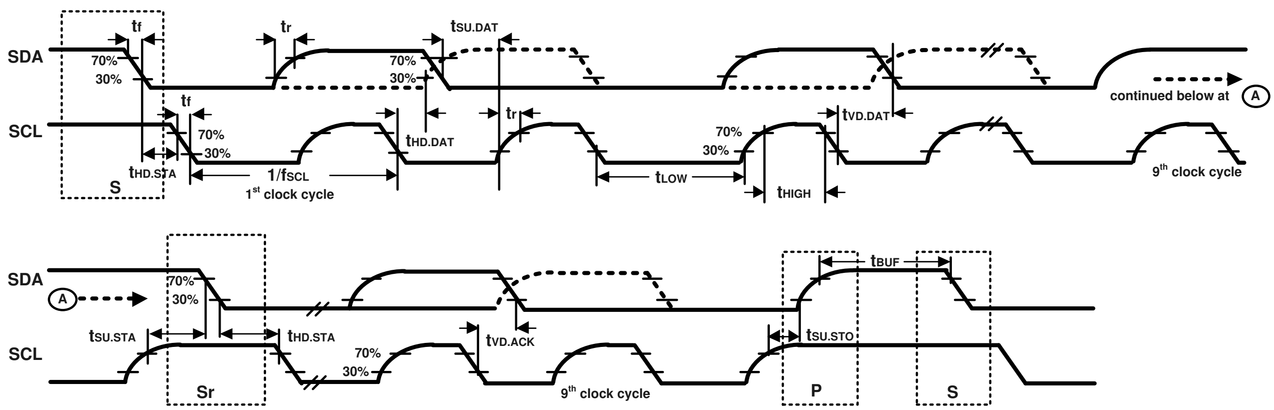


Figure 1. I²C Bus Timing Diagram

3.6 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 (for 6-axis MEMS)	-0.5V to +4V
Supply Voltage, VDDIO (for Pressure Sensor VDD and I/O)	-0.5V to +2.16V
REGOUT	-0.5V to 2V
Input Voltage Level (AD0, FSYNC, 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 +85°C
Storage Temperature Range	-40°C to +125°C
Electrostatic Discharge (ESD) Protection	2 kV (HBM); 250V (MM)
Latch-up	JEDEC Class II (2),125°C ±100 mA

Table 12. Absolute Maximum Ratings (6-Axis)

PARAMETER	RATING
Supply voltage, VDD	-0.3V to +2.16V
Supply Voltage, SCL & SDA	-0.3V to VDD +0.3V
Operating temperature range	-40°C to +85°C
Storage temperature range	-40°C to +125°C
ESD HBM	1.0 kV
ESD CDM	250V
Latch up, JESD78 Class II, 85°C	100 mA
Overpressure	>600 kPa

Table 13. Absolute Maximum Ratings (pressure sensor)

