# RPiOperant User Guide

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**Introduction**

RPiOperant is a self-contained operant conditioning system built around the Raspberry Pi single board computer and the PyOperant operant conditioning software package. It was developed by the Gentner lab in 2018 to replace a single server controlling multiple operant conditioning boxes with a computer to control each box individually. The system is modular, expandable, and hackable, permitting endless reconfiguration to suit the needs of a wide variety of behavioral and electrophysiological experiments.

## Contents

# 1 Functional Overview

RPiOperant consists of the following major components: [We need to establish a higher level of organization here – I think RPiOperant is the whole system. So in the functional overview we want to define MagPiServer, MagPiClient, and the operant panel. This would be a good place for a block diagram]

1. 24V, 12V, and 3.3V Power Supplies

   - The main power supply is a 24V, 5A DC power supply.
   - 7812 regulator provides 12V, 2A max.
   - 7833 regulator provides 3.3V, 1A max.

   > The 12V power supply must handle the current demand of the houselights. The 12V regulator also sources voltage for the 3.3V supply, so the combined current draw of the 3.3V and 12V supplies cannot exceed 2A or the circuits will overheat even with the heatsinks and fans.

2. Raspberry Pi 3B+ single board computer

   - Runs PyOperant software to control the operant logic, store stimuli, and record data.
   - Provides a network interface for remote control and data transfer

3. HiFiBerry Amp2 audio amplifier

   - Provides 2 output audio channels for stimulus playback
   - Regulates power for the Raspberry Pi

4. PCA9685 PWM LED Driver

   - Provides 16 channels of programmable PWM control for house lights, cue LEDs, or other functions
   - Interfaces with the Raspberry Pi through I2C channel 55

5. Beam break detectors

   - Uses the 7414 Schmitt-Trigger Inverter to provide digital inputs to the Raspberry Pi representing the status of the various peck ports.

6. OpenEphys Interface

   - Analog out provides a copy of both audio channels from the Amp2, down-converted to line level with an RC filter/divider.
   - Digital out provides a copy of main operant control signals (Hopper, L/R/C peck ports) plus additional control signals, level shifted to 5V logic.

# 2 MagPi Server

The MagPi Server manages the Local Area Network of RiPiOperant SBCs (MagPi's) controlling the operant interface in each sound isolation chamber. It serves as a temporary repository and WAN accessible point for monitoring behavioral data collected from each MagPi. The server can manage up to 8 channels of hi-quality audio acquisition from any subset of appropriately instrumented chambers.

## 2.1 System Requirements

- hardware
- software

## 2.2 Local Area Network

## 2.3 Data rsync

## 2.4 Audio Recording

# 3 Electrical Assembly

## 3.1 Surface-Mount Components

There are four surface mount components:

- PCA9685 PWM Driver
- SN74LVC4245A Octal Bus Tranceiver and Level Shifter
- HDMI Connectors

It is important to mount the surface mount components before any other components. The ICs must be mounted in the correct orientation.

1. Begin with the level shifter. Spread a thin line of solder paste across each column of pads.
2. Carefully place the IC onto the pads and center it. With the front of the board toward you, the pin 1 mark on the IC should be on the top left.
3. Use the hot air gun at 440 degrees C and airflow set to 4 to melt the solder paste. Make sure the IC does not blow off of the pads.

> Always inspect a surface mount soldering job under the microscope to look for shorts caused by loose balls of solder or excess solder. If necessary, remove excess solder with desoldering braid or remove solder balls with fine tweezers.

4. Install the PCA9685 PWM chip similarly. This chip should be mounted in the same orientation as the level shifter. It is helpful to flip the board around to bring the PWM chip closer, but keep in mind that in this position the pin 1 marker should be on the bottom right, and aligned with the mark on the board. Use hot air to melt the solder, and then check for shorts.

5. Install the HDMI connectors, starting with the Analog connector. Lay down a line of solder paste on the half of the pads furthest from the edge of the boards, then place the connector. Use 440 air, but set the flow to maximum. Check for shorts.

> The HDMI connectors are prone to getting solder balls stuck between pins. The solder stays liquid for longer than you think, so make sure you give the connectors enough time to cool before moving the board.

6. After surface mounting, solder the shield pins of the HDMI connectors in place. The surface mount connection is not mechanically strong enough to hold the connectors in place by itself.

