Buffalo II DAC Integration Guide Revision 1.0.5

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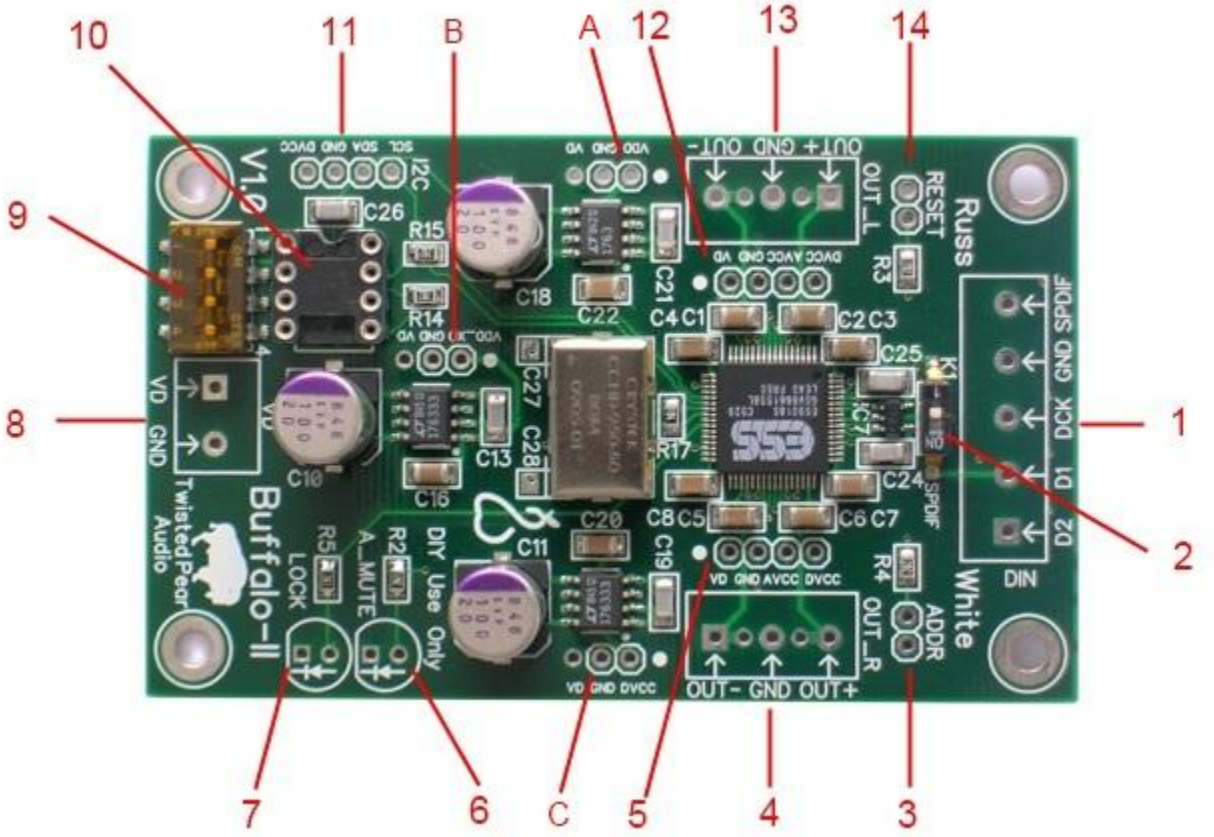
Lay-out of Buffalo II module



1	Input for I2S/SPDIF
2	SPDIF switch
3	Address jumper
4	Right channel output
5	AVCC header – right side
6	Mute LED header
7	Lock LED header
8	Power input
9	DIP switches for configuration
10	Firmware controller
11	I2C header
12	AVCC header – left side
13	Left channel output
14	Reset header
A	VDD header
B	VDD_XO header
C	DVCC header

About this manual

This manual provides an alternative for the official, separate module manuals. It combines information from the original Buffalo II manual, the DIYAudio forum (http://www.diyaudio.com/forums/twisted-pear/) and the Twisted Pear Audio forum. It handles the most popular Buffalo II configurations and is mainly intended for people new to the Twisted Pear Audio modules.

This is by no means a replacement for the official manuals: the modules features and specifications are subject to constant improvement. See http://www.twistedpearaudio.com/docs/docs.aspx for the latest versions of the official and community manuals.

Overview

The Buffalo-II is a 32-bit stereo audio reference DAC module designed for uncompromising audio quality. Based on the ESS Technology ES9018 Sabre Reference chip, the Buffalo-II accepts S/PDIF, PCM, and DSD digital audio signals at sample rates up to 32-bit/400Khz.

