Car Base Board

Datasheet

Great platform to jump start a robot car project.
Base for a STM32F411 “BlackPill” USB Stick board.
Includes headers and ports for popular external devices.
Includes on-board five-volt power management.
MIT License.

Version 1.4

Applying Microcontroller Solutions

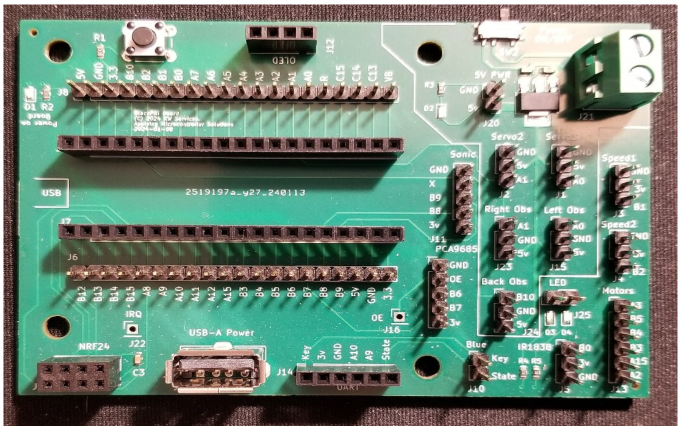
Document Date: 2024-04-12

Contents

Product Overview

The Car Base Board is a printed circuit board (PCB) designed for a robot car project that provides a base for the BlackPill[1] a USB stick board and headers to external devices. The headers provide a strong and organized method to wire connections to external devices (that avoid a rats nest of wires typical in development projects.) The ports permit the mounting of popular wireless communication devices. There should be no need to solder any wires nor drill holes for any parts.

The product is only the PCB. The BlackPill, the devices, wiring and battery are not included. However the low-cost BlackPill, wires/cables and many low-cost sensor boards are available from popular retailers.



FEATURES

- **A dual female port for the BlackPill.**
- **Organized headers and ports for external devices.**
- **Optional Battery power for five-volt devices.**
- **Multiple options for wireless communication to facilitate autonomous operation.**

APPLICATIONS

- **The board is designed for a Robot Car project.**
- **The flexible choice of devices means the board is a great general purpose development board.**
- **The board is compatible with popular Integrated Development Environments such as Thonny and Visual Studio.**

The headers and ports are wired to known I2C, SPI, and UART BlackPill pins. This generic approach allows you to choose your preferred sensors and devices. The matching BlackPill male headers provide an easy means to test BlackPill pins with a Logic Analyzer or even to add connections to sensors and devices on a breadboard.

Additionally, the Car Base Board has a separate connector for power from external batteries. The batteries can provide higher voltage and current to the control devices. On the PCB, the battery power is regulated down to

1 BlackPill is a product by WeAct Studios. ST and STM32 are Trademarks of STMicroelectronics. STM32F411 Base Board is a Copyright of KW Services. Thonny is owned by Aivar Annamaa and is distributed by https://thonny.org

five-volts. There the five-volt power is fed to several devices. Later, the five-volts can also be fed to the BlackPill USB Stick board so that now your project board has autonomous operation.

Connections for External Devices:

Control

- Motor Dual Control — Logic signals for a high power board.
- PC9685 Sensor (6v+ servos) — I2C logic signals to the high power board (board has 16-channels).
- (2x) Servos (5v servos) — Logic signal and five-volt power for each servo (e.g. MG90s).

Monitor

- Ultrasonic (HC-SR05) board — Logic signals and 3.3-volt power for the device.
- (2x) Slotted optical "Speed" board — Logic signals and 3.3-volt power for the device.
- (3x) Infrared Tracker board — Logic signal and five-volt power for each board.

Wireless Communication

- Infrared Receiver (IR1838) board — Logic signals and 3.3-volt power for the IR receiver.
- UART-Bluetooth (HC05 or BLE) — Logic signals and 3.3-volt power for the board. Breakout for the State and Key IO pins.
- NRF24 Port (J18) — SPI logic signals and 3.3-volt power for the device.