4 APPLICATIONS INFORMATION

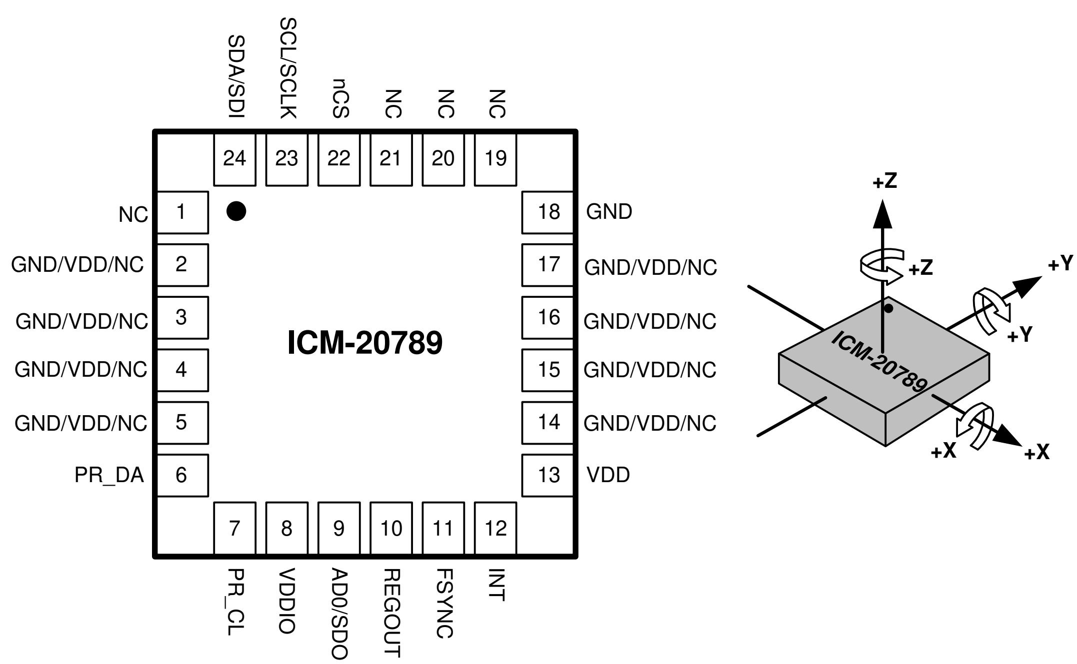
4.1 PIN OUT DIAGRAM AND SIGNAL DESCRIPTION

PIN NUMBER	PIN NAME	PIN DESCRIPTION
6	PR_DA	I²C interface data pin for Pressure Sensor access
7	PR_CL	I²C interface clock pin for Pressure Sensor access
8	VDDIO	Digital I/O supply voltage
9	AD0/SDO	I²C 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	INT	Interrupt digital output (totem pole or open-drain)
13	VDD	Power supply voltage
18	GND	Power supply ground
22	nCS	SPI chip select
23	SCL/SCLK	I²C serial clock (SCL); SPI serial clock (SCLK)
24	SDA/SDI	I²C serial data (SDA); SPI serial data input (SDI)
1, 19, 20, 21	NC	No Connect
2, 3, 4, 5, 14, 15, 16, 17	GND/VDD/NC	Connect to: GND or VDD or No Connection

Table 14. Signal Descriptions

Note:

1. VDD and VDDIO cannot be shorted if VDD > 1.98V
2. VDD & VDDIO should not violate operating range specifications as mentioned in Section 3.4



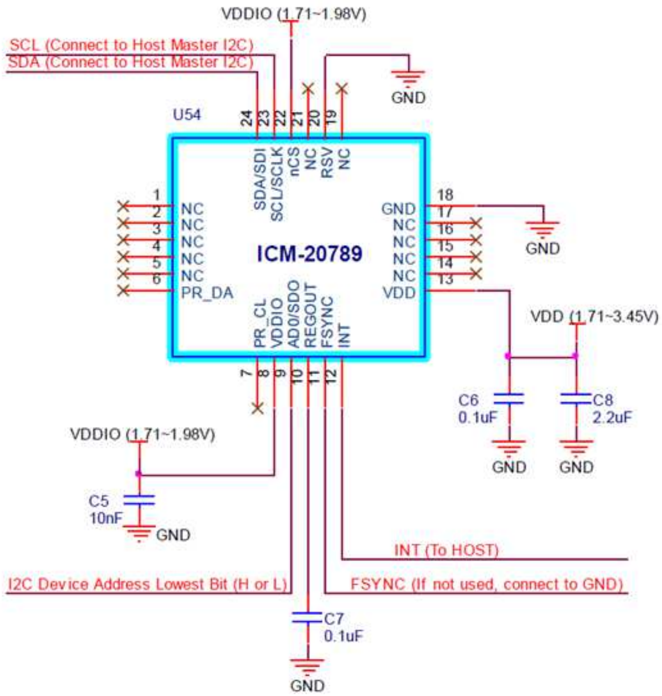
Top View – LGA Package
24-pin, 4mm x 4mm x 1.365mm

Orientation of Axes of Sensitivity and Polarity of Rotation

Figure 2. Pin out Diagram for ICM-20789

4.2 TYPICAL OPERATING CIRCUIT

I²C Communication – 1.8V Supply Schematic



I2C device address:

- Gyro/Accel = 0x68 (AD0=L, pin-9)
- Gyro/Accel = 0x69 (AD0=H, pin-9)
- Pressure sensor = 0x63

ICM-20789 Register Setting:

