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TITLE	OFFICE AUTOMATION USING ESP32	

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ABSTRACT:

This paper describes how to use an ESP32-based web server to monitor and/or gather statistics on the PV and battery current and voltage in a small photovoltaic (PV) power system. The developed system makes use of inexpensive sensors, an SD card reader, Wi-Fi, and a microcontroller called ESP32.

Data is gathered from sensors by the ESP32. The data are saved on an SD card that is attached to the ESP32 using SPI pins as a text file. The system keeps the text file on the SD card for a week or more before deleting it and moving on to saving new data.

The ESP32 is configured to view the web page using Wi-Fi from a laptop, smartphone, or tablet because the web page file is kept on an SD card as well. Additionally, visitors can download the data text file from the website by clicking on a link on the page.

This is also possible from a distance. The studies' findings show that the web server operates in real-time and is useful for keeping an eye on modest solar energy plants.

INTRODUCTION:

The ESP32 family of system on a chip microcontroller features integrated Wi-Fi and dual-mode Bluetooth and is inexpensive and low power. The Tensilica Xtensa LX6 dual-core or single-core microprocessor, Tensilica Xtensa LX7 dual-core, or a single-core RISC-V microprocessor is used in the ESP32 series, which also has integrated antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power-management modules. Chinese business Espressif Systems, with headquarters in Shanghai, invented and constructed the ESP32, which is produced by TSMC using their 40 nm technology. It is the ESP8266 microcontroller's replacement.

Features of the ESP32 include the following:

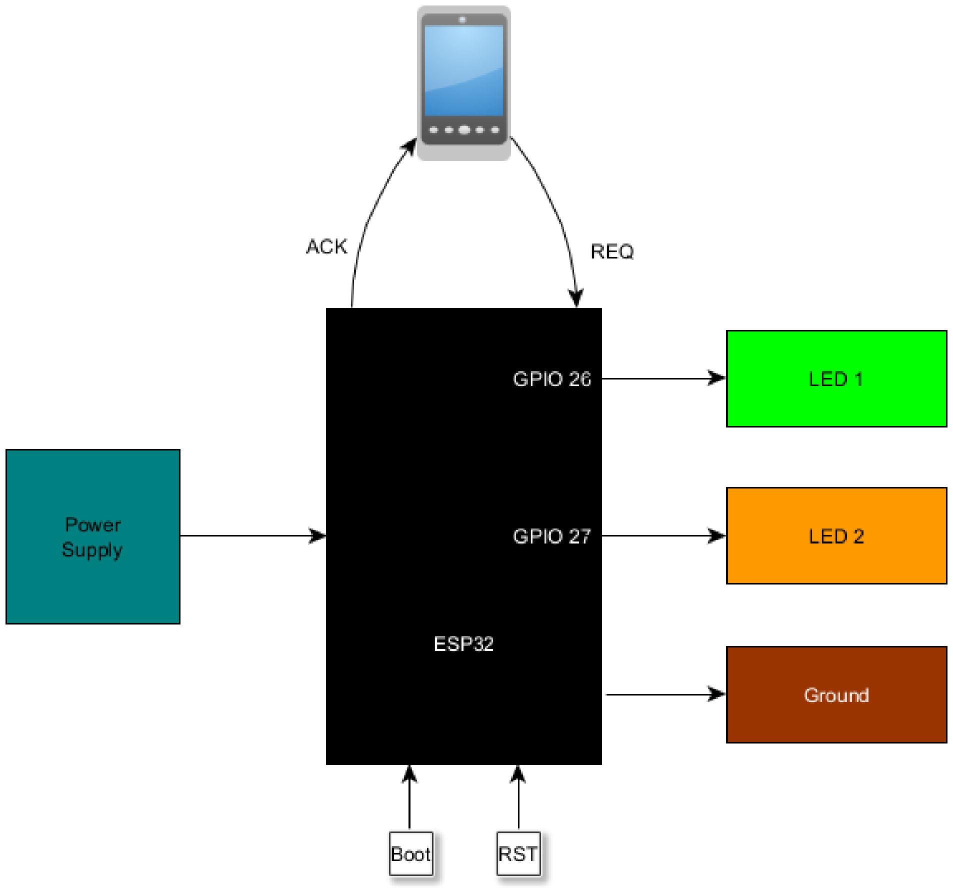
- Processors:
    - CPU: Xtensa dual-core 32-bit LX6 microprocessor, operating at 160 or 240 MHz and performing at up to 600 DMIPS
    - Ultra-low power co-processor
- Memory: 320 KiB RAM, 448 KiB ROM
- Wireless connectivity:
    - Wi-Fi: 802.11 b/g/n
    - Bluetooth: v4.2 BR/EDR and BLE
- Peripheral interfaces:
    - 34 × programmable GPIOs
    - 12-bit SAR ADC up to 18 channels
    - 2 × 8-bit DACs
    - 10 × touch sensors (capacitive sensing GPIOs)
    - 4 × SPI
    - 2 × I^2S interfaces
    - 2 × I^2C interfaces
    - 3 × UART
    - SD/SDIO/CE-ATA/MMC/eMMC host controller
    - SDIO/SPI slave controller
    - Ethernet MAC interface with dedicated DMA and planned IEEE 1588 Precision Time Protocol support
    - CAN bus 2.0
    - Infrared remote controller (TX/RX, up to 8 channels)
    - Pulse counter (capable of full quadrature decoding)
    - Motor PWM
    - LED PWM (up to 16 channels)

    - Hall effect sensor
    - Ultra-low power analog pre-amplifier
- Security:
    - IEEE 802.11 standard security features all supported, including WPA, WPA2, WPA3 and WLAN Authentication and Privacy Infrastructure
    - Secure boot
    - Flash encryption
    - 1024-bit OTP, up to 768-bit for customers
    - Cryptographic hardware acceleration: AES, SHA-2, RSA, elliptic curve cryptography (ECC), random number generator (RNG)
- Power management:
    - Internal low-dropout regulator
    - Individual power domain for RTC
    - 5 µA deep sleep current
    - Wake up from GPIO interrupt, timer, ADC measurements, capacitive touch sensor interrupt

ALGORITHM:

```
START
Set SSID & Password for the ESP32 WiFi Module
Initialize Web server port number to 80
Initialize variales to store HTTP request and current output state
Initialize output variables to GPIO pins
Start the WiFi client to listen for incoming clients
If new client connects
     loop while client is connected
          if two newline inputs in a row exit
               close the connection
          else check for GPIOs on and off

          Display the web page to client
          Do changes according to the input
     close the connection
END
```

BLOCK DIAGRAM:

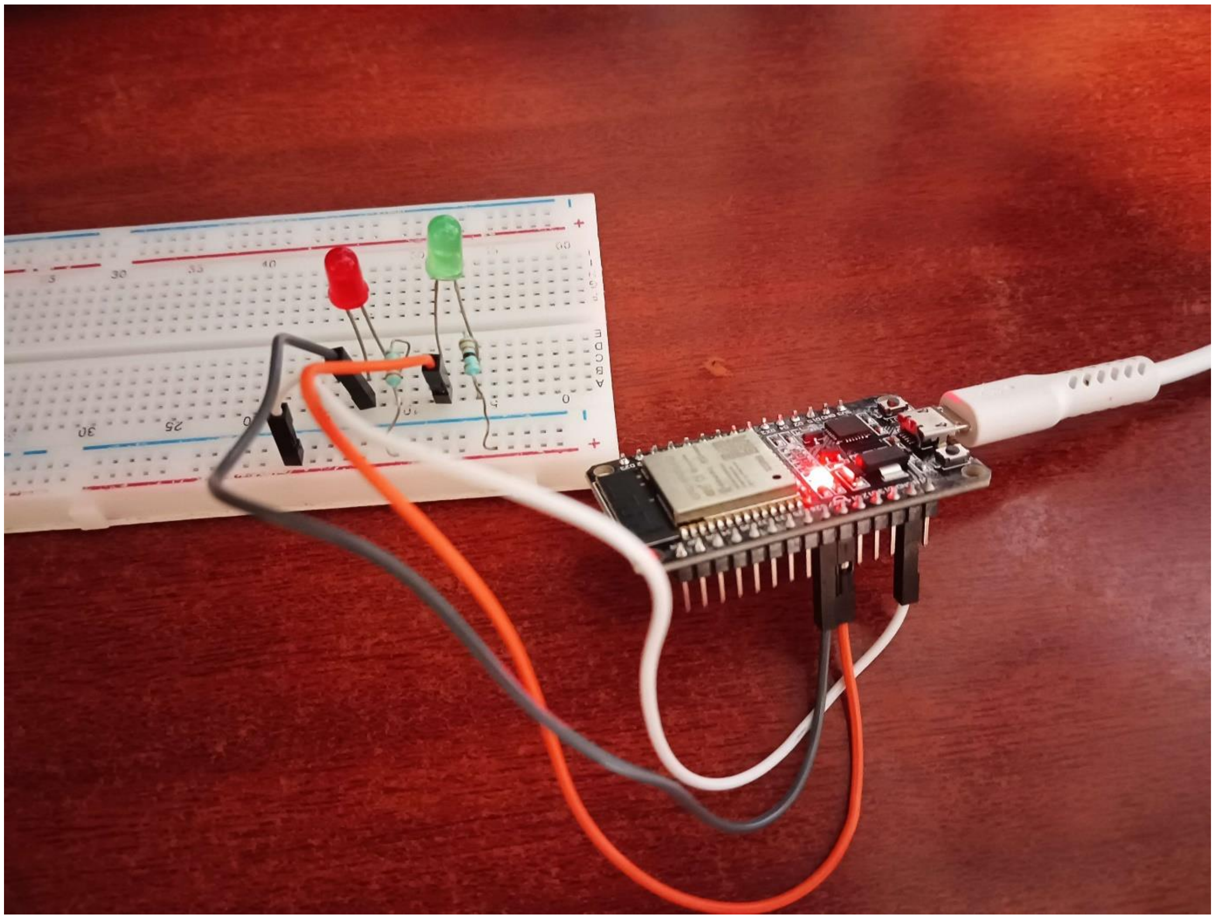


IMPLEMENTATION (REAL TIME):