## 3.2 Resistors and Capacitors

Install the discrete passive components

- 14 330Ω resistors
- 13 1kΩ resistors
- 12 4.3kΩ resistors
-

## 3.3 Regulators and MOSFETS

## 3.4 Pin Headers

1. Install the 2x20 pin male header into the HiFi Berry section of the board. Make sure the header sits flush against the board. You will need to use tape to ensure this.

2. Begin by soldering only the opposite corner pins. Then, confirm the connector sits flush. Adjust as necessary. Once satisfied, solder the remaining pins.

3. Install the 2x20 female header into the Raspberry Pi section of the board. Again, make sure the header if flush. The key on the header should face the adjacent male header.

4. Install the 50 pin shrouded header, making sure it is flush to the board. The key on the header must align with the center key marking on the board.

5. Finally, install the 16 pin male header similarly to the other headers.

### 3.5 Front Panel Connectors

1. Insert the DB-9 connector into the corresponding holes on the board. The DB-9 connector will hold itself in place.

2. Apply solder to both shroud pins on either side of the main connector. It is not necessary to fill these two holes completely with solder.

3. Solder the remaining DB-9 pins.

4. Insert the 2 port USB A female connector into the board.

5. Solder the 4 shroud pins with enough solder to make a strong connection.

6. Then solder the remaining pins.

### 3.6 Molex Connectors

1. Insert the two small, male 2-pin molex connectors into the audio section just above the potentiometers. Make sure the key faces towards the edge of the board. Solder in place.

2. Insert the small 4-pin molex connector into the holes just behind the HDMI connectors. The key should face away from the connectors, corresponding the mark on the board. Be sure the connector is flush to the board and solder in place.

3. Insert the two large, male 2-pin molex headers into the areas marked FAN and +24V. Be sure the key is on the side of the board closest to the voltage regulators.

4. Solder the pins, making sure the connectors are flush to the board.

## 4 Mechanical Assembly

### 4.1 Heat Sinks

- Mix equal proportions of the thermal adhesive Part A and Part B in a weigh boat.

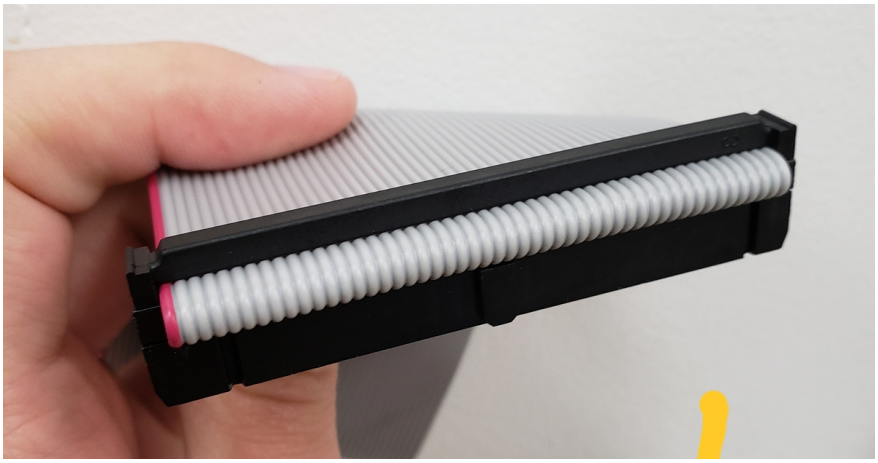
- Spread a small amount of the mixture onto the backs of the 12V regulator and the two TIP42 transistors.

- Press a heat sink onto each of the components with the fins facing into the board.
- Align the screw holes and clip with a small binding clip, taking care not to adhere the clip to the component with excess adhesive.

