ICM-30630 System Hardware Design Guide

Revision 1.1

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1. INTRODUCTION

1.1 PURPOSE AND SCOPE

This application note is intended for system designers who require an overview of hardware design considerations for the ICM-30630 sensor built-in MCU/DMP.

Topics covered in this app note include how to use the ICM-30630 in smart motion detection devices, such as smart phones, tablets, wearable activity monitors, and gaming machines, as well as potential design challenges for such applications, including InvenSense's system reference design called the ICM-30630 SDK (Software Development Kit).

Please note that this app note does not cover software architecture/development related topics.

1.2 PRODUCT OVERVIEW AND APPLICATIONS

The ICM-30630 is a MotionTracking device that combines a 3-axis gyroscope, 3-axis accelerometer, and tri-core processors (an ARM Cortex M0 CPU, a DMP3 and a DMP4 Digital Motion Processor™) in a small 3 mm x 3 mm x 1 mm LGA package. The device supports the following features:

- ARM Cortex M0-based open platform optimized for motion applications with dual-DMP-based motion accelerators
- Supports Android L and beyond
- Memory (DMP + FIFO): variable size FIFO based on DMP feature set
- Runtime Calibration

The ICM-30630 serves as a sensor hub, supporting the collection and processing of data from internal and external sensors. It can offload data processing from the Application Processor (AP) in a system, helping to save system power and improve performance. The device includes a primary serial interface (I^2C and 4-wire SPI) for communication from the host processor. There is an auxiliary master I^2C interface for external sensor communication.

ICM-30630 devices, with their 6-axis integration, ARM Cortex M0 CPU, DMPs, 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.

