Bluetooth Controlled Mobile Robot

Final report

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1. Device description

The device is a Bluetooth controlled robot on two controllable wheels and a balancing wheel. It can detect obstacles ahead of it with an ultrasonic sensor and warn the user with a buzzer when the obstacle is too close. The device has two buttons: one for powering and one for resetting the device. It also has an IMU for detecting acceleration and the position of the device. The device also has two LED: s for indicating power status and occurring Bluetooth data transfer.

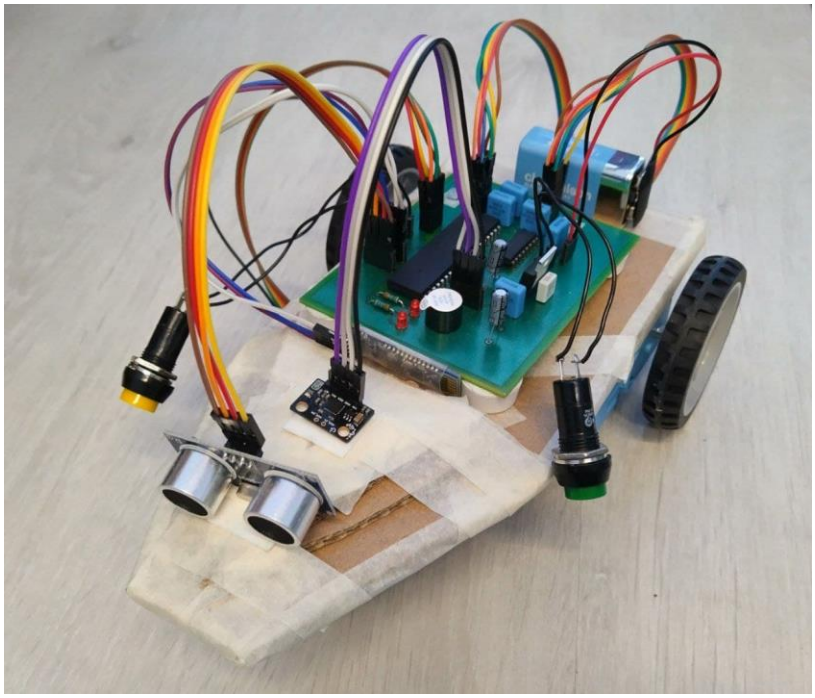


Image 1. The prototype

2. User manual

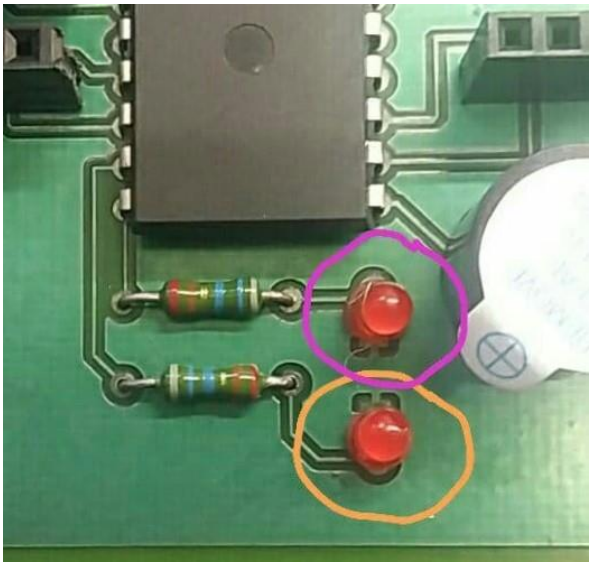


Image 2. LED P (orange circle) and LED BT (pink circle).

2.1. Powering the device

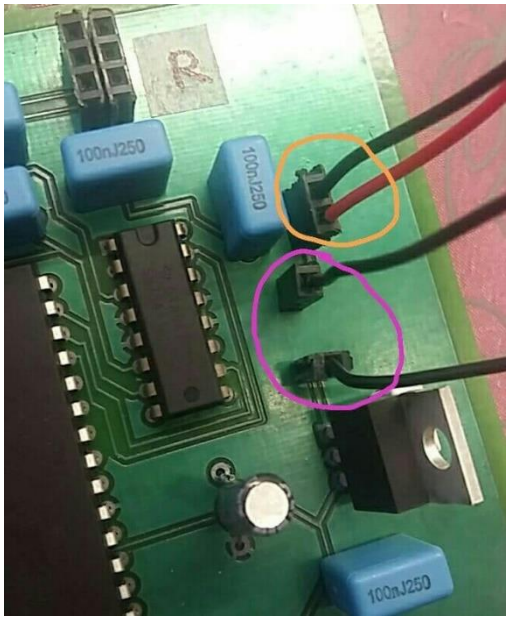


Image 3. Battery connector (orange circle) and power button (pink circle) connections.

