ESP32 Formats and Communication

Updates

Software versions listed in Table 1-10.

The latest Arduino IDE software is version 2.3.2 (Feb 2024) www.arduino.cc/en/software

The latest *esp32* Boards Manager are versions v3.0.3 (July 2024) and v2.0.17 (May 2023).

Chapter 2 I2S Audio

When playing internet radio (Listing 2-6) or MP3 files (Listing 2-9) with the *M5Core2 0.1.3* and the *Audio* libraries, the sound quality is fine. However, with the *M5Core2 0.1.4* or *M5Core2 0.1.5* libraries, the audio plays at a "slow speed".

The "slow speed" problem, for the *M5Core2 0.1.7* library, is resolved by replacing the instructions:

`M5.begin(true, true, true, true)` in Listing 2-6 with

`M5.begin(true, true, true, true, kMBusModeOutput, false)` or replacing

`M5.begin()` in Listing 2-9 with

`M5.begin(true, true, true, false, kMBusModeOutput, false).`

The changes set the *SpeakerEnable* variable to *false*, as the default `M5.begin` parameters are:

```
bool LCDEnable = true                         // LCD screen on
bool SDEnable = true                          // SD card on
bool SerialEnable = true                      // Serial display on
bool I2CEnable = false                        // I2C communication off
mbus_mode_t mode = kMBusModeOutput            // power option
bool SpeakerEnable = true                     // Speaker Enable on
```

with the power option equal to 0 or 1 when the M5Stack Core2 is powered by USB/battery or by outside input, respectively.

Chapter 4 TTGO T-Watch V2

Pages 213-214 Espressif Flash Download Tool V3.9.7, dated 7 June 2024, is available.

Chapter 5 BLE Beacons

The *MIT App Inventor BluetoothLE* extension has been updated to version 20230728, which is downloaded from mit-cml.github.io/extensions and saved as *edu.mit.appinventor.ble-20230728.aix*.

The *ESP32 BLE Arduino* library is not compatible with installation of the *ArduinoBLE* library as the compiler attempts to access both libraries. When using the *ESP32 BLE Arduino* library, the *ArduinoBLE* library must be deleted from the *User\Documents\Arduino\libraries* folder.

Formats for transmitting data with the *setValue* function are included in the *ESP32 BLE Arduino* library *src\BLECharacteristic.h* file, with the library located at *User \AppData\Local\Arduino15\packages\esp32\hardware\esp32\version\libraries\BLE*. Example formats are `uint8_t* data, size_t size` for an integer array, `std::string value` for a string with `int& data` and `float& data` for an integer and a float, respectively.

The UUIDs of the *Characteristic User Description* and *Client Characteristic Configuration* are *0x2901* and *0x2902*, respectively (see Section 3.7 of the GATT Assigned Numbers document). A user-defined descriptor is defined with the new `BLEDescriptor((uint16_t)0x2901)` and `setValue("used-defined text")` instructions. Notifications are turned on automatically with the `setNotifications(true)` instruction. See updated Listing 5-6.

Table 1 *User-defined description and automatic notification*

Standard setup	Improved setup
`battService = Server ->createService(battServUUID);`	`battService = Server ->createService(battServUUID);`
`battService ->addCharacteristic(&battChar);`	`battService ->addCharacteristic(&battChar);`
`battDesc = new BLE2902();`	`battDesc = new BLEDescriptor((uint16_t)0x2901);`
	`battDesc->setValue("Battery level text");`
`battNotfy = (BLE2902*)battDesc;`	`battNotfy = new BLE2902();`
	`battNotfy->setNotifications(true);`
`battChar.addDescriptor(battDesc);`	`battChar.addDescriptor(battDesc);`
	`battChar.addDescriptor(battNotfy);`
`battService->start();`	`battService->start();`

BLE Receive and Transmit App

The *BLE Receive App* in Chapter 9 used the Eddystone beacon framework for an ESP32 microcontroller to transmit data to an app built with MIT App Inventor. An alternative approach is to use the transmit and receive UUIDs outlined in Listings 5-6, 5-7 and 5-8. Comments specific to Listing 1 (see below) are included, rather than repeating comments from Listings 5-6, 5-7 and 5-8.

