MIRMADAN MOHANLAL GOVERNMENT POLYTECHNIC

Gobindapur, Plassey, Kaliganj, West Bengal, Nadia, 741156

Project Report Submitted for Practical Fulfilment of
Diploma in Electrical & Electronics Engineering

PROJECT TITLE–

Making Electric Bicycle Smart

Department of Electrical & Electronics Engineering

Submitted by–

Course Name– Electrical & Electronics Engineering
Name– Amit Mandal
Registration Number– D181915864
Roll– DMMPEEES6 **Number–** 10015883
Subject– Industrial Project

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Acknowledgement

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❖ INTRODUCTION

An increase in traffic, work-home distance and stress has led to the decline of the cycling culture. Cycling is a green and healthy choice. This project aims to make the cycle a more accessible vehicle. While different research tracks are being pursued to enable this, my project focuses on the electronic and computing aspects of it. The project thus aims to reintroduce the bicycle with more user friendly and low cost features. An attempt will be made to model a similar design for the simple bicycles.
An electric bicycle, also known as an e-bike or booster bike, is a bicycle with an integrated electric motor which can be used for propulsion. The proposed embedded system will be an add-on to an e-bike to include features like calorie measurement, biometric lock security and GPS tracking. Given the need to adopt a healthier and greener lifestyle, a 'smart' e-bike can enhance the user experience of bicycling. Enhanced security features can make purchasing the e-bike a low-risk option. While different research tracks are being pursued to enable this, my project focuses on the electronic and computing aspects of it.

Based on the readings from the accelerometer, gyroscope and user profile, the calorie measurements will be calculated and displayed to the user's mobile phone mounted on the handle. User can lock/unlock his bicycle using a centralised interface. A micro GPS chip added to the bicycle will help in detecting the location in case of an accident or theft. The chip can also help transmit data about the route of the bicycle and corresponding calorie statistics to a server. Centralised locking and GPS can provide a secure and reliable platform for cycle rental business. Bicycles can be reserved to be picked up from a particular location by an app and an Aadhar card number. The billing and user statistics will be synced with this number only. Calorie measurement data bundled with the GPS coordinates from multiple places can help build a 'calorie road-network' in the city based on average calories burned per route. This information can be used to estimate the calories a user might burn on a certain selected route. This data can also be used to suggest routes for people with health problems. GPS coordinates along with time data can be used to estimate time to travel from one location to another.
The features will be implemented using the existing power supply of the bicycle. To protect it from the harsh environmental factors, the final product will be padded, waterproof and temperature insensitive for a given temperature range.

❖ THE AIM OF MAKING THE PROJECT

Cycling is a green and healthy choice. This project aims to make the cycle a more accessible vehicle. The project thus aims to reintroduce the bicycle with more user friendly and low cost features. An attempt will be made to model a similar design for the simple bicycles.

❖ FEATURES OF THIS SYSTEM

- **Calorie measurement:** Based on the readings from the accelerometer, gyroscope and user profile, the calorie measurements will be calculated and displayed to the user's mobile phone mounted on the handle. The user can set the target calories that he/she wants to burn in the manual mode. After the target is accomplished, the user can now shift to the electric mode.

- **Biometric (Fingerprint lock detection system):** User can lock/unlock his bicycle using his fingerprints. The lock will operate on a separate mini rechargeable battery, such that even if the main battery is discharged, the bike can be locked/unlocked. Multiple bikes with such a feature can be used for bicycle rental based on Aadhaar Card credentials from select rental stations.

- **GPS tracking:** A micro GPS chip added to the bicycle will help in detecting the location in case of an accident or theft. The chip can also help transmit data about the route of the bicycle and corresponding calorie statistics to a server.

- **Business and Data Analytics:** Biometric locking and GPS can provide a secure and reliable platform for cycle rental business. Bicycles can be reserved to be picked up from a particular location by an app and an Aadhaar Card number. The billing and user statistics will be synced with this number only. Calorie measurement data bundled with the GPS coordinates from multiple places can help build a 'calorie road-network' in the city based on average calories burned per route. This information can be used to estimate the calories a user might burn on a certain selected route. This data can also be used to suggest routes for people with health problems. GPS coordinates along with time data can be used to estimate time to travel from one location to another.

