MAX21105

Low-Power, Ultra-Accurate 6 DoF IMU

General Description

The MAX21105 is a monolithic 3-axis gyroscopes plus 3-axis accelerometer inertial measurement units (IMU) that provide unprecedented accuracy and stability over temperature and time.

The MAX21105 is the industry's most accurate 6 DoF inertial measurement units capable of working with a supply voltage as low as 1.71V designed to serve applications such as drone/helicopter toys, handsets and tablets, game controllers, motion remote controls, and other consumer devices.

In particular, the MAX21105 features low gyroscope zero-rate level error (GZRLE), low and linear gyroscope zero-rate level drift over temperature (GZRLDT) and low gyroscope phase delay (GPD) that makes the MAX21105 ideally suited for both flight and camera platforms stabilization on drone applications.

A large 512-byte FIFO extends the time during which the application processor can stay in a power-saving state.

The MAX21105 is available in a 3mm x 3mm x 0.83mm package 16-lead plastic land grid array (LGA) package and can operate within a temperature range of -40°C to +85°C.

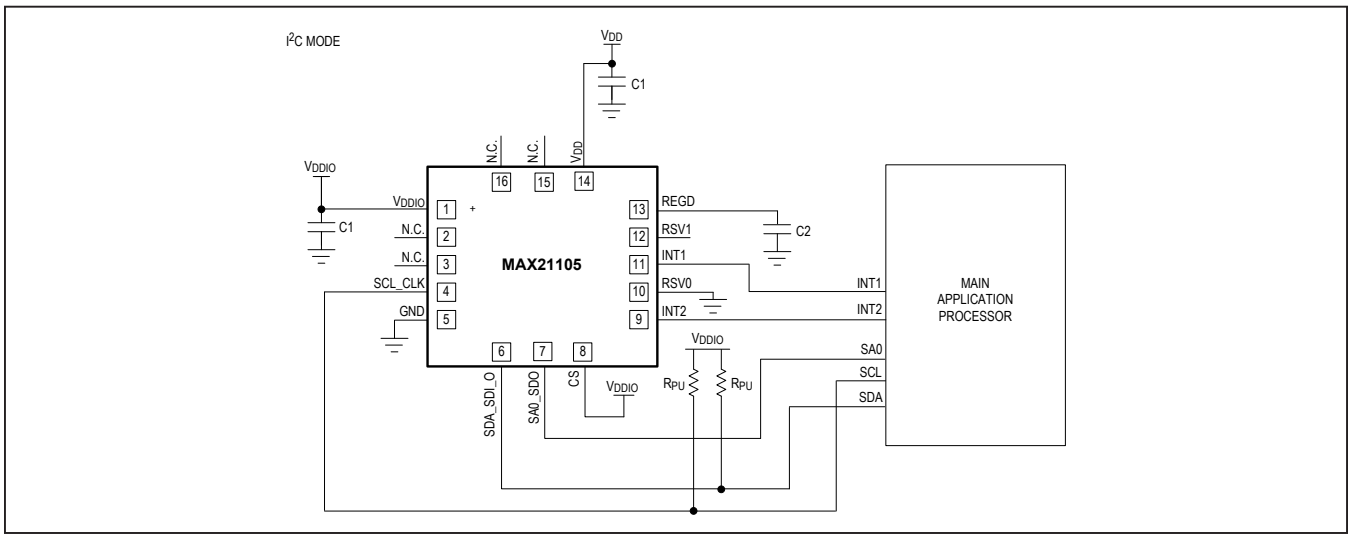
Benefits and Features

- Accurate and Stable Performance Over Temperature for Platform Stabilization
  - Low and Linear Zero-Rate Level Error Drift Over Temperature (0.025dps/°C typ)
  - Low Bias Instability (4°/hour)
  - 16-Bit Output Temperature Sensor
- Low-Power Operation Extends Battery Life
  - 3.8mA Low-Noise Mode Gyroscope + Accelerometer Current Consumption
  - 2.2mA Low-Power Mode Gyroscope + Low-Noise Mode Accelerometer Current Consumption
  - Power-Down Mode Current 1.5µA
- Compact Package Reduces Board Space and Enhances Device Reliability
  - 3mm x 3mm x 0.83mm 16L LGA
  - High Shock Survivability (10,000 g Shock Tolerant)
  - -40°C to +85°C Extended Operating Temperature

Applications

- Platform Stabilization
- Motion Control with HMI (Human-Machine Interface)
- Motion-Enabled Portable Gaming GPS Navigation
- Inertial Navigation Systems
- Handsets and Tablets

Recommended Application Schematics

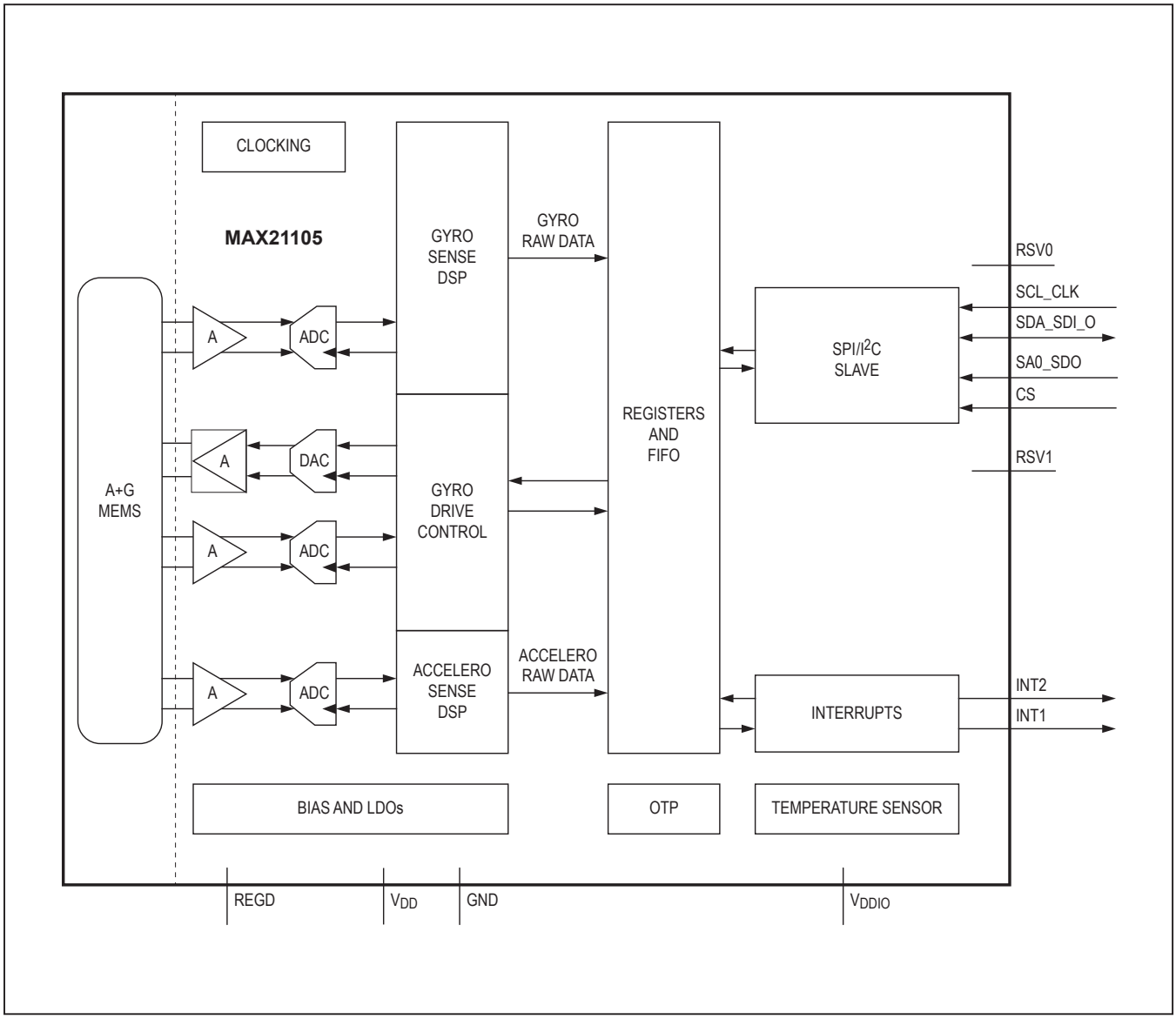


Ordering Information appears and Recommended Application Schematics continued at end of data sheet.

19-7458; Rev 0; 12/14

maxim integrated™

Functional Diagram



Absolute Maximum Ratings

V_{DD} .....-0.3V to +6.0V
V_{DDIO} .....-0.3V to +6.0V
REGD ..... -0.3V to min (V_{DD} + 0.3V,+2.2V)
INT1, INT2, SDA_SDI_O, SA0_SDO, SCL_CLK, CS, RSV0, RSV1.....-0.3V to min (V_{DDIO} + 0.3V, 6.0V)

Operating Temperature Range..... -40°C to +85°C
Junction Temperature.....+150°C
Storage Temperature Range..... -40°C to +150°C
Lead Temperature (soldering, 10s) .....+260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Drops onto hard surfaces can cause shocks of greater than 10,000g and can exceed the absolute maximum rating of the device. Exercise care in handling to avoid damage.

Package Thermal Characteristics (Note 1)

LGA

Junction-to-Case Thermal Resistance (θ_{JC}).....31.8°C/W

Junction-to-Ambient Thermal Resistance (θ_{JA}) .....160°C/W

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to **www.maximintegrated.com/thermal-tutorial**.

Electrical Characteristics

(V_{DD} = V_{DDIO} = 1.8V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OPERATING CONDITIONS						
V_{DD} Supply	V_{DD}		1.71	1.8	3.6	V
V_{DDIO} (Note 3)	V_{DDIO}		1.71	1.8	V_{DD} + 0.3	V
CURRENT CONSUMPTION						
IDD—Current Consumption G Only Low-Power Mode (Note 4)	IDDGE	T_A = +25°C, f_{GODR} = 100Hz		1.9	2.3	mA
IDD—Current Consumption G Low-Power + A Low-Noise Mode (Note 4)	IDDGEA	T_A = +25°C, f_{GODR} = 100Hz		2.2	2.6	mA
IDD—Current Consumption G Only Low-Noise Mode	IDDG	T_A = +25°C		3.6	4.2	mA
IDD—Current Consumption G + A Low-Noise Mode	IDDGA	T_A = +25°C		3.8	4.5	mA
IDD—Current Consumption G Standby Mode	IDDGSB	T_A = +25°C		1.7	2.1	mA
IDD—Current Consumption A Only, Low-Power Mode (Note 5)	IDDAE	f_{AODR} = 100Hz, 8 averages, T_A = +25°C		80	115	µA
		f_{AODR} = 25Hz, 8 averages, T_A = +25°C		20	33	
IDD—Current Consumption A Low-Noise Mode	IDDAN	T_A = +25°C		575	675	µA
IDD—Current Consumption Power Down	IDDPD	T_A = +25°C		1.5	10	µA

Mechanical Characteristics (Note 2)