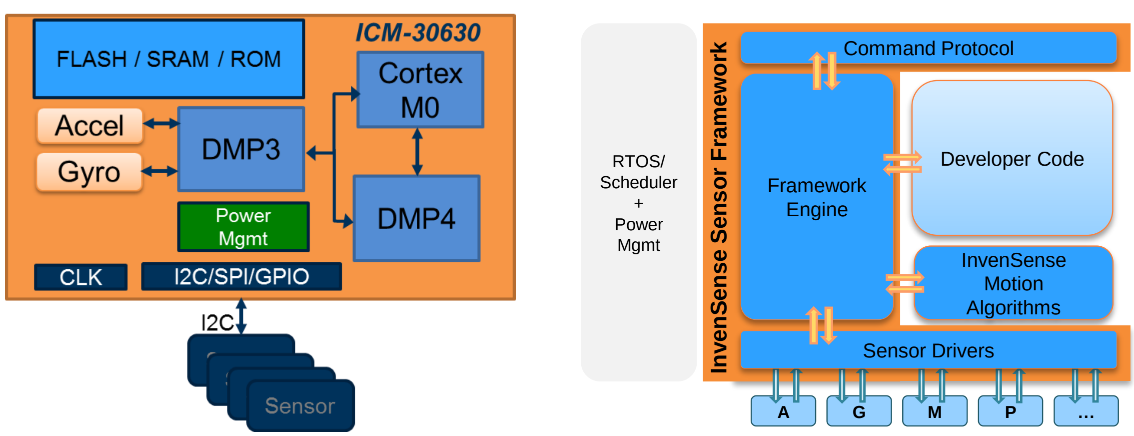

Figure 1. ICM-30630 Block Diagram and Software Architecture Diagram

1.3 ICM-30630 SIMPLIFIED BLOCK DIAGRAM

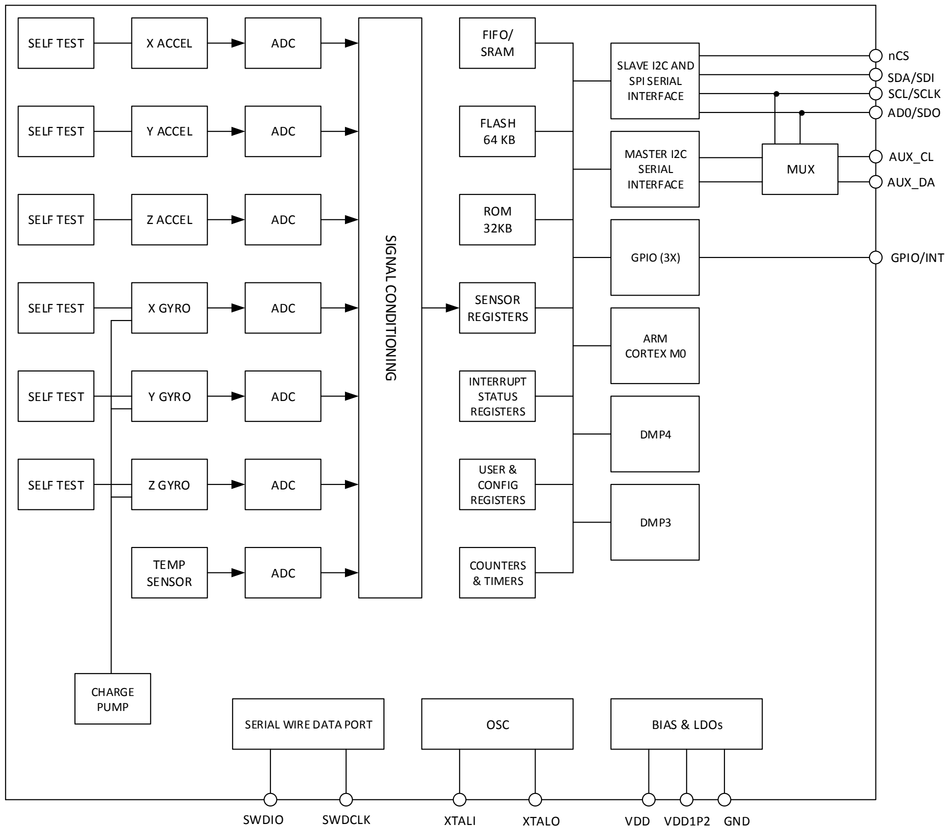

Figure 2. ICM-30630 Simplified Block Diagram

2 SENSOR HUB APPLICATION SYSTEMS

A sensor hub is a combination of a low-power MCU and embedded software that provides access to multiple sensors for use in various applications. The hub executes motion sensor fusion, provides sensor drivers, motion algorithms, and provides real-time information to offload the power hungry application processor (AP). Emerging sensor hubs for smart devices enable efficient processing.

The ICM-30630 serves as an intelligent sensor hub that allows the data collection and processing of such data from internal and external sensors. The multi-cores of ICM-30630 are designed to offload computing and processing tasks from the AP, thereby saving system power and streamlining the overall performance. The device also integrates industry leading InvenSense 6-axis Accel and Gyro MEMS.

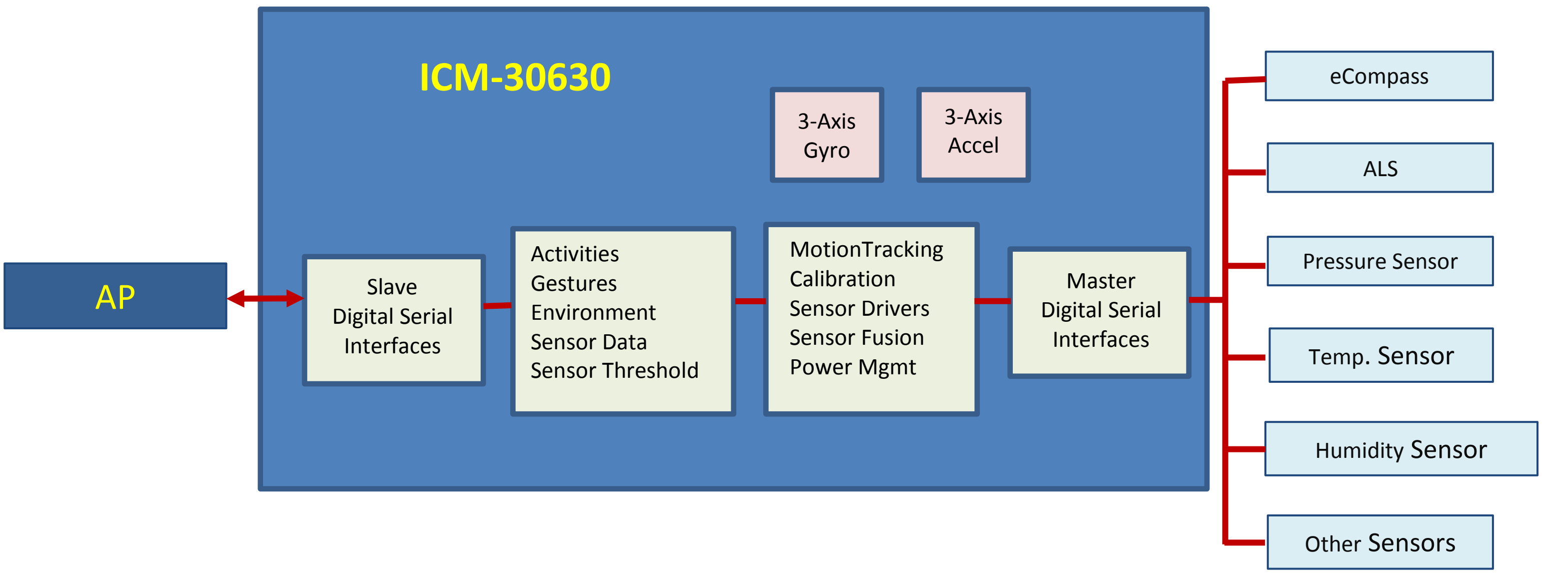

Figure 3. Sensor HUB Solution with ICM-30630

3 HARDWARE DESIGN CONSIDERATIONS

3.1 POWER SUPPLIES

ICM-30630 has four power blocks:

- A 1.2 V digital power supply that can be applied externally or provided internally. Do not connect VDD1P2 to an external source, if the internal power circuit is used.
- A VDD core power supply for built-in sensors, MCU and DMPs. The supported voltage level range is 1.71 V to 3.6V.
- A VDDIO digital supply to make the ICM-30630 digital interface compatible with the AP, wireless transceiver, and external sensors I/O levels. VDDIO allows for a range of 1.71 V to 3.6 V to be applied. The VDDIO voltage must be the same as the host AP, wireless transceiver, and external sensor I/O levels. All ICM-30630 digital I/O signal voltage levels are referenced to VDDIO.
- One of internal LDOs power blocks needs an external decoupling capacitor, applied to REGOUT. Usually a 0.1 µF capacitor is sufficient for decoupling purposes.

