

Question 2

We were using BNO055 IMU, that usually costs \$9 per piece. Now, with the global component shortage, we can find it only for \$50 per piece from retailers. Please propose a solution.

Approach to the solution

There are two types of solutions:

1. Find an alternative IC with large stock and the same specification and much less price than \$50.
2. Propose the electronic circuit with 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer and a central controller for similar spec and much lower price than \$50.

Firstly, I went to the BOSCH website to find out the current stock and the latest leading time of BNO055 IMU. The stock is currently 0 in all distributors and the re-stock time is too long for prototype and manufacture.

Secondly, I went to retailers including Mouser, Digikey, Farnell, RS Components and Arrow Electronics to find the similar cheap alternative. [Datasheets, Electronic Parts, Components, Search - Octopart](#) and [FindChips: Electronic Components, Distributor Inventories, Datasheets](#) are also used to help check the alternative availability with all distributors with little effort.

[SEN0373 DFRobot | Sensors, Transducers | DigiKey](#) is found with similar spec and price of £10.12 but with 132 stock. The IC BMX160 currently has much lead time. So this is not a good alternative.

It is hardly to find a good cheap single IC alternative to BNO055 IMU on distributors. Therefore, the following solution is to propose an alternative electronic circuit combined with the 3 types of IMUs and a central MCU for a lower price than \$50 (£36.18). I will attempt to reduce the price of the total system as low as \$9 (£6.51) with similar specification. It should have SPI communication protocols and matching supply voltage range to fit the origin design.

Solution

Part selection

Accelerometer and Gyroscope 1

[LSM6DSLTR Stmicroelectronics, MEMS Module, iNEMO LSM6D Series, IMU | Farnell](#) has +/-2g, 4g, 8g and 16g 3-axis accelerometer precision and 3-axis gyroscope functionality with down to 125dps angular rate. Furthermore, it has much more sensitivity than BNO055, which is 1LSB/mg. The operation voltage rate is under 3.6V, which means that the origin voltage supply of BNO055 is compatible of this IMU. It has SPI and I2C communication protocol so that it can pass the data to the central MCU for communication. The price of it is £4.25 per unit if more than 50 units are ordered for mass manufacturing. It has as much stock as 34890 to be delivered immediately.

Accelerometer and Gyroscope 2

[ICM-20608-G TDK InvenSense | Sensors, Transducers | DigiKey](#) has much lower price than LSM6DSLTR for mass order with down to £1.9555 per unit for 5000 unit ordering. It also has +/-2g, 4g, 8g and 16g 3-axis accelerometer precision and 3-axis gyroscope functionality with minimum 16.4 LSB per degree per second angular rate. The sensitivity is much higher than LSM6DSLTR. Basically, it has much lower price and better specification but the stock is only 5291 currently.

Accelerometer and Gyroscope 3

[IIM-42652 TDK InvenSense | Mouser United Kingdom](#) has the price of £3.68 per unit for the ordering of over 100 units but it only has 29 units currently. It is expected to have 5000 more stock by the end of January 2022. It has similar spec, matching supply voltage and SPI interface.

Magnetometer 1

Now the IMU measurement needs the additional 3-axis magnetometer sensor.

[MLX90395KDC-BBA-101-RE Melexis Technologies NV | Sensors, Transducers | DigiKey](#) is a tri-axis magnetometer with 16-bit register. It has the typical supply voltage at 3.3V, which matches the origin supply voltage. It also has the SPI interface to communicate with the central MCU. It has £0.82325 for over 1000 part ordering and there are 4642 in stock.

Magnetometer 2

[MLX90363LDC-ABB-000-SP Melexis | Mouser United Kingdom](#) is a 3-axis magnetometer with 14-bit output. SPI interface can be used to transmit the data to the central controller MCU. It has £2.72 per unit for over 100 parts ordering. However, it only has 161 in stock now and the lead time of the factory is 6 weeks. It is compatible with both 3.3V and 5V supply voltage.

MCU Choice

[MSP430FR2433IYQWR Texas Instruments | Integrated Circuits \(ICs\) | DigiKey](#) is a good cheap MCU with I2C, SPI and USART connectivity. It is 16-bit MCU so that the

data input from the IMUs can be directly stored into the buffer with less time than 8-bit ones. It can use FreeRTOS to prioritise the task to capture the data, process the data and output the processed result to the overall system. It costs £0.65872 for over 1000 parts ordering and has 6235 in stock. It needs 16MHz Oscillator to work more properly. [O 16,0-JO22-B-1V3-1-T1-LF Jauch Quartz | Crystals, Oscillators, Resonators | DigiKey](#) costs £0.49434 for over 500 parts ordering.

Final Proposed Solution

With the consideration of both ultimate spec and cost, I will choose [ICM-20608-G TDK InvenSense | Sensors, Transducers | DigiKey](#), [MLX90395KDC-BBA-101-RE Melexis Technologies NV | Sensors, Transducers | DigiKey](#), [MSP430FR2433IYQWR Texas Instruments | Integrated Circuits \(ICs\) | DigiKey](#) and [O 16,0-JO22-B-1V3-1-T1-LF Jauch Quartz | Crystals, Oscillators, Resonators | DigiKey](#) as the choices of system components. It will cost £3.93181 per unit. If some other passive components added, the cost will add maximum £1. As the system is manufactured as the 4-layer PCB module, the quote on JLCPCB will be £1.156 per unit. If the manufacturing is massive, the cost of stencil per unit will be negligible. So the worstcase cost will be £6.08781 per unit, which is still less than £6.51.

The system diagram is shown as below:



