Pi 2 Media

502DAC
Digital Pro Audio Hat
Hardware Reference Manual

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2 OPERATING SPECIFICATIONS

2.1 502DAC OPERATING SPECIFICATIONS

The 502DAC 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	250mw Typical, 1W Maximum

Table 1 – 502DAC Operating Specifications

3 OVERVIEW

3.1 INTRODUCTION

The 502DAC, 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 converts the Raspberry Pi® I2S Port to High Resolution Pro-Audio, Analog and Digital simultaneously.

The 502DAC combines the Audiophile grade 24-Bit@192Khz PCM5122 DAC, High Performance WM8804 Digital Audio S/PDIF Transmitter along with two Ultra-Low Jitter NDK Clocks for High
Quality Analog and Digital Audio.

The major features of the 502DAC are as follows:

- **FORM FACTOR –** Raspberry Pi ® Full Size w/40-Pin mating Connector.
- **24-Bit DAC –** Highly regarded 112db SNR PCM5122 running in Master Mode converts the I2S Stream to Analog at 24-Bit up to 192Khz Frame Rate
- **DIGITAL AUDIO** – Industry standard WM8804 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 PCM5122 and WM8804 to insure the lowest possible Jitter and Phase Noise.
- **ANALOG OUT –** 2Vrms Stereo Line Out is available via Dual RCA Gold Plated Jacks
- **BALANCED OUT –** Isolated Balanced AES/EBU Pro-Audio is via ¼" Connector (XLR Adapter is available)
- **COAX OUT -** A BNC COAX connector provides single ended, isolated S/PDIF with selectable Output levels for both Pro and Consumer equipment
- **OPTICAL OUT** – Via TX179 TOSLINK Transmitter
- **HIGH-PSRR LDO** – A Low-Noise Linear Tech LT3042 delivers 3.3V to all sections and provides 88db+ PSRR over the entire audio band
- **EXTERNAL 5V** – This option allows the 502DAC to be powered from an external low noise supply if desired.

3.2 BLOCK DIAGRAM

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

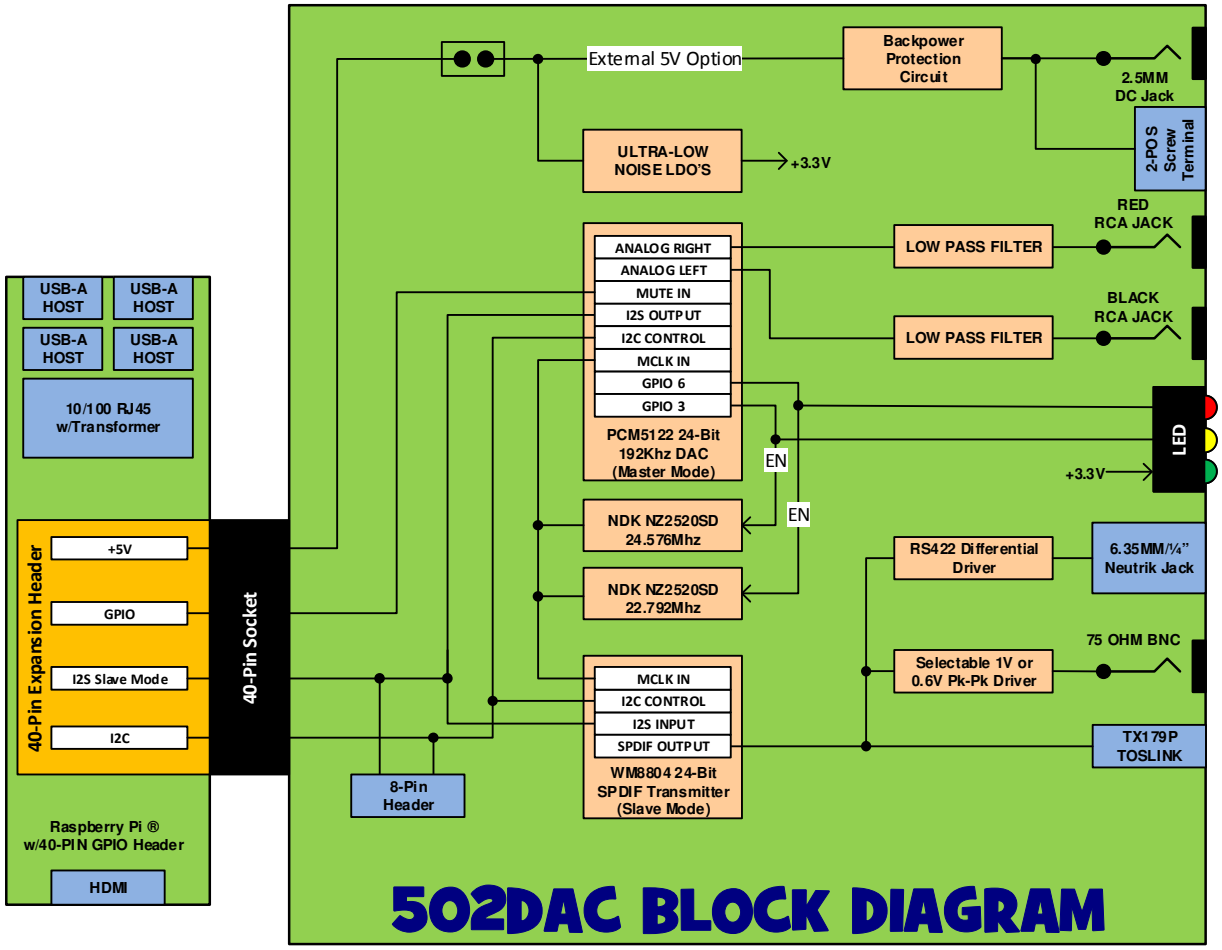

Figure 1 – 502DAC Block Diagram

4 ON-BOARD DEVICES

4.1 *OVERVIEW*

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

4.1 502DAC I2C BUS DEVICES

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

I2C Bus	7-Bit I2C Address	Description
I2C	0x4D	PCM5122 DAC
ID_I2C	0x24	32Kbit EEPROM for ID usage

Table 2 – 502DAC I2C Bus Devices

4.1 PCM5122, 24-BIT DAC

At the core of the 502DAC is the TI PCM5122 24-Bit DAC. This DAC operates in Master mode, thus providing the low-noise clocks to the Raspberry PI and the WM8804 SPDIF Transmitter. The connectivity between the PCM5122 and the Raspberry Pi is shown below.

