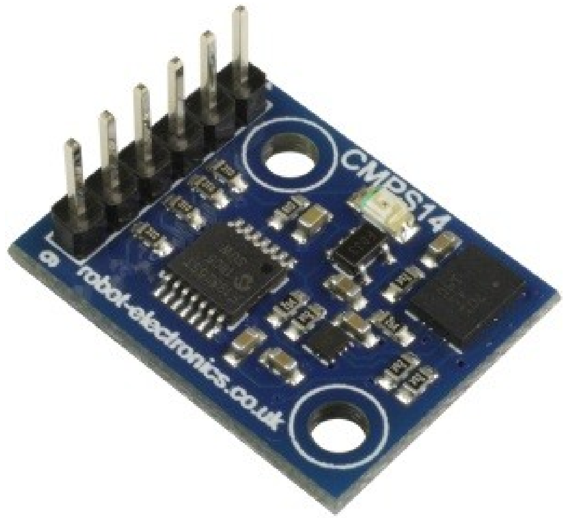
# CMPS14 – documentation




## Introduction

The CMPS14 is our 5th generation tilt compensated compass. Employing a 3-axis magnetometer, a 3-axis gyro and a 3-axis accelerometer. At the core of the module is the superb BNO080 running algorithms to remove the errors caused by tilting of the PCB. The module also allows the calibration to be stopped and instead rely on a static calibration profile.
Power supply requirements are flexible, you can feed between 3.3 - 5v and the module draws a nominal 18mA of current. A choice of serial or I2C interfaces can be used for communication.

**Overview of outputs**
**Heading, 16 bit** – 0-3599 for greater accuracy requirements
**Heading, 8 bit** – 0-255 scaled for simpler requirements
**Pitch** – +/- 0-90°
**Roll** – +/- 0-90° or +/- 0-180°
**Raw sensor outputs** – 3 x 16 bit integers for each of the Magnetometer, accelerometer and gyro

**Mode selection**
Serial or I2C mode is easily selected with the state of the mode pin. Note the CMPS14 looks at the mode selection pin at power-up only.


For **I2C** the mode pin can be left open or pulled to the supply voltage, for **serial mode** the mode pin should be connected to 0v ground.

# I2C Mode

| Register | Function |
|---|---|
| 0x00 | Command register (write) / Software version (read) |
| 0x01 | Compass Bearing 8 bit, i.e. 0-255 for a full circle |
| 0x02, 0x03 | Compass Bearing 16 bit, i.e. 0-3599, representing 0-359.9 degrees. register 2 being the high byte. This is calculated by the processor from quaternion outputs of the BNO080 |
| 0x04 | Pitch angle - signed byte giving angle in degrees from the horizontal plane (+/- 90°) |
| 0x05 | Roll angle - signed byte giving angle in degrees from the horizontal plane (+/- 90°) |
| 0x06, 0x07 | Magnetometer X axis (uTesla), 16 bit signed integer (register 0x06 high byte) Q point 4 |
| 0x08,0x09 | Magnetometer Y axis (uTesla), 16 bit signed integer (register 0x08 high byte) Q point 4 |
| 0x0A,0x0B | Magnetometer Z axis (uTesla), 16 bit signed integer (register 0x0A high byte) Q point 4 |
| 0x0C, 0x0D | Linear acceleration Axis X, 16 bit signed integer (register 0x0C high byte) Q point 8 |
| 0x0E, 0x0F | Linear acceleration Axis Y, 16 bit signed integer (register 0x0E high byte) Q point 8 |
| 0x10, 0x11 | Linear acceleration Axis Z, 16 bit signed integer (register 0x10 high byte) Q point 8 |
| 0x12, 0x13 | Gyroscope raw X axis output, 16 bit signed integer (register 0x12 high byte) |
| 0x14, 0x15 | Gyroscope raw Y axis output, 16 bit signed integer (register 0x14 high byte) |
| 0x16, 0x17 | Gyroscope raw Z axis output, 16 bit signed integer (register 0x16 high byte) |
| 0x1C, 0x1D | Roll angle 16 bit - signed byte giving angle in tenths of degrees from the horizontal plane (+/- 180°, 0x1C is the high byte) |
| 0x1E | Calibration state, bits 0 and 1 reflect the calibration status (0 un-calibrated, 3 fully calibrated) |
| Software V5+ commands below | |
| 0x1A, 0x1B | Pitch angle 16 bit - signed byte giving angle in tenths of degrees from the horizontal plane (+/- 90°, 0x1A is the high byte) |
| 0x1F, 0x20 | Accelerometer X axis output, 16 bit signed integer (register 0x1F high byte) Q point 8 |
| 0x21, 0x22 | Accelerometer Y axis output, 16 bit signed integer (register 0x21 high byte) Q point 8 |
| 0x23, 0x24 | Accelerometer Z axis output, 16 bit signed integer (register 0x23 high byte) Q point 8 |
| 0x25, 0x26 | Gyroscope calibrated X axis output, 16 bit signed integer (register 0x25 high byte) Q point 9 |
| 0x27, 0x28 | Gyroscope calibrated Y axis output, 16 bit signed integer (register 0x27 high byte) Q point 9 |
| 0x29, 0x2A | Gyroscope calibrated Z axis output, 16 bit signed integer (register 0x29 high byte) Q point 9 |