Modes

The ES9018 chip is an 8 channel DAC, capable of working in several different modes. The Buffalo-II is normally used in either of 2 modes: stereo or dual mono. In stereo mode, one board is used to drive both outputs (L+R channel). In that mode, four of the balanced DACs inside the ES9018 are combined to one output channel. This improves dynamic range when compared to the 7.1 mode (not available on the Buffalo II) where only one DAC is used per output channel.
In dual mono mode two Buffalo-II boards are used. One board is used for the left output and one for the right output. In that mode all 8 balanced DACs of the ES9018 are used for each output channel achieving the best possible dynamic range.

In the package

The Buffalo II is shipped with everything you need to integrate it into your project:

- Buffalo II DAC board
- AVCC module
- LEDs for Lock and Mute
- Connector blocks for power and input
- Stacking connectors for the AVCC module
- Stacking connectors for the Twisted Pear Audio I/V stages
- Connector blocks for other types of I/V stages
- LEDS for Mute and Lock indication

Note: contents of the package are subject to change without further notice.

AVCC Module

The AVCC module for the analog supply pins of the DAC should be connected so that the header pins connect to the same pin on the DAC board. You might note that we use an AVCC voltage that is slightly higher than 3.3VDC. This helps us achieve slightly better dynamic range. The module is supplied with a CCS fed shunt regulator especially designed for the analog section (AVCC) of the ES9018.
This manual assumes you are using that regulator module as it has been designed specifically for the Buffalo II.

Power requirements

The Buffalo II board makes extensive use of local voltage regulation with careful attention to each supply pin of the DAC chip. There is only one main power supply input in the standard configuration. The standard board requires an input voltage between 5V and 5.5V with the preference toward 5.5V and it draws approximately 290ma. We recommend using either a Placid tuned for shunting about 60ma (approx. 350ma CCS current) or half of a LCDPS. See the Placid manual for more detail.

Analog characteristics

The Buffalo II does not include an output stage but is designed to mate with a Twisted Pear Audio current-to-voltage stage (I/V stage). It is not recommended to use the Buffalo II output directly, but it is possible. The output can be used as a voltage source into a high impedance but THD+N will suffer. THD+N as a voltage source is about -108db whereas when used with a very low input impedance current to voltage stage such as the IVY-III it can achieve -120db THD+N in mono mode.

Clock

The Buffalo II DAC board uses a custom on-board ultra low jitter, low phase noise clock from Crystek. The clock module lowers jitter significantly when compared to normal clocks. The clock is placed on the board near the DAC chip to keep phase noise at low levels. It is recommended not to use an external clock to feed the DAC chip as the increased distance to the chip and resulting phase noise would likely offset any benefit from the external clock (even if you can find a better module).

For 2010 and earlier boards, the clock is an 80Mhz part, for boards shipped in 2011 and later, the clock is an 100Mhz version. When building a dual mono setup, it is recommended to use DAC boards with identical clock modules.

Preparing the board

Solder the input (see item 1 in the lay-out) and power (8) connector blocks to the DAC. When using a Twisted Pear Audio I/V stage, solder I/V stacking connectors to the underside of the DAC on the left and right output headers (13 and 4). Normal connector blocks are also provided for those who wish to use other types of I/V stages.
Solder the lower half of the AVCC stacking connectors (5 and 12) on top of the DAC. Solder the upper half to the AVCC module.

If desired, solder the Mute (6) and Lock (7) LEDs in place. These were not mounted to allow mounting them to the front panel of the DAC using a (thin) wire.

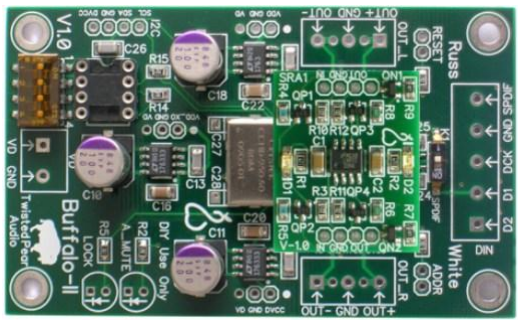
From this part onward, proceed to the section below that is relevant for the board you're working on right now.

Preparing the board for stereo operation
Make sure the ADDR header is not shorted.
Set the DIP switches (9): set switch 1 to ON.

Preparing the left board for dual mono operation
Make sure the ADDR header is not shorted.
Set the DIP switches (9): set switch 1 to OFF and set switch 2 to ON.

