Wolfson Audio Card User Documentation

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1. Introduction to Wolfson Audio Card for Raspberry Pi

Raspberry Pi, whilst being equipped with audio capability, is limited in a number of ways. The limitations are purposeful, in order to keep Raspberry Pi at a low price point.

In terms of audio, there are no ways to capture audio using Raspberry Pi alone, and audio output is limited to two paths; analogue, via its onboard 3.5 mm stereo output jack, and digital, via its onboard HDMI output.

Whilst the HDMI output provides the potential for high quality rendering of audio (depending on what HDMI devices are used to finally convert audio from its digital format to an analogue signal), the audio quality from the analogue 3.5 mm stereo output jack is universally recognised as being of an 'acceptable' quality level – no more.

The most important limitation is Raspberry Pi's lack flexibility in terms of multiple types of input sources, and outputs.

2. Features

This product, designed by element14 and Wolfson Microelectronics in partnership, addresses the above that by providing a rich set of high quality audio features as follows:

Features

- Analogue line-level output
- Analogue line-level input
- Digital stereo audio input (SPDIF)
- Digital stereo audio output (SPDIF)
- High quality headphone output, with microphone facility (for headphones with boom microphone)
- Onboard stereo digital microphones
- Ability to play High Definition (HD) Audio
- Arrives bundled with five High Definition Audio files to demonstrate the systems capability.
- Onboard power amplifier for directly driving loudspeakers. (Requires headers to be fitted.[1])

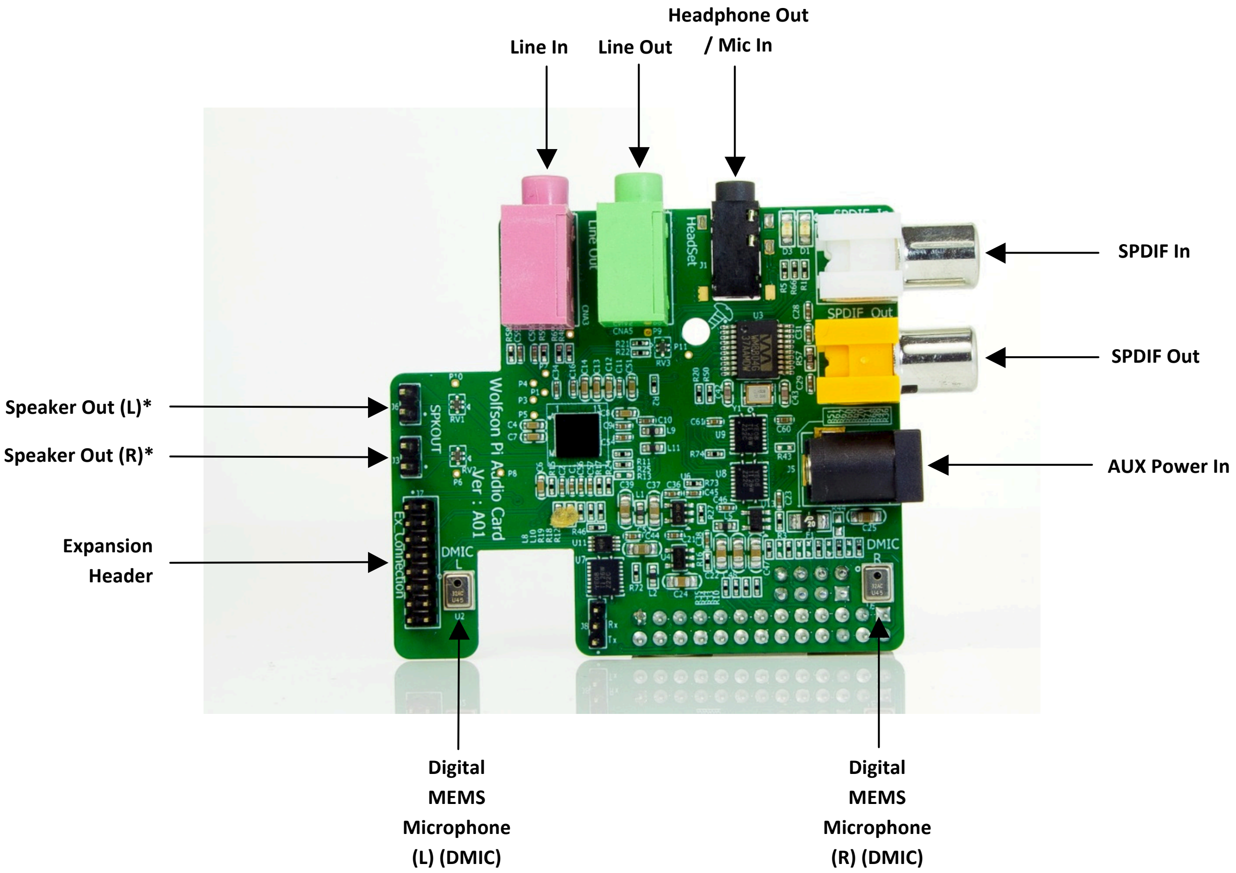

Diagram 1: Connections to and from the Wolfson Audio Card

3. How to connect the Wolfson Audio Card to Raspberry Pi

This Wolfson soundcard has been designed to plug in to Raspberry Pi simply and easily. It is compatible with Raspberry Pi Models A and B Hardware Revision 2.0 boards, which feature the 8-pin audio GPIO connector, known as P5, and located right next to the GPIO header as show below.

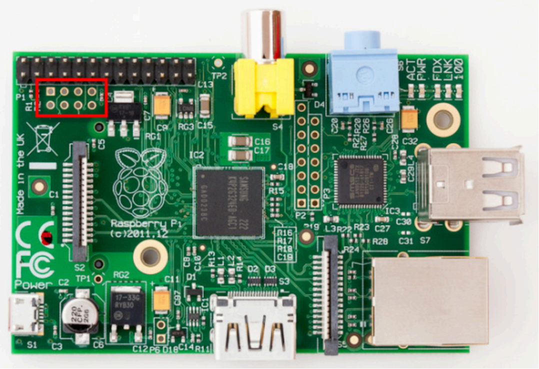

Diagram 2: Raspberry Pi with P5 connector outlined in red

It uses innovative sprung connectors to connect with Raspberry Pi. This avoids the need to solder an 8-pin header to your Raspberry Pi, thus making installation quick and easy.

a. Ensure the eight pads on connector P5 on Raspberry Pi are free of dirt and grease. If necessary, use a little degreaser, such as a very small amount of detergent on a lightly dampened paper towel, and wipe the eight pads clean. Leave them to dry thoroughly.

b. If necessary, repeat the process with the sprung connectors on the soundcard.

c. Locate the nylon pillar in the box contents, screw it into the mounting hole shown in the image below, and tighten. Don't over tighten.

d. Push the soundcard onto Raspberry Pi, making sure the board is pressed all the way, and that all eight pins have made contact with Raspberry Pi.

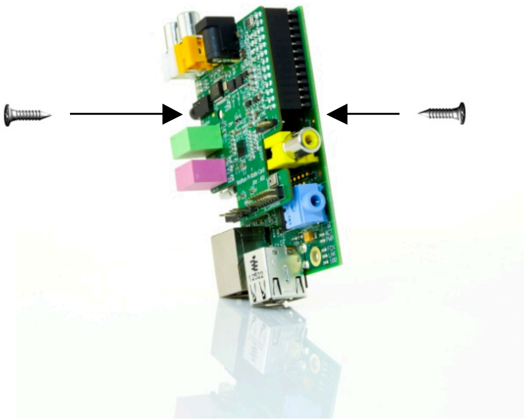

Diagram 3: The Audio Card must be secured to Raspberry Pi with the supplied pillar and screw set.

e. Line up the nylon pillar on the Raspberry Pi, with the mounting hole on the soundcard such that both holes are co-axial. Insert the other screw, and tighten. Don't over tighten.

f. The soundcard is now properly installed onto your Raspberry Pi.