Proper capacitor decoupling can reduce power supply noise, as capacitors act as a supplementing current source during short transient events. InvenSense recommends using separate 0.1 µF decoupling capacitors for VDD, VDDIO and REGOUT. If using external 1.2 V supply, a 0.1 µF decoupling capacitor is also needed. All decoupling capacitors must be placed as close as possible to their respective power and ground pins. Ceramic capacitors with X5R material with a change in capacitance of ±15% over a -55°C to +85°C temperature range are a good choice, covering the entire operating temperature range of the ICM-30630 at an acceptable accuracy and at reasonable cost.

Power supply connections are displayed in Figure 4 and Figure 5.

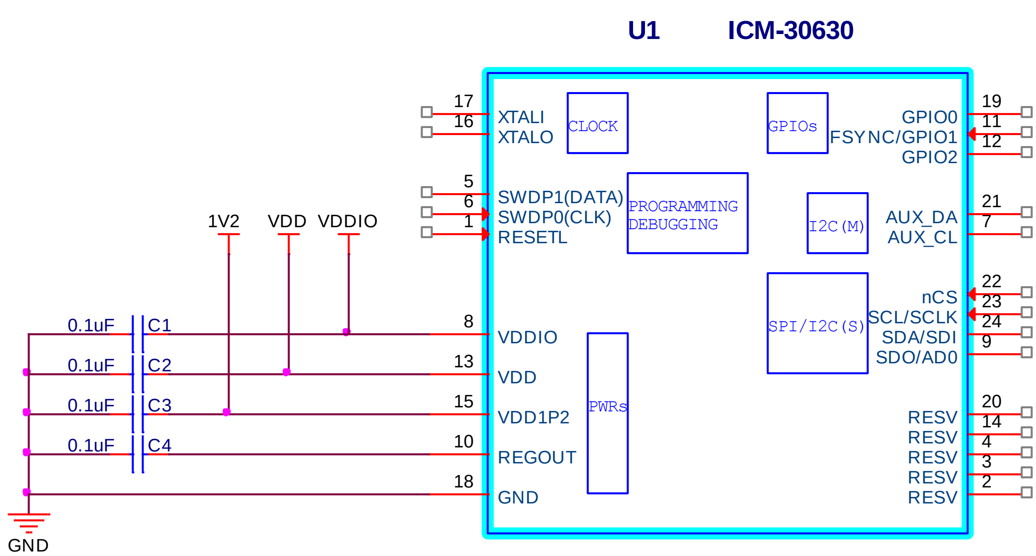

Figure 4. External Power Supply for VDD1P2

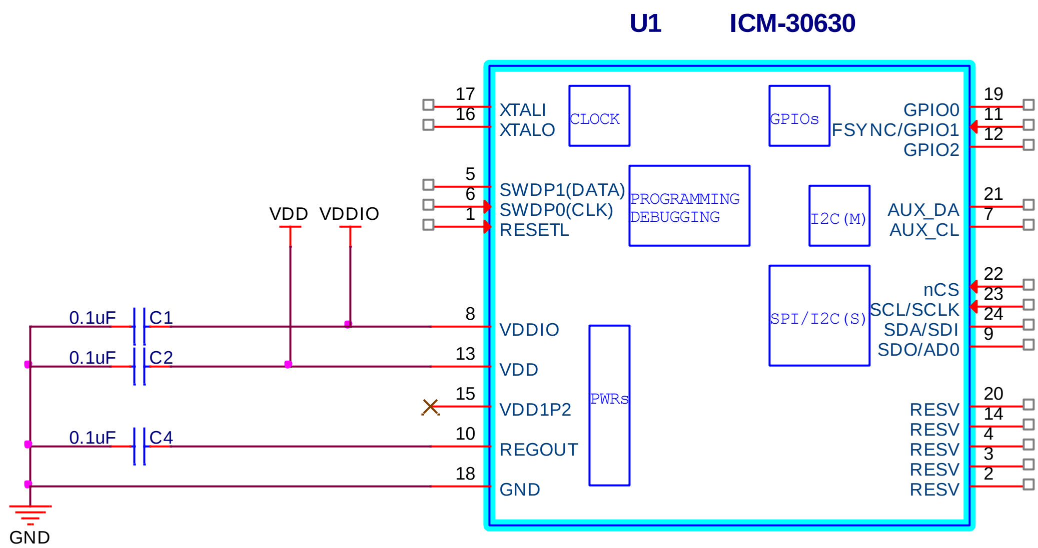

Figure 5. Internal Power Supply for VDD1P2

3.2 PROGRAM/DEBUG INTERFACE AND EXTERNAL RESET

The RESET signal can be controlled via a host (active low), or can be left pulled high, and the internal POR will provide the reset. For sensor HUB application, we recommend host control the reset. In addition to the hardware RESET input, a soft reset can be provided by the host via a serial interface register write.

There are two ways to program the ICM-30630's internal flash memory:

- Via the SPI / I2C host interface: The host AP or a SPI Host Controller tool, such as Total Phase's Cheetah system, can be used to program ICM-30630 FLASH. InvenSense will provide Android/Linux supported FLASH programming execution software.
- When using the Cheetah tool to program FLASH, a digital signal level shifter is required for VDDIO, as the digital supply voltage level is not the same as Cheetah's I/O level (3.3V). Figure 6 shows the suggested level shifter circuit incorporated in the ICM-30630 SDK board.

