Application Note

BNO055
Quick start guide

Bosch Sensortec

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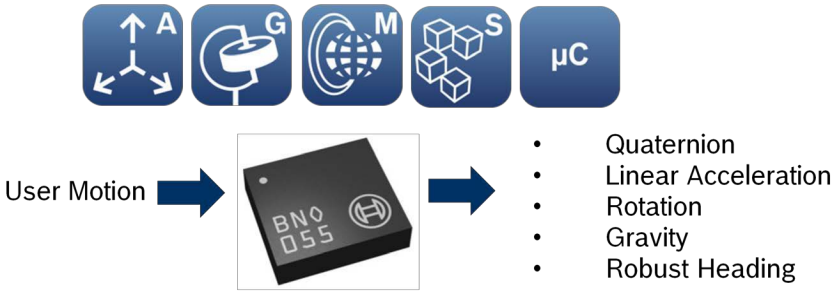

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Contents

1. Introduction 3
2. Hardware design 5
2.1 Schematics 5
3. Calibration 6
4. Sample codes 7
5 Legal disclaimer 8
5.1 Engineering samples 8
5.2 Product use 8
5.3 Application examples and hints 8

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1. Introduction

The BNO055 is a system in package (SiP) chip that includes a 3-axis 14-bit accelerometer, a 3-axis 16-bit gyroscope, a 3-axis magnetometer and a 32-bit Cortex M0+ microcontroller running the company's BSX3.0 FusionLib software.
Besides giving access to the individual sensor signals such as acceleration, rotation, and magnetic field strength, the sensor offers a total of five different sensor fusion modes. The table below provides a quick overview of all the different fusion and non-fusion modes of the sensor:

Operating Mode		Available sensor signals			Fusion Data	
		Accel	Mag	Gyro	Relative orientation	Absolute orientation
	CONFIGMODE	-	-	-	-	-
Non-fusionmodes	ACCONLY	X	-	-	-	-
	MAGONLY	-	X	-	-	-
	GYROONLY	-	-	X	-	-
	ACCMAG	X	X	-	-	-
	ACCGYRO	X	-	X	-	-
	MAGGYRO	-	X	X	-	-
	AMG	X	X	X	-	-
Fusion modes	IMU	X	-	X	X	-
	COMPASS	X	X	-	-	X
	M4G	X	X	X*	X	-
	NDOF_FMC_OFF	X	X	X	-	X
	NDOF	X	X	X	-	X

* software simulated gyro signal

Fusion Modes:

IMU or Inertial Measurement Unit is a fusion of the accelerometer and the gyroscope

Compass is a fusion of the accelerometer and magnetometer, also commonly known as a tilt-compensated compass

M4G (Magnet for gyroscope) is a fusion of the accelerometer and the magnetometer but the output data is similar to the IMU mode and hence the limitations of gyroscope is compensated in this mode.

NDOF_FMC_OFF is a fusion of all three sensors – accelerometer, gyroscope and the magnetometer thereby providing Nine Degrees of Freedom (NDOF). In this mode the 'FMC (Fast Magnetic Calibration)' feature is disabled and thereby the sensor needs a movement similar to 'figure 8 pattern' to calibrate the magnetometer.

NDOF is also a fusion of all the three sensors, but with the feature 'FMC' enabled. By enabling this feature, a quick movement (even an incomplete 'figure 8 pattern') will fully calibrate the magnetometer.

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Once the sensor is powered, it executes a power on self-test (POST) and stays in the configuration (CONFIG) mode. After POR or soft reset, users need to wait at least 650ms before talking to BNO055 through I2C interface. For the waiting time less than 650 ms, the I2C communication does not respond. The hardware reset using hardware RESET pin or writing to the RST_SYS bit in the SYS_TRIGGER register (0x3F) have the same effect as the power on rest (POR). Users can then change to one of the sensor operation modes by writing to the OPR_MODE register (0x3D). Once the sensor is configured, it is ready to send the sensor fusion results such as Quaternion, Euler angles, Linear acceleration and Gravity vector at fixed output data rate. Users can then access the sensor fusion results from the BNO055 through I2C, UART or HID-over I2C interface.