__Notes on this section:__

- **Please be aware that this soundcard is *not* compatible with accessory expanders, such as the Pi Face Pi Rack, as they usually only expand Raspberry Pi's P1 GPIO expansion port, and not the P5, which is essential for audio.**
- **The nylon pillar is essential for reliable operation of the soundcard. It holds the soundcard mechanically stable to ensure the sprung connectors make a good electrical connection with the Raspberry Pi P5 connector.**
- **The use of USB hubs with Raspberry Pi and the Wolfson Audio Card is not recommended.**

4. Installing software to run on Raspberry Pi

This version of the manual is written for early adopting users. The software required to run the card is downloaded as a fully integrated all-in-one package that will simply work out of the box. We have created a full operating system solution that contains all the drivers, and some bundled extras. It will work straight away when downloaded, written to an SD Card, and set up for the first time.

1. Download the most recent image file from **www.element14.com/wolfson**, and save it in a known location on your Windows computer. The file can be quite large, so be patient as the file downloads.

2. The file **.img** has been compressed into a **.zip** format in order to minimise download time. That means, before you can do anything else, that file needs to be restored to its original form again. You may already have a zip/unzip tool installed on your computer (check by right-clicking on the .zip file – if you see the **Extract all…** option, then you have it and should use it), but if not, try **PeaZip** available at http://peazip.com. In the case of PeaZip, simply right click on the .zip file, and select **Peazip > Extract here.**

3. When you have done this, you get a single file called an Image File, or **.img**. This is a snapshot of what needs to be written to the SD Card.

4. Next, you need a tool to install the **.img** file to the SD Card. A popular tool is called **Win32DiskImager**, and it is available at this address https://launchpad.net/win32-image-writer**.** Simply download this program file and follow the instructions to install it on your Windows computer.

5. Follow the instructions provided with **Win32DiskImager** for writing the Operating System to your SD Card. This process will require the SD Card to be inserted into a SD Card slot on your computer, and for you to know where you saved the **.img** file on your computer. The write process itself can take some time.

   WARNING: Make sure you select the correct device to write the Operating System to. Selecting the wrong destination could result in unrecoverable data loss. Be careful and DOUBLE CHECK.

6. **Win32DiskImager** will tell you when this process has been completed and when it has, remove the SD Card. Now insert it into the SD card slot of your Raspberry Pi. It is worth keeping the Operating System file on your computer for future rewrites to your SD Card, just in case.

7. Now, power up your Raspberry Pi and Wolfson Audio Card.

8. The **small red indicator** will light up on the Raspberry Pi, indicating the main chip has started up, and then a **small green indicator** will begin to flash, indicating data is being read from/written to the SD Card. The TV/monitor (provided it's switched on of course) will begin to show the Linux boot sequence.

9. This image has been designed to boot into the Graphical User Interface, so that when the boot process has been completed, you should see a desktop, then you are ready to go.

Notes on this section:

- **It is intended that, ultimately, drivers will be fully integrated in future OS downloads, starting with Raspbian. The All-in-One approach will then no longer be necessary.**
- **Even though they are already included in the All-in-One package, all the downloadable items required for the soundcard are available separately at www.element14.com/wolfson, including the HD Audio tracks, and the Use Case Scripts.**
- **Once the system has booted up, it is suggested that one complete reboot cycle is performed before attempting any of the next steps.**
- **You may notice 'trace errors' during boot up. These are regarded as harmless, and they will not appear on future releases.**

5. Getting started with audio on your Wolfson Audio Card

The Wolfson Audio Soundcard renders and captures high quality audio from a variety of sources. It is designed to work with the Linux operating system, and as such takes advantage of ALSA, the Advanced Linux Sound Architecture. You can read more about this at www.alsa-project.org.

In the OS download referred to in section 4. above, the supported audio player is **LXmusic,** and labelled **Music Player** on the desktop. In general, there are two main stages to performing an audio task, whether that is to play a file, or record one:

a. The **Use Case** has to be defined first, so that the sound device is configured properly. A Use Case is simply a set of commands that are run in series, which set the audio card up. They define the signal paths for any audio that is played or recorded. So, for example, if you want to play audio to speakers, you'd run the script for that case. A script is a collection of commands that can be run in a single instruction.
b. The action to **play/record** can then be executed.