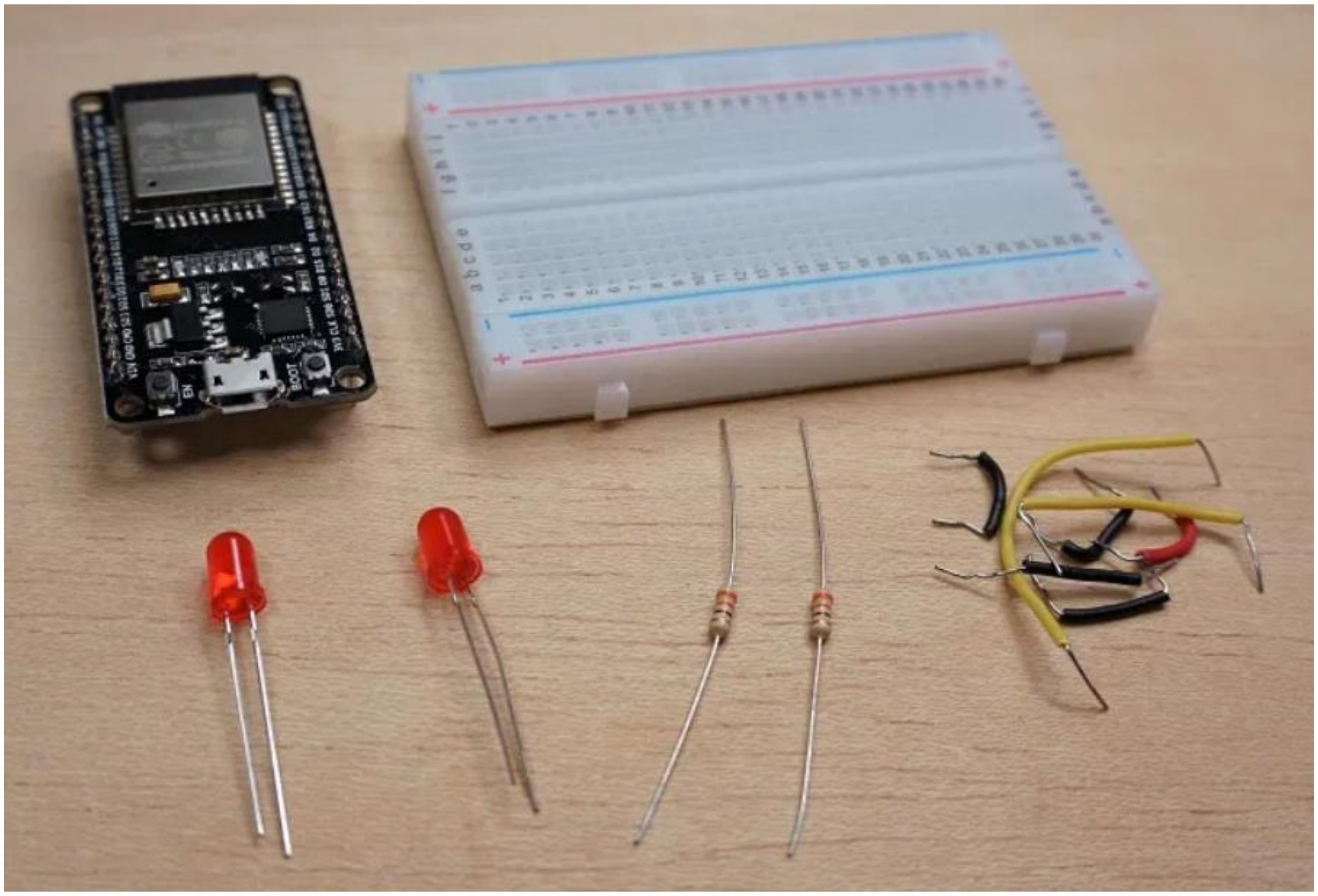
It is important to outline what our web server will do: -

- The web server you'll build controls two LEDs connected to the ESP32 GPIO 26 and GPIO 27;
- You can access the ESP32 web server by typing the ESP32 IP address on a browser in the local network;
- By clicking the buttons on your web server, you can instantly change the state of each LED.

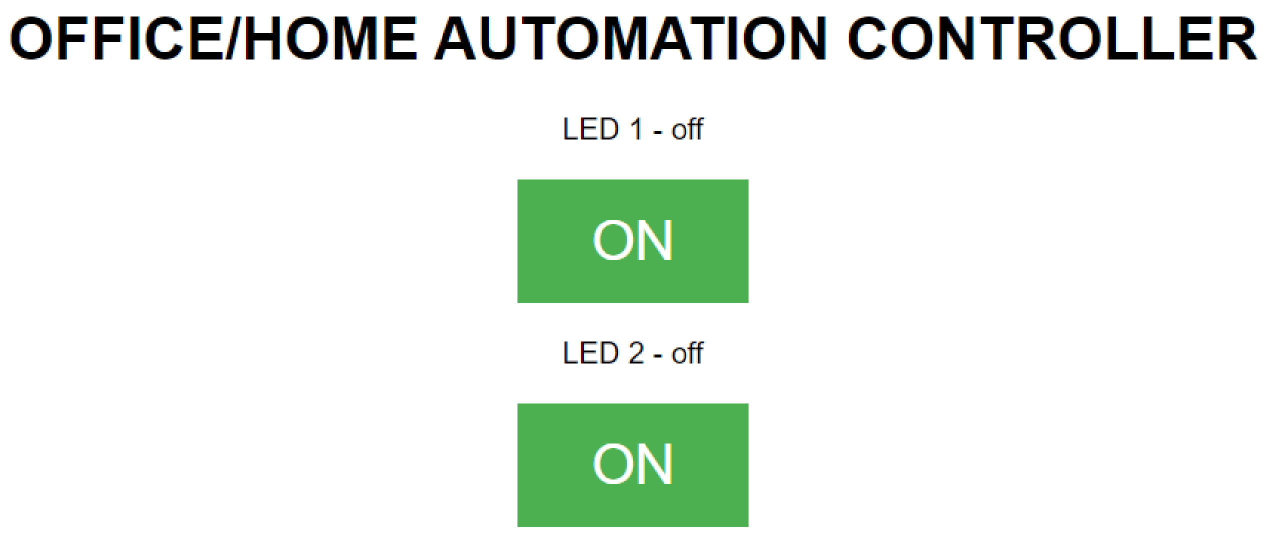
This is just a simple example to illustrate how to build a web server that controls outputs, the idea is to replace those LEDs with a relay, or any other electronic components you want in your office/home automation.

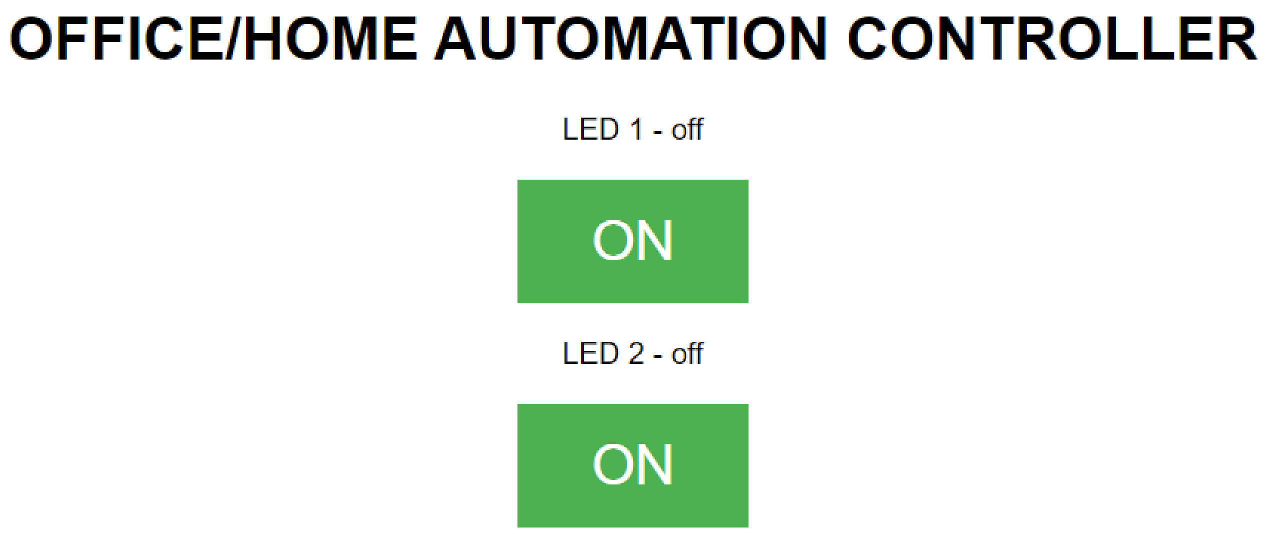

This is how the connections look like.