❖SYSTEM SPECIFICATIONS

1. FUNCTIONAL REQUIREMENTS—

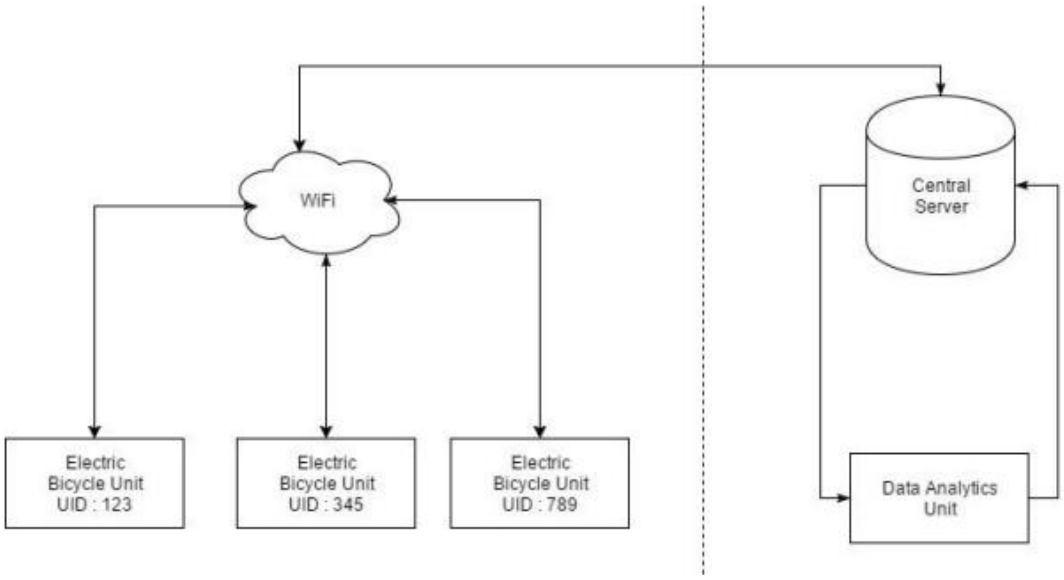
I. The device should be able to generate the calorie count
II. The device should lock and unlock with the fingerprint scan
III. The device should be able to talk to a remote server and send data
IV. The device should be able to track its own location
V. The device should be able to calculate distance between itself and user
VI. The device should be able to work over conventional power sources
VII. The device should be judicious in power usage
VIII. The device should be able to calculate distance travelled and incline of road

2. NON-FUNCTIONAL REQUIREMENTS—

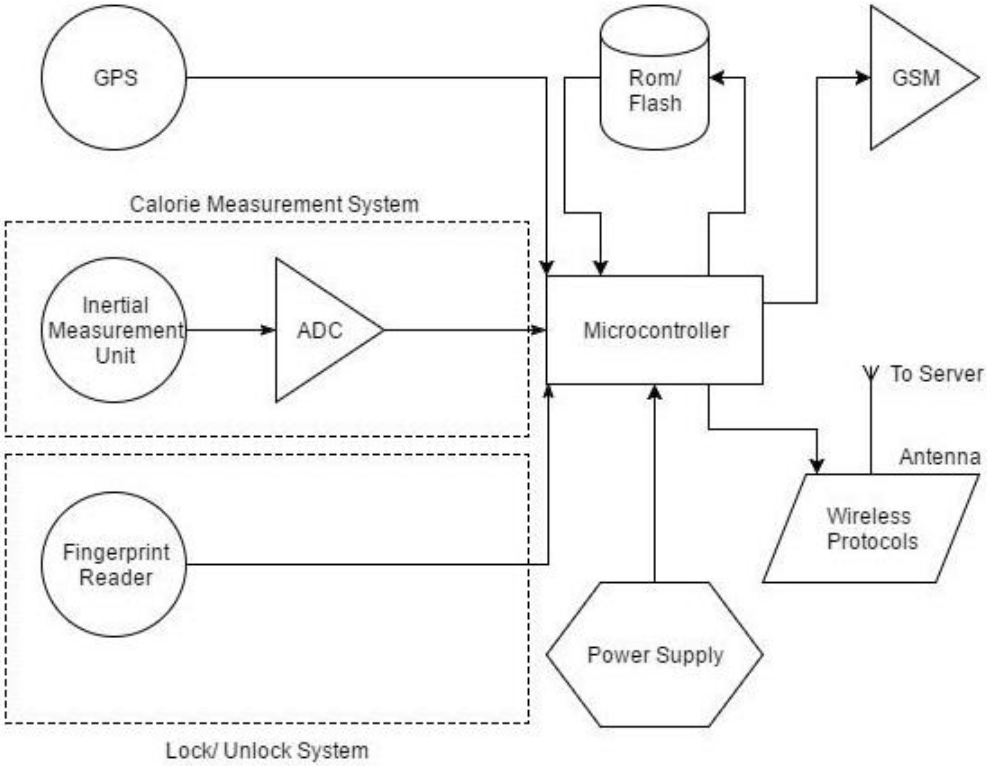
I. Solar Battery charging system: The device should be rechargeable by solar battery.
II. Performance and Efficiency: The battery should last long.
III. The user should be able to switch to electric mode after target calorie count is achieved.
IV. The system should be able to build a calorie map based on travel history.
V. Security: Should have high security features to prevent being hacked by someone.
VI. Simplicity and Ubiquity: Should be able to be integrated in any bicycle model.
VII. Usability: Should be easy to use and modify.
VIII. Cost: Should be low cost (within Rs- 8000/-).
IX. Durability: Should withstand harsh environmental conditions (temperature, humidity, rainfall), and terrain changes. System should not need replacement for minimum 2years.