The receive and transmit UUIDs obtained for Nordic Semiconductor (infocenter.nordicsemi.com and search for *UART/Serial BLE*) are relative to the client and are reversed when relative to the server, as in the sketch. The receive and transmit characteristics of the client have *NOTIFY* and *WRITE* properties, respectively, which correspond to the transmit and receive characteristics of the server. A message received from the client is formatted as `std::string` and is then converted to a `String` with the `c_str()` function. Messages are received from two client sources, a button and a slider, and to differentiate between sources, the message data is prefixed with "*B*" or "*S*", respectively. An alternative option is two receive UUIDs with the source identified from the UUID. Service and characteristic UUIDs are generated using an online generator, such as www.uuidgenerator.net.

A message transmitted to the client is initially formatted as a `String` and is then converted to a `std::string` with the `c_str()` function. Alternatively, a string is converted to a character array with the `toCharArray(string, N)` function, where *N* is the length of the character array.

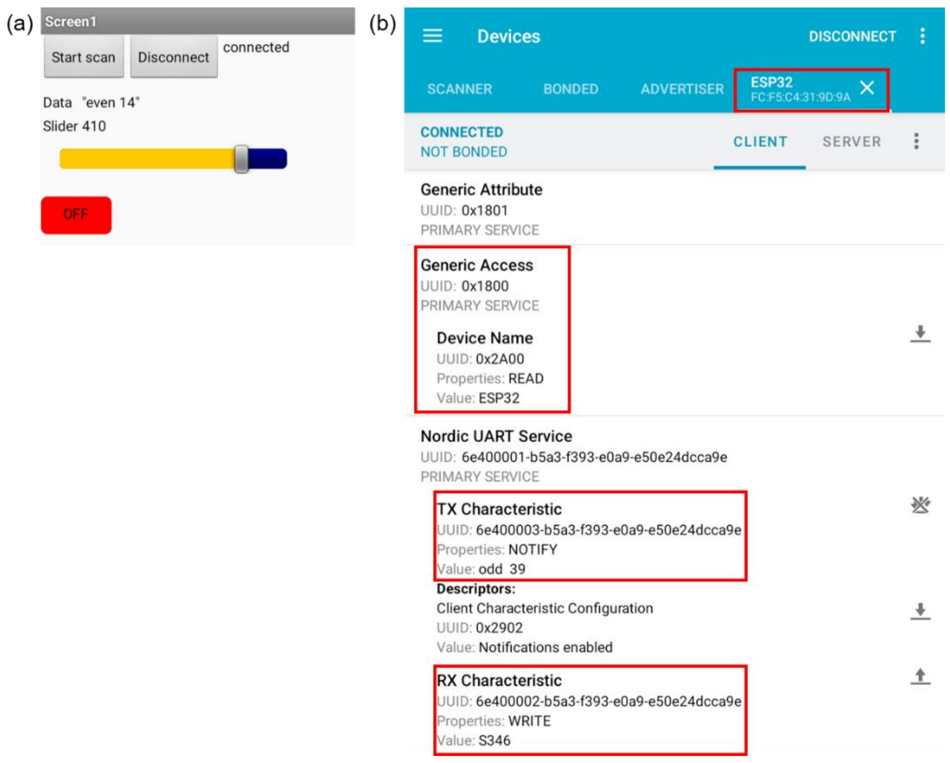
Listing 1 *BLE Receive and Transmit App*

```
#include <BLEDevice.h>
#include <BLE2902.h>
BLEServer * Server;
BLEService * Service;
BLECharacteristic * TXChar;                             // transmit characteristic
BLEDescriptor * TXDesc;                                 //   and descriptor
BLECharacteristic * RXChar;                             // receive characteristic
BLE2902 * Notfy;
char ServUUID[] = "6e400001-b5a3-f393-e0a9-e50e24dcca9e";
char RXUUID[] =   "6e400002-b5a3-f393-e0a9-e50e24dcca9e";            // receive UUID
char TXUUID[] =   "6e400003-b5a3-f393-e0a9-e50e24dcca9e";            // transmit UUID
uint32_t RXval, TXval = 0, clientCon = 0;
String source, RXstr, TXstr;

class RXCharCallback: public BLECharacteristicCallbacks     // receive callback
{
  void onWrite(BLECharacteristic * RXChar)              // receive message from client
  {
    std::string str = RXChar->getValue();
    RXstr = String(str.c_str());                        // convert to String
    source = RXstr.charAt(0);                           // first character of string
    RXstr.remove(0,1);                                  // remove first character
    RXval = RXstr.toInt();                              // convert string to integer
    if(source == "B") Serial.printf("Button %d \n", RXval);
    else if(source == "S") Serial.printf("Slider %d \n", RXval);
  }
};

class ServerCallback : public BLEServerCallbacks        // same as Listing 5-6

void setup()
{
  Serial.begin(115200);
  BLEDevice::init("ESP32");
  Server = BLEDevice::createServer();
  Server->setCallbacks(new ServerCallback());
  Service = Server->createService(ServUUID);
  TXChar = Service->createCharacteristic(TXUUID,        // add transmit characteristic
           BLECharacteristic::PROPERTY_NOTIFY);         //   with notify status
  TXDesc = new BLE2902();                               // add transmit
  TXChar->addDescriptor(TXDesc);                        //   descriptor to characteristic &
  Notfy = (BLE2902*)TXDesc;                             // transmit notifier to descriptor
  RXChar = Service->createCharacteristic(RXUUID,        // add receive characteristic
           BLECharacteristic::PROPERTY_WRITE);          //   with write status
  RXChar->setCallbacks(new RXCharCallback());           //   and callback
  Service->start();
  Server->getAdvertising()->start();
}

void loop()
```

```
{
  if(clientCon == 1)                                  // client connected to server
  {
    TXval++;
    if(TXval % 2 == 0) TXstr ="even " + String(TXval);        // create message
    else TXstr = "odd  " + String(TXval);
//  char msg[24];                                     // char array to store message
//  TXstr.toCharArray(msg, 24);                       // convert to character array
//  TXChar->setValue(msg);                            // set characteristic to message
    TXChar->setValue(TXstr.c_str());                  // convert String to std::string
    TXChar->notify();                                 // transmit message to client
    Serial.printf("TXval %d \n", TXval);
    delay(2000);
  }
}
```

