

# **Pi 2 Design**

**PI2AES  
Digital Pro Audio Hat  
Hardware Reference Manual  
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# I WARRANTY

The enclosed product ("the Product"), a part of the P2 2 Design Shield/Hat series, is warranted by Pi 2 Design for a period of one year for reasonable development, testing and use, all as further described and defined below. This warranty runs solely to the individual or entity purchasing the Product and is not transferable or assignable in any respect. This warranty is valid only for so long as the product is used intact as shipped from Pi 2 Design. Any attempt or effort to alter the Product, including but not limited to any attempt to solder, de-solder, unplug, replace, add or affix any part or component of or onto the Product, other than components specifically intended for the user to plug and unplug into appropriate sockets and/or Connectors to facilitate user programming, development and deployment, all as specifically described and authorized in this Product Hardware Reference Manual, shall void this warranty in all respects. Coverage under this warranty requires that the Product be used and stored at all times in conditions with proper electrostatic protection necessary and appropriate for a complex electronic device. These conditions include proper temperature, humidity, radiation, atmosphere and voltage (standard commercial environment, 0C to +70C, <60%RH). Any Product that has been modified without the express, prior written consent of Pi 2 Design is not covered by this warranty. The use or connection of any test or bus Connector, adapter or component with any device other than a Pi 2 Design Connector or adapter shall void this warranty and the warranty of all other components, parts and modules connected to the rest of the system. Pi 2 Design shall not be responsible for any damage to the Product as a result of a customer's use or application of circuitry not developed or approved by Pi 2 Design for use on or in connection with the Product.

This warranty does not cover defects caused by electrical or temperature fluctuations or from stress resulting from or caused by abuse, misuse or misapplication of the Product. Any evidence of tampering with the serial number on the Product shall immediately void this warranty. This Product is not intended to be used on or embedded in or otherwise used in connection with any life-sustaining or life-saving product and this warranty is not applicable nor is Pi 2 Design liable in any respect if the Product is so used. Notwithstanding anything to the contrary herein, Pi 2 Design expressly disclaims any implied warranty of merchantability or implied warranty of fitness for a particular purpose in connection with the manufacture or use of the Product.

## 2 OPERATING SPECIFICATIONS

### 2.1 PI2AES OPERATING SPECIFICATIONS

The PI2AES conforms to the following specifications:

| Specification         | Value                        |
|-----------------------|------------------------------|
| Dimensions            | 85mm x 56.5mm                |
| Weight                | ~10g                         |
| Storage Temperature   | -20C to +85C                 |
| Operating Temperature | 0C to +70C                   |
| Humidity              | 0% to 95% RH, Non-Condensing |
| Input Voltage (VIN)   | +19V to +32V, +24V nominal   |
| Power Consumption     | 250mw Typical, 1W Maximum    |

Table 1 – PI2AES Operating Specifications

## 3 OVERVIEW

### 3.1 INTRODUCTION

The PI2AES, designed and manufactured by PI 2 Design, is a professional I/O Shield designed to bring Professional Studio Grade Audio to the Raspberry Pi® family of Single Board Computers. This low-cost Shield converts the Raspberry Pi® I2S Interface to High Definition Digital Audio Coax, OPTO and Balanced XLR.

The addition of Parallel I2S Output along with LVDS Differential over HDMI allows the PI2AES to interface with virtually any High Performance DAC on the market.

The major features of the PI2AES are as follows:

- **FORM FACTOR** – Raspberry Pi® Shield Size w/40-Pin mating connector.
- **AES TRANSMITTER** – The industry standard WM8804 converts the RPi I2S stream to AES3/SPDIF formatted data at 24-Bit up to 192Khz Frame Rate
- **COAX OUTPUT** – A 1:1 Isolation Transformer provides Bit Perfect Impedance Controlled Coaxial Transmission of the Digital Audio Data
- **SPDIF OPTICAL OUTPUT** – Isolated Optical Transmitter Drives Consumer Level DAC and AVR
- **BALANCED OUTPUT** – An RS-422 Transmitter coupled with a 1:1 Isolation Transformer allows the transmission of balanced audio data via the Professional Audio Standard XLR Connector
- **BUFFERED I2S OUTPUT** – Parallel Buffered I2S is available for direct short distance connection to off-board D/A. Perfect for DIY use! I2C for control is also provided as well as 5V Regulated and Input Voltage Rails.
- **DIFFERENTIAL I2S OUTPUT** – A DS2063 Differential Transmitters is used to drive the I2S Bus over a standard HDMI Connector. The Pinout is Selectable Between the PS Audio and Gustard Standards.
- **HIGH RESOLUTION CLOCKS** – A pair of Ultra-Low Noise NDK NZ2520SD oscillators allow the WM8804 to operate in non-PLL mode for the lowest possible noise.
- **ULTRA-LOW NOISE LDO's** – Ultra-Low Noise AP1155ADL LDO (30uV noise and 80dB PSRR) is used to Supply the WM8804 Transmit Section, while an ADP150 (9uV noise and 70dB PSRR) and the High-Resolution Clocks.
- **LOW NOISE PCB LAYOUT** – Constructed with 4-layer Split Ground PCB with noise reduction techniques refined from years of High-Speed Mixed-Signal Design work