❖ SYSTEM DESIGN

1. SYSTEM ARCHITECTURE—



2. HARDWARE DESIGN—



3. SOFTWARE DESIGN—

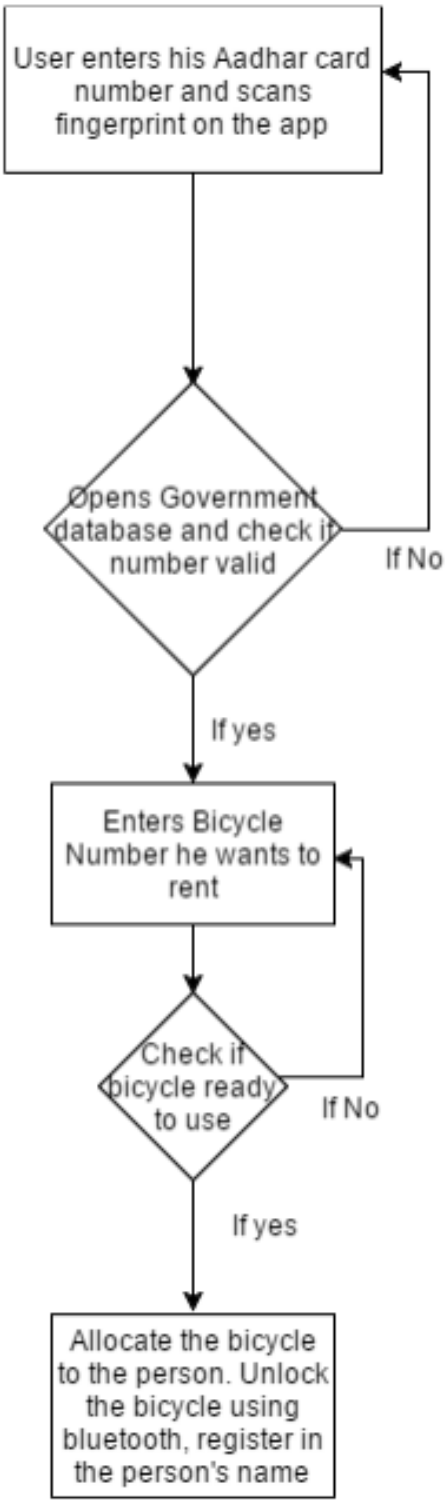


Fig. Basic Cycle Allocation Module

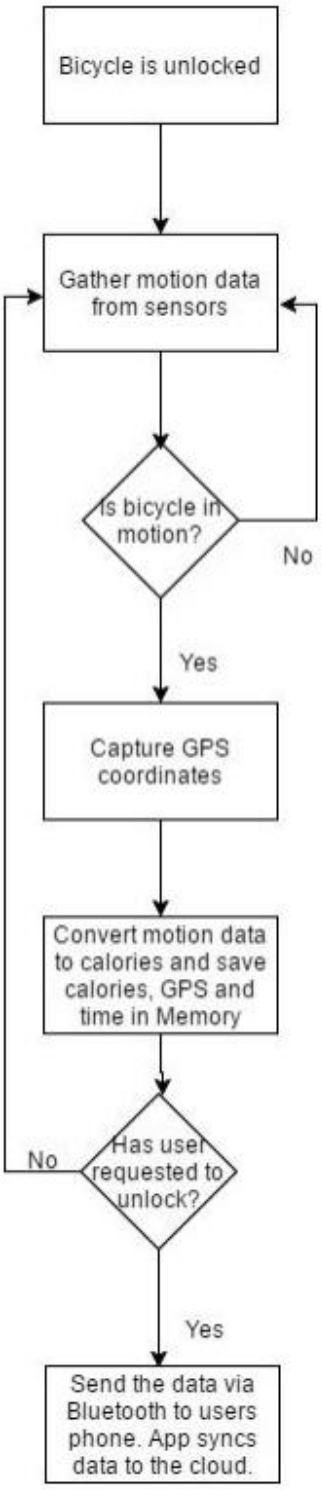


Fig. Calorie measurement and Tracking Module

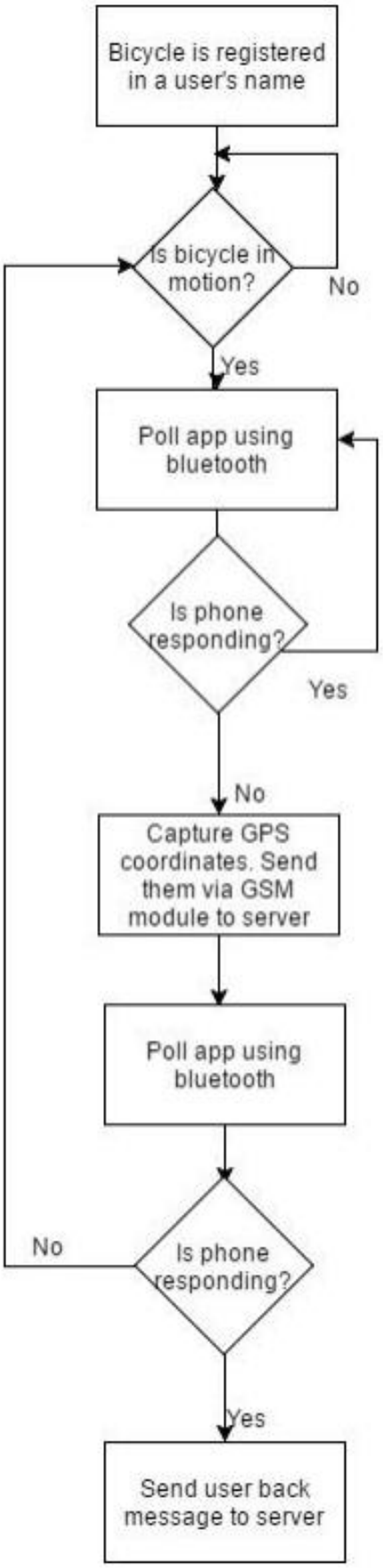


Fig. Antitheft Module

❖ SYSTEM IMPLEMENTATION

1. CALORIE MEASUREMENT:

- **Fitness Band:** Data from a wearable fitness band can be streamed to the device over PAN such as Bluetooth via a smartphone on the person of the user.

- **Leg Band:** An ad hoc leg band designed to transmit biological data to the device can be streamed to the device over any desired PAN (Personal Area Network) such as Wi-Fi, Bluetooth, Sub-GHz RF or ZigBee.

- **Sensor Fusion:** Intelligent software coded into the device acquires data from the accelerometer, gyroscope and GPS to estimate the speed, incline and distance travelled by the user in unit time. Alternatively, the same measurements can be made using hall effect sensors on the wheel rims to act as a rotary encoder as well as one on the gearbox to check for gear shifts. Distance and velocity, accompanied by the user's biological data such as height and weight will allow the device to compute calories burned.

2. LOCK-UNLOCK SYSTEM:

- **Smart Card:** An active RFID system with the receiver mounted on the frame of the bicycle will recognize the user when he is in close proximity of the bike and unlock the cycle. Conversely, it will lock the bicycle when the user is out of the proximity zone. This approach will require a dedicated RF transmitter card with its own power supply and a decoder mounted on the bike along with increased power usage for the active card system.

- **NFC:** A more power saving option with similar functionality to the smart card method is using NFC. The device will be fitted with an NFC receiver which will recognize the presence of the user via the NFC feature on the user's smartphone or a passive smart tag. Functionality similar to the smart card approach can be replicated using this method.

- **Bluetooth Low Energy:** BLE is a power saving alternative to classic Bluetooth. Using the advertisements feature offered by BLE enabled devices, the transmitter on the user's smartphone sends out intermittent pulses of information carrying its UID as the BLE client. Once the user is within range of the bicycle, fitted with a BLE server, the bicycle is unlocked.