The *BLE Receive and Transmit App* (see Figure 2a) is built in *MIT App Inventor* with button to start BLE scanning and to disconnected from a BLE device, which is a ESP32 microcontroller. The *Data* text is received by the client from the server with the slider position and button state transmitted by the client to the server.

When the *nRF Connect* app is connected to the server, the server device name is displayed under *Generic Access* and with the microcontroller MAC address at the top of the screen (see Figure 2b). The client receives and transmits on the *nRF Connect* app *TX* and *RX* characteristics, which are the UUIDs defined for the server in the sketch.



Data "even 14"
Slider 410

ESP32
FC:F5:C4:31:9D:9A

CONNECTED
NOT BONDED

Generic Attribute
UUID: 0x1801
PRIMARY SERVICE

Generic Access
UUID: 0x1800
PRIMARY SERVICE

Device Name
UUID: 0x2A00
Properties: READ
Value: ESP32

Nordic UART Service
UUID: 6e400001-b5a3-f393-e0a9-e50e24dcca9e
PRIMARY SERVICE

TX Characteristic
UUID: 6e400003-b5a3-f393-e0a9-e50e24dcca9e
Properties: NOTIFY
Value: odd 39
Descriptors:
Client Characteristic Configuration
UUID: 0x2902
Value: Notifications enabled

RX Characteristic
UUID: 6e400002-b5a3-f393-e0a9-e50e24dcca9e
Properties: WRITE
Value: S346

***Figure 2** Screenshots of BLE Receive and Transmit App and nRF Connect App*

Components of the app are shown in Figure 3. The displayed *Data* and *Slider* titles and values are contained in a table, *TableArrangement1*, with two rows and columns. The *BluetoothLE* extension is located in the *Extension Palette* of *MIT App Inventor* and is dragged onto the *Viewer* screen.