(V_{DD} = V_{DDIO} = 1.8V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
GYROSCOPE						
Full-Scale Range	GFSR	User selectable		±250		dps
				±500		
				±1000		
				±2000		
Rate Noise Density (Note 6)	GRND	Low-noise mode, T_A = +25°C		0.009	0.025	dps/√Hz
RMS Noise	GRMS	Low-noise mode, f_{GODR} = 2000Hz, f_{GBWL} = 32Hz		0.06		dps rms
	GRMSE	Low-power mode, f_{GODR} = 100Hz		0.22		
Sensitivity	GS	GFSR = 250		120		digit/dps
		GFSR = 500		60		
		GFSR = 1000		30		
		GFSR = 2000		15		
Sensitivity Error	GSE	T_A = +25°C	-2.5		+2.5	%
Sensitivity Drift Over Temperature (Note 6)	GSDT		-0.05		+0.05	%/°C
Zero Rate Level Error	GZRLE	T_A = +25°C	-6		+6	dps
Zero Rate Level Drift Over Temperature (Note 6)	GZRLDT		-0.15		+0.15	dps/°C
Angular Random Walk	GARW			0.45		deg/√hr
Bias Stability	GBS			4		deg/hr
Nonlinearity	GNL	GFSR = 2000		0.1		%FS
Cross Axis	GCA	Absolute, T_A = +25°C (Note 6)	-5	±1	+5	%
		Relative to the accelerometer reference system, T_A = +25°C	-3	±1	+3	
Linear Acceleration Effect	GLAE	±1g static applied, T_A = +25°C		±0.05		dps/g
Startup Time from Power Down	GSTPD			25	45	ms
Startup Time from Standby (Note 7)	GSTS	GODR = 8kHz, GBWL = 400Hz		4		ms
Output Data Rate	GODR	User selectable, low-noise mode	5		8000	Hz
		User selectable, low-power mode	5		200	
ODR Accuracy	GODRA	T_A = +25°C	-10		+10	%

Mechanical Characteristics (continued) (Note 2)

(V_{DD} = V_{DDIO} = 1.8V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Lowpass Bandwidth (Note 8)	GBWL		2		2000	Hz
Highpass Bandwidth (Note 9)	GBWH		0.1		100	Hz
Phase Delay at 10Hz	GPD	GODR = 8kHz GBWL = 2kHz		1.78		deg
Self-Test Output Shift	GSTO	X, Z axis, T_A = +25°C	+8		+50	%FS
		Y axis, T_A = +25°C	-50		-8	
ACCELEROMETER						
Full-Scale Range	AFSR	User selectable		±2		g
				±4		
				±8		
				±16		
Noise Density (Note 6)	AND	Low-noise mode, AFSR = ±2g, T_A = +25°C		100	185	µg/√Hz
RMS Noise	ARMS	Low-noise mode, AODR = 2000Hz, ABWL = AODR/3, AFSR = 2g		2.6		mg RMS
	ARMSE	Low-power mode, AODR = 100Hz, ABWL = AODR/3, AFSR = 2g, 8 averages		2.7		
Sensitivity	AS	AFS = ±2g		15		digit/mg
		AFS = ±4g		7.5		
		AFS = ±8g		3.75		
		AFS = ±16g		1.875		
Sensitivity Error	ASE	AFS = ±2g, T_A = +25°C	-2.5		+2.5	%
Sensitivity Drift Over Temperature (Note 6)	ASDT	AFSR = ±2g	-0.028		+0.028	%/°C
Zero G Level Error at Component Level	AZGLEC	AFSR = ±2g, X, Y axes, T_A = +25°C	-90		+90	mg
		AFSR = ±2g, Z axis, T_A = +25°C	-120		+120	
Zero G Level Error at Board Level (Notes 6, 10)	AZGLE	AFSR = ±2g, X, Y axes, T_A = +25°C	-120		+120	mg
		AFSR = ±2g, Z axis, T_A = +25°C	-180		+180	
Zero G Level Drift Over Temperature (Note 6)	AZGLDT	AFSR = ±2g, X, Y, Z axes	-2.25		+2.25	mg/°C
Nonlinearity	ANL	AFSR = ±2g		0.5		%FS
Cross Axis	AGCA	AFSR = ±2g		±1		%
Output Data Rate	AODR	User selectable, low-noise mode	5		2000	Hz
		User selectable, low-power mode	5		400	
ODR Accuracy	AODRA	T_A = +25°C	-10		+10	%

Mechanical Characteristics (continued) (Note 2)

(V_{DD} = V_{DDIO} = 1.8V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at T_A = +25°C.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Lowpass Bandwidth (Note 8)	ABWL	Low-noise mode	AODR/48		AODR/3	Hz
		Low-power mode	AODR/48		AODR/2	
Highpass Bandwidth (Note 9)	ABWH		AODR/400		AODR/50	Hz
Self-Test Output Shift	ASTO	T_A = +25°C	±80		±800	mg
TEMPERATURE SENSOR						
Sensitivity	TSS	8 bit		1		digit/°C
		16 bit		256		digit/°C
Sensitivity Error	TSSE			±2		%
Output at +25°C	TSO	8 bit		25		digit
		16 bit		6400		
Bandwidth	TSBW			4		Hz

Interface Specifications (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
ESD PROTECTION						
Human Body Model	HBM			2000		V
Charged Device Model	CDM			500		V
IOs DC SPECIFICATIONS (Note 6)						
Input Threshold Low	V_{IL}				0.3 x V_{DDIO}	V
Input Threshold High	V_{IH}		0.7 x V_{DDIO}			V
Hysteresis of Schmitt Trigger Input	V_{HYS}		0.05 x V_{DDIO}			V
Input Leakage Current	I_{LK}		-1		+1	µA
I^2C Internal Pullup Resistance (Note 11)	R_{I2CPU}		4.5		10	kΩ
SPI SLAVE TIMING VALUES (Note 12)						
CLK Frequency	f_{C_CLK}				10	MHz
CS Setup Time	t_{SU_CS}		10			ns
CS Hold Time	t_{H_CS}		15			ns
SDI Input Setup Time	t_{SU_SDI}		10			ns
SDI Input Hold Time	t_{H_SDI}		15			ns
CLK Fall to SDO Valid Output Time	t_{V_SDO}				40	ns
SDO Output Hold Time	t_{H_SDO}		5			ns

Interface Specifications (continued) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
I²C TIMING VALUES (Note 6)						
SCL Clock Frequency	f_{SCL}	Standard mode			100	kHz
		Fast mode			400	
Hold Time (Repeated) START Condition	$t_{HD;STA}$	Standard mode	4			µs
		Fast mode	0.6			
Low Period of SCL Clock	t_{LOW}	Standard mode	4.7			µs
		Fast mode	1.3			
High Period of SCL Clock	t_{HIGH}	Standard mode	4.0			µs
		Fast mode	0.6			
Setup Time for a Repeated START Condition	$t_{SU;STA}$	Standard mode	4.7			µs
		Fast mode	0.6			
Data Hold Time	$t_{HD;DAT}$	Standard mode	0			µs
		Fast mode	0			
Data Setup Time	$t_{SU;DAT}$	Standard mode	250			ns
		Fast mode	100			
Setup Time for STOP Condition	$t_{SU;STO}$	Standard mode	4.0			µs
		Fast mode	0.6			
Bus Free Time Between a STOP and a START Condition	t_{BUF}	Standard mode	4.7			µs
		Fast mode	1.3			
Data Valid Time	$t_{VD;DAT}$	Standard mode			3.45	µs
		Fast mode			0.9	
Data Valid Acknowledge Time	$t_{VD;ACK}$	Standard mode			3.45	µs
		Fast mode			0.9	
I²C TIMING VALUES (High-Speed Mode, Note 6)						
SCLH Clock Frequency	f_{SCLH}	HS mode			3.4	MHz
Setup Time for A REPEATED START Condition	$t_{SU;STA}$	HS mode	160			ns
Hold Time (Repeated) START Condition	$t_{HD;STA}$	HS mode	160			ns
Low Period of SCL Clock	t_{LOW}	HS mode	160			ns
High Period of SCL Clock	t_{HIGH}	HS mode	100			ns
Data Setup Time	$t_{SU;DAT}$	HS mode	10			ns
Data Hold Time	$t_{HD;DAT}$	HS mode	0		70	ns
Setup Time for STOP Condition	$t_{SU;STO}$	HS mode	160			ns

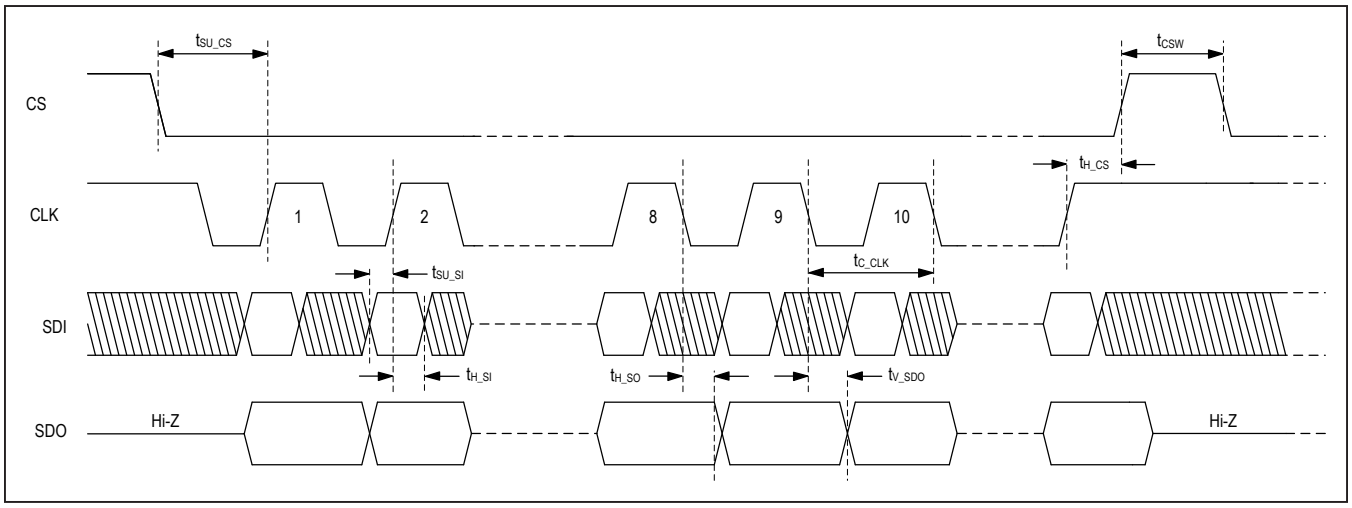
Note 2: Limits are 100% tested at T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization.

Note 3: V_{DDIO} must be lower or equal than V_{DD} supply for normal operation. With V_{DDIO} supplied and V_{DD} not supplied, the I/O pads are in high impedance.

