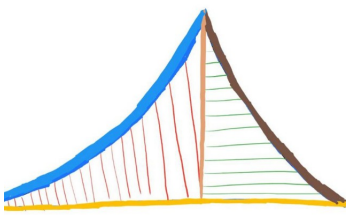
EMBEDDED SYSTEM

G. V. V. Sharma



Contents

Introduction

This book introduces Embedded Systems through using the Vaman framework.

Chapter 1

Vaman-ESP32

1.1. Flash Vaman-ESP32 using Arduino

1.1.1. Make sure that Vaman board do not power any devices.

1.1.2. Make connections as shown in Table 1.1.3.1 and Fig. 1.1.3.1.

1.1.3. The Vaman pin diagram is available in Fig. 1.1.3.2

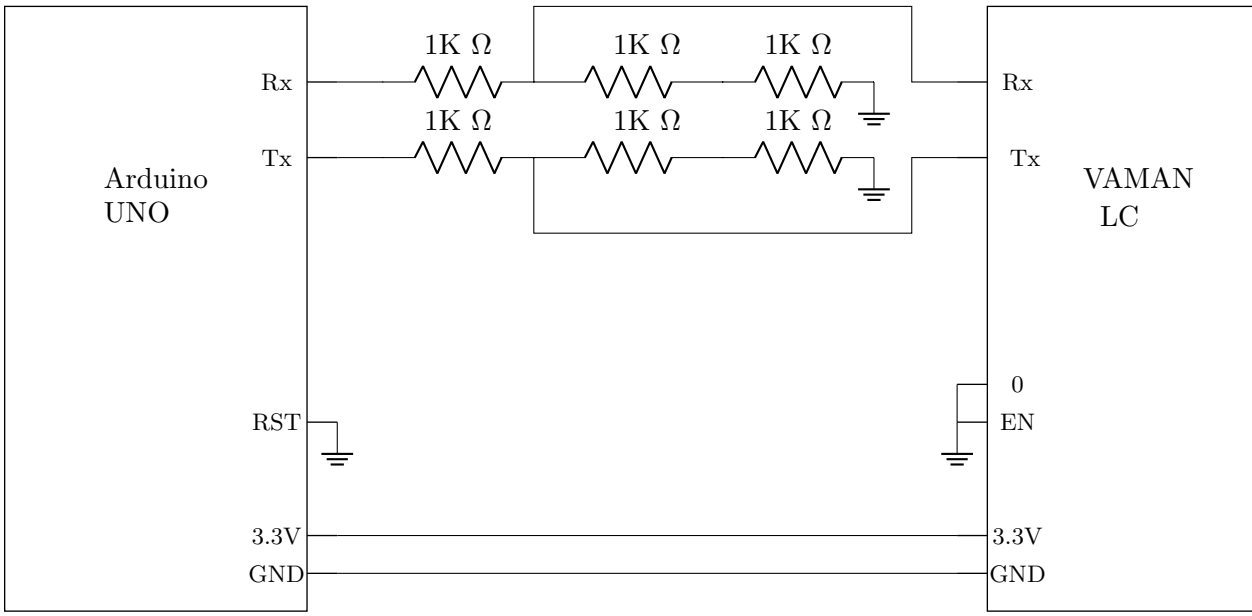


Figure 1.1.3.1: Circuit Connections

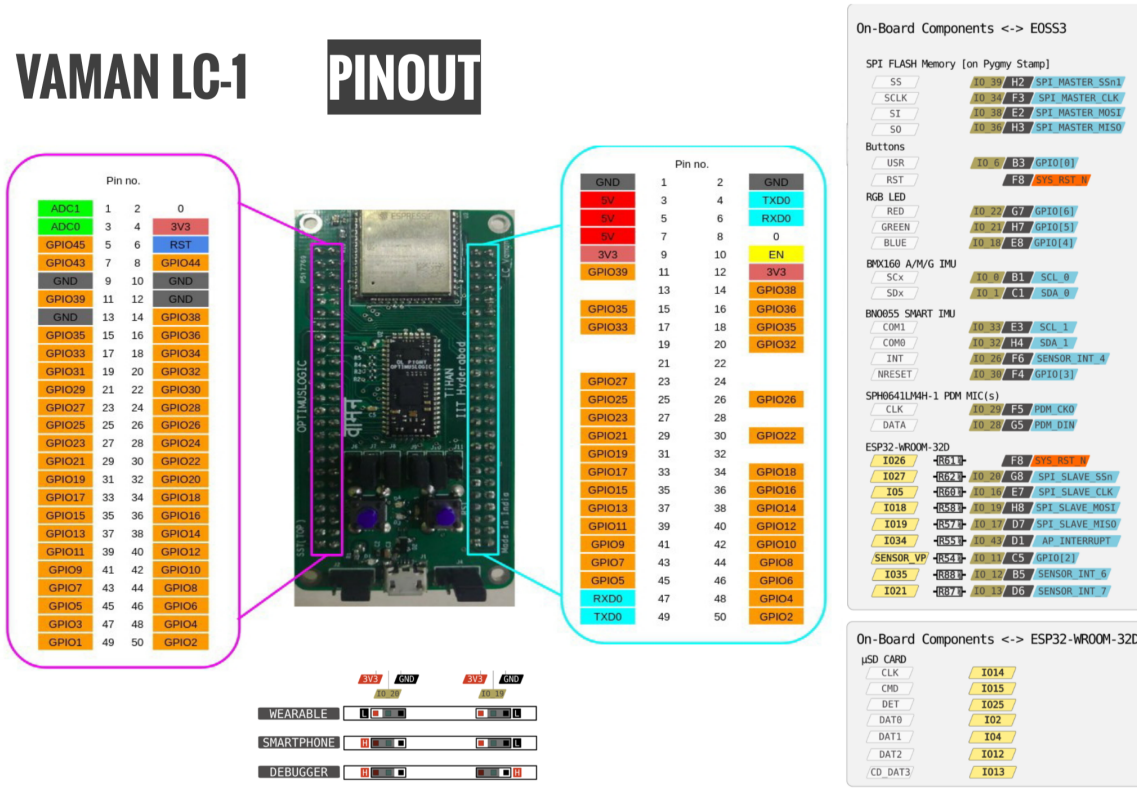


Figure 1.1.3.2: Vaman pins

VAMAN LC PINS	ARDUINO PINS
3.3	3.3
GND	GND
TXD0	TXD
RXD0	RXD
0	GND
EN	GND

Table 1.1.3.1:

1.1.4. For compiling and genrating the bin file

1.1.5. make sure that platformio.ini file contains these lines

```
[env:esp32doit-devkit-v1]
platform = espressif32
board = esp32doit-devkit-v1
framework = arduino
platform_packages = toolchain-xtensa-esp32@https://github.com/esphome/
    esphome-docker-base/releases/download/v1.4.0/toolchain-xtensa32.tar.gz
framework-arduinoespressif32@<3.10006.210326
```

1.1.6. For uploading bin file to Vaman through ArduinoDroid application

1. Open the Droid Application
2. Click the three dots **in** the top right corner
3. Navigate to Settings -> Board Type
4. Select ESP32 -> DOIT ESP32 DEVKIT V1
5. Change the upload speed to 115200
6. Upload the generated .bin file

1.1.7. While the dots are printed on the screen, disconnect the EN wire from GND. Make sure that the Vaman board is not powering any device while flashing. The Vaman-ESP should now flash.

1.1.8. After flashing, disconnect pin 0 on Vaman-ESP from GND. Power on Vaman appropriately.

1.2. Measuring Unknown Resistance Using Vaman-ESP

T:hrough this manual, we learn how to measure an unknown resistance through Vaman-ESP and display it on an LCD.

1.2.1. Components

Component	Value	Quantity
Resistor	220 Ohm	1
	1K	1
ESP32	Devkit V1	1
Jumper Wires		20
Bread board		1
LCD	16 X 2	1
Potentiometer	10K	1