- Bypass = enable
- Master I2C = disable

Figure 3. I²C Communication – 1.8V Supply Schematic

I²C Communication MCU Interface at 3V or 1.8V Schematic

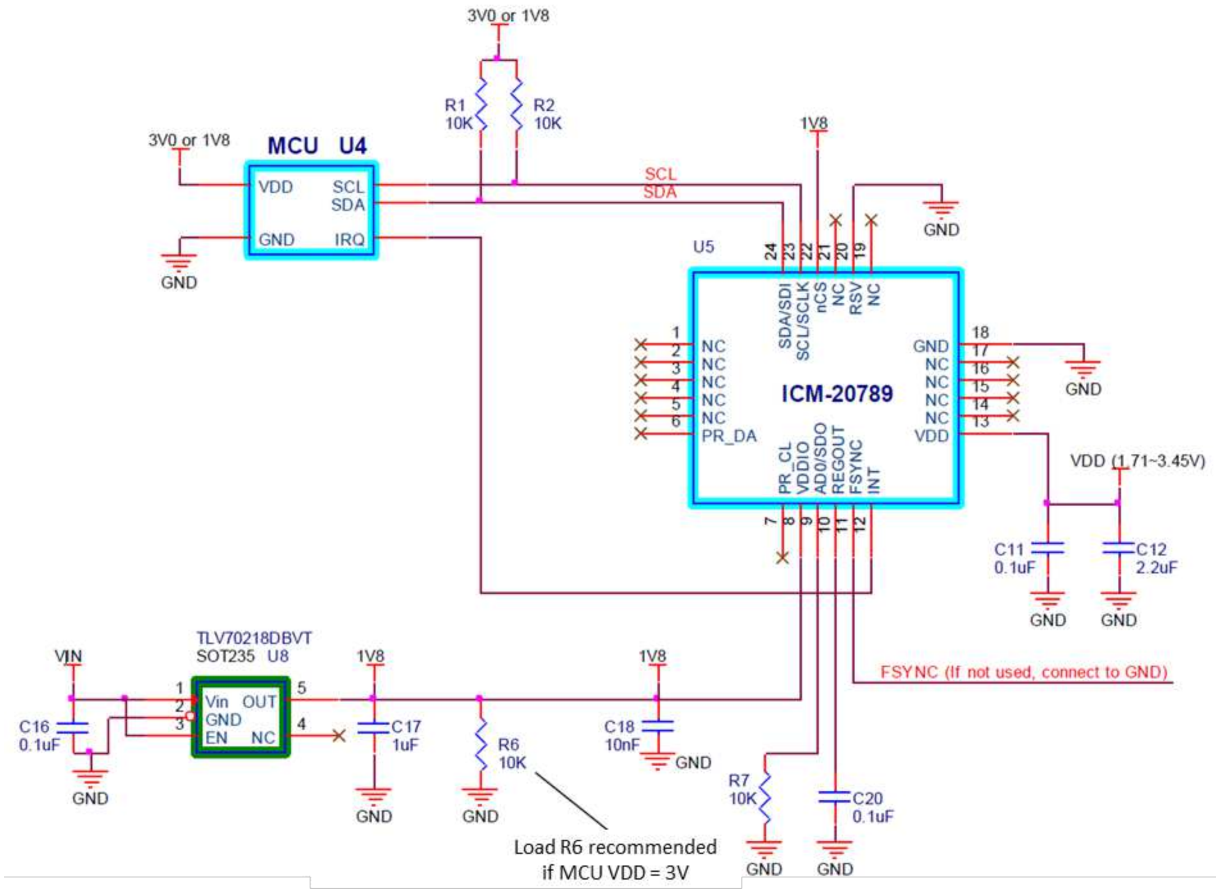


Figure 4. I²C Communication MCU Interface at 3V or 1.8V Schematic