### 3.2 BLOCK DIAGRAM

Refer to the following figure for a block diagram of the PI2AES Shield.

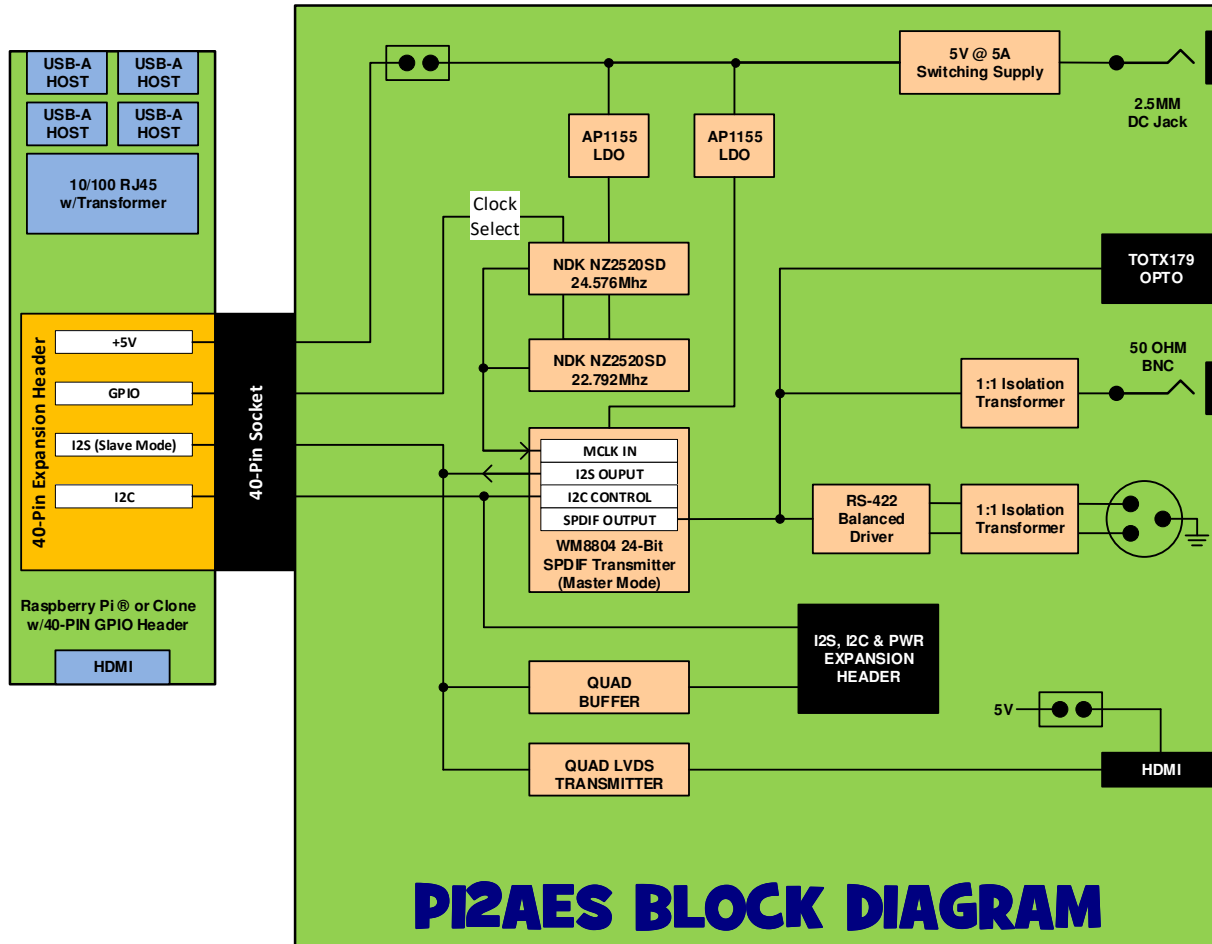


Figure 1 – PI2AES Block Diagram

## 4 ON-BOARD DEVICES

### 4.1 OVERVIEW

The PI2AES interfaces to the RPi via the 40-Pin GPIO Connector. This section describes in detail the devices located on the PI2AES.