Components Required: -

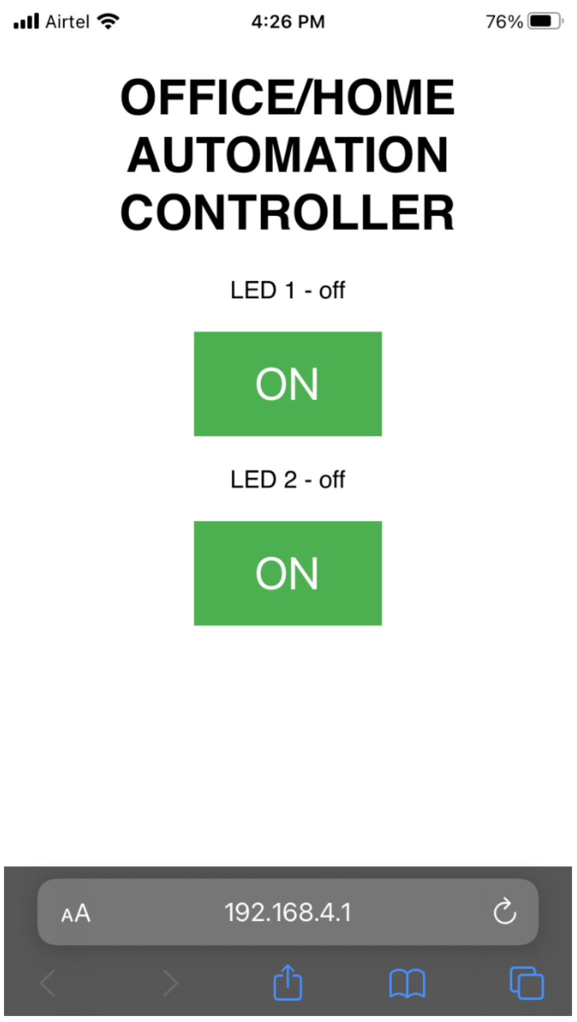


Web Page: - (We accessed this web page using the IP Address generated by the ESP32 in serial monitor)





