VARIABLE PRESSURE RETRIEVAL DEVICE (VPRD) BOE-BOT ORIENTEERING KIT

The VPRD add-on kit adapts a Boe-Bot for orienteering events, enabling it to be remote-controlled, travel faster and traverse obstacles. With a versatile pneumatic object collection system, small objects of varying shapes and materials can be collected and transported with ease.

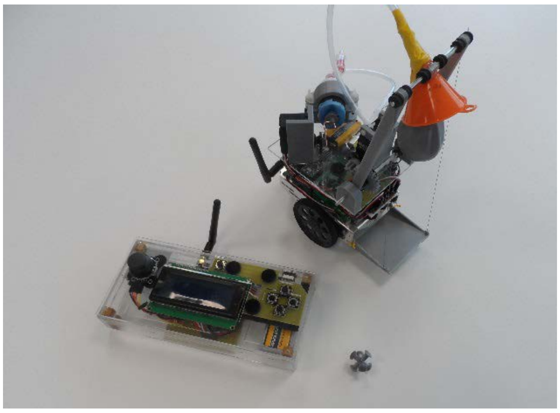

Figure 1: The VPRD Add-On and Boe-Bot

Key features include:

- Vacuum pump powered Universal Gripper Sub-System (UGS) to collect small tokens;
- Intuitive controller, complete with an LCD screen and user interface;
- 2.4GHz communications system with 128 channels;
- Algorithms for auto-synchronisation and clear-channel searching;
- 180RPM drive servos with variable speed modes and additional high-precision control.

SYSTEM OVERVIEW

The VPRD contains an Arduino Pro Mini, an interfacing shield, two 180RPM Parallax continuous rotation servos, the UGS (comprising: a universal gripper, vacuum pump, lifting arm, servo brackets, base plate and solenoid valve), a collection drawbridge and a controller.

The controller is ready-assembled and only requires a PP3 battery inserted in the holder.

The Boe-Bot interfaces with the VPRD kit as follows:

1. The Arduino Pro-Mini is inserted in place of the Basic STAMP 2 microcontroller.
2. The shield is plugged into the female headers on the Boe-Bot Board, with the power board and transceiver attached by Velcro to the chassis.
3. The power cable from the AA batteries is connected into the shield's power board.
4. The two new drive servos replace the original 50 RPM versions. Their power and data lines are connected into the shield's power board.
5. The UGS plate is connected onto the hexagonal standoffs with nylon screws. The power cables for the solenoid valve are plugged into the shield.
6. The drawbridge is screwed onto the Boe-Bot's front plate and cabling connects the end to the lever arms.
7. The lifting arm gear collar and vacuum pump piston collar are friction-fitted onto the original 50RPM drive servos.
8. These servos are bolted into their brackets on the UGS plate, and their power and data lines are connected to the shield's power board.
9. The lifting arm servo's collar gear must mesh with the lifting arm gear. The vacuum pump servo's collar piston must hook into the eyelet of the vacuum pump.
10. A PP3 battery is connected into the terminals on the Boe-Bot.

Figure 2, below, is the block diagram of the VPRD system:

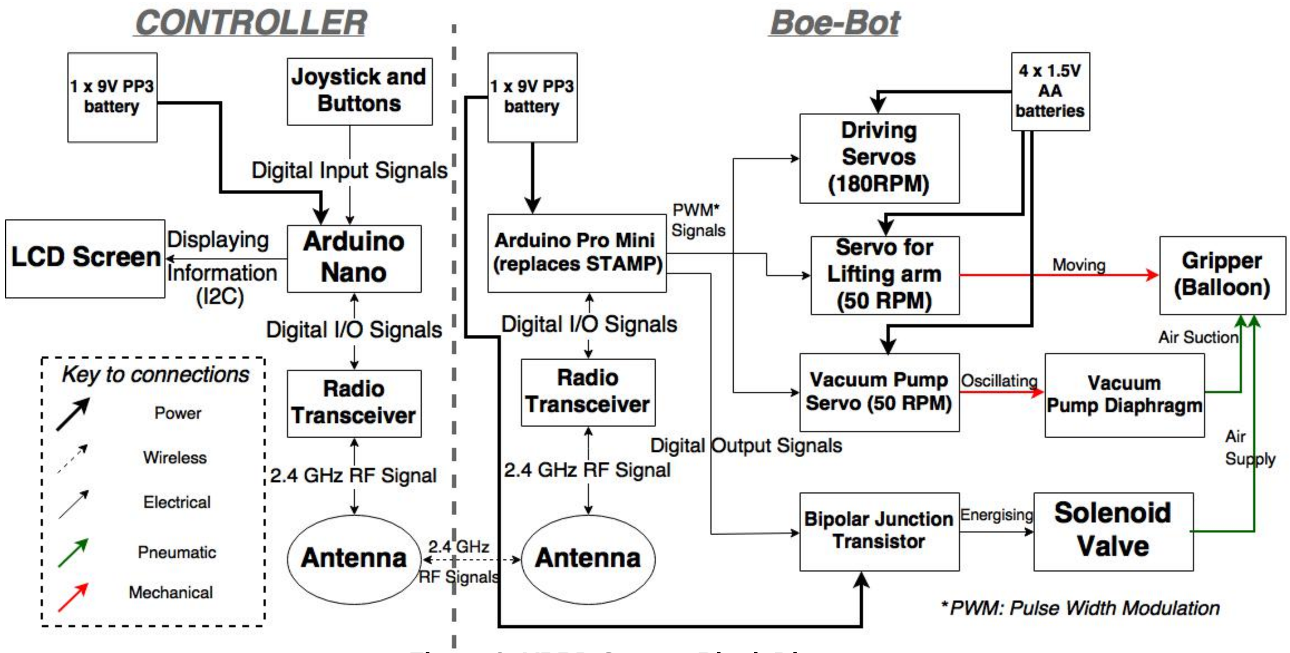

Figure 2: VPRD System Block Diagram

The Arduino Nano, powered by a PP3 battery, communicates with the Boe-Bot via the transceiver's antenna.

In normal operation, the joystick controls general Boe-Bot movement and the four directional buttons are for accurate movement around obstacles. Holding the 'down' button whilst using the joystick puts the servos into low-speed mode. The function button allows the use of the UGS, with the joystick reassigned to control the lifting arm. When pressed, the joystick button toggles the vacuum pump and solenoid valve. Holding the right directional button and joystick button for two seconds switches the system into channel management mode. The LCD screen displays information about the current mode.

On the Boe-Bot, signals from the controller are received by the transceiver's antenna and decoded by the Arduino Pro Mini to perform the required actions. All servos are powered by the existing 4x AA batteries, with the Pro Mini and Bipolar Junction Transistor (BJT) powered by a PP3.

The lifting arm servo raises and lowers the lifting arm with the gripper (balloon) on the end. Once the gripper (containing granular material) is positioned over an object, the vacuum pump diaphragm is actuated by its respective servo, removing air from the gripper. A strong hold is created around the object as the granular material is compressed. When the object is ready to be released, the BJT switches on the solenoid valve, allowing air back into the gripper and dropping the object.

CIRCUIT SCHEMATICS

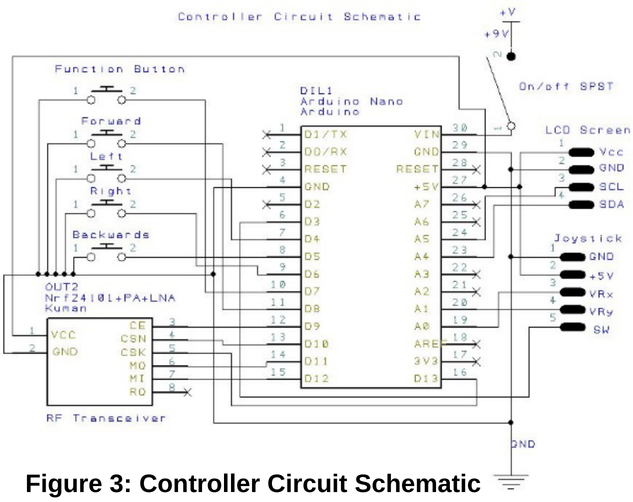

Figure 3: Controller Circuit Schematic

Figure 3 shows the controller circuit. The LCD screen uses the I2C protocol to communicate with the Arduino Nano via the SCL (A5) and SDA (A4) pins.