- **Fingerprint Reader:** Using either a dedicated biometric scanner for fingerprints or one embedded in modern smartphones, the device will receive fingerprint validation data over a wired USB connection or Bluetooth respectively. The fingerprint will provide identification for the user which will unlock the bicycle.

3. LOCATION TRACKING:

- Location tracking can be achieved using the difference between coordinates of the device's on board GPS and the GPS module embedded in the user's smartphone.
- One unassailable drawback of this setup is the variable latency of the response time of commercial GPS satellites.
- Location tracking will be useful in two major areas of the application—
  i. **Crowdsourced calorific value mapping of paths**
     - The device will log the calories burned by the user for a specific stretch of the road. This data will be sent to a central server to be recorded. If another user plans to cycle via that route, estimates for his consumed calories will be calculated using the logged values as empirical data.

  ii. **Anti-Theft Measures**
     - Initially, the device will check if the bicycle has been unlocked. If it has, the device will determine the distance between the user and the bicycle. If the distance is above a certain threshold, the device will understand that the bicycle has been stolen.

4. COMMUNICATION WITH SERVER:

- The device is connected to a central server. This server will house the data generated by the device about distance travelled, location, calories burned, etc. to apply analytical algorithms to receive insight about bicycle usage.
- The device will have a robust wireless communication stack to enable this exchange.
- The 2.4Ghz spectrum of Wi-Fi is the most ubiquitous wireless network for commercial applications, and hence is a suitable choice for the physical layer of the stack.
- HTTPS protocol can be used for secure client-server communication to ensure encryption and privacy of sensitive data.
- For data where latency is more important than privacy, low payload, fire and forget protocols such as MQTT or CoAP can be used to stream lightweight payloads.

