



**502DAC Pro
Digital Pro Audio Hat
Hardware Reference Manual
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I WARRANTY

The enclosed product ("the Product"), a part of the PI2MEDIA 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 502DAC PRO OPERATING SPECIFICATIONS

The 502DAC Pro conforms to the following specifications:

Specification	Value
Dimensions	65mm x 56.5mm – Hat Compliant
Weight	~10g
Storage Temperature	-20C to +85C
Operating Temperature	0C to +70C
Humidity	0% to 95% RH, Non-Condensing
Input Voltage (VIN)	+5V +/- 5% 100ma Peak
Power Consumption	1W Typical, 4W Maximum (HPOUT 6Vrms @ 32 ohm)

Table 1 – 502DAC Pro Operating Specifications

3 OVERVIEW

3.1 INTRODUCTION

The 502DAC Pro, designed and manufactured by Pi2Media (a division of PI 2 Design), is a professional I/O Shield designed to bring audiophile quality to the Raspberry Pi® family of Single Board Computers. The 502DAC Pro converts the Raspberry Pi® I2S Port to High Resolution Pro-Audio, Analog and Digital simultaneously.

The 502DAC Pro combines the High Performance WM8804 Digital Audio S/PDIF Transmitter, an Audiophile Quality 24-Bit PCM1792 D/A Converter along with two Ultra-Low Jitter NDK Clocks for High Quality Analog and Digital Audio.

The major features of the 502DAC Pro are as follows:

- **FORM FACTOR** – Raspberry Pi® Full Size Shield.
- **24-Bit DAC** – Audiophile Quality PCM1792 running in Slave Mode converts the I2S Stream to Analog at 24-Bit up to 192Khz Frame Rate
- **DIGITAL AUDIO** – Industry standard WM8804 running in master mode converts the I2S stream to Pro-Audio Standard AES/SPDIF formatted data at 24-Bit up to 192Khz Frame Rate
- **ULTRA-LOW NOISE CLOCKS** – Two NDK NZ2520SD Oscillators feed the WM8804 I2S Master to insure the lowest possible Jitter and Phase Noise
- **ANALOG OUT** – 2Vrms Stereo Line Out, buffered with a pair of LME49720's, is available via Dual RCA Gold Plated Jacks
- **HIGH POWERED HEADPHONE AMP** – A pair of LME49720 Op Amps and LME49600 Buffers drive up to 8V RMS output and can handle high and low impedance headphones with ease. Selectable Gain of 6db (x2) or 12db (x4)
- **BALANCED OUT** – Isolated Balanced AES/EBU Pro-Audio is via 1/4" Connector (XLR Male Adapter included)
- **COAX OUT** - A BNC COAX connector provides single ended, isolated S/PDIF with selectable Output levels for both Pro and Consumer (RCA Adapter included)
- **OPTICAL OUT** – Via TX179 TOSLINK Transmitter
- **HIGH-PSRR LDO** – A Low-Noise Linear Tech LT3042 delivers 3.3V to all sections with 88db+ PSRR from 10hz to 100khz
- **EXTERNAL 5V** – This option allows the 502DAC to be powered from an external low noise supply if desired
- **EXPANSION CONNECTORS** – A number of JST XH connectors allow access to functions and GPIO for IrDA, Rotary and Power Control. Block Diagram

Refer to the following figure for a block diagram of the 502DAC Pro Shield.

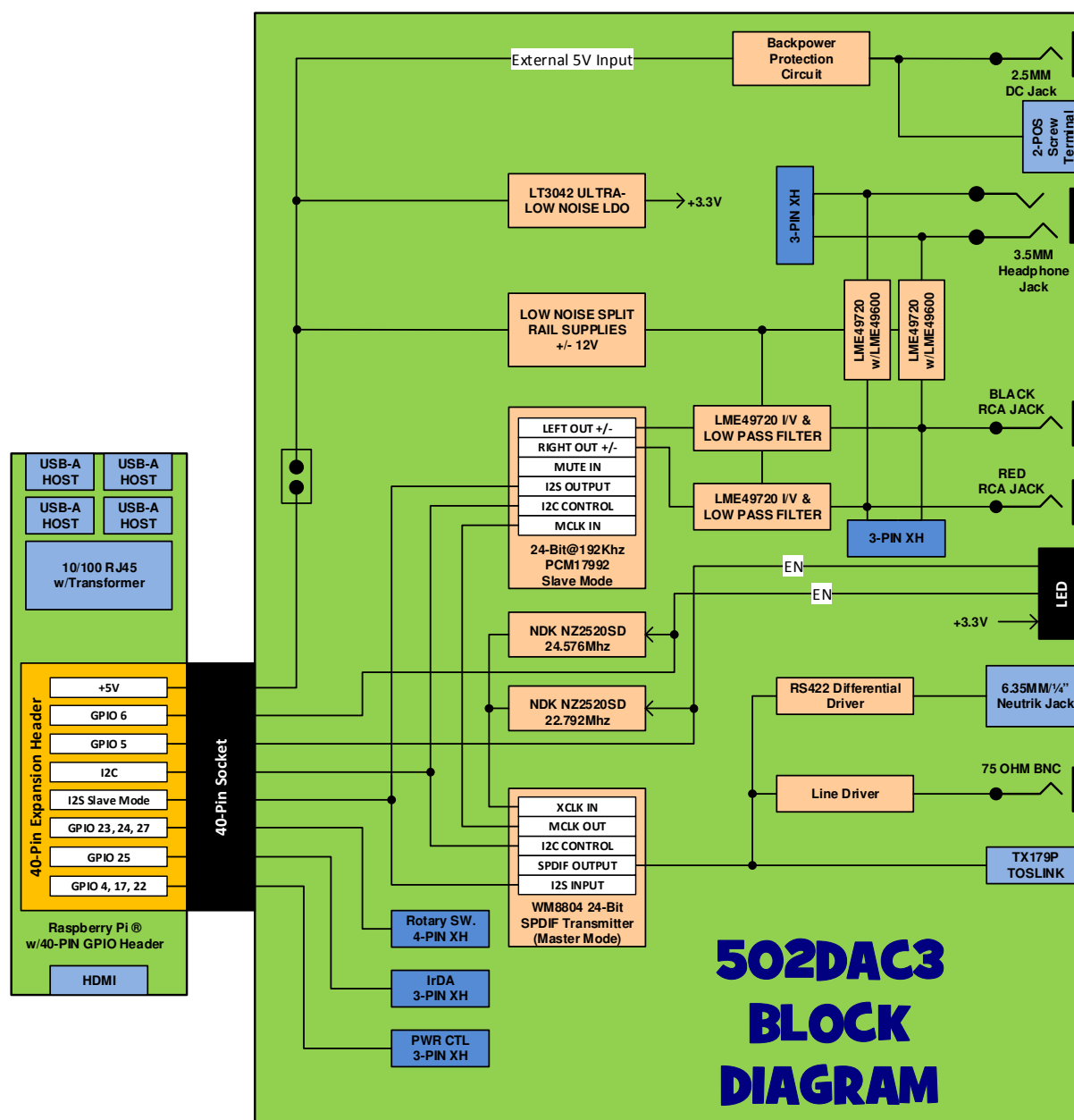


Figure 1 – 502DAC Pro Block Diagram

4 ON-BOARD DEVICES

4.1 OVERVIEW

The 502DAC Pro interfaces to the RPi via the 40-Pin GPIO Connector. This section describes in detail the devices located on the 502DAC Pro.

4.1 502DAC PRO I2C BUS DEVICES

The following table describes the CPU I2C Bus usage of the 502DAC Pro. Refer to the respective device documentation for more detail.

I2C Bus	7-Bit I2C Address	Description
I2C	0x3B	WM8804 SPDIF Transmitter
ID_I2C	0x24	32Kbit EEPROM for ID usage

Table 2 – 502DAC Pro I2C Bus Devices

4.1 WM8804 SPDIF TRANSMITTER

A Cirrus Logic WM8804 SPDIF Transmitter operating in Master Mode converts the I2S data into an AES3/SPDIF digital audio stream for the Optical, BNC/RCA and 1/4"/XLR Balanced outputs. This device interfaces to the Raspberry Pi via the I2S. The signals used to interface with the WM8804 are shown in the following table.