The Use Case definition is set up by running one of a set of scripts that are supplied in the software package. It is done this way:

a. To run any kind of script, it is necessary to start a **Terminal** session. Double click on **LXTerminal** on the desktop (or indeed, any other terminal programme you prefer).
b. The terminal allows you type commands directly instructing the OS to form operations you want to perform. Start by typing **dir**. That will give you a list of files and folders that are contained in the home directory that the Terminal session opens in.
c. A set of use cases have been put placed into this directory for you, as follows:

#	Audio Function	Script to run
1.	Play an audio file to your headphones	`Playback_to_Headset.sh`
2.	Play an audio file to the line out jack	`Playback_to_Lineout.sh`
3.	Play an audio file to loudspeakers	`Playback_to_Speakers.sh`
4.	Play an audio file to the SPDIF output of your card.	`SPDIF_playback.sh`
5.	Record from onboard digital microphones	`Record_from_DMIC.sh`
6.	Record from the boom microphone of your gamer/VoIP headphones	`Record_from_Headset.sh`
7.	Record from the analogue Line In socket	`Record_from_lineIn.sh`
9.	Record from the SPDIF input of your card.	`SPDIF_record.sh`
10.	Reset all audio paths	`Reset_paths.sh`

Table 1: A list of the Use Case Scripts for setting up the audio card.

As an example, let us say that you want to play one of the bundled High Definition audio tracks that are included in the software package, and you want to play it to your headset. In this case, and at the command line in **LXTerminal**, type the following command:

```
./Playback_to_Headset.sh <Enter>
```

The script will run, and you will be returned to the command prompt again. If at any time during the time the script runs, you see the following message displayed on the screen:

amixer: Cannot find the given element from control hw:0

This means the card was not detected and registered properly during start up. It is recommended in this case that you check the card is properly secured to your Raspberry Pi, and perform a hard reboot (issue a **sudo halt**, switch of the power, re-apply power and allow to boot up).

Assuming all was well, you system has now been configured to play audio.

Next, start **Music Player** by double-clicking on it on the desktop. The programme will launch. To select a file for playback, it must first be added to the playlist. Select **Playlist > Add To Playlist > Add Files or Folders**, and you will be presented with a dialogue box where you can navigate to the location of your music files. In the case of the bundled HD Audio tracks, these are located in the **Home** directory.

Select the file(s) you want to play, and then click on the **Add** button.

The files you added will now be available for playback in the Playlist.

Finally, plug in your headphones in to the Headphone socket.

Now, double-click on the item you wish to play, and **Music Player** will play the audio track to your headphones.

The scripts for playback are cumulative in nature. So, taking the above example into account, where we have enabled playback to a headset, if we then run the script to play audio to the line out jack as well with the following command:

```
Playback_to_Lineout.sh <Enter>
```

What happens is that audio playback is enabled for both headset *and* line out.

If that is not what you want, and simply want to reset all the paths back to NO playback paths enabled, then just run the following command first:

```
Reset_paths.sh <Enter>
```

Now, select the single output that you want to play to.

<u>**Notes on this section:**</u>

- **If you are recording to, or playing back from your SD Card, it is important that you use an SD Card that is Class 6 and above. The class directly correlates with speed of reading and writing to the card. When playing HD Audio, the rate of data being read from the card is significant, and a low card will leave occasional gaps in the audio experience. Similarly when recording.**
- **Whilst the onboard hardware CODEC is capable of handling multichannel audio, Raspberry Pi is not. Therefore, the card will not allow the decoding of compressed multichannel audio via its SPDIF in connector.**
- **The system will remember what the last used use case was. After a reboot, it will return to that one unless you choose another.**

6. Soundcard usage scenarios

The Wolfson Audio Card is flexible with regards to how it can be connected to various types of input devices (sources), and output devices (sinks). If you'd prefer to keep your audio in the digital domain, the SPDIF digital audio connections allow this. High quality analogue audio capture and playback is also made available with this card.

- **Connecting speakers to your Audio Card**
  The Wolfson Pi Audio Card contains an on board Class D power amplifier, capable of delivering up to 1.4W per channel, directly to external loudspeakers. The connectors required to allow this are in locations J6 (left) and J3 (right), but they are not populated as standard.