The device is powered by an 9V battery. Make sure that the battery connector is connected to correct pins (Image 3), and that the battery is on place. The LED P (Image 2) will stay on when the device is powered by pushing the power button (green).

2.2. Reset

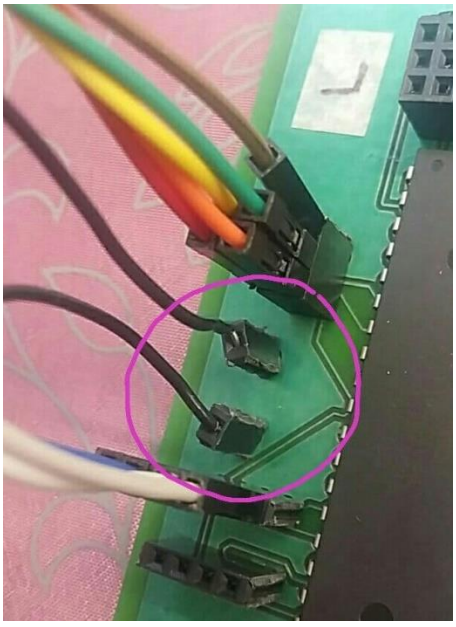


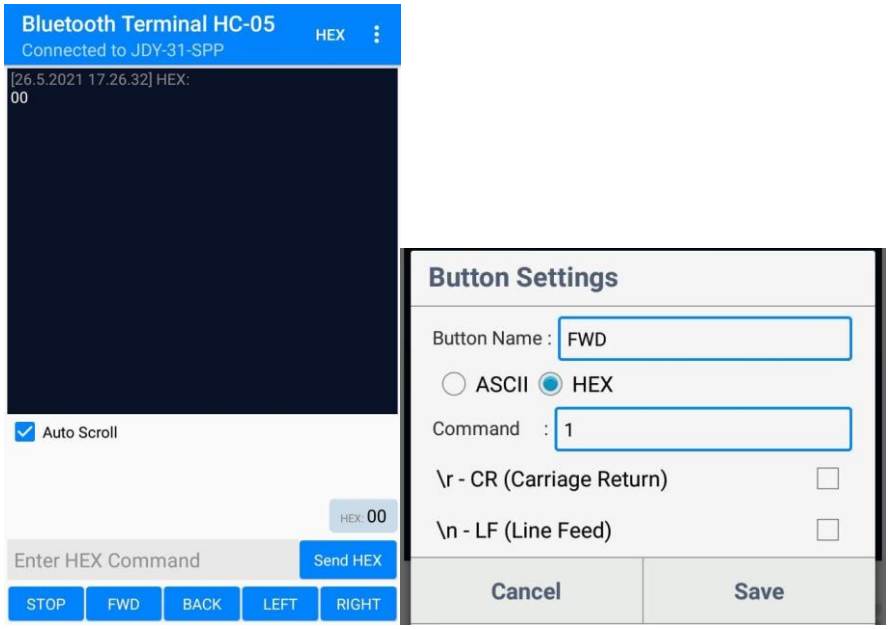
Image 4. Reset button pins (circled in pink).

Make sure the yellow reset button is connected to the correct pins (Image 4). Push the button down for a second to reset the device.

2.3. Bluetooth control

For Bluetooth control, no UI was created because of lack of time, so a Bluetooth terminal application is utilized for sending the commands to the device (https://play.google.com/store/apps/details?id=project.bluetoothterminal&hl=en).

The pairing is done by enabling Bluetooth on your mobile phone and scanning for devices. Make sure your mobile phone is set as visible to other devices. The Bluetooth module is named JDY-31-SPP, and the default PIN code is 1234. After the pairing is done, the application should show the module in the device list, and allow the connection. The app should show the text 'Connected to JDY-31-SPP' if the connection is established properly (Image 5) and the LED on Bluetooth module should stop blinking and stay on.



Images 5 & 6. The application used and button settings.

There are five buttons at the bottom of the terminal app. If you want to, you can define a button by pressing it long and setting the options like seen above in images 5 and 6. The control values are seen in table below.

Meaning	Value (HEX)
STOP	00
FWD	01
BACK	02
LEFT	03
RIGHT	04

Table 1. Movement instructions

2.3.1. Movement

The control options are seen in Table 1. When sending any of the commands, the device moves to the direction specified for 100 milliseconds. The LED BT blinks every time a valid command is received. If there is an obstacle in front of the device, the buzzer makes a beeping sound. If the sensor does not seem to work properly, please reset the device with the reset button and try again.