#### 4.1 PI2AES I2C BUS DEVICES

The following table describes the CPU I2C Bus usage of the PI2AES. Most of these addresses are set by the startup script supplied by Pi2Design. Refer to the respective device documentation for more detail.

| I2C Bus | 7-Bit I2C Address | Description              |
|---------|-------------------|--------------------------|
| I2C     | 0x3B              | WM8804 SPDIF Transmitter |

Table 2 – PI2AES I2C Bus Devices

#### 4.1 WM8804 SPDIF TRANSMITTER

At the core of the PI2AES is the Cirrus Logic WM8804 AES Digital Audio Transmitter. This device interfaces to the Raspberry Pi via I2S and I2C. The signals used to interface with the WM8804 are shown in the following table.

| WM8804 Signal | RPi Signal | Description   |
|---------------|------------|---|
| MCLK          | -          | Unused  |
| BCLK          | BCLK       | I2S Bit Clock Output to Pi  |
| LRCLK         | LRCLK      | I2S Word Clock Output to Pi   |
| SDIN          | SDOUT      | I2S Serial Audio Data Input from Pi   |
| SCL           | SCL        | I2C Clock from Pi   |
| SDA           | SDA        | I2C Data to/from Pi   |
| XIN           | GPIO5      | 1 = Select 22.5792Mhz Input Clock for 44.1Khz, 88.2Khz and 176.4Khz Frame Rates |
| XIN           | GPIO6      | 1 = Select 24.576Mhz Input Clock for 48Khz, 96Khz and 192Khz Frame Rates        |

|     |   |   |
|-----|---|---|
| TXO | - | AES3/SPDIF encoded digital audio output |
|-----|---|---|

Table 3 – RPi to WM8804 Connections

#### ***4.1.1 WM8804 SPDIF TRANSMITTER NOTES***

1. The WM8804 is controlled using the I2C port. Refer to the WM8804 documentation and Pi 2 Design supplied driver code for more detail.
2. The PI2AES is designed to operate the WM8804 in Master mode. In this mode the WM8804 receives its master clock from XIN and drives MCLK (unused), BCLK and LRCLK to the Pi. Serial Data in is received from Pi.
3. Pi GPIO's 6 and 13 are used to select the desired clock input. GPIO 6 and 13 are pulled low by default. CAUTION - Do not select more than one clock at a time!

#### ***4.2 DUAL HIGH RESOLUTION NDK CLOCKS***

A pair of NDK NZ2520SD Ultra-Low Noise clocks provide the critical timing signals for the WM8804. They are selected via Raspberry PI GPIO5 (22.5792Mhz) and GPIO6 (24.576Mhz).

#### ***4.3 RS-422 DIFFERENTIAL TRANSMITTER***

An RS-422 Differential Transmitter accepts the SPDIF output from the WM8804 and sends it as a balanced pair to the 1:1 Isolation Transformer and then to the XLR connector.

#### ***4.4 I2S PARALLEL BUFFER***

A 74FCT125 CMOS Buffer is used to drive the I2S signals (MCLK, BCKL, LRCLK and SDO) to the I2S Expansion Header. This device is designed to drive the I2S Bus short distances (<12 inches).

#### ***4.5 I2S DIFFERENTIAL DRIVER***

A DS2063 Quad Differential LVDS Driver takes the I2S Bus and converts each signal into a balanced differential signal. This is then connected to the HDMI connector. This device is designed to drive the I2S Bus up to 3 meters.

#### ***4.6 AUDIO DATA RATE AND POWER LED'S***

A triple stack LED is used to provide visual indication of: Power On (Green), Audio Data Rate of 48/96/192Khz (Yellow) and Audio Data Rate of 44.1/88.2/176.4Khz (Red).



## 5 RPI GPIO

### 5.1 OVERVIEW

The PI2AES uses a number of signals from the RPi GPIO header for control and status purposes. This usage is defined in the following table.