Display

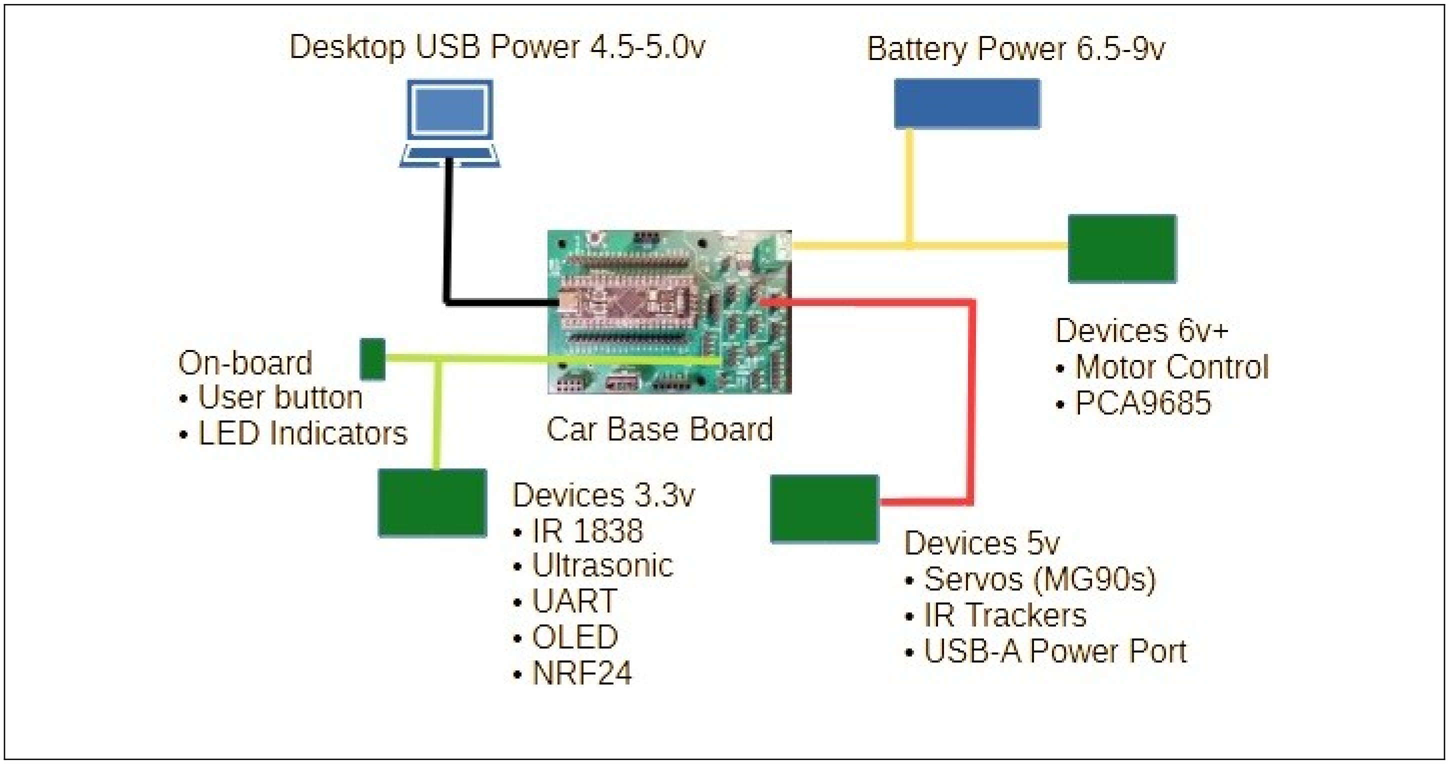
- I2C Port (OLED) — I2C logic signals and 3.3-volt power for an OLED device.

Most of the BlackPill general-purpose input/output (GPIO) pins are connected to the above mentioned sensor ports. However, a port can be left unpopulated and the pins defined to a different purpose (and wired via the "matching male header").

Power Management

For development, there are two sources of power on the board: (1) USB power from a desktop computer through the USB-C connector of the BlackPill (thence the BlackPill provides 3.3v power to the PCB), and (2) Battery power from an external power source to the Phoenix connector (this provides five-volts to several headers via a five volt regulator.) Note: All of the grounds are interconnected on the PCB.

The below diagram depicts the suggested distribution of power across the PCB and devices. The battery provides power for the high power (and current draw) devices.   This allows every component to be tested even while the project is still powered from the desktop.



Later, one can connect a simple USB power cable to the BlackPill from a port on the PCB. In this manner everything is ultimately powered by the batteries alone.   A schematic for the Car Base Board is provided at the end of this document.