WM8804 Signal	RPi Signal	Description
XCLK	GPIO5	1 = NDK NZ2520SD 22.5792Mhz Selected
XCLK	GPIO6	1 = NDK NZ2520SD 24.576Mhz Selected
MCLK	-	I2S Master Clock Output to DAC
BCLK	BCLK	I2S Bit Clock Output to DAC and Pi
LRCLK	LRCLK	I2S Word Clock Output to DAC and Pi
SDIN	SDOUT	I2S Serial Audio Data from the Pi
TXO	-	AES3/SPDIF encoded digital audio output

Table 3 – WM8804 Connections

4.1.1 WM8804 SPDIF TRANSMITTER NOTES

1. The 502DAC Pro is designed to operate the WM8804 in Master Mode. In this mode the WM8804 receives its operating clock from selected low-noise clock. It then creates and drives the Master, Bit and Word Clocks to the DAC and the Raspberry Pi. Serial Data in is received from Pi. All data and clock formatting is controlled by the WM8804 driver.
2. 22.5792Mhz and 24.576Mhz Clock selection is controlled by Raspberry GPIO5 and GPIO6 respectively. Driving the GPIO High selects the clock. Do not enable both clocks simultaneously.
3. The BNC and 1/4" outputs are transformer isolated for use in noisy studio environments, as well as with long cable runs for lowest interference.
4. An RS-422 Differential Transmitter accepts the SPDIF output from the WM8804 and sends it as a balanced pair via the 1/4" connector. A 1/4" to XLR Male adapter is provided with the unit.
5. A TOTX179P Transmitter converts the SPDIF output of the WM8804 to Toslink compatible optical.

4.2 PCM1792, 24-BIT DAC – DAC3 ONLY

At the core of the 502DAC Pro is the TI PCM179224-Bit DAC. This DAC operates in slave mode with a hardware interface. The connectivity between the PCM1792 and the Raspberry Pi is shown below.

PCM1792 Signal	RPi Signal	Description
MCLK	-	I2S Master Clock Input from the WM8804
BCLK	BCLK	I2S Bit Clock Input from the WM8804
LRCLK	LRCLK	I2S Word Clock Input from the WM8804
SDIN	SDOUT	I2S Serial Audio Data from the Pi
SCL	SCL	I2C Clock from the Pi
SDA	SDA	I2C Data to/from the Pi
OUTL+/-	-	Current Mode Analog Audio Out, Left Channel
OUTR+/-	-	Current Mode Analog Audio Out, Right Channel

Table 3 – PCM1792 Connections

4.2.1 PCM1792 24-BIT DAC NOTES

1. The 502DAC Pro operates the PCM1792 in Hardware mode. In this mode, the PCM1792 receives its Master Clock, Bit Clock and Word Clock from the WM8804. Serial Data in is received from Pi. All data and clock formatting is controlled by the WM8804 driver.
2. The PCM1792 digital filter is set to sharp rolloff. The 44.1Khz De-emphasis circuit is disabled.
3. The current mode output of the PCM1792 is converted to 2.9V P-P (2.1Vrms) in the I/V stage using ultra-low noise LME49720 Op Amps. This output is made available via the dual RCA Jack Connectors.

4.3 LME49720/LME49600 HEADPHONE AMPLIFIER

The DAC output is also routed to a pair of LME49720s each with an LME49600 output buffer. This output can drive 4Vrms (gain = 2) or 8Vrms (gain = 4) at up to 150ma. The gain is selected by the jumper P6. When open the gain is 2 (6db), when closed the gain is 4 (12db). The output of the headphone amp is made available via a 3.5mm Jack and a 3-pin XH connector (P7).

4.4 24AA32T ID EEPROM

A Microchip 24AA32T EEPROM provides user programmable EEPROM. It is on the RPi ID I2C Bus at I2C address 0x50. The signals used to interface with the 24AA32T are shown in the following table.

24AA32T Signal	CPU Signal	Description
SCL	ID_SCL	I2C Bus Clock
SDA	ID_SDA	I2C Bus Data

Table 4 – 24AA32T EEPROM Connections

4.4.1 24AA32T EEPROM NOTES

1. By default, the ID EEPROM delivered with the 502DAC Pro is blank.

5 RPI GPIO

5.1 OVERVIEW

The 502DAC Pro 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	502DAC Pro Name	Description/Notes
1	-	-	-	-	RPi +3.3V - Unused
2	-	-	-	+5V	+5V Power to/from the RPi (with W1 installed)
3	I/O	Y	PUP	I2C_SDA	I2C Bus Data
4	-	-	-	+5V	+5V Power to/from the RPi (with W1 installed)
5	OUT	Y	PUP	I2C_SCL	I2C Bus Clock
6	-	-	-	GND	
7	I/O	-	-	GPIO4	XH Connector P5, Pin 1
8	-	-	-	GPIO14	Unused
9	-	-	-	GND	Unused
10	-	-	-	GPIO15	Unused
11	I/O	-	-	GPIO17	XH Connector P5, Pin 2
12	IN	Y	-	BCLK	I2S Bit Clock from WM8804
13	I/O	-	-	GPIO27	XH Connector P4, Pin 4 – Rotary Switch Select
14	-	-	-	GND	
15	-	-	-	GPIO22	XH Connector P5, Pin 3
16	-	-	-	GPIO23	XH Connector P4, Pin 4 – Rotary Switch A
17	-	-	-	-	RPi +3.3V - Unused
18	-	-	-	GPIO24	XH Connector P4, Pin 4 – Rotary Switch B
19	-	-	-	GPIO10	Unused
20	-	-	-	GND	
21	-	-	-	GPIO9	Unused

RPi PIN	DIR	AF	PUP/PDN	502DAC Pro Name	Description/Notes
22	-	-	-	GPIO25	XH Connector P8, Pin 1 – IrDA Data In
23	-	-	-	GPIO11	Unused
24	-	-	-	GPIO8	Unused
25	-	-	-	GND	
26	-	-	-	GPIO1	Unused
27	I/O	Y	-	ID_SDA	ID I2C Bus Data to/from 24AA32
28	OUT	Y	-	ID_SCL	ID I2C Bus Clock to 24AA32
29	-	-	-	GPIO5	Unused
30	-	-	-	GND	
31	-	-	-	GPIO6	Unused
32	-	-	-	GPIO12	Unused
33	-	-	-	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	I2S Serial Data Out to WM8804 and DAC

Table 5 – 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.

5. All GPIO signals connected to XH connectors P4 (Rotary), P5 (Power Control) and P8 (IrDA) must be assigned by software for the desired functionality prior to use.

6 502DAC PRO POWER

6.1 OVERVIEW

The 502DAC Pro is designed to be powered from either the 40-Pin Pi GPIO connector (P2) or from an external 5V +/- 10% source. Jumper W1, when installed, allows the Hat and the PI to be powered together regardless of the source. When jumper W1 is removed external 5V power must be supplied to the HAT via J1 or the 2-pin Screw Terminal P1. See section 8 for the location of P1, P2, W1 and J1.

Note that an on-board protection circuit insures proper operation if jumper W1 is installed while power is applied via J1 (or P1) AND from the Pi (P2) simultaneously.

7 502DAC PRO SOFTWARE

7.1 OVERVIEW

The 502DAC Pro uses the standard WM8804 driver and most Raspberry Pi player software (Moode, PI Musicbox, Volumio, Rune, etc) can be configured to the Hifiberry DIGI+ PRO setting. No further software is required.

8 TOP SIDE CONNECTORS

8.1 OVERVIEW

This section provides the type and location for the various connectors on the 502DAC Pro Top Side. These are shown in the 3D rendering below.

