QUADCOPTER CONTROL USING ARDUINO MICROCONTROLLER

PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE

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IN

APPLIED ELECTRONICS AND INSTRUMENTATION ENGINEERING,

BY

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CERTIFICATE OF APPROVAL

The project report titled “Quadcopter Control Using Arduino Microcontroller” prepared by **Angshuman Bhattacharjee** Roll No: 11705514004, **Arghya Hazra** Roll No: 11705514007 and **Suvam Kumar Sar** Roll No: 11705514036 is hereby approved and certified as a creditable study in technological subjects performed in a way sufficient for its acceptance for partial fulfilment of the degree for which it is submitted.

It is to be understood that by this approval, the undersigned do not, necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein, but approve the project only for the purpose for which it is submitted.

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RECOMMENDATION

I hereby recommend that the project report titled “**Quadcopter Control Using Arduino Microcontroller**” prepared by **Angshuman Bhattacharjee** Roll No: 11705514004, **Arghya Hazra** Roll No: 11705514007 and **Suvam Kumar Sar** Roll No: 11705514036 be accepted in partial fulfillment of the requirement for the Degree of Bachelor of Technology in Applied Electronics &Instrumentation Engineering, RCC Institute of Information Technology.

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ABSTRACT

Technological advancements in fields of rescue operations as well as in remote package delivering systems has led us to the development of a quadcopter. The quadcopter's flight controller is an Arduino microcontroller and its flight movements can be controlled using a transmitter-receiver setup. The quadcopter is designed mainly for the purpose of search & rescue operations as well as for remote package delivering operations.

On the quadcopter is attached a pressure, temperature and humidity sensor which gives the readings of a particular place. Also, there is a magnetometer attached which indicates the direction of the quadcopter to where it is facing. These readings are being sent from the quadcopter to a base station using a server-client concept. For this, a Wi-Fi module, namely ESP8266 has been used.

At a later stage of the project, a GPS module would be attached which would give the coordinates of the place to where the quadcopter is travelling. Also, a camera would be installed which would prove a live feed of the area for better performance of the quadcopter.

CHAPTER 1
INTRODUCTION

In this modern age of technology, quadcopter has become one of the most popular inventions in the field of science. A quadcopter, also known as UAV (Unmanned Aerial Vehicle) uses four propellers for lift and stabilization. The rotors are directed upwards and they are placed in a square formation with equal distance from the center of mass of the quadcopter. The quadcopter is controlled by adjusting the angular velocities of the rotors which are spun by electric motors. Now-a-days, quadcopters have received considerable attention from researchers as the complex phenomena of the quadcopter has generated several areas of interest. [1]

The basic concept of flight mechanism is as follows:

- **YAW** (turning left and right) is controlled by turning up the speed of the regular rotating motors and taking away power from the counter rotating; by taking away the same amount that you put in on the regular rotors produces no extra lift (it won't go higher) but since the counter torque is now less, the quadcopter rotates.

- **ROLL** (tilting left and right) is controlled by increasing speed on one motor and lowering on the opposite one.

- **PITCH** (moving up and down, similar to nodding) is controlled the same way as roll but using the second set of motors. This may be confusing but roll and pitch are determined from where the "front" of the drone is. To roll or pitch, one rotor's thrust is decreased and the opposite rotor's thrust is increased by the same amount. This causes the quadcopter to tilt. When the quadcopter tilts, the force vector is split into a horizontal component and a vertical component. [1-2]

CHAPTER 2
FLIGHT DYNAMICS AND DEVELOPMENTS

A quadcopter is operated by varying spin RPM of its four rotors to control lift and torque. The thrust is determined using altitude, pitch, and roll angles and is obtained from the ratio of the angles. The thrust plays a key role in maneuvering, enables the user to perform flying routine which includes aerial maneuvers. To conduct such maneuvers precise angle handling is required. It serves as a solution to handle the copter with angular precision which illustrates how the spin of four rotors is varied simultaneously to achieve angular orientation along with takeoff, landing and hovering at an altitude. [1]

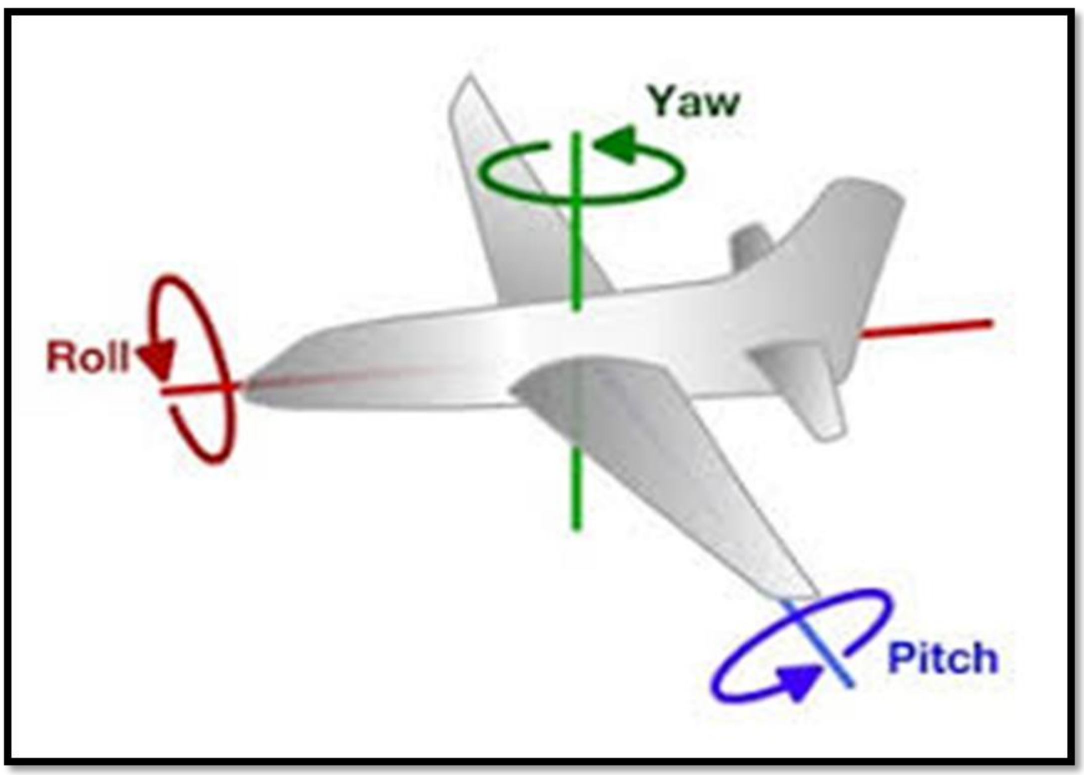

Figure 1. Roll, pitch, Yaw of a quadcopter

2.1 EARLY DEVELOPMENTS

The earliest invention of the quadcopter dates back to 1907 when Louis Breguet invented and flew the first quad rotor helicopter. The drones were then used mainly by the US army for military purposes. The literal introduction of quadcopter was in the late 2000s where advances in electronics allowed the production of cheap lightweight flight controllers which had the capability of flying an Unmanned Aerial Vehicle. Furthermore, a number of sensors were incorporated into the flight controller in order to increase the stability of the quadcopter. These sensors were accelerometers ,gyroscope and magnetometer. This resulted in the quadcopter becoming popular for small unmanned aerial vehicles. With their small size and maneuverability, these quadcopters can be flown indoors as well as outdoors. But these quadcopters at the initial stages lacked in basic stability and controllability. Thus, new designs were incorporated in the quadcopters using more stable sensors. These sensors increased the stability of the quadcopter and also allowed it to hover at a predefined altitude. At this stage, the microcontrollers used were complex in nature and flight control was difficult as well due to errors from the controller output.