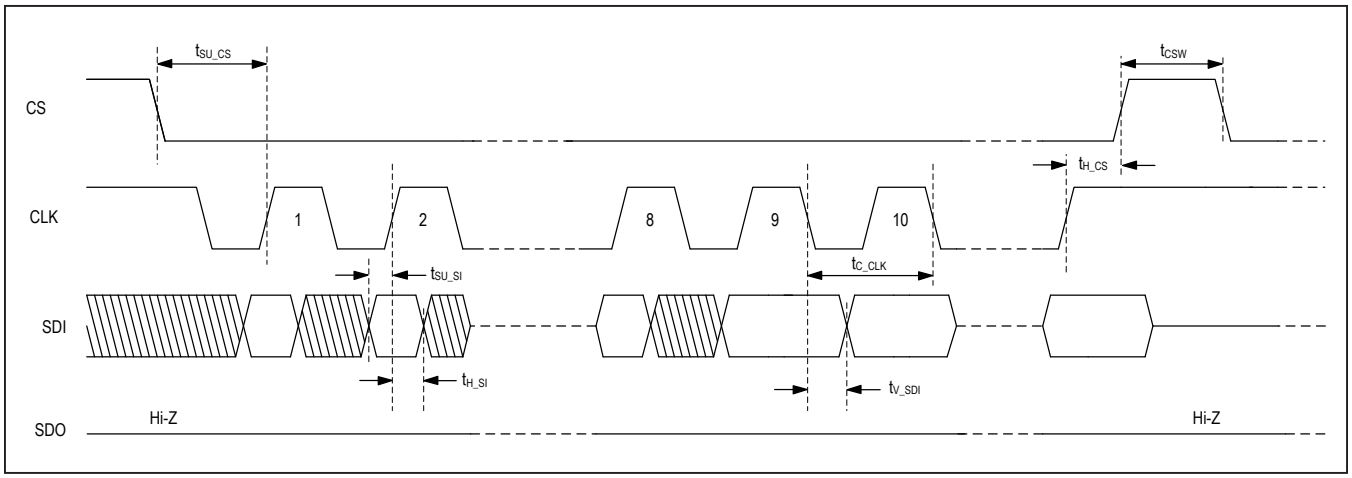
Note 4: In low-power mode, the gyroscope has higher rate noise density, but lower current consumption. In this condition, the gyro selectable output data rate (ODR) ranges from 5Hz to 200Hz.
Note 5: In low-power mode, the accelerometer has higher noise density, but lower current consumption. In this condition, the selectable output data rate (ODR) of the accelerometer ranges from 5Hz to 400Hz.
Note 6: Guaranteed by design, not production tested.
Note 7: In standby, only the gyro drive circuit is powered on, and in this condition, the outputs are not available. In this condition, the startup time depends only on the filters responses.
Note 8: User selectable.
Note 9: Enable/disable with user-selectable bandwidth.
Note 10: Values after MSL3 preconditioning and 3 reflow cycles.
Note 11: Pullup resistances are user selectable.
Note 12: 10pF load on SPI lines. Min Max based on characterization results.

SPI Timing

4-Wire SPI Mode

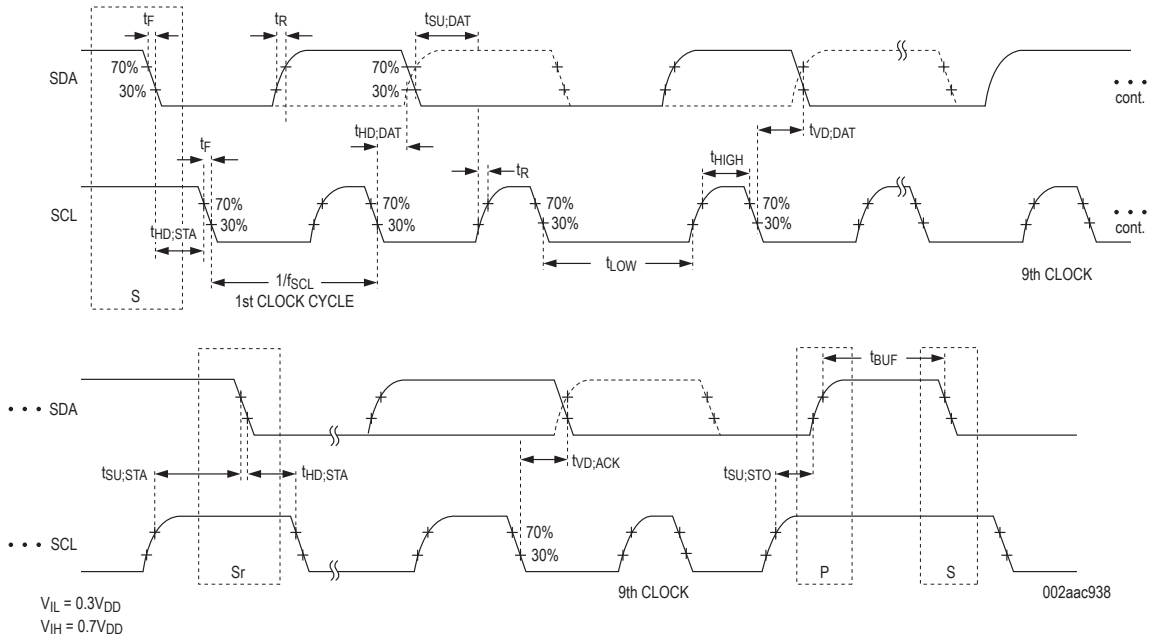


3-Wire SPI Mode

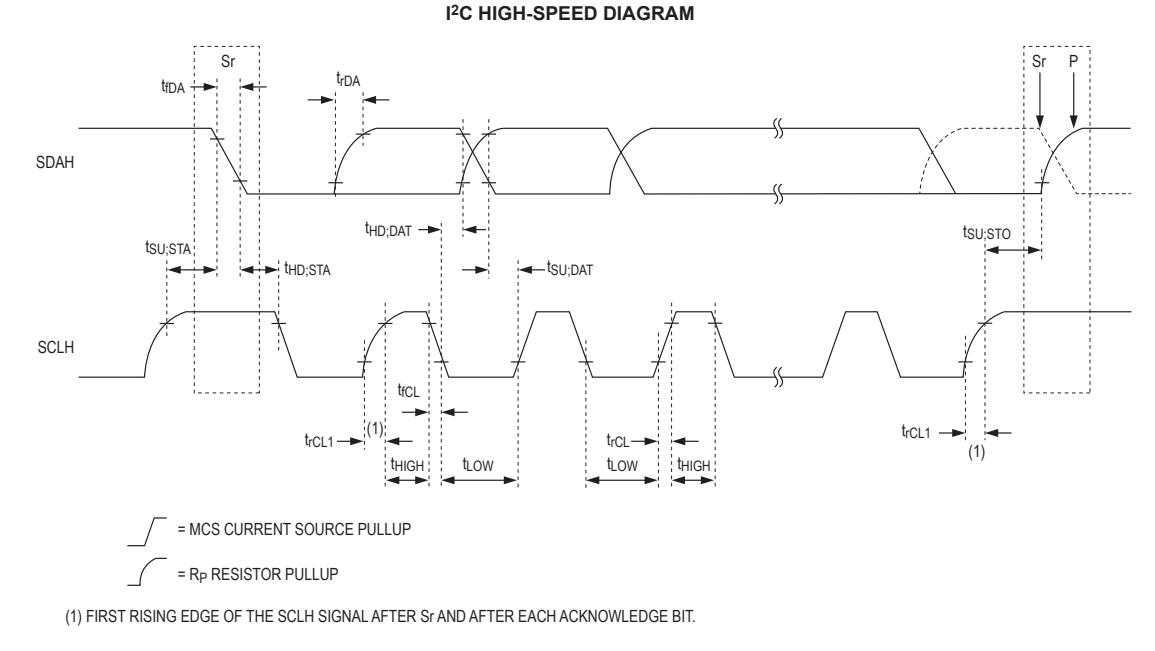


I²C Timing

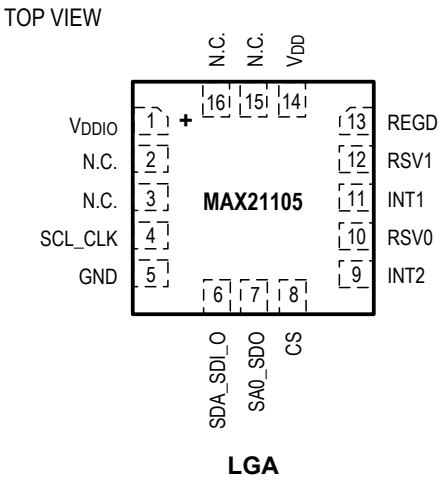
Standard/Fast Mode I²C Bus Timing



High-Speed Mode I²C Bus Timing



Pin Configuration



Pin Description

PIN	NAME	FUNCTION
1	V_{DDIO}	Interface and Interrupt Pad Supply Voltage
2, 3, 15, 16	N.C.	Not Connected Internally
4	SCL_CLK	SPI and I^2C Slave Clock. When in I^2C mode, the IO has selectable antispike filter and delay to ensure correct hold time.
5	GND	Power-Supply Ground.
6	SDA_SDI_O	SPI In/Out Pin and I^2C Slave Serial Data. When in I^2C mode, the IO has selectable antispike filter and delay to ensure correct hold time.
7	SA0_SDO	SPI Serial Data Out and I^2C Slave Address LSB
8	CS	SPI Chip Select/Serial Interface Selection
9	INT2	Second Interrupt Line
10	RSV0	Reserved. Must be connected to GND.
11	INT1	First Interrupt Line
12	RSV1	Reserved. Must be left unconnected or connected to GND.
13	REGD	Internal regulator output 2.2V max. A 100nF capacitor has to be connected to this pin for ensuring proper device operation.
14	V_{DD}	Analog Power Supply. Bypass to GND with a 0.1µF capacitor.

Detailed Description

The MAX21105 is a low-power, low voltage, small package 6-axis inertial measurement unit that provides unprecedented accuracy and stability over temperature and time.

The MAX21105 integrates a 3-axis gyroscope and 3-axis linear accelerometer in a 3mm x 3mm x 0.83mm package capable of working with a supply voltage as low as 1.71V.

They include a sensing element and an IC interface capable of providing the measured angular rate and acceleration to the external world through a digital interface (I^2C/SPI).

The MAX21105 sensor data can be stored into a 512-byte, fully configurable, embedded FIFO.

The MAX21105 features a wide selection of dynamically selectable power modes that allow the user to optimize the system power consumption based on the application needs.

The MAX21105 has a full scale of ±250/±500/±1000/±2000 dps for gyroscope and ±2/±4/±8/±16g for accelerometer. It is capable of measuring angular rates and accelerations with a user-selectable bandwidth.

The MAX21105 is available in a 3mm x 3mm x 0.83mm 16-lead plastic land grid array (LGA) package and operate over the -40°C to +85°C temperature range.

Definitions

Power supply [V]: This parameter defines the operating DC power-supply voltage range of the 6DoF inertial measurement unit. Although it is always a good practice to keep V_{DD} clean with minimum ripple, unlike most of the competitors, who require an ultra-low noise, low-dropout regulator to power the device, the MAX21105 can operate at 1.71V, but that supply can also be provided by a switching regulator to minimize the system power consumption.

Current consumption in low-noise mode [mA]: This parameter defines the typical current consumption when the 6DoF inertial measurement unit is operating with the lowest noise for both the accelerometer and gyroscope.

Current consumption in low-power mode [mA]: This parameter defines the current consumption when the 6DoF inertial measurement unit is in low-power mode. Whilst in low-power mode, the MAX21105 significantly reduces power consumption, but increase noise.

Current consumption in power-down mode [µA]: This parameter defines the current consumption when the 6DoF inertial measurement unit is powered down. In this mode, both the mechanical sensing structure and reading chain are turned off. Users can configure the control register through the I^2C/SPI interface for this mode. Full access to the control registers through the I^2C/SPI interfaces is also guaranteed in power-down mode.