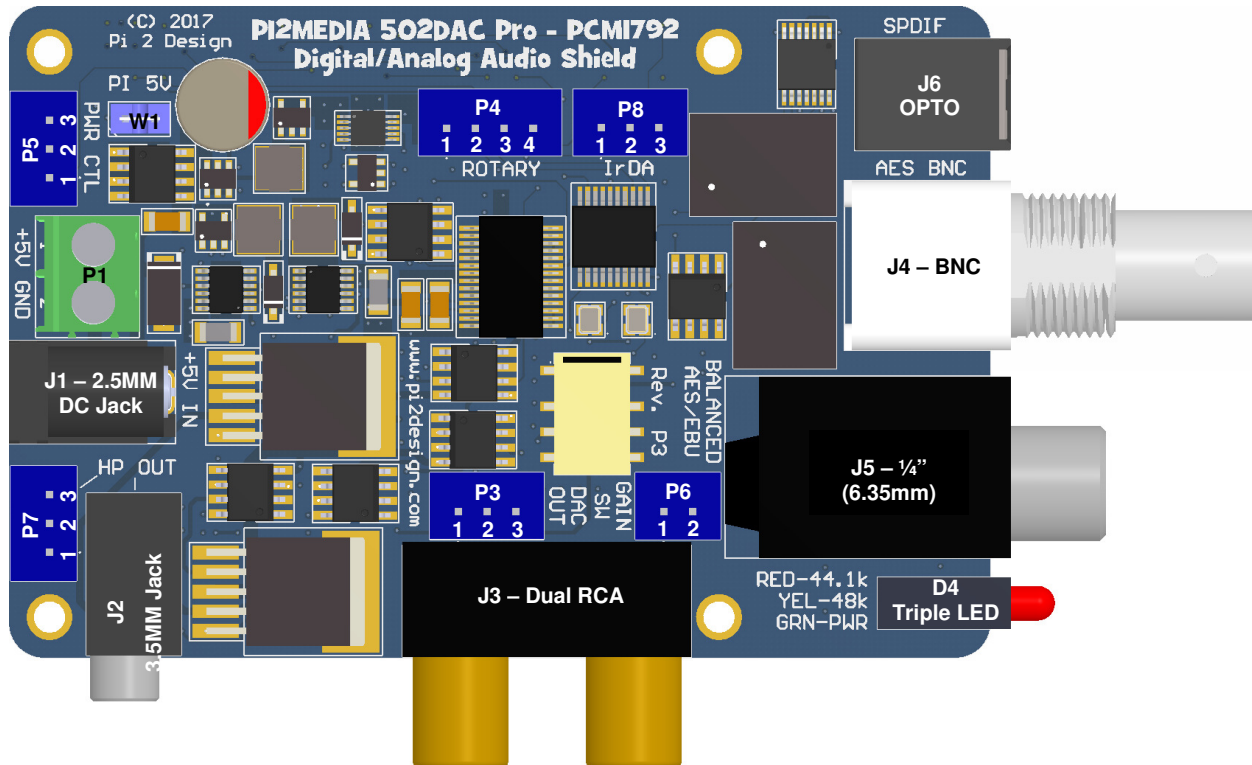


Figure 2 – 502DAC Pro Top Side Connector and Indicators Location

8.2 P1 – 2-WIRE SCREW TERMINAL

This allows discrete wires to provide the external 5V to the 502DAC Pro. Voltage must be 5V +/- 10% @ 1A (3A if powering the Pi also).

8.3 P2 – 40-PIN GPIO HEADER

This is a standard 40-Pin .1" Dual Row Female Header. It is designed to accept an RPi single board and conforms to the standard RPi pinout. It is located on the bottom side of the 502DAC Pro.

8.4 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 5V +/- 10%.

8.1 J2 – 3.5MM STEREO JACK

J2 provides the stereo headphone output from the headphone amplifier.

8.2 J3 – DUAL RCA JACK

J3 is a dual RCA connector providing stereo analog output from the DAC.

8.3 J2 - BNC CONNECTOR

This Connector is a BNC connector for Coax transmission of the digital audio data. An RCA to BNC adapter is provided for consumer applications.

8.4 J5 – ¼” BALANCED OUTPUT

J5 is a ¼” TRS Connector. This connector carries the balanced digital audio output. A ¼” to XLR Male adapter is provided with the 502DAC Pro.

8.5 J6 –TOSLINK

J6 is a TOTX179P TOSLINK Transmitter.

8.6 P3 –3-PIN XLH

P3 carries the DAC analog output. Pin 1 is Right, Pin 2 is Ground and Pin 3 is Left.

8.7 P4 – 4-PIN XLH

P4 carries the GPIO used for an optional Rotary Encoder. Pin 1 is Switch A, Pin 2 is Ground, Pin 3 is Switch B and Pin 4 is the Center Push Switch.

8.8 P5 – 3-PIN XLH

P5 is used to connect to the optional Audiophonics Power Control Board. Pin 1 is GPIO4, Pin 2 is GPIO17 and Pin 3 is GPIO22. For more information go to:

<http://www.audiophonics.fr/en/raspberry-pi-and-other-sbc-accessories/audiophonics-pi-touch-power-management-module-for-raspberry-pi-p-11504.html>

8.9 P6 – 2-PIN XLH

P6 is used to select the gain of the headphone amplifier. When Pin 1 and 2 are shorted (via jumper plug or external switch) the gain is 4 (12db). When they are not connected

the gain is 2 (6db).

8.10 P7 –3-PIN XLH

P7 carries the headphone amplifier output. Pin 1 is Right, Pin 2 is Ground and Pin 3 is Left.

8.11 P8 –3-PIN XLH

P8 is used to connect to an optional IrDA receiver. Pin 1 is the IrDA data, Pin 2 is ground and Pin 3 is tied to +5V through a 100 ohm resistor.

8.12 W1 –2-PIN JUMPER

W1 is used to connect the Pi 5V rail to the 502DAC Pro 5V rail when the jumper is installed.

9 DOCUMENT REVISIONS

Date	Revision	Change
06/14/2017	P1.0	First Release
08/13/2017	P2.1	New Revision PCB, Test Results Added, References to 502DAC2 removed
08/16/2017	P2.2	502DAC3 renamed to 502DAC Pro

Table 6 – Document Revisions

IO ERRATA

10.1 OVERVIEW

There are currently no known errata for the 502DAC Pro Rev. P2.

II TEST RESULTS

11.1 TEST RESULTS SUMMARY

502DAC Pro test conditions were:

- Raspberry Pi 2 running Volumio Version 2.23, Hifiberry Digi+ Pro driver selected
- External 5V from low noise benchtop supply
- All Test Files are encoded as 24-Bit@96Khz unless otherwise noted
- 0db reference = 0dbu = 775mv rms
- Analog In Load resistance = 600 ohm
- Analyzer FFT = 32K, no weighting

11.2 DIGITAL TEST RESULTS

All digital interfaces (BNC, 1/4" and Toslink) show -150db noise floor with less than -140db THD. These are both at the measurement limits of the dScope IIle.

11.3 ANALOG LINE OUT TEST RESULTS

The following plots were captured on the dScope IIle analyzer and saved as PNG files.

