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**CPE 592: Graduation Project Final Report**  
**[Special Needs Control System]**

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## **A. Abstract.**

Cerebral palsy (CP) is a problem that affects muscle tone, movement, and motor skills. It hinders the body's ability to move in a coordinated and purposeful way, It also can affect other body functions that involve motor skills and muscles. It occurs in about 2.1 per 1,000 live births.

CP can have a huge impact on most patients and their families .Feelings of depression, anxiety, and fear are very common and normal responses to this life-changing experience .

The goal of our project is to help those people by promoting physical activities , especially mild exercises such as daily walks and engaging them in activities they enjoy by building a simple wheelchair that moves without a high effort just by reading the brain signals and translating them into the wheelchair movements .

Our wheelchair moves forward , backward , left and right according to certain values of attention , meditation and eye blink read from the EEG sensor, which are transmitted wirelessly via Bluetooth from the Neurosky to the microcontroller.

## **B. Introduction.**

### **1. Statement**

The widespread availability of affordable EEG sensors has opened the doors to the limitless possibilities in the field of brainwave technology, the integration of brainwave technology into modern-day wheelchairs will give doctors and patients alike new options in addressing motor-related handicaps.

This project aimed to help solve the following issues:

complete dependency of people with no limbs or those with motor-related diseases with similar effects and partial paralysis that only leaves the affected access to only the most basic of motor movements such as eye-blinking.

### **2. Significance**

This project is aimed towards quadriplegics, paraplegics, people involved in freak accidents that have left them without an extremity or any for that matter and people with motor conditions severe enough to impair movement of the extremities; it will give them an alternative way of controlling traditional wheelchairs.

### **3. Goal**

The primary goal of our project is to develop a miniature wheelchair prototype that is controlled via the user's brain waves data .

### **4. Impact on society**

It helps to block negative thoughts or distract the patient from daily worries , also it may help reduce the patient's distress and the distress of those who care about her/him.

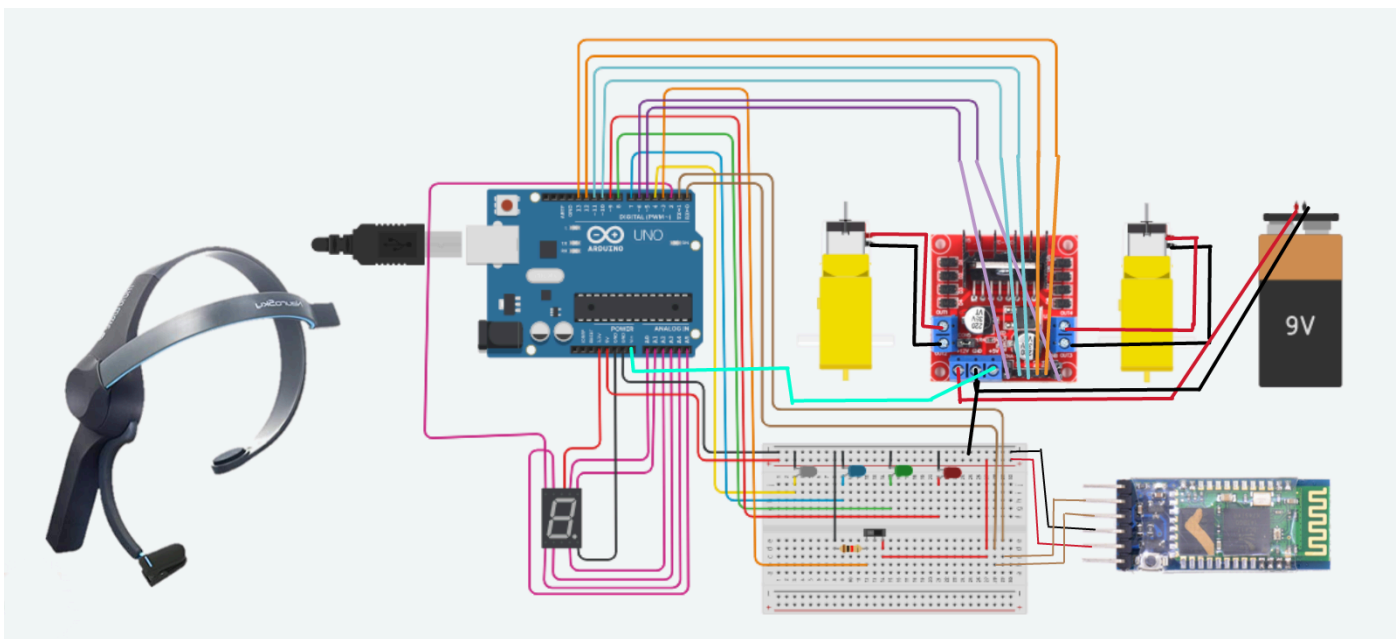
### **5. Main limitation**

Due to the nature of brainwaves, complete and absolute control over them is impossible.

## **C. Professional practice constraints.**

1. For brainwave detection, the inconsistencies and fluctuations in brainwave data can mostly be attributed to human's inability to have complete control over their brainwaves.
2. The available financial resources we had at hand played a huge role in the choice of NeuroSky Mindwave Mobile2 sensor and only a miniature wheelchair prototype will be created.
3. The NeuroSky Mindwave Mobile2 sensor can only use attention, meditation and blink strength levels as methods of control and cannot identify a human being's specific thoughts.
4. Quality of transmission signal may be affected by interference from other devices.
5. Life of AAA battery that used to power the NeuroSky Mindwave Mobile2 sensor is short , we had to replace it daily.