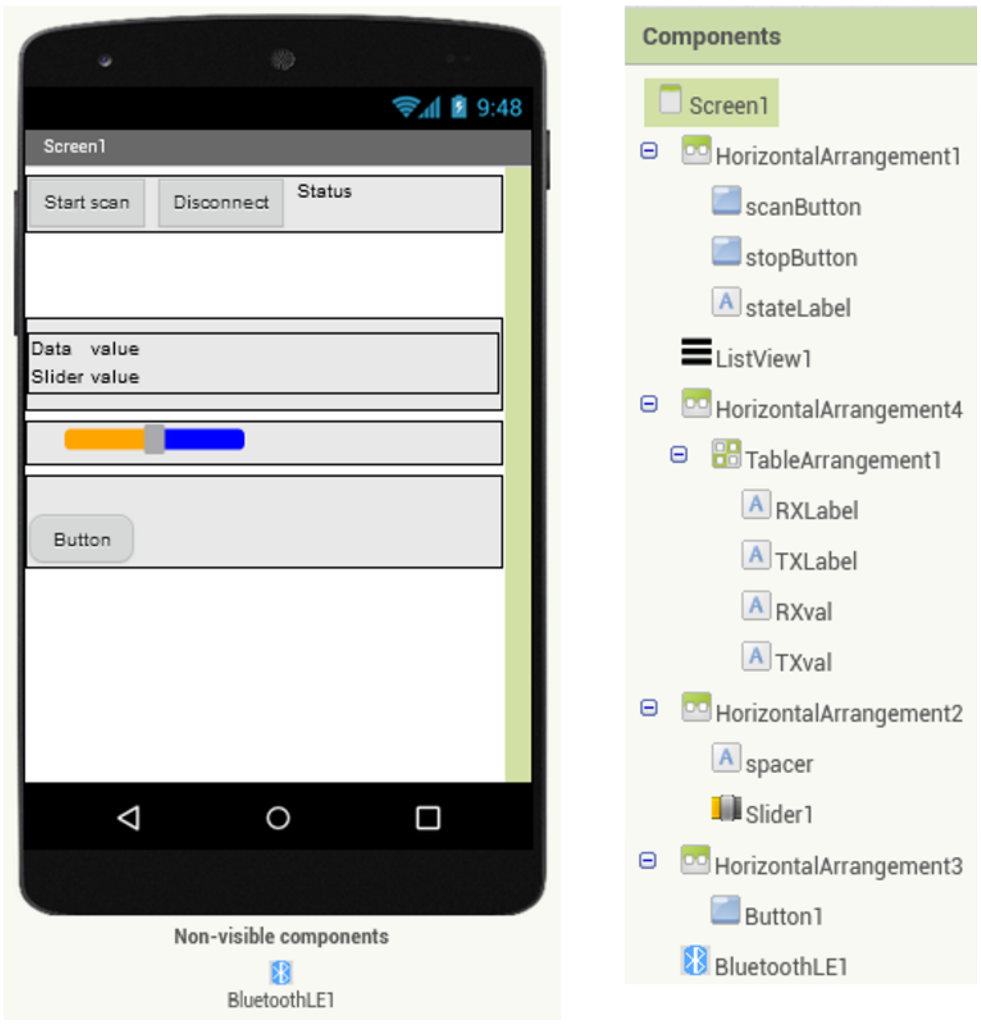
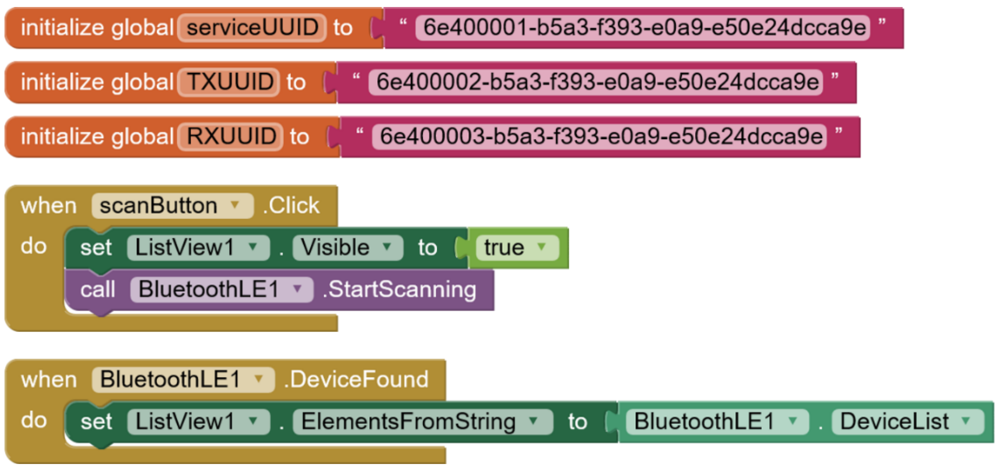