Preparing the right board for dual mono operation
When using an external I2C controller like the Volumite, put a jumper on the ADDR header (3).
Set the DIP switches (9): set switch 1 to OFF and set switch 2 to OFF.

Finally, for all boards
Optionally, mount the Trident regulator modules (see: Adding the Trident regulator). Attach the AVCC to the DAC. Make sure the AVCC module is mounted correctly: the pears on both the AVCC and BII boards should point in the same direction (see picture).



Input options for the DAC module

The Buffalo II DAC board has SPDIF and I2S input options. Only one of these inputs can be connected at a time. When using I2S set the SPDIF switch (2) to OFF. When using high resolution sources I2S input is preferred, as unlike the SPDIF input it is not limited to 24 bits / 192 KHz. Keep I2S wires as short as possible, and when using dual mono mode make sure the I2S wires are of equal length to eliminate timing issues.

Coax (SPDIF) can be connected directly to the DAC module. For TOSLINK (the optical version of SPDIF) you need a TOSLINK Optical Input Module Kit. It can be connected similar to the coax input.

For USB input, an USB Receiver is available. The USB receiver module offers SPDIF and I2S output. There are two versions of the USB receiver: the first generation is based on the Texas Instruments PCM2707 USB DAC chip. This version is limited to 16-bit/48-KHz signals. The latest generation is based on an XMOS controller, and allows up to 32-bit / 384KHz.

Multiple connections

If multiple input connectors are needed, the S/PDIF 4:1 MUX/Receiver Module is required. This module allows you to switch between 4 different SPDIF inputs. The recommended way of connecting it is I2S, with lines that are kept as short as possible. See below how to connect the MUX module to the DAC board. Do not forget to set the SPDIF switch (2) to OFF.

MUX unit and other I2S sources	Buffalo II DAC board
MCK	Not connected
GND	GND
BCK (Bit clock)	DCK
LRCK (Word clock)	D1
DOUT (Data)	D2
SPDIF -	Not connected
SPDIF +	Not connected

If multiple connections and a high resolution USB receiver are used two I2S connections are needed. This can be achieved using the OTTO 2:1 Switching Module. This module makes it possible to switch between two I2S inputs. Both the MUX and the OTTO module can be operated using an microcontroller like for instance an Arduino board or the Audio Controller. For advanced users this allows for more flexible interface options.

Connecting digital sources

Consumer Level SPDIF
Make sure the SPDIF switch (2) is closed (ON).
Connect consumer level SPDIF signals to SPDIF and GND at the input terminal block (1).
TTL Level SPDIF
Make sure the SPDIF switch (2) is open (OFF).
Connect TTL level SPDIF signals to D1 and GND at the input terminal block (1).
TTL Level I2S
Make sure the SPDIF switch (2) is open (OFF).
Connect I2S signals as in the scheme for the MUX module (see Multiple connections) and other I2S sources.
TTL Level DSD
Make sure the SPDIF switch (2) is open (OFF).
Connect DSD signals as follows:

Source	Buffalo II DAC board
Ground (GND)	GND
Bit Clock	DCK
Data 1(usually left)	D1
Data 2(usually right)	D2

SPDIF and dual mono

When using SPDIF with a dual mono setup do not run parallel input wires to both DAC boards. The termination would no longer be 75Ω, as both boards have a 75Ω termination resistor on-board. Instead of sending it to two boards (going direct into SPDIF on both DACs) feed the SPDIF into one of the DACs as you normally would do with the SPDIF switch closed (ON) as usual. Then wire from GND and D1 on that DAC to GND and D1 on the second DAC and keep the SPDIF switch open (OFF) on the second DAC.

Now you have a single termination for the SPDIF and you will be feeding the second DAC with a TTL signal from the comparator of the first DAC.

In case of I2S connection problems

Some I2S sources, in particular high resolution ones, do not play correctly with the Buffalo II DAC board. As a result, lock problems may occur. This can be a result of the source itself or the wiring from the source to the DAC board. Make sure the I2S wires are of equal length, and as short as they can be (preferably below 4”/10 cm).

If one is experiencing I2S connection issues that can not be solved by improving the wiring, some DPLL register settings should be changed in the DAC. An alternative firmware is available for users of either the plain Buffalo II DAC board or for the Volumite to alter these settings. Or one could use either the AC2 or an Arduino to set these registers in the DAC.

Note: It is not recommended to use the alternative firmware if you do not experience any problems.