Phone GUI: -



OFFICE/HOME AUTOMATION CONTROLLER

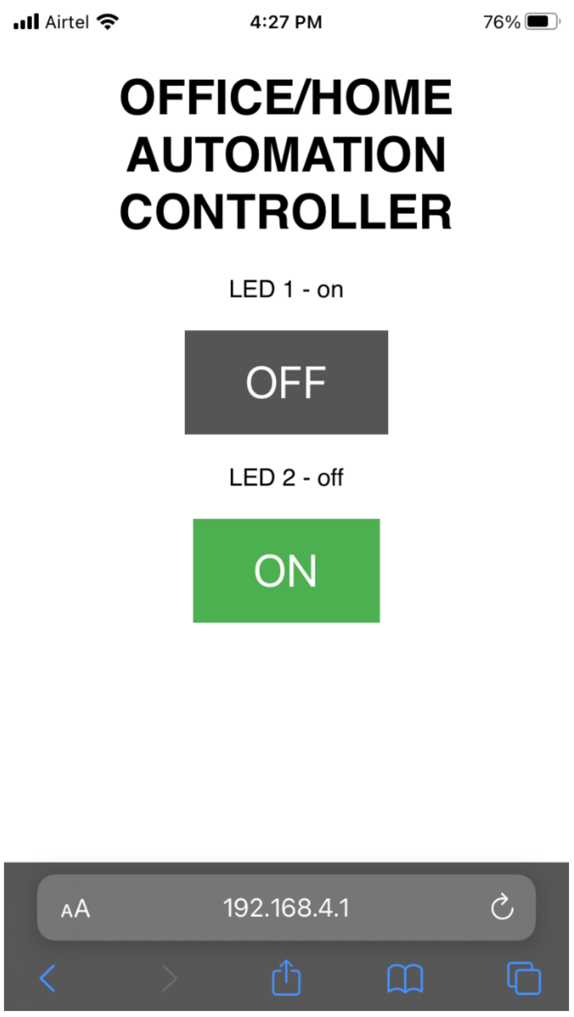
LED 1 - off

ON

LED 2 - off

ON

192.168.4.1



OFFICE/HOME AUTOMATION CONTROLLER

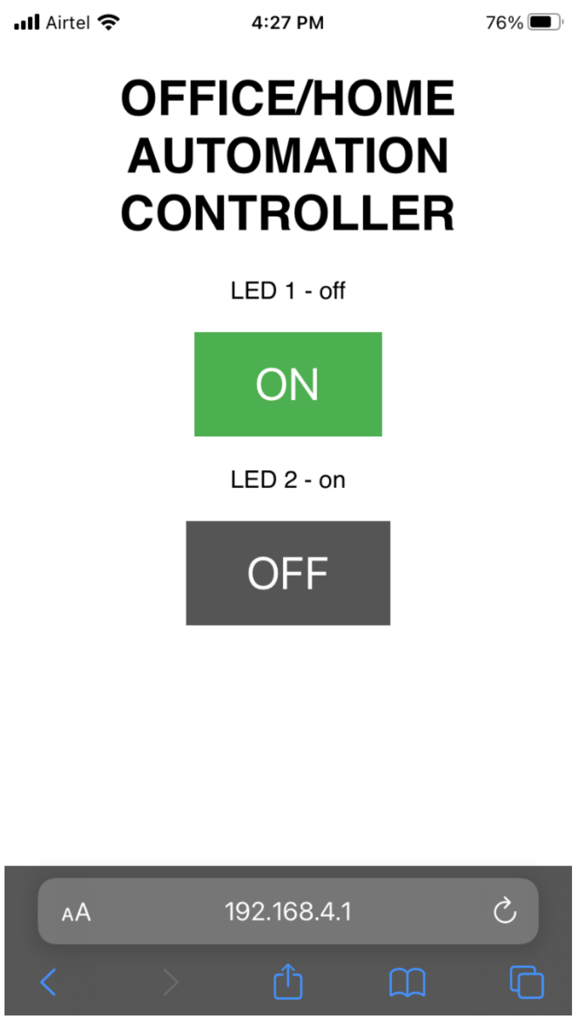
LED 1 - on

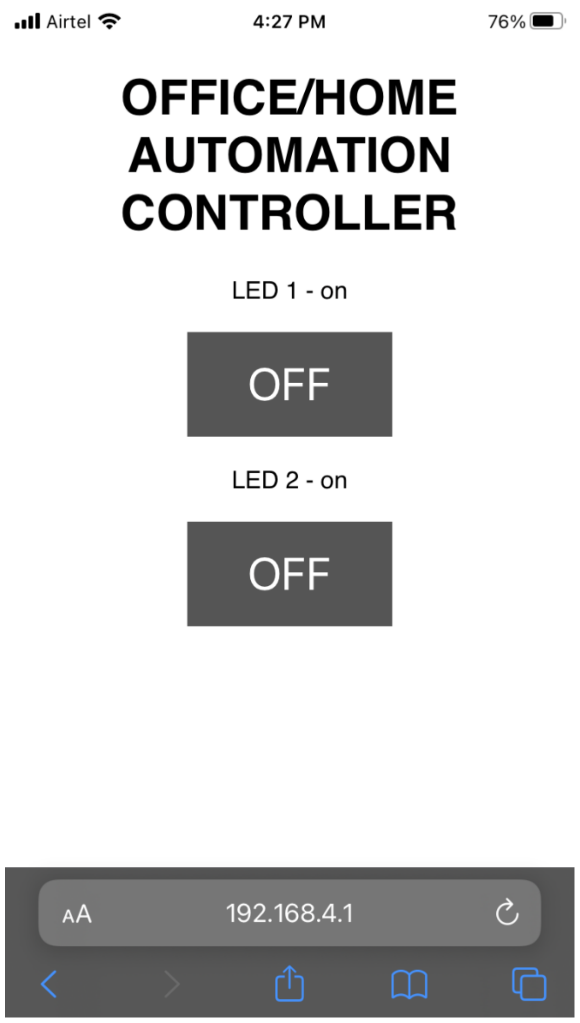
OFF

LED 2 - off

ON

192.168.4.1

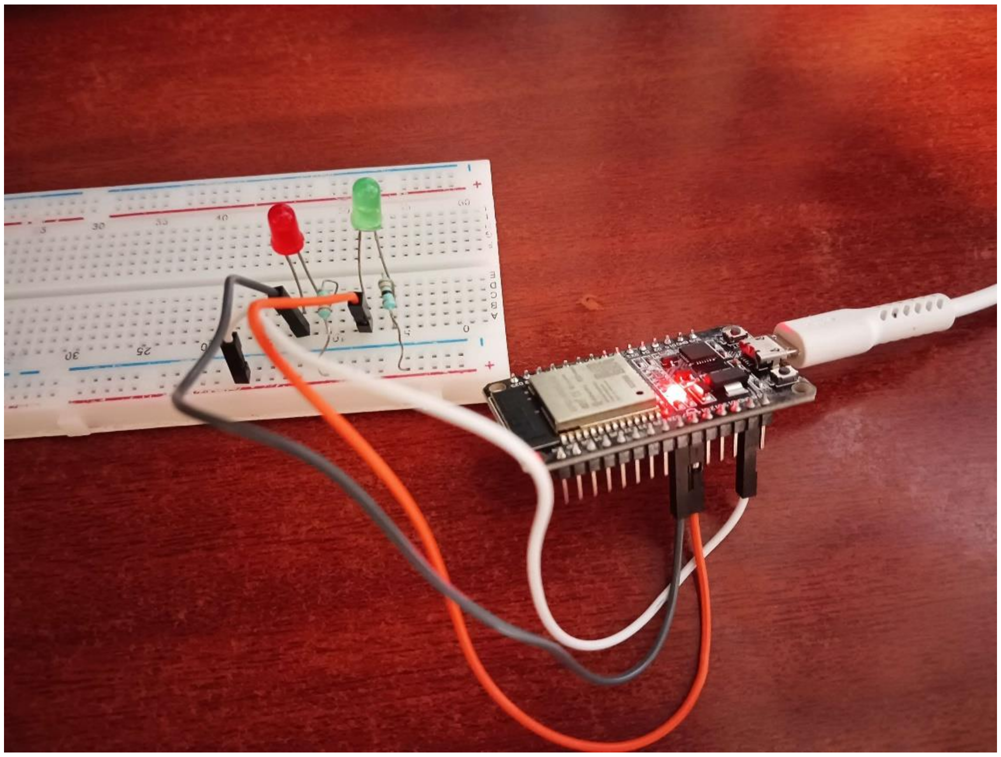




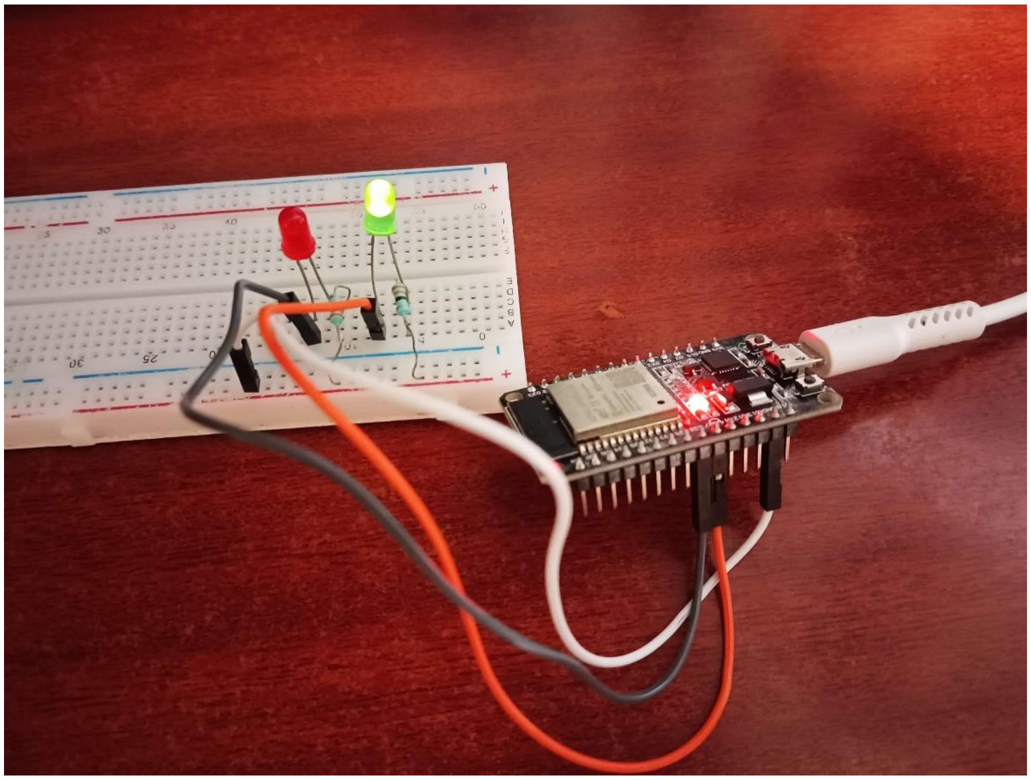
LED 1 is connected to the GPIO PIN no. 26
LED 2 is connected to the GPIO PIN no. 27