## D. System architecture and design.



**Fig 1: Hardware implementation.**

The hardware components and supplies are:

- § Arduino Uno.
- § L298N motor driver.
- § 2 DC-Motor.
- § HC-05 Bluetooth.
- § LED.
- § Switch.
- § Seven Segment display.
- § 9V battery.

**1. Arduino UNO [1].**

Is an open-source micro-controller board based on the Microchip ATmega328P micro-controller and developed by Arduino. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 20 volts. (shown in figure 5)



Fig2 : Arduino uno.

**2. Dc Motor [2].**

Is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromagnetically or electronic, to periodically change the direction of current flow in part of the motor. [3] (shown in figure 1)



Fig3 : DC motor.

### 3. Hc-05 Bluetooth.

the easier way to transfer the data from NeuroSky to Arduino is via the Bluetooth serial interface, we use in this project HC-05 Bluetooth.(shown in figures 3&4)

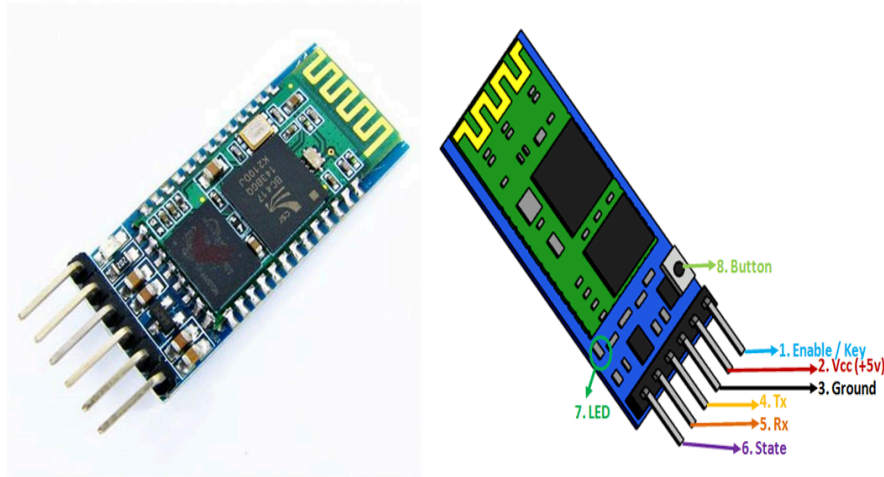


Fig4: Hc-05 Bluetooth.

### 4. L298 Motor Driver [3].

It is a dual H-Bridge motor driver which allows speed and direction control of two DC motors at the same time. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A. It enables the control of DC motors by amplifying the low-current signal from the Arduino into a higher-current signal suitable for motor control .(show in figure 6)

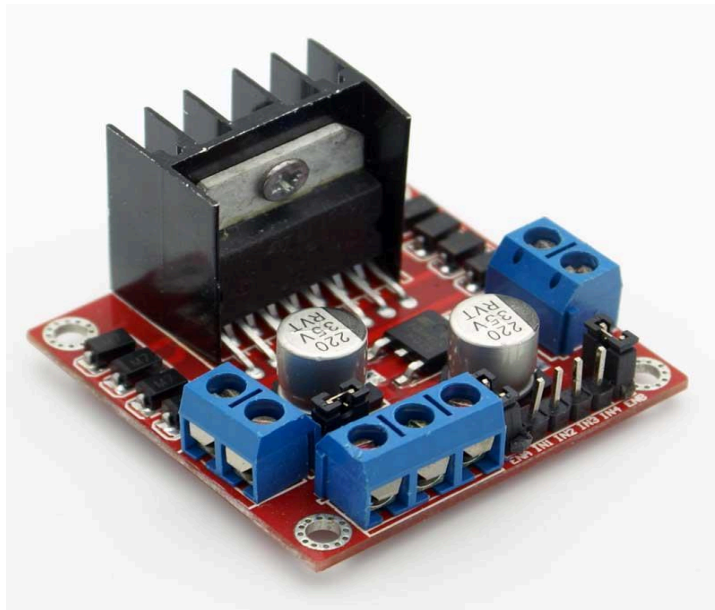


Fig 5:Motor driver.

## 5. Battery [4].

Is a collection of one or more cells whose chemical reactions create a flow of electrons in a circuit. All batteries are made up of three basic components: an anode (the '-' side), a cathode (the '+' side), and electrolyte (a substance that chemically reacts with the anode and cathode). When the anode and cathode of a battery is connected to a circuit, a chemical reaction takes place between the anode and the electrolyte. This reaction causes electrons to flow through the circuit and back into the cathode where another chemical reaction takes place.[5](shown in figure 7&8) .