| RPI PIN | DIR | AF | PUP/PDN | PI2AES Name | Description/Notes         |
|---------|-----|----|---------|-------------|---------------------------|
| 1       | -   | -  | -       | -           | RPi +3.3V - Unused        |
| 2       | -   | -  | -       | +5V         | +5V Power to/from the RPi |
| 3       | I/O | Y  | PUP     | I2C_SDA     | I2C Bus Data              |
| 4       | -   | -  | -       | +5V         | +5V Power to/from the RPi |
| 5       | OUT | Y  | PUP     | I2C_SCL     | I2C Bus Clock             |
| 6       | -   | -  | -       | GND         |                           |
| 7       | OUT | -  | -       | GPIO4       | Unused                    |
| 8       | -   | -  | -       | GPIO14      | Unused                    |
| 9       | -   | -  | -       | GND         | Unused                    |
| 10      | -   | -  | -       | GPIO15      | Unused                    |
| 11      | -   | -  | -       | GPIO17      | Unused                    |
| 12      | IN  | Y  | -       | BCLK        | I2S Bit Clock from WM8804 |
| 13      | -   | -  | -       | GPIO27      | Unused                    |
| 14      | -   | -  | -       | GND         |                           |
| 15      | -   | -  | -       | GPIO22      | Unused                    |
| 16      | -   | -  | -       | GPIO23      | Unused                    |
| 17      | -   | -  | -       | -           | RPi +3.3V - Unused        |
| 18      | -   | -  | -       | GPIO24      | Unused                    |
| 19      | -   | -  | -       | GPIO10      | Unused                    |
| 20      | -   | -  | -       | GND         |                           |
| 21      | -   | -  | -       | GPIO9       | Unused                    |
| 22      | -   | -  | -       | GPIO25      | Unused                    |

| RPi PIN | DIR | AF | PUP/PDN | PI2AES Name | Description/Notes                           |
|---------|-----|----|---------|-------------|---|
| 23      | -   | -  | -       | GPIO11      | Unused                                      |
| 24      | -   | -  | -       | GPIO8       | Unused                                      |
| 25      | -   | -  | -       | GND         |   |
| 26      | -   | -  | -       | GPIO1       | Unused                                      |
| 27      | I/O | Y  | -       | ID_SDA      | Unused                                      |
| 28      | OUT | Y  | -       | ID_SCL      | Unused                                      |
| 29      | -   | -  | -       | GPIO5       | 1 = Select 22.5792Mhz Clock Input to WM8804 |
| 30      | -   | -  | -       | GND         |   |
| 31      | OUT | -  | PUP     | GPIO6       | 1 = Select 24.576Mhz Clock Input to WM8804  |
| 32      | -   | -  | -       | GPIO12      | Unused                                      |
| 33      | OUT | -  | -       | GPIO13      | Unused                                      |
| 34      | -   | -  | -       | GND         |   |
| 35      | IN  | Y  | -       | LRCLK       | I2S Left/Right Clock from WM8804            |
| 36      | -   | -  | -       | GPIO16      | Unused                                      |
| 37      | -   | -  | -       | GPIO26      | Unused                                      |
| 38      | -   | -  | -       | GPIO20      | Unused                                      |
| 39      | -   | -  | -       | GND         |   |
| 40      | OUT | Y  | -       | SDOUT       | Pi I2S Serial Audio Data Out                |

**Table 4 – CPU GPIO Pin Assignments**

***5.1.1 RPI GPIO NOTES***

1. DIR is from the point of view of the RPi.
2. Y in the Alternate Function (AF) column indicates that the use of this pin requires the pin to be assigned to the function as defined by the RPi specifications.
3. PUP/PDN indicates if the GPIO should have its associated Pullup (PUP) or Pulldown (PDN) resistor enabled.
4. An asterisk “\*” at the beginning of the name indicates a low true signal.

# 6 PI2AES POWER

## 6.1 OVERVIEW

The PI2AES is designed to be powered from an external +19V to +32V source. Jumper W2, when installed, allows the Raspberry PI to be powered from the PI2AES. When jumper W2 is removed, separate 5V power must be supplied to the Raspberry PI.

Note that an on-board protection circuit ensures proper operation when jumper W2 is installed while power is applied via J1 AND from the Pi (P1) simultaneously.

See the below block diagram for a simplified view of the PI2AES power.