PCM5122 Signal	RPi Signal	Description
MCLK	-	Input from clock select mux, unused by the Pi
BCLK	BCLK	I2S Bit Clock Output to the Pi and WM8804
LRCLK	LRCLK	I2S Word Clock Output to the Pi and 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
GPIO3	-	PCM5122 GPIO selects the 24.576Mhz clock when high. This is the master clock for 48Khz encoded audio

GPIO6	-	PCM5122 GPIO selects the 22.5792Mhz clock when high. This is the master clock for 44.1Khz encoded audio
OUTL	-	2Vrms Analog Audio Out, Left Channel
OUTR	-	2Vrms Analog Audio Out, Right Channel

Table 3 – PCM5122 Connections

4.2 WM8804 SPDIF TRANSMITTER

A Cirrus Logic WM8804 SPDIF Transmitter operating in slave mode converts the I2S data into an AES3/SPDIF digital audio stream for the Optical, BNC/RCA and ¼"/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
MCLK	-	Unused
BCLK	BCLK	I2S Bit Clock Input from PCM5122
LRCLK	LRCLK	I2S Word Clock Input from PCM5122
SDIN	SDOUT	I2S Serial Audio Data from the Pi
TXO	-	AES3/SPDIF encoded digital audio output

Table 3 – WM8804 Connections

4.2.1 WM8804 SPDIF TRANSMITTER NOTES

1. The 502DAC is designed to operate the WM8804 in Slave mode. In this mode the WM8804 receives its master clock from selected low-noise clock and the Bit and Word Clocks from the PCM5122. Serial Data in is received from Pi. All data and clock formatting is controlled by the PCM5122 driver.

2. The BNC and ¼" outputs are transformer isolated for use in noisy studio environments, as well as with long cable runs for lowest interference. Both are terminated to a nominal 100 impedance.

3. The BNC output has two voltage levels selected by jumper P4. With the jumper installed, the output level is 1V P-P. This is the desired level for standard AES3 via BNC, used primarily by professional audio devices. Removing the jumper sets the level to 600mv P-P, which is compatible with consumer level devices via RCA.

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 via the ¼" connector. A ¼" to XLR Male adapter is provided with the unit.

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 is blank.

5 RPI GPIO

5.1 OVERVIEW

The 502DAC 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 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	-	-	-	GPIO4	Unused
8	-	-	-	GPIO14	Unused
9	-	-	-	GND	Unused
10	-	-	-	GPIO15	Unused
11	-	-	-	GPIO17	Unused
12	IN	Y	-	BCLK	I2S Bit Clock from PCM5122
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	502DAC Name	Description/Notes
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 PCM5122
36	-	-	-	GPIO16	Unused
37	-	-	-	-	GPIO26 - Unused
38	-	-	-	GPIO20	Unused
39	-	-	-	GND	
40	OUT	Y	-	SDOUT	Pi I2S Serial Audio Data Out

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.

6 502DAC POWER

6.1 OVERVIEW

The 502DAC is designed to be powered from either the 40-Pin Pi GPIO connector (P1) 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. See section 8 for the location of P1, W1 and J1.

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

7 502DAC SOFTWARE

7.1 OVERVIEW

The 502DAC uses the standard PCM5122 driver and most Raspberry Pi player software (Moode, PI Musicbox, Volumio, Rune, etc) can be configured to the Hifiberry DAC+ 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 Top Side. These are shown in the 3D rendering below.

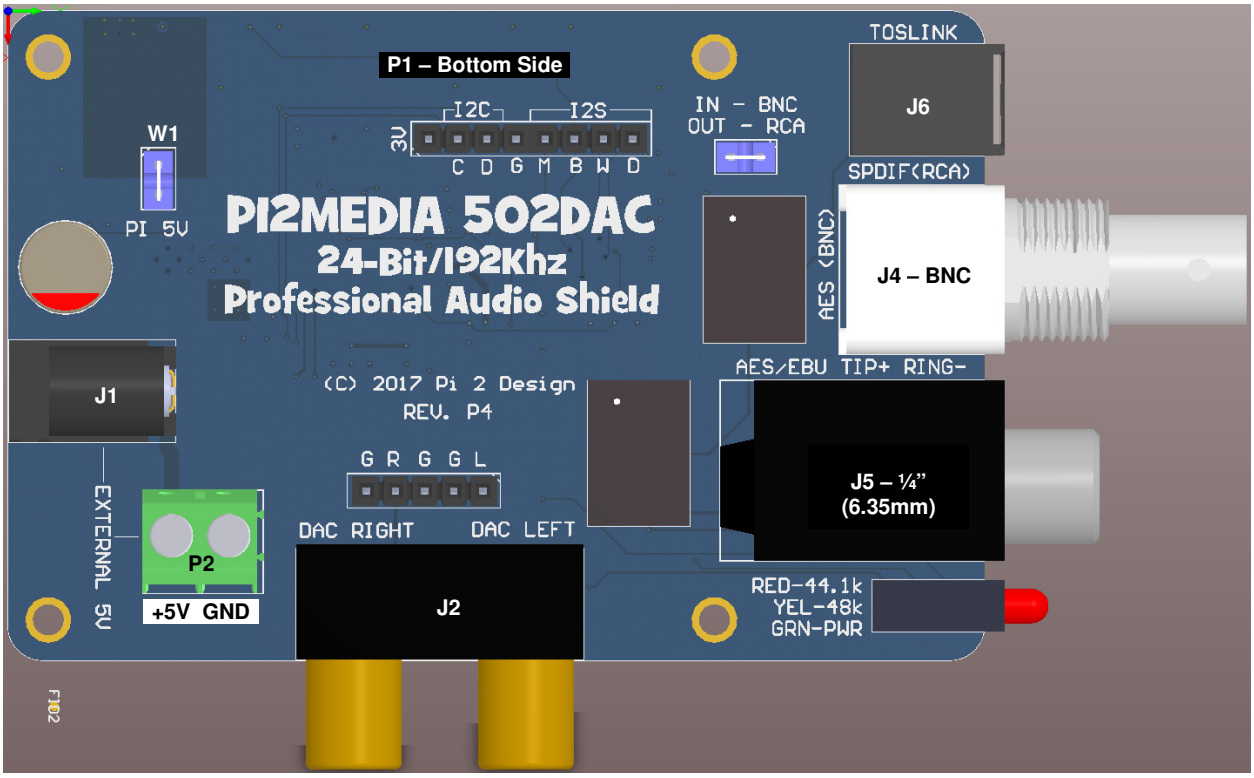

Figure 2 – 502DAC Top Side Connector Designators

8.2 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 – DUAL RCA JACK

J2 is a dual RCA connector providing stereo analog output from the PCM5122.