2.2 SUBSEQUENT DEVELOPMENTS

The introduction of the advanced and stable sensors helped in increasing the hovering stability of the drone. The hover control was achieved by the PID controller of the microcontroller. This led to the increase in the demand of the drones in the field of agriculture to monitor crops of an area.[3] But still the drones were not upgraded enough to perform specific tasks. There were scopes of further developments in the future. Thus, scientists introduced few other sensors like tilt sensors, infrared sensors etc. to make the drones more efficient in their tasks. The tilt sensor monitors the pitch of the drone and the infrared sensor separates the subject of interest from the other objects by the different radiation emitted from the body.[4]

The drones at this stage were still less efficient because it had no sensors to monitor the location to where it was flying and remote controlling the drone was a difficult task. Scientists later added a GPS (Global Positioning System) module which located the coordinates of the area where it was flying and sent it to the remote controller. At this time, the quadcopter and the remote controller were connected to each other using Wi-Fi instead of the traditional radio waves. This increased the range of the controller several times and could be remotely controller from a faraway place. The quadcopter at this stage could follow a preset path loaded into the memory of the controller. [4-5]

The drones were comfortably flown indoors at low wind speeds. But it suffered aerodynamic drag forces at outdoors due to heavy wind flow. The sensors used were insufficient in overcoming the wind forces outdoors and lost stability. This ultimately led to the drone being drifted away towards the wind flow.[5] To make the flight more stable, the sensors were made more efficient. But the advanced sensors were not compatible with the old microcontrollers used. Thus, new microcontrollers are being introduced since the last decade which provides the required output to the sensors and stabilize the flight. The most popular microcontrollers used till date are the FY80, GY80, ARDUINO, X-BEE since they were easy to use and program.[6-7]

2.3 RECENT DEVELOPMENTS

Great advancements in the field of quadcopters has been achieved over the last decade as the quadcopters have evolved in designs as well as in flight controllability. This is due to the fact that more better microcontrollers are being used along with better sensors attached. The introduction of BMP085(pressure+altitude) sensor along with the gyroscope helped the drone in altitude hold control pre-determined by the microcontroller. At this stage, the GUI at the remote station were improved to give the user a nice flight experience. The drones proved useful in the military in remote package delivering missions. [7]

With the passage of time, ARDUINO became a popular microcontroller in making the drones because of its flexibility in the programming. Besides that, additional sensors like a camera, an ultrasonic sensor was attached to the drones. This helped the drones in calculating distance from the ground which previously the drones were unable to do. This revolutionary addition increased its popularity several times. The drones could now be used in way point navigation systems. The coordinates of the waypoints for predetermined flight is fed to the microcontroller. The algorithm calculates the distance between the current positions obtained from GPS to the first waypoint and the heading angle of the current position with respect to geographical north. Similarly succeeding waypoints are calculated. From these calculated values, the pulse width modulated signal is generated by controller which controls the quadrotor altitude. It is useful in applications such as autonomous security surveillance, fire suppression system, and a terrain mapping vehicle. [8-9]

Also, similar other models are made using FY90 microcontroller and are used in coast guard surveillance and rescue missions. Infrared sensors attached to the drones could search for live targets in rescue missions. [11]

The other demand of these drones is in the field of agriculture where it is being used in crop surveillance, fertilizer spraying and in precision agriculture. The infrared sensor attached in the drones could identify the healthy crops from the infected ones. These drones reduced the human efforts and increased the monitoring quality of the crops. [12-15]

Another field where it can be useful in earthquake or tsunami where it can warn people of the situation and lead them to safety and also by helping localized victims. The later can be done by incorporating heat sensors along with the microphone and camera used for reconnaissance. Here for this additional security purposes we need following components like microphone, pistol with immobilizing darts, heat resistant frame, small medical devices, mini size quad copter and recognition devices. [16]

2.4 LATEST DEVELOPMENTS

The developments with these drones is huge. Previously, the drones could follow a pre-determined path. But the drone was vulnerable to collisions. Lately, quadcopters are being designed which has the technology of obstacle detection and collision avoidance. The quadcopters use a number of ultrasonic sensors in coordination to detect objects around it and avoid them by using simple algorithms. The signals from the sensors are controlled by an Arduino microcontroller. Here the signals from the sensors are integrated to give a collision avoidance display on the remote controller which can be used to control the quadcopter precisely. But then again, the quadcopter could not provide the location to where it was travelling. This was eliminated in the future where a gps module is introduced in the system which allows the quadcopter to fly between two coordinates avoiding collision. This development found applications in package delivering avoiding collisions on the way. [17-18]

More latest developments have been made where the quadcopters are being controlled by voice commands of the user or by simple hand gestures. These developments are still in the development stages but are soon to become a reality. [19-21]