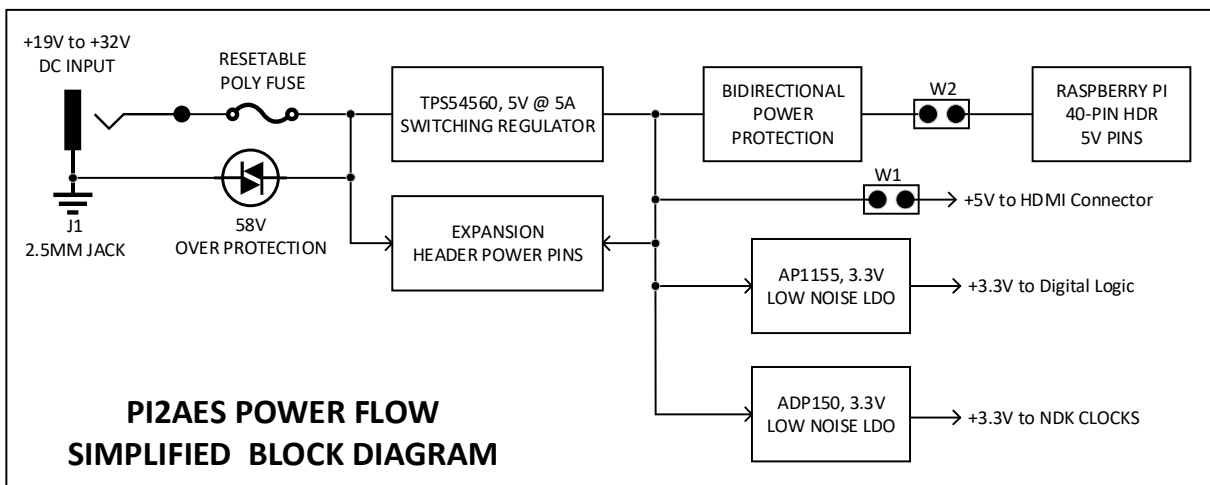


Figure 2 – PI2AES Power, Simplified Block Diagram

## 7 PI2AES SOFTWARE

### *7.1 OVERVIEW*

Due to the various resources interfaced on the PI2AES, both internal and external to the RPi, it is necessary to initialize a large number of CPU registers and external devices before correct operation can begin. These values and their proper sequencing are beyond the scope of this document. For most Raspberry Pi Software, the HifiBerry Digi+ Pro driver can be used.

## 8 TOP SIDE CONNECTORS

### *8.1 OVERVIEW*

This section provides the type, location and pinout for the various connectors on the PI2AES. Top View and Front View are shown in the following 3D renders.