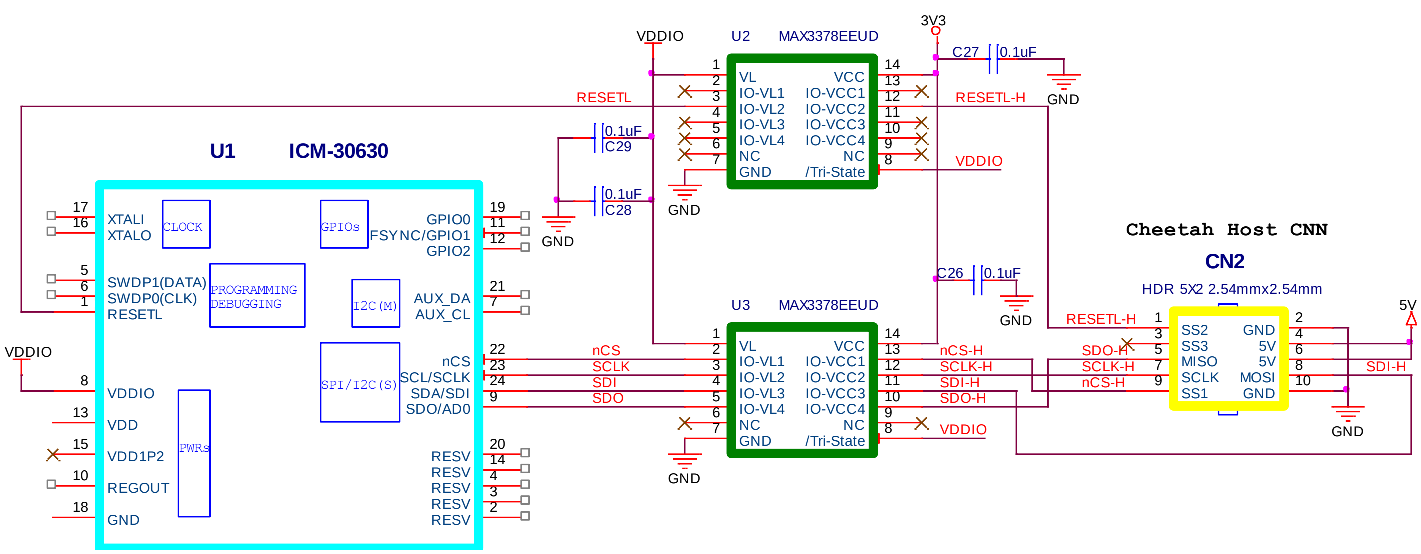

Figure 6. Programming the ICM-30630 Flash Memory through a Total Phase Cheetah System With a Level Shifter

- ICM-30630's FLASH can also be programmed through the SWD interface by utilizing SWDCLK and SWDIO signal lines. The same serial-wire debug interface also serves as debug interface port.
- **SWDP0 (pin-6) must be connected to GND in normal operation mode. When in debug/program mode, do not connect the SWDP0 (pin-6) to GND.**

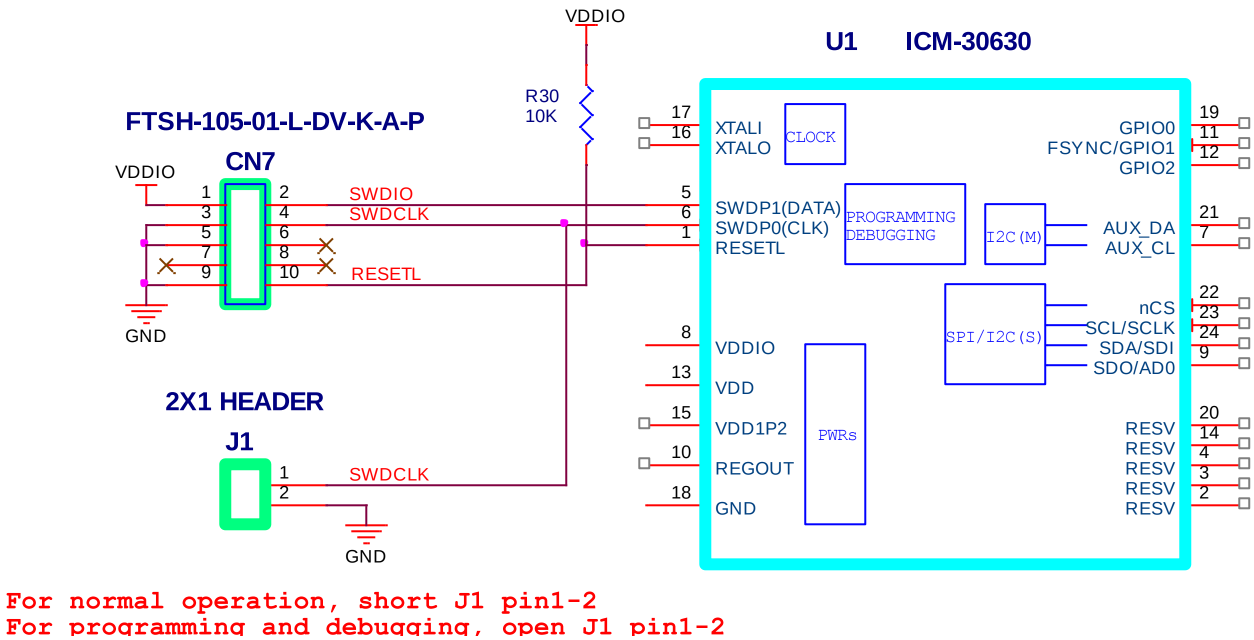

Figure 7. SWD Programming/Debugging Interface Connection

3.3 CLOCK GENERATION UNIT AND EXTERNAL CLOCK SOURCE

The ICM-30630 offers three different clock sources:

1. Built-in high-frequency RC oscillator for the system clock
2. Built-in low-frequency RC oscillator for periodic wake up
3. External 32.768 kHz crystal for accurate time stamping.
   An external crystal is connected to XTALI and XTALO (Pins 17 and 18). **There is no need to mount crystal load capacitors on PCB board because they are built in ICM-30630.**
4. CMOS external 32.768 KHz clock.