OUTPUTS: -

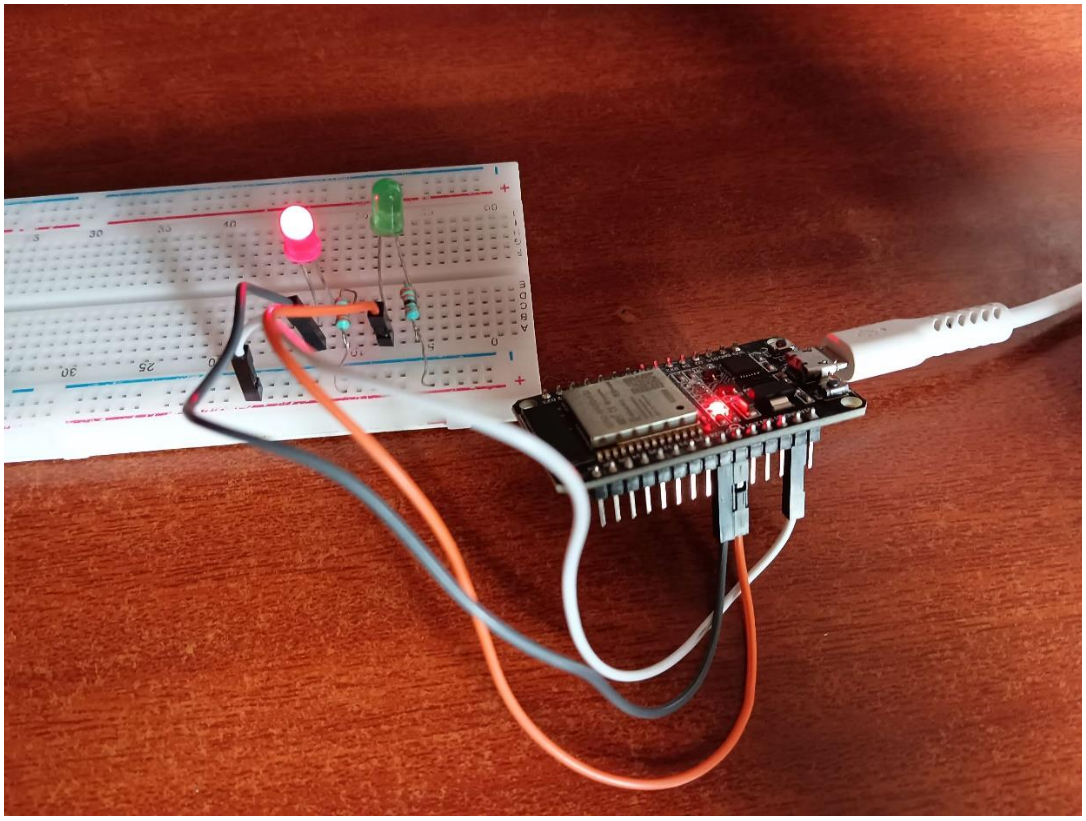
BOTH OFF: -



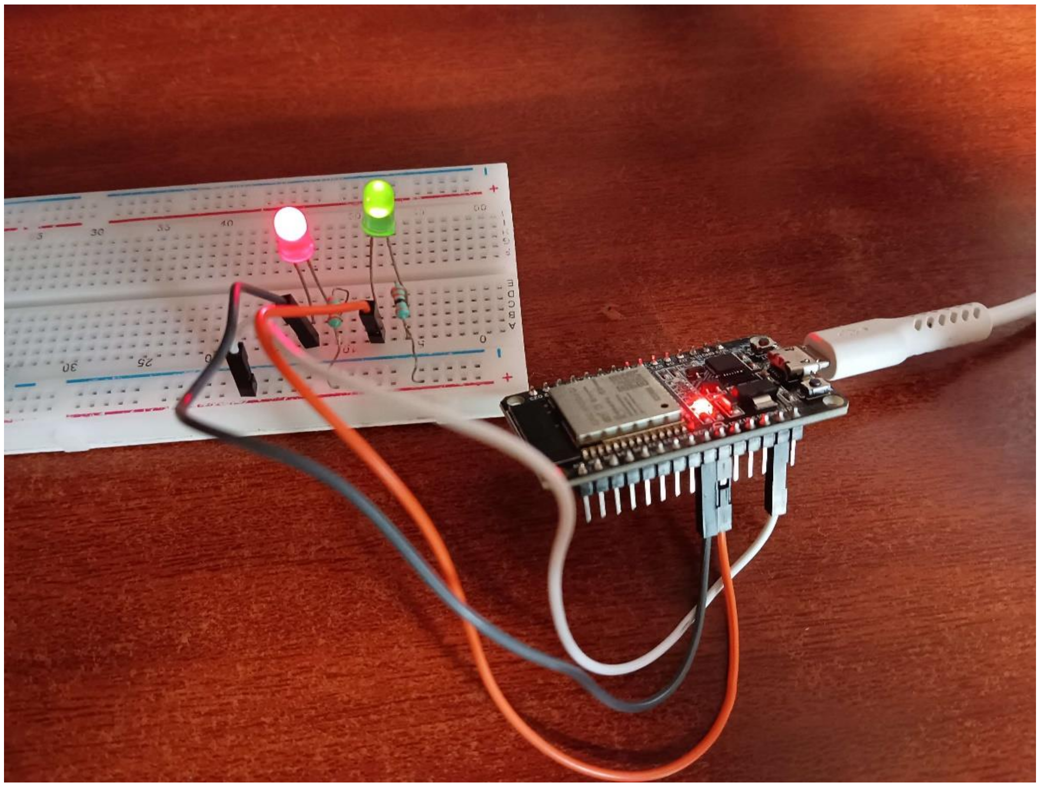
GPIO 27 (STATE ON): -



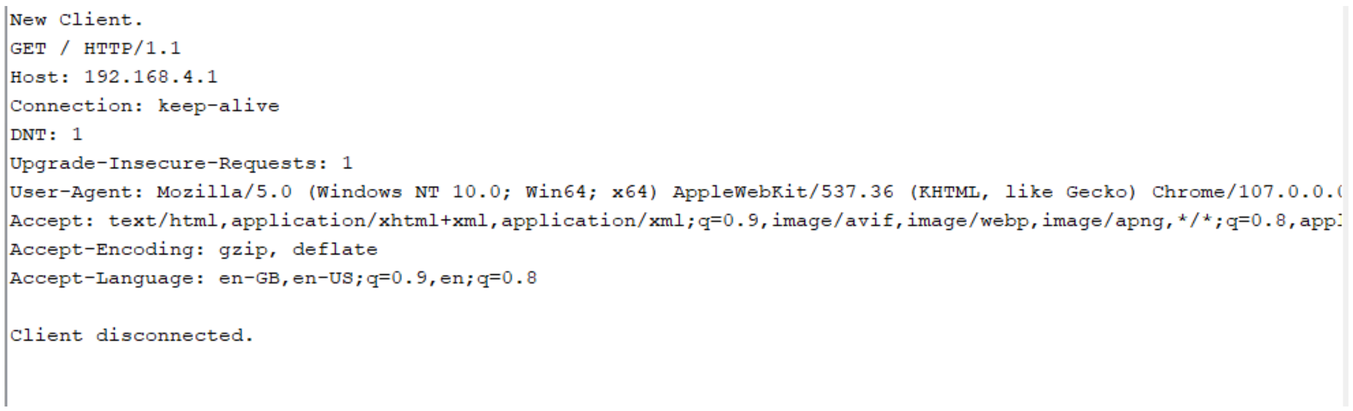
GPIO 26 (STATE ON): -



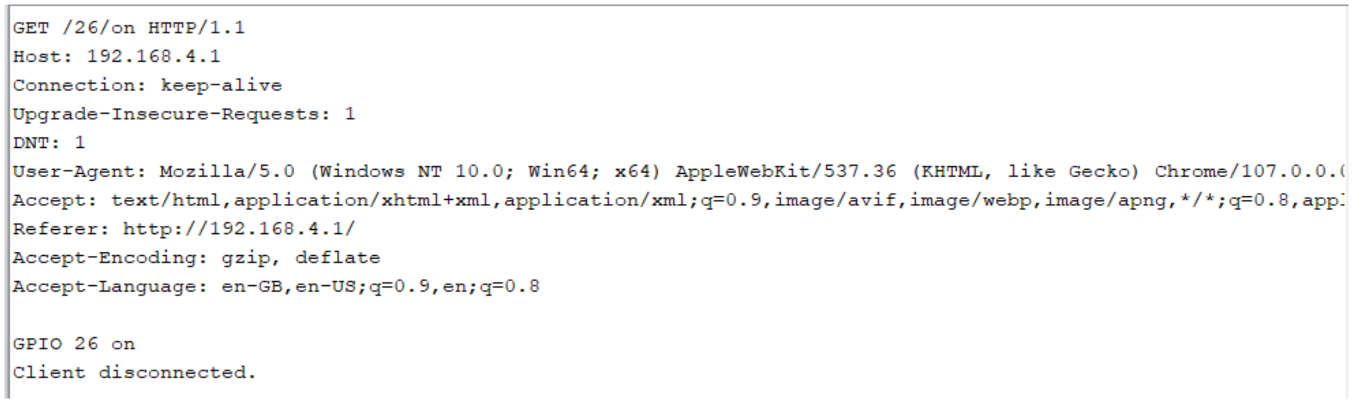
BOTH ON: -



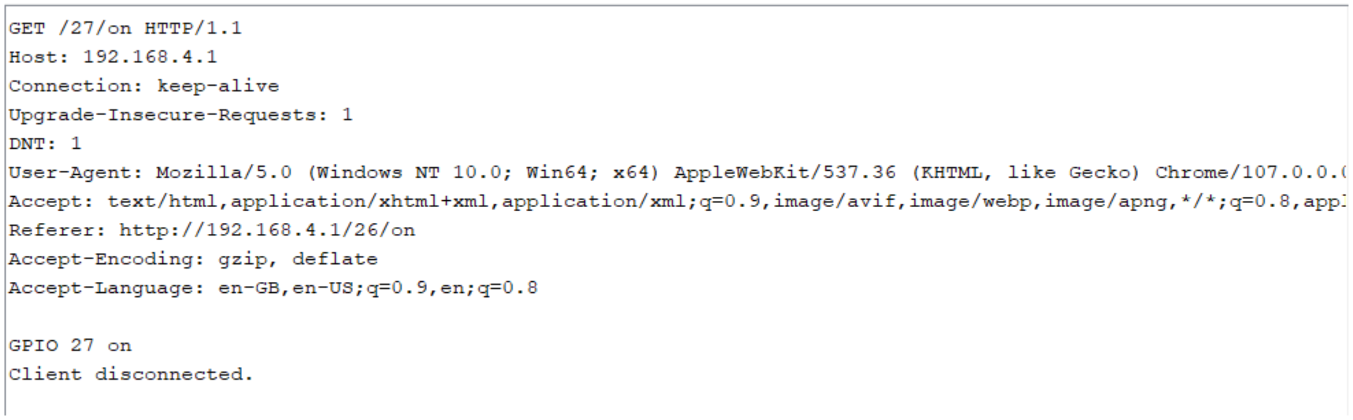
Product testing was done in the Arduino Uno IDE and the output was also verified in the serial monitor: -



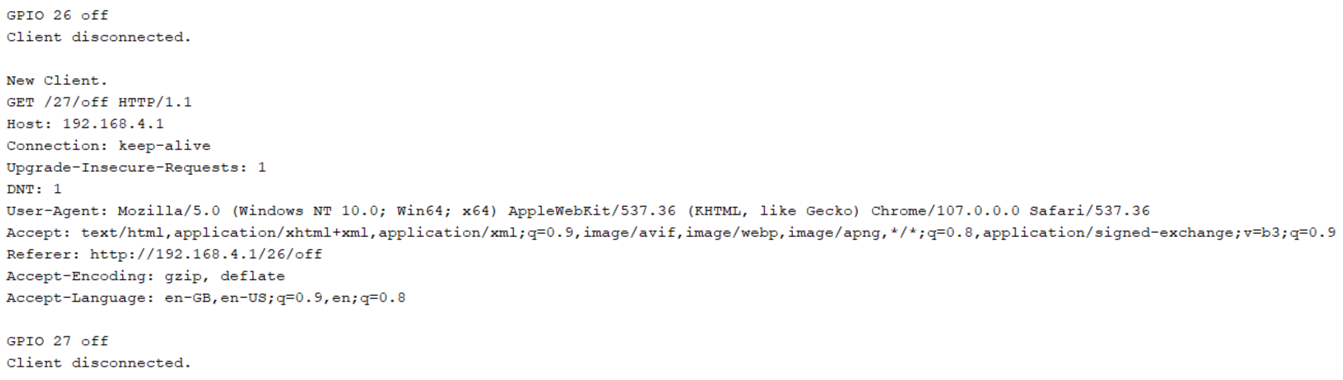
```
New Client.
GET / HTTP/1.1
Host: 192.168.4.1
Connection: keep-alive
DNT: 1
Upgrade-Insecure-Requests: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/107.0.0.
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,appl
Accept-Encoding: gzip, deflate
Accept-Language: en-GB,en-US;q=0.9,en;q=0.8

Client disconnected.
```



```
GET /26/on HTTP/1.1
Host: 192.168.4.1
Connection: keep-alive
Upgrade-Insecure-Requests: 1
DNT: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/107.0.0.
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,appl
Referer: http://192.168.4.1/
Accept-Encoding: gzip, deflate
Accept-Language: en-GB,en-US;q=0.9,en;q=0.8

GPIO 26 on
Client disconnected.
```



```
GET /27/on HTTP/1.1
Host: 192.168.4.1
Connection: keep-alive
Upgrade-Insecure-Requests: 1
DNT: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/107.0.0.
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,appl
Referer: http://192.168.4.1/26/on
Accept-Encoding: gzip, deflate
Accept-Language: en-GB,en-US;q=0.9,en;q=0.8

GPIO 27 on
Client disconnected.
```



```
GPIO 26 off
Client disconnected.

New Client.
GET /27/off HTTP/1.1
Host: 192.168.4.1
Connection: keep-alive
Upgrade-Insecure-Requests: 1
DNT: 1
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/107.0.0.0 Safari/537.36
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.9
Referer: http://192.168.4.1/26/off
Accept-Encoding: gzip, deflate
Accept-Language: en-GB,en-US;q=0.9,en;q=0.8

GPIO 27 off
Client disconnected.
```

