Systems & Control

Floating Ball Apparatus

(SCFBA)

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Version History

Revisions will be marked from the previous revision only.

12 January 12, 2022	• Preliminary release
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Document Purpose

This document describes the functional requirements for Rowan University's Electrical and Computer Engineering Department's Systems & Control Floating Ball Apparatus (SCFBA).

The apparatus was designed to provide students with a platform to perform tests and experiments related to systems control utilizing various control system algorithms on an external PID controller (computer). The system provides students with a hands-on experience bringing control theory to light in a practical manner.

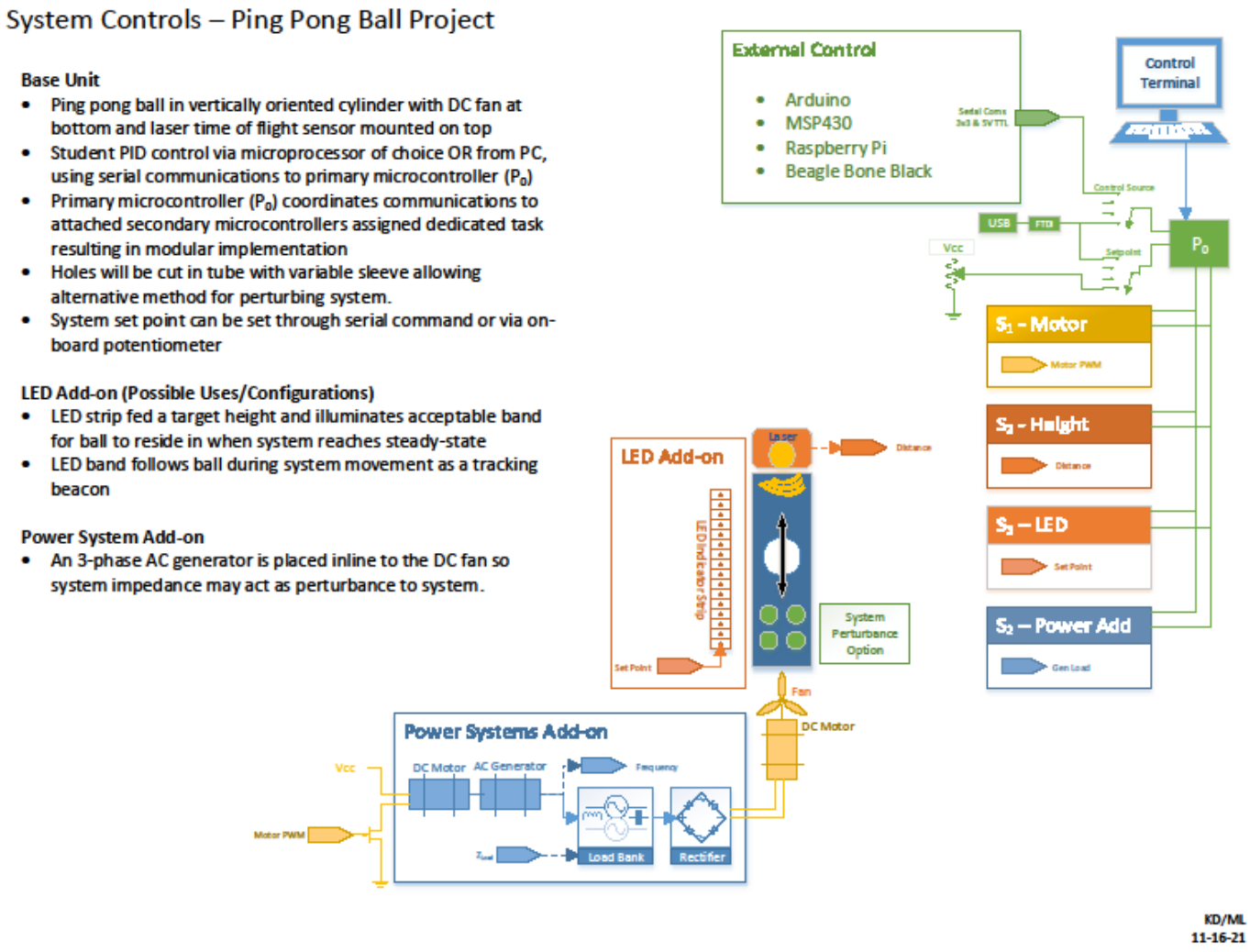
Glossary

Console – A computer system running a terminal emulator program used to manage the administrative functions of the SCFBA via a menu interface.

PID (Controller) – A computational system running a PID control algorithm and communicating with the SCFBA's PID interface, effecting control over the ball (system).