For the ICM-30630, it is recommended to utilize precise external oscillators or crystals/ceramic resonators. The accuracy of an external oscillator or crystals/ceramic resonator must be 30 ppm or better.

An external digital level clock input from a 32.768 kHz source often found on PMICs and other platform devices can be connected to XTALI pin. We recommend this methodology as it allows ICM-30630 to be synchronized with other devices (i.e. the host) who are also using the same reference clock.

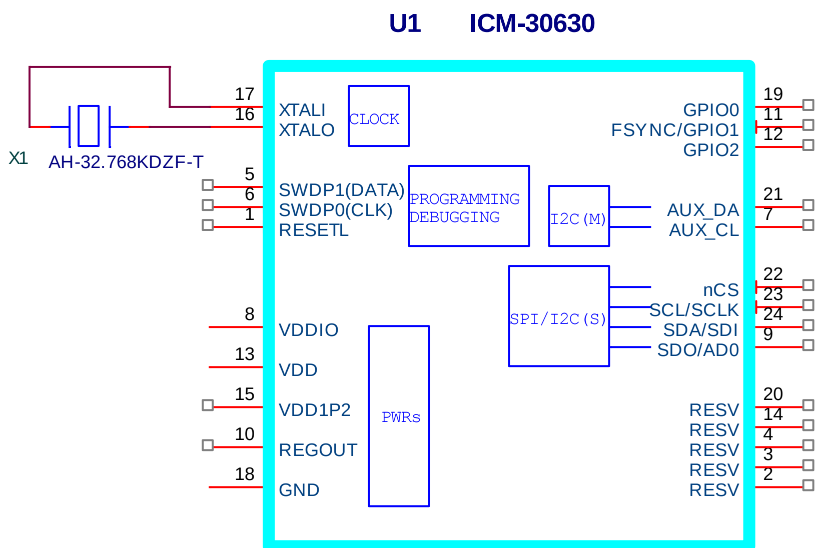

Figure 8. External Crystal Oscillator Circuit

3.4 SERIAL INTERFACE DIGITAL LINE TERMINATIONS

The ICM-30630 has one master I^2C, one slave I^2C (shared with slave SPI) and one slave SPI (shared with slave I^2C) serial interface available for sensor and AP communications. I^2C is a two-wire interface comprised of the signals serial data (SDA) and serial clock (SCL). The lines are open-drain and pullup resistors (e.g. 10kΩ) are required.

3.4.1 Slave I^2C interface

The ICM-30630 always operates as a slave device when communicating with the AP (master).

The slave address of the ICM-30630 is 7 bits long with the LSB (X) determining the final address. The LSB bit of the 7-bit address is determined by the logic level on Pin AD0 (GND or VDDIO). The slave address is 0x6A (Pin AD0 is logic low) and 0x6B (Pin AD0 is logic high).

To use ICM-30630 in slave I^2C mode, Pin 22 (nCS) must be set to the same level as VDDIO. Figure 9 shows the ICM-30630 operating in slave I^2C mode with its 7-bit device address set to 0x6A.

The I^2C open-drain pullup resister value can be adjusted based on how many slave devices are connected and the bus speed. The 10K ohm in the below circuit is just for reference. When the bus in fast and fast-plus mode, please reference the Table 1 for the pullup resisters value.

	Fscl = 400KHz	Fscl = 1MHz	Vddio (V)
Rp (min.) KOhm	0.867	0.867	3.0
	0.480	0.480	1.8
Rp (max.) KOhm	2.356	1.131	3.0
	2.548	1.223	1.8

