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Migrating from MPU-9250 to ICM-20948

Application Note

Version 2.0

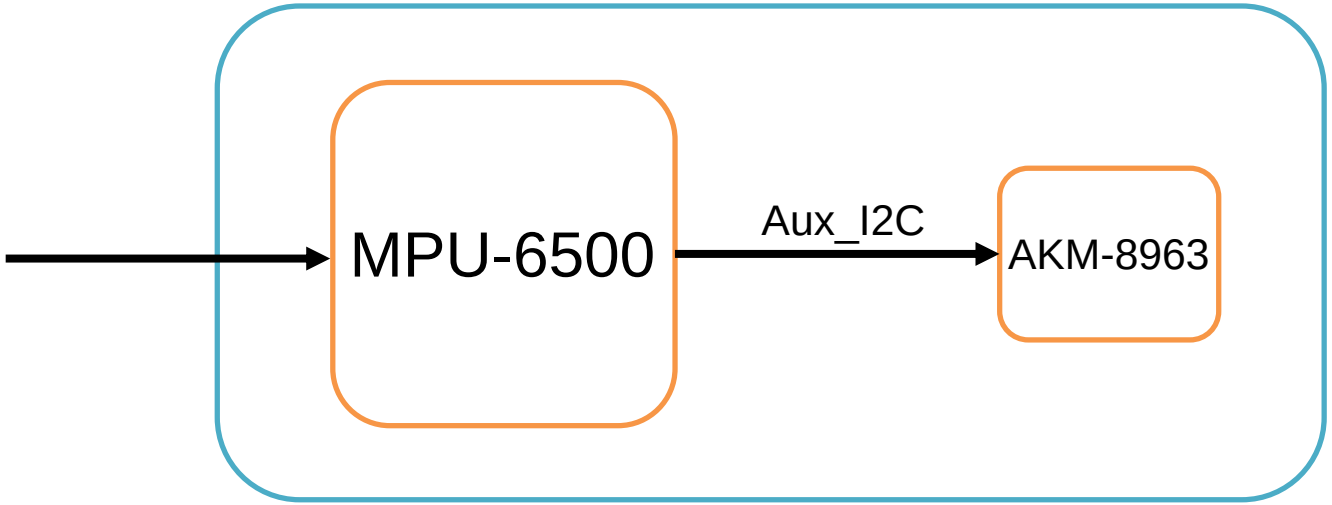
September 2018

TDK-Invensense
MEMS Sensor Business Group
Sensor System Business Company

End of Life on MPU-9250/MPU-9255, 9-Axis Inertial Motion Sensor

- TDK-INVN has announced MPU-9250/MPU-9255 EOL by 12/31/2018

- MPU-9250/55 is a 9-axis MCM with:
  - TDK-INVN 6-axis IMU MPU-6500 and
  - AKM Magnetometer AKM-8963
  - These are connected through the AUX-I2C of the MPU-6500



- MPU-9250 can be replaced with a newer 9-axis part from TDK, namely, ICM-20948

→This Application note covers the hardware and software considerations for migrating to ICM-20948

Functional comparison, MPU-9250/55 and ICM-20948

Feature \ Part		MPU-9250/55	ICM-20948	ICM-20948 Compatibility
Accel Range		±2g to ±16g	±2g to ±16g	Equivalent
Gyro Range		±250 to ±2000 dps	±250 to ±2000 dps	Equivalent
Magnetometer Range		4800µT	4900µT	Superset
DMP		Yes with 6-axis fusion	Yes with 9-axis fusion	Superset
Communication interfaces	I2C Slave	400Khz	400Khz	Equivalent
	I2C Master	Auxiliary, 400KHz	Auxiliary, 400KHz	Equivalent
	SPI Slave	1Mhz 20Mhz sensor data read	7Mhz	Compatible
I2C Address		7b'110100x	7b'110100x	Compatible