Hardware Details

The PCB was designed to use "generic" external devices for easier upgrading/replacement. The layout of the headers distribute wiring-cables to significantly reduce clutter (no rats nest of wires). Also the design ensures there is a pathway to get power to all components via batteries. Finally, the design allows the builder to choose their preferred wireless communication device.

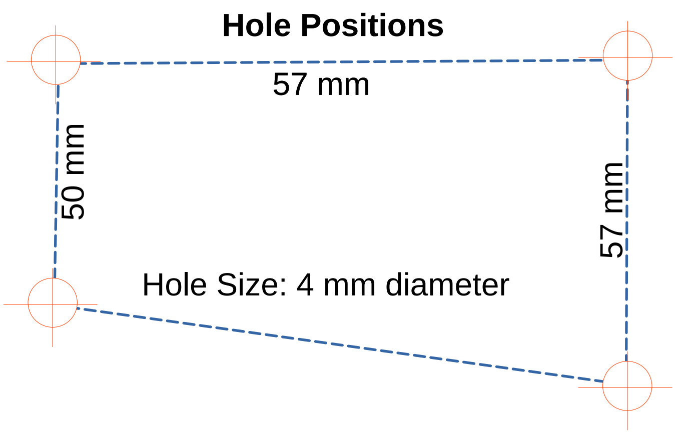
All components (the PCB and optional external devices) are self-contained and accessed via male headers. There should be no need to solder any wire nor drill holes for any parts.

Desktop Power to the BlackPill

Insert a standard USB-C "data" cable into a desktop computer and plug the smaller end into the BlackPill's USB-C port. This provides a nominal five volts (low-current) to the BlackPill. The BlackPill board regulates this power to 3.3 volts. The BlackPill provides power to all of the GPIO and 3.3v logic devices. The Car Base Board indicates the availability of power from the BlackPill by illuminating a small red LED on the left edge of the PCB.

Mounting Holes

The mounting hole dimensions are shown below. One hole was moved to accommodate the NRF24 Port.



The holes are at least 5mm from the PCB board edge. This placement fits two of the mounting holes on a "generic" Robot Car acrylic platform.   The holes can fit M3 Nylon or brass hex spacers and screws.

Headers/Ports

The headers are standard 2.54 mm pitch male connectors that can be utilized by standard "DuPont" Female-to-Female 3/4/5-line wiring cables (20-40mm long). The ports are standard 2.54 mm pitch female connectors that can be utilized by devices with standard pitch male headers (basically, you just plug the device into the port).

Battery Power to the BlackPill

When ready for autonomous operation, remove the end of the USB cable from the desktop, and plug it into the USB-A port on the Car Base Board. The USB-A port provides five-volt power (via the batteries.) Using a short USB-C cable will reduce wiring clutter.

Pin Definitions

The BlackPill pins are wired to various Headers and Ports (Connections). The BlackPill has 40 pins; twenty pins on each side of the board. Below is a table listing the BlackPill pin assignments to each header/port. By leaving a Connection unpopulated, one can re-use its pins elsewhere. For better understanding, please see the schematic in the appendix.

Below is a table listing the BlackPill pin assignments to each header/port.

Header and Port GPIO Pin Assignment
Sorted by Pin

Left Side		Right Side	
B12	NRF24 Port (J18)	B10	User Button and IR Track (J24)
B13	NRF24 Port (J18)	B2	IR1838 Receiver Header (J5)
B14	NRF24 Port (J18)	B1	IR Speed Header (J4)
B15	NRF24 Port (J18)	B0	IR Speed Header (J3)
A8	NRF24 Port (J18)	A7	SPI-1-Flash
A9	UART1 Port (J14)	A6	SPI-1-Flash
A10	UART1 Port (J14)	A5	SPI-1-Flash
A11	USB-	A4	SPI-1-Flash
A12	USB+	A3	Motor Enable (J13)
A15	Motor Header (J13)	A2	Motor Enable (J13)
B3	Motor Header (J13)	A1**	Servo2 (J2) or IR Track (J23)
B4	Motor Header (J13)	A0 **	Servo1 (J1) or IR Track (J15)
B5	Motor Header (J13)	R	NRST
B6*	PCA Header (J17), OLED Port (J12)	C15	OSC32 out
B7*	PCA Header (J17), OLED Port (J12)	C14	OSC32 in
B8	Ultrasonic Header (J11)	C13	Onboard LED
B9	Ultrasonic Header (J11)		

Notes:

* The B6/B7 pins are I2C and can be utilized by several devices as each device has its own distinct address.