Table 1.2.1: Components

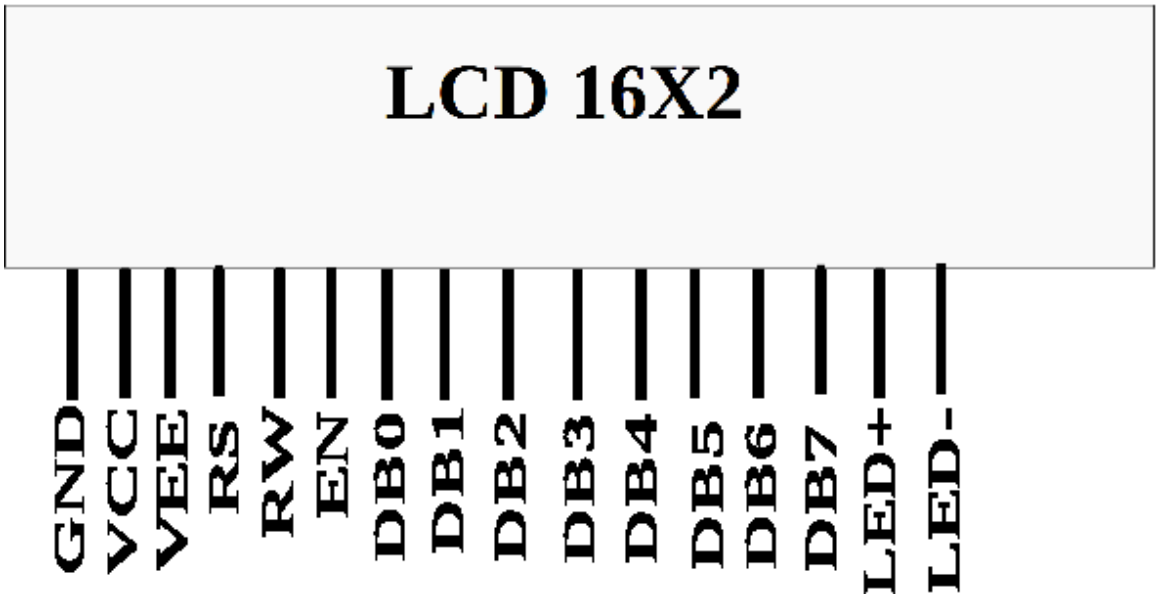


Figure 1.2.1.1: LCD pins

1.2.2. Setting up the Display

1.2.1. Plug the LCD in Fig. 1.2.1.1 to the breadboard.

1.2.2. Connect the Vaman-ESP pins to LCD pins as per Table 1.2.3.1. Make sure that all 5V sources are connected to the LCD through a 220 Ω resistance.

1.2.3. The Vaman pin diagram is available in Fig. 1.1.3.2

1.2.4. Execute the following code after editing the wifi credentials

vaman/vaman−esp/lcd/codes/setup

You should see the following message

Hi This is CSP Lab

ESP32	**LCD Pins**	**LCD Pin Label**	**LCD Pin Description**
GND	1	GND	
5V	2	Vcc	
GND	3	Vee	Contrast
GPIO 19	4	RS	Register Select
GND	5	R/W	Read/Write
GPIO 23	6	EN	Enable
GPIO 18	11	DB4	Serial Connection
GPIO 17	12	DB5	Serial Connection
GPIO 16	13	DB6	Serial Connection
GPIO 15	14	DB7	Serial Connection
5V	15	LED+	Backlight
GND	16	LED-	Backlight

Table 1.2.3.1: Make sure that all 5V sources are connected to the LCD through a 220 Ω resistance.

1.2.5. Modify the above code to display your name.

1.2.3. Measuring the resistance

1.2.1. Connect the 5V pin of the Vaman-ESP to an extreme pin of the Breadboard shown in Fig. 1.2.1.1. Let this pin be V_{cc}.

1.2.2. Connect the GND pin of the Vaman-ESP to the opposite extreme pin of the Breadboard.

1.2.3. Let R_1 be the known resistor and R_2 be the unknown resistor. Connect R_1 and R_2

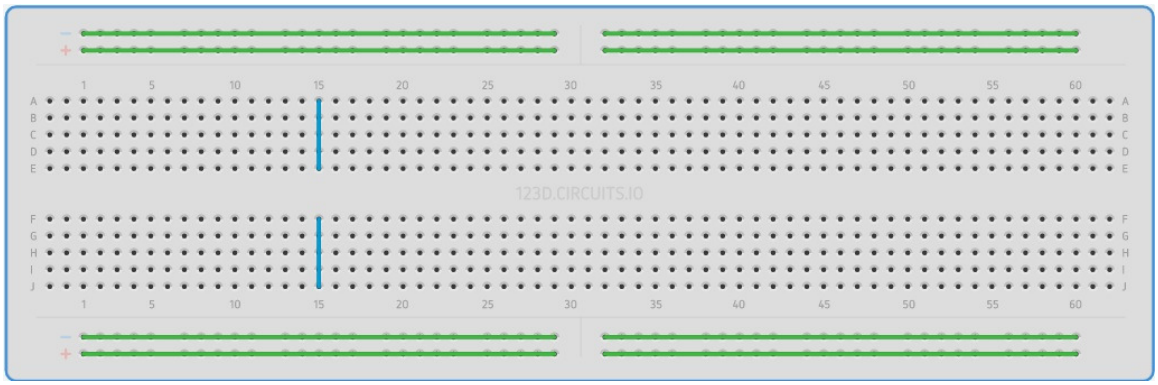


Figure 1.2.1.1: Breadboard

in series such that R_1 is connected to V_{cc} and R_2 is connected to GND. Refer to Fig. 1.2.3.1