2.3.2. Sending sensor data

This feature was unfortunately not implemented due to lack of time and Bluetooth module issues in transmitting the data from MCU.

3. Test results

Basic hardware tests without power or ICs.

Test-ID	**Description**	**Result**
Test-1.1	There is no short cuts or bad soldering seen on the board.	PASS
Test-1.2	GND and VCC lines are not short cut.	PASS
Test-1.3	GND is connected to GND pins of IC sockets.	PASS
Test-1.4	VCC is connected to VCC pins of IC sockets.	PASS
Test-1.5	Data pins of Bluetooth module are connected to corresponding data pins of the MCU.	PASS
Test-1.6	Bluetooth data pins are not connected to GND or VCC.	PASS
Test-1.7	The Buzzer is contacted to GND and correct pin of MCU.	PASS
Test-1.8	The data pins of IMU (accelerometer/gyroscope) are connected to the corresponding data pins of the MCU.	PASS
Test-1.9	The data pins of IMU are not connected to GND or VCC.	PASS
Test-1.10	The data pins of ISP are connected to corresponding data pins of the MCU.	PASS
Test-1.11	ISP data pins are not connected to GND or VCC.	PASS

Test-1.12	Voltage regulator is connected to Button P, GND and correct pin of the MCU.	PASS
Test-1.12	Data pins of Sensor F are connected to corresponding data pins of the MCU, GND pin to GND and VCC pin to VCC.	PASS
Test-1.13	The motor poles are connected to the corresponding pins of the H-bridge.	PASS
Test-1.14	The H-bridge is connected to GND, VCC and 9V. The data pins of the H-bridge are connected to corresponding data pins of the MCU.	PASS
Test-1.15	The data pins of rotary encoders are connected to the corresponding pins of the MCU, GND pin to GND and VCC pin to VCC.	PASS
Test-1.16	Button P is connected to the power source and voltage regulator.	PASS
Test-1.17	Button R is connected to GND and reset pin of the MCU.	PASS
Test-1.18	The LEDs are connected to correct pins of the MCU and GND.	PASS

Bacic hardware tests with power, but without ICs.

Test-ID	**Description**	**Result**
Test-2.1	The voltage between GND and VCC is 5V with a tolerance of 0.2 V.	PASS
Test-2.2	When powering the device is powered up, the current consumption does not exceed 500 mA.	PASS
Test-2.3	Any of the components do not heat up at an alarming rate.	PASS

Basic hardware tests with ICs connected, but without power.

Test-ID	**Description**	**Result**
Test-3.1	The GND and VCC lines are not short cut.	PASS

Basic hardware tests with power and ICs.

Test-ID	**Description**	**Result**
Test-4.1	When powering the device is powered up, the current consumption does not exceed 500 mA.	PASS
Test-4.2	Any of the components do not heat up at an alarming rate.	PASS

Unit tests

Test-5.1	**MCU is operational.**
Tools	Device with MCU attached.

Steps	Turn the device's power on.
Acceptable result	LED P turns on.
Result	PASS

Test-5.2	**Bluetooth module is operational.**
Tools	Device with MCU and Bluetooth module attached. A controlling device (such as computer or phone) with Bluetooth connectivity. Terminal application.
Steps	Turn the device on. Wait for Bluetooth connection between the device and the. Send ASCII-character "a" to the device via the terminal.
Acceptable result	Device must send respond: "a".
Result	PASS

Test-5.3	**The Buzzer is operational.**
Tools	Device with MCU and buzzer attached.
Steps	Enable The Buzzer test from source code. Flash new software to the device. Switch device power on. After test flash the original software back to the device.
Acceptable result	The buzzer makes a sound.
Result	PASS

Test-5.4	**Acceleration detector is operational.**
Tools	Device with MCU, buzzer and acceleration attached.
Steps	Enable acceleration detector test from source code. Flash new software to the device. Switch device power on. Hold the device in a normal position (upside up), then turn it upside down. Alternate between the two positions. After test flash the original software back to the device.
Acceptable result	When the device is not upside down the buzzer is silent, and when the device is upside down, the buzzer makes a sound.
Result	PASS

Test-5.5	**Obstacle sensors are operational.**
Tools	Device with MCU, buzzer and obstacle sensors attached.
Steps	Enable obstacle sensor test from source code. Flash new software to the device. Keep the area in front of the sensor free. Switch device power on. Put an obstacle in front of the sensor. Remove the obstacle. After test flash the original software back to the device.
Acceptable result	The buzzer makes a sound whenever there is something in front of the sensor (in 20cm distance).