  [1] You can solder your own pair of male 0.1" headers, by purchasing from Farnell/Newark/element14. Suggested models are as follows:

Region	Distributor	Part Number
North America	Newark	60H4177
Europe	Farnell	9733302
Asia Pacific	element14	9733302

Table 2: Suppliers of 0.1" headers.

Warning:

- **Once fitted, be extremely careful not to accidently short the speaker pins. Doing so could damage the Audio Card.**
- **It is necessary to supply auxiliary power to the Audio Card in order to drive external loudspeakers. An external power supply with output voltage of 5V, current delivery capability of 2,000mA, a centre positive power plug of internal diameter 2.1mm, and external diameter 5.5mm.**

With your Raspberry Pi powered down, connect speakers to the newly fitted headers. Make sure your speakers are connected in phase. To do this, observe on the header pins that one pin is marked with a white dot. Your speaker cable should be polarised as well, with perhaps one core being coloured red, and the other black. Be consistent with how you connect, for example, the red cable goes to the connector with the dot on both pins.

Before playing a file to your speakers, you must run the appropriate Use Case Script to play to loudspeakers. Then play a file using the **LXmusic player**.

- **Connecting your audio card to a SPDIF sink**

You can connect your audio card to digital amplifiers and receivers (also known collectively as ‘sinks’) using the phono/RCA/Cinch SPDIF output jack. The Wolfson Audio Card can deliver audio in bit depths of up to 24-bit. Make sure your sink can support resolutions this high.

<u>Warnings:</u>

- **Be very careful when setting the output gain and volume control on your amplifier, especially if it is a powerful type. Loudspeaker damage can easily occur if the volume is too high.**

- **Connecting your audio card to a Line level sink**
  You can connect your audio card to analogue amplifiers and receivers by using the green 3.5mm line output jack. The use case scripts have been set up to provide a line out level that is not too high, and should be suitable for most amplifiers and receivers.

- **Connecting your audio card to a Line level source**
  Capturing audio using your Wolfson Audio Card is straightforward as well. In the case of an analogue line level source, simply connect your analogue source to the Audio Card by connecting to the red 3.5 mm input jack. Then, run the appropriate use case to set up the audio card routing and gains properly.

You can capture audio to a file by using the **arecord** command at a command prompt on Raspberry Pi. The **arecord** command will allow you to flexibly capture live audio, and saves it directly to Raspberry Pi’s mass storage memory as an uncompressed audio file.

For example, if you would like to capture audio from the line in jack, first of all, it is necessary to tell the audio card to switch audio into the card from that source. This is done by running the following command:

```
./Record_from_lineIn.sh <Enter>
```

Now, we need to use the arecord command to capture the audio to a specified file as follows:

```
arecord –Dhw:0 –c 2 –f S16_LE –r 44100
record_from_line_in.wav  <Enter>
```

(Note: the above should be entered as a single line, and not two lines as shown here.)

Recording will start. Press CTRL-C to stop recording.

A brief explanation of the options above is as follows:
-c = Number of channels. Here, we specify two, for stereo.

-f = Recording format. In this case, we are asking for 16-bit, Little Endian.
- r = Sample rate. We ask here for 44,100 audio samples per second.

To find out more about this command, type:

```
arecord ––help <Enter>
```

If you wish to compress the audio file into other formats, there are other programmes that can be installed on Raspberry Pi to do this. **ffmpeg** is such a programme, available at **www.ffmpeg.org**. Its use and implementation is beyond the scope of this document.

A General Warning If Editing Use Case Scripts

- **Use case scripts can be adjusted to accommodate various types of sources.**
- **In particular, the gain of those inputs can be adjusted to make them very sensitive.**
- **The result can be an extremely LOUD output signal. It is always advisable to reduce the volume of any amplifier, or active speaker connected to this card, before playing back any audio tracks.**