Adding the Volumite

The Volumite adds volume control to the Buffalo II DAC board. When combined with the MUX unit it changes the DAC into a flexible DAC/Pre-amplifier configuration. The Volumite is a precise and affordable volume control, and uses the volume control mechanism built into the ES9018.

Volumite data	
Voltage required (without on-board voltage regulator)	2.7 – 5.5 V (DC)
Voltage input (with on-board voltage regulator)	3.5 – 20 V (DC)
Current	±25mA maximum

Volume control in the DAC

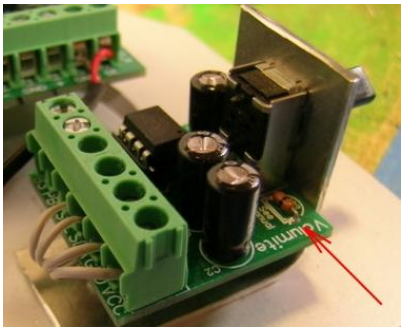
The ES9018 chip has a well designed volume control mechanism built into the chip. The ES9018 has a DSP section that uses 48 bits internally for all important operations. So even with a 32-bit signal there is some precision left for digital attenuation of the signal.

The output volume is set by registers in the DAC, ranging from 0 to -127dB, in 0.5 dB steps. The Volumite simply sets the volume registers in the DAC using I2C. So the pot is not in the signal way, it is just a means of measuring the desired attenuation. A change of output volume is done gradually: internally the DAC adjusts the volume in steps of less than 1/64 dB, so the unit smoothly changes it's output signal from the old setting to the new one.

Powering the Volumite

The Volumite requires 2.7 to 5.5V DC to function. There are two easy ways of achieving this:

1. Power the Volumite from a single DAC board using the DVCC wire in the I2C header (11). In this case, do not use the small TO-92 LDO voltage regulator (vreg) included in the Volumite package. Put a jumper on the Volumite instead. Jumper the two outer pads for the vreg (see picture). Be sure the jumper does not touch the center hole.
2. Power the Volumite from an external 3.5 to 20V DC power supply. In this case, put the vreg in place on the Volumite board. Do not connect the DVCC wire on the DAC board.



We highly recommend you use the Buffalo to power the Volumite, as it will prevent the possibility of startup timing issues.

Volumite in stereo mode

Connect the Volumite to the DAC board. Make sure to connect the remaining wires (GND, SDA and SDL) correctly, as the order on the Volumite may be different from that on the DAC board (it depends on the version). When adding the Volumite, remove the default firmware controller (10) from the Buffalo II board.

Volumite in dual mono mode

Connect the pin PB1 to GND on the Volumite. This is done with a short wire. Now run wires of equal length to both DAC boards. Connect the wires (GND, SDA and SDL) to both DAC boards. If you power the Volumite from a DAC board, do not connect the DVCC wire to both boards, just on one. Remember to remove the firmware controller (10) from both boards.

Adding the Trident regulator

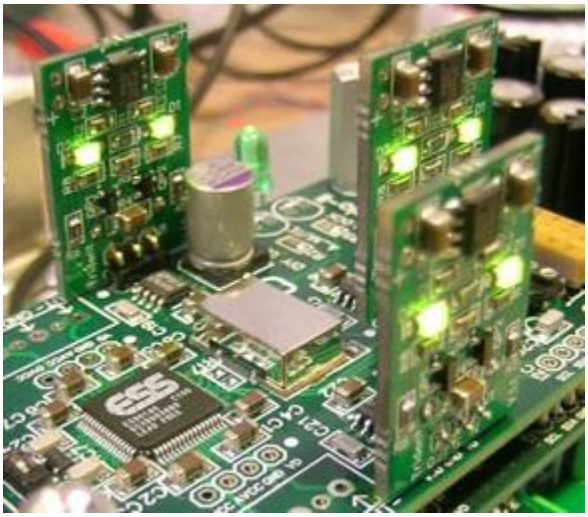
A Trident regulator replaces part of the Buffalo II's on-board regulated power supply by a low noise shunt regulator. As mounting them requires modifying the Buffalo II board this option is not supported by Twisted Pear Audio. The alternative power supply option is provided for people to experiment with different types of power supply circuits; it is not recommended or supported. If you decide to do this do not expect any support should your DAC fail. You are on your own.