Gyroscope full-scale range [dps]: This parameter defines the measurement range of the gyroscope in degrees per second (dps). When the applied angular rate is beyond the full-scale range, the gyroscope output becomes saturated.

Zero-rate level [dps]: This parameter defines the DC device output when there is no external angular rate applied to the gyroscope.

Gyroscope sensitivity [digit/dps]: Sensitivity is the relationship between 1 LSb and dps. It can be used to convert a digital gyroscope's measurement from digits to angular rate.

Zero-rate level change vs. temperature [dps/°C]: This parameter defines the zero-rate level change in dps/°C over the operating temperature range.

Gyroscope sensitivity change vs. temperature [%/°C]: This parameter defines the gyroscope sensitivity change as a percentage (%) over the operating temperature range specified in the data sheet.

Gyroscope nonlinearity [% FS]: This parameter defines the maximum absolute difference between the gyroscope output and the best-fit straight line as a percentage of the gyroscope full-scale (GFS) range.

Gyroscope bandwidth [Hz]: This parameter defines the frequency of the angular rate signal from DC to the built-in bandwidth (GBWL) that the gyroscope can measure. A dedicated register can be used to select the gyroscope bandwidth.

Rate noise density [dps/√Hz]: This parameter defines the square root of the equivalent noise power density of the gyroscope angular rate.

Accelerometer full-scale range [g]: This parameter defines the measurement range of the accelerometer in g. When the applied acceleration is beyond the full-scale range, the accelerometer output becomes saturated.

Zero-g level [mg]: This parameter defines the DC device output when there is no external acceleration applied to the accelerometer.

Accelerometer sensitivity [digit/g]: Sensitivity is the relationship between LSb and g. It can be used to convert a digital acceleration measurement from digits to g.

Zero-g level change vs. Temperature [mg/°C]: This parameter defines the zero-g level change in mg/°C over the operating temperature range.

Accelerometer Sensitivity change vs. temperature [%/°C]: This parameter defines the accelerometer sensitivity change as a percentage (%) over the operating temperature range specified in the data sheet.

Accelerometer nonlinearity [% FS]: This parameter defines the maximum absolute difference between the accelerometer output and the best-fit straight line as a percentage of the full-scale (FS) range.

Accelerometer bandwidth [Hz]: This parameter defines the frequency of the acceleration signal from DC to the built-in bandwidth (ABWL) that the accelerometer can measure. A dedicated register can be used to select the accelerometer bandwidth.

Accelerometer noise density [µg/√Hz]: This parameter defines the square root of the equivalent noise power density of accelerometer linear acceleration.

MAX21105 Architecture

The MAX21105 comprises the following key blocks and functions:

- 3-axis MEMS gyroscope sensor with 16-bit ADCs and signal conditioning
- 3-axis MEMS accelerometer sensor with 16-bit ADCs and signal conditioning
- Slave I2C and SPI serial communications interfaces
- Interrupt generators
- Digital output temperature sensor
- Power management enabling different power modes
- Sensor data registers
- FIFO
- Self-test functionality

Three-Axis MEMS Gyroscope with 16-Bit ADCs and Signal Conditioning

The MAX21105 includes a MEMS gyroscope that detects angular rates around the X, Y, and Z axes through the related IC interface. When the gyroscope rotates around any of the sensing axes, the Coriolis Force determines a displacement in the MEMS structure, which is detected as a capacitive variation. The resulting signal is then processed by the 16-bit ADC to produce a digital output proportional to the angular rate. The gyro full-scale range can be digitally programmed at ±250, ±500, ±1000 or ±2000 dps.

Three-Axis MEMS Accelerometer Sensor with 16-Bit ADCs and Signal Conditioning

The MAX21105 includes a MEMS accelerometer that detects linear accelerations along the X, Y, and Z axes. The acceleration applied to one of the sensing axes causes a displacement of the MEMS structure which is detected as a capacitive variation. The signal is then converted in the digital domain by 16-bit ADC and is available to the user as a digital output proportional to the applied acceleration. The accelerometer full-scale range can be digitally programmed at ±2, ±4, ±8 or ±16 g.

Slave I2C and SPI Serial Communications Interfaces

The registers embedded inside the MAX21105 can be accessed through both the slave I2C and SPI serial interfaces. The latter can be SW configured to operate either in 3-wire or 4-wire interface mode.

The serial interfaces are mapped onto the same pins. To select/exploit the I2C interface, CS line must be tied high (i.e., connected to V_{DDIO}).

I2C Interface

I2C is a two-wire interface comprised of the signals serial data (SDA) and serial clock (SCL). In general, the lines are open-drain and bidirectional. In a generalized I2C interface implementation, attached devices can be a master or a slave. The master device puts the slave address on the bus, and the slave device with the matching address acknowledges the master.

The MAX21105 operates as a slave device when communicating to the system processor, which thus acts as the master. SDA and SCL lines typically need pull-up resistors to V_{DDIO}. The maximum bus speed is 3.4MHz (I2C HS); this reduces the amount of time the system processor is kept busy in supporting the exchange of data.

The slave address of the MAX21105 is b101100X, which is 7 bits long. The LSb of the 7-bit address is determined by the logic level on pin SA0. This allows two MAX21105s to be connected on the same I2C bus.

When used in this configuration, the address of one of the two devices should be b1011000 (pin SA0_SD0 is set to logic low) and the address of the other should be b1011001 (pin SA0_SD0 is set to logic-high).

SPI Interface

The MAX21105 SPI can operate up to 10MHz, in both 3-wires (half duplex) and 4-wires mode (full duplex).

It is recommended to set the I2C_OFF bit at address 0x16 if the MAX21105 is used together with other SPI devices to avoid the possibility to switch inadvertently into I²C mode when traffic is detected with the CS unasserted.

The MAX21105 operates as an SPI slave device.Both the read register and write register commands are completed in 16 clock pulses, or in multiples of 8 in case of multiple read/write bytes. Bit duration is the time between two falling edges of CLK.

The first bit (bit 0) starts at the first falling edge of CLK after the falling edge of CS while the last bit (bit 15, bit 23, etc.) starts at the last falling edge of CLK just before the rising edge of CS.

Bit 0: RW bit. When 0, the data DI(7:0) is written to the device. When 1, the data DO(7:0) from the device is read. In the latter case, the chip drives SDO at the start of bit 8.

Bit 1: MS bit. Depending on the configuration of IF_PARITY this bit may either be used to operate in multi-addressing standard mode or to check the parity with the register address.

If used as a MS bit, when 1, the address remains unchanged in multiple read/write commands, whilst when 0, the address is autoincremented in multiple read/write commands.

Bit 2–7: Address AD(5:0). This is the address field of the indexed register.

Bit 8–15: Data DI(7:0) (write mode). This is the data that is written to the device (MSb first).

Bit 8–15: Data DO(7:0) (read mode). This is the data that is read from the device (MSb first).

SPI Half- and Full-Duplex Operation

The MAX21105 can be programmed to operate in half-duplex (a bidirectional data pin) or full-duplex (one data-in and one data-out pin) mode. The SPI master sets a register bit called SPI_3_WIRE into I2C_CFG (0x16) to 0 for full-duplex, and 1 for half-duplex operation. Full duplex is the power-on default.

Full-Duplex Operation

The MAX21105 is put into full-duplex mode at power-up. When the SPI master clears the SPI_3_WIRE bit, the SPI interface uses separate data pins, SDI and SDO, to transfer data. Because of the separate data pins, bits can be simultaneously clocked into and out of the MAX21105. The MAX21105 makes use of this feature by clocking out 8 output data bits as the command byte is clocked in.

Table 1. Digital Interface Pin Description

NAME	DESCRIPTION
CS	SPI enable and I2C/SPI mode selection (1: I²C mode, 0: SPI enabled)
SCL/CLK	SPI and I²C clock. When in I²C mode, the IO has selectable anti-spike filter and delay to ensure correct hold time.
SDA/SDI/SDO	SPI in/out pin and I²C serial data. When in I²C mode, the IO has selectable antispike filter and delay to ensure correct hold time.
SDO/SA0	SPI serial data out or I²C slave address LSb

Table 2. I²C Address

I²C BASE ADDRESS	SA0/SDO PIN	R/W BIT	RESULTING ADDRESS
0x2C (6 bit)	0	0	0xB0
0x2C	0	1	0xB1
0x2C	1	0	0xB2
0x2C	1	1	0xB3

Reading from the SPI Slave Interface (SDO)

The SPI master reads data from the MAX21105 slave interface using the following steps:

1) When CS is high, the MAX21105 is unselected and three-states the SDO output.
2) After driving SCL_CLK to its inactive state, the SPI master selects the MAX21105 by driving CS low.
3) The SPI master clocks the command byte into the MAX21105. The SPI read command is performed with 16 clock pulses. Multiple byte read command is performed adding blocks of 8 clock pulses at the previous one.

   Bit 0: READ bit. The value is 1.

   Bit 1: MS bit. When 1, do not increment address, when 0, increment address in multiple reading.

   Bit 2–7: Address AD(5:0). This is the address field of the indexed register.

   Bit 8–15: Data DO(7:0) (read mode). This is the data that is read from the device (MSb first).

   Bit 16–... : Data DO(...-8). Further data in multiple byte reading. After 16 clock cycles, the master can drive CS high to deselect the MAX21105, causing it to three-state its SDO output. The falling edge of the clock puts the MSB of the next data byte in the sequence on the SDO output.
4) By keeping CS low, the master clocks register data bytes out of the MAX21105 by continuing to supply SCL_CLK pulses (burst mode). The master terminates the transfer by driving CS high. The master must ensure that SCL_CLK is in its inactive state at the beginning of the next access (when it drives CS low).

Writing to the SPI Slave Interface (SDI)

The SPI master writes data to the MAX21105 slave interface through the following steps:

1) The SPI master sets the clock to its inactive state. While CS is high, the master can drive the SDI input.
2) The SPI master selects the MAX21105 by driving CS low
3) The SPI master clocks the command byte into the MAX21105. The SPI write command is performed with 16 clock pulses. Multiple byte write command is performed adding blocks of 8 clock pulses at the previous one.

   Bit 0: WRITE bit. The value is 0.

   Bit 1: MS bit. When 1, do not increment address, when 0, increment address in multiple writing.

   Bit 2–7: address AD(5:0). This is the address field of the indexed register.

   Bit 8–15: Data DI(7:0) (write mode). This is the data that is written inside the device (MSb first).

   Bit 16–... : data DI(...-8). Further data in multiple byte writing.
4) By keeping CS low, the master clocks data bytes into the MAX21105 by continuing to supply SCL_CLK pulses (burst mode). The master terminates the transfer by driving CS high. The master must ensure that SCL_CLK is inactive at the beginning of the next access (when it drives CS low).

Half-Duplex Operation

When the SPI master sets SPI_3_WIRE = 1, the MAX21105 is put into half-duplex mode. In half-duplex mode, the MAX21105 three-states its SDO pin and makes the SDI pin bidirectional, saving a pin in the SPI interface. The SDO pin can be left unconnected in half-duplex operation. The SPI master accesses a MAX21105 register as follows: the SPI master sets the clock to its inactive state. While CS is high, the master can drive the SDI pin to any value.