Figure 3 *Components of BLE Receive and Transmit App*

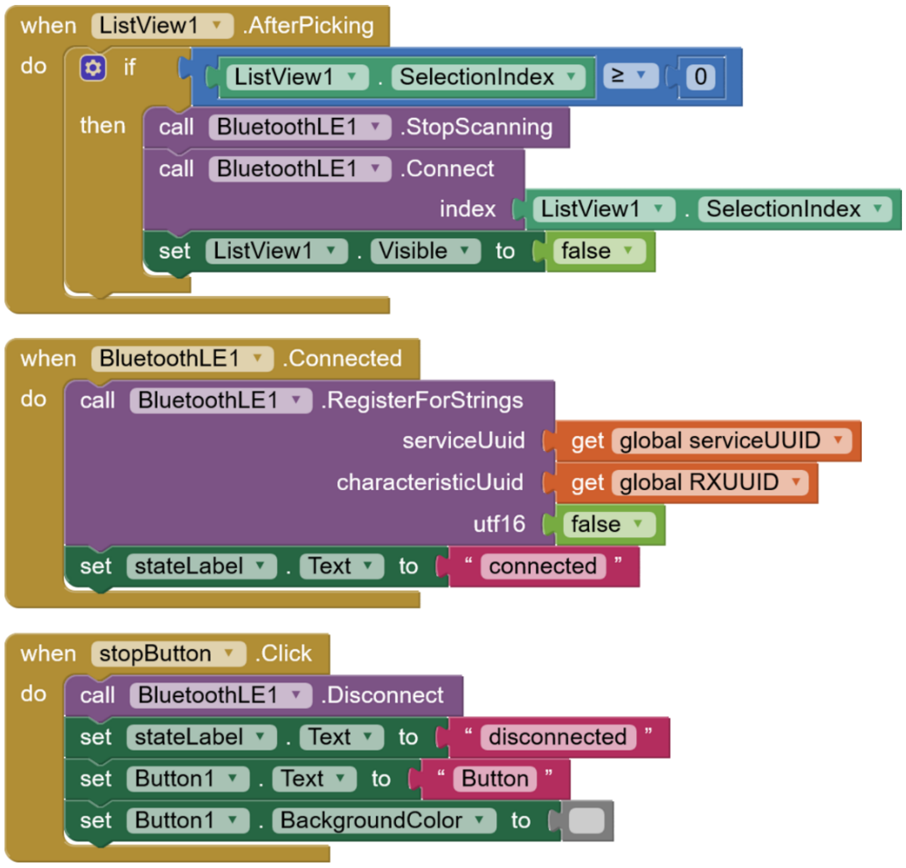
When the *scanButton* is clicked, Bluetooth BLE scanning is initiated and each detected BLE device is added to the *ListView* (see Figure 4). Note that naming of the *TX* and *RX* UUIDs are relative to the client.



```
initialize global serviceUUID to " 6e400001-b5a3-f393-e0a9-e50e24dcca9e "
initialize global TXUUID to " 6e400002-b5a3-f393-e0a9-e50e24dcca9e "
initialize global RXUUID to " 6e400003-b5a3-f393-e0a9-e50e24dcca9e "

when scanButton .Click
do  set ListView1 . Visible to true
    call BluetoothLE1 .StartScanning

when BluetoothLE1 .DeviceFound
do  set ListView1 . ElementsFromString to BluetoothLE1 . DeviceList
```