5. ON-BOARD COMMUNICATION:

- Even at a local level, the application is that of a distributed system. It will require robust wired and wireless level networks as well.
- For sensor to chip communication, using a Two-wire I2C connection is suitable due to its minimal hardware requirements, ease of implementation and maintenance and reasonable speed. Alternatively, an SPI interface will compromise hardware requirements for a faster transmission speed.
- For device to user communication, using the user's existing smartphone as a user interface platform makes more sense than deploying a used case oriented ad hoc design. Hence, a wireless link between the device and the smartphone is needed.
- Using Bluetooth or BLE for this purpose is most suitable as it is a low energy protocol, which allows for streaming and advertising lightweight data locally.

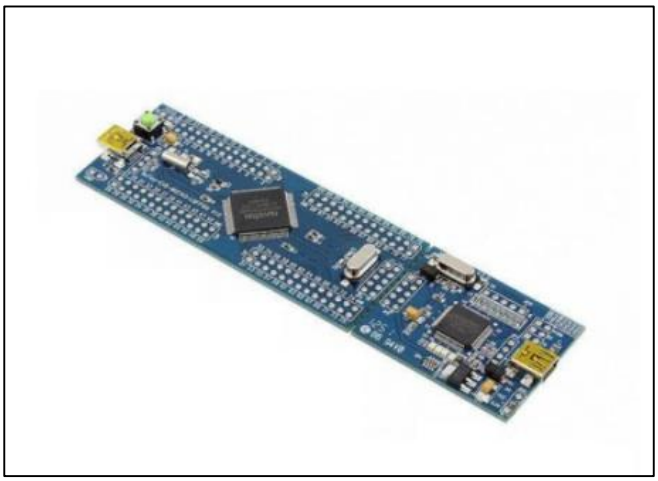
6. POWER SUPPLY:

- In the spirit of a greener implementation, the power derived to run the device will be sourced from a solar charger and/or a dynamo fitted to the rear wheel of the bicycle.
- However, both these options provide a fluctuating power supply with intermittent null zones. Hence, in order to overcome this obstacle, the device will be supplied with power from a Lithium polymer battery which will be charged by the solar charger or dynamo.

❖ COMPONENTS REQUIRED–

1. ARM Cortex-M0 microcontroller:

I have selected an ARM Cortex-M0 microcontroller. The Cortex-M0 core is optimized for small silicon die size and use in the lowest price chips. The main reason I chose an ARM Cortex-M is to have a higher speed which guarantees me a more effective response even in simple applications, the largest memory capacity is also an important factor, allowing the use of more complex algorithms, and clear the scalability of processors, since my focus is more academic can start the project in a smaller version and adopt a more robust microcontroller if the project course is identified to need more resources without worrying about having to rewrite the code to a new architecture. Already 32-bit, end up becoming a gift for the project.
There is also choice of different vendors. Although the code may not be directly portable from one vendor's processor to another, still it gives a peace of mind that choice is available without major disruptions to the software.



- Cost: Rs 450 per piece

2. Accelerometer/ IMU Units—

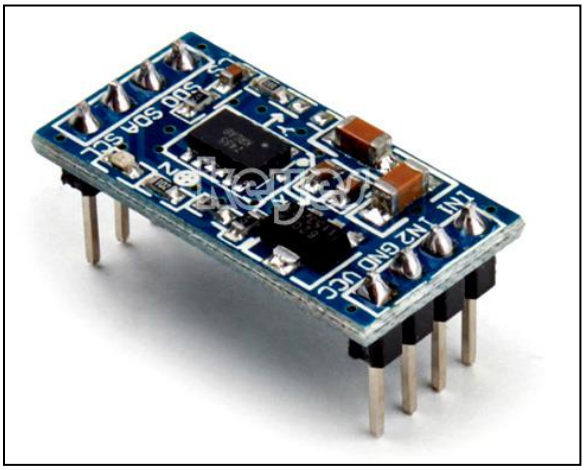
i. MPU 6050:

The Communication with all registers of the device is performed using either I2C at 400kHz or SPI at 1MHz (MPU-6000 only). For applications requiring faster communications, the sensor and interrupt registers may be read using SPI at 20MHz (MPU-6000 only). Additional features include an embedded temperature sensor and an on-chip oscillator with ±1% variation over the operating temperature range. The part features a robust 10,000g shock tolerance, and has programmable low-pass filters for the gyroscopes, accelerometers, and the on-chip temperature sensor.

- Cost: Rs. 195 per piece

ii. MMA7455:

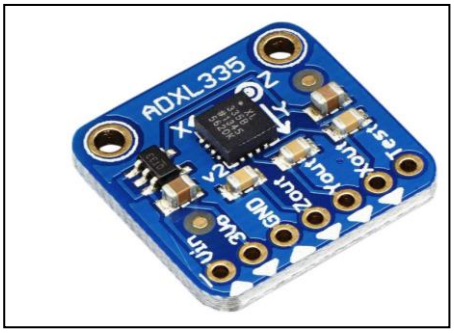
The MMA7455L is a Digital Output (I2C/SPI), low power, low profile capacitive micro machined accelerometer featuring signal conditioning, a low pass filter, temperature compensation, self-test, configurable to detect 0g through interrupt pins (INT1 or INT2), and pulse detect for quick motion detection. 0g offset and sensitivity are factory set and require no external devices. The 0g offset can be customer calibrated using assigned 0g registers and g-Select which allows for command selection for 3 acceleration ranges (2g/4g/8g). The MMA7455L includes a Standby Mode that makes it ideal for handheld battery powered electronics.