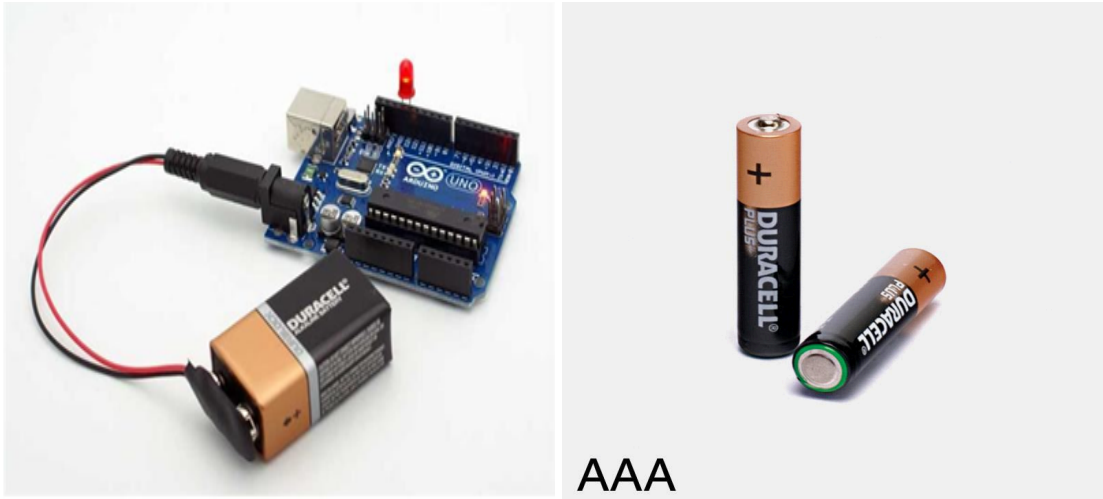


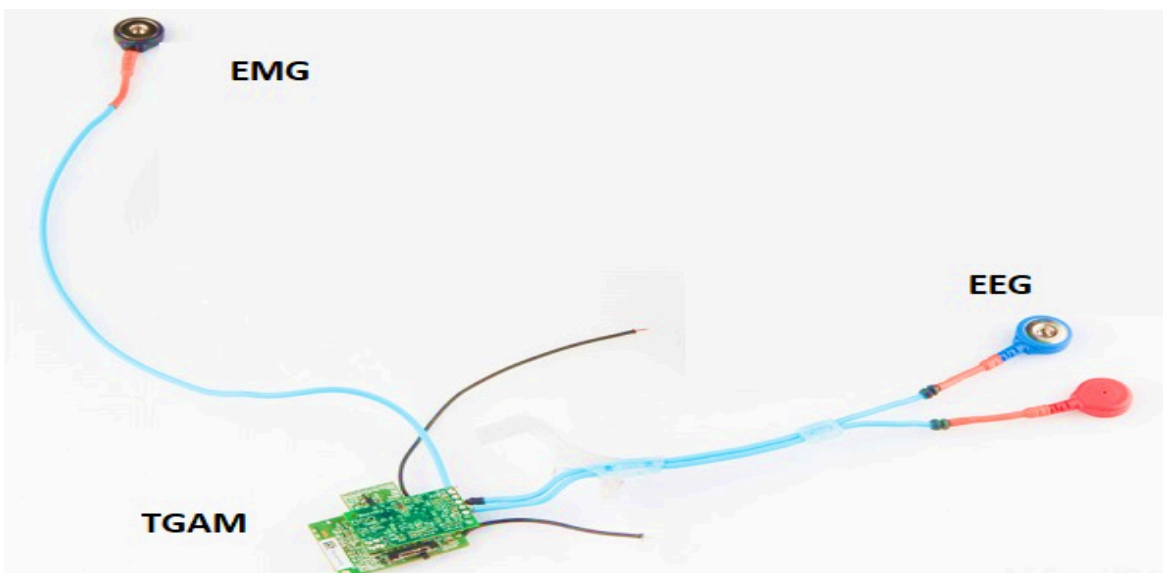
Fig 6: Battery.

6. **NeuroSky Mind-wave Mobile2 [6].**

Is an EEG headset that safely measures and transfers the power spectrum (alpha waves, beta waves, etc.) data via Bluetooth Low Energy (BLE) or Bluetooth Classic to wirelessly communicate with your computer, iOS, or Android device.

The Mind-Wave Mobile 2 is simple, consisting only of a headset with a T-shaped headband , a wider ear clip , and a flexible sensor arm . The headset's reference and ground electrodes are on the ear clip, while the EEG electrode is on the flexible sensor arm, resting on the forehead above the eye.

Fig 7: The sensors inside the neurosky device EEG and EMG.



## **The NeuroSky consists of three main components :**

### **I. EMG.**

EMG records the electrical movement of our muscles. It is based on whenever a muscle contracts, a burst of electric activity is generated which propagates through adjacent tissue and bone and can be recorded from neighboring skin areas, in our project, EMG sensor is placed on the top of the left eye to measure the eye blinking using EMG sensor that track very deep muscles in the face.

### **II. EEG.**

EEG is an electrophysiological monitoring method to record electrical activity of the brain. EEG sensors are placed on the head then measure voltage fluctuations resulting from current within the neurons of the brain then transmit them to a chip called Think-geek chip , this chip represents a special processor that processes these signals and filter them out extraneous noise and electrical interference and convert them to digital power.

### **III. ThinkGear AM.**

The ThinkGear AM (TGAM) is the core of our brainwave sensing technology. TGAM allows NeuroSky partners to bring EEG-based consumer technologies to market quickly and efficiently.

Together with dry electrode, it senses the signals from the human brain, filters out extraneous noise and electrical interference and converts to digital power.

Embedded within the TGAM, is the TGAT chip, a powerful, fully integrated single chip EEG sensor. The chip comes programmed with NeuroSky eSense, A/D, amplification off head detection, and noise filtering for EMG and 50/60Hz AC powerline interference.

## **7. LED**



Fig 9: LED.

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.

#### 8. Seven Segment display

A seven-segment display is a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot matrix displays.

Seven-segment displays are widely used in digital clocks, electronic meters, basic calculators, and other electronic devices that display numerical information.

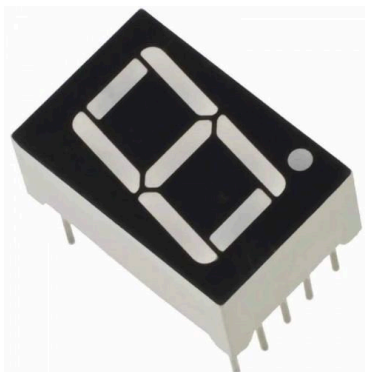


Fig 10: Seven segment.