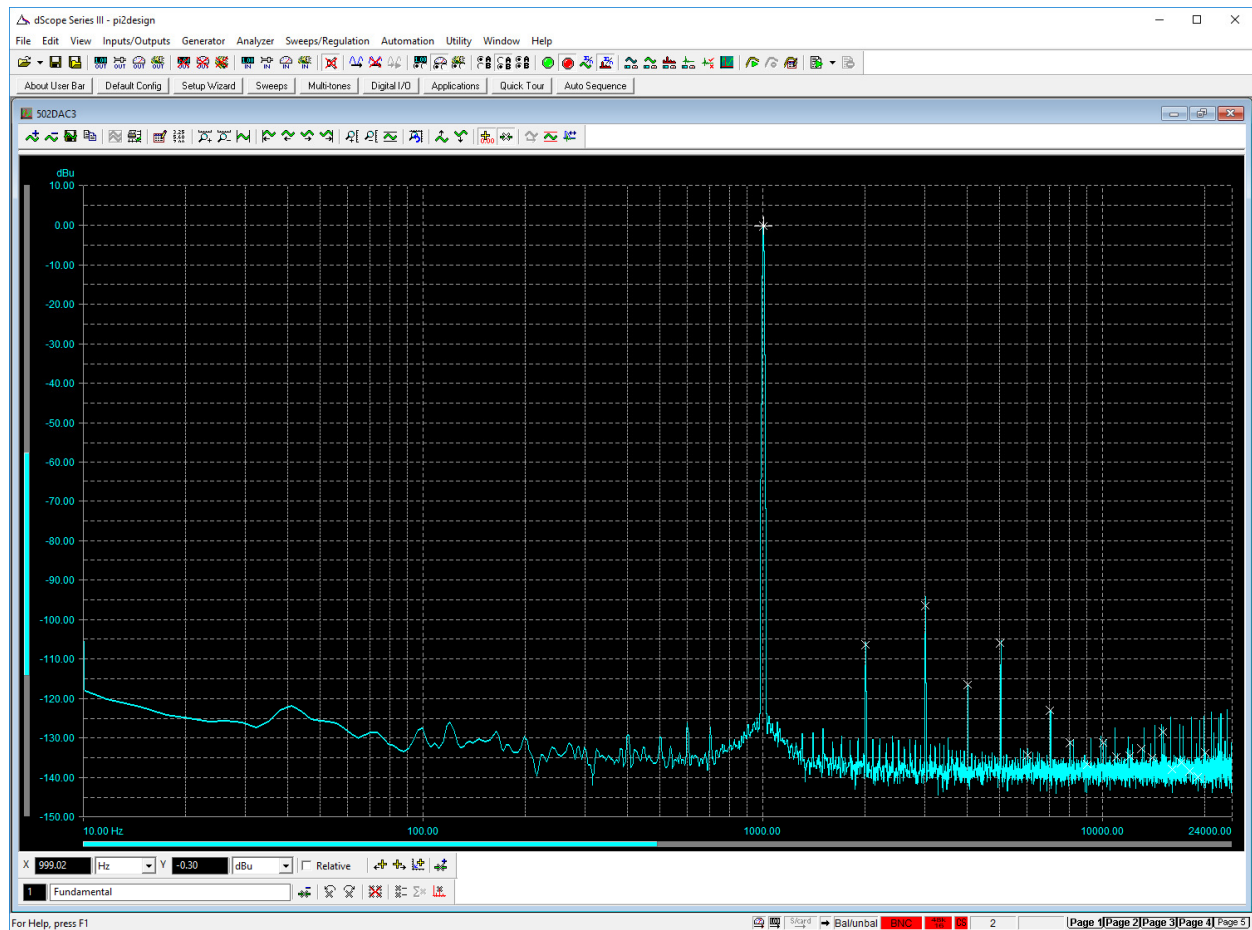


Figure 3 - 1Khz, 24-Bit@96Khz, 0db, 600 ohm

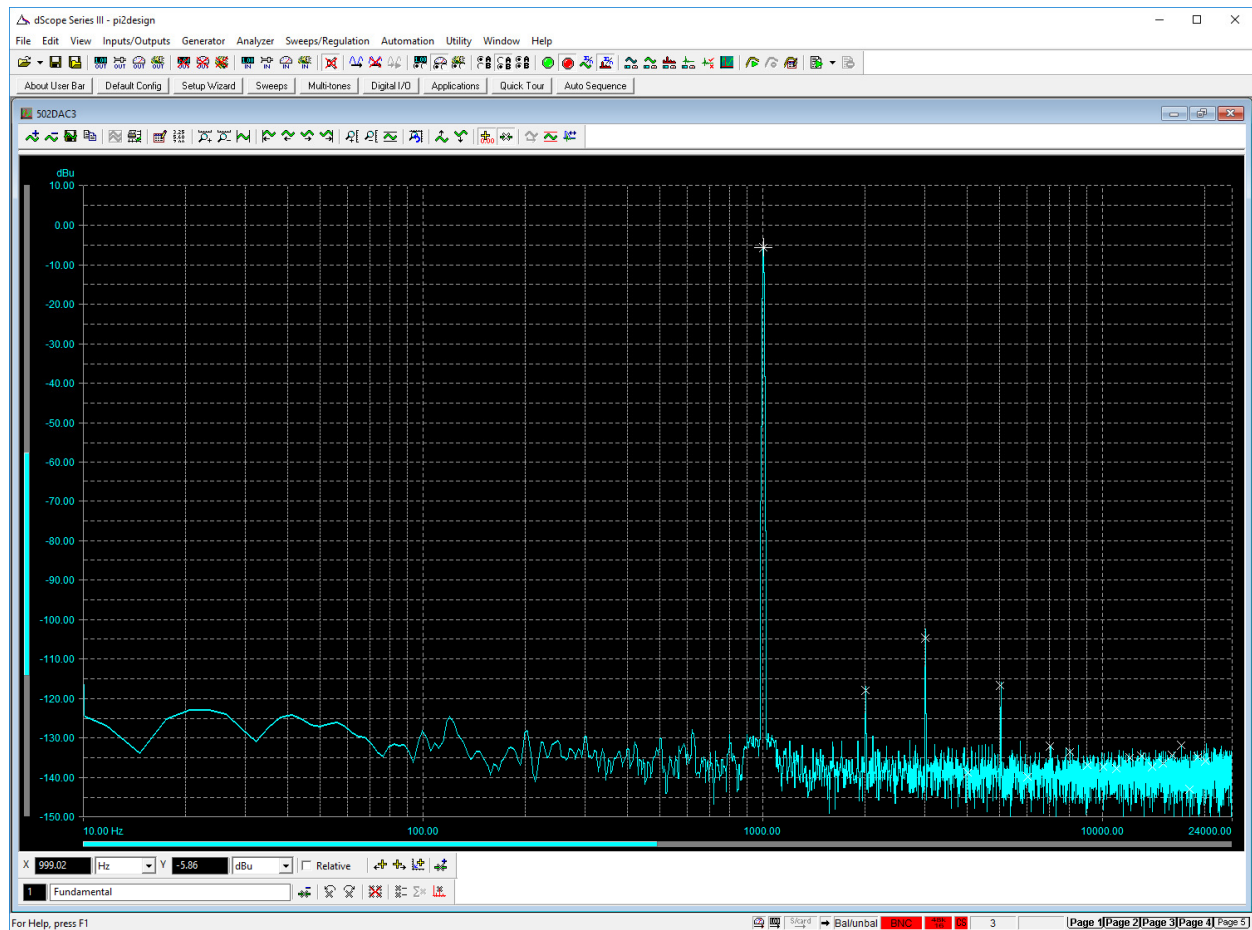


Figure 4 - 1Khz, 24-Bit@96Khz, -6db, 600 ohm

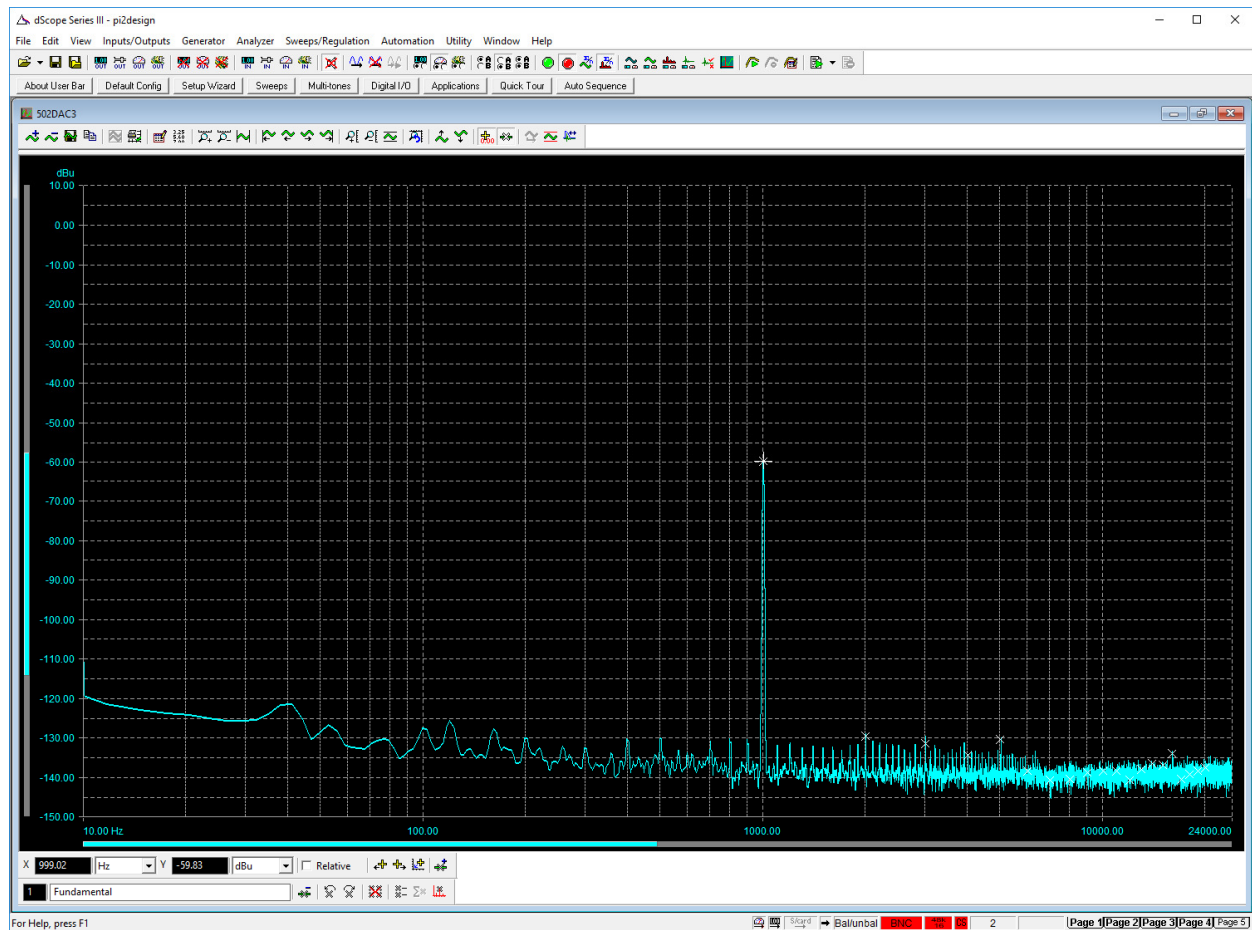


Figure 5 - 1Khz, 24-Bit@96Khz, -60db, 600 ohm