7. Annexe

a. Datasheet of WM5102 audio CODEC

The key technology that is used at the heart of the Wolfson Audio Card, is an Audio Hub (CODEC) device. The WM5102 is a highly-integrated low-power audio system that has been designed for use in smartphones, tablets and other portable audio devices. It combines wideband telephony voice processing with a flexible, high-performance audio hub CODEC, and is capable of delivering HD audio. If you'd like to know more about this device, take a look at it here:

www. element14.com/wolfson/<name of file or forward to Wolfson URL>

b. Datasheet of WM8804 SPDIF receiver/transmitter

The WM8804 allows digital audio data to be transmitted and received to the audio card via the phono/RCA jacks, and works in partnership with the WM5102. You can read more about this device by checking out the following datasheet:

www. element14.com/wolfson/<name of file or forward to Wolfson URL>

c. Datasheet of WM7220 Digital Microphone Module (MEMS)

The WM7220 is a Digital Microphone Module (DMIC), that is based on MEMS technology. MEMS, or Micro-Electrical-Mechanical Systems, are devices that combine small scale electronics on a silicon die, together with a mechanical component that can interact with the physical environment. In this case, the mechanical element responds to acoustic pressure waves and converts them in to a digital audio data stream. Read more here:

www. element14.com/wolfson/<name of file or forward to Wolfson URL>

d. Schematic diagram

If you are interested in knowing how the Wolfson Audio Card has been designed, the schematic diagram is available to view as a .pdf document, on the element14.com website at the following address:

www. element14.com/wolfson/<name of file or forward to Wolfson URL>

e. Feature header signal assignment

Pin	Name	Type	Power domain	Description
1	+5V	Power Pin	5.0V	5V supply, less than 300ma.
2	+3.3V	Power Pin	3.3V	3.3V supply, less than 300ma.
3	AIF3LRCLK	Digital in/out	0 - 3.3V	Audio interface 3 left/right clock
4	AIF3TXDAT	Digital out	0 - 3.3V	Audio interface 3 TX digital audio data
5	AIF3RXDAT	Digital in	0 - 3.3V	Audio interface 3 RX digital audio data
6	AIF3BCLK	Digital in/out	0 - 3.3V	Audio interface 3 bit clock
7	GND	Power Pin	0	Digital ground
8	GND	Power Pin	0	Digital ground
9	SCLK	Digital in	0 - 3.3V	Control Interface clock input
10	SDA	Digital in/out	0 - 3.3V	Control Interface data input and output
11	PDMDAT	Digital out	0 - 3.3V	Digital speaker (PDM) data output
12	PDMCLK	Digital out	0 - 3.3V	Digital speaker (PDM) clock output
13	GND	Power Pin	0	Digital ground
14	GND	Power Pin	0	Digital ground
15	GPIO4	Digital in/out	0 - 3.3V	General purpose pin GPIO4
16	GPIO3	Digital in/out	0 - 3.3V	General purpose pin GPIO3

Table 3: GPIO signal definitions

f. Performance and Specification

During the design process, the board layout was optimised to ensure each of the Wolfson Microelectronics devices performed optimally, providing users with an exceptional audio experience. Measured performance of the board is as follows:

SPDIF Output			
Parameter	**Description**	**Typical Value**	**Units**
Connector	Electrical output via phono connector		
Rout	Output impedance	75	Ohms
Supported Sample Rates	32, 48, 96, 192, 44.1, 88.2, 176.4, 192		kHz
Sample depth	Max bit depth of samples	24	bits
Notes	Sample rate must be the same as TX if both are enabled concurrently		

SPDIF Input

Parameter	Description	Typical Value	Units
Connector	Electrical input via phono connector		
Rin	Input impedance	75	Ohms
Supported Sample Rates	32, 48, 96, 192, 44.1, 88.2, 176.4, 192		kHz
Sample depth	Max bit depth of samples	24	bits
Notes	Sample rate must be the same as RX if both are enabled concurrently		

Line Output

Parameter	Description/Conditions	Typical Value	Units
Connector	Electrical output via 3 pole 3.5mm Socket		
Rout	Output impedance	16	Ohms
Cload	Max capacitive load on output	2	nF
Rload		10	kOhms
Vout	Full scale output signal level	1	Vrms
Vnoise	Noise Floor, no signal applied, A-weighting filter	4.5	uVrms
THD	Total Harmonic Distortion	0.005	%
Notes	Test conditions as follows unless otherwise noted: 48kHz sample rate, test signal 1kHz sine wave, bandwidth measured 20Hz to 20kHz, Rload = 10kOhms		