#### 9. Switch

a switch is an electrical component that can disconnect or connect the conducting path in an electrical circuit, interrupting the electric current or diverting it from one conductor to another. The most common type of switch is an electromechanical device consisting of one or more sets of movable electrical contacts connected to

external circuits. When a pair of contacts is touching current can pass between them, while when the contacts are



separated no current can flow.

Fig 11: Switch.

## E. Hardware implementation.

### 1. Construction.

The major components of this project are as follows: the Neurosky Mindwave Mobile for brainwaves, an HC-05 Bluetooth module for wireless transmission of data, , an Arduino UNO microcontroller to process the data from the Neurosky into a car movement , and a motor driver module to operate the miniature car's motors. The devices mentioned work together to give a person control over the car using only his mind.

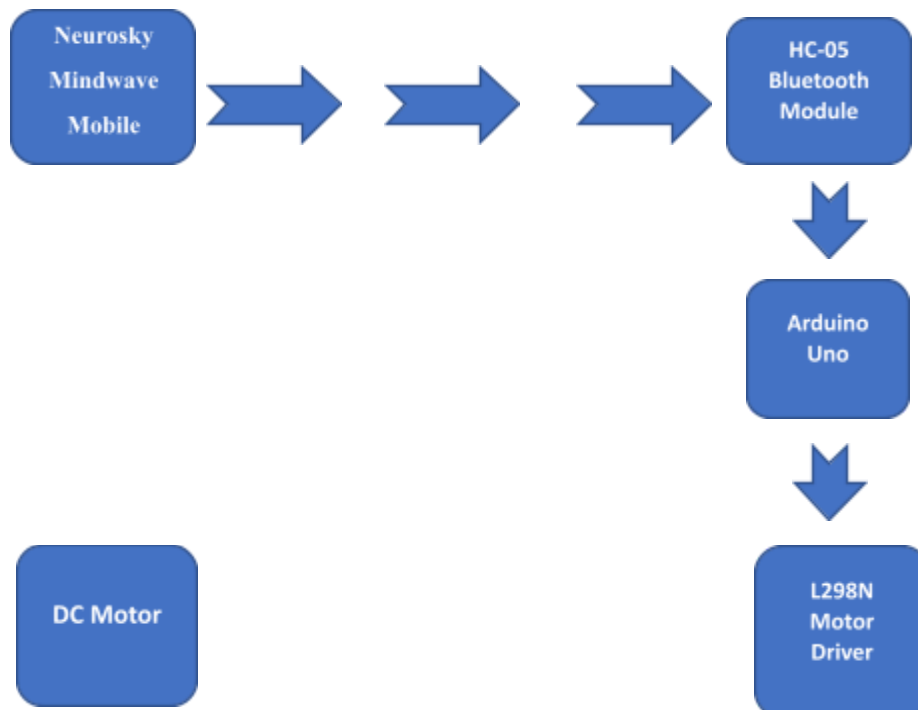




Fig 12: A basic description of how the project works.

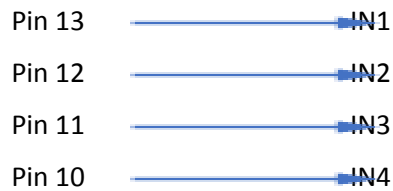
## 2. Pin to pin connection

### I. Arduino to Motor driver

#### - Direction Control Pins

IN1&IN2 pins are used to control spinning direction of Motor A. When one of them is HIGH and other is LOW, the Motor A will spin. If both the inputs are either HIGH or LOW the Motor A will stop.

IN3&IN4 pins are used to control spinning direction of Motor B. When one of them is HIGH and other is LOW, the Motor B will spin. If both the inputs are either HIGH or LOW the Motor B will stop.



The spinning direction of a motor can be controlled by applying either a logic HIGH(5 Volts) or logic LOW(Ground) to these inputs. The below chart illustrates how this is done.

Input1	Input2	Spinning Direction
Low(0)	Low(0)	Motor OFF
High(1)	Low(0)	Forward
Low(0)	High(1)	Backward
High(1)	High(1)	Motor OFF

Table 1: A description of the movement of the motor.

#### - Speed Control Pins

ENA & ENB pins are used to control the speed of each Motor. Pulling them HIGH (Keeping the jumper in place) will make the Motor spin, pulling LOW will make the motor stop. But if we remove the jumper and connect these pins to PWM input we can control the speed of the motor .



### - Power Supply Pins

The L298N motor driver module is powered through 3-pin. It consists of pins for motor power supply( $V_s$ ), ground and 5V logic power supply( $V_{ss}$ ).

## II. Arduino to HC-05

The VCC pin on the HC-05 Bluetooth Module is connected to the 5V pin on the Arduino Uno, the HC-05 TX pin to the Arduino RX pin, the HC-05 RX pin to the Arduino TX pin and the HC-05 GND pin to the Arduino GND pin.

## III. Motor driver to DC motor

OUT1 and OUT2 on the L298N Motor Driver is connected to the positive and negative terminals of the first and second DC motor.

## f. Software implementation.

### 1.Auto connect NeuroSky with Arduino via HC-05 Bluetooth.

Reprogramming hc05 Bluetooth using AT command mode follow these steps  
1-connect hc05 with Arduino (show figure 13).

HC05 (VCC)	- ARDUINO (5V)
HC05 (GND)	- ARDUINO (GND)
HC05 (RX)	- ARDUINO (11)
HC05 (TX)	- ARDUINO (10)
HC05 (EV)	- ARDUINO (09)

Fig 13: The HC05 connection to the Arduino.