SPI Communication for Gyro/Accel; I²C for Pressure Schematic

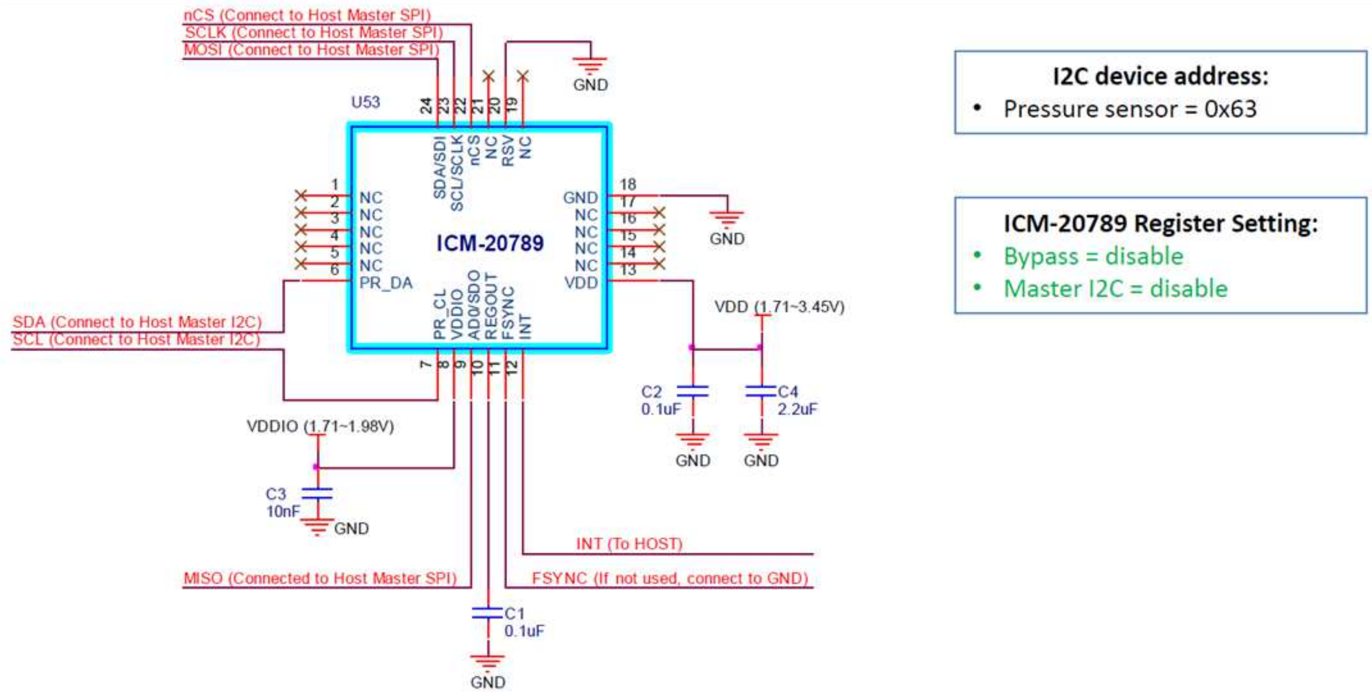


Figure 5. SPI Communication for Gyro/Accel; I²C for Pressure Schematic

SPI Communication for Gyro/Accel; I²C Pressure; MCU Digital Interface: 1.8V Schematic