Line Input

Parameter	Description	Typical Value	Units
Connector	Electrical input via 3 pole 3.5mm Socket		
Rin	Input Impedance	16	kOhms
Fcut	-3dB down from 1kHz signal level at this frequency	13	Hz
Vin	Full scale input signal	1	Vrms
Vnoise	Equivalent input noise level, no signal applied	20	uVrms
THD	Total Harmonic Distortion @ 0.9Vrms Input	0.035	%
Notes	Test conditions as follows unless otherwise noted: 48kHz sample rate, test signal 1kHz sine wave and bandwidth measured is 20Hz to 20kHz		

Headphone Output

Parameter	Description/Conditions	Typical Value	Units
Connector	Electrical output via 4 pole 3.5mm Socket		
Rout	Output impedance	0.2	Ohms
Cload	Max capacitive load on output	130	pF
Vout	Full scale output signal level (note that the headphone use case script limits this to 0.5Vrms for safety)	1	Vrms
Vnoise	Noise Floor, no signal applied, A-weighting filter	2.3	uVrms
THD	Total Harmonic Distortion @ 400mVrms output	0.0035	%
Notes	Test conditions as follows unless otherwise noted: 48kHz sample rate, test signal 1kHz sine wave, bandwidth measured 20Hz to 20kHz, Rload = 32Ohms		

Headset Input

Parameter	Description	Typical Value	Units
Connector	Electrical input via 4 pole 3.5mm Socket, MIC on Sleeve		
Vbias	Microphone voltage bias level	2.8	V
Rbias	Microphone bias resistor	2.2	kOhms
Fcut	-3dB down from 1kHz signal level at this frequency	13	Hz
Vin	Full scale input signal (500mVrms to 14mVrms depending on input gain setting)	63	mVrms
Vnoise	Equivalent input noise level, no signal applied, (settings for 63mVrms signal)	3.2	uVrms
THD	Total Harmonic Distortion @ 57mVrms Input	0.01	%
Notes	Test conditions as follows unless otherwise noted: 48kHz sample rate, test signal 1kHz sine wave and bandwidth measured is 20Hz to 20kHz		

Speaker Output			
Parameter	**Description/Conditions**	**Typical Value**	**Units**
Connector	Unpopulated 2.54mm pitch headers		
Rout	Output impedance	0.4	Ohms
Rload	Minimum Rload	3	Ohms
Power Out	Max power output	1.4	W
Vnoise	Noise Floor, no signal applied, A-weighting filter	30	uVrms
THD	Total Harmonic Distortion @ 0.5W output	0.06	%
Notes	Test conditions as follows unless otherwise noted: 48kHz sample rate, test signal 1kHz sine wave, bandwidth measured 20Hz to 20kHz, Rload = 8 Ohms, SPKVDD=5V		