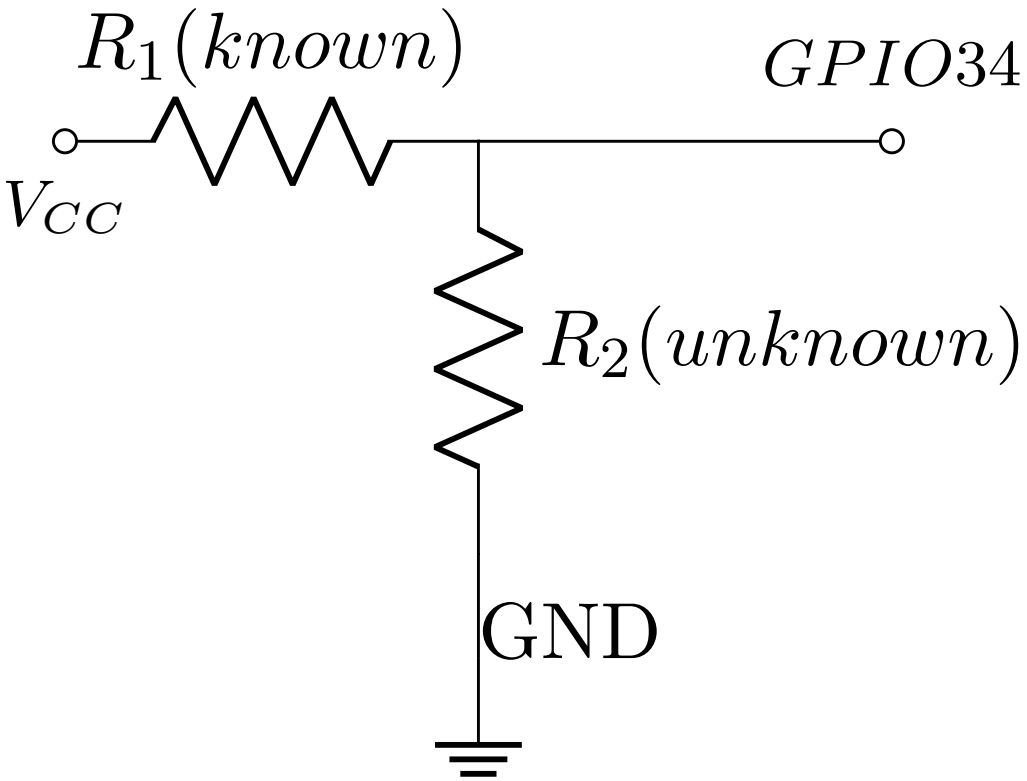


Figure 1.2.3.1: Voltage Divider

1.2.4. Connect the junction between the two resistors to the GPIO34 pin on the Vaman-ESP.

1.2.5. Connect the Vaman-ESP to the computer so that it is powered.

1.2.6. Execute the following code after editing the wifi credentials

```
vaman/vaman−esp/lcd/codes/resistance
```

1.2.4. Displaying the Measured resistance on LCD and website

1.2.1. The unknown resistance is measured and diplayed the measured resistance on the LCD display and also on the Vaman-ESP webserver.

1.2.2. Connect the Vaman-ESP pins to LCD pins as per Table 1.2.3.1.

1.2.3. Execute the following code after editing the wifi credentials

```
vaman/vaman−esp/lcd/webserver/codes
```

1.2.4. After flashing the code to vaman-ESP, the board will be connected to the wifi credentials provided.

1.2.5. Now connect the same WiFi credentials to the mobile phone for accessing the IP address, which can be accessed by

```
ifconfig
nmap −sn 192.168.x.x/24
```

1.2.6. Change the IP address in the second command accordingly with the IP address provided by first command.

1.2.7. By the above commands the IP address of vaman-ESP will be diplayed.

1.2.8. Now the vaman-ESP will be hosting a webserver

1.2.9. Inorder to access the webserver type the IP address of the vaman-ESP in the web browser.

1.2.10. In the website loaded by the IP address of vaman-ESP the Unknown resitance is displayed as shown in Fig. 1.2.10.1

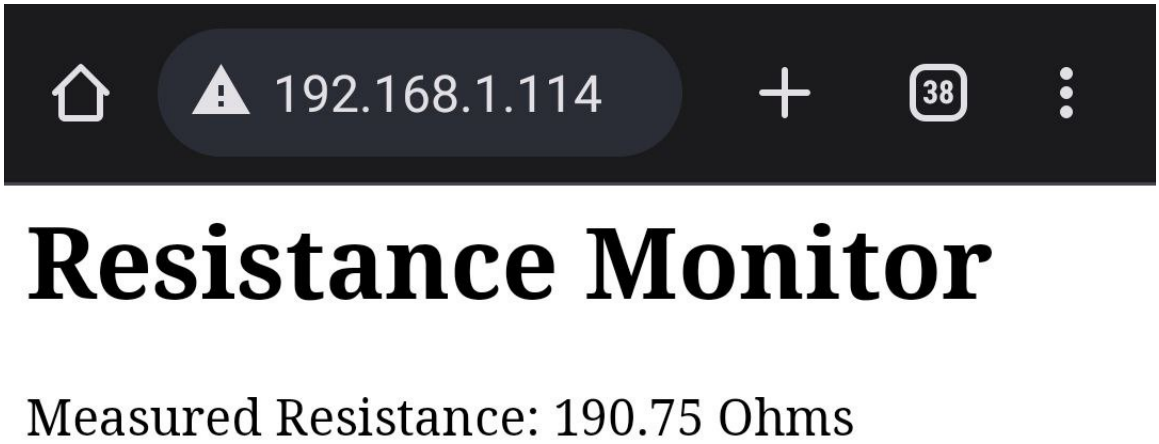


Figure 1.2.10.1: Website

1.2.5. Explanation

1.2.1. We create a variable called analogPin and assign it to 0. This is because the voltage value we are going to read is connected to analogPin GPIO34.