Figure 4 *App UUIDs and BLE scanning*

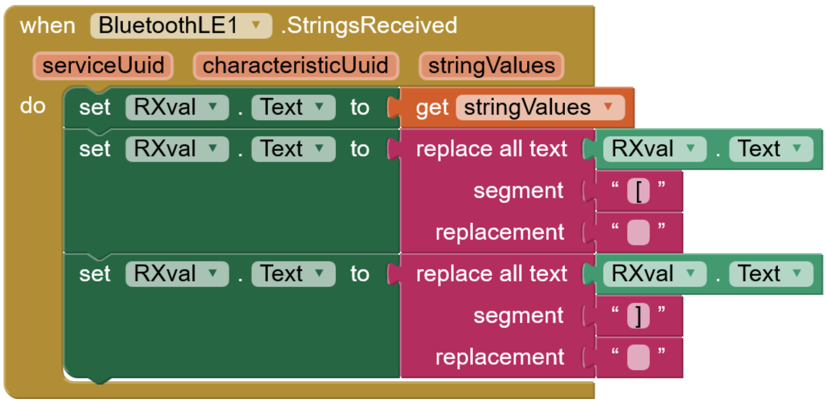
When a BLE device is selected on the *ListView*, Bluetooth BLE scanning is stopped, a connection with the selected BLE device is established and the client receive UUID is defined for the client to receive strings from the server (see Figure 5). When the *stopButton* is clicked, the Bluetooth BLE connection is disconnected.



```
when ListView1 .AfterPicking
do  if    ListView1 . SelectionIndex ≥ 0
    then  call BluetoothLE1 .StopScanning
          call BluetoothLE1 .Connect
                          index  ListView1 . SelectionIndex
          set ListView1 . Visible to false

when BluetoothLE1 .Connected
do  call BluetoothLE1 .RegisterForStrings
                   serviceUuid  get global serviceUUID
            characteristicUuid  get global RXUUID
                         utf16  false
    set stateLabel . Text to " connected "

when stopButton .Click
do  call BluetoothLE1 .Disconnect
    set stateLabel . Text to " disconnected "
    set Button1 . Text to " Button "
    set Button1 . BackgroundColor to
```