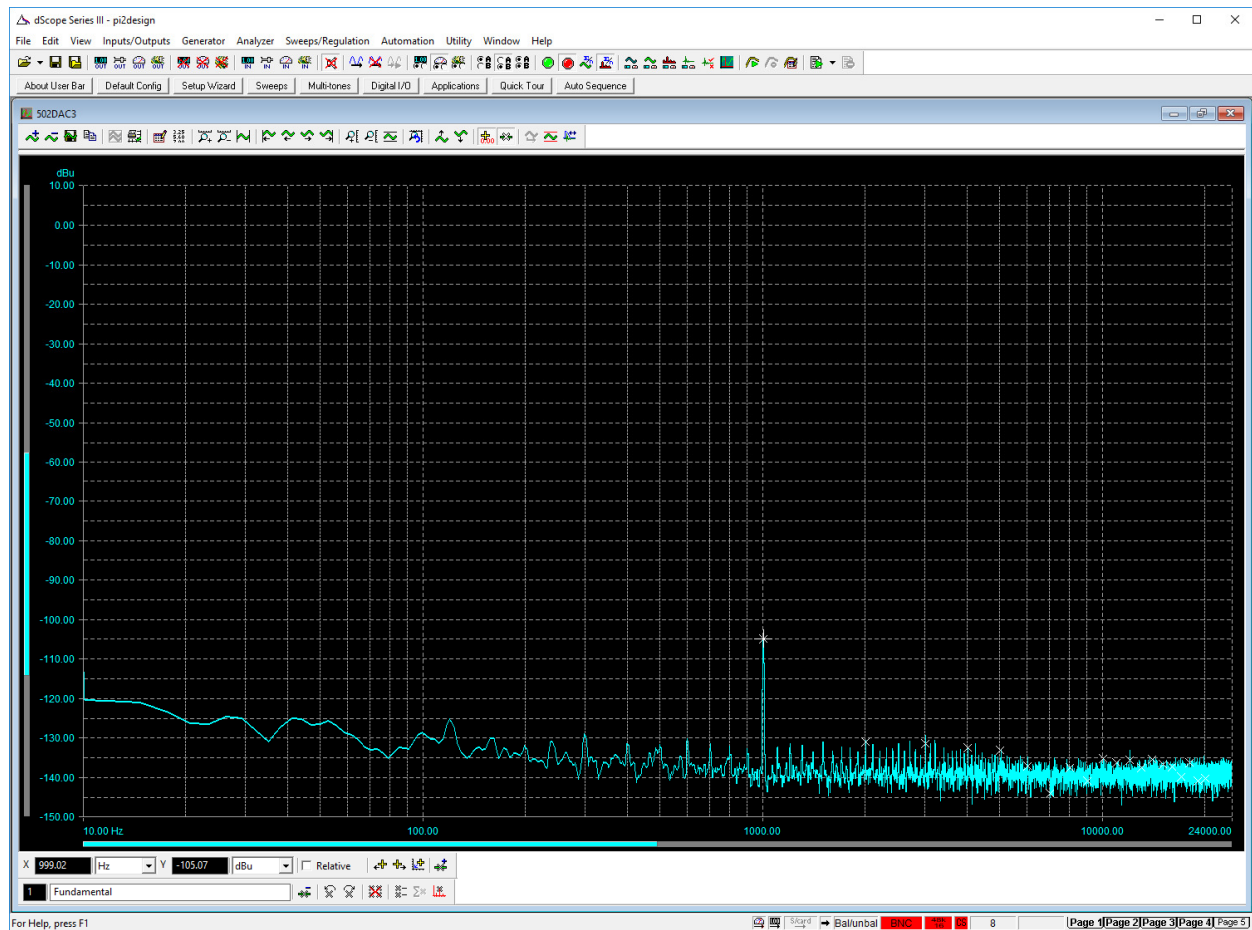


Figure 6 - 1Khz, 24-Bit@96Khz, -105db, 600 ohm

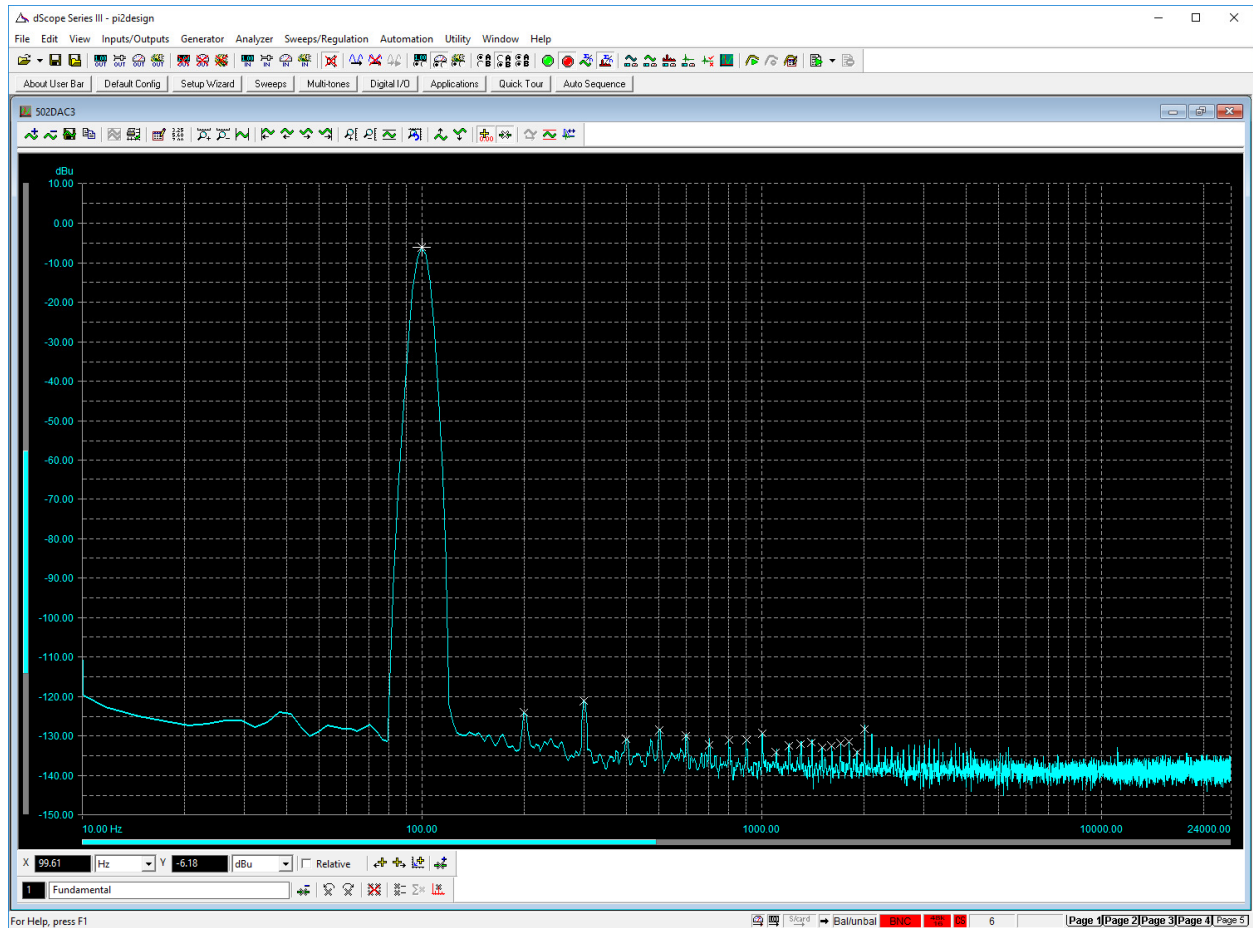


Figure 7 - 100Hz, 24-Bit@96Khz, -6db, 600 ohm

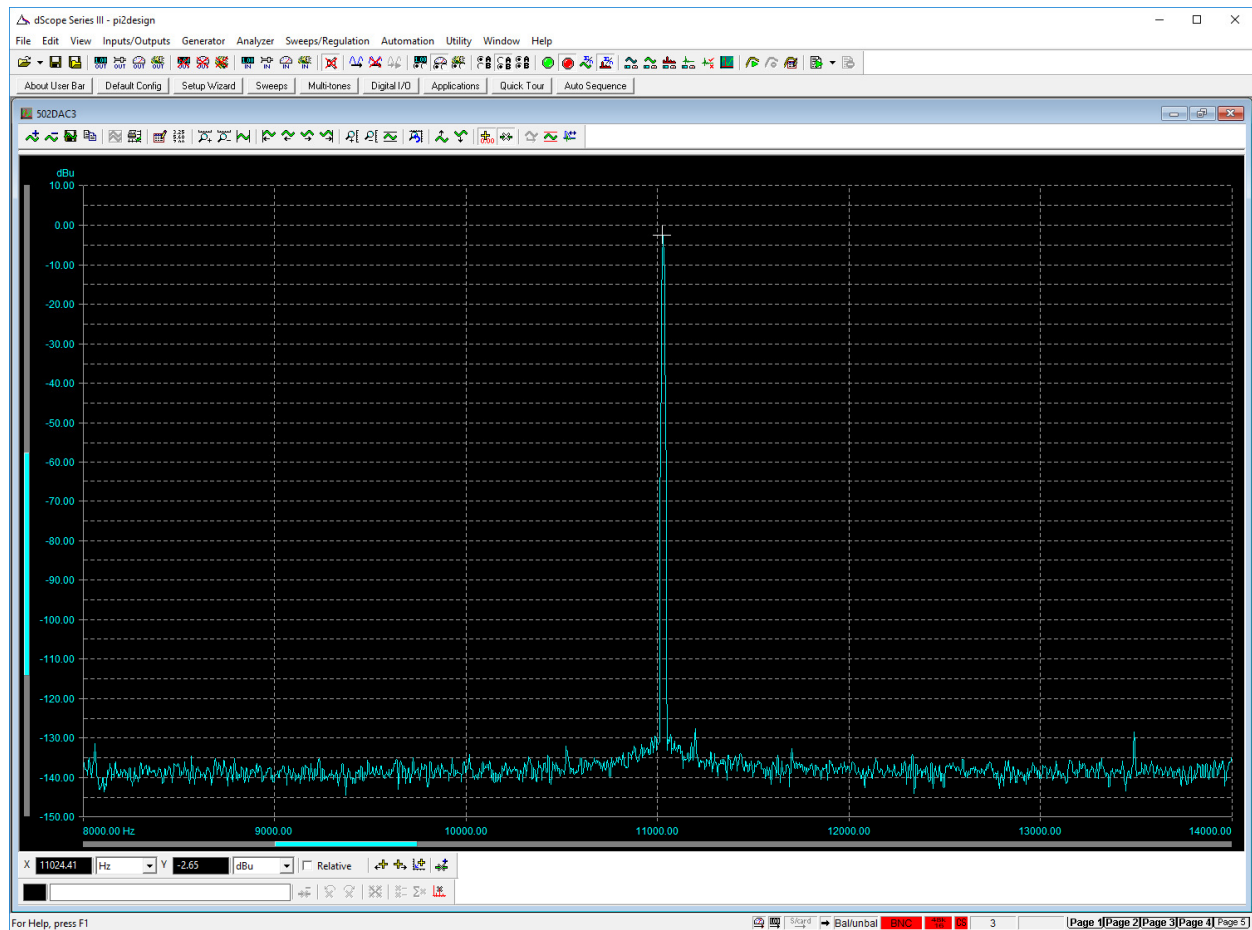


Figure 8 - 11.025Khz, 16-Bit@44.1Khz, -3db, Jitter Test