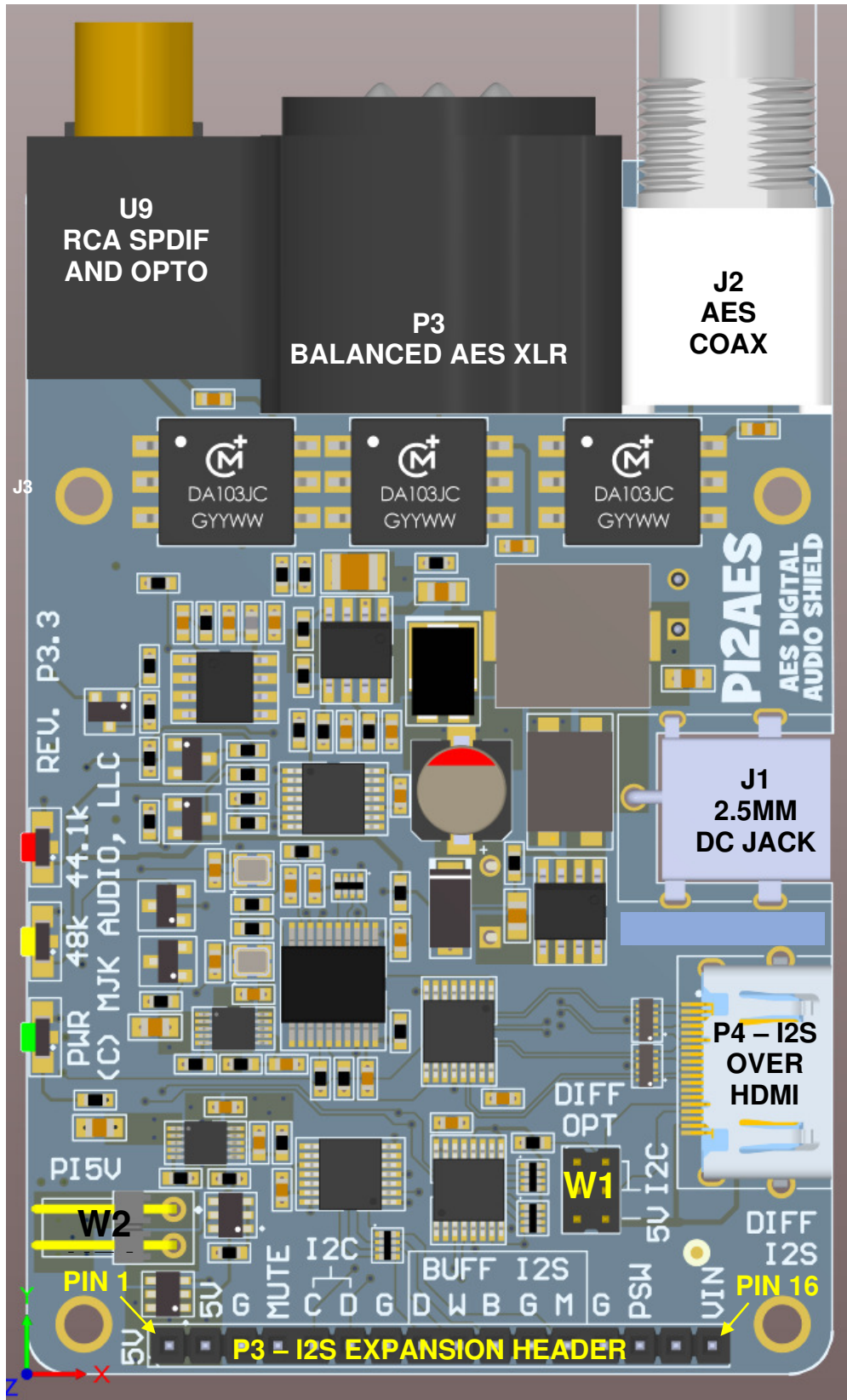


Figure 3 – PI2AES Top View

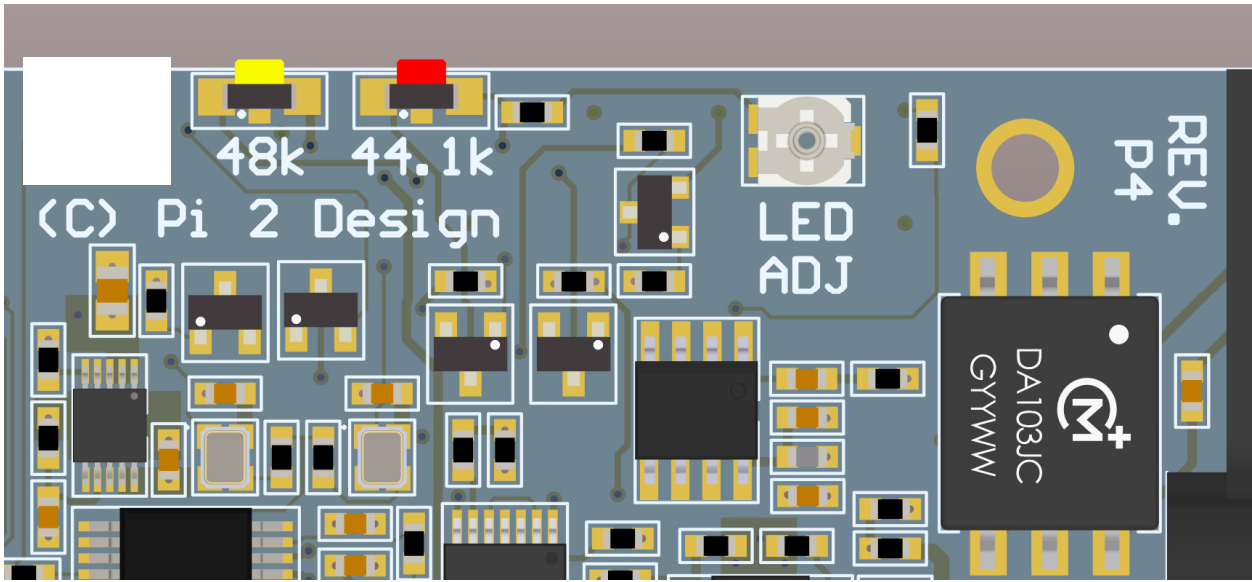


Figure 4 – PI2AES LED Brightness Adjust (P4.x Only)