Hardware comparison, MPU-9250/55 and ICM-20948

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Feature \ Part		MPU-9250/55	ICM-20948	ICM-20948 Compatibility
Package		3x3x1 mm^3 QFN	3x3x1 mm^3 QFN	Compatible
Pin count, descriptions		24, same as ICM-20948	24, same as MPU-9250	Compatible
VDD		2.4 to 3.6V	1.71 to 3.6V	Superset
VDDIO		1.71 to VDD	1.71 to 1.95V	Subset
Power Consumption	DMP off	3.7mA	3.1mA	Compatible
	I2C Master	Auxiliary, 400KHz	Auxiliary, 400KHz	Equivalent
	SPI Slave	1Mhz 20Mhz for sensor data read	7Mhz	Compatible

Hardware Considerations

- **VDDIO considerations**
  - Range of VDDIO for ICM-20948 is lower compared to MPU-9250.
  - They are both compatible at the low end which is 1.71V.
  - However, at the high end, the MPU-9250 VDDIO can be as high as 3.6V, whereas ICM-20948 VDDIO is limited to 1.95V. This may entail redesign of the power supply to bring the VDDIO voltage in the range of ICM-20948.
  - The maximum I/O voltage of ICM-20948 is VDDIO+0.5V. Voltage above this may cause chip to misbehave or get damaged. In order to bring the I/O voltage levels within the range of ICM-20948, it may require one of 2 possible solutions:
    (a) redesign of the power supply *or*
    (b) addition of level translators to bring the voltage of connecting AP I/Os in the range of ICM-20948.

- **Power consumption considerations**
  - Being a newer design, the ICM-20948 consumes less power than MPU-9250 in all equivalent operating modes. The lower VDDIO also helps lower power consumption.
  - Hence, barring VDDIO incompatibility covered in section on “VDDIO considerations” above, migrating to ICM-20948 does not require any power supply design changes.

- **Hardware Drop-in compatibility**
  - A typical system design may use VDDIO of 1.8V which lies in the range of MPU-9250, ICM-20948 as well as the I2C/SPI Master AP/MCU
  - In such case, no power supply redesign is necessary.
  - For such a design that already limits VDDIO in the range of 1.71V to 1.95V, the ICM-20948 can drop-in replace MPU-9250 without any board/design change, from a hardware perspective. Software considerations are covered below.

  Note: Power up with SCL/SCLK and nCS pins held low is not a supported use case. In case this power up approach is used, software reset is required using the PWR_MGMT_1 register, prior to initialization.

Pin List Comparison

Pin Number	MPU-9250 Pin Name	ICM-20948 Pin Name	Pin Description	ICM-20948 compatibility
7	AUX_CL	AUX_CL	I²C Master serial clock, for connecting to external sensors	Same
8	VDDIO	VDDIO	Digital I/O supply voltage	Same Pin function Different voltage range*: MPU-9250: 1.71V to VDD ICM-20948: 1.71V to 1.95V
9	AD0 / SDO	AD0 / SDO	I²C Slave Address LSB (AD0); SPI serial data output (SDO)	Same
10	REGOUT	REGOUT	Regulator filter capacitor connection	Same
11	FSYNC	FSYNC	Frame synchronization digital input. Connect to GND if unused	Same
12	INT	INT1	Interrupt 1	Same
13	VDD	VDD	Power supply voltage	Same
18	GND	GND	Power supply ground	Same
19	RESV	RESV	Reserved. Connect to GND.	Same
20	RESV	RESV	Reserved. Connect to GND.	Same
21	AUX_DA	AUX_DA	I²C master serial data, for connecting to external sensors	Same
22	nCS	nCS	Chip select (SPI mode only)	Same
23	SCL / SCLK	SCL / SCLK	I²C serial clock (SCL); SPI serial clock (SCLK)	Same
24	SDA / SDI	SDA / SDI	I²C serial data (SDA); SPI serial data input (SDI)	Same
2 – 6, 14 - 17		NC	Do not connect	Same
1	RESV	NC	MPU-9250: Must Connect to VDD ICM-20948: OK to Connect to VDD	Compatible for replacing MPU-9250 with ICM-20948