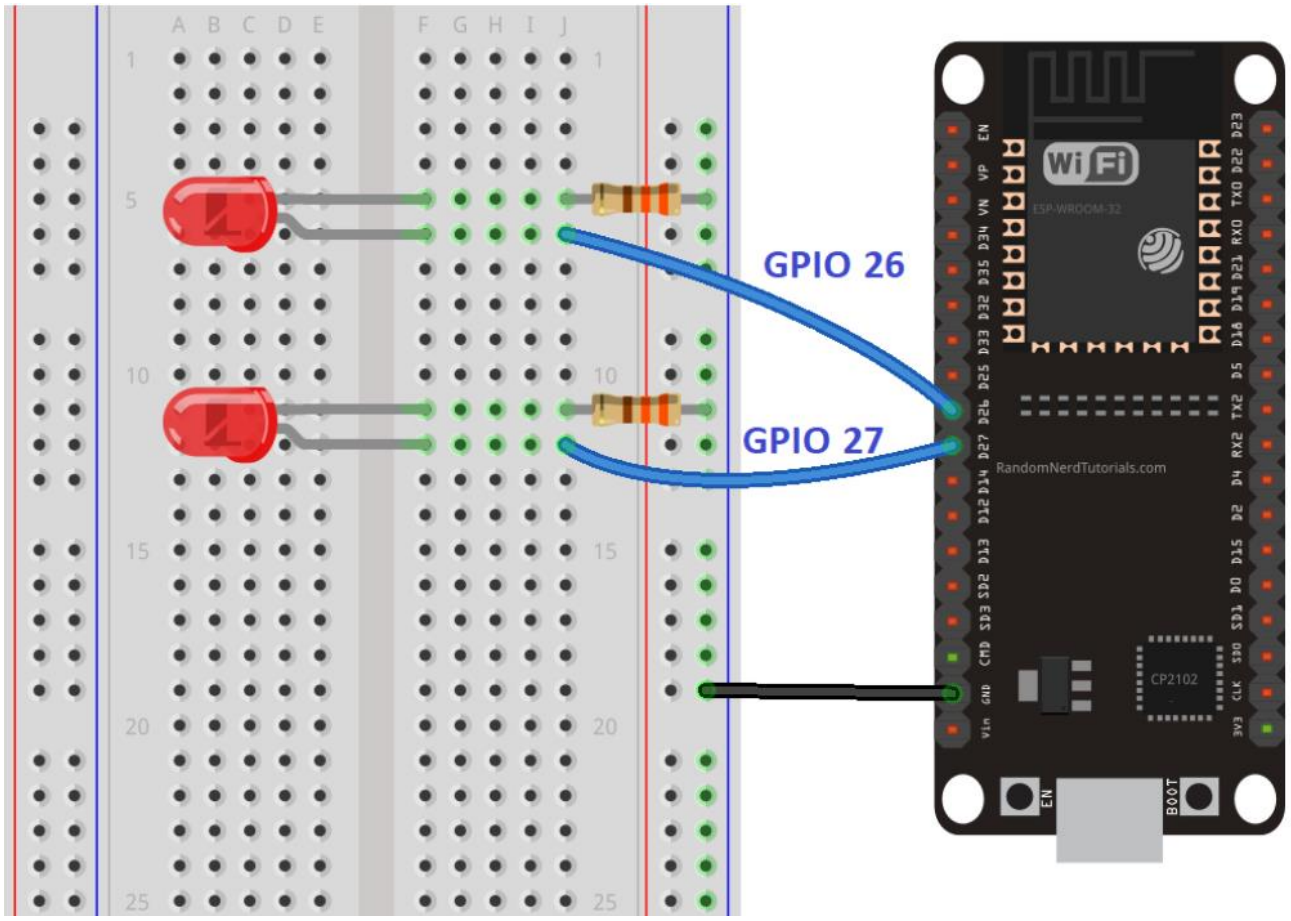
CODE: -

GITHUB LINK: - https://github.com/aryanpandey3333/WEB_SERVER_USING_ESP_32.git

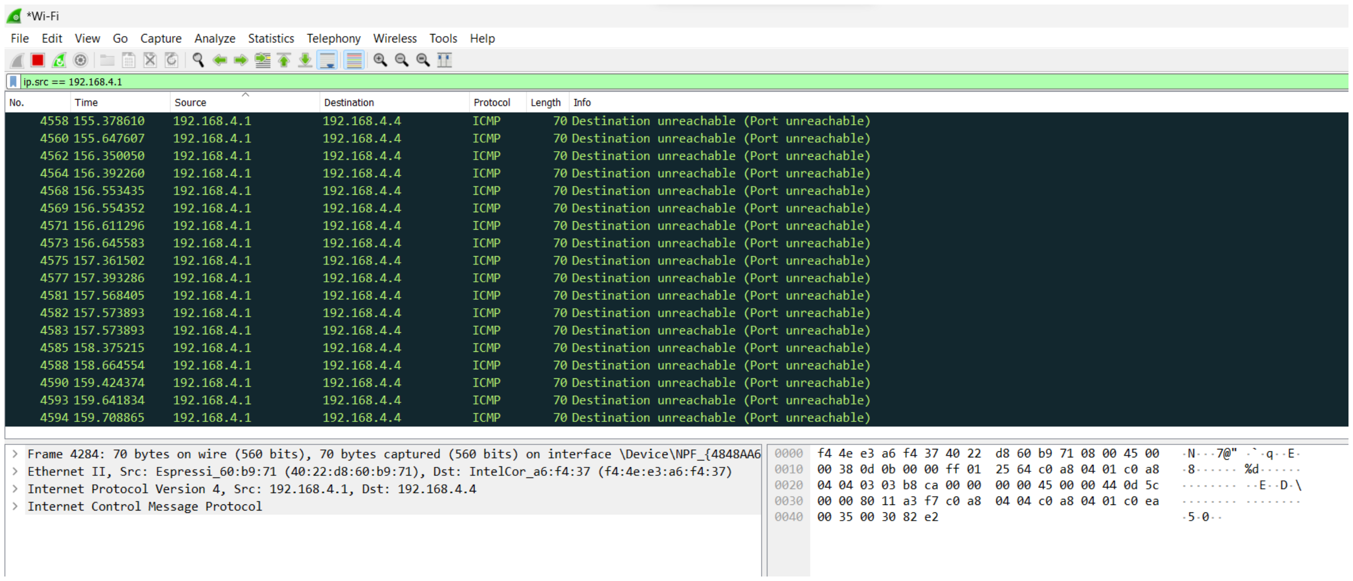
```
#include <WiFi.h>
const char* ssid     = "ESP32-Access-Point";
const char* password = "123456789";
WiFiServer server(80);
String header;
String output26State = "off";
String output27State = "off";
const int output26 = 26;
const int output27 = 27;
void setup() {
  Serial.begin(115200);
  pinMode(output26, OUTPUT);
  pinMode(output27, OUTPUT);
  digitalWrite(output26, LOW);
  digitalWrite(output27, LOW);
  Serial.print("Setting AP (Access Point");
  WiFi.softAP(ssid, password)
  IPAddress IP = WiFi.softAPIP();
  Serial.print("AP IP address: ");
  Serial.println(IP);
  server.begin();
}
void loop(){
  WiFiClient client = server.available();
  if (client) {
    Serial.println("New Client.");
    String currentLine = "";
    while (client.connected())
     {
      if (client.available())
        char c = client.read();
        Serial.write(c);
        header += c;
        if (c == '\n')
          if (currentLine.length() == 0) {
            client.println("HTTP/1.1 200 OK");
            client.println("Content-type:text/html");
            client.println("Connection: close");
            client.println();
            if (header.indexOf("GET /26/on") >= 0) {
              Serial.println("GPIO 26 on");
              output26State = "on";
              digitalWrite(output26, HIGH);
            } else if (header.indexOf("GET /26/off") >= 0) {
              Serial.println("GPIO 26 off");
              output26State = "off";
              digitalWrite(output26, LOW);
            } else if (header.indexOf("GET /27/on") >= 0) {
              Serial.println("GPIO 27 on");
              output27State = "on";
              digitalWrite(output27, HIGH);
            } else if (header.indexOf("GET /27/off") >= 0) {
              Serial.println("GPIO 27 off");
              output27State = "off";
              digitalWrite(output27, LOW);
            }
            client.println("<!DOCTYPE html><html>");
            client.println("<head><metaname=\"viewport\"
content=\"width=device-width, initial-scale=1\">");
            client.println("<link rel=\"icon\" href=\"data:,\">");
            client.println("<style>html { font-family: Helvetica;
display: inline-block; margin: 0px auto; text-align: center;}");
            client.println(".button { background-color: #4CAF50;
border: none; color: white; padding: 16px 40px;");
            client.println("text-decoration: none; font-size: 30px;
margin: 2px; cursor: pointer;}");
            client.println(".button2{background-color:
#555555;}</style></head>");
            // Web Page Heading
            client.println("<body><h1>OFFICE/HOME AUTOMATION
CONTROLLER</h1>");
            // Display current state, and ON/OFF buttons for GPIO 26
            client.println("<p>LED 1 - " + output26State + "</p>");
            // If the output26State is off, it displays the ON button
            if (output26State=="off") {
              client.println("<p><a href=\"/26/on\"><button
class=\"button\">ON</button></a></p>");
            } else {
              client.println("<p><a href=\"/26/off\"><button
class=\"button button2\">OFF</button></a></p>");
            }
            client.println("<p>LED 2 - " + output27State + "</p>");
            // If the output27State is off, it displays the ON button
            if (output27State=="off") {
              client.println("<p><a href=\"/27/on\"><button
class=\"button\">ON</button></a></p>");
            } else {
              client.println("<p><a href=\"/27/off\"><button
class=\"button button2\">OFF</button></a></p>");
            }
            client.println("</body></html>");
            client.println();
            break;
          } else {
            currentLine = "";
          }
        } else if (c != '\r') {
          currentLine += c;
        }
      }
    }
    header = "";
    client.stop();
    Serial.println("Client disconnected.");
    Serial.println("");
  }
}
```