2-Upload code in figure 14 on Arduino where this code read command from serial monitor then send it to hc05 then hc05 resend "OK" as acknowledgment .

```

#include <SoftwareSerial.h>
SoftwareSerial BTSerial(10,11);
void setup()
{
  Serial.begin(9600);
  BTSerial.begin(38400);
  Serial.println("Enter AT commands:");
}

void loop()
{
  if(BTSerial.available())
    Serial.write(BTSerial.read());

  if(Serial.available())
    BTSerial.write(Serial.read());
}

```

Fig 14: Code to accomplish the AT mode .

3-Power on HC05 in Command Mode by pressing the button on HC05 while switching on the Arduino.

4-Open serial monitor and select baud rate 9600 and both NL & CR options when sending stuff from the monitor to the Arduino because each command must end with `\r\n`.

5-Enter the commands (show in table x), you may have to try multiple times until OK is returned for each command except `AT+INQM`.

COMMAND	DISCRIBTION	Respond
AT	Enter AT command mode	OK
AT+UART:38400,0,0	Param1: Baud rate is 38400 bps Param2: Stop bit is 0 Param3: Parity bit is 0	OK

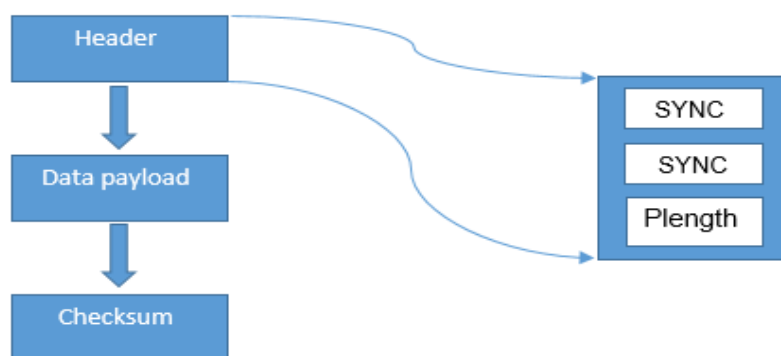
<b>AT+ROLE:1</b>	Param: 1: master mode 0: slave mode 2-Slave-Loop	OK
<b>AT+PSWD:0000</b>	The password must be "0000" because the default password for Neurosky is "0000" so when hc05 connect with neurosky enter "0000" as password	OK
<b>AT+CMOD:0</b>	Param: 0 : connect fixed address 1 : connect any address 2 : slave-Loop	OK
<b>AT+INQM:1,1,48</b>	Param1: 0: inquiry_mode_standard 1: inquiry_mode_rssi Param2: Maximum number of Bluetooth devices to respond to. Param3: Timeout (1-48 : 1.28s to 61.44s).	OK
<b>AT+IAC:9C8B33</b>	The Inquiry Access Code (IAC) is the first level of filtering for finding Bluetooth devices and services. The main purpose of defining multiple IACs is to limit the number of responses when scanning devices within range.	OK
<b>AT+BIND:81,F9,138708</b>	Fixed address for neurosky	OK

<b>AT+NAME:CPE_2015</b>	Set the module name to "CPE_2015"	OK

Table 2: A description of each command in the AT mode.

## 2. ThinkGear packet structure[7].

Packets are sent as an asynchronous serial stream of bytes. Each Packet begins with its Header, followed by .Data Payload, and ends with the Payload's Checksum Byte as shown in figure Below

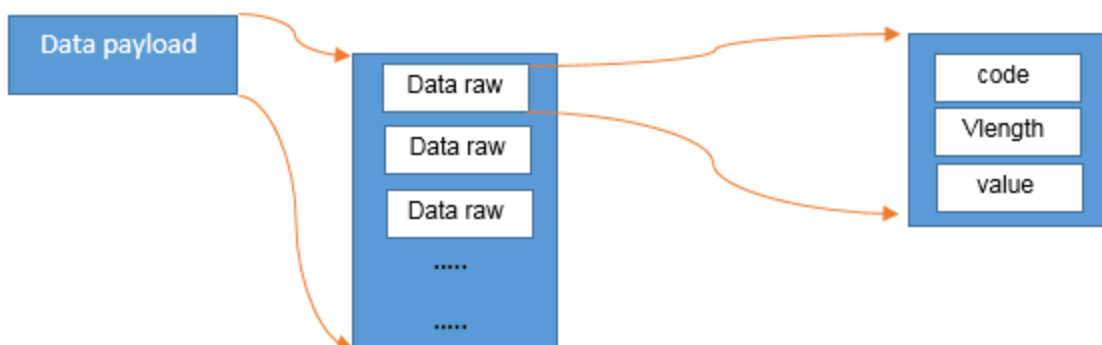


.Fig 15: The header structure inside the packet

The Header of a Packet consists of 3 bytes: two synchronization bytes have value 170 in decimal (0xAA) refers to the beginning of a new arriving Packet, followed by a [PLENGTH] value indicates the length of the packet's Data .Payload [PAYLOAD...] in bytes with range from 0 up to 169

Note that the synchronization is two bytes long, instead of only one, to reduce the chance that (0xAA) bytes .occurring within the Packet could be mistaken for the beginning of a Packet

Data payload contain the series of data rows each data row contain (code, V\_Length, value) as shown below, except the data row that have code whose values between 0x00 to 0x7f ,they not have V\_Length ,so their . length is one byte



.Fig 16: Data payload structure

The code byte indicates the type of Data Value encoded in the Data raw, for a list of defend [CODE] meanings, see .the tables below

Code	(Length(byte	Data value meaning
0x02	1	Poor signal quality
0x04	1	Attention
0x05	1	Meditation
0x80	2	RAW Wave Value
0x83	24	ASIC_EEG_POWER

Table 3:The code value in the packet with its meaning.