8.2 J4, BNC CONNECTOR

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

8.3 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.

8.4 J6 –TOSLINK

J6 is a TOTX179P TOSLINK Transmitter.

8.5 P1 – 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.

8.6 P2 – 2-WIRE SCREW TERMINAL

This allows discrete wires to provide the external 5V to the 502HTA. Voltage must be 5V +/- 10%.

9 DOCUMENT REVISIONS

Date	Revision	Change
03/18/2017	P3.0	First Release
04/09/2017	P4.0	Reflect P4 PCB version, added 2-Wire Screw Terminal.
06/13/2017	P4.1	Correct 2-Wire Terminal Label
08/13/2017	P4.2	Added dScope IIIe Test Results

Table 6 – Document Revisions

IO ERRATA

10.1 OVERVIEW

There are currently no known errata for the 502DAC Rev. P4.

11 TEST RESULTS

11.1 TEST RESULTS SUMMARY

502DAC3 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/RCA, ¼"/XLR and Toslink) show a noise floor below -150db with less than -130db (0.00003%) THD. These are both at the measurement limits of the dScope IIIe. A few examples are shown in the following plots.

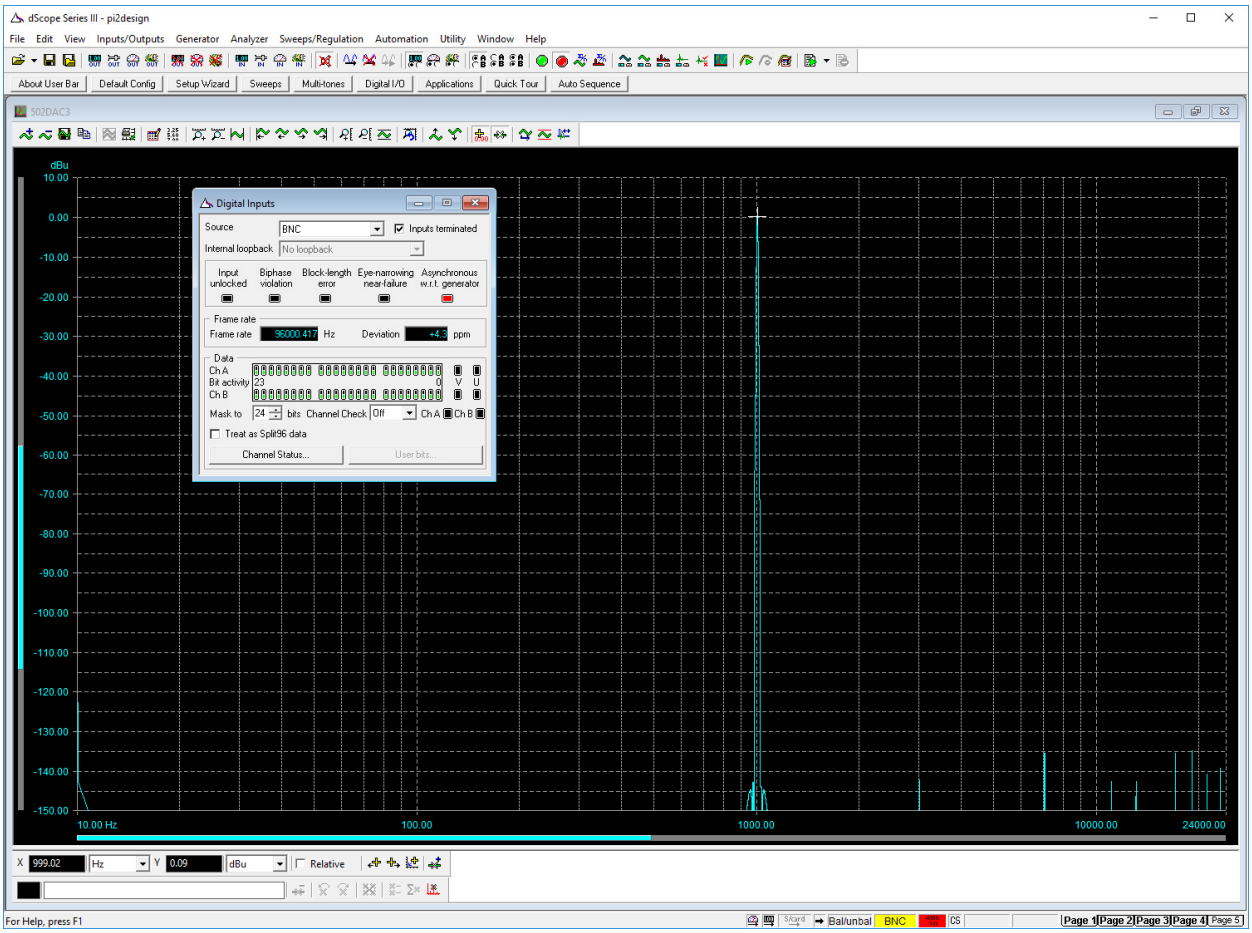

Figure 3 - 1Khz, 24-Bit@96Khz, 0db, BNC w/RCA Adapter

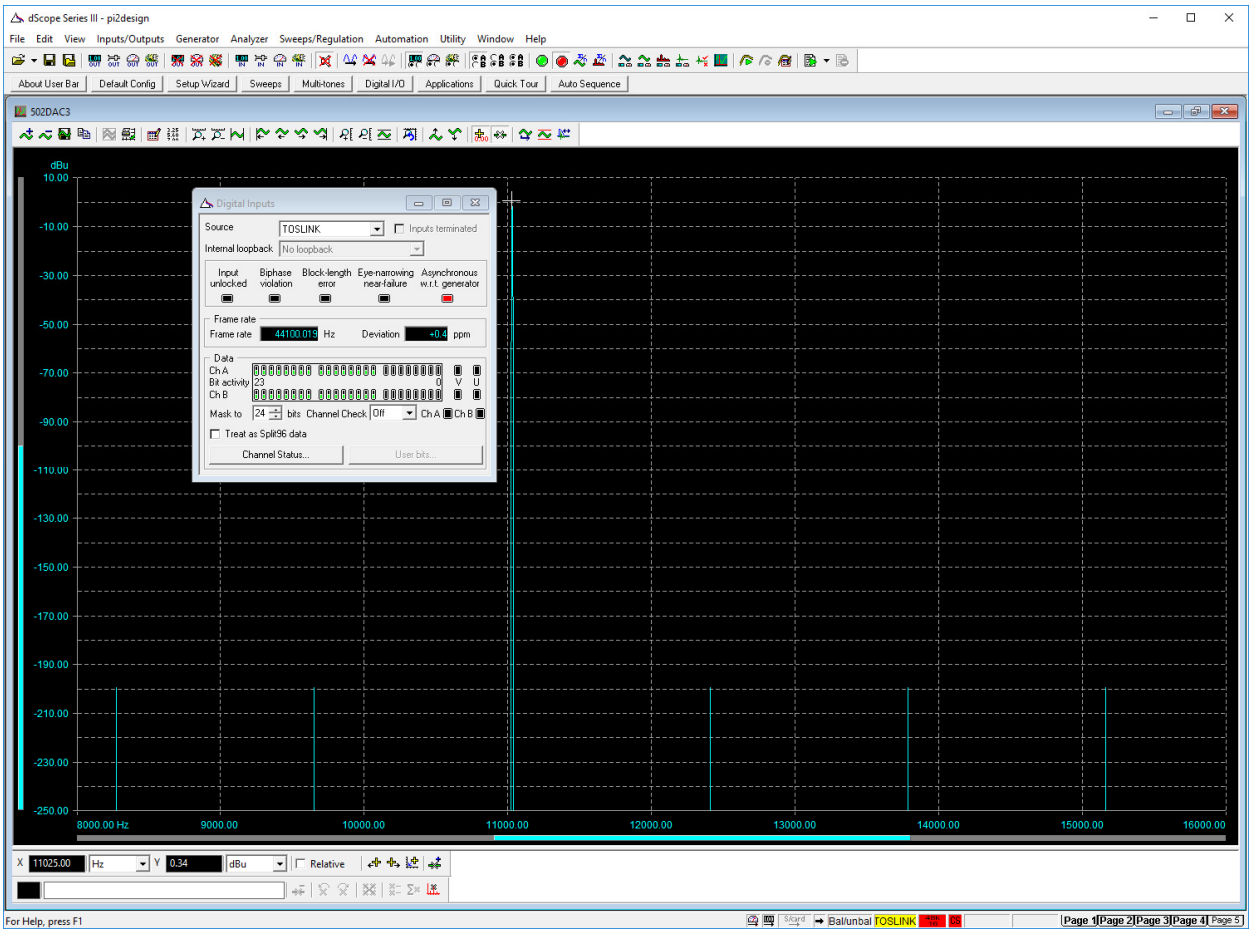

Figure 4 - 11.025Khz, 16-Bit@44.1Khz, 0db, Jitter Test, TOSLINK

11.3 ANALOG LINE OUT TEST RESULTS

The following plots were captured on the dScope IIIe analyzer and saved as PNG files. (Please note that the dScope trace window incorrectly labelled as 502DAC3)