Table 1. I2C Bus Pullup Resistor Value Reference Table

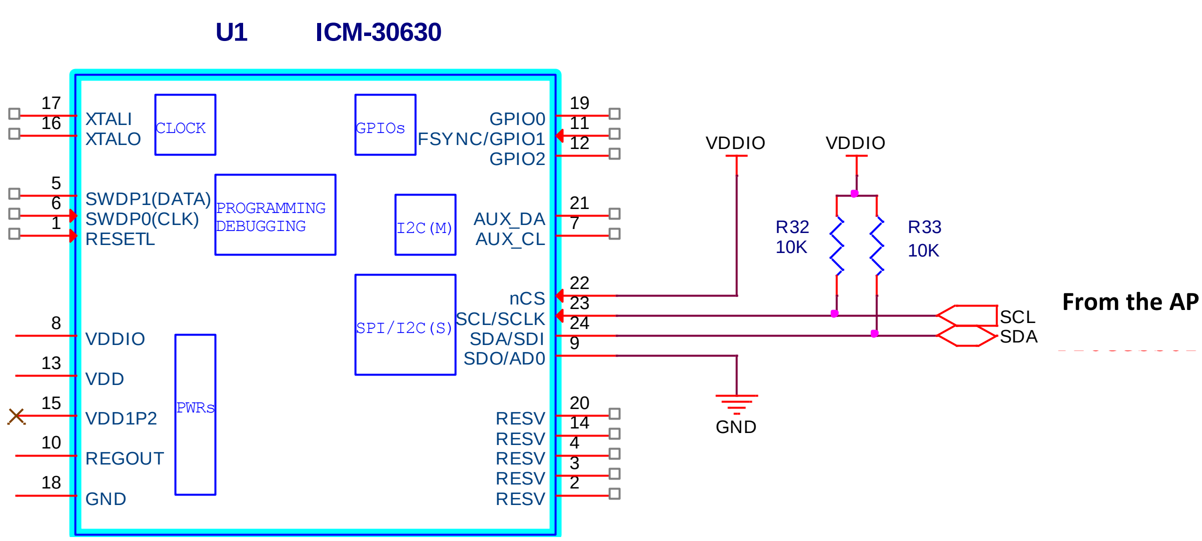

Figure 9. ICM-30630 Operating in Slave I^2C Mode

3.4.2 Slave SPI interface

The ICM-30630 always operates as a slave device when communicating with the AP (master). For SPI operation, all logic levels are referenced to VDDIO.

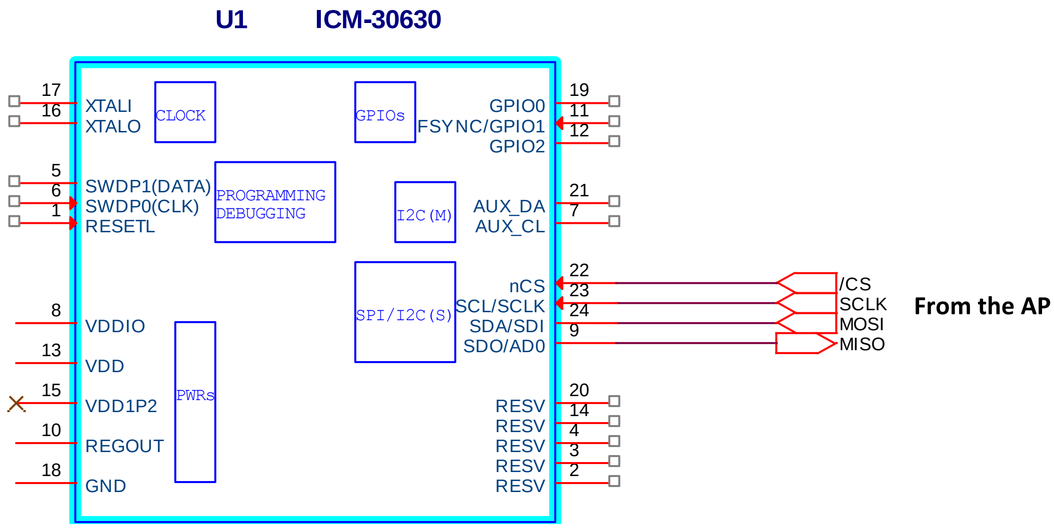

Figure 10. ICM-30630 Operating in Slave SPI Mode

3.4.3 Master I²C Interface

The ICM-30630 offers one master I²C interface for communications with external sensors. The I²C open-drain pullup resistor value can be adjusted based on the number of external sensors connected to the bus and the overall desired/specified interface speed.
The I²C open-drain pullup resister value can be adjusted based on how many slave devices are connected and the bus speed. The 10K ohm in the below circuit is just for reference. When the bus is in fast and fast-plus mode, please reference the Table 1 for the pullup resistors value.

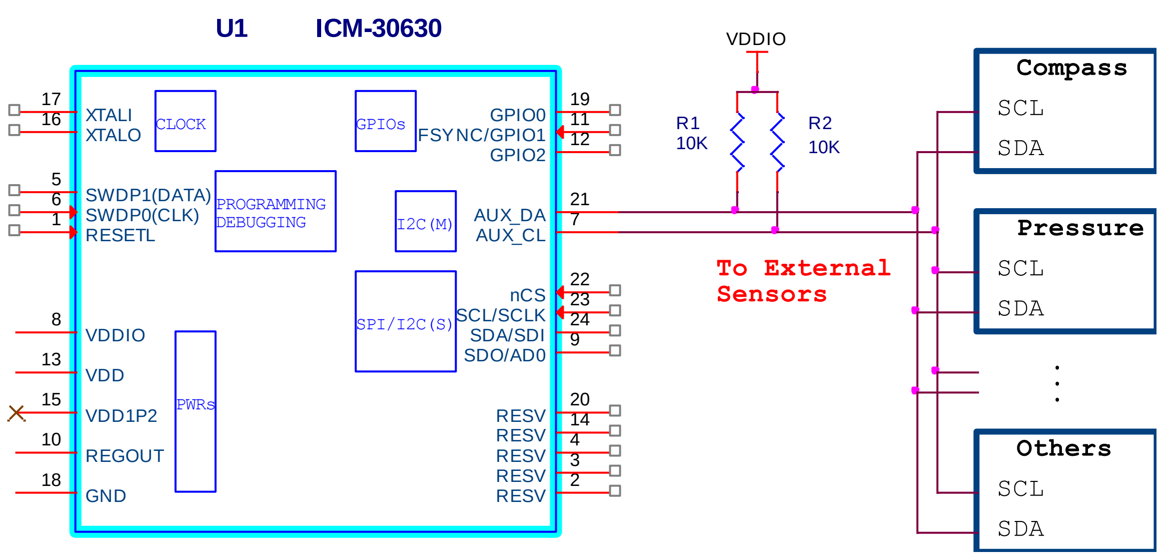

Figure 11. ICM-30630 Master I²C Bus Connection

3.5 GPIO LINES

The ICM-30630 supports three bidirectional GPIO lines that can be configured as general purpose I/O, interrupt input, or interrupt output. All GPIO voltage levels are referenced to VDDIO.