## 4.2 Back Panel

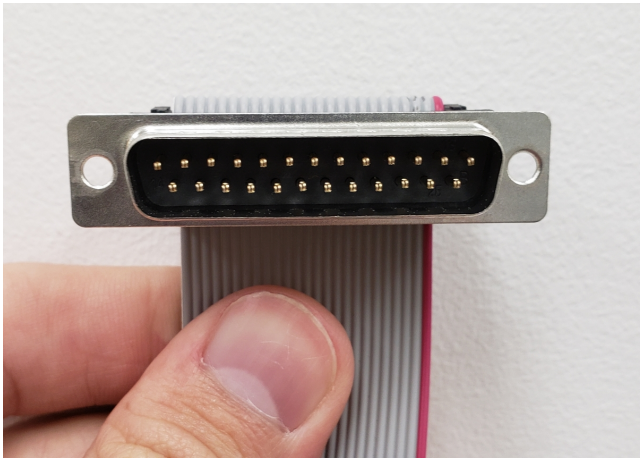
1. Cut the required lengths of wire
   - Two 6.5 inch lengths of 20 gauge wire, one red, one black.
   - Two 6.5 inch lengths of 24 gauge wire, one red, one black.
   - Two 6.5 inch lengths of blue 20 gauge wire.
   - Two 6.5 inch lengths of yellow 20 gauge wire.
   - One 3 inch length of 24 gauge black wire.
   - Approximately 6.5 inches of 50-wire IDC ribbon cable.
2. Solder red and black 20 gauge lengths to the positive and negative terminals of the DC power jack, respectively.
3. Solder the 3 inch length of black 24 gauge wire to the negative terminal of the jack.
4. Cover the joints with heat-shrink tubing.
5. Crimp two large male molex pins to the 6.5 inch lengths of red and black wire attached to the DC power jack.
6. Insert the pins into the molex housing. Ensure that the red (positive) pin matches with the + mark next to the header on the board.
7. Cut 2 inches of wire off the ends of the wires attached to the fan.
8. Twist together the stripped ends of the red and black 24 gauge wire with the stripped ends of the fan leads.
9. Crimp two large male molex pins to the twisted leads.
10. Insert the pins into the molex housing, again aligning the red (positive) pin with the + mark next to the header labeled FAN on the board.
11. Screw the DC power jack into the back panel and screw on the washer and nut included with the jack.
12. Solder the yellow and blue wires onto the terminals of the audio connector, with the pattern YELLOW, BLUE, BLUE, YELLOW
13. Cover the joints with heat shrink tubing

14. Thread the wires through the back panel from the outside and bolt the audio connector in place with 4-40 screws and nuts.
15. Screw the fan onto the housing. Make sure the arrow on the fan indicating airflow direction points into the box. Use (bolts).
16. Crimp a 50-pin IDC female header onto one end of the ribbon cable.



The red wire on the ribbon must align with the arrow on the header. This arrow is to the left of the header key if you are looking at the key.

17. Carefully divide the other end of the IDC ribbon cable into two 25-wire sections.
18. Crimp a male DB-25 IDC connector onto the half of the split ribbon cable with the red wire.



Looking at the pins of the DB-25, the red wire goes on the right.

19. Crimp another male DB-25 IDC connector onto the other half of the ribbon cable, following the same orientation of the connector.

### 4.3 Front Panel

### 4.4 Final Assembly

### 4.5 Testing

## 5 Operant Box Assembly

### 5.1 Sound Isolation Chambers

### 5.2 Breakout Boards

### 5.3 Panel

The operant conditioning panel is the physical device with which the animal interacts. While the RPiOperant board is capable of handling multiple configurations of the panel, the configuration we use in the Gentner lab typically consists of:

- One sheet metal panel
- Three peckports
- One food hopper
- One solenoid to control the food hopper

Each peckport consists of:

- One infrared breakbeam to sense pecking into the port
- One LED light to act as a cue
- One 3D printed body to mount the IR breakbeam and cue LED
- One machined plastic pecking piece.

The three peckports, as well as the solenoid and hopper are mounted onto the sheet metal panel, which is mounted on the animals cage.

CAD drawings are available in the section CAD Drawings. Schematics for 3D printing the peckports, as well as machining the sheet metal panels, the hoppers, and the plastic pecking piece are available on the GitHub repository.

### 5.4 House Lights

# 6 Software Setup

## 6.1 Cloning SD card image

A basic RPiOperant image is available containing the bare-bones setup to run an operant box with PyOperant. This image may need to be updated from time to time

### 6.1.1 Preparing the SD Card

1. Insert the blank SD card into the computer.
2. Locate the image at `/mnt/cube/RPiOperantOS.img`
3. Use `lsblk` to find the device name of the SD card.
4. Unmount the SD card
5. Use `dd` to copy the raw image to the SD Card. In this example, the command would be `sudo dd if=/mnt/cube/RPiOperantOS.img of=/dev/sdc bs=4M`
6. Insert the SD card into the Raspberry Pi.

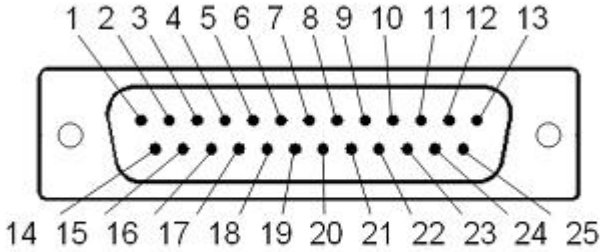
### 6.1.2 Setting Up the Image

Assume that the box number is XX (01, 09, 14, etc).