Neurosky device can detect five brainwaves (signals) that are measured and reported originate from different parts of the brain, the signals are : Delta, Theta, Alpha, Low Beta, High Beta and Gamma, and a calculated value for attention and meditation.

**Gamma waves** are oscillating waves with frequencies around 40 Hz, although they can be as high as 100 Hz and as low as 24 Hz. These originate from the thalamus (buried deep in the center of the brain) and are responsible for states of high attention and concentration.

**Alpha waves** originate at the Occipital lobe and have a frequency of 8-12Hz. These are most present when you are awake but are very drowsy or relaxed.

**Theta waves** are oscillating waves that are located in the Hippocampus and are associated with dreaming. They are in the 4-7Hz range

**Beta waves** are between 12 and 30 Hz and are the states associated with normal waking consciousness. These are emitted from the motor cortex, a region of the cerebral cortex, which is the outermost layer of tissue on the brain. Beta waves are split into three sections: Low Beta Waves (12.5-16 Hz, "Beta 1 power"); Beta Waves (16.5–20 Hz, "Beta 2 power"); and High Beta Waves (20.5-28 Hz, "Beta 3 power")..

**Delta waves** are associated with very deep, dreamless sleep cycles and are high amplitude waves, which have a 0 to 3Hz frequency. These waves emit from both the thalamus and the cortex.

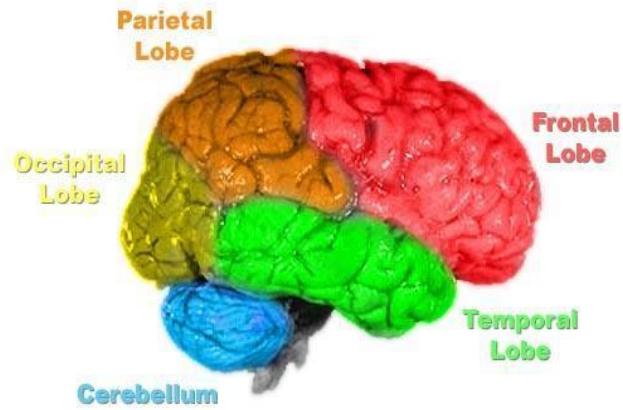


Fig 17: Brain divisions.

## Programming

The software design starts with initializing variables then it followed by a list of functions as shown:

- 1- **setup(void)**: function to initialize variables, pin modes and set the data rate in bits per second (baud) for serial data transmission .It will run only once, each time you power up or reset the Arduino board.
- 2- **loop(void)**: function that allows program to change , respond and control the Arduino board, the first thing to do is check if the first two synchronization bytes of the received packet have a value of 0XAA , then it calls either Small\_Packet or Big\_Packet functions depends on the value of plength, and then if big packet is received the function start with a series of tests based on signal quality , time and blink values then it sets the flag values that indicate which direction the car should move.

After that, it checks the status of switch if on then the code sends low signals to stop the car from moving, else it send signals to car motors based on direction flags.

- 3- **sevseg (void)** :function receive the number of packets when the first blink is received to display it on seven-segment display , the number is compared with the values of each case from zero to nine ,If there is a match, it send the appropriate signals to each LEDs on seven-segment display to show this number.
- 4- **read\_3byte\_int(void)**: function to read three sequential bytes and concatenate them into one integer value.
- 5- **read\_waves(void)**: function to read EEG waves (Delta, Theta, Low Alpha, High Alpha, Low beta, High Beta, Low Gamma, High Gamma) respectively.
- 6- **Small\_Packet (void)**: function to read small packet from NeuroSky, which contains only raw data value then it detects if it has any errors using checksum algorithm.
- 7- **Big\_Packet(void)**: function to read big packet from NeuroSky, which contains attention ,meditation, blink, and EEG waves values or all of them then detects if it has any errors using checksum algorithm .

8- **Eye\_Blink (void)**: function that calculate value of eye blink based on the average of blinks value then returns it.

## G. Algorithm of testing

The training strategy used in moving and controlling the car directions is based on the brain signals that were read by the Neurosky, the main is Eyeblink, also poor Quality and mediation are used.

Here are brief descriptions and some samples :

### 1.Eye Blink [5]:

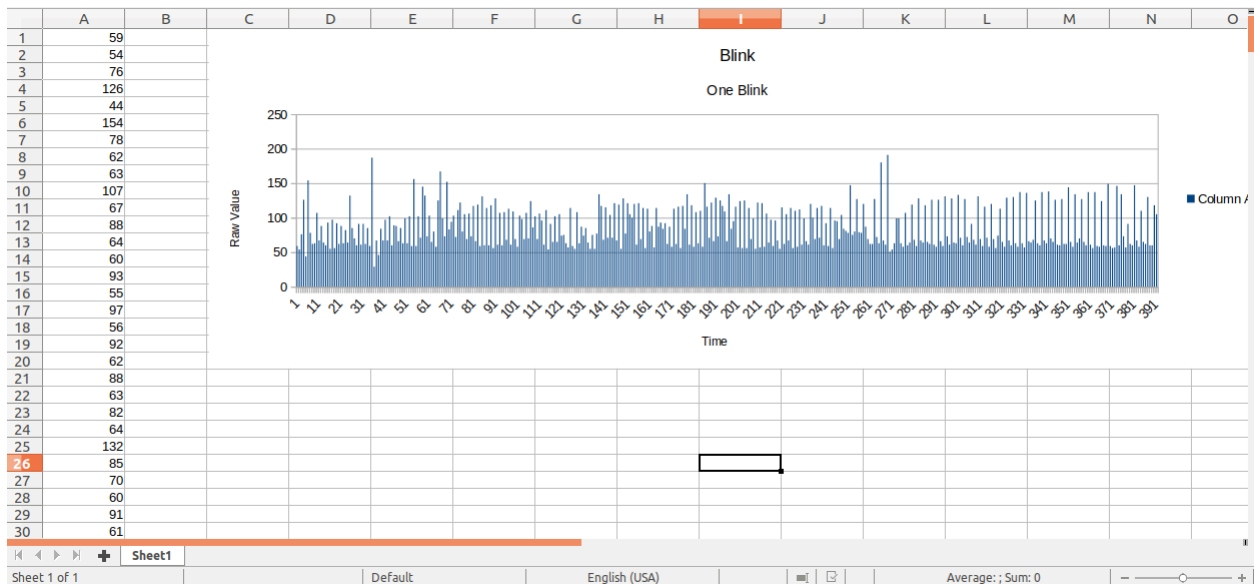
The Mindwave Mobile can detect blinks. It does this by using Electrooculography or EOG. EOG measures the electrical potential between electrodes placed at points near the eye or in the ocular region. Blink detection with EOG follows the concept that whenever a person blinks, a resulting spike in the EOG data.