We recommend the following GPIO usage assignment:

a. Use ICM-30630 GPIO0 as output to wakeup host MCU. Connect the GPIO0 to host MCU wake-up interrupt input.
b. Use ICM-30630 GPIO1 as output for general (non-wakeup) interrupt of host MCU. Connect the GPIO1 to host MCU interrupt input.
c. ICM-30630 GPIO2 is used as a sensor interrupt input or GPIO.
d. Host wakes up ICM-30630 with an interrupt write via digital serial interface.

4. PCB DESIGN GUIDELINES

To achieve maximum ICM-30630 performance, the following recommendations should be followed during the board design process:

4.1 EXTERNAL CRYSTAL

Keep any PCB traces between the crystal and the ICM-30630 (Pins 16 and 17), as short as possible. Although currents running through the crystal oscillator are very small, any long lines will make it more sensitive to EMI, ESD and crosstalk. Long lines also add parasitic capacitance and some series resistance to the oscillator, which could impact the start-up characteristics of the oscillator. It is recommended to shield the crystal traces with ground traces, and keep other fast switching clock/signal lines as far away from the crystal connections as possible. Placing a ground plane underneath the crystal will reduce interference from other layers.

4.2 I^2C AND SPI LINES

Keeping signal speeds, skews, and rise times in mind for high-speed digital bus, all I^2C and SPI data and clock lines should be length and impedance matched. Keep the bus traces as short as possible to reduce bus capacitance. Avoid routing high-energy traces near digital bus lines.

4.3 POWER AND GND

Although the ICM-30630 is low-power component, wider power and ground PCB traces are very helpful to reduce system noise. It is recommended to design power and ground traces for PCBs with a least an 8 mil width in mind. Avoid split ground and power planes, as they act as antennas and can radiate with detrimental effects on fast bus and/or sensitive signals.

4.4 MEMS COMPONENT PLACEMENT

The gyroscope and accelerometer inside the ICM-30630 are MEMS-based designs, making the ICM-30630 placement sensitive to mechanical strength. Placing MEMS sensors in areas where the board flexes puts unnecessary mechanical stress on the MEMS sensor package, which leads to the possibility of higher offsets and damage to the sensor. For details on proper sensor placement, please refer to InvenSense's application notes *MEMS Motion Handling and Assembly Guide*, *Accelerometer and Gyroscope Design Guidelines* and *Compass Design Guidelines*.