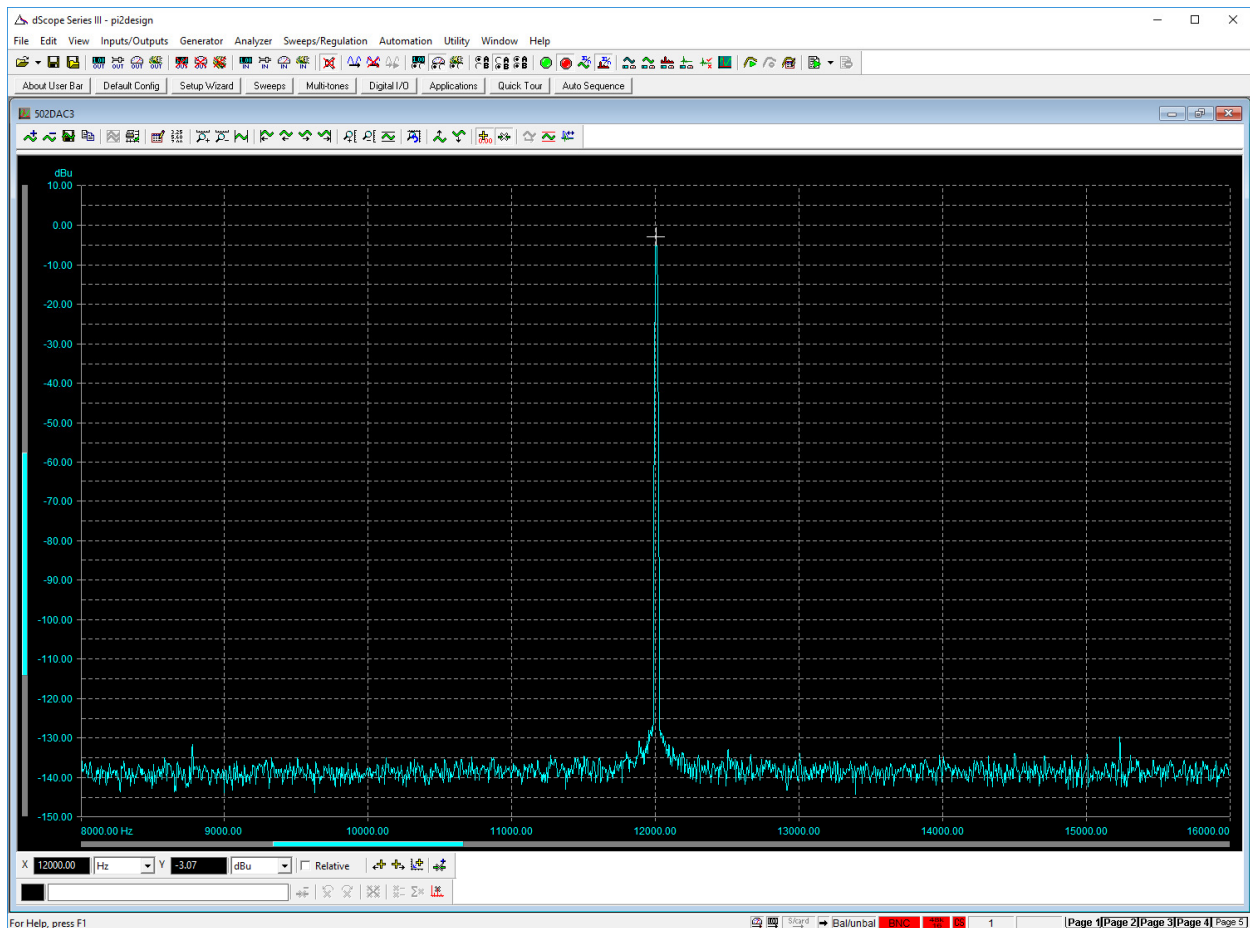


Figure 9 - 12Khz, 24-Bit@48Khz, -3db, Jitter Test

11.4 HEADPHONE OUT TEST RESULTS

The following plots were captured on a dScope IIIe analyzer from the Headphone Output. Test conditions were the same as Line Out, but impedance was set to 150 ohms.