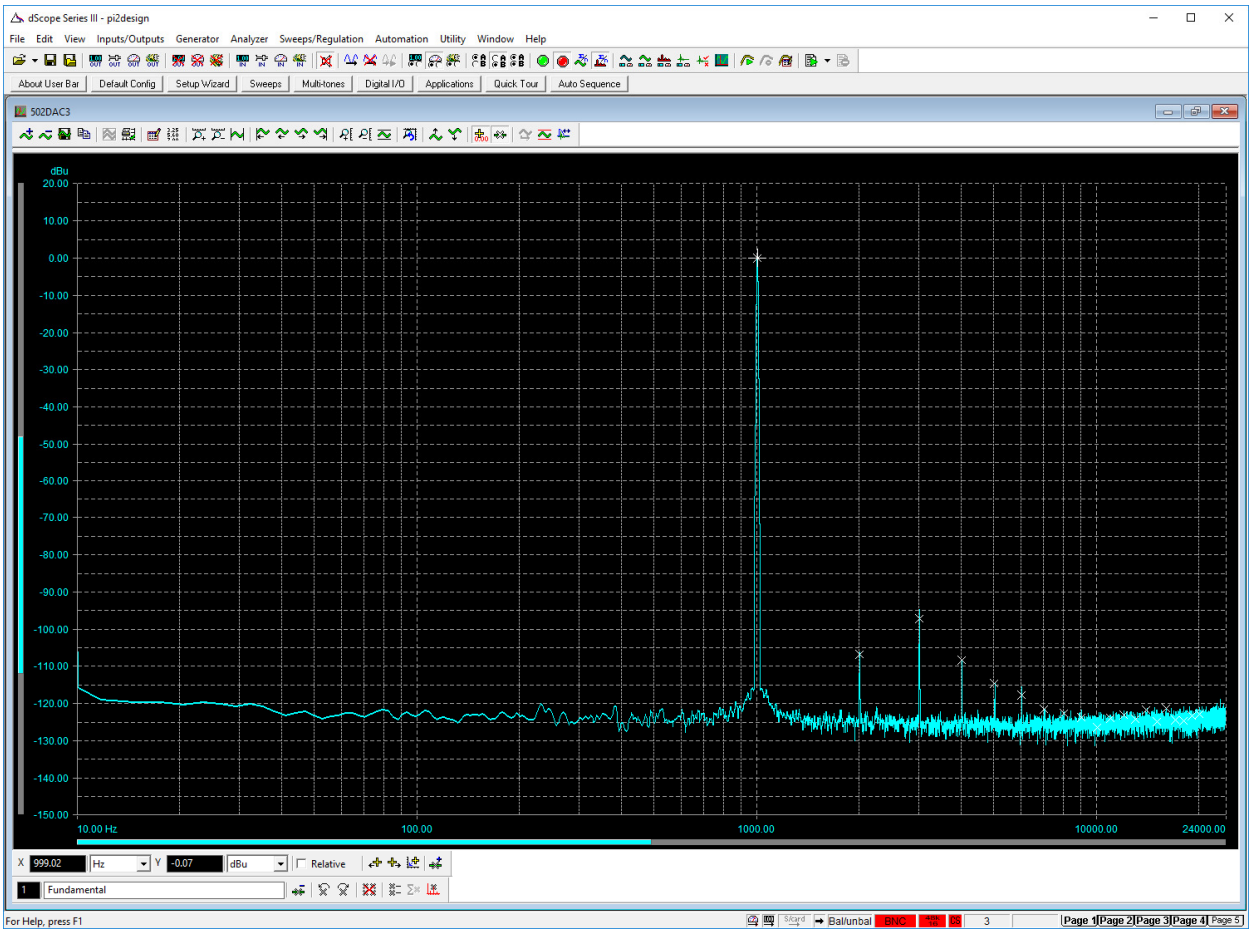

Figure 5 - 1Khz, 24-Bit@96Khz, 0db, 10K ohm

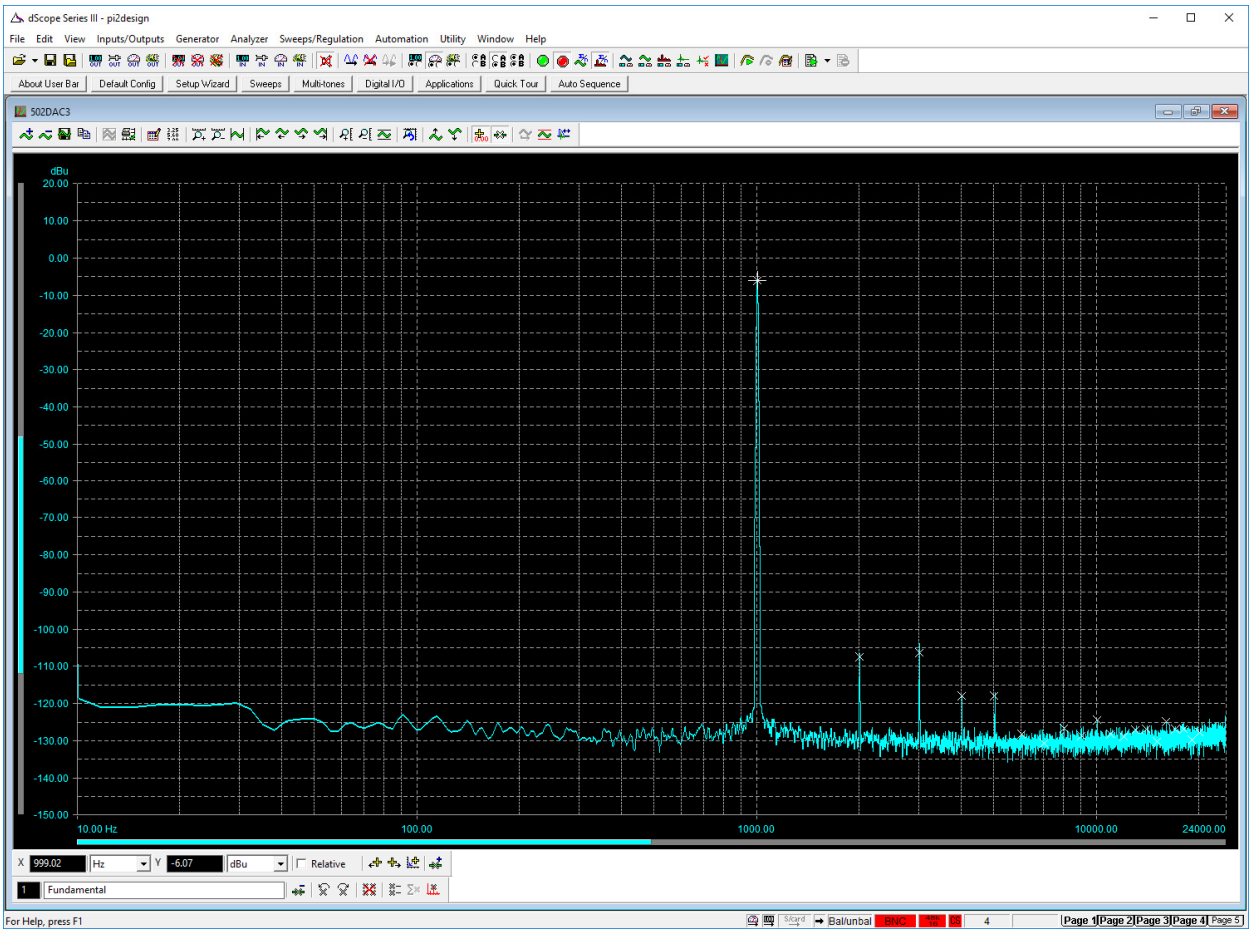

Figure 6 - 1Khz, 24-Bit@96Khz, -6db, 10K ohm