5. REFERENCE DESIGN

5.1 SCHEMATICS

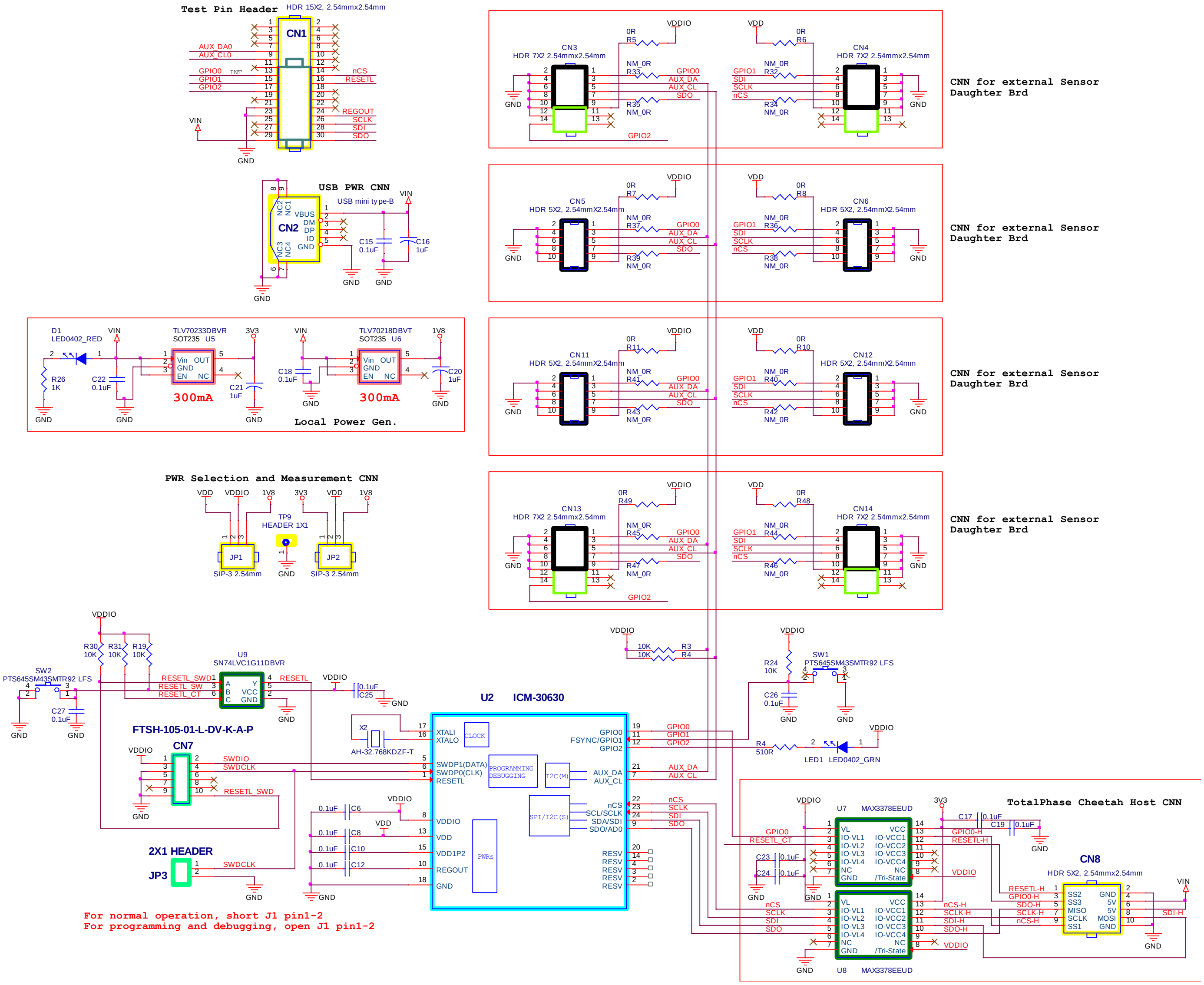

Figure 12. ICM-30630 Reference Design Schematics (SDK)

5.2 BILL OF MATERIALS

Table 2. Reference Design BOM

ITEM	QTY	REFERENCE	PART TYPE /VALUE	MANUFACTURER	MANUFACTURER PART NUMBER	PCB FOOTPRINT
1	1	CN1	HDR 15X2, 2.54mmx2.54mm	Sullins	PREC015DAAN-RC	J100\30DF-VRA
2	1	CN2	USB mini type-B	On Shore Tech	USB-M26FTR	USB_MINI_B_F
3	4	CN3,CN4,CN13,CN14	HDR 7X2 2.54mmx2.54mm	FCI	67996-114HLF	J100\7X2
4	4	CN5,CN6,CN11,CN12	HDR 5X2, 2.54mmX2.54mm	FCI	67997-210HLF	HEADER2x5
5	1	CN7	FTSH-105-01-L-DV-K-A-P	Samtec	FTSH-105-01-L-DV-K-A-P	FTSH-105-01-L-DV-K-A-P
6	1	CN8	HDR 5X2, 2.54mmx2.54mm	FCI	67997-210HLF	CON2X5-100MIL
7	14	C6,C8,C10,C12,C15,C17,C18,C19, C22,C23,C24,C25,C26,C27	0.1uF	Yageo	CC0402KRX5R6BB104	C0402
8	3	C16,C20,C21	1uF	TDK	C1005X5R0J105K	C0402
9	1	D1	LED0402_RED	Kingbright Corp	APHHS1005SURCK	LED0402
10	2	JP1,JP2	SIP-3 2.54mm	FCI	68000-103HLF	sip-3p
11	1	JP3	2X1 HEADER	Samtec	TS-102-T-A	sip-2p
12	1	LED1	LED0402_GRN	Kingbright Corp	APHHS1005CGCK	LED0402
13	6	R3,R4,R19,R24,R30,R31	10K	Yageo	RC0402JR-0710KL	R0402
14	1	R4	510R	Vishay	CRCW0402510RFKED	R0402
15	8	R5,R6,R7,R8,R10,R11,R48,R49	0R	Panasonic	ERJ-2GE0R00X	R0402
16	1	R26	1K	Panasonic	ERJ-2RKF1001X	R0402
17	16	R32,R33,R34,R35,R36,R37,R38, R39,R40,R41,R42,R43,R44,R45, R46,R47	NM_0R	Panasonic	ERJ-2GE0R00X	R0402
18	2	SW1,SW2	PTS645SM43SMTR92 LFS	C&K	PTS645SM43SMTR92 LFS	PTS645SM43SMTR92 LFS
19	1	TP9	HEADER 1X1	xx	xx	PAD9
20	1	U2	ICM-30630	InvenSense	Garnet+Ivory	24LGA_3X3_REV1BE
21	1	U5	TLV70233DBVR	TI	TLV70233DBVR	SOT235
22	1	U6	TLV70218DBVT	TI	TLV70218DBVT	SOT235
23	2	U7,U8	MAX3378EEUD	Maxim	MAX3378EEUD+	TSSOP14
24	1	U9	SN74LVC1G11DBVR	TI	SN74LVC1G11DBVR	R-PDSO-G6
25	1	X2	AH-32.768KDZF-T	TXC CORPORATION	AH-32.768KDZF-T	2-SMD-3.2x1.5

REVISION HISTORY

REVISION DATE	REVISION	DESCRIPTION
11/21/2014	1.0	Initial Release
05/07/2015	1.1	Added SWDP0 operation and programming/debugging modes selections. Removed external crystal load capacitors

COMPLIANCE DECLARATION DISCLAIMER

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