Figure 5 *App Bluetooth BLE connection and disconnect*

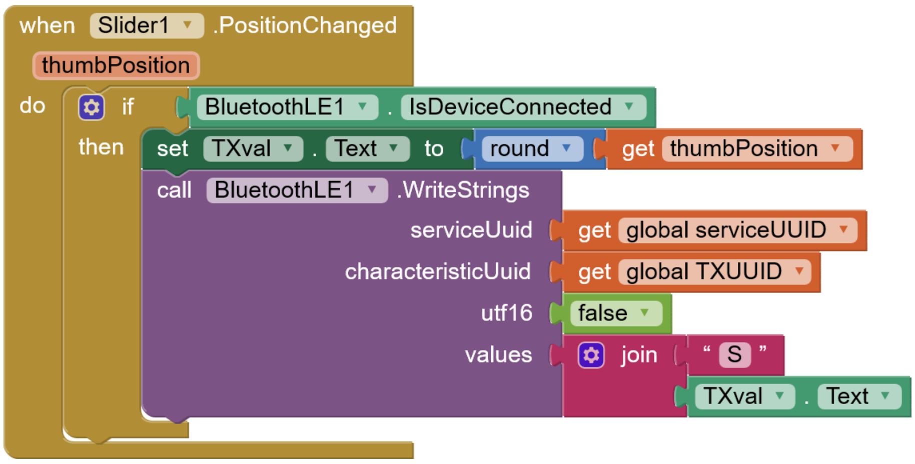
When the client receives a string from the server, the "*[*" and "*]*" characters are removed and the string is displayed on the app (see Figure 6).



```
when BluetoothLE1 .StringsReceived
  serviceUuid  characteristicUuid  stringValues
do  set RXval . Text to  get stringValues
    set RXval . Text to  replace all text  RXval . Text
                         segment      " [ "
                         replacement  "  "
    set RXval . Text to  replace all text  RXval . Text
                         segment      " ] "
                         replacement  "  "
```

***Figure 6** Client receiving from server*

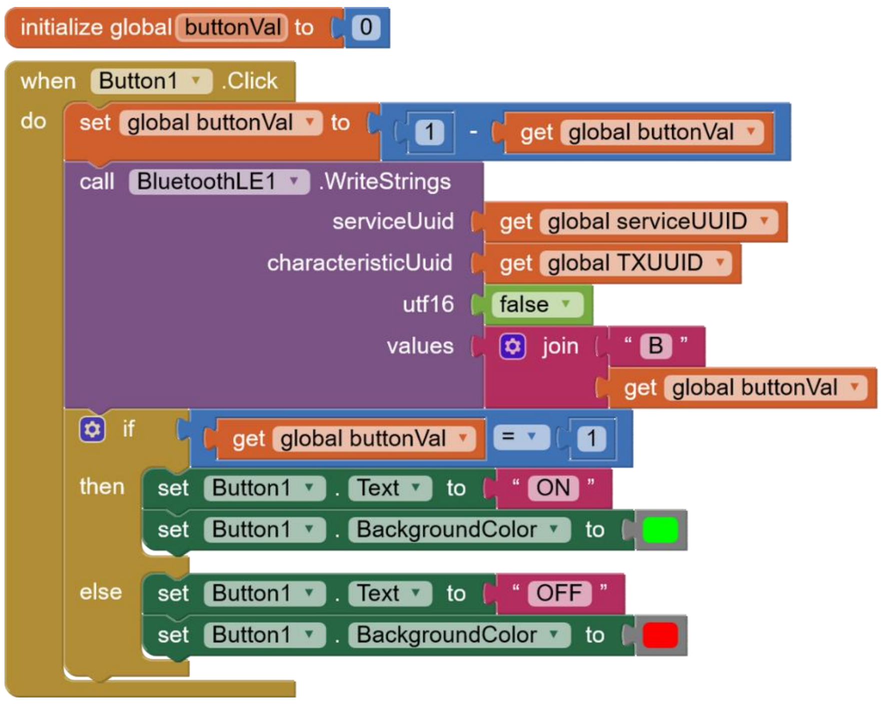
When the slider position is updated, the client transmits a string, prefixed with the character "*S*", to the server with the transmit UUID (see Figure 7).



```
when Slider1 .PositionChanged
  thumbPosition
do  if  BluetoothLE1 . IsDeviceConnected
    then  set TXval . Text to  round  get thumbPosition
          call BluetoothLE1 .WriteStrings
                         serviceUuid  get global serviceUUID
                  characteristicUuid  get global TXUUID
                               utf16  false
                              values  join  " S "
                                            TXval . Text
```