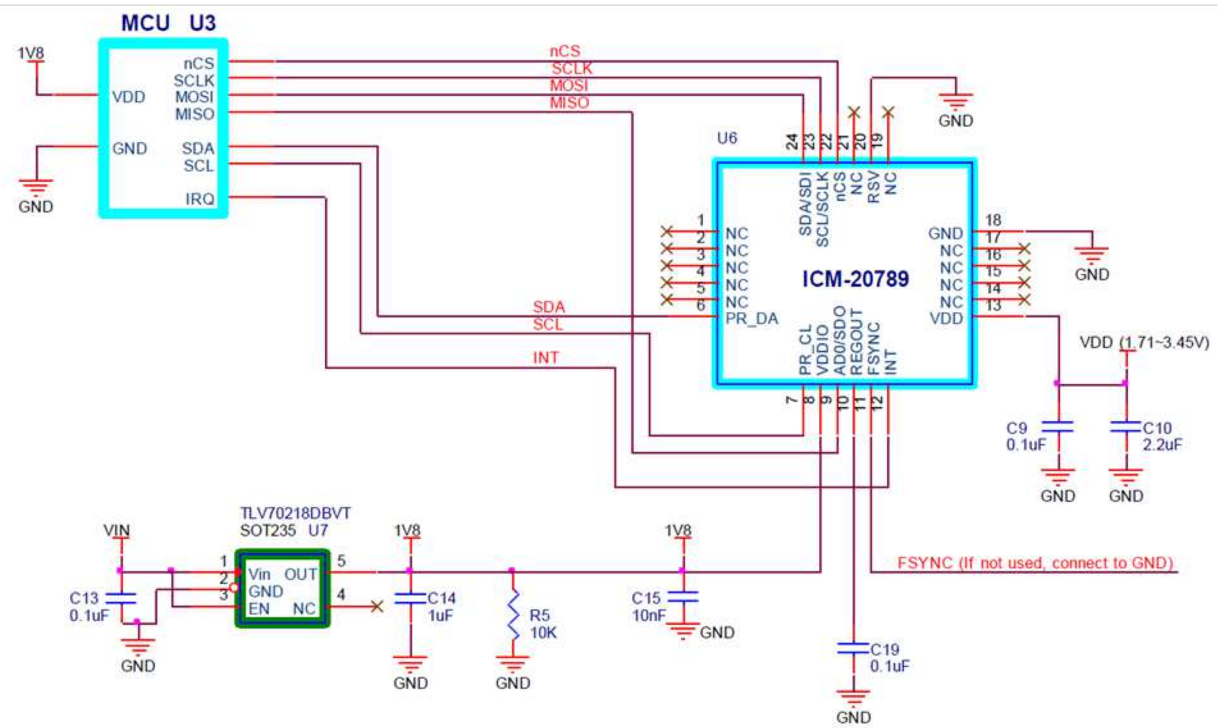


Figure 6. SPI Communication for Gyro/Accel; I²C Pressure; MCU Digital Interface: 1.8V Schematic

SPI Communication for Gyro/Accel; I²C for Pressure; MCU Digital Interface: 3.0V Schematic

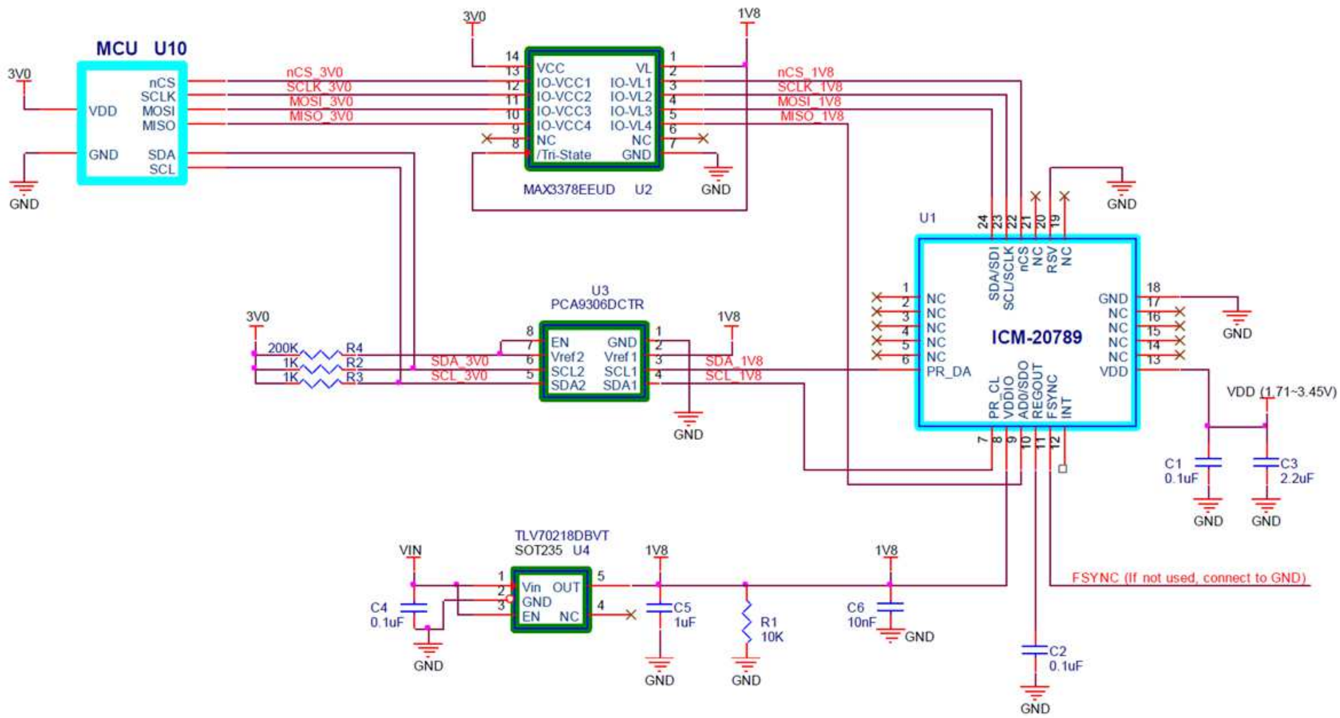


Figure 7. SPI Communication for Gyro/Accel; I²C for Pressure; MCU Digital Interface: 3.0V Schematic

Note: I²C lines are open drain and pullup resistors (e.g. 10 kΩ) are required.