1) The SPI master selects the MAX21105 by driving CS low and placing the first data bit (MSB) to write on the SDI input.
2) The SPI master turns on its output driver and clocks the command byte into the MAX21105. The SPI read command is performed with 16 clock pulses:

   Bit 0: READ bit. The value is 1.

   Bit 1: MS bit. When 1, do not increment address, when 0, increment address in multiple reading.

   Bit 2-7: address AD(5:0). This is the address field of the indexed register.

   Bit 8-15: data DO(7:0) (read mode). This is the data that is read from the device (MSb first).

   Multiple read command is also available in 3-wire mode.

Interrupt Generators

The MAX21105 offers two completely independent interrupt generators, to ease the SW management of the interrupt generated. For instance, one line could be used to signal a DATA_READY event whilst the other line might be used, for instance, to notify the completion of the internal start-up sequence.

Interrupt functionality can be configured through the Interrupt Configuration registers. Configurable items include the INT pin level and duration, the clearing method as well as the required triggers for the interrupts.

The interrupt status can be read from the Interrupt Status registers.

The event that has generated an interrupt is available in both forms: latched and unlatched.

Interrupt sources may be enabled/ disabled and cleared individually. The list of possible interrupt sources includes the following conditions: DATA_READY, FIFO_EMPTY, FIFO_THRESHOLD, FIFO_OVERRUN, OTP_DOWNLOAD.

The interrupt generation can also be configured as latched, unlatched or timed, with programmable length.

When configured as latched, the interrupt can be cleared by reading the corresponding status register (clear-on-read) or by writing an appropriate mask to the status register (clear-on-write).

Digital-Output Temperature Sensor

An digital output temperature sensor is used to measure the MAX21105 die temperature. The readings from the ADC can be accessed from the Sensor Data registers.

The temperature data is split over 2 bytes. For faster and less accurate reading, accessing the MSB allows to read the temperature data as an absolute value expressed in Celsius degrees. By reading the LSB, the accuracy is greatly increased, up to 256 digit/°C.

Power Modes

The MAX21105 features nine power modes, allowing selecting the appropriate tradeoff between power consumption, noise level, accuracy and turn-on time.

The transition between different power modes can be controlled with the software by explicitly setting a power mode in the Configuration register.

Gyro Low-Noise Mode

In gyro low-noise mode, only the gyro is switched on and it is operational with minimum noise level.

Gyro Low-Power Mode

In this power mode, only the gyro is switched on and it is operating in low-power mode. The low-power mode allows to reduce power consumption with the same sensor accuracy at the price of a higher rate noise density.

This unique MAX21105 features can be activated for the gyro with different ODR from 5Hz to 200Hz.

Gyro Standby Mode

To reduce power consumption and have a shorter turn-on time, the IC features a standby mode for the gyro. In standby mode, the MAX21105 gyro does not generate data because a significant portion of the signal processing resources is turned off to save power. Still, this mode enables a much quicker turn-on time.

Acc Low-Noise Mode

In acc low-noise mode, only the accelerometer is switched on. It is operational with minimum noise level.

Acc Low-Power Mode

In this power mode, only the accelerometer is switched on, and it is operating in low-power mode. The low-power mode allows to reduce power consumption with the same sensor accuracy at the price of a higher accelerometer noise density.

This feature can be activated for accelerometer with different ODR from 5Hz to 400Hz.

Power-Down Mode

In Power-Down Mode, the IC is configured to minimize the power consumption. In Power-Down Mode, registers can still be read and written, but neither sensor can generate new data. Compared to Standby Mode, it takes longer to activate the IC and start collecting data from the sensors.

Sensor Data Output Registers

The sensor data registers contain the latest gyroscope, accelerometer, and temperature measurement data.

They are read-only registers and are accessed through the serial interface. Data from these registers can be read at anytime. However, the interrupt function can be used to determine when new data is available.

FIFO

The MAX21105 embeds a 512-byte data FIFO. The user can flexibly select the set of axis data to be stored in FIFO.This allows a power saving at system level as the host processor does not need to continuously poll data from the sensor, but it can wake up only when needed and burst the significant data out from the FIFO.

The FIFO buffer can work according to four main modes: off, normal, interrupt, and snapshot.

When configured in snapshot mode, it offers the ideal mechanism to capture the data following an external interrupt event.

Both normal and interrupt modes can be optionally configured to operate in overrun mode, depending on whether, in case of buffer underrun, newer or older data are accepted to be lost.

Various FIFO status flags can be enabled to generate interrupt events on INT1/INT2 pin.

FIFO Off Mode

In this mode, the FIFO is turned off; data are stored only in the data registers and no data are available from the FIFO if read.

When the FIFO is turned off, there are essentially two options to use the device: synchronous and asynchronous reading through the data registers.

Synchronous Reading

In this mode, the processor reads the data set (e.g., 6 bytes for a 3 axes configuration) generated by the MAX21105 every time that DATA_READY is set. The processor must read once and only once the data set in order to avoid data inconsistencies.

Benefits of using this approach include the perfect reconstruction of the signals coming the MAX21105 with the minimum data traffic.

Asynchronous Reading

In this mode, the processor reads the data generated by the MAX21105, regardless the status of the DATA_READY flag. To minimize the error caused by different samples being read a different number of times, the access frequency to be used must be much higher than the selected ODR. This approach normally requires a much higher BW.

FIFO Normal Mode

Overrun = false

- FIFO is turned on.
- FIFO is filled with the data at the selected output data rate (ODR).
- When FIFO is full, an interrupt can be generated.
- When FIFO is full, all the new incoming data is discharged. Reading only a subset of the data already stored into the FIFO keeps locked the possibility for new data to be written.
- Only if all the data are read, the FIFO restarts saving data.
- If communication speed is high, data loss can be prevented.
- To prevent a FIFO-full condition, the required condition is to complete the reading of the data set before the next DATA_READY occurs.
- If this condition is not guaranteed, data can be lost.

Overrun = true

- FIFO is turned on.
- FIFO is filled with the data at the selected ODR.
- When FIFO is full, an interrupt can be generated.
- When FIFO is full, the oldest data is overwritten with the new ones.
- If communication speed is high, data integrity can be preserved.
- In order to prevent a FIFO_WR_FULL condition, the required condition is to complete the reading of the data set before the next DATA_READY occurs.
- If this condition is not guaranteed, data can be overwritten.

Interrupt Mode

Overrun = false

- FIFO is initially disabled. Data are stored only in the data registers.
- When an interrupt (either INT_OR or INT_AND) is generated, the FIFO is turned on automatically. It stores the data at the selected ODR.
- When FIFO is full, all the new incoming data is discharged. Reading only a subset of the data already stored into the FIFO keeps locked the possibility for new data to be written.
- Only if all the data are read the FIFO restarts saving data when a new event is generated.

Overrun = true

- FIFO is initially disabled. Data are stored only in the data registers.
- When an interrupt (either INT_OR or INT_AND) is generated, the FIFO is turned on automatically. It stores the data at the selected ODR.
- When FIFO is full, an interrupt can be generated.
- When FIFO is full, the oldest data is overwritten with the new ones.
- If communication speed is high, data integrity can be preserved.
- In order to prevent a FIFO_WR_FULL condition, the required condition is to complete the reading of the data set before the next DATA_READY occurs.
- If this condition is not guaranteed, data can be overwritten.

Snapshot Mode

- FIFO is initially in normal mode with overrun enabled.
- When an interrupt (either INT_OR or INT_AND) is generated, the FIFO switches automatically to not-overrun mode, and data stops being saved in the FIFO, regardless whether the FIFO is full or not.
- When FIFO is full, an interrupt can be generated.
- When FIFO is full, all the new incoming data is discharged. Reading only a subset of the data already stored into the FIFO keeps locked the possibility for new data to be written.
- Only if all the data are read the FIFO restarts saving data in overrun mode.

Table 3. Power Modes

NAME	DESCRIPTION
Gyro Low Noise	Only gyroscope is switched on and it is operational with maximum performances.
Gyro Low Power	Only gyroscope is switched on and operates to reduce the average current consumption.
Gyro Standby	The gyroscope is in standby mode, the current consumption is reduced by 50%, with a shorter turn-on time.
Acc Low Noise	Only accelerometer is switched on and it is operational with maximum performances.
Acc Low Power	Only accelerometer is switched on and operates to reduce the average current consumption.
Gyro Low-Noise Mode + Acc Low-Noise Mode	Acc and gyro are both switched on in low-noise mode.
Gyro Low-Power + Acc Low-Noise Mode	Acc is in low-noise mode, while the gyro is low-power mode.
Gyro Standby + Acc Low-Noise Mode	Acc is in low-noise mode, while the gyro is standby mode.
Power-Down	This is the minimum power consumption mode, at the price of a longer turn-on time.

Self-Test

Gyroscope

This gyroscope embedded self-test feature can be used to verify if the gyroscope is working properly without physically rotating the device. That may be used either before or after it is assembled on a PCB. If the gyroscope's outputs are within the specified self-test values in the data sheet, then the gyroscope is working properly.

Accelerometer

The accelerometer embedded self-test feature is used to verify the sensor functionality without physically moving the device. When this feature is enabled, an electrostatic test force is applied to the mechanical sensing element