CHAPTER 3
OVERVIEW OF THE PROJECT

3.1 BLOCK DIAGRAM

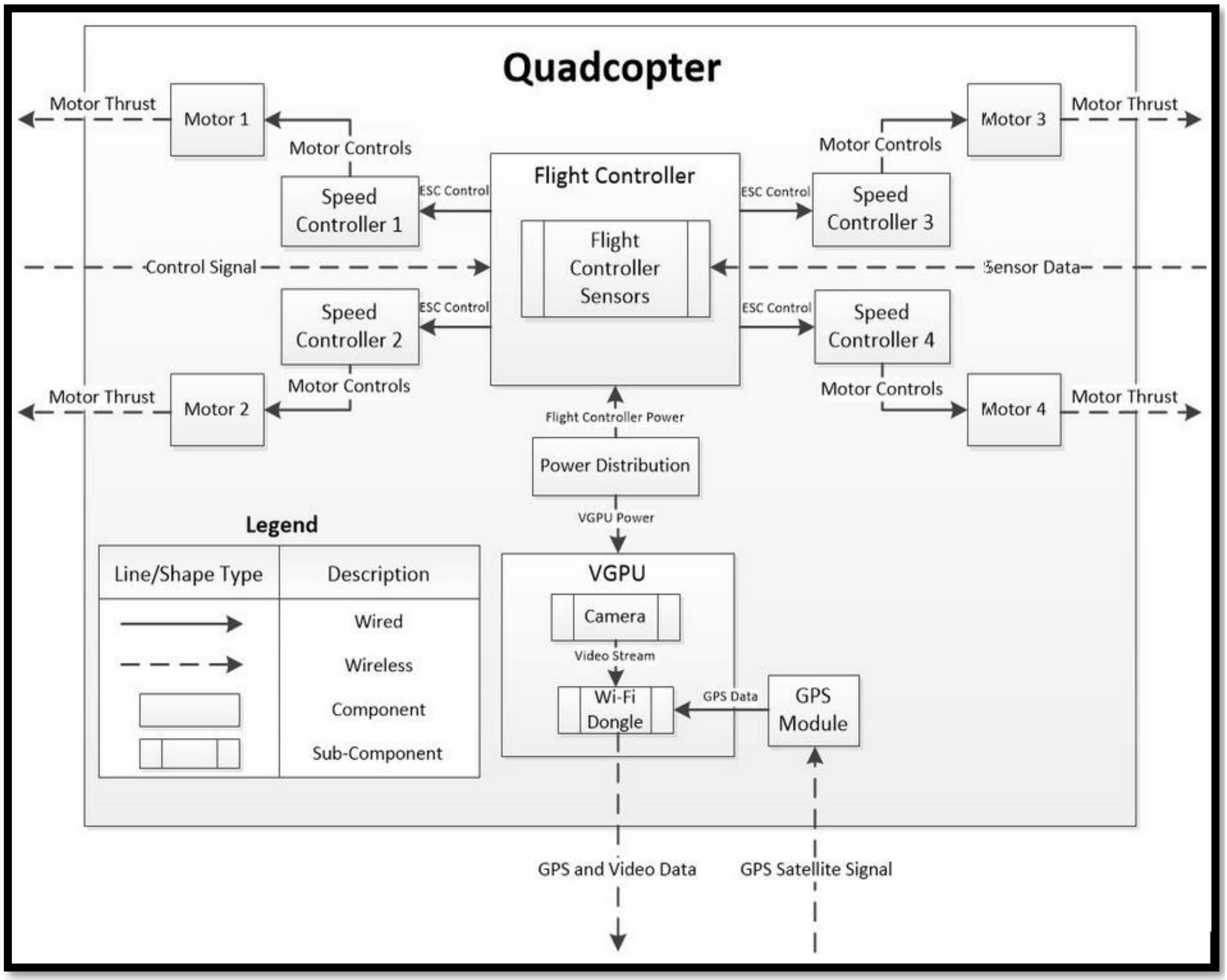

Figure 2. Block diagram of quadcopter

3.2 CIRCUIT DIAGRAM

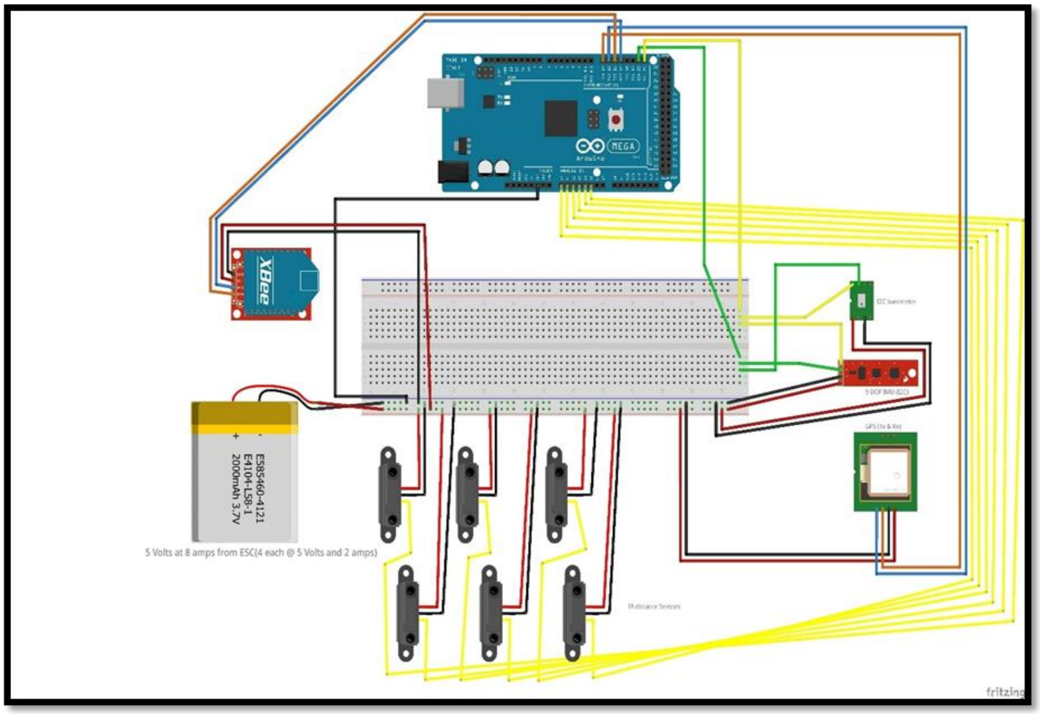

Figure 3. Circuit diagram of quadcopter

3.3 HARDWARE REQUIREMENTS

- ARDUINO microcontroller
- MPU-6050 (3-axis Accelerometer & Gyroscope)
- HMC-5883L magnetometer
- BME-280 (temperature, pressure, humidity)
- 4 no's of BLDC motors and ESCS
- GPS module
- Node MCU ESP8266 (Wi-Fi module)
- Connecting wires

3.4 COMPONENT DESCRIPTION

ARDUINO MICROCONTROLLER

Arduino refers to an open-source electronics platform or board and the software used to program it. **Arduino** is designed to make electronics more accessible to artists, designers, hobbyists and anyone interested in creating interactive objects or environments.

In our project, an Arduino mega microcontroller is used to control the quadcopter flight dynamics.