1. Log in to the box with `ssh bird@192.168.1.1`, password `starling`
2. Use `raspi-config` to set the hostname to `magpiXX`
3. Use `raspi-config` to expand the root filesystem
4. Reboot the pi. `raspi-config` should ask, otherwise use `sudo reboot`
5. Log back in.
6. Run `sudo vim /etc/network/interfaces` to set the IP address to `192.168.1.XX`
7. Run `mv /etc/profile.d/wifi-country.sh /etc/profile.d/wifi-country.sh.old`
8. Reboot. The box will now be accessible at IP `192.168.1.XX`

# 8 Connector Pinouts

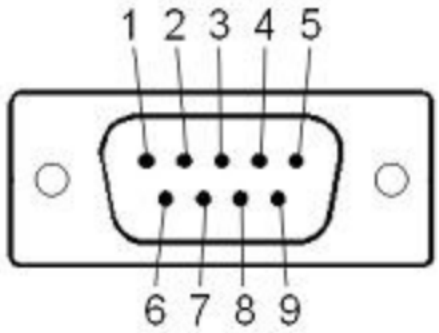
## 8.1 Top DB-25




Male DB-25

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 1 | Load Cell E+ | 14 | Load Cell E- |
| 2 | +3.3V | 15 | House Light R |
| 3 | Houselight G | 16 | House Light B |
| 4 | Houselight W | 17 | USB1 VBUS |
| 5 | USB1 D- | 18 | USB1 D+ |
| 6 | Load Cell A+ | 19 | Load Cell A- |
| 7 | Hopper IR | 20 | Left IR |
| 8 | Center IR | 21 | Right IR |
| 9 | Left LED | 22 | Center LED |
| 10 | Right LED | 23 | Hopper |
| 11 | RGB Cue R | 24 | RGB Cue B |
| 12 | RGB Cue G | 25 | +12V |
| 13 | +24V | | |

## 8.2 Front Panel DB-9



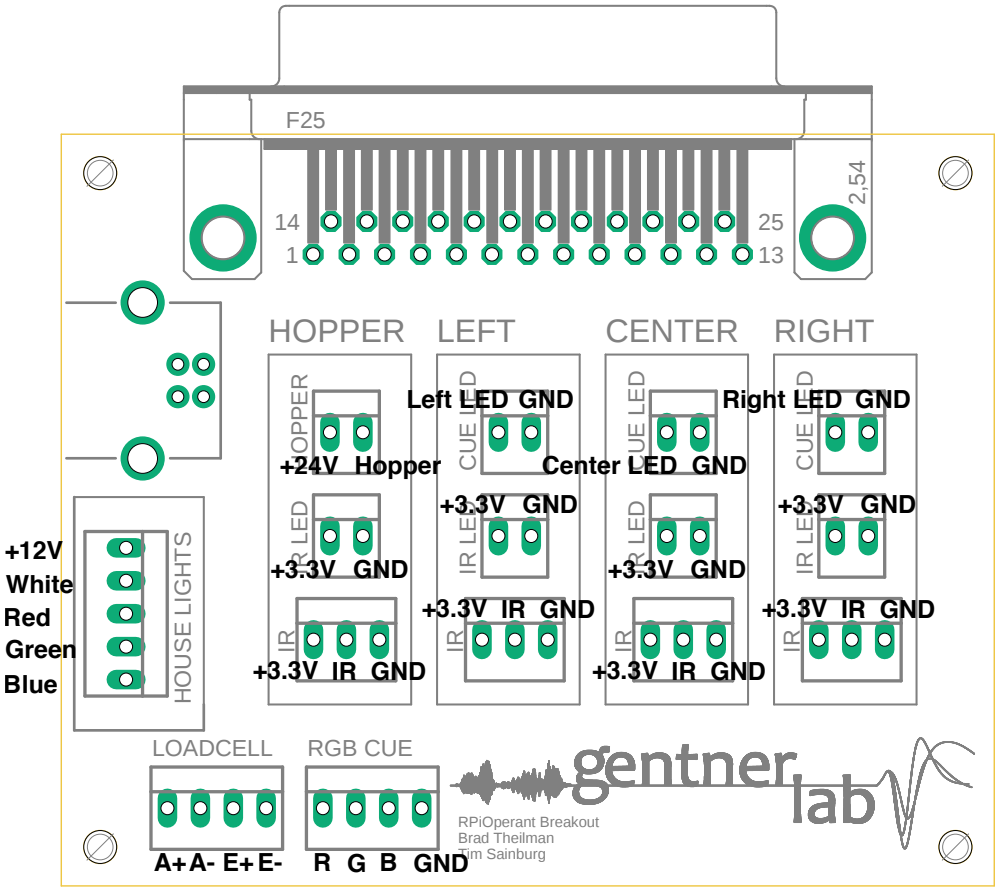

## 8.3 Raspberry Pi GPIO

(Include picture of header with pin numbers labeled)