The push buttons are input pull-up, connected between the ground and digital pins of the Nano, therefore, they are constantly 'high' and when pressed the Nano registers a 'low'.

The joystick contains two potentiometers and a push button, connected to analogue and digital pins respectively. This data is used by the Nano to calculate movement.

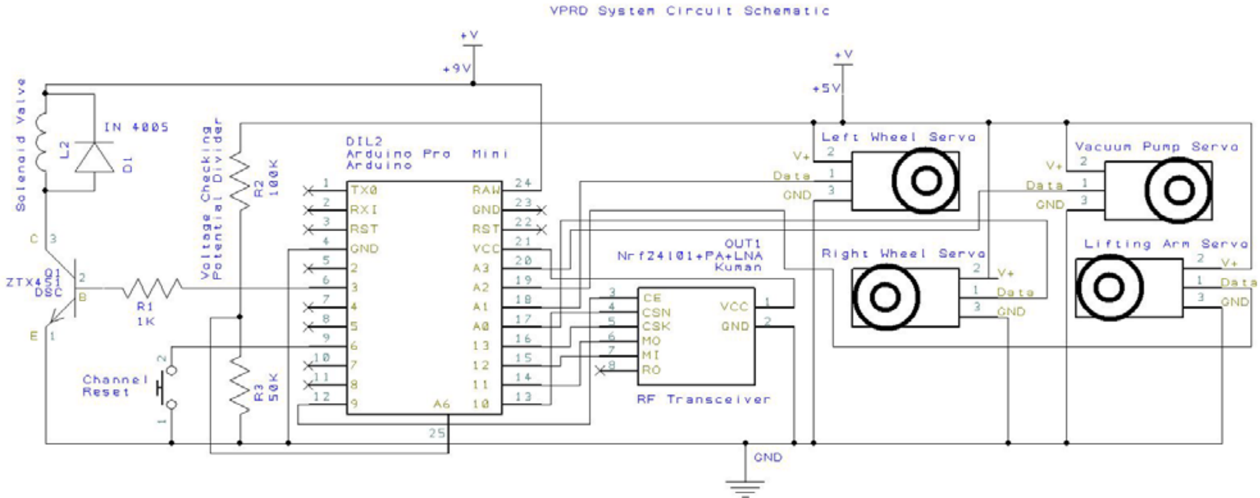

Figure 4: VPRD System Circuit Schematic

Figure 4 displays the pin names of the Arduino Pro Mini, whereas the pin names of the BASIC Stamp 2 are printed on the female headers on the Boe-Bot board.

Pulse Width Modulation controls the speed and direction of the four continuous rotation servos.

The Pro Mini is used to control the operation of the solenoid valve by sending a digital signal to the base terminal of the BJT, which behaves as a switch. The Flyback diode protects the BJT from damage caused by the inductive discharge of the solenoid valve as it is switched off.

The potential divider circuit, used to monitor the battery level, is connected to analogue pin 6.

MECHANICAL CONSTRUCTION

Figure 5 details the positioning and dimensions of the UGS when mounted on the Boe-Bot. Figure 6 details the dimensions of the front and side controller panels, and the position of the components.

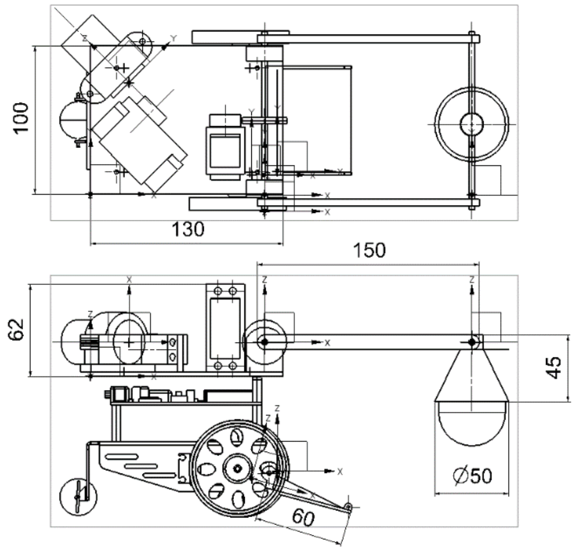

Figure 5: UGS Mounting Technical Drawing (dimensions in mm)