The user can switch between Windows or the Android orientation format. By default however, the sensor axes orientation of the sensor is of Android format as shown in Figure 1. The Android rotation vector definition can be found at http://developer.android.com/guide/topics/sensors/sensors_motion.html

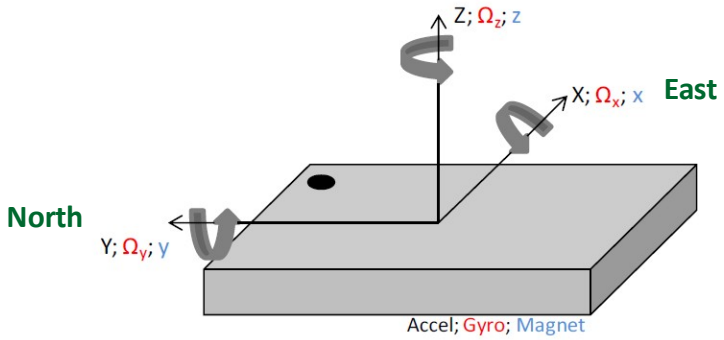

Figure 1 BNO055 coordinate definition

- Heading: rotation around the Z axis (0° <= heading < 360°). 0° = North, 90° = East, 180° = South, 270° = West. The heading value increases when you rotate around the Z axis clockwise from top view of Figure 1.Pitch: rotation around the X axis (-180° <= pitch <= 180°) with positive values increasing when the Z axis moves towards the Y axis.
- Roll: rotation around the Y axis (-90° <= roll <= 90°) with positive values increasing when the X axis moves toward the Z axis.

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2. Hardware design

2.1 Schematics

BNO055 schematic is as shown in figure 2 with I2C interface to an external microcontroller (MCU)[1].

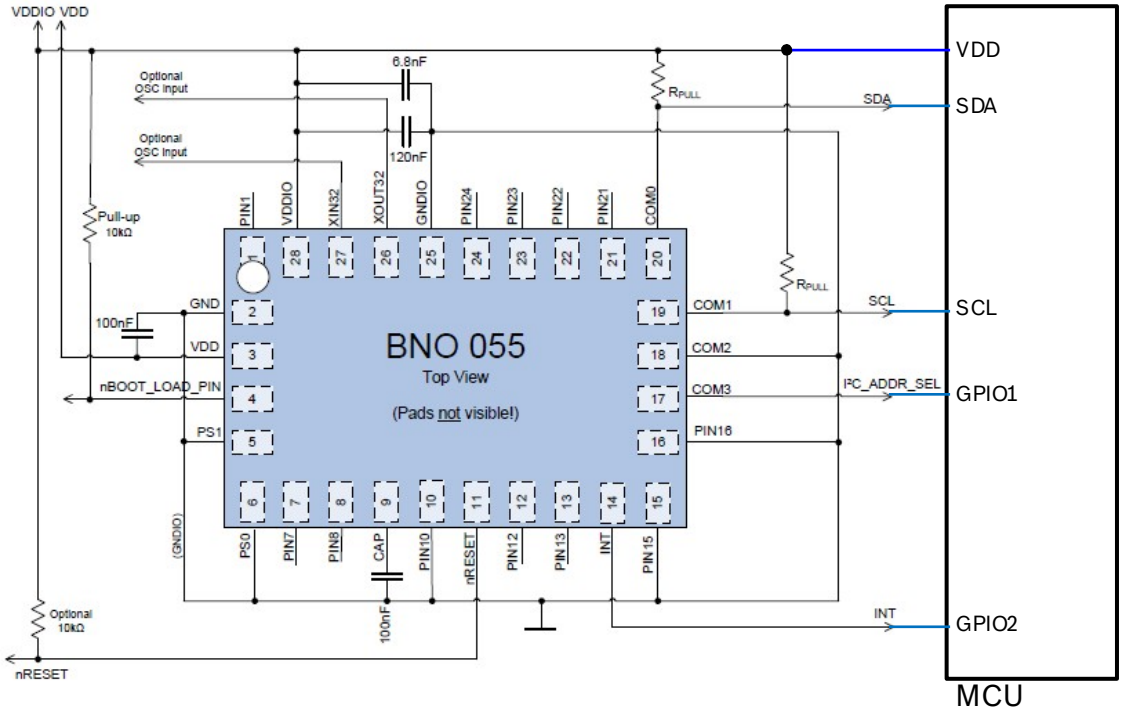

Figure 2 BNO055 schematics with I2C interface

Notes:

- The external 32.768 kHz crystal is optional. Pin-26 (XOUT32) and Pin-27 (XIN32) can be floating when the external crystal is not used.
- Pin-5 (PS1) and Pin-6 (PS0) should be tied to GND directly or through a zero Ohm resistor to GND to select I2C interface protocol. Don't use a pull-down resistor for these two pins.
- The MCU GPIO1 can be used to select the BNO055 7-bit I2C slave address, which will be 0x29 when GPIO1 is high and 0x28 when low.
- Pin-14 (INT) is push-pull and can be tied to MCU GPIO2 directly. This pin can be floating if BNO055 interrupt is not used.
- Pin-4 (nBOOT_LOAD_PIN) is pulled high through a 10K Ohms resistor. It is not necessary to tie it to the other MCU GPIO pin.