| Pin | Signal | Pin | Signal |
|---|---|---|---|
| 1 | RPi +3.3V | 2 | RPi +5V |
| 3 | SDA | 4 | RPi +5V |
| 5 | SCL | 6 | GND |
| 7 | GPIO 4 (HiFiBerry Mute) | 8 | TXD |
| 9 | GND | 10 | RXD |
| 11 | GPIO17 (Load Cell DAT) | 12 | PCM CLK |
| 13 | GPIO27 | 14 | GND |
| 15 | GPIO22 | 16 | IR 1 |
| 17 | RPi +3.3V | 18 | IR 2 |
| 19 | IR 6 (GPIO10) | 20 | GND |
| 21 | IR 4 (GPIO9) | 22 | IR 3 (GPIO25) |
| 23 | IR 5 (GPIO11) | 24 | GPIO8 (Load Cell CLK) |
| 25 | GND | 26 | IR 7 (GPIO7) |
| 27 | ID_SD | 28 | ID_SC |
| 29 | Hopper IR (GPIO5) | 30 | GND |
| 31 | Left IR (GPIO6) | 32 | IR 8 (GPIO12) |
| 33 | Center IR (GPIO13) | 34 | GND |
| 35 | PCM FS | 36 | Hopper Trigger (GPIO16) |
| 37 | Right IR (GPIO26) | 38 | PCM DIN |
| 39 | GND | 40 | PCM DOUT |

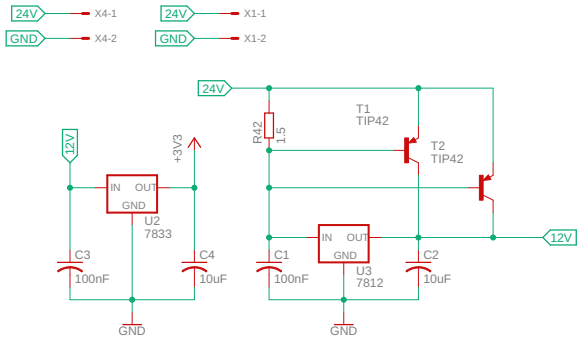
## 8.4 OpenEphys HDMI

## 8.5 Breakout Boards



# 9 Schematics

## 9.1 Power Supply

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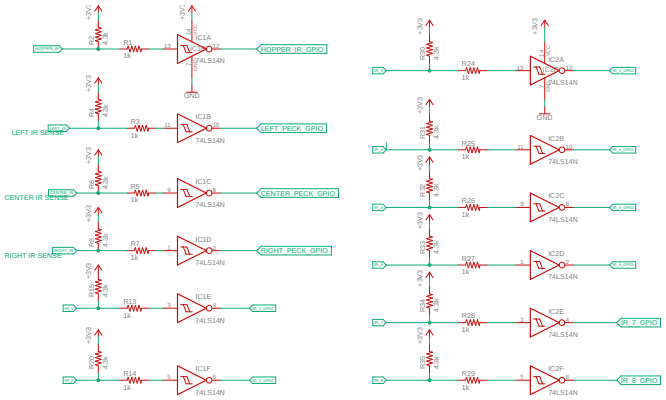
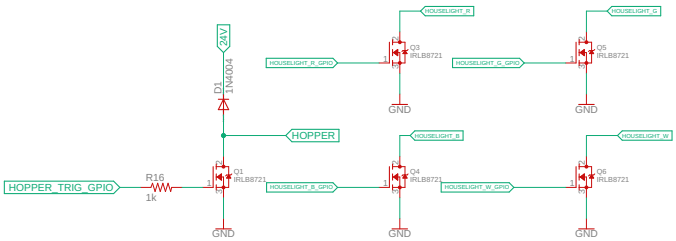
## 9.2 IR Ports



## 9.3 House Lights and Hopper




# 10 CAD Drawings

# 11 Parts Lists

## 11.1 Electrical Parts List

## 11.2 Mechanical Parts List

# References