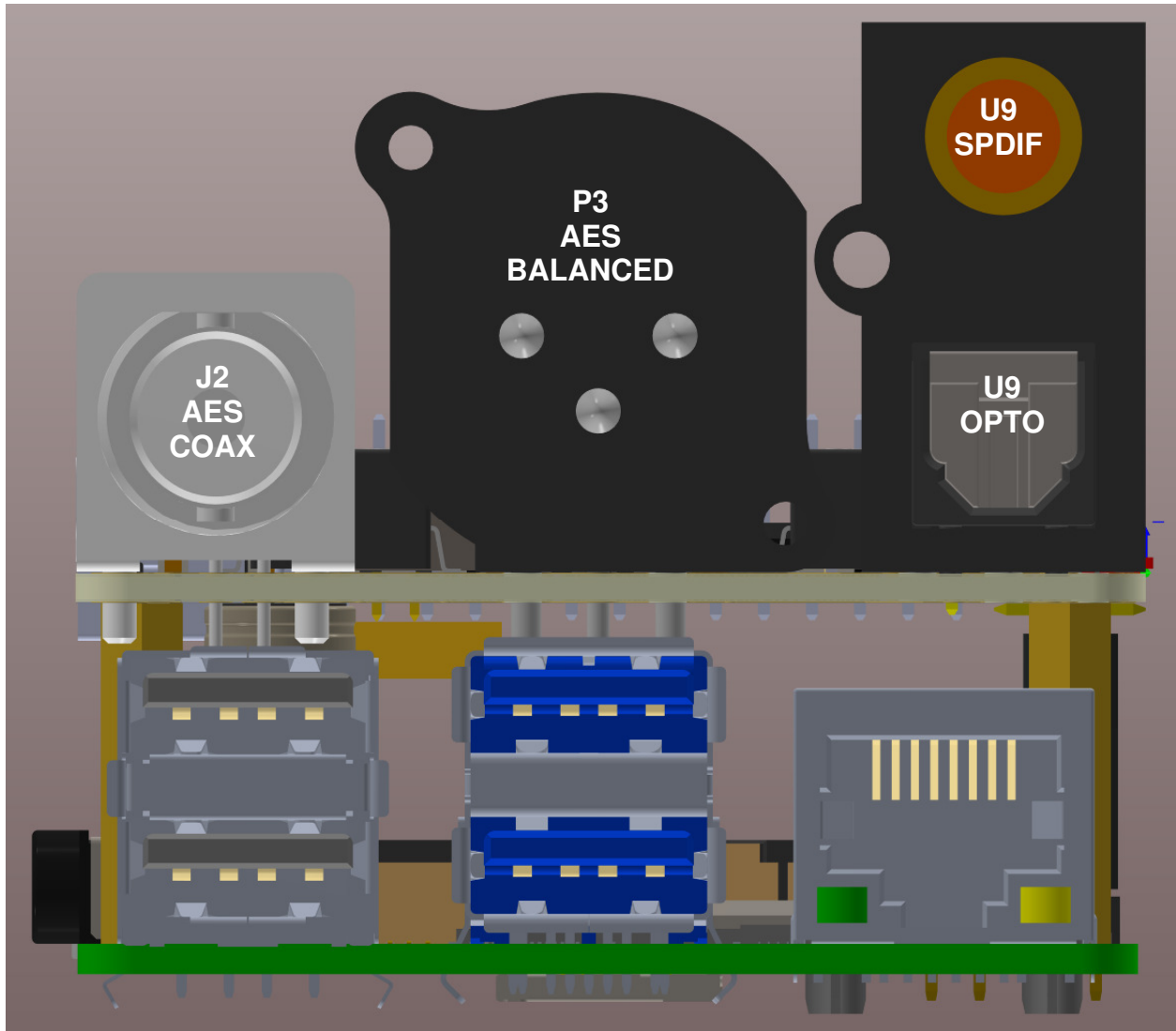


Figure 5 – PI2AES Front View (shown mounted on Raspberry Pi 4)





Figure 6 – PI2AES Side View (shown mounted on Raspberry Pi 4)

### ***8.2 RP1 – LED BRIGHTNESS***

This adjustable resistor pot is located on the PI2AES P4.0 and above only. This allows the overall brightness of the three LED's to be adjusted from full (clockwise) to dimmest (counter clockwise).

### ***8.3 J1 – DC JACK***

This jack is designed to accept a 5.5mm x 2.5mm center positive plug for external power in. Voltage must be between +19V to +19V, optimized for +24V.

### ***8.4 P1 – 40-PIN GPIO HEADER***

This is a standard 40-Pin .1" Dual Row Female Header. It is designed to accept a Raspberry Pi single board and conforms to the standard Raspberry Pi 40-Pin GPIO Header pinout.

### ***8.5 P2 - I2S EXPANSION HEADER***

This is a 16-Pin, .1" Single Row Header that carries I2S, I2C, and Power for expansion use. The Pinout for P2 is shown in the following table.

| P2 PIN | Name  | Description                                   |
|--------|-------|---|
| 1      | 5V    | +5V direct from Regulator                     |
| 2      | 5V    | +5V direct from Regulator                     |
| 3      | GND   | Ground  |
| 4      | MUTE  | 1 = Mute On                                   |
| 5      | SCL   | I2C Clock                                     |
| 6      | SDA   | I2C Data                                      |
| 7      | GND   | Ground  |
| 8      | SDO   | Buffered I2S Data                             |
| 9      | LRCLK | Buffered I2S Left/Right (Word) Clock          |
| 10     | BCLK  | Buffered I2S Bit Clock                        |
| 11     | GND   | Ground  |
| 12     | MCLK  | Buffered I2S Master Clock                     |
| 13     | GND   | Ground  |
| 14     | *PSW  | Power Enable – Jumper with Pin 13 for auto on |
| 15     | VIN   | +12V to +48V Input                            |
| 16     | VIN   | +12V to +48V Input                            |

Table 5 – I2S Expansion Header Pinout

**8.1 P3 – XLR BALANCED OUTPUT**

P3 is a 3-Pin XLR Connector. This 100-ohm connector carries the balanced digital audio output.