Result	PASS

Test-5.6	**Motors are operational.**
Tools	Device with MCU and both motors with wheels attached.
Steps	Enable motors test from source code. Flash new software to the device. Switch device power on. Observe motors' movements. After test flash the original software back to the device.
Acceptable result	After 1 second of delay, the right motor will first spin 0.5 seconds forward, then 0.5 seconds backward, after 1 second of delay, perform the same routine to left motor.
Result	PASS

Test-5.7	**LEDs are operational.**
Tools	Device with MCU and both LEDs attached.
Steps	Enable LED test from source code. Flash new software to the device. Switch device power on. After test flash the original software back to the device.
Acceptable result	The LEDs blink simultaneously multiple times, then they start blinking one after other for some time, and then they go back to simultaneous blinking and repeat this behavior.
Result	PASS

Test-5.8	**Button R is operational.**
Tools	Device with MCU, button R and LED P attached.
Steps	Enable any test code. Switch device power on. Press button R for a second when more than 1 second is passed after switching power on. After test flash the original software back to the device.
Acceptable result	The test code should start running. When the button R is pressed the execution is halted. After the button is released, the execution restarts.
Result	PASS

Test-5.9	**Button P is operational.**
Tools	Device with MCU attached. Voltage meter.
Steps	Turn the device off if it is not already. Measure the voltage between button pin and voltage regulator output pin. Push the Button P. Measure the voltage between the same pins again.
Acceptable result	The first voltage measurement between the pins is 0V with tolerance of 0V. The second voltage measurement between the pins is 5V with tolerance of 0.2V.
Result	PASS

Test-5.10	**Battery is operational.**

Tools	Device with MCU attached. Voltage meter.
Steps	Switch device power on. Measure the voltage between battery and voltage regulator input pin, and the voltage in voltage regulator output.
Acceptable result	The voltage measured in voltage regulator output is 5V (with tolerance of 0.2 V), and the voltage measured from the battery in pins is 8.5 V (with tolerance of 0.5 V).
Result	PASS

Test-5.11	**Wheels are usable.**
Tools	Device with wheels R and L attached to the motors, and B attached to the base.
Steps	Move the robot along flat surface with hand, also move it backwards, and try turning left and right.
Acceptable result	The wheels turn both forward and backward, and the robot will move left or right with ease.
Result	PASS

System tests

General functionality tests

Test ID	**Requirement**	**Description**	**Result**
Test-7.1.1	Req-2.1.1	Locate Wheel R, Wheel L and Wheel B. The test is passed if all the wheels are found in following places: Wheel R is connected to the right motor's shaft. Wheel L is connected to the left motor's shaft. Wheel B is connected to the front of the base and is centered.	PASS
Test-7.1.2	Req-2.1.2	Locate Motor R and Motor L. The test is passed if the Motor R is found connected to the right of the base and the Motor L is connected to the left of the base.	PASS
Test-7.1.3	Req-2.1.3	Locate the Sensor F. The test is passed if the Sensor F is found at the front of Robot.	PASS
Test-7.1.4	Req-2.1.4	Find The Buzzer. The test is passed if The Buzzer is found.	PASS
Test-7.1.5	Req-2.1.5	Find Button P (green). The test is passed if the Button P is found.	PASS
Test-7.1.6	Req-2.1.6	Find Button R (yellow).	PASS

		The test is passed if the Button R is found.	
Test-7.1.7	Req-2.1.7	While device turned on and Bluetooth is connected to a computer with terminal, move the device. The test is passed if there is 3-dimensional acceleration information seen on the terminal window.	FAIL (BT issues)
Test-7.1.8	Req-2.1.8	While the device is turned on and Bluetooth is connected to a computer with terminal, move the device. The test is passed if there is 3-dimensional orientation information seen on the terminal window.	FAIL (BT issues)
Test-7.1.9	Req-2.1.9	While the device is turned on, put the device near a wall facing it. The test is passed if the buzzer makes a sound.	PASS
Test-7.1.10	Req-2.1.10	Find LED BT and LED P. The test is passed if both LEDs are found.	PASS
Test-7.1.11	Req-2.1.11	While the device is turned on and Bluetooth is connected to a computer with a terminal open, move the device with rotating its motors with any move command. The test is passed if the encoder information is seen in the terminal.	FAIL (BT issues)
Test-7.1.12	Req-2.1.12	Locate the H-bridge. The test is passed if the H-bridges are found.	PASS
Test-7.1.13	Req-2.1.13	Connect the device to a computer with Bluetooth. The test is passed if the device is connected to the computer, and the connection is not lost in a 10m radius from the computer.	PASS
Test-7.1.14	Req-2.1.14	With turned on device connected to a computer with Bluetooth, send and/or receive commands/data to/from the device. The test is passed if LED BT is turned on when data is sent or received via Bluetooth connection.	PASS
Test-7.1.15	Req-2.1.15	Locate the MCU. The test is passed if the MCU is found.	PASS
Test-7.1.16	Req-2.1.16	Turn on the device.	PASS