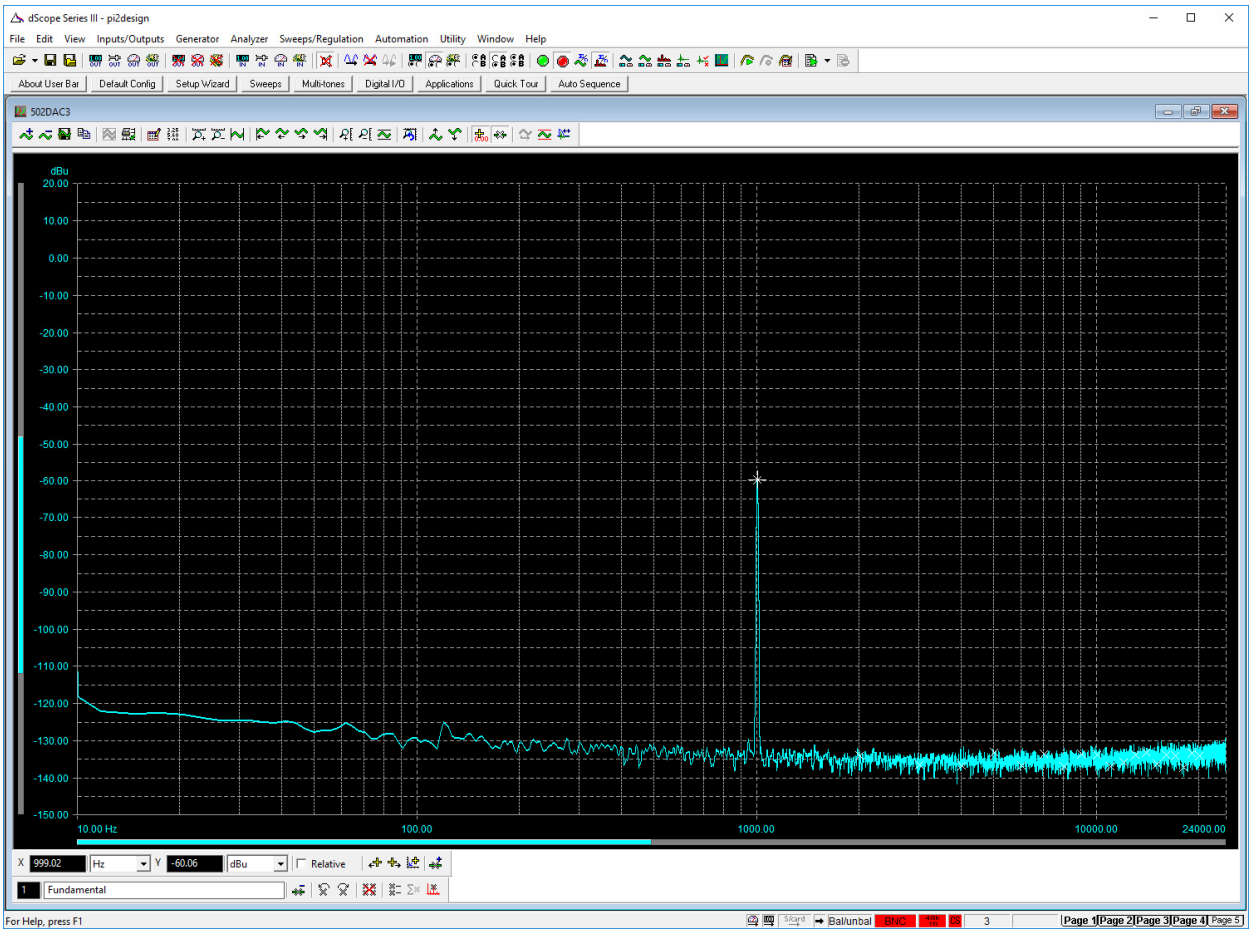

Figure 7 - 1Khz, 24-Bit@96Khz, -60db, 10K ohm

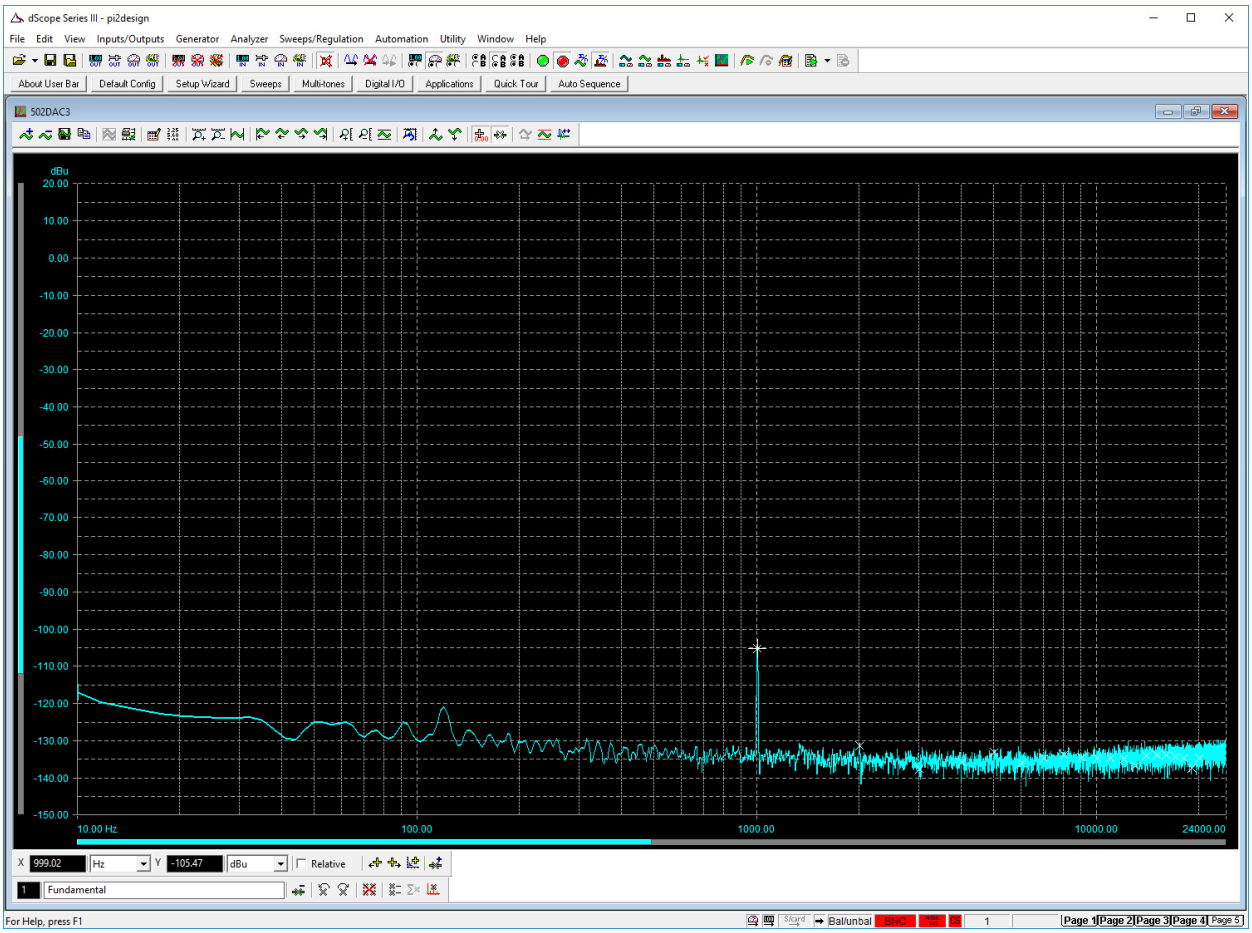