1.2.2. The 12-bit ADC can differentiate 4096 discrete voltage levels, 5 volt is applied to 2 resistors and the voltage sample is taken in between the resistors. The value which we get from analogPin can be between 0 and 4095. 0 would represent 0 volts falls across the unknown resistor. A value of 4095 would mean that practically all 5 volts falls across the unknown resistor.

1.2.3. V_{out} represents the divided voltage that falls across the unknown resistor.

1.2.4. The Ohm meter in this manual works on the principle of the voltage divider shown in Fig. 1.2.3.1.

$$V_{out} = \frac{R_1}{R_1 + R_2} V_{in} \tag{1.2.4.1}$$

$$\Rightarrow R_2 = R_1 \left(\frac{V_{in}}{V_{out}} - 1 \right) \tag{1.2.4.2}$$

In the above, $V_{in} = 5\text{V}$, $R_1 = 220\Omega$.

1.2.5. Repeat the exercise with another unknown resistance.

1.3. I2C Communication Between Vaman-ESP and Arduino

T:hrough this manual, we will learn how to setting up the vaman-ESP as a Master and Arduino as a Slave using I2C protocol.

Component	Value	Quantity
ESP32	Devkit V1	1
Arduino	UNO	1
Connecting Wires		30
LCD	16 X 2	1

Table 1.3.1: Components

1.3.1. Components

1.3.2. Setting up the Master and Slave

1.3.1. Connect the vaman-ESP pins to Arduino pins as per Table 1.3.1.1.

I2C	ESP32	Arduino
SDA	GPIO 21	A4
SDC	GPIO 22	A5
	VCC	VCC
	GND	GND

Table 1.3.1.1:

1.3.2. Connect the vaman-ESP pins to LCD pins as per 1.2.3.1..

1.3.3. The Vaman pin diagram is available in Fig. 1.1.3.2

1.3.4. Configure Arduino Uno as a Slave using the following code.

vaman/vaman−esp/I2C/codes/I2C_Sender_Arduino/src/main.cpp

1.3.5. Now configure vaman-ESP as a Master using the following code.

vaman/vaman−esp/I2C/codes/I2C_Reciever_ESP32/src/main.cpp

1.4. UART Communication between Vaman-ESP and Arduino

T:hrough this manual, we learn how to communicate between Vaman-ESP32 and Arduino UNO through UART Protocol. The Unknown resistance is measured using Arduino and sending the value to Vaman through UART and displaying the unkwnown Resistance on ESP-Webserver.

1.4.1. Components

Component	Value	Quantity
Resistor	220 Ohm	1
	1K	1
Vaman	LC	1
Arduino	UNO	1
Jumper Wires		10
Bread board		1

Table 1.4.2: Components

1.4.2. Connections

1.4.1. Connect the Vaman and Arduino as shown Table. 1.4.1.2.

Arduino UNO	Vaman-ESP
Rx(Pin-0)	17 (Tx)
Tx (Pin-1)	16 (Rx)

Table 1.4.1.2: Connections

1.4.2. The Vaman pin diagram is available in Fig. 1.1.3.2

1.4.3. Upload the following code to Arduino UNO

vaman/vaman−esp/UART/codes/UNO

1.4.3. Measuring the resistance

1.4.1. Connect the 5V pin of the Vaman-ESP to an extreme pin of the Breadboard shown in Fig. 1.2.1.1. Let this pin be V_{cc}.

1.4.2. Connect the GND pin of the Vaman-ESP to the opposite extreme pin of the Breadboard.

1.4.3. Let R_1 be the known resistor and R_2 be the unknown resistor. Connect R_1 and R_2 in series such that R_1 is connected to V_{cc} and R_2 is connected to GND. Refer to Fig. 1.2.3.1

1.4.4. Connect the junction between the two resistors to the A0 pin on the Arduino board.

1.4.5. Now Power the Vaman board

1.4.6. Execute the following code after editing the wifi credentials

vaman/vaman−esp/UART/codes/VAMAN

1.4.4. Displaying the Measured resistance on website

1.4.1. The unknown resistance is measured and diplayed the measured resistance on the Vaman-ESP webserver.

1.4.2. After flashing the code to vaman-ESP, the board will be connected to the wifi credentials provided.

1.4.3. Now connect the same WiFi credentials to the mobile phone for accessing the IP address, which can be accessed by

```
ifconfig
nmap −sn 192.168.x.x/24
```

1.4.4. Change the IP address in the second command accordingly with the IP address provided by first command.

1.4.5. By the above commands the IP address of vaman-ESP will be diplayed.

1.4.6. Now the vaman-ESP will be hosting a webserver

1.4.7. Inorder to access the webserver type the IP address of the vaman-ESP in the web browser.

1.4.8. In the website loaded by the IP address of vaman-ESP the Unknown resitance is displayed as shown in Fig. 1.2.10.1

1.5. Bluetooth Controlled Seven segment Display

T:his manual shows how to control the Seven Segment Display through the Dabble android application using Bluetooth in Digital mode and display on the seven segment according the controls in the android app.