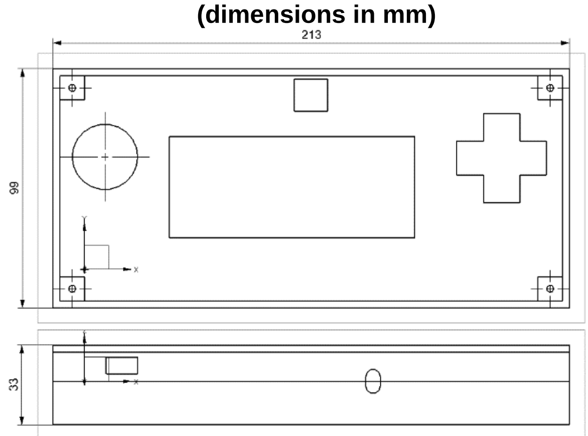

Figure 6: Controller Casing Technical Drawing (dimensions in mm)

SOFTWARE

Figures 7 and 8 are the high level software flow diagrams for the Boe-Bot system and the controller respectively .

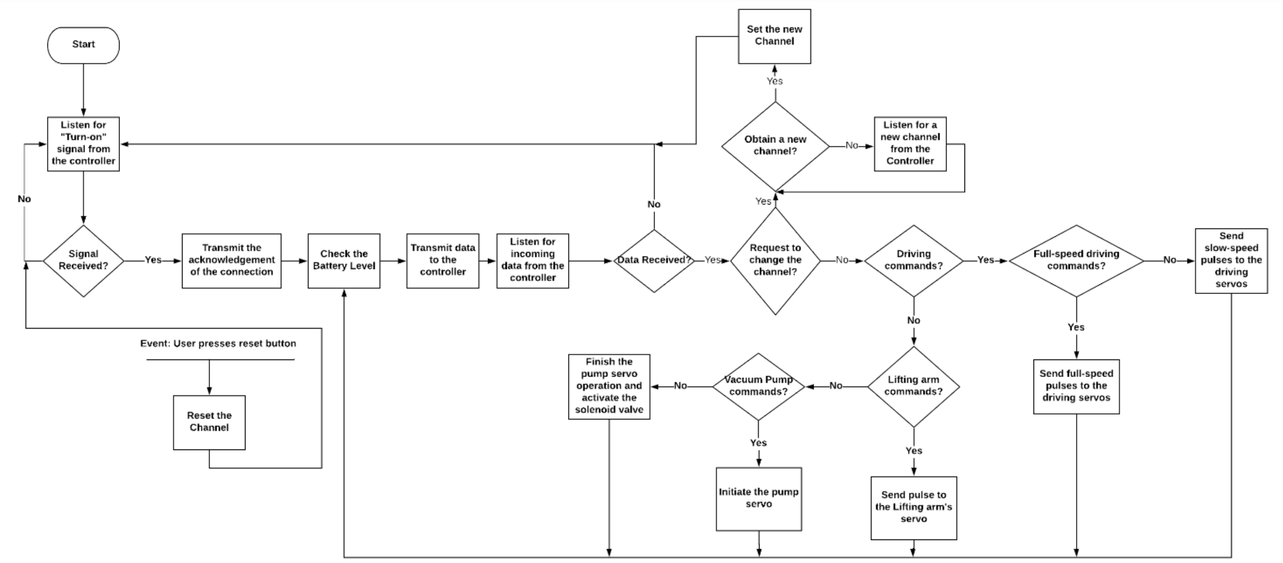

Figure 7: Software Flow Diagram for the Boe-Bot Sub-Systems

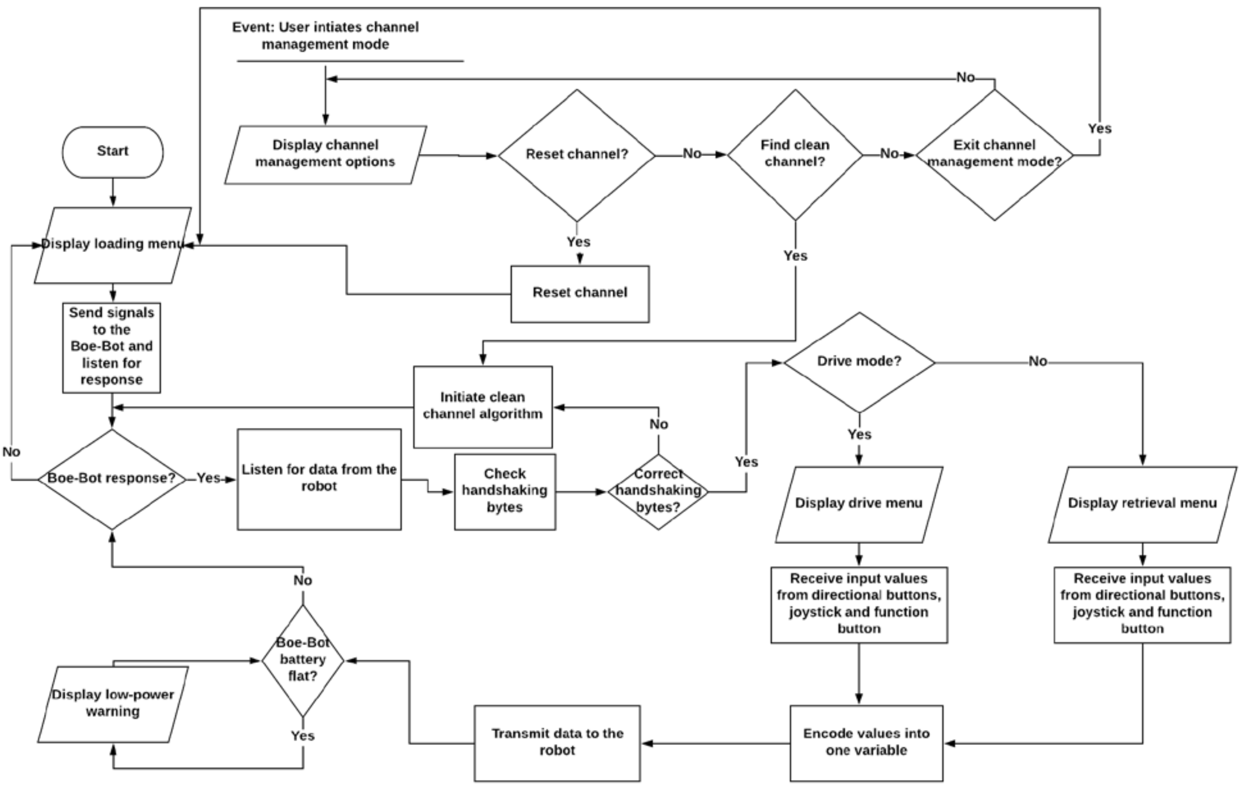

Figure 8: Software Flow Diagram for the Controller

The user can modify: the power mode of the transceivers (thus varying the range), the data rate (i.e. changing transceiver sensitivity), the image displayed on the 'connecting' screen (i.e. from the company logo), and the encoding/decoding subroutines.

The encoding subroutine interprets the inputs from the controller, encoding them into a single integer variable value (e.g. 1 for forward movement). This value is then converted into a binary byte for transmission to the Boe-Bot. The Boe-Bot transceiver receives this byte, which is decoded by the Pro Mini to provide the required actuation.

Advanced users may wish to edit the encoding and decoding subroutines to add more functionality to the existing system, by assigning integer values to more controller input combinations. The maximum number of commands that could be encoded into the single byte is 255 (the VPRD system only uses 15).

The code can be accessed at the below QR code for customisation:

Figure 9: Source Code QR Code, found at https://github.com/Afonia27/VPRD

TEST DATA

Property	Minimum	Average	Maximum
Drive motor torque			0.15Nm
Lift force provided by UGS			5.4N
Speed		$0.34ms^{-1}$	
Servo power consumption when idle		0.15W	
Servo power consumption at full-speed mode	0.883W	0.989W	1.08W
Power consumption of lifting arm and vacuum pump servos		1.2W	
Power consumption of Pro Mini when connected to controller		0.567W	
Power consumption of Pro Mini when solenoid valve in use		1.62W	
Power consumption of controller		0.628W	
Controller run time		1 hour	
Boe-Bot run time		4.5 hours	