		The test is passed if LED P is turned on the whole time the device is on.	
Test-7.1.17	Req-2.1.17	While the device is turned on, put the device near (20 cm or closer) a wall facing it. The test is passed if the buzzer makes a sound.	PASS
Test-7.1.18	Req-2.1.18	Do all the tests above while indoors. The test is passed if the device functions indoors and none of the parts malfunction. (Excludes features not implemented due to lack of time.)	PASS

Control functionality tests

Test ID	**Requirement**	**Description**	**Result**
Test-7.2.1	Req-2.2.1	Locate the simple UI from a computer that is connected to the device with Bluetooth. The test is passed if there is a simple UI for controlling the device implemented.	FAIL (lack of time)
Test-7.2.2	Req-2.2.2	Send “FORWARD”, “BACKWARD”, “RIGHT” and “LEFT” commands with a terminal from a computer with a Bluetooth connection to the device. The test is passed if the wheels move to the direction specified with the commands given.	PASS
Test-7.2.3	Req-2.2.3	Send “RIGHT”, “LEFT”, “FORWARD” and “BACKWARD” commands with a terminal from a computer with a Bluetooth connection to the device. The test is passed if each command is echoed back to the terminal.	FAIL (BT issues)
Test-7.2.4	Req-2.2.4	Send “DATA” command via a terminal in computer that is connected to the device with Bluetooth. The test is passed if the data from sensors is received from the device to the computer.	FAIL (BT issues)

Electrical functionality tests

Test ID	Requirement	Description	Result
Test-7.3.1	Req-2.3.1	Measure the operating voltage. The test is passed if the operating voltage is 5V.	PASS
Test-7.3.2	Req-2.3.2	Find a 9V battery as a power source. The test is passed if a 9v battery is found as a power source.	PASS
Test-7.3.3	Req-2.3.3	Operate the device for 1 hour with a full battery. The test is passed if the device has not run out of power after 1 hour.	PASS

Mechanical functionality tests

Test ID	Requirement	Description	Result
Test-7.4.1	Req-2.4.1	Locate and inspect a frame of the device. The test is passed if a frame is found, and it can fit all the components of the device.	PASS
Test-7.4.2	Req-2.4.2	Move the device left, right, back and forth. The test is passed if the frame does not interfere with the movement of the device (Blocking wheels, hitting grounds, etc.).	PASS
Test-7.4.3	Req-2.4.3	Yaw the balancing wheel 360 degrees and then 360 to the other direction. The test is passed if the wheel can yaw the whole way and there are no point or direction where the wheel moves slower or gets stuck.	PASS
Opt-Test-7.4.4	Opt-2.4.4	Find a casing. The test is passed if there is a casing to be found.	FAIL

Other tests

Test ID	Requirement	Description	Result

Test-7.5.1	Req-2.5.1	Calculate the price of all the components used in the device. The test is passed if the component price total does not exceed 100€.	PASS

4. Implementation

4.1. Used tools

IDE: Microchip Studio 7.0

Uploading the code: AVRDUDE with ISP programmer

Keeping track of the code: GITHUB

We chose Microchip Studio as our IDE because it was compatible with our chosen MCU (atmega644p) and allowed for easier programming. We built the projects with Microchip Studio and then uploaded the resulting hex-files to MCU with our ISP programmer and avrdude, as we did not have a Microchip Studio compatible programmer in use.

We kept track of the code with GITHUB and uploaded all of our code from initial tests to the final project there.

4.2. Results

All the hardware is operational and there were no bad soldering or other errors on the board on the hardware side. Most of the functionality was implemented and all of the unit tests worked, which shows that the parts are operational. However, as the BT module did not receive the data correctly, and showed corrupted data, it caused test cases to fail. To be noted, the data from IMU can be read from the MCU via TWI, and motor encoders also work, and commands can be used to move the device, the test cases only fail because the data is not sent back from the MCU by BT in correct format.

In addition, we had some fails that were because of lack of time. There were no simple UI implemented, but the BT connecting app we used was good enough for us to test that the device works. The time issues also caused the optional casing test to fail, as we could not allocate time to design and manufacture it.