4.3 BILL OF MATERIALS FOR EXTERNAL COMPONENTS

COMPONENT	LABEL	SPECIFICATION	QUANTITY
REGOUT Capacitor	C1	X7R, 0.1 µF ±10%	1
VDD Bypass Capacitors	C2	X7R, 0.1 µF ±10%	1
	C4	X7R, 2.2 µF ±10%	1
VDDIO Bypass Capacitor	C3	X7R, 10 nF ±10%	1

Table 15. Bill of Materials

4.4 BLOCK DIAGRAM

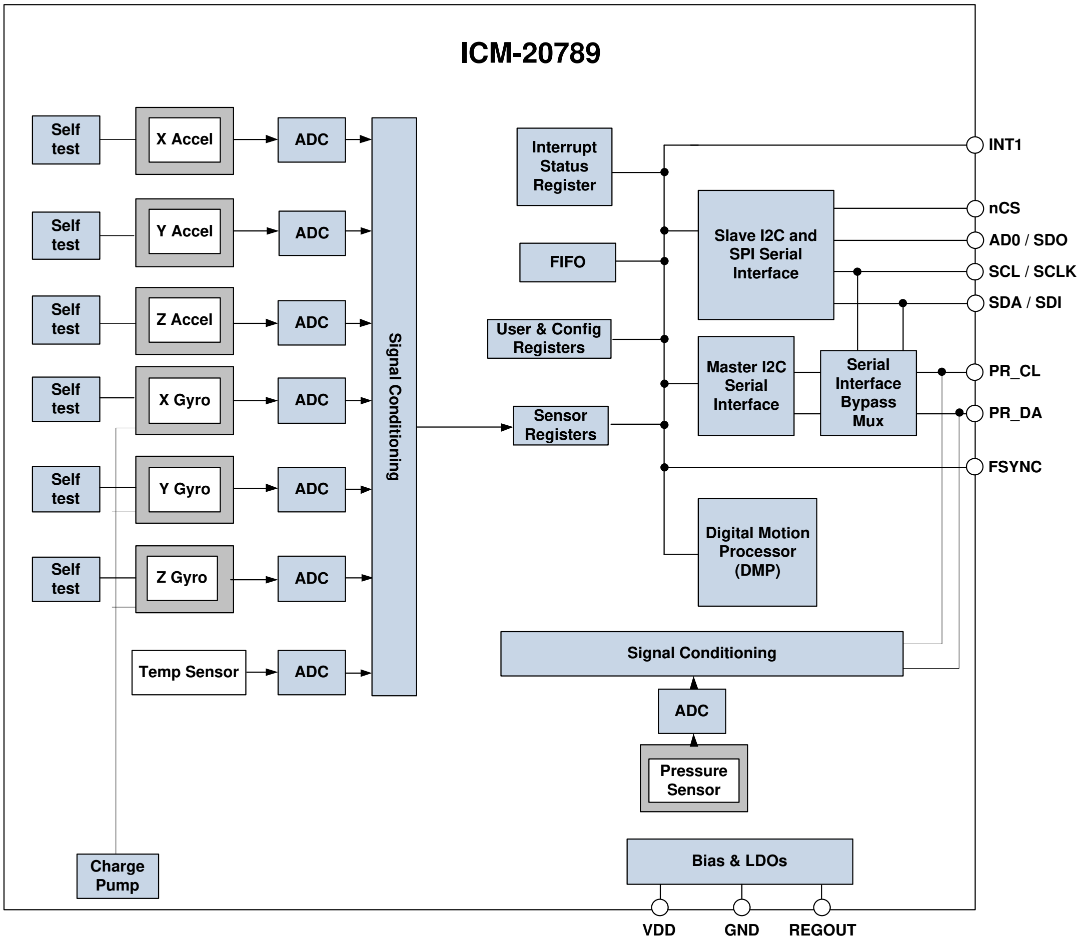


Figure 8. ICM-20789 Block Diagram (I²C interface)