** There are conflicting pins for the Servo1/Servo2 and IR Tracker headers. The builder has to choose which function they prefer. Note: These headers use five volt battery power.

Battery Power

The Power circuit utilizes a Phoenix connector for VIN and Ground wires from a (6.5-9v) battery source and is controlled by a small dedicated ON/OFF Power Switch. When switched ON, power is fed to the linear regulator and a nearby LED indicator is lit.

The line of power from the battery to VIN pin must be at least 6.5v. This is because the PCB uses a standard AMS1117 linear regulator with 1.4v dropout. The linear regulator is rated for 1.0 A. There is a two-pin male ("5V PWR") header for verify the regulator output.

Because a robot car has current needs, the project must receive its source of power from several batteries (e.g. 7.4-8 volts from two 18650 or nine volts from six AA batteries). Battery holders are suggested in the next section. A small 9-volt "radio" battery is not sufficient.

External Devices

The builder is free to choose their favorite external devices and battery source. This is possible because the connections are via the wire cables. Below is specifications and expectations for devices tested on the Car Base Board. The board is wired for specific pins as described in the Pin Definitions above to facilitate the organized wiring of a project. But they can freely defined for other devices. Of course the matching BlackPill headers can also be utilized for off-board devices or to attach a Logic Analyser.

Wire Cables

The 2.54 mm male headers are expecting standard 2.54 mm female-to-female cables that are approximately 22 cm (8.5 inches) in length. Standard single strand DuPont wires will work, but a “cable” with multiple wires will stay attached and be tidy.

The board has the following device needs:

- (1x) Six-wire cable for Motor Control
- (2x) Five-wire cables for PCA9685 and Ultrasonic SR-HC05 devices
- (6x) Three-wire cables for IR Detect, Speed, and IR1838 devices. (2x) Servo devices include a 3-wire cable.
- (4x) Single-wires for optional Bluetooth signals and the optional LED indicators.
- Two single-wire headers are unpopulated as they were not needed but are available if required.

The board also has these needs:

- (2x) single-wire solid-core wires between the power source and the PCA9685 board’s VIN and Ground.
- (2x) single-wire solid-core wires between the power source and the car base board’s VIN and Ground.

Power Source

Look for plastic holders for several batteries with power leads pre-soldered, mounting holes and ideally an on/off switch.

The two options are 18650 (3.7-4.2 volt) and “AA” (1.5 volt) batteries. Since the board regulator requires 6.5 to 9 volts DC, the smallest packs are:

- (2x) cells for 18650 batteries will provide 7.4 to 8.4 volts.
- (6x) cells for “AA” batteries will provide 9 volts.

Control Devices

These boards need to receive 6v+ power from the batteries. The logic signals come from the Car base Board headers.

The Motor Control header is designed for a device requiring six logic pins: (2x) an Enable PWM pin and two directional input pins. Power to the Motor Control

The PCA9685 header is

Monitor

These are interesting as there are numerous devices that can be added. One is only limited by the available GPIO pins. I choose these so that I could program the car to avoid obstacles and verify its movement.

The Cat Base Board has headers for devices that monitor

- Three-pin (two power and one logic signal):
  - Infrared Obstacle Tracker
  - Speed Sensor
- Five-pin (two power and three logic signal):
  - Ultrasonic Distance Sensor

Wireless Communication

Communication inherently is between two devices: a receiver and a transmitter.

IR 1838 Header

The Infrared Receiver kit can be purchased with an IR Receiver board and an inexpensive handheld "remote". (Note: some TV remotes work as well.) A **keypress** on the remote sends a hex code to the IR Receiver. A "TV" style remote keypad layout is very intuitive to use, since directions and special functions can be defined for specific keys.

UART Port

The inexpensive six-pin UART Bluetooth (HC-05) board or six-pin UART BLE board can be inserted directly into the UART Port on the PCB. A connection can be made to any Bluetooth central host such as a smart phone, Raspberry PI or desktop. For example, a smart phone can perform a Bluetooth connection and then use a Bluetooth Serial Terminal application. These devices are capable of transmitting short **words.** These boards typically short distances (up to 40 m.)