***Figure 7** Client transmitting to server (1)*

Similarly, when the button is pressed, the client transmits a string, prefixed with the character "*B*" (see Figure 8) with the button colour and label also updated.



```
initialize global buttonVal to 0
when Button1 .Click
do  set global buttonVal to 1 - get global buttonVal
    call BluetoothLE1 .WriteStrings
                  serviceUuid  get global serviceUUID
           characteristicUuid  get global TXUUID
                       utf16   false
                      values   join  " B "
                                     get global buttonVal
    if   get global buttonVal = 1
    then set Button1 . Text to " ON "
         set Button1 . BackgroundColor to 🟩
    else set Button1 . Text to " OFF "
         set Button1 . BackgroundColor to 🟥
```

Figure 8 *Client transmitting to server (2)*

Chapter 9 MQTT

Cayenne (developers.mydevices.com) announced that Cayenne MQTT broker will be discontinued in September 2023 (community.mydevices.com/t/end-of-life-announcement-for-cayenne/18926). Chapter 9 *MQTT* has been updated with the Blynk, Arduino IoT Cloud and Adafruit IO MQTT broker services. The updated Chapter and accompanying sketches are included in the **Chapter 9_NEW_V2** folder on GitHub (github.com/Apress/ESP32-Formats-and-Communication/tree/main/Chapter9_NEW_V2).

Chapter 10 Managing Images

The plugin to load files into SPIFFS for Arduino IDE version 1 is available from:
github.com/me-no-dev/arduino-esp32fs-plugin/releases/tag/1.1 esp32fs last updated 6 Mar 2023
The *mklittlefs* folder containing the *mklittlefs* application (Sept 2023) is downloaded from github.com/earlephilhower/mklittlefs/releases as referenced by github.com/lorol/LITTLEFS.
The plugin to load files into SPIFFS for Arduino IDE version 2 is downloaded from:
github.com/earlephilhower/arduino-littlefs-upload

Since publishing *ESP32 Formats and Communication*, a plugin for Arduino IDE version 2 is now available. Instructions for installing and running the plugin are available at github.com/earlephilhower/arduino-littlefs-upload. The *arduino-littlefs-upload-1.1.8.vsix* file is downloaded and the *.vsiz* file is moved to the folder *User\.arduinoIDE\plugins*, which may have to be created. Note that the *plugin-storage* folder already exists. If the Arduino IDE is open, then the Arduino IDE must be closed and restarted after the *arduino-littlefs-upload-1.1.8.vsix* file is moved to the *plugin* folder. In the Arduino IDE, the command palette is opened by pressing *CRTL Shift P* to list the available commands, which will now include the *Upload LittleFS to Pico/ESP8266/ESP32* command.

A text file or image file is stored in SPIFFS by locating the file in the *data* folder within the sketch folder. In the Arduino IDE, select the *Sketch* menu, click *Show Sketch Folder*, create a folder named *data*, and then move the file into the *data* folder. A file *filename.txt* or *image.jpg* is referenced in the sketch as */filename.txt* or */image.jpg*. Prior to compiling and uploading the sketch in the Arduino IDE, ensure that both a *Board* and a *Port* are selected and that the Serial Monitor is closed.

Open the command palette by pressing *CRTL Shift P*, scroll through the list of commands to the *Upload LittleFS to Pico/ESP8266/ESP32* command and click on the command. After the *Completed upload* message is displayed in the *LittleFS upload* panel, compile and upload the sketch.

Corrections

Despite repeatedly checking the page proofs, some typos may have persisted.

If you find typos, then please either email *esp32ndc@gmail.com* or use *GitHub Issues* to log the typo or other issues.

Page 88 last – 5 line	Change expression to `(A > B) ? C : D` by inserting a `?`
Page 243 last line	Change `LEDpin = 27` to `LEDpin = 5`
Page 367 Line 10	Change `SCTpin = 37` to `SCTpin = 36` (as in Figure 9-7)
Page 395 Line 9	Change comment to "Clear LCD screen"
Page 409 Lines 9-10	Change to *User\AppData\Local\Arduino15\packages\esp32\tools*

Neil Cameron

August 2024