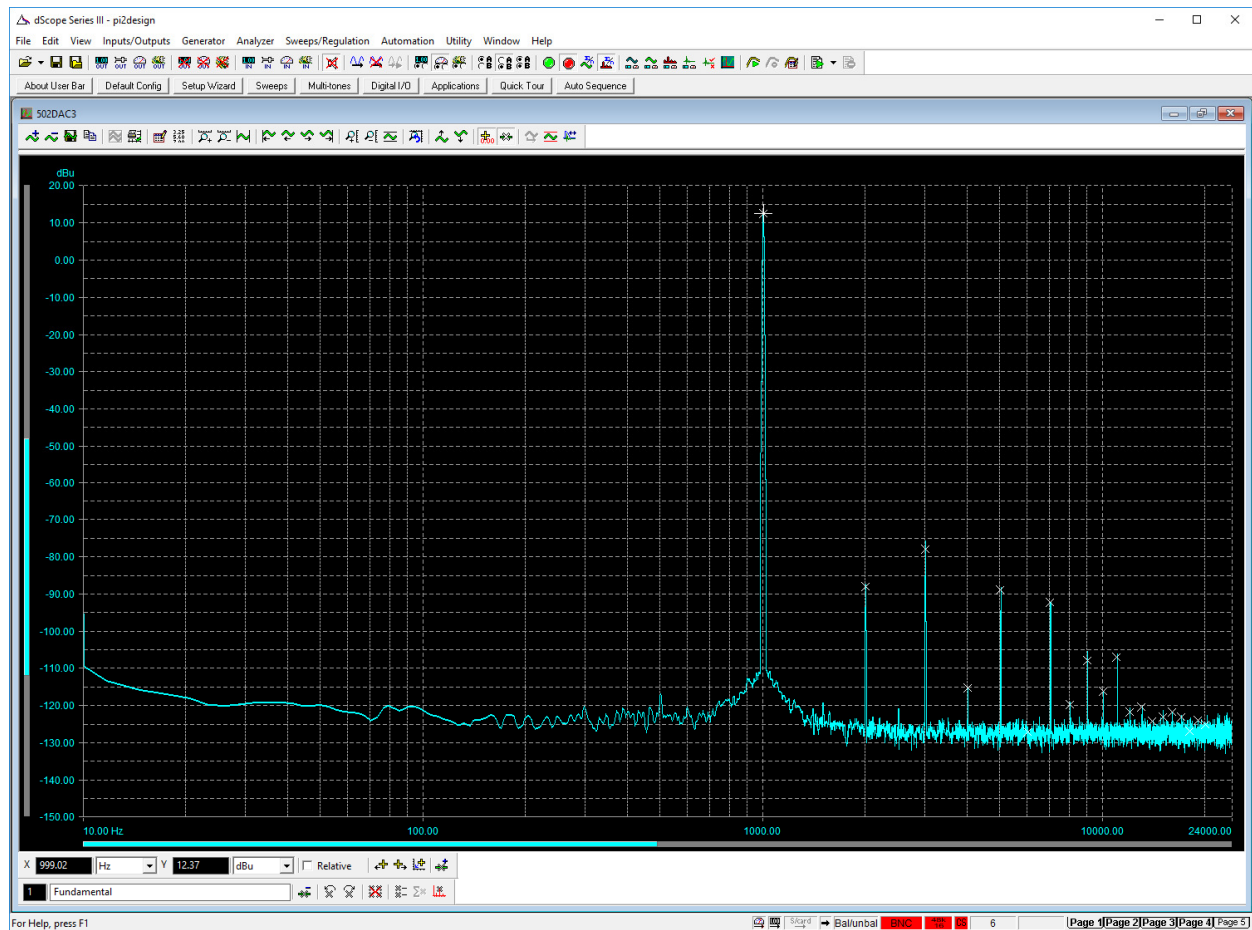


Figure 10 – HPOUT, 1Khz, 24-Bit@96Khz, 12db, 150 ohms

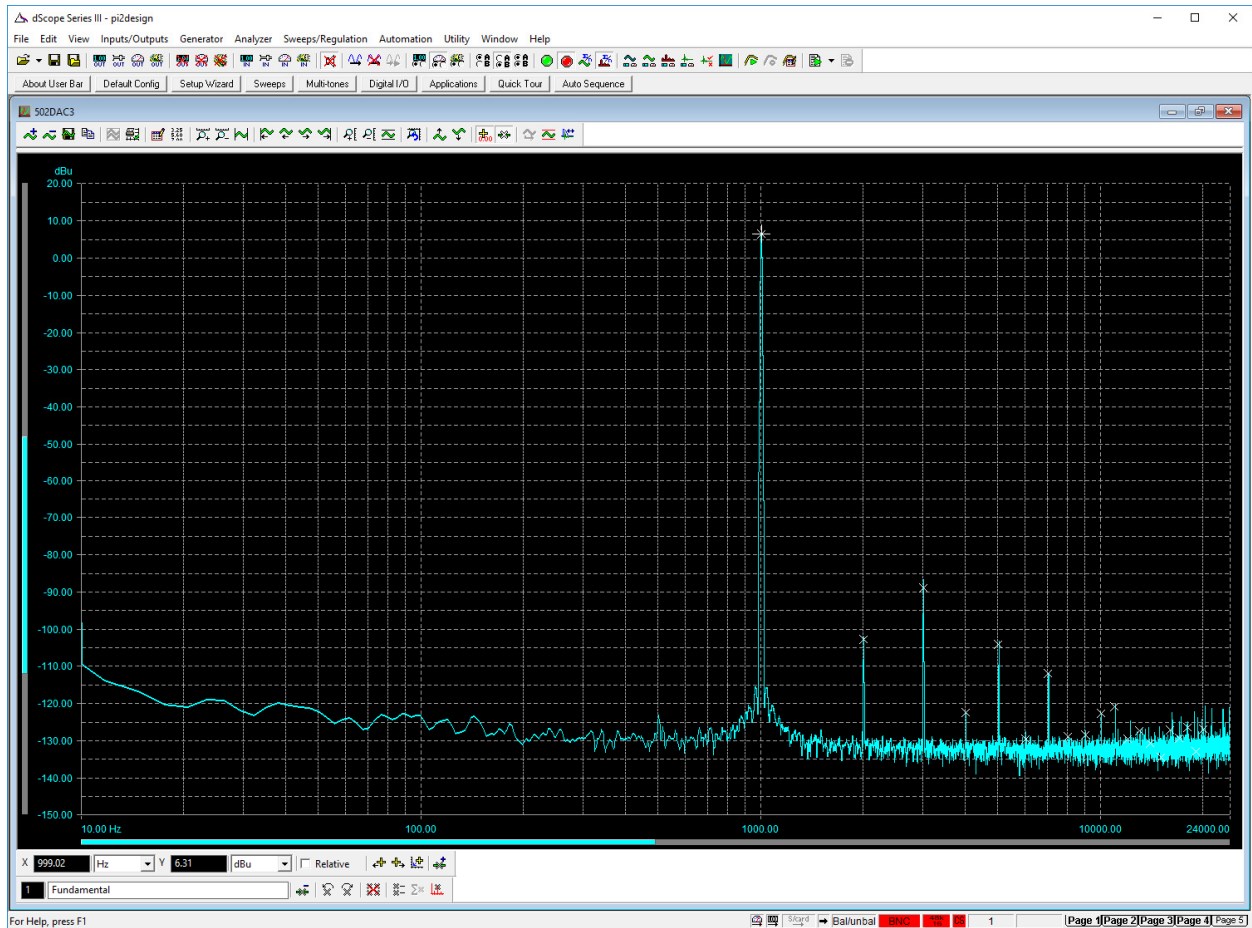


Figure 11 – HPOUT, 1Khz, 24-Bit@96Khz, 6db, 150 ohms

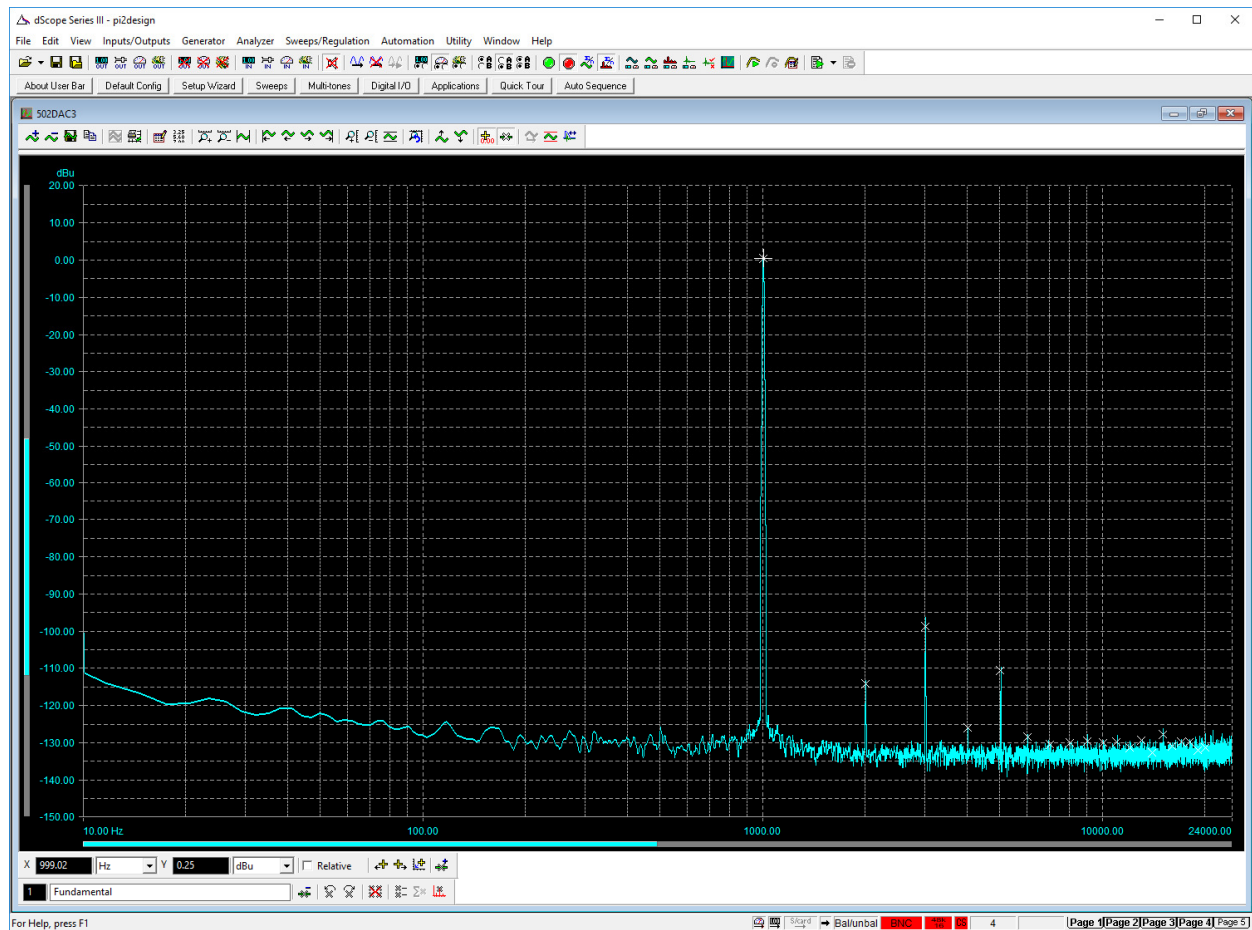