*Refer “VDDIO Considerations” in previous slide

Application Comparison

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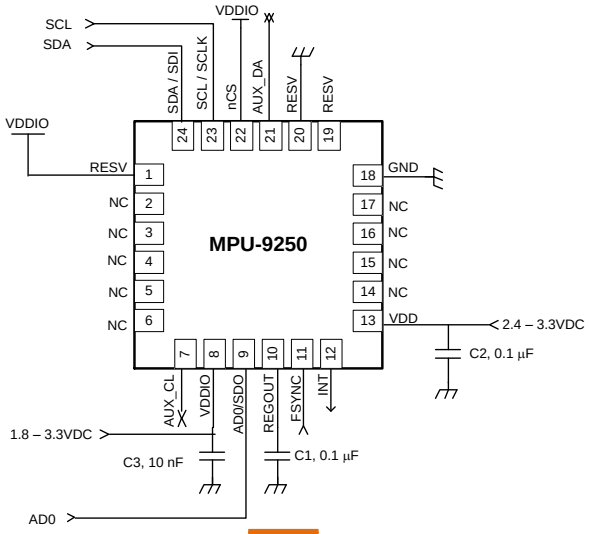
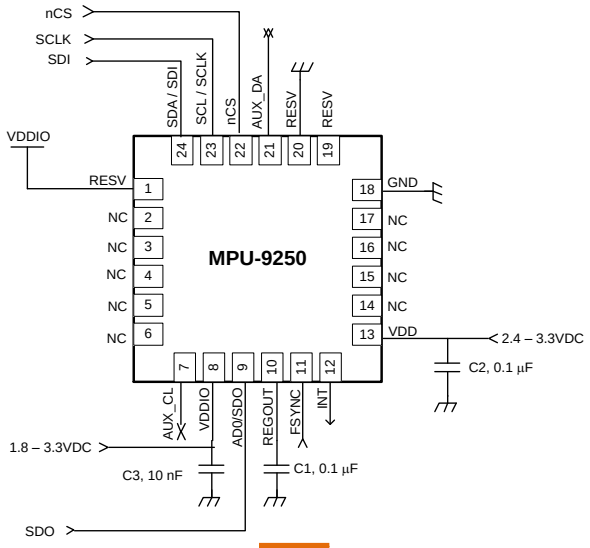
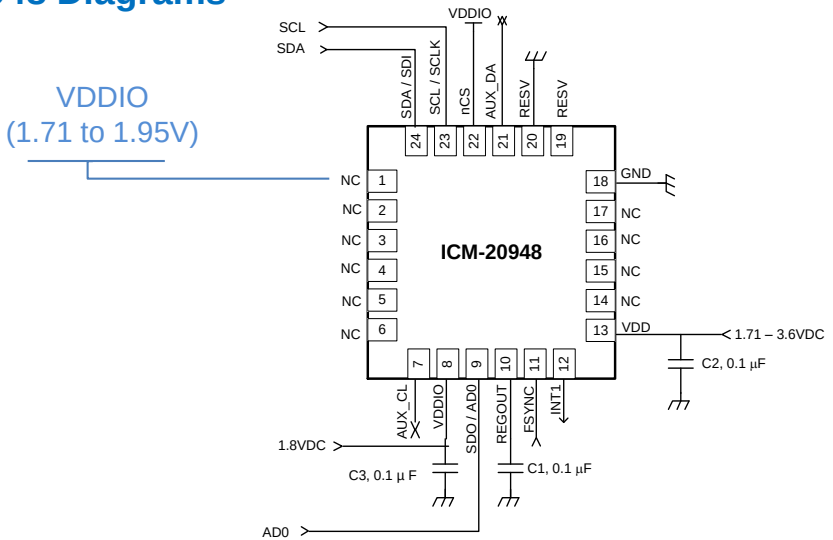
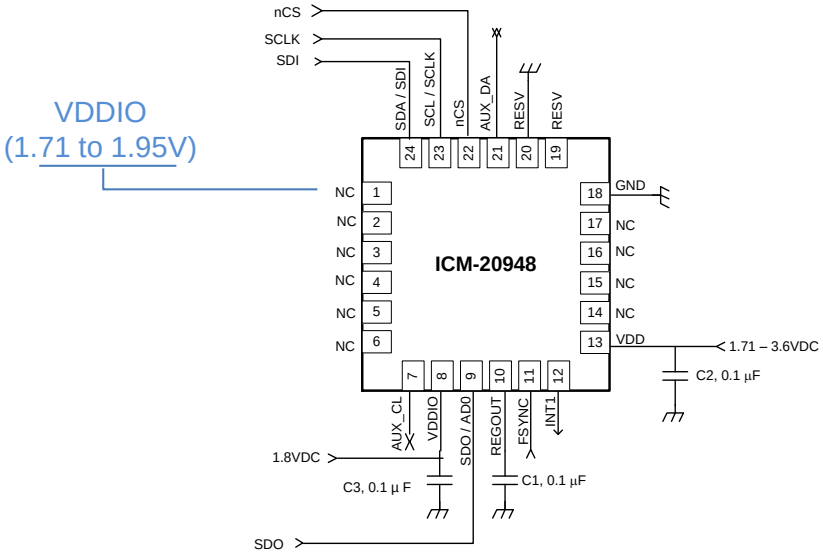
MPU-9250 Diagrams