- Cost: Rs. 259.00 per piece

iii. ADXL335:

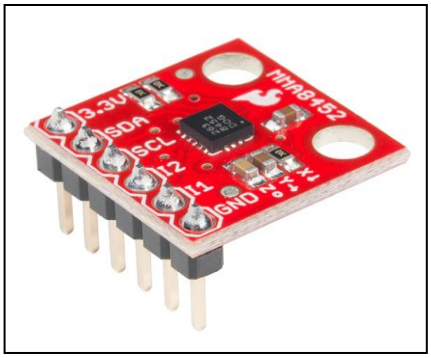
The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. The ADXL335 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ)



- Cost: Rs. 449 per piece

iv. MMA8452:

The MMA8452Q is a smart, low-power, three-axis, capacitive, micro machined accelerometer with 12 bits of resolution. This accelerometer is packed with embedded functions with flexible user programmable options, configurable to two interrupt pins. Embedded interrupt functions allow for overall power savings relieving the host processor from continuously polling data. The MMA8452Q has user selectable full scales of ±2 g/±4 g/±8 g with high-pass filtered data as well as non-filtered data available real-time. The device can be configured to generate inertial wakeup interrupt signals from any combination of the configurable embedded functions allowing the MMA8452Q to monitor events and remain in a low-power mode during periods of inactivity. The MMA8452Q is available in a 16-pin.



- Cost: Rs. 285 per piece

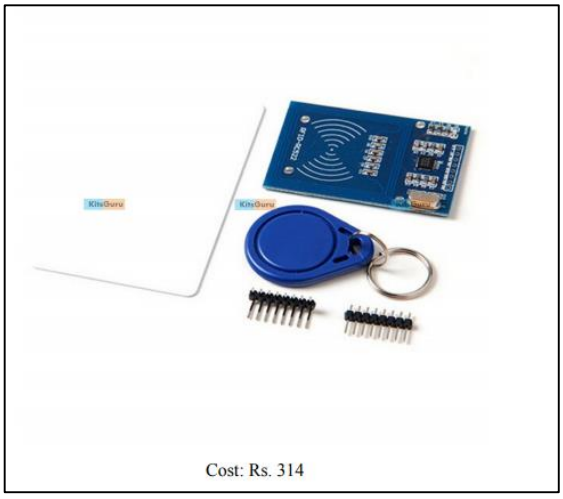
v. GY 85:

I. 9 axis module (3 axis gyroscope + 3 accelerometer + 3 axis magnetic field).
II. Immersion Gold PCB process.
III. Chip ITG3205 + ADXL345 + HMC5883L.
IV. Power Supply :3-5v. Communication: IIC communication protocol (fully compatible with the 3-5v System, circuit LLC is contained).

3. RFID Smart Cards—

i. MFRC522:

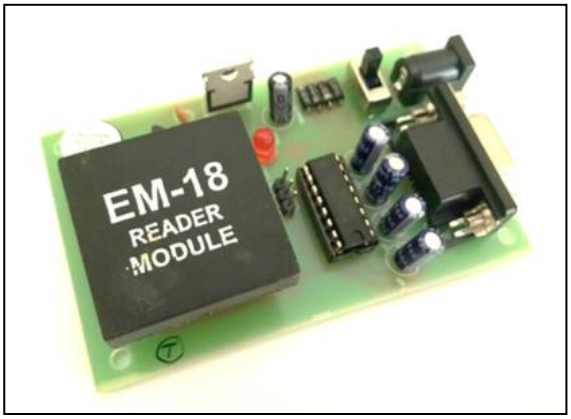
The MFRC522 is a highly integrated reader/writer IC for contactless communication at 13.56 MHz The MFRC522 reader supports ISO/IEC 14443 A/MIFARE and NTAG. The MFRC522's internal transmitter is able to drive a reader/writer antenna designed to communicate with ISO/IEC 14443 A/MIFARE cards and transponders without additional active circuitry. The receiver module provides a robust and efficient implementation for demodulating and decoding signals from ISO/IEC 14443 A/MIFARE compatible cards and transponders. The digital module manages the complete ISO/IEC 14443 A framing and error detection (parity and CRC) functionality. The MFRC522 supports MF1xxS20, MF1xxS70 and MF1xxS50 products. The MFRC522 supports contactless communication and uses MIFARE higher transfer speeds up to 848 kB in both directions.