RESULTS & INFERENCES:

Schematic: -

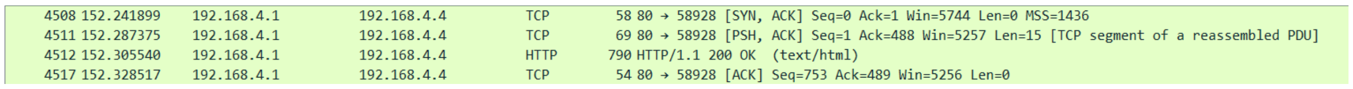


It keeps on pinging the port to see whether the destination port is reachable or not.

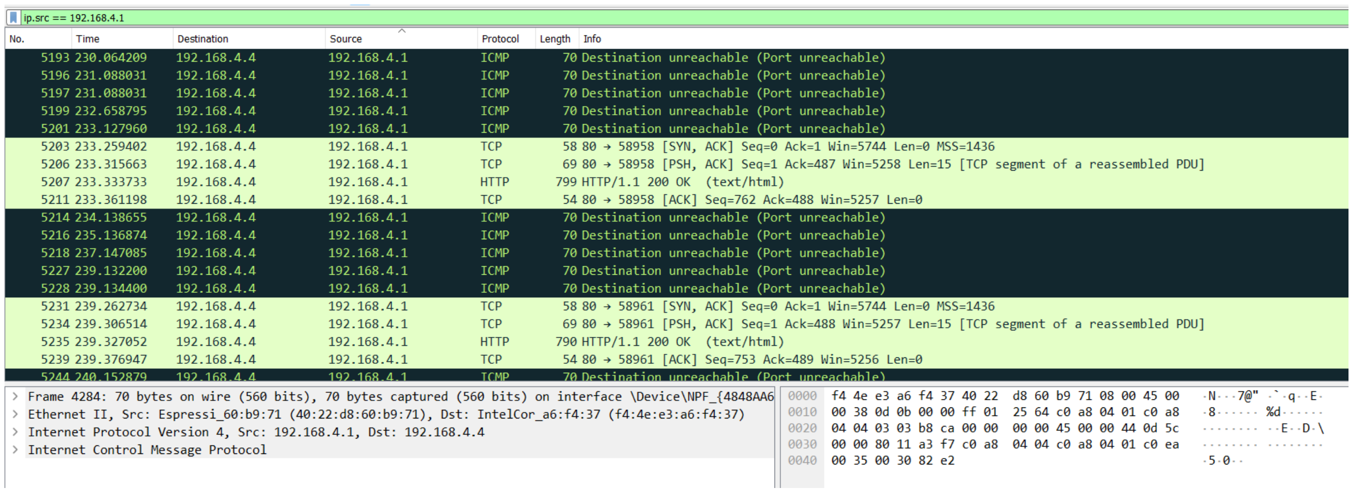

*Wi-Fi
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

```
ip.src == 192.168.4.1
No.   Time        Source        Destination   Protocol  Length Info
 4558 155.378610  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4560 155.647607  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4562 156.350050  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4564 156.392260  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4568 156.553435  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4569 156.554352  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4571 156.611296  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4573 156.645583  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4575 157.361502  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4577 157.393286  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4581 157.568405  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4582 157.573893  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4583 157.573893  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4585 158.375215  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4588 158.664554  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4590 159.424374  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4593 159.641834  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)
 4594 159.708865  192.168.4.1   192.168.4.4   ICMP       70 Destination unreachable (Port unreachable)

> Frame 4284: 70 bytes on wire (560 bits), 70 bytes captured (560 bits) on interface \Device\NPF_{4848AA6
> Ethernet II, Src: Espressi_60:b9:71 (40:22:d8:60:b9:71), Dst: IntelCor_a6:f4:37 (f4:4e:e3:a6:f4:37)
> Internet Protocol Version 4, Src: 192.168.4.1, Dst: 192.168.4.4
> Internet Control Message Protocol

0000  f4 4e e3 a6 f4 37 40 22  d8 60 b9 71 08 00 45 00   ·N···7@" ·`·q··E·
0010  00 38 0d 0b 00 00 ff 01  25 64 c0 a8 04 01 c0 a8   ·8······ %d······
0020  04 04 03 03 b8 ca 00 00  00 00 45 00 00 44 0d 5c   ········ ··E··D·\
0030  00 00 80 11 a3 f7 c0 a8  04 04 c0 a8 04 01 c0 ea   ········ ········
0040  00 35 00 30 82 e2                                  ·5·0··
```

When the on and off buttons are pressed the protocols to send the data changes from ICMP to TCP and HTTP.



```
 4508 152.241899  192.168.4.1   192.168.4.4   TCP      58 80 → 58928 [SYN, ACK] Seq=0 Ack=1 Win=5744 Len=0 MSS=1436
 4511 152.287375  192.168.4.1   192.168.4.4   TCP      69 80 → 58928 [PSH, ACK] Seq=1 Ack=488 Win=5257 Len=15 [TCP segment of a reassembled PDU]
 4512 152.305540  192.168.4.1   192.168.4.4   HTTP    790 HTTP/1.1 200 OK  (text/html)
 4517 152.328517  192.168.4.1   192.168.4.4   TCP      54 80 → 58928 [ACK] Seq=753 Ack=489 Win=5256 Len=0
```