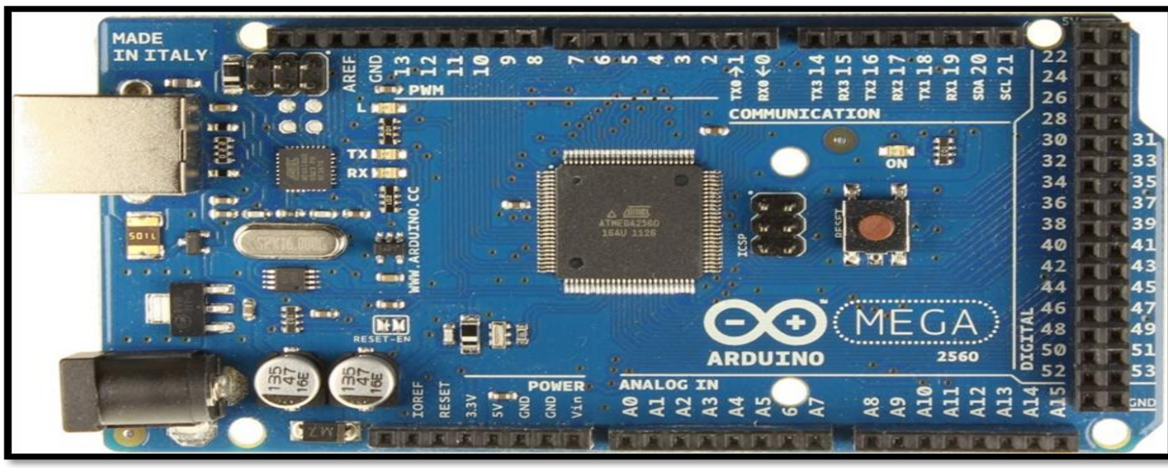

Figure 4. Arduino Mega microcontroller

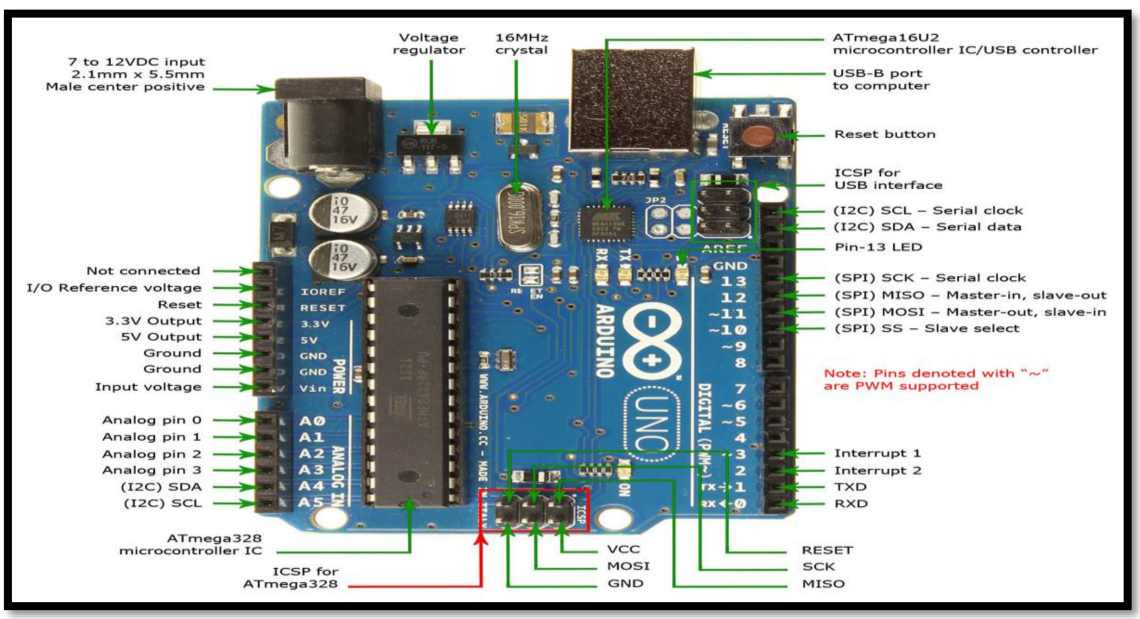

Figure 5. Arduino Uno microcontroller

MPU-6050 (3-AXIS ACCELEROMETER & GYROSCOPE)

The MPU6050 contains both a 3-Axis Gyroscope and a 3-Axis accelerometer allowing measurements of both independently, but all based around the same axes, thus eliminating the problems of cross-axis errors when using separate devices.

In our project, we have used the MPU-6050 to help in balancing the flight of the quadcopter and maintain its flight dynamics.

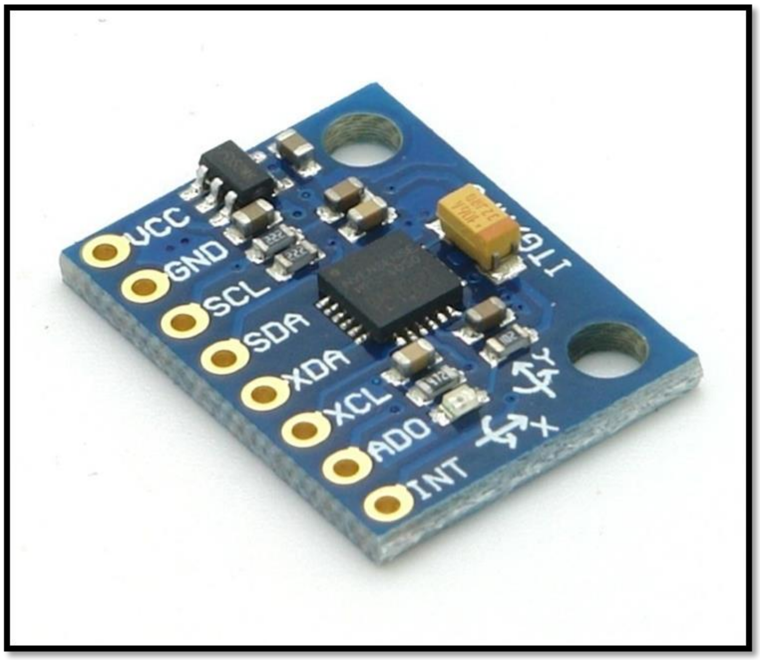

Figure 6. MPU-6050 (Triple axis gyroscope & accelerometer)

3-AXIS MAGNETOMETER(HMC5883L)

The HMC5883L is a triple-axis magnetometer compass, which uses I2C for communication. This is 5 pin IC.

Compass heading accuracy of 1° to 2°, provided by internal 12-bit ADC (Analog-to-Digital Converter).

In our project, we have used the 3-axis magnetometer to help the quadcopter judge the direction to where it is going.

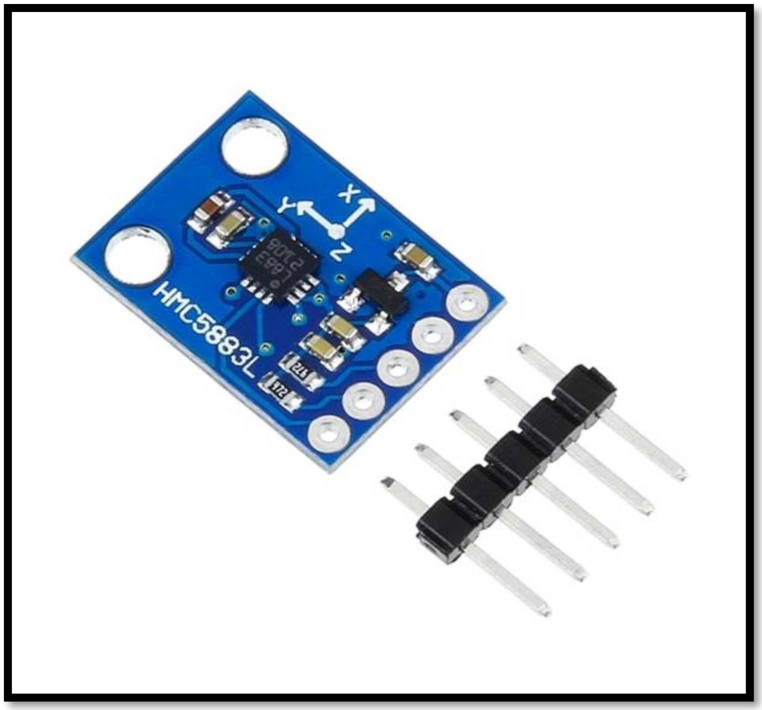

Figure 7. HMC5883L Magnetometer

PRESSURE, HUMIDITY AND TEMPERATURE SENSOR (BME 280)

BME280, the precision sensor from Bosch, is soldered onto PCB. Not only the pressure and the temperature, this sensor can measure humidity. It uses both I2C and SPI (supports 3-, 4-wire SPI) interface.