1.5.1. Components

Component		**Quantity**
Resistor	220 Ohm	1
Seven Segment Display		1
Vaman	LC	1
Arduino	UNO	1
Jumper Wires		10
Bread board		1

Table 1.5.2: Components

1.5.2. Connections

1.5.1. Connect the Arduino-UART to VAMAN as per Table. 1.1.3.1 and Figure 1.1.3.1.

1.5.2. Now, execute the following code

vaman/vaman−esp/bluetooth/codes/src

1.5.3. Make sure to give the path to DabbleESP32-master folder path in the platformio.ini file as shown below

lib_extra_dirs = /"Path to DabbleESP32−master folder"/DabbleESP32/src

1.5.4. Install the Dabble Android application and give the necessary permissions.

1.5.5. Connect the bluetooth of vaman ESP-32 bluetooth to the mobile- where the bluetooth is labled as "ESP-32"

1.5.6. Open the Dabble application. Select gamepad option in the app and then select Digital Mode and connect it app to ESP-32 by connecting it ESP-32 bluetooth as shown in Figure 1.5.6.1.

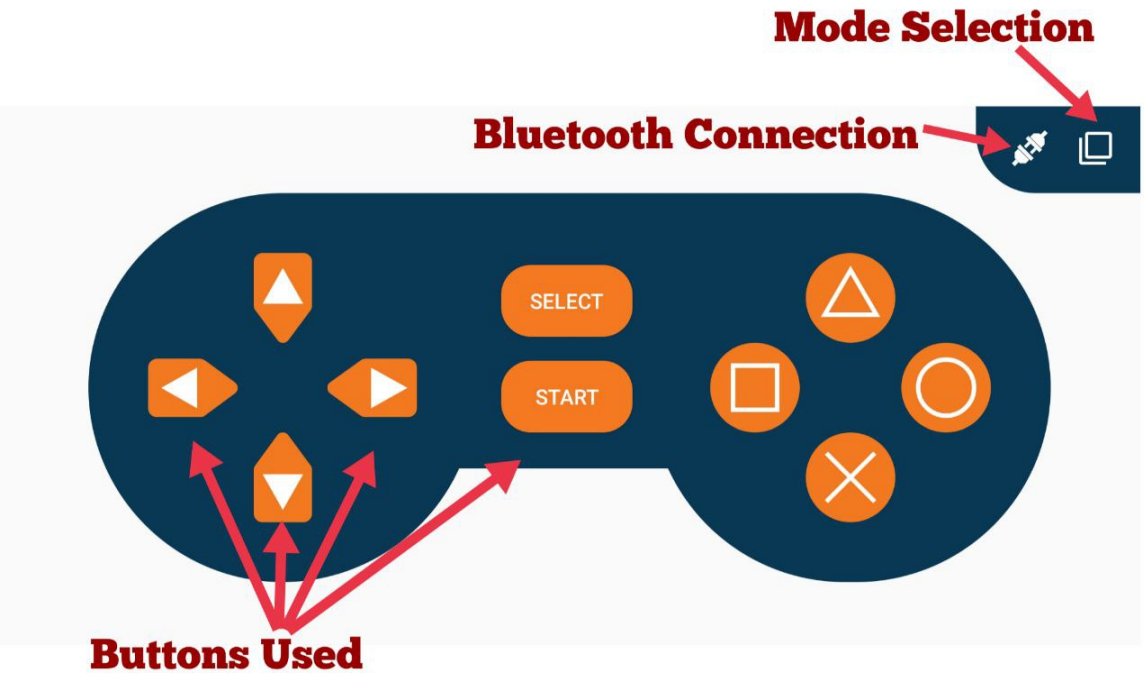


Figure 1.5.6.1: Dabble app Interface

1.5.7. Now connect the Seven Segment to the Vaman board according to the given Table. 1.5.7.2

VAMAN ESP pins	Seven Segment pins
IO-32	a
IO-33	b
IO-25	c
IO-26	d
IO-27	e
IO-14	f
IO-12	g

Table 1.5.7.2: Connections

1.5.8. Now you can observe the changes on sevensegment display for Start, Up, Down, Right and Left keys pressed on the Digital Mode on the android application

Chapter 2

Toy car

T:hrough this manual, we learn how to communicate between SPI, Wishbone Interfacing and Address Mapping. On the Vaman Board, we have an EOS S3 and ESP32. The Communication between these two happens via SPI i.e, Serial Peripheral Interface.And this is facilitated only when all the 4 jumpers on the board are closed.