Blinking harder or with more force will output a larger value while blinking with less force will output a smaller value, using multiple tests to determine the average threshold value of forced blinks, normal blinks, one blink and two blinks.

It is very important to know that the Mindwave Mobile's blink detection is not 100% accurate. This is not due to inefficient or improper coding but rather due to the sensor itself and the nature of blink detection

“ Neurosky itself has stated that their blink detection is not 100% accurate” .

Fig

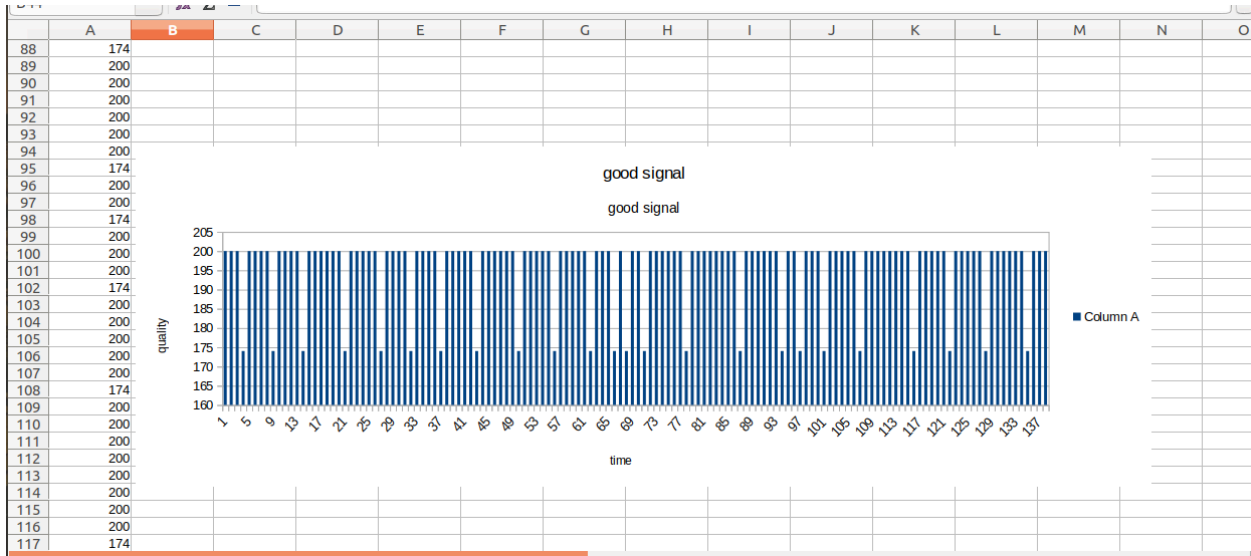


18.one blink

## 2. Poor Quality [5]:

This unsigned one-byte integer value describes how poor the signal measured by the ThinkGear is. It ranges in value from 0 to 200. Any non-zero value indicates that some sort of noise contamination is detected. The higher the number, the more noise is detected. A value of 200 has a special meaning, specially that the ThinkGear contacts are not touching the user's skin. This value is typically output every second and indicates the poorness of the most recent measurements.

Fig



19.good signal

## 3. Meditation [5]:

This unsigned one-byte value reports the current eSense Meditation meter of the user, which indicates the level of a user's mental "calmness" or "relaxation". Its value ranges from 0 to 100. The Meditation is a measure of a person's mental levels, not physical levels, increases when a person relaxes his mind and decreases when he becomes stressed.