Initial Apparatus Proposal

Below is the one-page, high-level system originally proposed. The current implementation is a proof-of-concept Alpha version. It includes the primary microcontroller (Po), motor microcontroller (S_1), height microcontroller (S_2), and setpoint potentiometer, implemented on a single microcontroller on a single PCB. Two additional potentiometers were added to provide manual control of the motor speed as well as setting the hysteresis for bang-bang control.



Serial Interfaces – Console & PID

The SCFBA uses two serial links to communicate with the faculty and student computers. Both utilize a TTL to USB serial translation interface based on the FTDI FT232RL USB to serial IC, Windows recognizes this USB device and will install the necessary drivers automatically.

The links are configured as follows:

- Connector: USB-A male
- COM port settings:
  - Baud: 19200
  - Data bits: 8
  - Parity: None
  - Stop bits: 1
  - Flow control: None
- ACK/NAK: None
- All bytes are printable ASCII characters, case insensitive
- There is no end of packet terminator

Console

The Console link provides the system administrator (faculty) with the ability to control and set system operations via a terminal emulator program such as puTTY. The interface is a simple text-based menu system.

PID Controller

The PID interface is a simple communication interface which allows the PID controller to control certain aspects of the system (request sensor data and set PWM). Command/response details are listed below.

Basic SCFBA/PID Protocol Definition

General Guidelines

All communications between the SCFBA the PID Controller relies upon the following key features:

- All bytes are printable ASCII characters, case insensitive
- There is no end of packet terminator

Protocol Packet Structure (SCFBA to PID Controller)

- All packets begin with the preamble (colon)
- All packets are of the same length

The packet structure is defined as follows:

Field Name	Number of Bytes	Explanation
Preamble	**1**	Always ":" (colon)
Distance	**4**	0000-1000 (nominally, in mm)
Delimiter	**1**	Always "," (comma)
Manual PWM potentiometer reading	**4**	0000-4095 (12-bit value read from the ADC, zero-padded)
Delimiter	**1**	Always "," (comma)
Setpoint (read from potentiometer)	**4**	0000-4095 (12-bit value read from the ADC, zero-padded)
Delimiter	**1**	Always "," (comma)
Hysteresis (Deadpan - read from potentiometer)	**4**	0000-4095 (12-bit value read from the ADC, zero-padded)

Protocol Packet Structure (PID Controller to SCFBA)

The communications between the PID Controller and the SCFBA relies upon the following key features:

- There is no preamble
- All packets begin with a command byte

Request Sensor Read Message (single packet response) – command code “S”

Valid Communication Direction

- Command packets (packet type: “S”) are sent from the PID Controller to the SCFBA.

Data Definition

No data required, this is a single byte message

Sample Communication Transaction

Command string for an SCFBA sensor read issued by the PID Controller:

S

The SCFBA responds with the following string:

:dddd,pppp,ssss,hhhh

Where:

dddd = distance of ball from the Time of Flight (TOF) sensor (in mm)
pppp = manual PWM potentiometer value (0000-4095)
ssss = setpoint potentiometer value (0000-4095)
hhhh = hysteresis potentiometer value (0000-4095)

Continuous Sensor Read Message Mode – command code “C”

Valid Communication Direction

- Command packets (packet type: “C”) are sent from the PID Controller to the SCFBA.

Data Definition

No data required, this is a single byte message

Sample Communication Transaction

Command string for an SCFBA sensor read issued by the PID Controller:

```
C
```

The SCFBA responds with the following string every 50mS:

```
:dddd,ssss,hhhh
```


Halt Continuous Sensor Read Mode – command code “H”

Valid Communication Direction

- Command packets (packet type: “H”) are sent from the PID Controller to the SCFBA.

Data Definition

No data required, this is a single byte message

Sample Communication Transaction

Command string for an SCFBA sensor read issued by the PID Controller:

H

There is no SCFBA response.

PWM (Fan) Speed Set – command code “P”

Valid Communication Direction

- Command packets (packet type: “P”) are sent from the PID Controller to the SCFBA.

Data Definition

The packet structure is defined as follows:

Field Name	Number of Bytes	Explanation
Command	**1**	Always “P”
Duty Cycle	**4**	0000-4095 (12-bit PWM register value, represents 0-100% duty cycle), zero-padded

Sample Communication Transaction

Command string for an SCFBA PWM duty cycle set (fan speed) issued by the PID Controller:

Pxxxx

There is no SCFBA response.

Enable PWM (Fan) Speed Control from Potentiometer – command code “N”

Valid Communication Direction

- Command packets (packet type: “N”) are sent from the PID Controller to the SCFBA.

Data Definition

No data required, this is a single byte message

Sample Communication Transaction

Command string for an SCFBA sensor read issued by the PID Controller:

N

There is no SCFBA response.