In this project, the BME 280 sensor is used to measure the pressure, humidity and temperature of the area to where the quadcopter is travelling to.

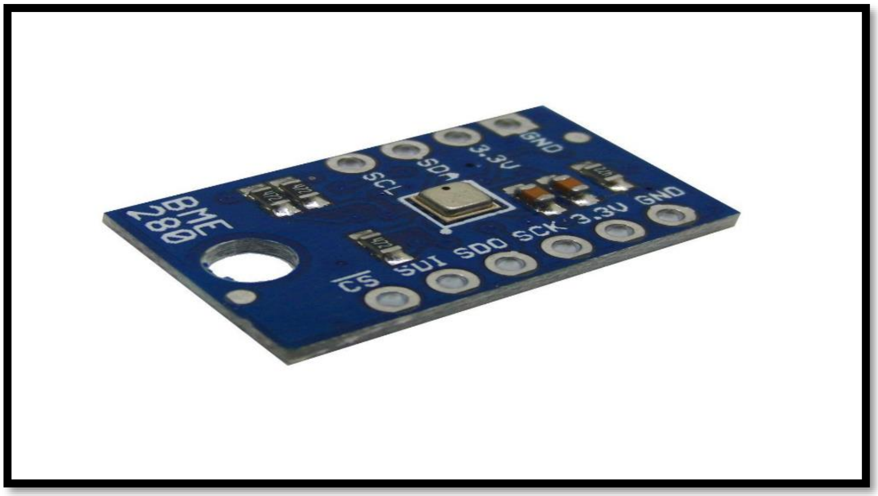

Figure 8. BME280 Pressure, temperature & humidity

NODE MCU ESP 8266

The MCU ESP8266 is low cost Wi-Fi module with MCU (microcontroller unit) capability. This small module allows microcontrollers to connect to a Wi-Fi network. It is manufactured by Espressif system which is a Chinese manufacturer.

In our project we have used this Wi-Fi module to wirelessly communicate with the quadcopter from the ground station.

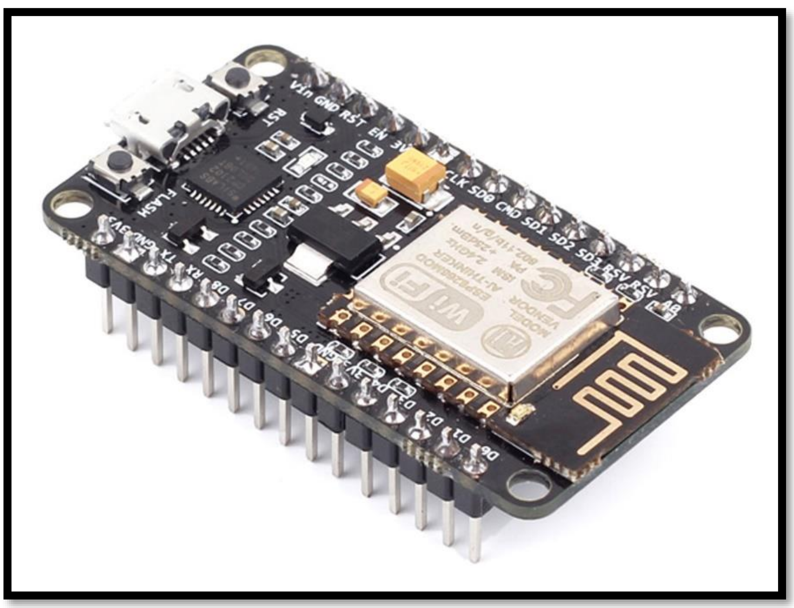

Figure 9. Node MCU Esp8266 Wi-Fi module

3.5 COST ESTIMATION STRUCTURE

Table 1. Cost Estimation Table

Sl. No	Component name	Quantity	Description	Price (Rs.)
1	Arduino Mega	1	Used as the main flight controller	810
2	MPU-6050	1	3-axis gyroscope & accelerometer. Used to balance flight.	289
3	HMC5883L	1	Used to sense the direction of flight	375
4	BME 280	1	Used to measure pressure, humidity of a place	719
5	BLDC motors	4	Used as the rotors to lift the quadcopter and fly	1900
6	ESCs	4	Used to provide proper current to the motors	1400
7	Propellers	4	Used to provide the thrust and lift to the quadcopter.	400
8	NodeMCU Esp8266	2	Used in communication between the quadcopter and the transmitter	898
9	Connecting Wires		Used in connections	200
10	Li-Po battery	1	Used to power the whole quadcopter	1200
TOTAL				8191

CHAPTER 4
DESCRIPTION & WORK PLAN

4.1 DESCRIPTION OF THE PROJECT

In this project, we as a group have decided to make a quadcopter which would be used in remote package delivering systems and rescue operations.

Firstly, we have studied the associated works related to the quadcopter developments over the last few decades. Then we have compiled the reviews of the individual papers and made a single literature review out of the individual papers. Next, we have bought the individual components of the quadcopter.

After that we have done the interfacing of individual sensors with the Arduino, then we have assembled all the sensors together to achieve interfacing with Arduino and also to calibrate it.

Next, we have used the ESP8266 MOD as the server client concept to send some data over a Wi-Fi network. Here we have used server to send some data over the network by generating an IP address and the client is being used here to receive those data which is being sent. For this we have done the interfacing of all the sensors individually with the ESP8266 MOD and later we have combined all the sensors together to achieve interfacing with this Wi-Fi module.

Next, we have made all the required connections of Arduino with different sensors to make the quadcopter fly. Hence, we have done the quadcopter setup with the transmitter and also Esc's (Electronic Speed Controller) calibration is made. Moreover, we have upload the flight controller program on Arduino platform and the controlling of the quadcopter is achieved through transmitter. The only thing which needs to be done is to make it fly by controlling the transmitter.

4.2 OBJECTIVE

The main objective of our project is to make a quad copter which could be used in rescue missions as well as in package delivering operations. The quadcopter will be controlled by an Arduino microcontroller which will be program flexible according to the user. The flight will be
made stable with the accumulation of various sensors like the gyroscope, accelerometer and magnetometer. Additionally, a GPS module, a camera and infrared sensors will be attached to increase its performance. The GPS module would give the coordinates of the quadcopter to where

it will be flying and the camera would provide live streaming of the area back to the ground controller. The quadcopter is estimated to give a flight time of nearly 6 minutes. The quadcopter will be controlled using Wi-Fi instead of a radio controller to increase its range.