g. Electrical architecture of the audio card

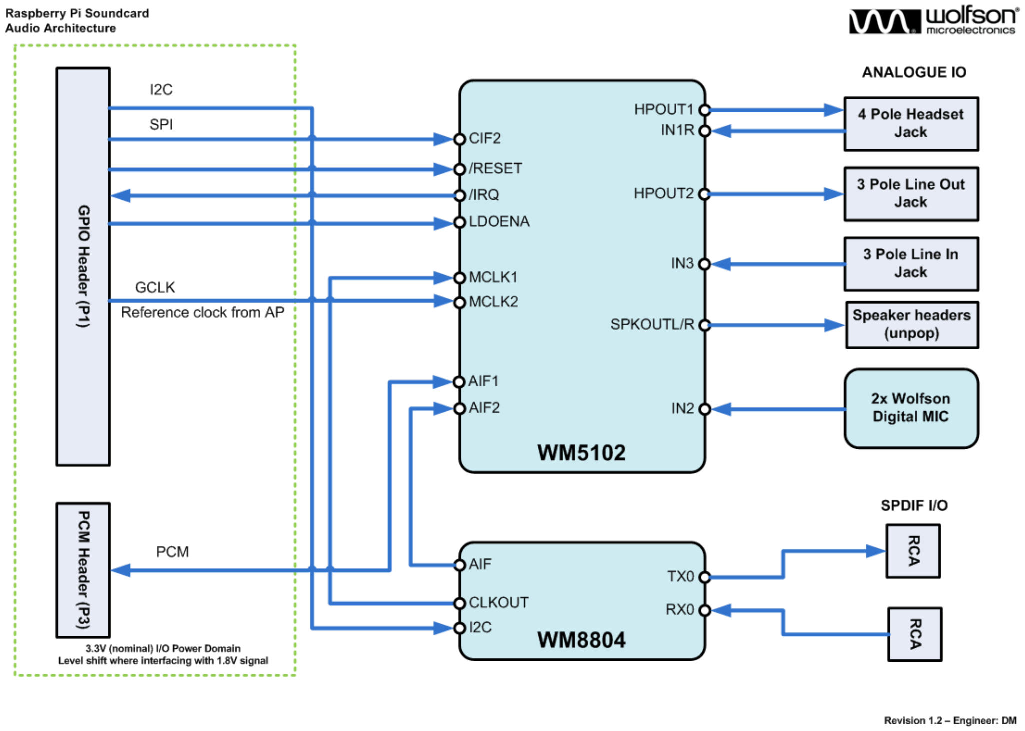

Diagram 4: Audio architecture of the Wolfson audio card

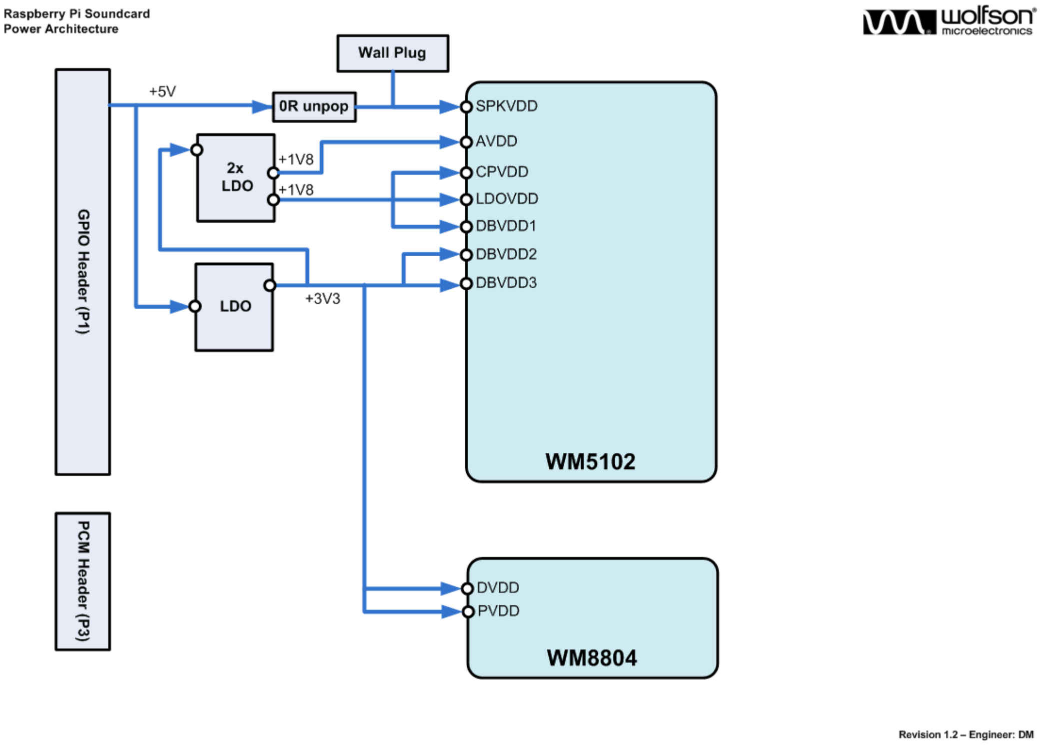

Diagram 5: Power management architecture of the Wolfson audio card

Revisions

Revision	Created	Revision
1.00	28-Jan-2014	Initial publication.
1.10	05-Mar-2014	Command error corrected. Schematic diagrams updated.