Register descriptions:

0x00 in the event of a read the CMPS14 will reply with the software version, for a write it acts as the command register.

0x01 is the bearing as a 0-255 value, this may be easier for some applications than 0-3599 which requires two bytes.

0x02 and 0x03 (high byte first) form a 16 bit unsigned integer in the range 0-3599 to represent the bearing (yaw angle). The result should be divided by 10 to scale 0-359.9°.

0x04 and 0x05 are the pitch and roll angles, giving an angle of 0 when the board is flat and up to +/- 90° at maximum tilt in either direction.

0x06-0x0B Geomagnetic field calibrated for hard and soft iron effects such that the vector is aligned with the declination and heading of Earth's magnetic field. The units are uTesla. The Q point is 4.
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

0x0c-0x11 The linear acceleration sensor reports the acceleration of the device minus gravity. The units are m/s^2. The Q point is 8.
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

0x12-0x17 The gyroscope sensor reports raw readings from the physical gyroscope MEMS sensor. The units are ADCs. Interpretation of the reported values is sensor dependent.
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

Registers 0x1C (high byte) and 0x1D (low byte) form a 16 bit roll angle for +/- 180 from the horizontal plane. Value is in tenths of degrees (range of +/- 1800).

0x1E provides feedback on the degree of the calibration that the automatic calibration routines have achieved. Please see the calibration section for more details.

Added in V5 commands below:

Registers 0x1A (high byte) and 0x1B (low byte) form a 16 bit pitch angle for +/- 90 from the horizontal plane. Value is in tenths of degrees (range of +/- 900).
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

0x1F – 0x24 The accelerometer sensor reports the total acceleration of the device. The units are m/s^2. The Q point is 8.
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

0x25 – 0x2A The gyroscope calibrated sensor reports drift-compensated rotational velocity. The units are rad/s. The Q point is 9.
Registers are ordered axis X MSB, axis X LSB, axis Y MSB, axis Y LSB, axis Z MSB, axis Z LSB

## Calibration of the CMPS14

The CMPS14 is shipped with a static factory calibration, but the module is able to automatically update its calibration with algorithms running in the background if desired. To achieve background calibration the user just needs to turn the functionality on and perform the required simple movements.