4.3 WORK PLAN

Table 2. Work plan structure

SL.NO	DURATION	PROGRESS
1.	August-September (2017)	Selection of project topic and study of the project topic.
2.	October-November (2017)	Study of previous work done related to our project and preparing a literature review of our topic.
3.	December-January, 2018	Purchase of required components and assembling them.
4.	February-March (2018)	Operation of the components in coordination to make the quadcopter fly.
5.	March- 15st May,2018	Perform various tasks with the quadcopter and error detection & correction.

CHAPTER 5
RESULTS & FUTURE SCOPE

5.1 RESULTS AND DISCUSSIONS

Firstly, the values of different sensors are displayed on the serial monitor while interfacing with Arduino.

Then, a Wi-Fi network is created and the server-client concept is implemented using two ESP8266 modules. Next, the various data of the sensors are displayed on the client side's serial monitor.

Lastly, the calibration and the setup of the quadcopter is achieved through transmitter and the controlling of the motors with the different speeds of rotation is done.

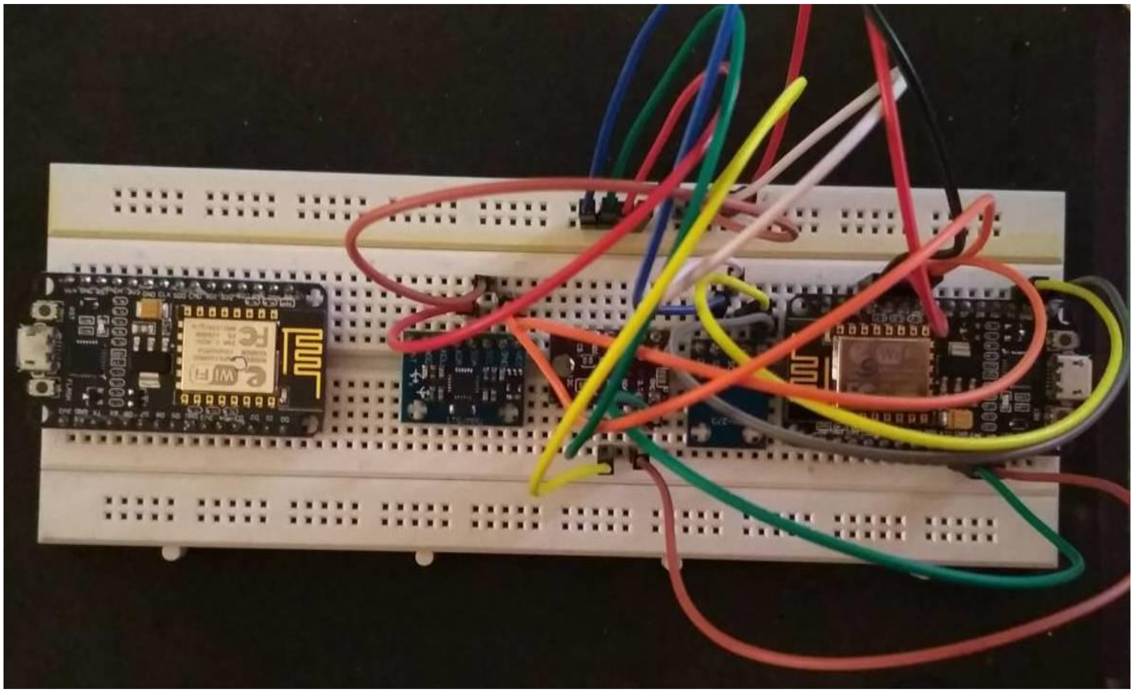

Fig 10: Server Client Concept

Table 3. Values of Sensors

SENSORS	PARAMETERS	DISPLAYED VALUE
1. BME280	Temperature	32.577 ° C
	Humidity	69.8%
	Dew point	22.0 ° F
	Pressure	1000.5 hPa
2. MPU 6050	Gyro (X axis)	4.519 °
	Gyro (Y axis)	10.710 °
	Gyro (Z axis)	14.702 °
	Acc (X axis)	9.077g
	Acc (Y axis)	0.028g
	Acc (Z axis)	1.054g
3. HMC5883L	Heading Angle	23.2409 °