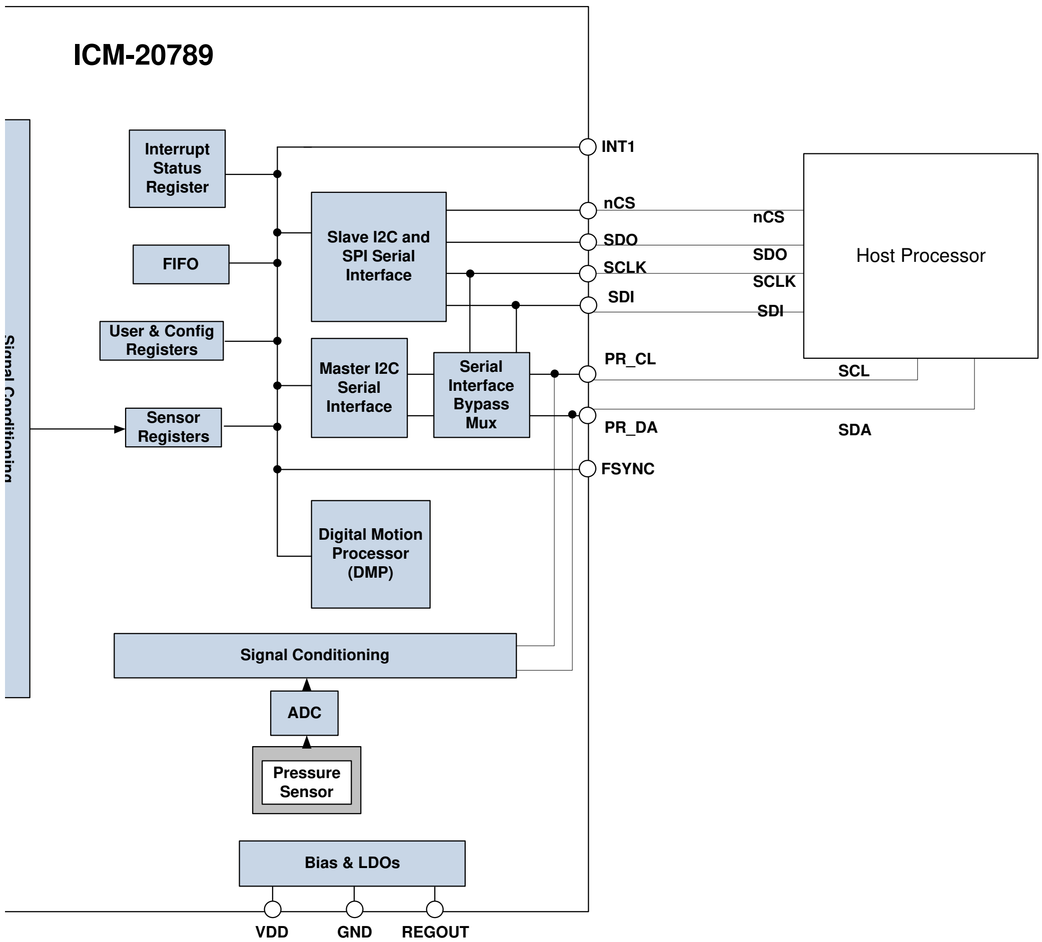


Figure 9. ICM-20789 Block Diagram (SPI/ I²C interface)

4.5 OVERVIEW

The ICM-20789 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
- I²C serial communications interfaces
- Self-Test
- Clocking
- Sensor Data Registers
- FIFO
- Interrupts
- Digital-Output Temperature Sensor
- Bias and LDOs
- Charge Pump
- Standard Power Modes
- Pressure Sensor

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

The ICM-20789 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 ±250, ±500, ±1000, or ±2000 degrees/sec (dps). The ADC sample rate is programmable from 8,000 samples/sec, to 3.9 samples/sec, and user-selectable low-pass filters enable a wide range of cut-off frequencies.

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

The ICM-20789'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-20789'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 ±2*g*, ±4*g*, ±8*g*, or ±16*g*.

4.8 DIGITAL MOTION PROCESSOR

The embedded Digital Motion Processor (DMP) offloads computation of motion processing algorithms from the host processor. The DMP acquires data from the accelerometer and gyroscope, processes the data, and the results can be read from the FIFO. The DMP has access to one of 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. DMP operation is possible in low-power gyroscope and low-power accelerometer modes.

4.9 PRESSURE SENSOR

The pressure sensor is a capacitive pressure sensor, and has a membrane over a sealed cavity at a reference pressure. External pressure changes relative to the sealed cavity pressure cause the membrane to deflect. The membrane and the floor of the cavity form a capacitor where the capacitance changes in response to changes in external pressure. The capacitance measurement is converted to a voltage proportional to the external pressure by the on-chip electronics. An external algorithm is used to compensate for temperature effects on the pressure accuracy.

4.10 I^{2}C SERIAL COMMUNICATIONS INTERFACE

The ICM-20789 communicates to a system processor using a I^{2}C serial interface. The ICM-20789 always acts as a slave when communicating to the system processor. The LSB of the I^{2}C slave address is set by pin 9 (AD0).