- Cost: Rs. 314 per piece

ii. EM 18:

EM18 RFID Reader Module working at 125KHz suitable for Arduino, AVR, Raspberry Pi, 8051.Positron's EM-18 RFID Reader operated at 125kHz frequency and has a read range of 5cm-10cm. It works at 5V DC. It is an inexpensive solution for your RFID based application. The TTL output pins can be connected to interface with RFID Reader with any microcontroller development board such as Arduino, The Reader module comes with an on-chip antenna and can be powered up with a 5V power supply. Power-up the module and connect the transmit pin of the module to receive pin of your microcontroller. Show your card within the reading distance and the card number is thrown at the output. It follows serial communication UART interface and works at 9600 baud rate.

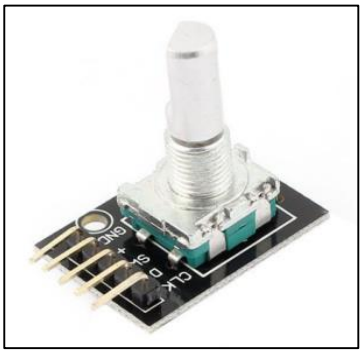


- Cost: Rs. 450 per piece

4. Rotary Encoders/Hall Effect Sensor based IMU—

i. M274:

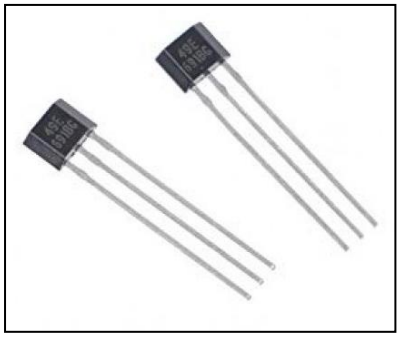
By rotating the rotary encoder can count forward and backward direction of rotation of the output pulse frequency during rotation count unlike potentiometers, this rotation count is not limited. With the button on the rotary encoder can be reset to the initial state, that is, from 0 to start counting.



- Cost: Rs. 120 per piece

ii. SS49E:

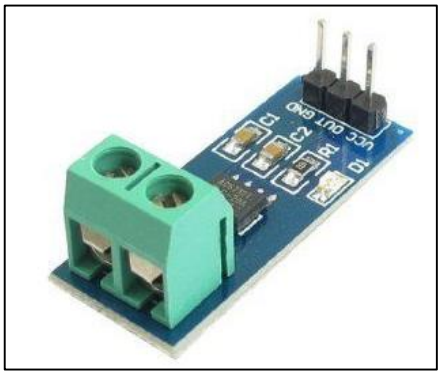
SS49E Linear Hall-effect sensor is small, versatile linear Hall-effect device that is operated by the magnetic field from a permanent magnet or an electromagnet. The linear sourcing output voltage is set by the supply voltage and varies in proportion to the strength of the magnetic field. The integrated circuitry features low noise output, which makes it unnecessary to use external filtering. It also includes thin film resistors to provide increased temperature stability and accuracy. The linear Hall sensor has an operating temperature range of -40 °C to 85 °C appropriate for commercial, consumer and industrial environments.



- Cost: Rs. 120 per piece

iii. ACS712:

By rotating the rotary encoder can count forward and backward direction of rotation of the output pulse frequency during rotation count unlike potentiometers, this rotation count is not limited. With the button on the rotary encoder can be reset to the initial state, that is, from 0 to start counting. 80kHz bandwidth, 66 to 185 mV/A output sensitivity, Low-noise analog signal path, Device bandwidth is set via the new FILTER pin, 1.2 mΩ internal conductor resistance, Total output error of 1.5% at TA = 25°C.



- Cost: Rs. 220 per piece

5. GPS System—

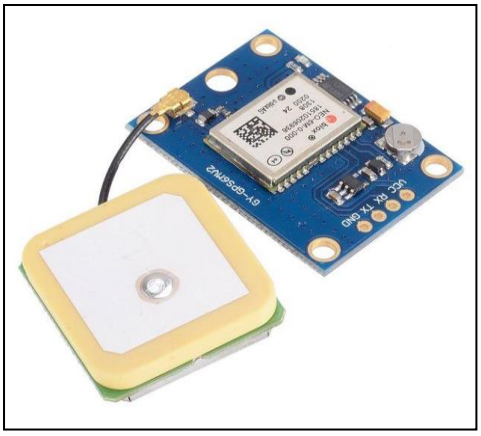
i. SIM 28:

SIMCom presents a high performance and reliable assisted GPS module-SIM28. This is a standalone L1 frequency GPS module in a SMT type and it is designed with the high sensitivity navigation engine, which allows you to achieve the industry's highest levels of sensitivity, accuracy, and Time-to-First-Fix (TTFF) with lowest power consumption.