Disable PWM (Fan) Speed Control from Potentiometer – command code “F”

Valid Communication Direction

- Command packets (packet type: “F”) are sent from the PID Controller to the SCFBA.

Data Definition

No data required, this is a single byte message

Sample Communication Transaction

Command string for an SCFBA sensor read issued by the PID Controller:

F

There is no SCFBA response.

Console Interface

There is an administrative console to provide system level control, typically used by the authors for diagnostic purposes, or by the faculty to set system parameters. The console is accessed by connecting the "Console" cable to a computer USB port and launching a terminal emulation program (e.g. puTTY) as mentioned in the section on **Serial Interfaces**. A screenshot of the current menu is shown below:

```
Systems and Controls Floating Ball Apparatus
        Revision: 0v2
        Revision Date: Jan 17 2022
        Revision Time: 16:48:34
        (C)2022 Michelle Frolio & Mario Leone, Rowan University


Console Menu


           POT Read
         (0-4095) Manual PWM = 3690
         (0-4095) Setpoint = 3537
         (0-4095) Hysteresis = 3560

           MODE
        M: Turn ON User Mode
        N: Turn OFF User Mode
        B: Turn ON Bang Bang Control Mode
        A: Turn OFF Bang Bang Control Mode

           Distance
        T: Send Single Packet to PID
        W: Power Cycle Sensor

           Fan Control
        C: Set PWM Duty Cycle [0000-4095]. With Console
        D: Set PWM Duty Cycle [000-100%]. With Console
        E: Set PWM Duty Cycle [000-100%]. With Manual PWM SINGLE
        F: Set PWM Duty Cycle [000-100%]. With Manual PWM CONTINUOUS ON
        G: Set PWM Duty Cycle [000-100%]. With Manual PWM CONTINUOUS OFF

           Set Start Up Modes
        H: PWM for Fan. Current Value: 0
        I: Continuous Mode for PID. Current: OFF
        J: User Mode. Current: OFF
        K: Continuous Mode for Manual PWM Control. Current: OFF
        L: Bang Bang Control Mode. Current: OFF

        Z: RESET SCA

Enter a menu choice:
```


When the menu is refreshed it will read and display the values of the there (3) front panel potentiometers

There are four commands controlling Modes.

M = enables the acceptance of user (PID controller) commands
N = disables all PID controller commands
B = enables bang-bang control mode, enforcing hysteresis times between commands (both the front panel pushbutton and PID controller commands)
A = disables bang-bang mode

The Fan Control section selects manual PWM settings (a.k.a. fan speed).

C = queries the console operator to enter a PWM duty cycle value (0000-4095)
D = queries the console operator to enter a PWM duty cycle percentage (000-100)
E = sets the PWM duty cycle based on a single read of the Manual PWM potentiometer
F = continually updates the PWM duty cycle based on the potentiometer setting
G = turns off continuous PWM duty cycle updates (disables the F command)

The Set Start Up Modes section allows the console operator to set system power-on settings/modes, these are written to and read from non-volatile memory.

H = sets power on fan speed, e.g. similar to command C
I = sets either the C or H command
J = sets either the M or N command
K = sets either the F or G command
L = prototype command, may not be in the final release

The Z command will perform a reset of the SCFBA controller, reverting back to a power up state.

Panel Controls

The SCFBA controller is equipped with three front panel potentiometers and one push button, and a power switch on the side of the unit.

The three potentiometers are assigned as follows:

Position	Label	Scale	Data Range
Left	Manual PWM	0000-4095	0000-4095
Middle	Setpoint	0000-4095	0000-4095
Right	Hysteresis	0-1	0000-4095

The value of all 3 potentiometers are read and displayed by the menu system every time the menu is refreshed.

- The Manual PWM control sets the PWM duty cycle when enabled (commands E or F)
- The Setpoint control is read by the PID controller and manually sets the desired height of the ball
- The Hysteresis control sets the dead-band for bang-bang control (see below)

Bang-Bang Control

Bang-bang control provides the students with manual control of the fan via the front panel push button. Pressing the button turns the fan on full (100%), releasing the button turns the fan off. By pressing and releasing the button rapidly you can attempt to control the height of the ball. Button transitions trigger the speed changes, so button press/release transitions received during the dead-band time (see below) will be ignored.

The PID controller can also effect bang-bang control by issuing alternating P0000 and P4095 commands. When bang-bang is enabled, P0001-P4094 commands are ignored.

The hysteresis potentiometer will set the dead-band time, disabling command inputs during this blackout (dead-band) period. The dead-band time can be set from 0000-4095, which will be translated by the SCFBA to 0-1 second. Any command to change the PWM speed will be ignored during the dead-band time. Dead-band time is enforced by the SCFBA.