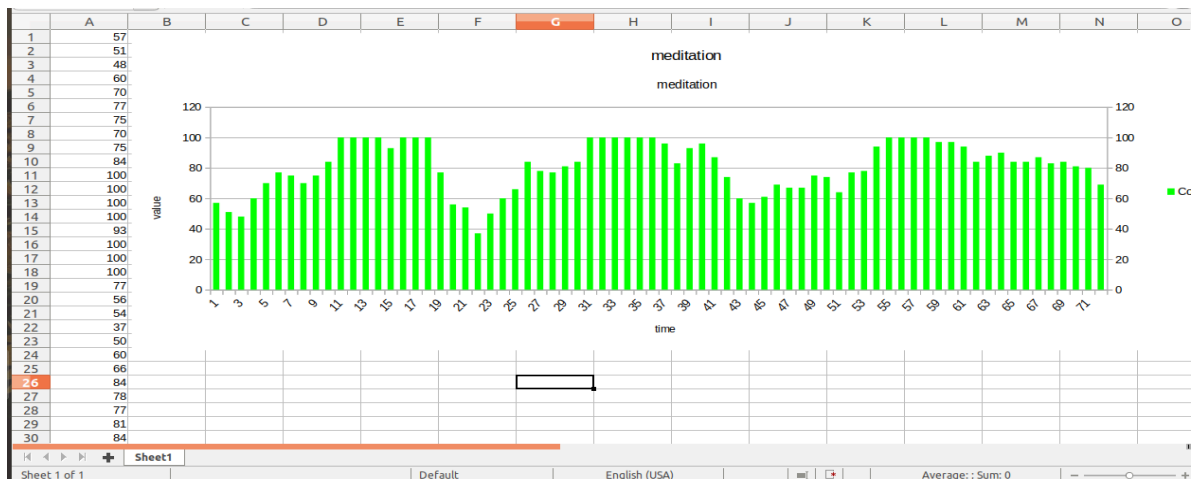


Fig 20. Meditation

**4. Flow Chart of the testing algorithm :**

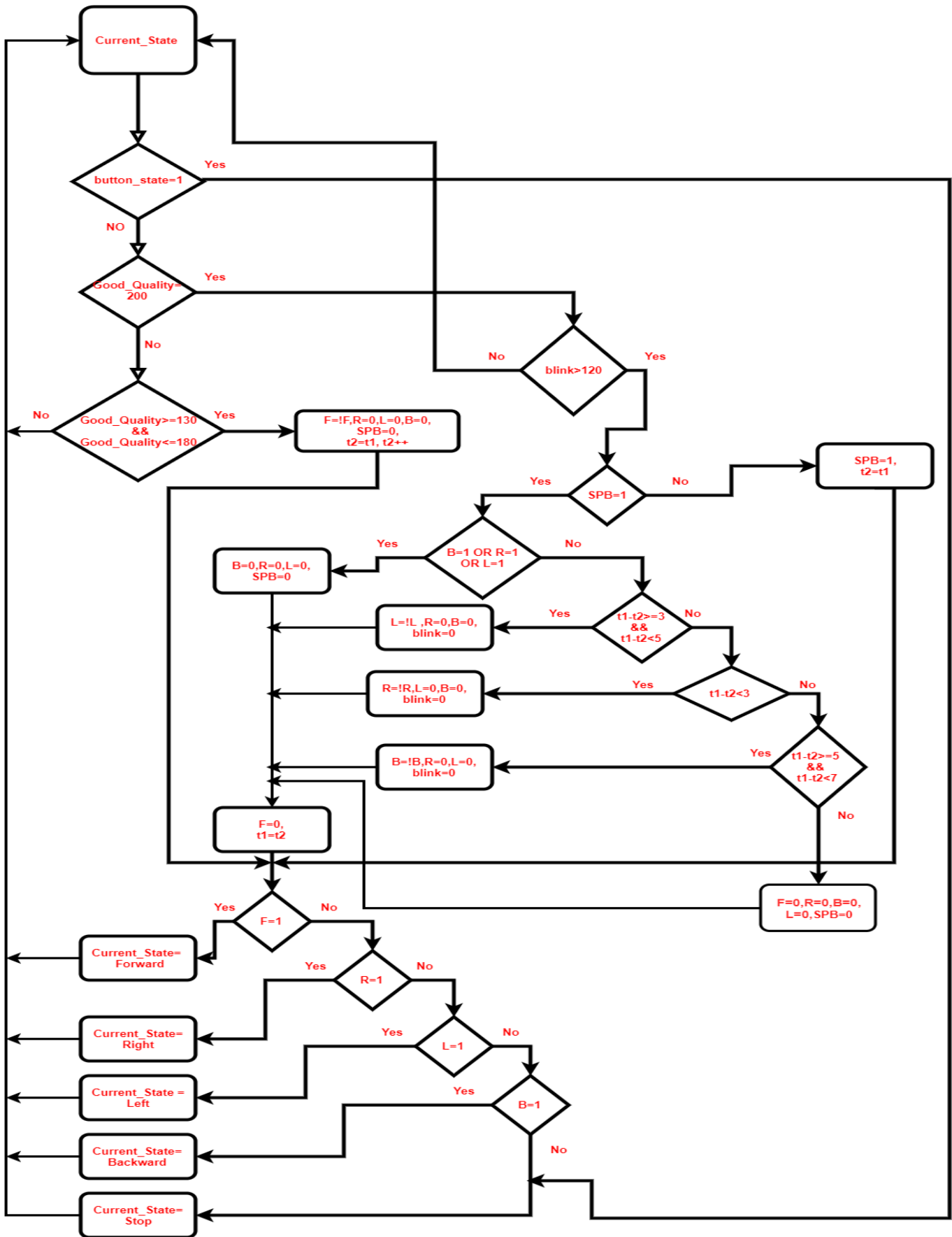


Fig 21 :Algorithm flow chart

The flow chart above represents the algorithm used to get 4 directions (right,left,forward,backward) , moving the car according to them and stop it .

Where F refers to Forward Direction Flag , R □ Right Direction Flag , L □ Left Direction Flag , B □ Back Direction Flag , SPB □ Start Blink Packet .

- The car moves **Forward** if you brow lifted .So a packet with poor quality received since the ThinkGear contacts moves away from its position.
  
- The car moves **Right** if a blink packet received within the two packets received after the beginning of the blink packet.
  
- The car moves **Left** if a blink packet received within the 3-4 packets received after after the beginning of the blink packet.
  
- The car moves **Backward** if a blink packet received within the 5-6 packets received after the beginning of the blink packet.

#### H. Bibliography

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