## Changing the calibration configuration

To change the configuration write the following to the command register 0x98, 0x95, 0x99 with a 20ms delay after each of the three bytes. You can then pass the setup byte to the command register, it takes the form:

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|
| Calibration config | 1 | x | x | Periodic auto save enable | x | Gyro Cal enable | Accel Cal enable | Mag Cal enable |

Bit 7 is always logic high
Bits 6,5 and 3 are undefined
Bit 4 enables a periodic automatic save of calibration data so manual saving is not required
Bit 2 enables the background gyro calibration – recommended to be off for very still applications
Bit 1 enables the accelerometer background calibration
Bit 0 enables the magnetometer background calibration

Gyro – calibrated by the CMPS14 being in a stationary state.
Accelerometer – calibrated by tilting the module to roughly 45 and 90 degrees on one axis.
Magnetometer – a few random movements easily calibrates the CMPS14

The level to which the CMPS14 has been calibrated can be checked by reading register 0x1E, the gyro, accelerometer and magnetometer are allocated 2 bits each in the register. A value of 0 in the two bits reflects an uncalibrated state, when fully calibrated this will become 3 (both bits set). There is also a complete system calibration level. Please note the Gyro feedback does not currently work, this is a bug in the sensor itself that is scheduled to be fixed.

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|
| Cal status | System calibration | | Gyro calibration | | Accelerometer calibration | | Magnetometer calibration | |

## Storing and erasing calibration profiles

After calibrating the compass the profile can be stored so it will be automatically reloaded when the module is ready for use again.
To **store a profile** write the following to the command register 0xF0, 0xF5, 0xF6 with a 20ms delay after each of the three bytes.
If you wish to **erase the stored profile** write the following to the command register 0xE0, 0xE5, 0xE2 with a 20ms delay after each of first two bytes. The final byte will reset the BNO080 so a delay of 300ms is recommended.

**Changing the I2C Bus Address**
To change the I2C address of the CMPS14 you must have only one module on the bus. Write the 3 sequence commands in the correct order followed by the address with 20ms between writes. Example; to change the address of a compass currently at 0xC0 (the default shipped address) to 0xC2, write the following to the command register 0 at address 0xC0: (0xA0, 0xAA, 0xA5, 0xC2 ) with a 20ms delay after each of the first three bytes. These commands must be sent in the correct sequence to change the I2C address, additionally, No other command may be issued in the middle of the sequence. The sequence must be sent to the command register at location 0, which means 4 separate write transactions on the I2C bus. When the CMPS14 is re-powered will flash its address out on the LED.

| Address | | flashes |
|---|---|---|
| Decimal | Hex | |
| 192 | C0 | 1 |
| 194 | C2 | 2 |
| 196 | C4 | 3 |
| 198 | C6 | 4 |
| 200 | C8 | 5 |
| 202 | CA | 6 |
| 204 | CC | 7 |
| 206 | CE | 8 |

Take care not to set more than one device to the same address, there will be a bus collision and very unpredictable results.

# Serial mode

**Communication settings**
The Serial mode operates over a link with a default baud rate of 9600 bps (no parity, 1 stop bit) and 3.3v-5v signal levels. This is not RS232. Do not connect RS232 to the module, the high RS232 voltages will irreversibly damage the module.