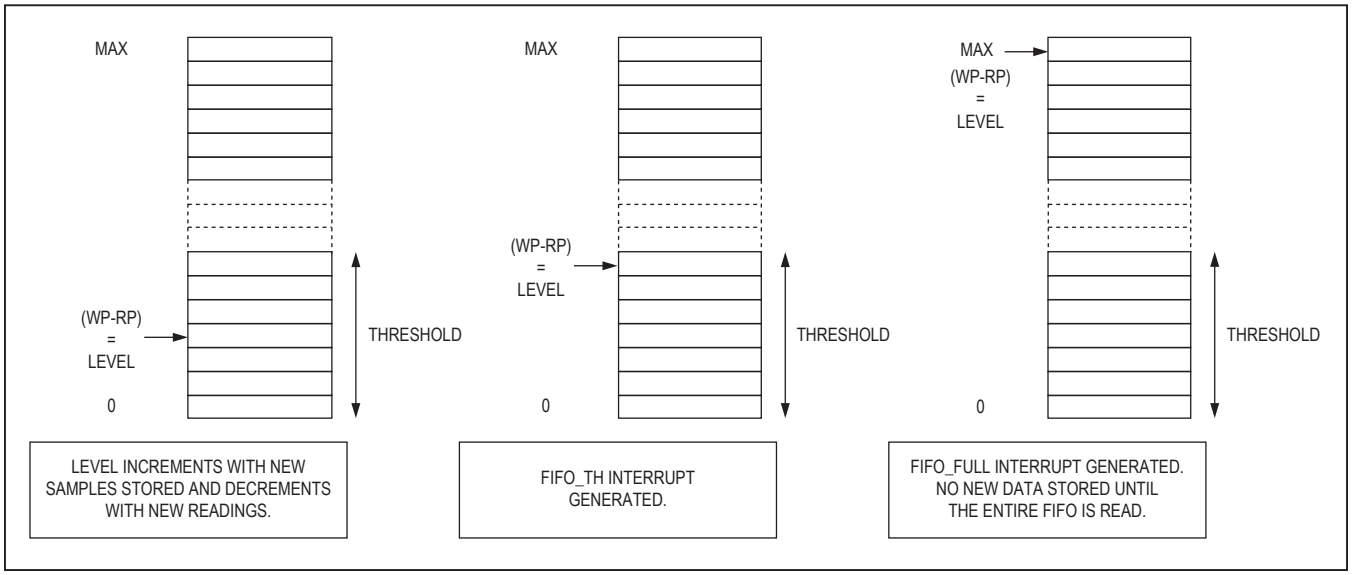


Figure 1. FIFO Normal mode, Overrun = False

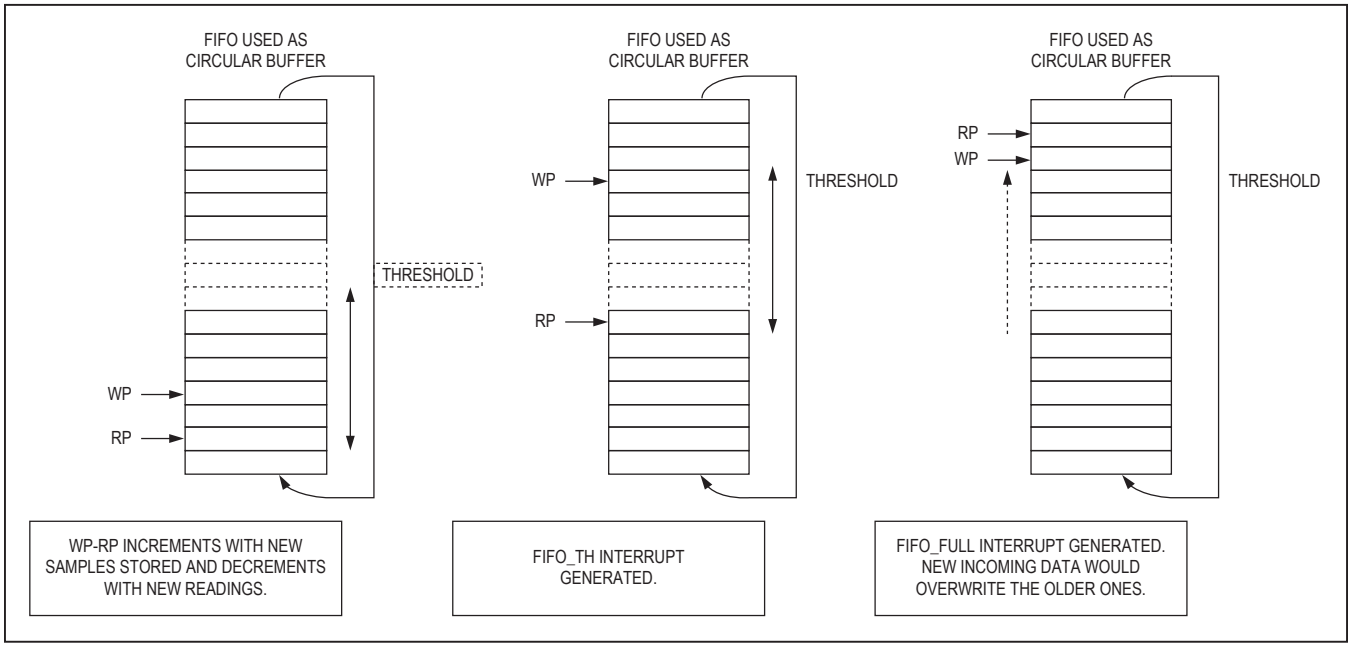


Figure 2. FIFO Normal Mode, Overrun = True

and causes the moving part to move away from its original position, emulating a definite input acceleration. In this case the sensor outputs exhibit a change in their DC levels which is related to the selected full scale through the device sensitivity. The output in this self-test mode is then compared with the output data of the device when the self-test is disabled. If the absolute value of the output difference is within the minimum and maximum range of the preselected full scale range, the accelerometer is working properly.

Revision ID

The MAX21105 has a register used to identify the revision ID of the device and to identify the specific part number. Even though different part numbers may share the same WHO_AM_I value, they would still be identified by means of different Revision ID values.

Unique Serial Number

Each MAX21105 device is uniquely identified by 48 bits that can be used to track the history of the sample, including manufacturing, assembly, and testing information.

Register File

The register file is organized per banks. On the Common Bank are mapped addresses from 0x20 to 0x3F and these registers are always available. It is possible to map on addresses 0x00 to 0x1F three different user banks by properly programming address 0x22. The purpose of this structure is to limit the management of the register map addresses in the 0x00 to 0x3F range even though the number of physical registers is in excess of 64. Refer to the MAX21105 user guide for a complete register map structure.

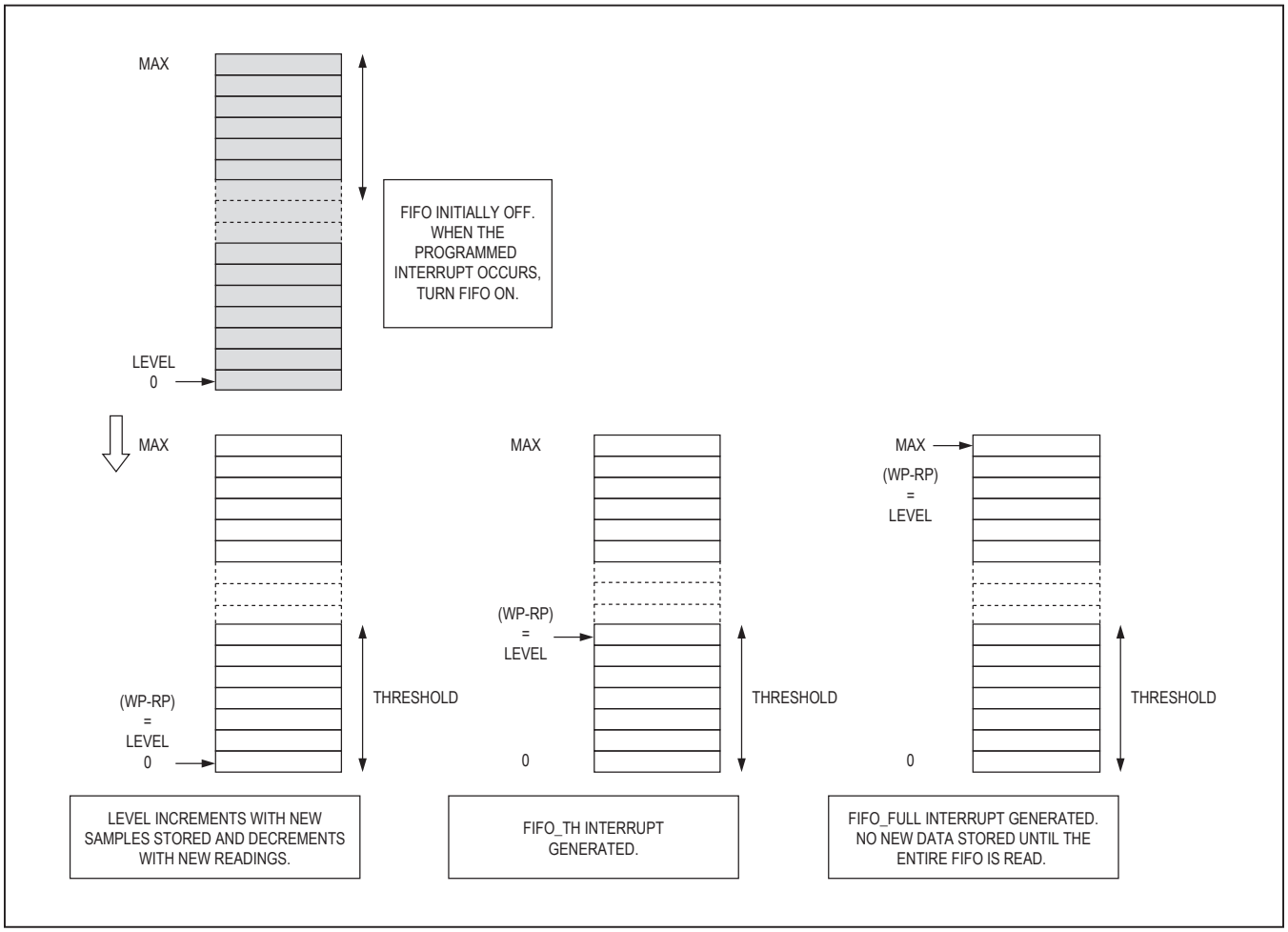


Figure 3. FIFO Interrupt Mode, Overrun = False

Orientation of Axes

Figure 6 and Figure 7 show the orientation of the axes of sensitivity and the polarity of rotation and linear acceleration. Note the pin 1 identifier (●) in the figure.

Soldering Information

Application Notes

Bypass V_{DD} and V_{DDIO} to the ground plane with 0.1µF ceramic chip capacitors on each pin as close as possible to the device to minimize parasitic inductance.

Connect to REGD 100nF ceramic chip capacitor as close as possible to the MAX21105 to minimize parasitic inductance.

Depending on the specific application board, an additional bulk decoupling capacitor to V_{DD} and V_{DDIO} might be needed. For best performance, keep separate V_{DD} and V_{DDIO} power supplies.