Figure 12 – HPOUT, 1Khz, 24-Bit@96Khz, 0db, 150 ohms

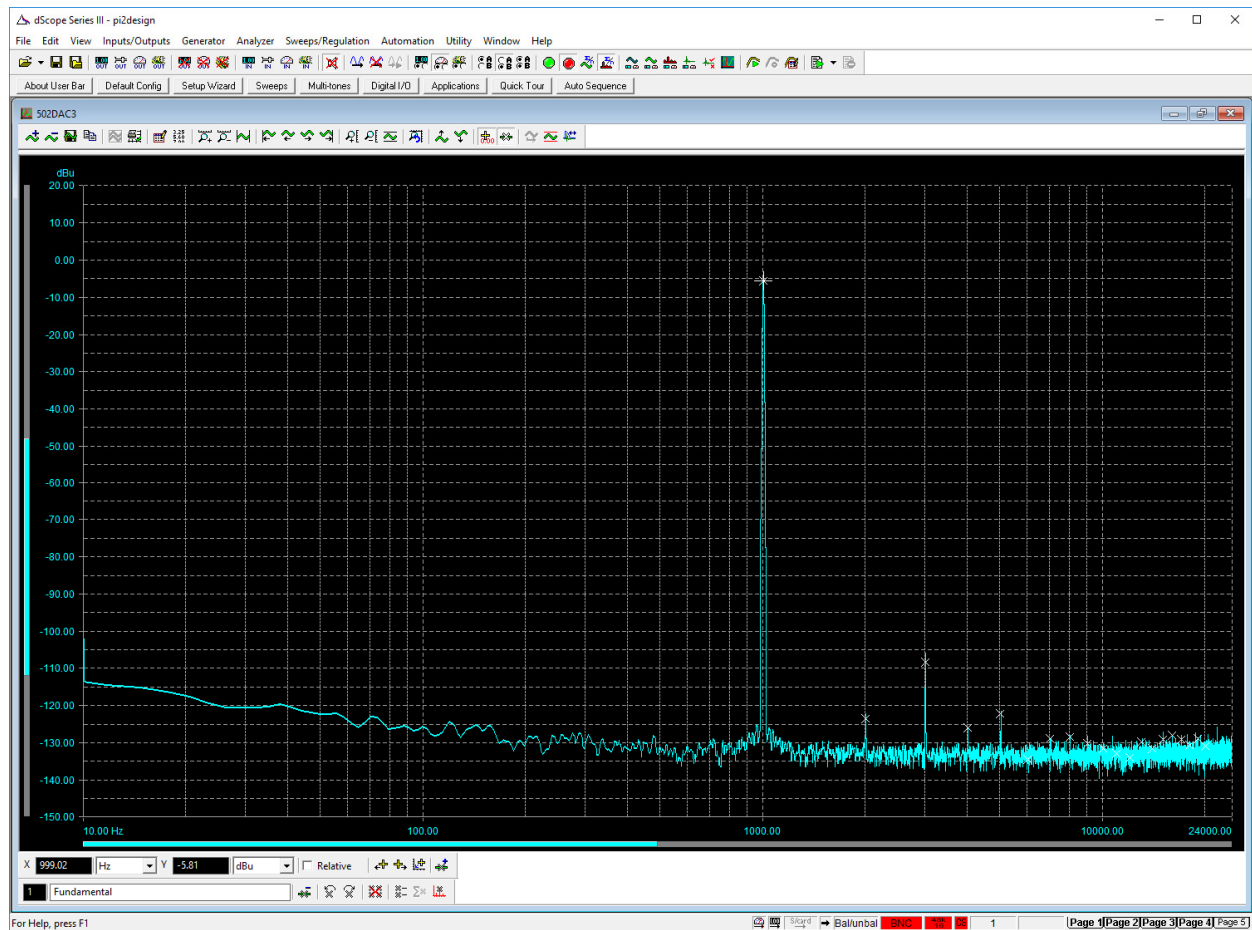


Figure 13 – HPOUT, 1Khz, 24-Bit@96Khz, -6db, 150 ohms

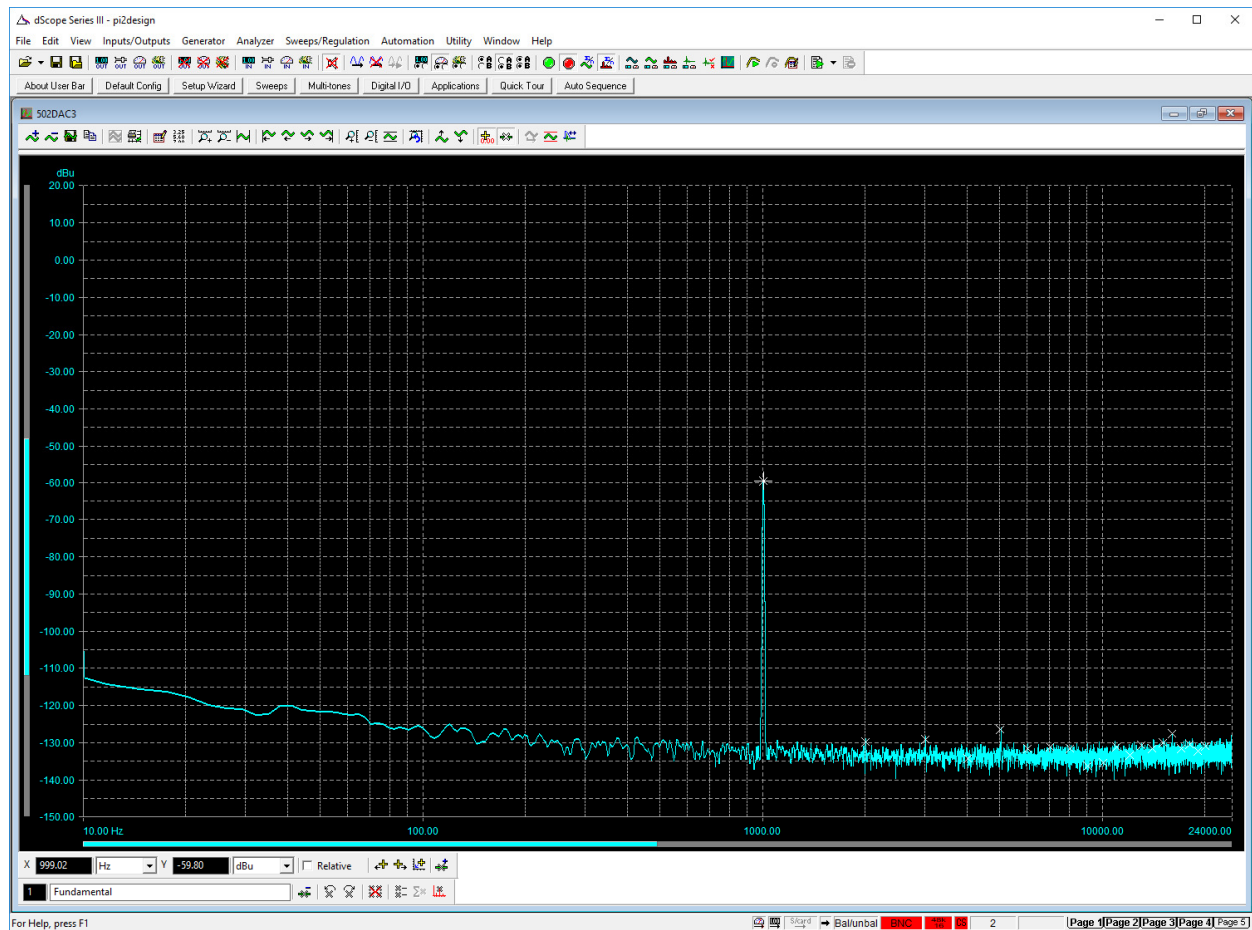


Figure 14 – HPOUT, 1Khz, 24-Bit@96Khz, -60db, 150 ohms