[1] Since majority of the application use I2C, the quick reference guide explains this communication protocol more in detail.

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3. Calibration

Calibration of the sensor plays a major role in the sensor fusion software. In the BNO055, the calibration of the accelerometer, gyroscope and the magnetometer runs in the background as part of the sensor fusion software. The status of each sensor calibration is as shown in Figure 4.

4.3.54 **CALIB_STAT 0x35**

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Access	r	r	r	r	r	r	r	r
Reset	0	0	0	0	0	0	0	0
Content	SYS Calib Status <0:1>		GYR Calib Status <0:1>		ACC Calib Status <0:1>		MAG Calib Status <0:1>	

DATA	bits	Description
SYS Calib Status <0:1>	<7:6>	Current system calibration status, depends on status of all sensors, read-only Read: 3 indicates fully calibrated; 0 indicates not calibrated
GYR Calib Status <0:1>	<5:4>	Current calibration status of Gyroscope, read-only Read: 3 indicates fully calibrated; 0 indicates not calibrated
ACC Calib Status <0:1>	<3:2>	Current calibration status of Accelerometer, read-only Read: 3 indicates fully calibrated; 0 indicates not calibrated
MAG Calib Status <0:1>	<1:0>	Current calibration status of Magnetometer, read-only Read: 3 indicates fully calibrated; 0 indicates not calibrated

Figure 4: BNO055 sensor calibration status register

The accelerometer and the gyroscope are relatively less susceptible to external disturbances, as a result of which the offset is negligible. Moreover the accelerometer is factory calibrated, and hence the calibration is not mandatory. For the gyroscope however leaving the BNO055 stationary for a few seconds at any time during the operation, will facilitate full calibration and thereby remove the zero rate offsets. Unlike the accelerometer and gyroscope, the magnetometer calibration is mandatory immediately after every 'power on reset' in order for sensor fusion to create accurate results.

Therefore, it is highly recommended to check the magnetometer calibration status periodically. If the value of the two bits 'MAG Calib Status' is 3, then it means that the magnetometer is fully calibrated and ready to go. If the value is 2, then the sensor fusion's performance is still OK. If the value is 1, then it is highly recommended to perform a Figure-8 motion to calibrate the magnetometer. And if the value is 0, this means that the magnetometer just got disturbed by the magnetic interference fields nearby or the environment's magnetic fields have just changed. And therefore the magnetometer calibration must be performed. For further details please refer section '3.10 Calibration' in the datasheet.

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4. Sample codes

It is highly recommended to use the BNO055 standard APIs to ease the integration. The APIs can be downloaded from https://github.com/BoschSensortec/BNO055_driver.
Below mentioned steps demonstrate how to get BNO055 up and running with few API calls.

Step	Description	Code snippet
1	Power on the BNO055	
2	Create a structure to hold device information	`struct bno055_t myBNO;`

3	Link the I2C driver functions to the API communication function pointer	`myBNO.bus_read = BNO055_I2C_bus_read;`
		`myBNO.bus_write = BNO055_I2C_bus_write;`
		`myBNO.delay_msec = delay;`

4	Set the correct I2C address in the BNO055 API	`myBNO.dev_addr = BNO055_I2C_ADDR1;` `//myBNO.dev_addr = BNO055_I2C_ADDR2;`
5	API initialization	`bno055_init(&myBNO);`
6	Change the operation mode to NDOF	`bno055_set_operation_mode (OPERATION_MODE_NDOF);`
7	Read Euler angles	`struct bno055_euler_float_t eulerData;` `bno055_convert_float_euler_hpr_deg(&eulerData);`

8	Read calibration status	`unsigned char accel_calib_status = 0;`
		`unsigned char gyro_calib_status = 0;`
		`unsigned char mag_calib_status = 0;`
		`unsigned char sys_calib_status = 0;`
		
		`bno055_get_accel_calib_stat(&accel_calib_status);`
		`bno055_get_mag_calib_stat(&mag_calib_status);`
		`bno055_get_gyro_calib_stat(&gyro_calib_status);`
		`bno055_get_sys_calib_stat(&sys_calib_status);`

Note: It is advisable to check the calibration status periodically and provide accuracy status to the user for re-calibration.

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Bosch Sensortec GmbH
Gerhard-Kindler-Strasse 8
72770 Reutlingen/ Germany

contact@bosch-sensortec.com
www.bosch-sensortec.com

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