- Cost: Rs. 999 per piece

ii. GY-NEO6MV2:

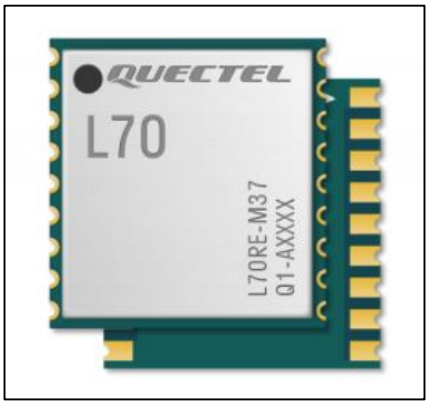
GY-NEO6MV2 board features the u-blox NEO-6M GPS module with antenna and built-in EEPROM. This is compatible with various flight controller boards designed to work with a GPS module. The NEO6MV2 GPS module makes it possible to receive GPS signals. This allows a project to determine exactly where it is on earth, how fast it is moving, in which direction it is moving and how many satellites are visible. The communication is via a serial TX / RX connection (only 2 I/O required).



- Cost: Rs. 1230 per piece

iii. Quectel L70 (Without Antenna):

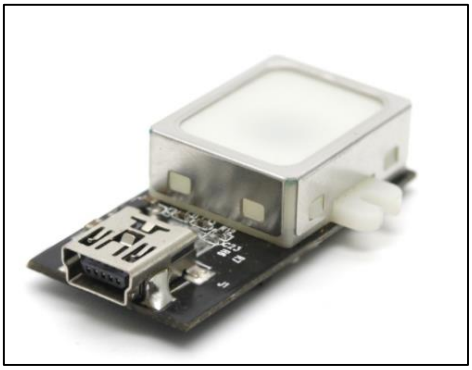
The L70 is an SMD type module measuring 10.1mm × 9.7mm × 2.5mm with 66 acquisition channels and 22 tracking channels, and a high-performance MTK positioning engine. The L70 combines EASY™ (Embedded Assist System for self-generated orbit prediction). the L70 to calculate and predict orbits automatically using up to 3 days of ephemeris data stored in the RAM, so it can fix position quickly and with low power consumption, even when signal levels are lower.



- Cost: Rs. 675 per piece

6. Fingerprint Sensor Reader Module GT-511C1R:

The GT-511C1R FPS (fingerprint scanner) is a small embedded module which consists of an optical sensor mounted on a small circuit board. The optical sensor scans a fingerprint. The microcontroller and software provides the modules functionality which automatically processes the scanned fingerprint. ARM Cortex M3 Core (Holtek HT32F2755) CPU, GT-511C1R3 (20 fingerprints), 504 Bytes (template) + 2 Bytes (checksum).



- Cost: Rs. 2050 per piece

7. HC-08 Bluetooth UART Module:

HC-08 Bluetooth UART communication module is a new generation of Bluetooth specification V4.0 BLE Bluetooth protocol based on the transmission module. Wireless working frequency is 2.4GHz ISM, modulation is GFSK. The maximum transmit power module 4dBm, the receiving sensitivity is -93dBm, and iphone4s can achieve 80 meters of super long distance communication under open environment.

- Cost: Rs. 250 per piece

❖ Advantages of this system–

1. This system Given the need to adopt a healthier and greener lifestyle.
2. This project 'smart' e-bike can enhance the user experience of bicycling.
3. Enhanced security features can make purchasing the e-bike a low-risk option.
4. Different research tracks are being pursued to enable this.
5. A micro GPS chip added to the bicycle will help in detecting the location in case of an accident or theft.
6. Centralized locking and GPS can provide a secure and reliable platform for cycle rental business.

❖ Disadvantages of this system–

1. This system is little costly, but we can look at your healthy lifestyle and environment this cost is nothing.
2. This system is requiring all time battery supply.
3. Diagram is little costly.
4. This system is requiring a little more space to install it, in bicycle this space allocation is more complicated.

❖ Conclusion

Different models of calorie measurement need to be reviewed and tested to find which one is the most suitable to be adopted for a range of bicycles. For further direction, a research on having one model that can fit all bicycles can be done, to reduce the calibrations required for every individual cycle. Incentive based approaches for e-bikes can be tried to have practices like switch bicycle from manual mode to electric mode if calories burned have attained them goal. A circuit that can implement the same needs to be thought of. The anti-theft relies on the battery supply. A more reliable battery supply is required to make that happen. On a business level, a cost model needs to be figured out to assign a renting rate and mode of payment

❖ REFERENCES

1. MPU-6000 and MPU-6050 Product Specification
2. MMA7455 Datasheet
3. ADXL 335 Datasheet
4. MMA8452 Datasheet
5. GY 85 Datasheet
6. MFRC522 Datasheet
7. PN532 Datasheet
8. EM 18 Datasheet
9. M274 Datasheet
10. SS49E Datasheet
11. ACS712 Datasheet
12. SIM28 Datasheet
13. GY-NEO6MV2 Datasheet
14. Quectel L70 Datasheet
15. GT-511C1R Datasheet
16. HC-08 Datasheet
17. Prices of all sensors obtained from eBay, Amazon, or other online sellers.
18. Arm CortexM0 Datasheet