ICM-20948 Diagrams





Software Comparison

Registers and Driver

- The register addresses, bit-field definitions between the MPU-9250 and ICM-20948 are different
  - while the functionality remains common.
    - Please refer to the full data sheet of ICM-20948 for the register map.
- Hence, the driver for MPU-9250 must be replaced by the driver for ICM-20948.

→ Invensense provides ICM-20948 driver free of charge for OEMs to use directly or use as a reference for their own drivers.
→ Using Invensense driver in one of these ways can speed up the migration significantly.

3.3.2 Driver code size

- Invensense driver code size has increased from MPU-9250 to ICM-20948.
- The AP/MCU will need to accommodate an extra ~64KB of storage. This includes the DMP code size increase in table below.
- Customer's own driver may be smaller if driver uses a subset of the ICM-20948 personality corresponding to functions available in MPU-9250.

Software Comparison

- **DMP Architecture and Functionality**
  - DMP of ICM-20948 is more powerful, providing 9-axis fusion data to AP
  - MPU-9250 can only perform 6-axis fusion in its DMP
    - passes the fusion data along with the magnetometer raw data to the AP for 9-axis fusion in the AP.
  - The DMP in ICM-20948 therefore has higher memory for code storage
    - Hence, the AP/MCU must accommodate higher memory required to hold the DMP image

Part / DMP Features/Functions	MPU-9250	ICM-20948	Compatibility
6-axis fusion	Yes	Yes	Equivalent
9-axis fusion	MPU-9250 provides 6-axis fusion data along with raw Magnetometer data to AP; AP then performs 9-axis fusion with this information	provides 6-axis and 9-axis fusion data along with raw Magnetometer data to AP; AP then performs 9-axis fusion with this information	ICM-20948 DMP functionality is a Superset of MPU-9250
DMP Code Size	3KB	16KB	AP/MCU must be able to store more code to accommodate expanded DMP code size. However, if Application does not use DMP functions, then this code size can be avoided.

Revision History

Revision #	Date	Type	Originator	Description
1.0	9/12/2018	Major	P Madhvapathy	Initial Release
2.0	9/13/2018	Minor	P Madhvapathy	Added Note to Slide 5

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