NRF24 Port

An device is the nRF24L01 Transceiver module (twith onboard or a directional antenna). The PCB has an 8-pin port designed to fit a NRF24 Transceiver device. One can simply insert the device into the port. To operate this device you need two Transceivers. The signals from the BlackPill are wired to the NRF24 Port on the PCB. A web search suggests that it can operate up to 100 meters.

Display

The four-pin female port allows a small inexpensive OLED display (with its four-pin header) to be inserted into the OLED Port on the PCB. The port is wired as: (a) Ground, (b) 3.3 Volt, (c) SCL signal and (d) SDA signal.

Small OLED devices are available that are capable of 128 x 64 pixels and can be programmed for text and graphics.

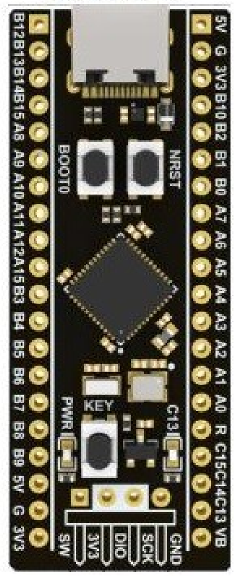
BlackPill (STM32F411CEU6) USB Stick

The BlackPill v3.1 is manufactured by WeAct Studios and is a USB Board with the ST Microelectronics' STM32F411CEU6 48-pin chip. The picture below provides a simplified view of the BlackPill. An image with more pin information is available at the WeAct Studios GitHub web site. Link

STM32F411CEU6
BLACKPILL

UART	SPI	I2C	USED		#
	SPI2-NSS			PB12	25
	SPI2-SCK			PB13	26
	SPI2-MISO			PB14	27
	SPI2-MOSI			PB15	28
		I2C3-SCL		PA8	29
UART1-TX				PA9	30
UART1-RX				PA10	31
UART6-TX			USB	PA11	32
UART6-RX			USB	PA12	33
	SPI3-NSS			PA15	38
	SPI3-SCK			PB3	39
	SPI3-MISO			PB4	40
	SPI3-MOSI			PB5	41
		I2C1-SCL		PB6	42
		I2C1-SDA		PB7	43
		I2C3-SDA		PB8	45
		I2C2-SDA		PB9	46
				VIN_5	
				GND	
				VCC	

USB-C SIDE



SWD pins SIDE

#		USED	ANALOG	SPI	UART
	VIN_5				
	GND				
	VCC				
21	PB10		I2C2-SCL		
20	PB2				
19	PB1		ADC9		
18	PB0		ADC8		
17	PA7	FLASH	ADC7	SPI1-MOSI	
16	PA6	FLASH	ADC6	SPI1-MISO	
15	PA5	FLASH	ADC5	SPI1-SCK	
14	PA4	FLASH	ADC4	SPI1-NSS	
13	PA3		ADC3		UART2-RX
12	PA2		ADC2		UART2-TX
11	PA1		ADC1		
10	PA0	KEY	ADC0	WAKEUP	
7	NRST				
4	PC15	OSC32			
3	PC14	OSC32			
2	PC13	LED			
1	VBAT				

The BlackPill board includes a USB-C connector, a 4-pin SWD header, onboard buttons, a blue LED and an optional 8MB flash. The GPIO and Power are distributed out to 40 pins separated into two 20 pin headers. The user button called KEY is attached to pin PA0. The blue LED is attached to pin PC13. The board includes a primary 25 MHz crystal and a secondary low-speed 32.768 KHz crystal. The BlackPill board uses a SOT-223 LDO regulator marked 3AVL which per WeAct Studio's GitHub site is a ME6206 LDO that provides 3.3 Volts at 300 mA. The WeAct Studios GitHub web site says there is a protection diode on the BlackPill v3.1 board.

One should read the ST STM32F411 datasheet and understand the functions available for the various pins. The 4-port SWD header or the USB-C port can be utilized to flash the chip. Registered users at the STMicroelectronics (ST) web site can download for free the STM32Cube Programmer ("PRG"). The PRG software is the easiest way to flash the firmware (as it can use either USB or ST-LINK "SWD"). I found that a completely new BlackPill can be flashed through the USB-C port. But that the best way is using the ST-LINK "SWD" port connected to an inexpensive ST-LINK v2 device (from your favorite online retailer).

Schematic

The schematic was created on Kicad 7.