2.1. Components

2.1.1. (Vaman Board)

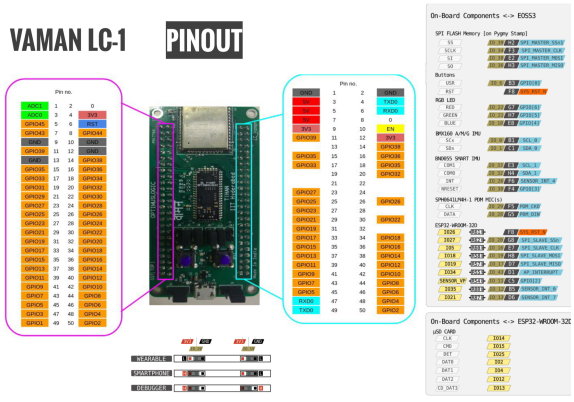


Figure 8.1: vaman Board pins

2.1.2. ESP 32

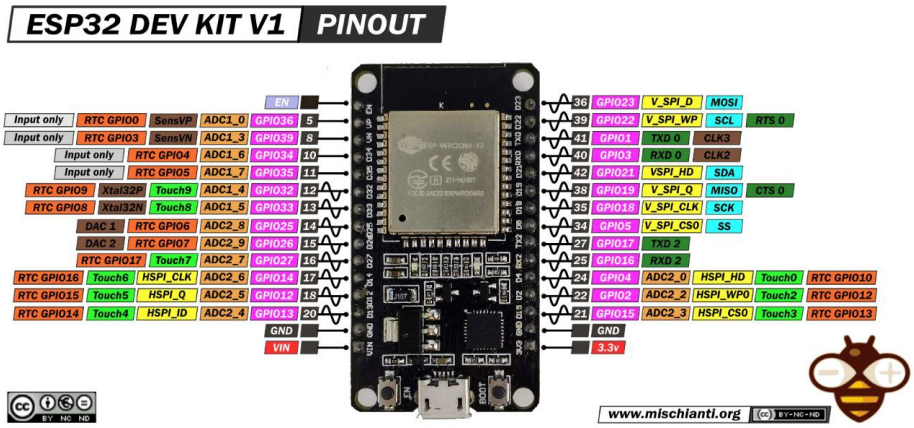


Figure 8.2: ESP32 Board pins

2.1.3. DC Motors

Figure 8.3: ESP32 Dc motors

2.1.4. UGV frame/chassis

Figure 8.4: UGV frame/chassis

2.1.5. L298 N motor driver

Figure 8.5: L298 N motor driver

2.1.6. Batteries for powering various equipment

Figure 8.6: Batteries for powering various equipment

2.2. Assembling the UGV kit

2.2.1. Assemble the Chassis using the provided nuts/screws, Wheels, and parts.

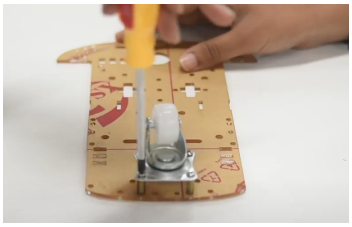


Figure 2.2.1.1: screws connecting

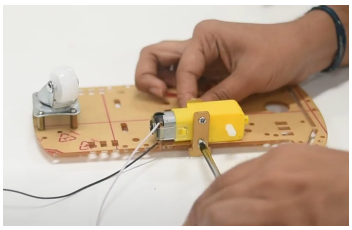


Figure 2.2.1.2: Dc motors connecting

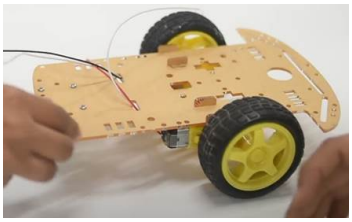


Figure 2.2.1.3: wheels connections

2.2.2. Fix the Vaman controller and ESP32 on the chassis.

2.2.3. Fix the Dual motor driver IC along with a small breadboard on the chassis.

2.2.4. Fix the Li-Po battery on the chassis and insert AA batteries in the battery holder.

2.3. Circuit Connections

2.3.5. Make the Circuit Connections as per the table below 2.3.5.2.

Vaman Board	**Motor Driver Unit**
Pin 21	Right Motor Input 1
Pin 18	Right Motor Input 2
Pin 23	Left Motor Input 1
Pin 22	Left Motor Input 2
5v	VCC
GND	GND

Table 2.3.5.2: connection with vaman board

2.3.6. Make the Motor Driver Connections as per the table below.

2.3.7. Make the Circuit Connections as per the table below.

INPUT	VAMAN BOARD	OUTPUT	MOTOR
A1	PYGMY 21	Vcc	5V
A2	PYGMY 18	GND	GND
EN	-	MA1	MOTOR A1
VCC	5V	MA2	MOTOR A2
B2	PYGMY 23	MB1	MOTOR B1
B1	PYGMY 22	MB2	MOTOR B2
5V	VCC	-	-
GND	GND	-	-