**8.2 P4 – I2S OVER HDMI**

P4 is a standard HDMI Connector that carries the Differential I2S signal. Pinout conforms to either the PS Audio (default) or Gustard standards. The Pinout for P4 is shown in the following table. **%FIXME%**

| P4 PIN | Name | Description, Rev. P4.x<br>PS Audio Pinout | Description, Rev P3.x<br>Gustard Pinout |
|--------|------|---|---|
| 1      | TD2+ | SDO- Data Minus                           | SDO+ Data Plus                          |
| 2      | GND  | Ground                                    | Ground                                  |

| <b>P4 PIN</b> | <b>Name</b> | <b>Description, Rev. P4.x<br/>PS Audio Pinout</b> | <b>Description, Rev P3.x<br/>Gustard Pinout</b> |
|---------------|-------------|---|---|
| 3             | TD2-        | SDO+ Data Plus                                    | SDO- Data Minus                                 |
| 4             | TD1+        | BCK+ Bit Clock Plus                               | BCK+ Bit Clock Plus                             |
| 5             | GND         | Ground  | Ground  |
| 6             | TD1-        | BCK- Bit Clock Minus                              | BCK- Bit Clock Minus                            |
| 7             | TD0+        | WCK- Word Clock Minus                             | WCK+ Word Clock Plus                            |
| 8             | GND         | Ground  | Ground  |
| 9             | TDO-        | WCK+ Word Clock Plus                              | WCK- Word Clock Minus                           |
| 10            | TDC+        | MCK+ Master Clock Plus                            | MCK+ Master Clock Plus                          |
| 11            | GND         | Ground  | Ground  |
| 12            | TDC -       | MCK- Master Clock Minus                           | MCK- Master Clock Minus                         |
| 13            | NC          | No Connect  | No Connect                                      |
| 14            | NC          | No Connect  | No Connect                                      |
| 15            | SDA         | I2C Data<br>From Jumper W1<br>Pins 1-2            | I2C Data<br>From Jumper W1<br>Pins 1-2          |
| 16            | SCL         | I2C Clock<br>From Jumper W1<br>Pins 3-4           | I2C Clock<br>From Jumper W1<br>Pins 3-4         |
| 17            | GND         | Ground  | Ground  |
| 18            | +5V         | +5V from<br>Jumper W1<br>Pins 5-6                 | +5V from<br>Jumper W1<br>Pins 5-6               |
| 19            | NC          | No Connect  | No Connect                                      |

Table 6 – I2S Over HDMI Pinout

### ***8.3 U9 – COMBO RCA/OPTO TRANSMITTER***

U9 is a Cliff OTJ6 that contains the RCA for AES COAX digital audio output and a Toslink Transmitter for SPDIF Optical digital audio output.

### ***8.4 D1 – STATUS LEDs***

There are multiple LEDs on the PI2AES: Power ON (Green, P3.x only); 48Khz/96Khz/192Khz Clock (Yellow); and 44.1Khz/88.2Khz/176.4Khz Clock (Red).

## 9 DOCUMENT REVISIONS

| Date       | Revision | Change   |
|------------|----------|--|
| 03/26/2019 | P0.1     | Preliminary Release  |
| 06/02/2019 | P2       | Design Revision P2 Initial Release   |
| 08/15/2019 | P3       | Design Revision P3 Initial Release<br>Added description of I2S over HDMI option block W1 |
| 08/16/2019 | P3.1     | Added entry for HifiBerry Digi+ Pro compatibility  |
| 11/23/2019 | P3.2     | Changed VIN range, now +24V to +48V  |
| 12/19/2019 | P3.3     | Corrected voltage range table  |
| 06/02/2020 | P3.4     | Corrected I2S over HDMI Connector Pinout, removing PS Audio/Gustard selection option     |
| 01/30/2022 | P4.0     | Updated for PI2 AES P3.0 and above<br>Change VIN range to +19V to +32V                   |
| 03/15/2022 | P4.1     | Remove references to Power LED   |
| 05/16/2022 | P4.2     | Add I2S/HDMI Jumper info   |
| 05/25/2022 | P4.3     | Correct I2S Pinout Table   |

Table 7 – Document Revisions

# IO ERRATA

## *10.1 OVERVIEW*

There are currently no known errata for the PI2AES Rev. P4.