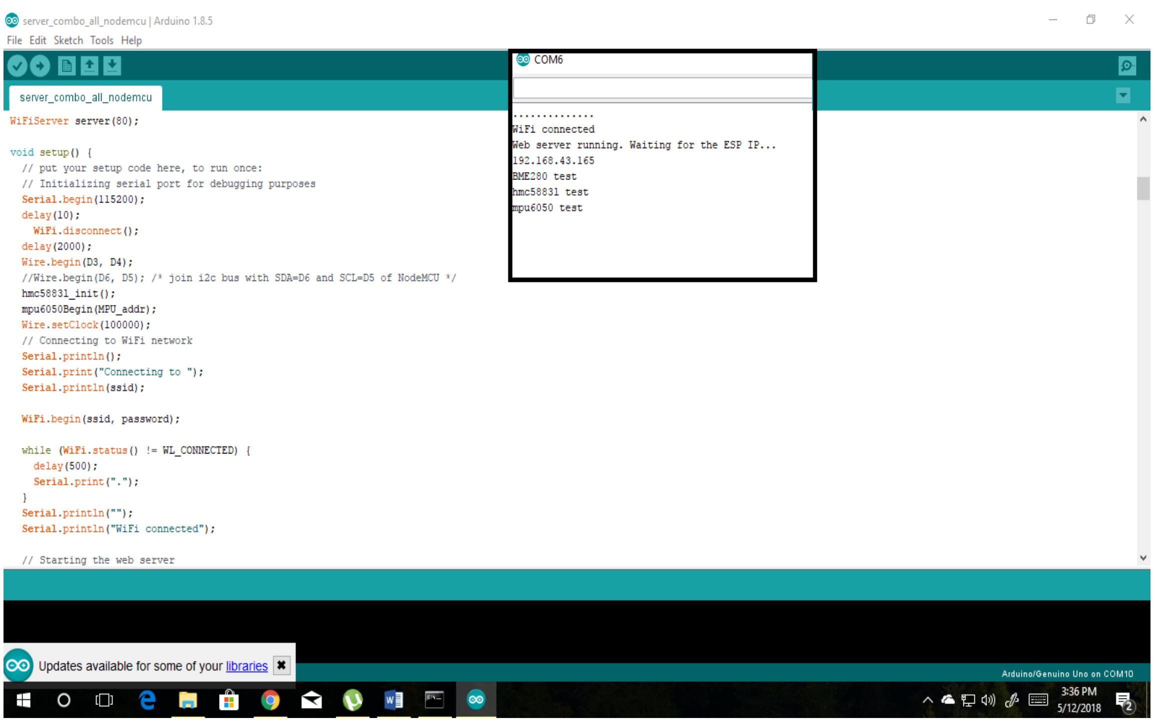

Fig 11. Server code & output

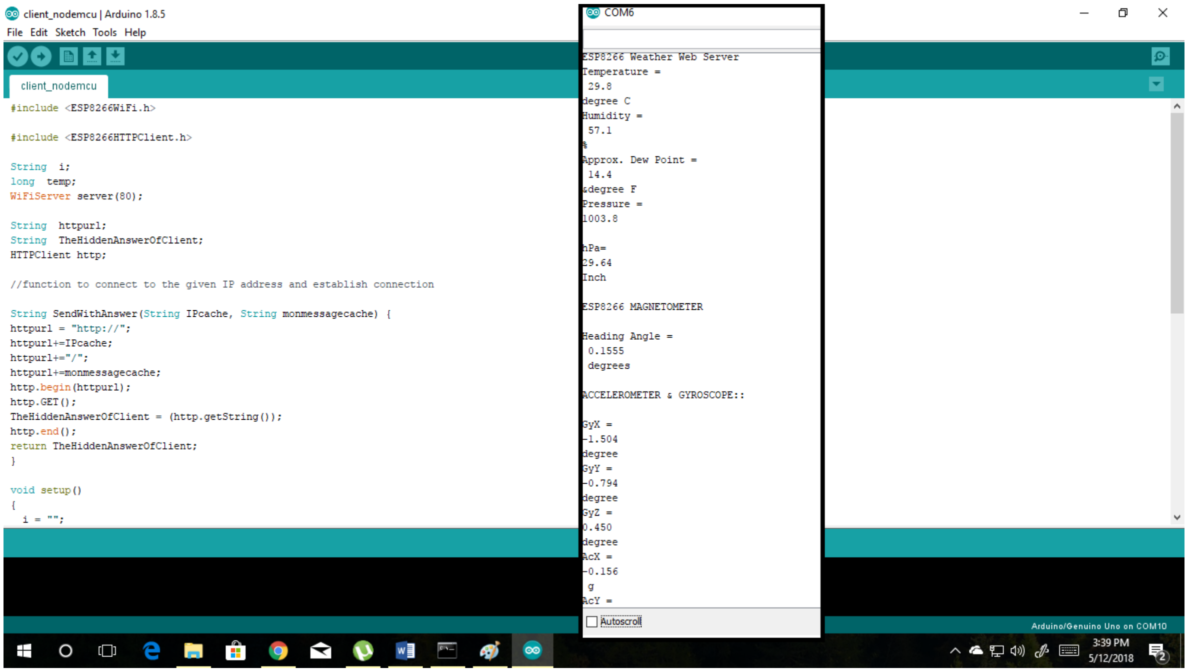

Fig 12. Client code & output

5.2 FUTURE SCOPE OF STUDY

In this project, we have developed a quadcopter using Arduino microcontroller, which will be used in remote package delivering as well as in search & rescue operations. The quadcopter at present is being manually controlled using a remote-controlled transmitter. But in future, an autonomous control can be incorporated using a pre-designed algorithm. Additionally, a camera could be fixed on the quadcopter for a live transmission of the location to where the quadcopter is flying. This feature can be used to survey a remote location from a safe location without actually going there. Also, the coordinates of the remote location can be obtained by attaching a GPS module in the quadcopter.

CHAPTER 6
DATASHEETS

HMC5883L

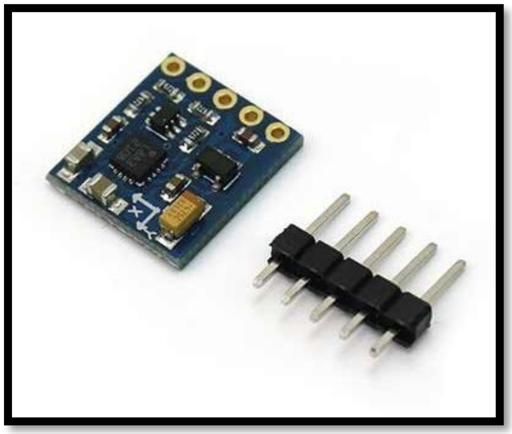

Figure 13. HMC5883L magnetometer front view (datasheet)

Description

The Compass Module is designed for low-field magnetic sensing with a digital interface and perfect to give precise heading information. This compact sensor fits into small projects such as UAVs and robot navigation systems. The sensor converts any magnetic field to a differential voltage output on 3 axes. This voltage shift is the raw digital output value, which can then be used to calculate headings or sense magnetic fields coming from different directions.

Specifications

- Power 3V-5V DC
- Chipset HMC5883L
- Communication via I2C protocol
- Measuring range: ± 1.3-8 Gauss
- Dimensions 14.8 x 13.5 x 3.5mm

Pin Configuration

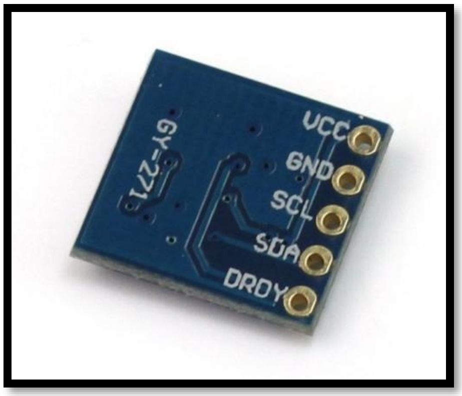

Figure 14. HMC5883L magnetometer back view (datasheet)

1. VCC: 3V-5V DC
2. GND: ground
3. SCL: analog input (A5)
4. SDA: analog input (A4)
5. DRDY: not connected

MPU-6050

The MPU-60X0 is the world's first integrated 6-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer, and a Digital Motion Processor™ (DMP) all in a small 4x4x0.9mm package. With its dedicated I^2C sensor bus, it directly accepts inputs from an external 3-axis compass to provide a complete 9-axis Motion Fusion™ output. The MPU-60X0 Motion Tracking device, with its 6-axis integration, on-board Motion Fusion™, and run-time calibration firmware, enables manufacturers to eliminate the costly and complex selection, qualification, and system level integration of discrete devices, guaranteeing optimal motion performance for consumers. The MPU-60X0 is also designed to interface with multiple non-inertial digital sensors, such as pressure sensors, on its auxiliary I^2C port. The MPU-60X0 is footprint compatible with the MPU-30X0 family.

The MPU-60X0 features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs and three 16-bit ADCs for digitizing the accelerometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope full-scale range of ±250, ±500, ±1000, and ±2000°/sec (dps) and a user-programmable accelerometer full-scale range of ±2*g*, ±4*g*, ±8*g*, and ±16.

The MPU-6050 module has 8 pins:-

INT: Interrupt digital output pin.

AD0: I2C Slave Address LSB pin. This is 0th bit in 7-bit slave address of device. If connected to VCC then it is read as logic one and slave address changes.

XCL: Auxiliary Serial Clock pin. This pin is used to connect other I2C interface enabled sensors SCL pin to MPU-6050.

XDA: Auxiliary Serial Data pin. This pin is used to connect other I2C interface enabled sensors SDA pin to MPU-6050.

SCL: Serial Clock pin. Connect this pin to microcontrollers SCL pin.