ICM-20789 Solution Using I²C Interface

Recommended operation mode is described in Figure 5, with the system processor being an I²C master to the ICM-20789.

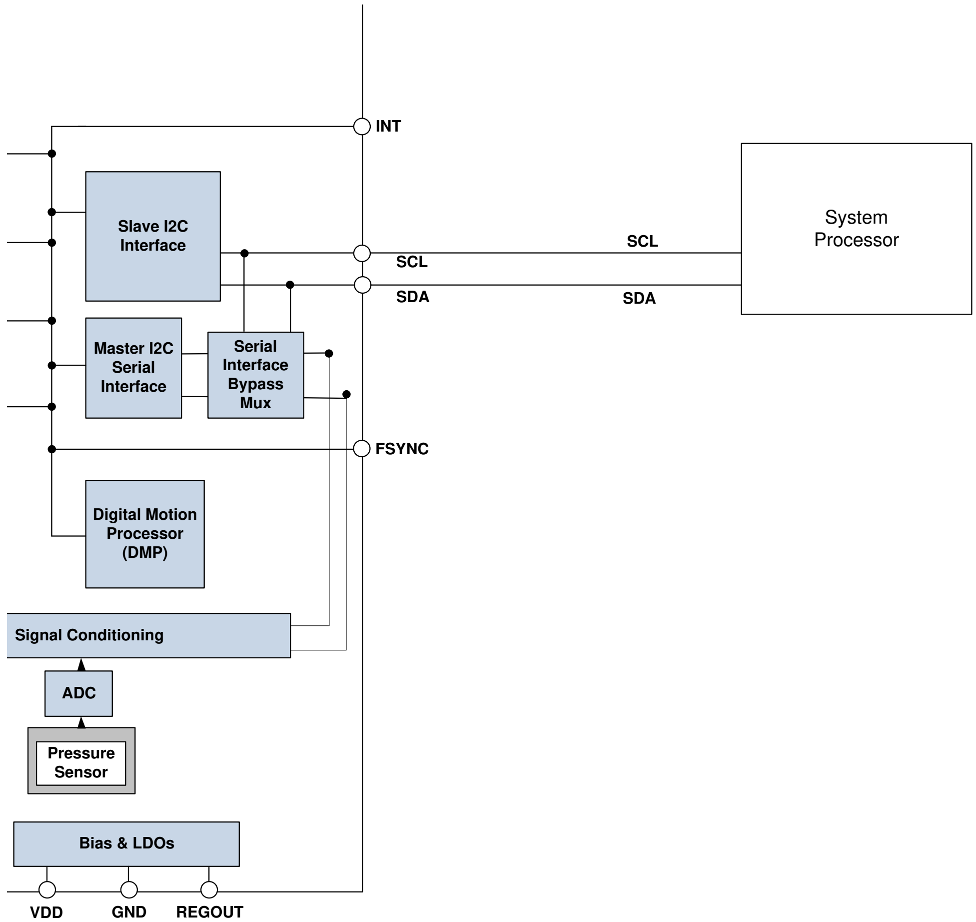


Figure 10. ICM-20789 Solution Using I²C Interface

Note: I²C lines are open drain and pullup resistors (e.g. 10 kΩ) are required.

Accessing Pressure Sensor Data

Pressure sensor data can be accessed in the following mode:

- Bypass Mode: Set register INT_PIN_CFG (Address: 55 (Decimal); 37 (Hex)) bit 1 to value 1 and I2C_MST_EN bit is '0' (Address: 106 (Decimal); 6A (Hex). Pressure sensor data can then be accessed using the procedure described in Section 10.

4.11 SELF-TEST

Self-test allows for the testing of the mechanical and electrical portions of the sensors. The self-test for each measurement axis can be activated by means of the gyroscope and accelerometer self-test registers (registers 27 and 28).

When the self-test is activated, the electronics cause the sensors to be actuated and produce an output signal. The output signal is used to observe the self-test response.

The self-test response is defined as follows:

SELF-TEST RESPONSE = SENSOR OUTPUT WITH SELF-TEST ENABLED – SENSOR OUTPUT WITH SELF-TEST DISABLED

When the value of the self-test response is within the specified min/max limits of the product specification, the part has passed self-test. When the self-test response exceeds the min/max values, the part is deemed to have failed self-test. It is recommended to use TDK-InvenSense MotionApps software for executing self-test.