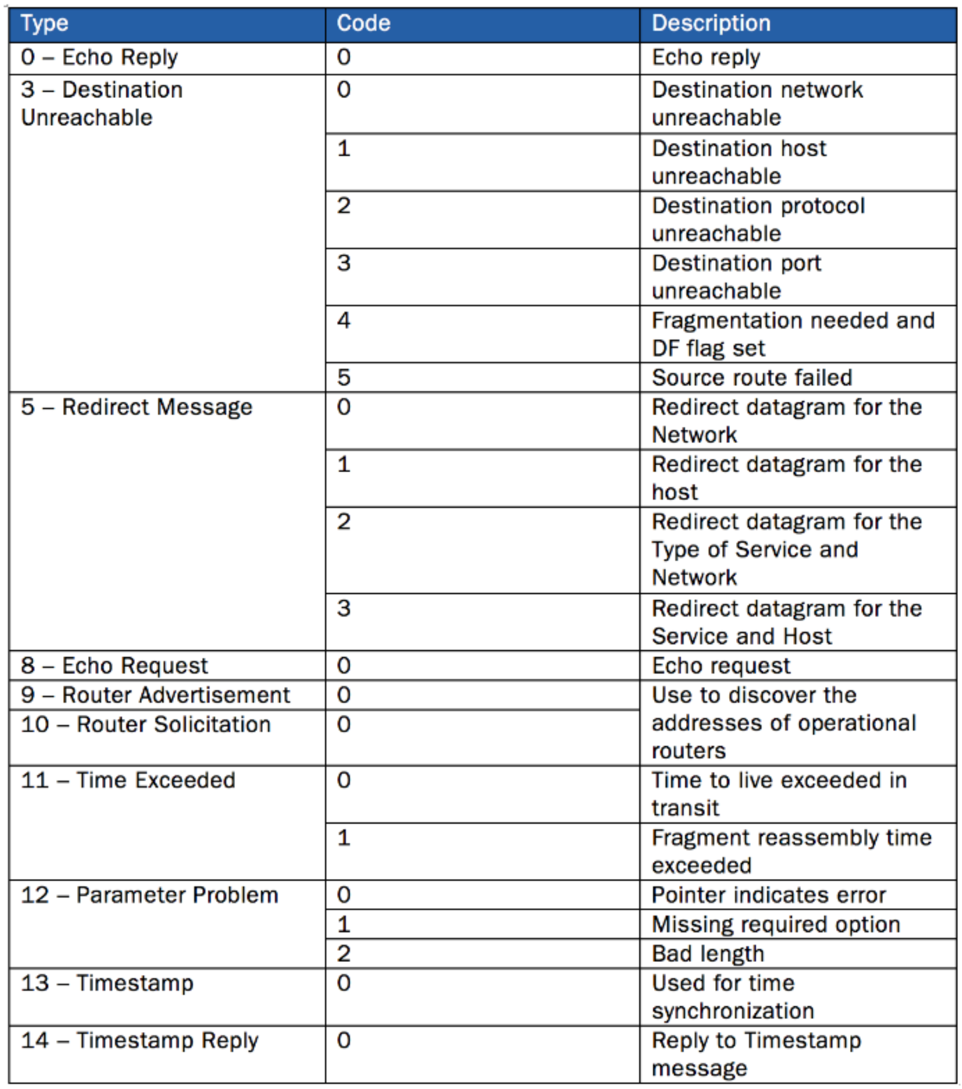


```
ip.src == 192.168.4.1
No.   Time        Destination   Source        Protocol  Length Info
 5193 230.064209  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5196 231.088031  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5197 231.088031  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5199 232.658795  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5201 233.127960  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5203 233.259402  192.168.4.4   192.168.4.1   TCP       58 80 → 58958 [SYN, ACK] Seq=0 Ack=1 Win=5744 Len=0 MSS=1436
 5206 233.315663  192.168.4.4   192.168.4.1   TCP       69 80 → 58958 [PSH, ACK] Seq=1 Ack=487 Win=5258 Len=15 [TCP segment of a reassembled PDU]
 5207 233.333733  192.168.4.4   192.168.4.1   HTTP     799 HTTP/1.1 200 OK  (text/html)
 5211 233.361198  192.168.4.4   192.168.4.1   TCP       54 80 → 58958 [ACK] Seq=762 Ack=488 Win=5257 Len=0
 5214 234.138655  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5216 235.136874  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5218 237.147085  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5227 239.132200  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5228 239.134400  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)
 5231 239.262734  192.168.4.4   192.168.4.1   TCP       58 80 → 58961 [SYN, ACK] Seq=0 Ack=1 Win=5744 Len=0 MSS=1436
 5234 239.306514  192.168.4.4   192.168.4.1   TCP       69 80 → 58961 [PSH, ACK] Seq=1 Ack=488 Win=5257 Len=15 [TCP segment of a reassembled PDU]
 5235 239.327052  192.168.4.4   192.168.4.1   HTTP     790 HTTP/1.1 200 OK  (text/html)
 5239 239.376947  192.168.4.4   192.168.4.1   TCP       54 80 → 58961 [ACK] Seq=753 Ack=489 Win=5256 Len=0
 5244 240.152879  192.168.4.4   192.168.4.1   ICMP      70 Destination unreachable (Port unreachable)

> Frame 4284: 70 bytes on wire (560 bits), 70 bytes captured (560 bits) on interface \Device\NPF_{4848AA6
> Ethernet II, Src: Espressi_60:b9:71 (40:22:d8:60:b9:71), Dst: IntelCor_a6:f4:37 (f4:4e:e3:a6:f4:37)
> Internet Protocol Version 4, Src: 192.168.4.1, Dst: 192.168.4.4
> Internet Control Message Protocol

0000  f4 4e e3 a6 f4 37 40 22  d8 60 b9 71 08 00 45 00   ·N···7@" ·`·q··E·
0010  00 38 0d 0b 00 00 ff 01  25 64 c0 a8 04 01 c0 a8   ·8······ %d······
0020  04 04 03 03 b8 ca 00 00  00 00 45 00 00 44 0d 5c   ········ ··E··D·\
0030  00 00 80 11 a3 f7 c0 a8  04 04 c0 a8 04 01 c0 ea   ········ ········
0040  00 35 00 30 82 e2                                  ·5·0··
```

As shown above, the type of an ICMP packet contains the overall message that the message is intended to convey. For example, a type value of 3 means that the intended destination is unreachable. For some types, there are multiple code values intended to provide additional information.

Unlike the Transport Control Protocol (TCP) and User Datagram Protocol (UDP), the Internet Control Message Protocol (ICMP) is not designed for carrying data.

While ICMP packets do have a data section, their purpose is not to wrap and carry protocols like HTTP and DNS. Instead, ICMP is designed as a low-level management protocol for the internet. It carries error messages and implements simple management functions.



Type	Code	Description
0 – Echo Reply	0	Echo reply
3 – Destination Unreachable	0	Destination network unreachable
	1	Destination host unreachable
	2	Destination protocol unreachable
	3	Destination port unreachable
	4	Fragmentation needed and DF flag set
	5	Source route failed
5 – Redirect Message	0	Redirect datagram for the Network
	1	Redirect datagram for the host
	2	Redirect datagram for the Type of Service and Network
	3	Redirect datagram for the Service and Host
8 – Echo Request	0	Echo request
9 – Router Advertisement	0	Use to discover the addresses of operational routers
10 – Router Solicitation	0	
11 – Time Exceeded	0	Time to live exceeded in transit
	1	Fragment reassembly time exceeded
12 – Parameter Problem	0	Pointer indicates error
	1	Missing required option
	2	Bad length
13 – Timestamp	0	Used for time synchronization
14 – Timestamp Reply	0	Reply to Timestamp message

In HTTP GET response, the requested data (e.g., an HTML page) is returned. Wireshark will show the hex dump of the data in a new tab “Uncompressed entity body” in the “Packet Bytes” pane.

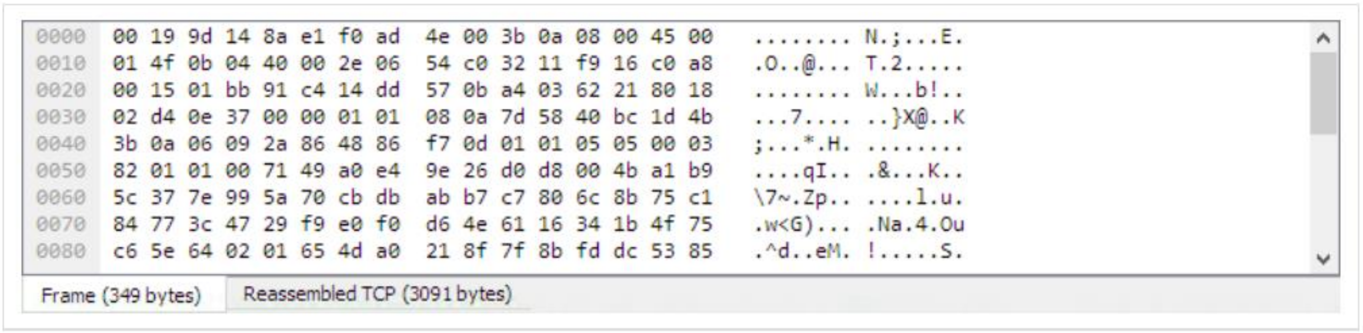
Reassembly is enabled in the preferences by default but can be disabled in the preferences for the protocol in question.

Enabling or disabling reassembly settings for a protocol typically requires two things:

- The lower-level protocol (e.g., TCP) must support reassembly. Often this reassembly can be enabled or disabled via the protocol preferences.
- The higher-level protocol (e.g., HTTP) must use the reassembly mechanism to reassemble fragmented protocol data. This too can often be enabled or disabled via the protocol preferences.

The tooltip of the higher-level protocol setting will notify you if and which lower-level protocol setting also has to be considered.

Figure 7.8. The "Packet Bytes" pane with a reassembled tab



```
0000  00 19 9d 14 8a e1 f0 ad  4e 00 3b 0a 08 00 45 00   ........ N.;...E.
0010  01 4f 0b 04 40 00 2e 06  54 c0 32 11 f9 16 c0 a8   .O..@... T.2.....
0020  00 15 01 bb 91 c4 14 dd  57 0b a4 03 62 21 80 18   ........ W...b!..
0030  02 d4 0e 37 00 00 01 01  08 0a 7d 58 40 bc 1d 4b   ...7.... ..}X@..K
0040  3b 0a 06 09 2a 86 48 86  f7 0d 01 01 05 05 00 03   ;...*.H. ........
0050  82 01 01 00 71 49 a0 e4  9e 26 d0 d8 00 4b a1 b9   ....qI.. .&...K..
0060  5c 37 7e 99 5a 70 cb db  ab b7 c7 80 6c 8b 75 c1   \7~.Zp.. ....l.u.
0070  84 77 3c 47 29 f9 e0 f0  d6 4e 61 16 34 1b 4f 75   .w<G)... .Na.4.Ou
0080  c6 5e 64 02 01 65 4d a0  21 8f 7f 8b fd dc 53 85   .^d..eM. !.....S.
```

Reassembly might take place at several protocol layers, so it's possible that multiple tabs in the "Packet Bytes" pane appear.

APPLICATION ORIENTED LEARNING:

Real-Time Application: -

- Smart industrial devices, including Programmable Logic Controllers (PLCs)
- Smart medical devices, including wearable health monitors.
- Smart energy devices, including HVAC and thermostats.
- Smart security devices, including surveillance cameras and smart locks.

Computer Communication Concepts Learned: -

- Measuring capacity of communication media
- Bandwidth
- Data transfer rate

Protocols we got more familiar with: -

- TCP

- ICMP
- HTTP

Cost of our project: -
If we just consider the basic prototyping it costs us around Rs.850

CONCLUSION:

One of the most useful features of the ESP32 is its ability to not only connect to an existing Wi-Fi network and act as a Web Server, but also to create its own network, allowing other devices to connect directly to it and access web pages. This project helps us understand many concepts.

This is possible because the ESP32 can operate in three modes: Station (STA) mode, Soft Access Point (AP) mode, and both simultaneously.

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