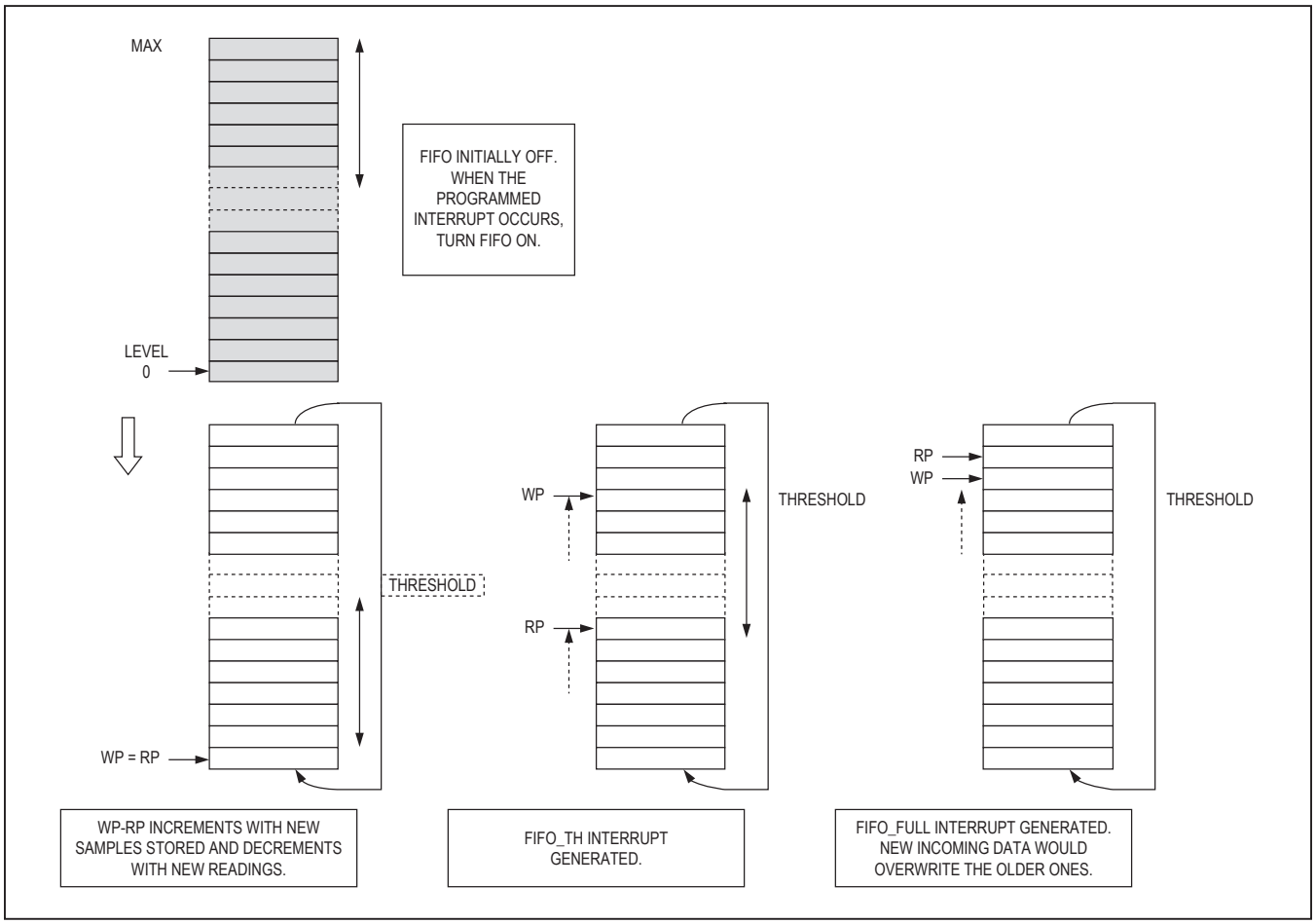


Figure 4. FIFO Interrupt Mode, Overrun = True

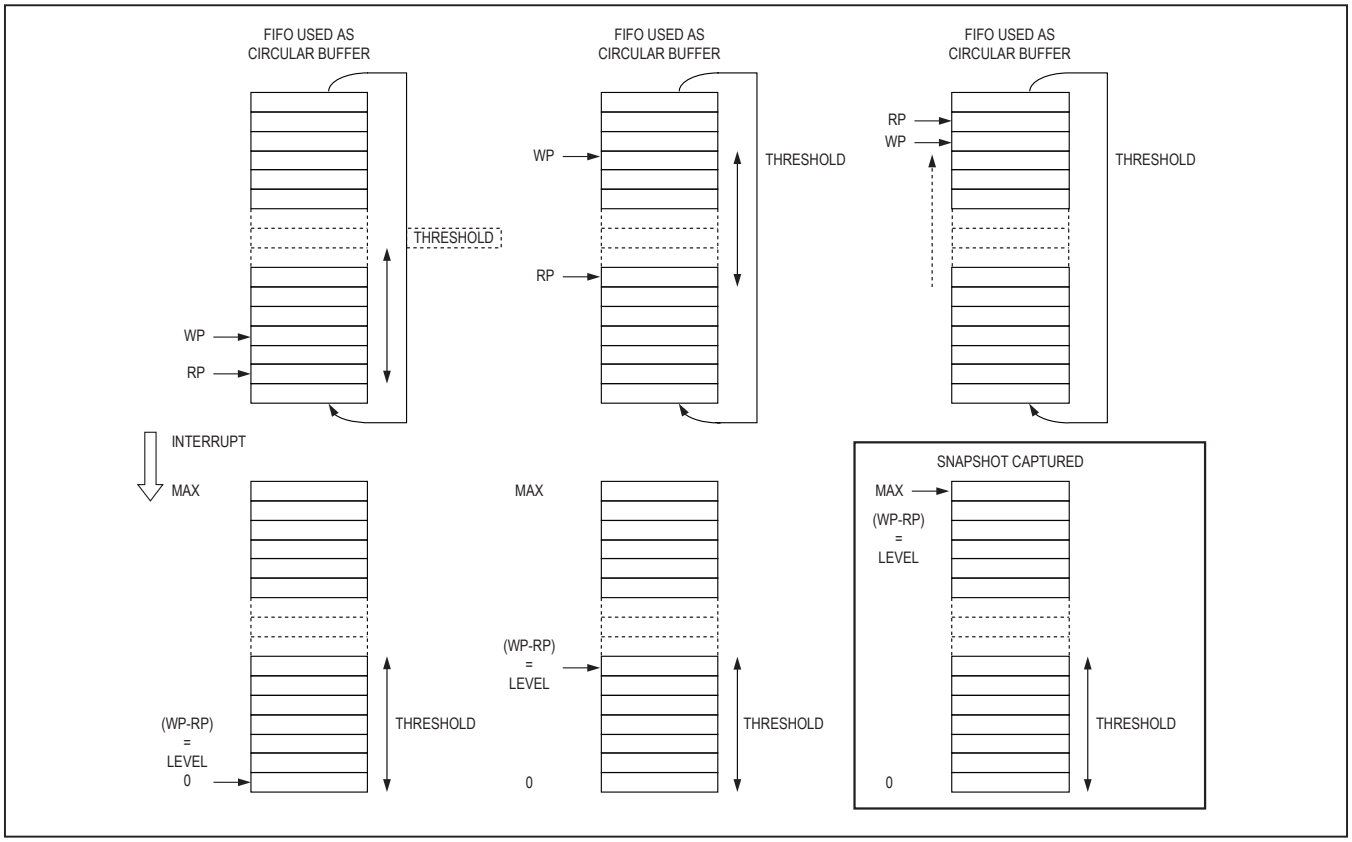


Figure 5. FIFO Snapshot Mode

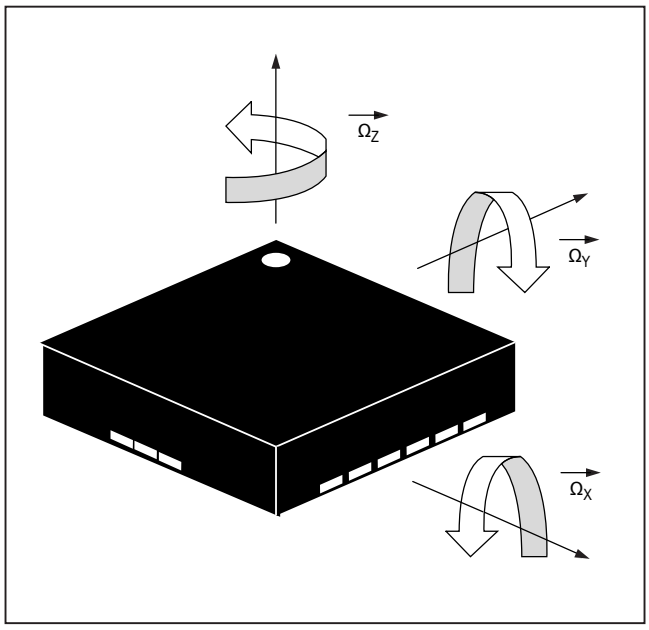


Figure 6. Orientation of Gyro Axes

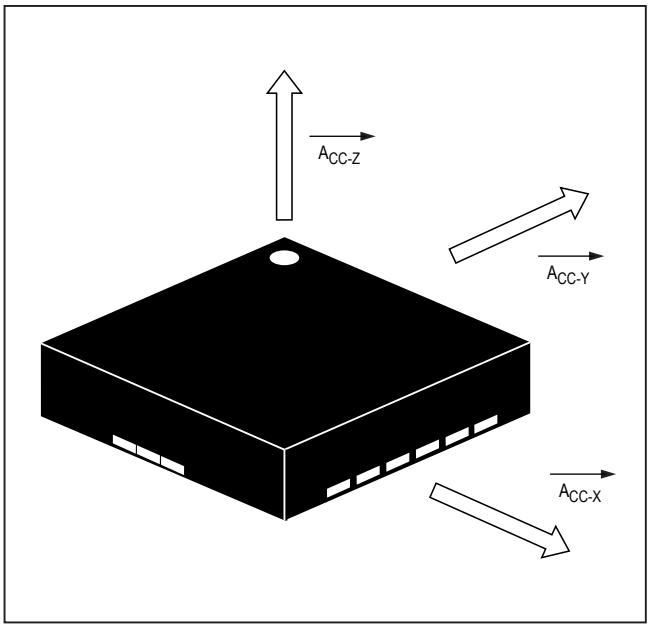


Figure 7 Orientation of Accelerometer Axes

Recommended Application Schematics (continued)

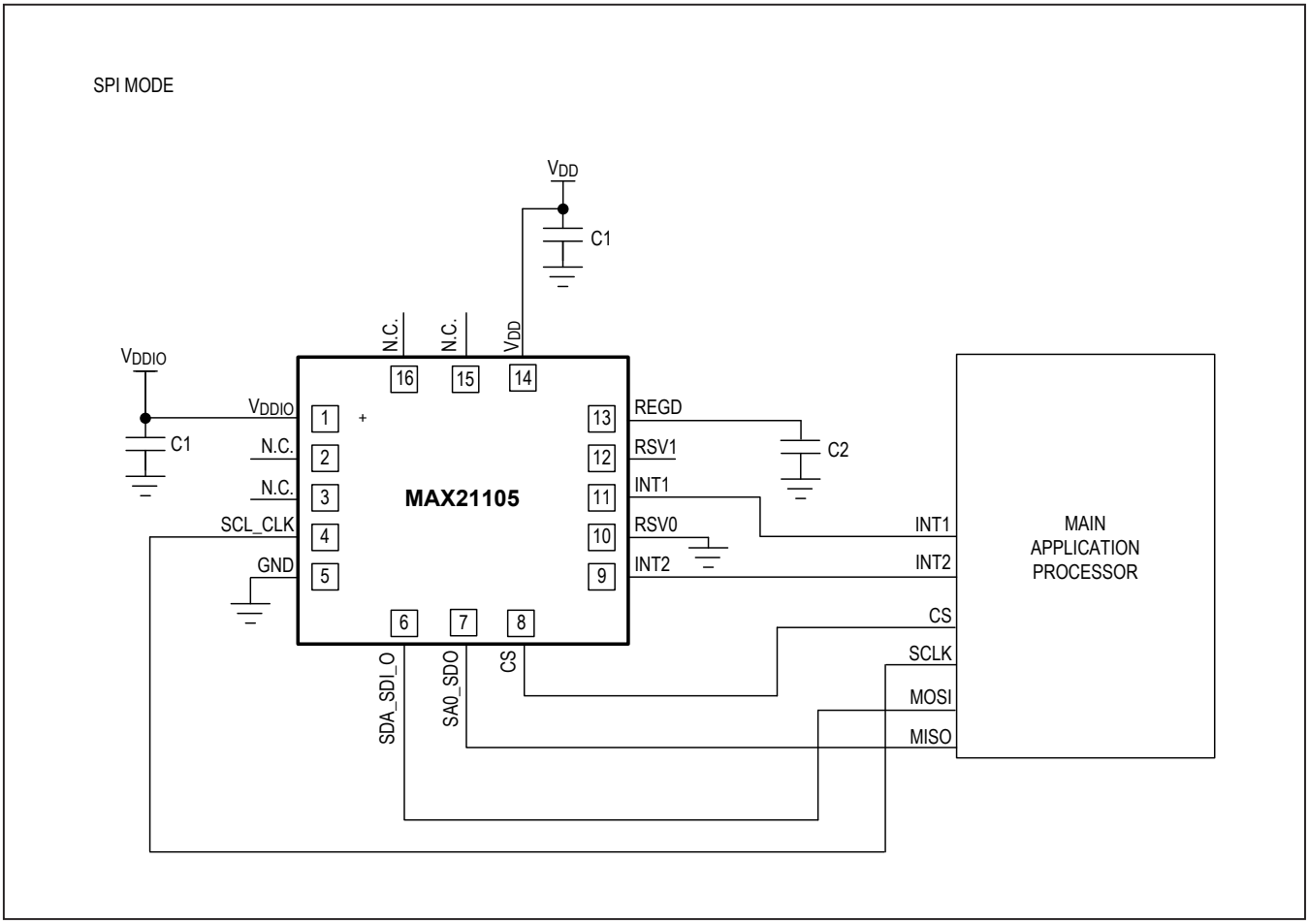


Table 8. Bill of Materials for External Components

COMPONENT	LABEL	SPECIFICATION	QUANTITY
V_{DD}/V_{DDIO} Bypass Capacitor	C1	Ceramic, X7R, 100nF ±10%, 4V	2
REGD Capacitor	C2	Ceramic, X7R, 100nF ±10%, 2V	1
Pullup Resistor (I^2C Mode Only)	R_{PU}	1.1kΩ/10kΩ (min/max)	2