Table 2.3.6.2: connection with L293 Motor Driver

Vaman Board ESP 32	Motor Driver Unit
Pin 16	Right Motor Input 1
Pin 17	Right Motor Input 2
Pin 18	Left Motor Input 1
Pin 19	Left Motor Input 2
5v	VCC
GND	GND

Table 2.3.7.2: WIFI CAR Connections

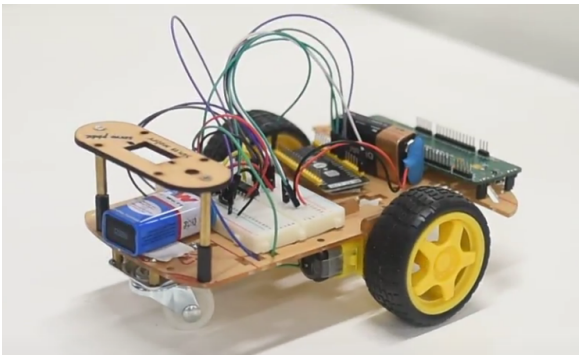


Figure 2.3.7.1: After all connections

2.3.8. Download the “dabble” application from the play store on an Android phone.

2.3.9. Using dabble application, connect to the ESP32 on the UGV kit using Bluetooth connection.

2.3.10. Control the navigation of the UGV kit using the GUI controls on the dabble application.

Figure 2.3.10.1: UGV kit using the GUI controls on the dabble application

2.3.1. Code:

In the code also there are three major processes that take place in ESP32, ARM Core and FPGA.

Firstly, The ESP32 collects the joystick movement data from the Dabble app connected via bluetooth. It receives the x,y co-ordinates in the range [-7,7]. EP32 then scales it to [0,255] and places it in the Arrays declared in the ARM Core.

The ARM Core now has the joystick movement data in its 8 bit registers. Which it passes on to the mapped FPGA Registers via the AHB.

Then in FPGA we implement the Wishbone slave interface to read the data sent by the ARM Core via AHB. Now in the FPGA Unit, the Pulse Width Modulation takes place. The corresponding PWM values for the joystick movement data are generated and sent back to the ARM Core.

Now the ARM Core running a loop, Checks if the Cross or Square button is pressed and also reads these changes in the PWM values. It then sends signal to the DC Motors of the UGV to rotate the wheels accordingly.

2.4. Execution

2.4.11. Download the repository

```
svn co https://github.com/srikanth9515/FWC/tree/main/UGV
```

2.4.12. Build the ESP32 firmware

```
cd esp32_pwmctrl
pio run
```

2.4.13. Flash ESP32 firmware (connect USB-UART adapter)

```
pio run −t nobuild −t upload
```

2.4.14. If using termux, send .pio/build/esp32doit-devkit-v1/firmware.bin to PC using

```
scp .pio/build/esp32doit-devkit-v1/firmware.bin Username@IPAddress:
```

2.4.15. Modify line 140 of config.mk to setup path to pygmy-sdk and then Build m4 firmware using

```
cd m4_pwmctrl/GCC_Project
make
```

2.4.16. If using termux, send output/m4_pwmctrl.bin to PC using

```
scp output/m4_pwmctrl.bin username@IPaddress:
```

2.4.17. Build fpga source (.bin file)

```
cd fpga_pwmctrl/rtl
ql_symbiflow -compile -d ql-eos-s3 -P pu64 -v *.v -t AL4S3B_FPGA_Top -p
    quickfeather.pcf -dump jlink binary
```

2.4.18. If using termux, send AL4S3B_FPGA_Top.bin to PC using

```
scp AL4S3B_FPGA_Top.bin username@IPaddress:
```

2.4.19. Connect usb cable to vaman board and Flash eos s3 soc, using

```
sudo python3 <Type path to tiny fpga programmer application> --port /dev/
    ttyACM0 --appfpga AL4S3B_FPGA_Top.bin --m4app m4_pwmctrl.bin --
    mode m4-fpga --reset
```

2.4.20. Install the **Dabble app** on the Mobile from the **Playstore**. Connect it to the **ESP32** on the Vaman Board using **Bluetooth**. Change the controls to **Joystick mode** to navigate the UGV.

2.5. Execution For WIFI UGV

2.5.21. Download the repository

```
https://github.com/srikanth9515/FWC/tree/main/WIFI_UGV
```

2.5.22. Build the ESP32 firmware

```
CD WIFI_UGV
pio run
```

2.5.23. Flash ESP32 firmware (connect USB-UART adapter)

```
pio run −t upload
```

2.5.24. Connect your own TAB /Phone Hot spot and Enter Your SSID and Password

```
const char* ssid = "fwc"; /*Enter Your SSID*/
const char* password = "fwc123"; /*Enter Your Password*
```