Figure 8 - 1Khz, 24-Bit@96Khz, -105db, 10K ohm

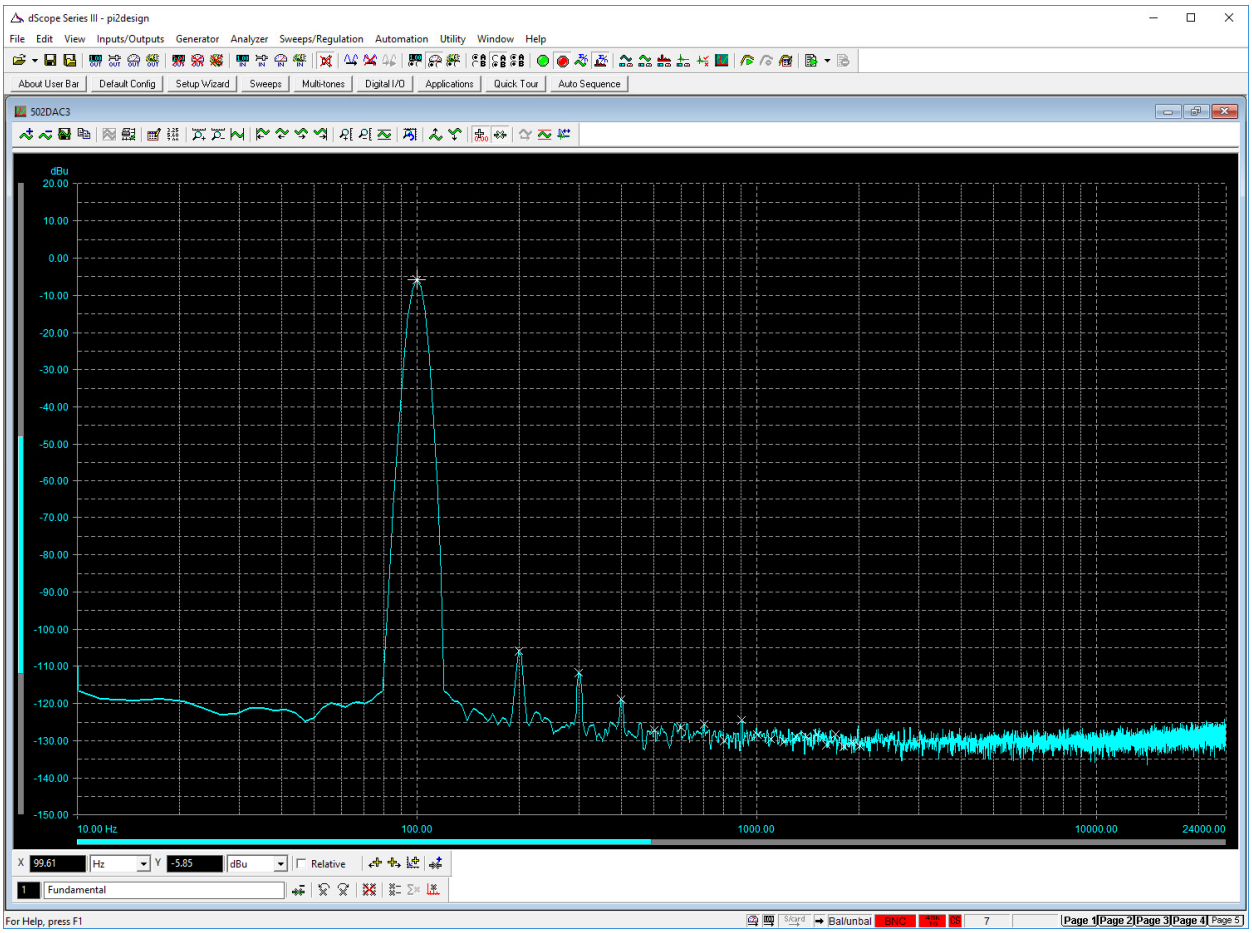

Figure 9 - 100Hz, 24-Bit@96Khz, -6db, 10K ohm

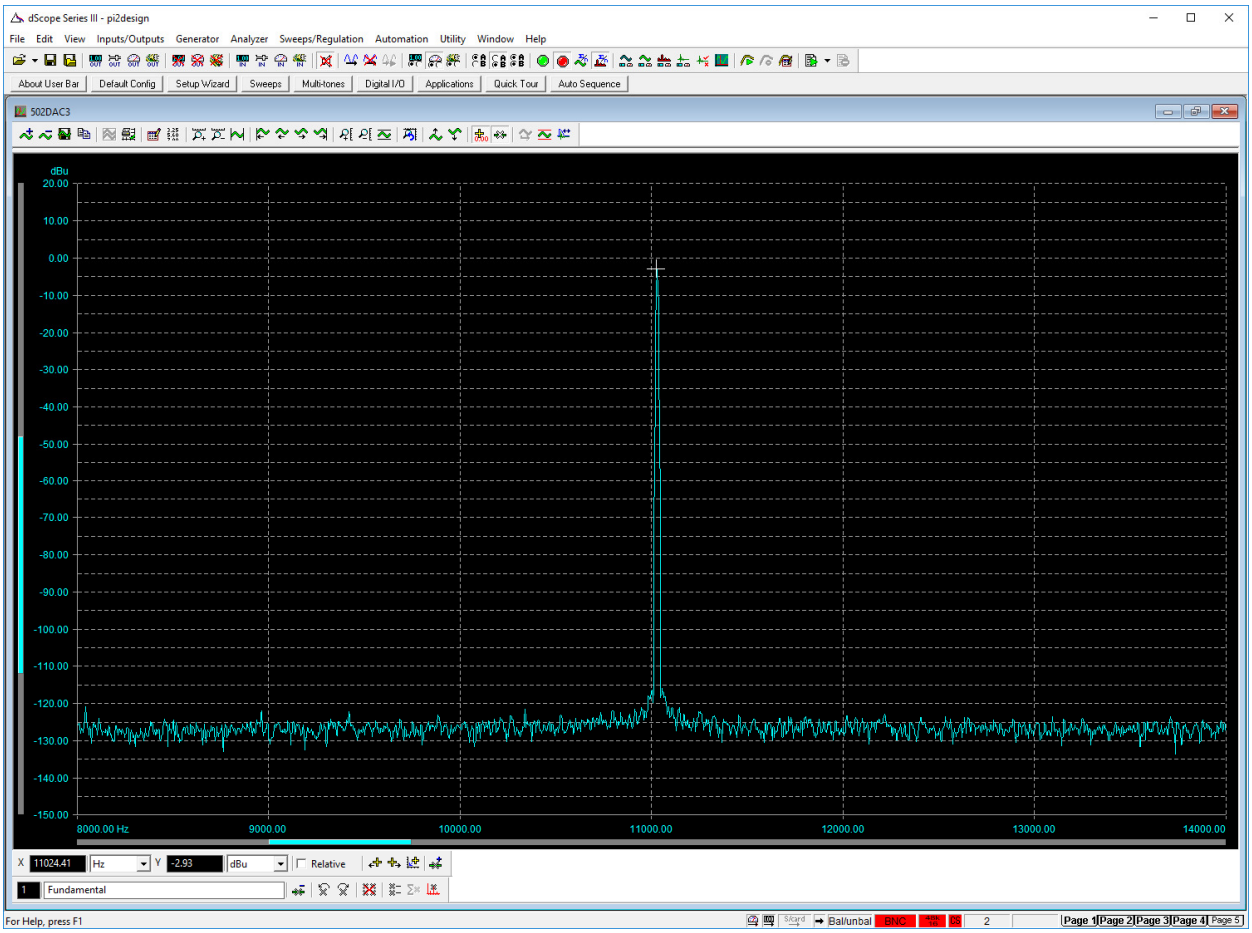