**Commands for Serial**

| Command | Name | Bytes returned | Returned data description |
|---|---|---|---|
| 0x11 | GET VERSION | 1 | Software version |
| 0x12 | GET BEARING 8 BIT | 1 | Bearing as a single byte 0-255 |
| 0x13 | GET BEARING 16 BIT | 2 | Bearing (16 bit), high byte first 0-3599 |
| 0x14 | GET PITCH | 1 | Pitch angle +/- 0-90° |
| 0x15 | GET ROLL | 1 | Roll angle +/- 0-90° |
| 0x19 | GET MAGNETOMETER Q point 4 | 6 | Magnetic data uTesla, 16 bit signed: X high, X low, Y high, Y low, Z high, Z low |
| 0x20 | GET LINEAR ACCELEROMETER Q point 8 | 6 | Linear acceleration m/s^2 (no gravity acceleration), 16 bit signed: X high, X low, Y high, Y low, Z high, Z low |
| 0x21 | GET GYRO RAW | 6 | Raw gyro data, 16 bit signed: X high, X low, Y high, Y low, Z high, Z low |
| 0x23 | GET ALL | 4 | Angle high, angle low (0-3599), pitch (+/- 0-90), roll (+/- 0-90) |
| 0x24 | GET CALIBRATION STATE | 1 | Bits 0 and 1 reflect the calibration status (0 un-calibrated, 3 fully calibrated) |
| 0x26 | GET ROLL 180 | 2 | Roll angle (16 bit) MSB first +/- 0-180° |
| 0x27 | GET PITCH 180 – added in software V5 | 2 | Pitch angle (16 bit) MSB first +/- 0-90° |
| 0x28 | GET ACCELEROMETER Q point 8 – added in software V5 | 6 | Acceleration m/s^2, 16 bit signed: X high, X low, Y high, Y low, Z high, Z low |
| 0x29 | GET CALIBRATED GYRO Q point 9 – added in software V5 | 6 | Gyro rad/s, 16 bit signed: X high, X low, Y high, Y low, Z high, Z low |
| 0x98 | CHANGE CALIBRATION CONFIG BYTE 1 | 1 | Returns ok (0x55) |
| 0x95 | CHANGE CALIBRATION CONFIG BYTE 2 | 1 | Returns ok (0x55) |
| 0x99 | CHANGE CALIBRATION CONFIG BYTE 3 | 1 | Returns ok (0x55) |
| 0xF0 | STORE CALIBRATION BYTE 1 | 1 | Returns ok (0x55) |
| 0xF5 | STORE CALIBRATION BYTE 2 | 1 | Returns ok (0x55) |
| 0xF6 | STORE CALIBRATION BYTE 3 | 1 | Returns ok (0x55) |
| 0xE0 | DELETE CALIBRATION BYTE 1 | 1 | Returns ok (0x55) |
| 0xE5 | DELETE CALIBRATION BYTE 2 | 1 | Returns ok (0x55) |
| 0xE2 | DELETE CALIBRATION BYTE 3 | 1 | Returns ok (0x55) |
| 0xA0 | BAUD 19200 | 1 | Returns ok (0x55) |
| 0xA1 | BAUD 38400 | 1 | Returns ok (0x55) |

## Calibration of the CMPS14

The CMPS14 is shipped with a static factory calibration, but the module is able to automatically update its calibration with algorithms running in the background if desired. To achieve background calibration the user just needs to turn the functionality on and perform the required simple movements.

## Changing the calibration configuration

To change the configuration write the following sequence of bytes 0x98, 0x95, 0x99 , remembering to pick up the response byte OK (0x55) after each byte. You can then pass the setup byte, it takes the form:

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|
| Calibration config | 1 | x | x | Periodic auto save enable | x | Gyro Cal enable | Accel Cal enable | Mag Cal enable |

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The level to which the CMPS14 has been calibrated can be checked by using command 0x24, the gyro, accelerometer and magnetometer are allocated 2 bits each in the register. A value of 0 in the two bits reflects an uncalibrated state, when fully calibrated this will become 3 (both bits set). There is also a complete system calibration level.. Please note the Gyro feedback does not currently work, this is a bug in the sensor itself that is scheduled to be fixed.

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|
| Cal status | System calibration | | Gyro calibration | | Accelerometer calibration | | Magnetometer calibration | |

## Storing and erasing calibration profiles

After calibrating the compass the profile can be stored so it will be automatically reloaded when the module is ready for use again. To do this we need to write a sequence of 3 bytes.
To **store a profile** send the sequence 0xF0, 0xF5, 0xF6 to the CMPS14, remembering to pick up the response byte OK (0x55) after each byte.
If you wish to **erase the stored profile** send the sequence 0xE0, 0xE5, 0xE2 again each byte will return an OK (0x55). The final byte will reset the BNO080 so a delay of 300ms is recommended.

## Changing the baud rate

The default serial baud rate of 9600 can be changed. There are two other baud rates that can be used, for 19200 just send 0xA0 or alternatively for 38400 send 0xA1. Please note that the CMPS14 will always default to its 9600 bps rate after power cycling and after setting a new baud rate the ok response (0x55) will be sent at the newly selected speed.

**Board dimensions**