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX21105ELE+	-40°C to +85°C	16 LGA
MAX21105ELE+T	-40°C to +85°C	16 LGA

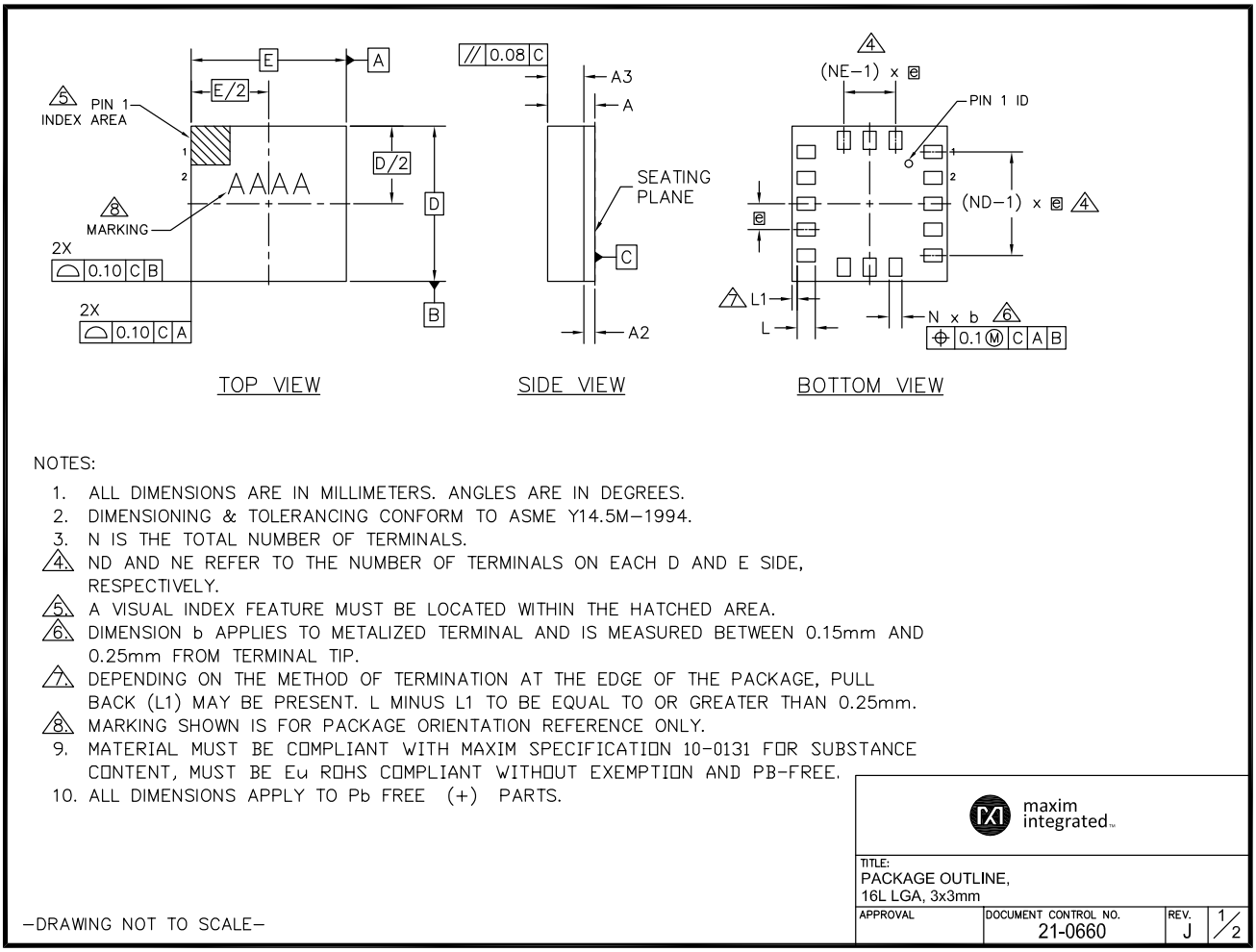
+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel.

Package Information

For the latest package outline information and land patterns (footprints), go to **www.maximintegrated.com/packages**. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
16 LGA	L1633MK+3	21-0660	90-0396



NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
2. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE, RESPECTIVELY.
5. A VISUAL INDEX FEATURE MUST BE LOCATED WITHIN THE HATCHED AREA.
6. DIMENSION b APPLIES TO METALIZED TERMINAL AND IS MEASURED BETWEEN 0.15mm AND 0.25mm FROM TERMINAL TIP.
7. DEPENDING ON THE METHOD OF TERMINATION AT THE EDGE OF THE PACKAGE, PULL BACK (L1) MAY BE PRESENT. L MINUS L1 TO BE EQUAL TO OR GREATER THAN 0.25mm.
8. MARKING SHOWN IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
9. MATERIAL MUST BE COMPLIANT WITH MAXIM SPECIFICATION 10-0131 FOR SUBSTANCE CONTENT, MUST BE Eu ROHS COMPLIANT WITHOUT EXEMPTION AND PB-FREE.
10. ALL DIMENSIONS APPLY TO Pb FREE (+) PARTS.

-DRAWING NOT TO SCALE-

maxim integrated

TITLE: PACKAGE OUTLINE, 16L LGA, 3x3mm			
APPROVAL	DOCUMENT CONTROL NO. 21-0660	REV. J	1/2

Package Information (continued)

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REF.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.86	0.91	0.96	0.78	0.83	0.88	0.78	0.83	0.88
A2	0.21 REF			0.13 REF			0.13 REF		
A3	0.65	0.70	0.75	0.65	0.70	0.75	0.65	0.70	0.75
b	0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30
D	3.00 BSC			3.00 BSC			3.00 BSC		
E	3.00 BSC			3.00 BSC			3.00 BSC		
e	0.50 BSC			0.50 BSC			0.50 BSC		
L	0.30	0.35	0.40	0.30	0.35	0.40	0.275	0.325	0.375
L1	0.05	0.10	0.15	0.05	0.10	0.15	0.05	0.10	0.15
N	16			16			16		
ND	5			5			5		
NE	3			3			3		
PKG CODE	L1633MK+2			L1633MK+3			L1633MK+5		

–DRAWING NOT TO SCALE–

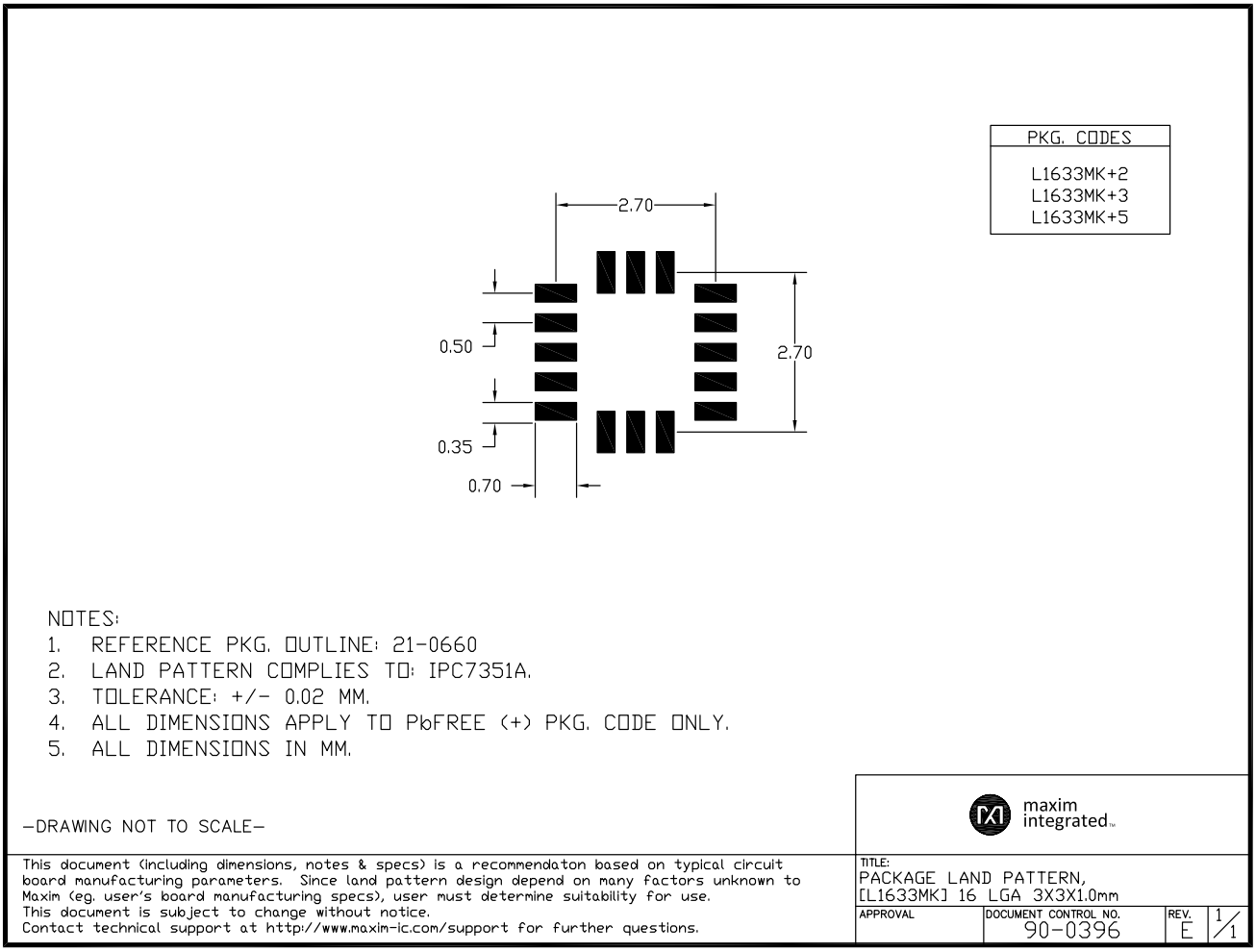
maxim integrated™

TITLE:
PACKAGE OUTLINE,
16L LGA, 3x3mm

APPROVAL	DOCUMENT CONTROL NO.	REV.	2/2
	21-0660	J	

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Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	12/14	Initial release	—

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