Figure 10 - 11.025Khz, 16-Bit@44.1Khz, -3db, Jitter Test

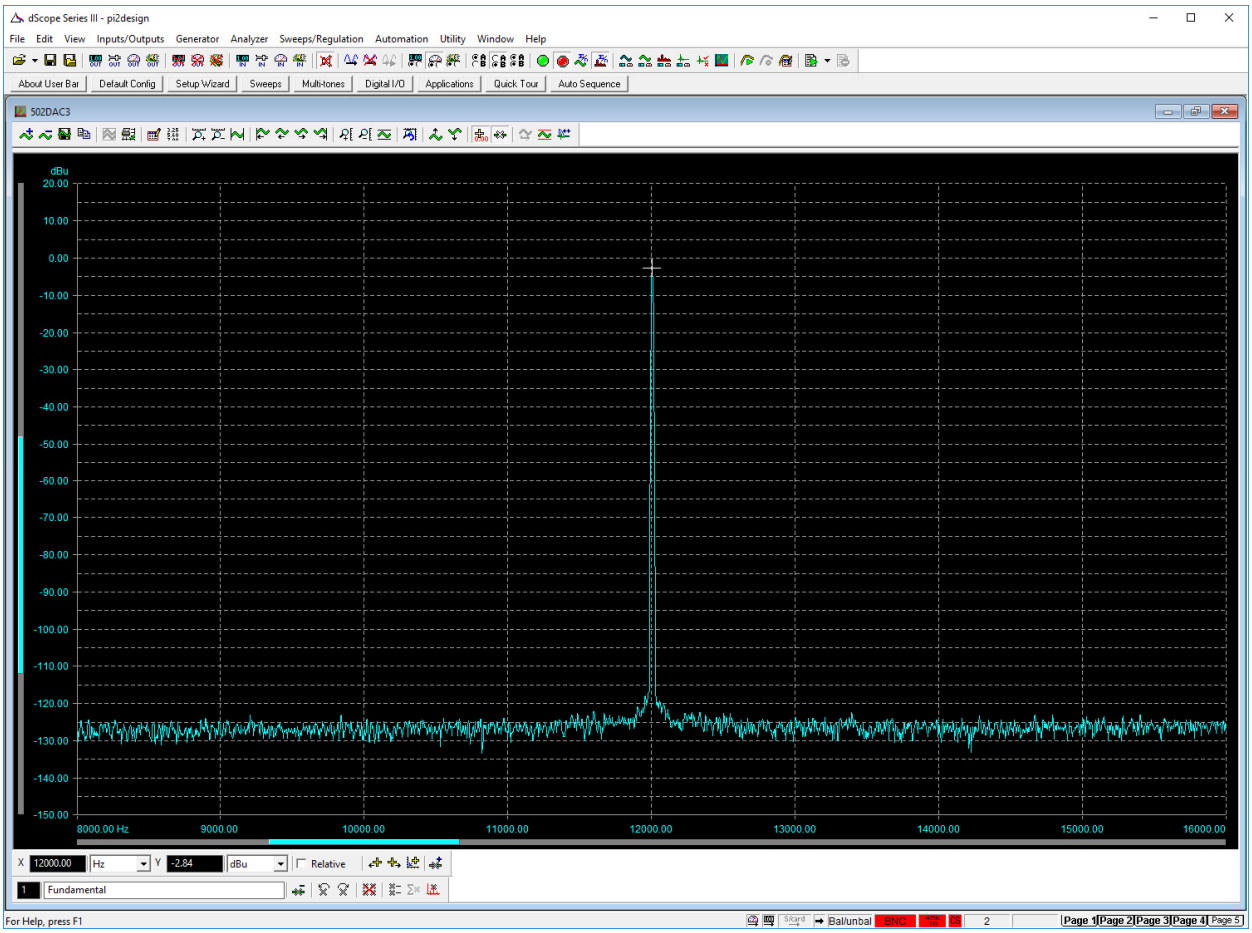

Figure 11 - 12Khz, 24-Bit@48Khz, -3db, Jitter Test