SDA: Serial Data pin. Connect this pin to microcontrollers SDA pin.

GND: Ground pin. Connect this pin to ground connection.

VCC: Power supply pin. Connect this pin to +5V DC supply.

MPU-6050 module has Slave address (When AD0 = 0, i.e. it is not connected to Vcc) as,

Slave Write address(SLA+W): 0xD0

Slave Read address(SLA+R): 0xD1

ARDUINO MEGA

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

TECHNICAL SPECIFICATIONS

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

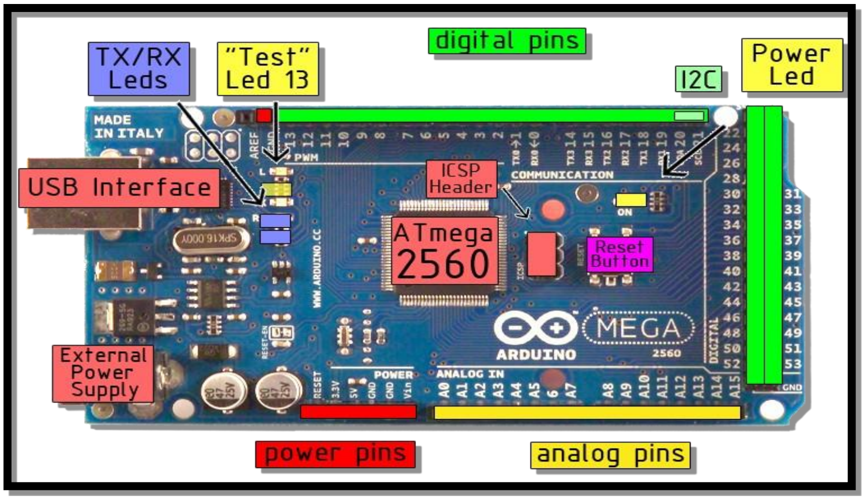

Figure 15. Arduino mega front view (datasheet)

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- 5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator or be supplied by USB or another regulated 5V supply.
- 3V3. A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- GND. Ground pins.

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(),digitalWrite(), and digitalRead()functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt()function for details.
- PWM: 0 to 13. Provide 8-bit PWM output with the analogWrite()function.
- SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Duemilanove and Diecimila.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- I^2C: 20 (SDA) and 21 (SCL). Support I^2C (TWI) communication using the Wire library(documentation on the Wiring website). Note that these pins are not in the same location as the I^2C pins on the Duemilanove.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

NODEMCU ESP-8266

Espressif's ESP8266EX delivers highly integrated Wi-Fi SoC solution to meet users' continuous demands for efficient power usage, compact design and reliable performance in the Internet of Things industry.

With the complete and self-contained Wi-Fi networking capabilities, ESP8266EX can perform either as a standalone application or as the slave to a host MCU. When
ESP8266EX hosts the application, it promptly boots up from the flash. The integrated highspeed cache helps to increase the system performance and optimize the system memory.

Wi-Fi Protocols

- 802.11 b/g/n/e/i support.
- Wi-Fi Direct (P2P) support.
- P2P Discovery, P2P GO (Group Owner) mode, GC(Group Client) mode and P2P Power Management.
- Infrastructure BSS Station mode / P2P mode / SoftAP mode support.
- Hardware accelerators for CCMP (CBC-MAC, counter mode), TKIP (MIC, RC4), WAPI (SMS4), WEP (RC4), CRC.
- WPA/WPA2 PSK, and WPS driver.
- Additional 802.11i security features such as pre-authentication, and TSN.
- Open Interface for various upper layer authentication schemes over EAP such as TLS, PEAP, LEAP, SIM, AKA, or customer specific.
- 802.11n support (2.4 GHz).
- Supports MIMO 1×1 and 2×1, STBC, A-MPDU and A-MSDU frame aggregation and 0.4 μs guard interval
- WMM power low U-APSD.
- Multiple queue management to fully utilize traffic prioritization defined by 802.11e standard.
- UMA compliant and certified.

- 802.1h/RFC1042 frame encapsulation.
- Scattered DMA for optimal CPU off load on Zero Copy data transfer operations.
- Antenna diversity and selection (software managed hardware).
- Clock/power gating combined with 802.11-compliant power management dynamically adapted to current connection condition providing minimal power consumption.
- Adaptive rate fallback algorithm sets the optimum transmission rate and Tx power based on actual SNR and packet loss information.
- Automatic retransmission and response on MAC to avoid packet discarding on slow host environment.
- Seamless roaming support.
- Configurable packet traffic arbitration (PTA) with dedicated slave processor-based design provides flexible and exact timing Bluetooth co-existence support for a wide range of Bluetooth Chip vendors.

Dual and single antenna Bluetooth co-existence support with optional simultaneous receive (Wi-Fi/Bluetooth) capability.

Pin Configuration

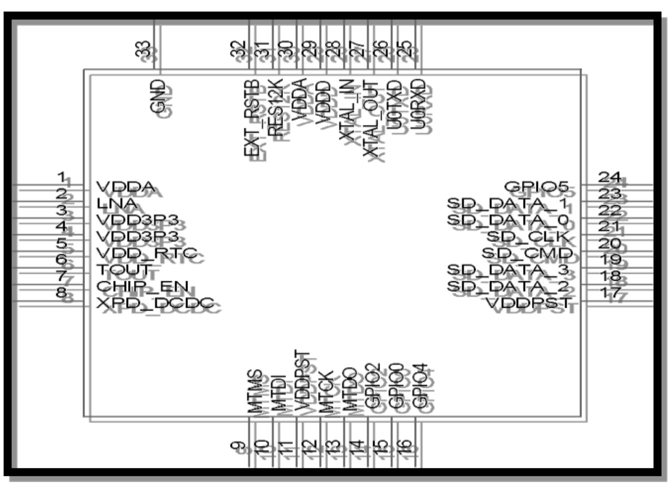

Figure 16. Pin configuration of Node MCU Esp8266 Wi-Fi module

CPU

ESP8266EX integrates Ten silica L106 32-bit micro controller (MCU) and ultra-low-power 16-bit RSIC. The CPU clock speed is 80 MHz It can also reach a maximum value of 160 MHz The CPU includes the interfaces as below.

- Programmable RAM/ROM interfaces (iBus), which can be connected with memory controller, and can also be used to visit flash.
- Data RAM interface (dBus), which can have connected with memory controller.

  AHB interface which can be used to visit the register.

Memory

ESP8266EX Wi-Fi SoC integrates memory controller and memory units including SRAM and ROM. MCU can access the memory units through iBus, dBus, and AHB interfaces. All memory units can be accessed upon request, while a memory arbiter will decide the running sequence according to the time when these requests are received by the processor.

According to our current version of SDK, SRAM space available to users is assigned as below.

- RAM size < 50 kB, that is, when ESP8266EX is working under the Station mode and connects to the router, programmable space accessible in heap + data section is around 50 kB.

There is no programmable ROM in the SoC, therefore, user program must be stored in an external SPI flash.

CHAPTER 7
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