There are 3 power supply circuits on the Buffalo II board that can be replaced:

Circuit	Voltage	Ferrite bead	Header in the lay-out	R4 Resistor value	R8 resistor Value
VDD	1.2V	L6	A	10Ω, 1%	100KΩ
VDD_XO	3.3V	L7	B	20Ω, 1%	
DVCC	3.3V	L8	C	20Ω, 1%	

To fully replace the normal regulated power supply, Twisted Pear Audio offers a combo set of 3 Trident regulators, with the correct amount of power for each of the Buffalo II's circuits. For now we assume you will use this option, although it is possible to replace each of the circuits as one sees fit. You need 1 combo set for each Buffalo II board, so order 2 combo sets when you want a dual mono configuration. In case your sets got mixed up: in the table above are is the data you need to sort things out and place them correctly.

Trident regulator data	
Maximum current output	150mA
Input voltage range	5 - 5.5 V (DC)
Recommended input	5.25 V (DC)
Voltage Tolerance	+/- 1%
Board size (inches)	0.75" x 1.075"
Board size (mm)	19 x 27.3 mm



To install the Trident set, remove the Ferrite beads L6, L7 and L8 from the underside of the Buffalo II board. Make sure the voltage of the Trident you mount is correct, and the right resistor is soldered on position R4 of the regulator. In the combo set, the bags are marked with the circuit, voltage and packed with the correct resistor for their position.

Before soldering the module on the board make sure it is correctly aligned and enough clearance is left for other wiring/items you wish to add. 90 degree headers as pictured in the photo are supplied with the board to mount the regulators vertically on top of the board. The VDD_XO regulator comes with an extra mounting socket, to raise the regulator so enough clearance is left when using the on-board firmware chip. Please note that although the AVCC is not shown in the picture, it still is recommended to be used to obtain the best results.

When delivered the headers are not soldered on the regulator board to allow for alternative methods of connecting them to the DAC board. Fi. You can mount these at the underside of the DAC board if there isn't enough clearance above the DAC board.

If you have chosen to install the screw type headers instead of using the stacking connectors make sure you keep enough clearance when installing the header on the Trident module.

Powering the Buffalo II with the Trident modules attached
Since the Trident modules are shunt regulators with a high noise rejection, one doesn't need to use a Placid shunt regulated power supply. Using an LCDPS is the most sensible option, especially in a dual mono setup since a single LCDPS can power 2 circuits.

The power draw of a Buffalo II board with a full Trident combo set installed is around 450mA. When using an old style LCDPS power supply, replace the resistors R1 to R4 on the LCDPS with 1Ω versions, or simply put jumpers on these positions to enable it to deliver more than 400mA. Newer versions of the LCDPS ship with suitable resistors (2.7Ω, 3W) for higher currents and don't need to be modified.

If you already have a Placid it is possible to use it, but beware that the amount of power supplied to the DAC board needs to be increased as the Trident regulators use more power than the original circuits. See the Placid manual about adjusting the shunt current. Depending on the situation, one may have to increase the size of the heatsinks on the Placid to counter the increased heat dissipation.

If the power range on the Placid does not allow you to go to the desired power level, you could try the following, depending on the power supply used:

Power supply	Raise power by
Placid V2.0	Reduce R6 to 4.7Ω, or even short it
Placid V2.0.1	Reduce R5 to 4.7Ω, or even short it
LCDPS (old version)	Reduce R1 to R4 to 1Ω, or even short it

Tip: For IVY owners, shorting is the easiest way to raise the power as several jumpers (0Ω) are included with the IVY kit and in most cases, those jumpers will remain unused.

Caution: lower voltage to the Buffalo II with Trident modules attached
The amount of voltage to the Buffalo II board may need to be decreased from the normal voltage of 5.5V to the recommended 5.25V. Increasing the voltage to a value above the recommended value does not provide any benefits but it will increase the amount of heat produced. Beware that if the input is above 5.5V, the Tridents and AVCC may be damaged.

When using a Placid take in account that a shunt PSU like the Placid may drift a bit in voltage during warm up. Usually the output voltage will be slightly higher when the PSU is still cold. The typical change may be a few tenths of a volt. Under no circumstance allow the voltage to get too high.

Advanced features

Using external I2C controllers
The onboard firmware controller (10) is an I2C bus master. Since only one master is allowed on this bus, remove the controller when using an external controller on the I2C bus (Volumite for example).

The I2C header (11) is used to communicate with the DAC from a controller such as the Volumite. It includes a 3.3V supply voltage for modules that can use it. If using the 3.3V supply do not exceed 75ma load.

When using dual mono mode, the left and right boards get different I2C addresses:

Mode	Address
Stereo	0x90 (144 decimal)
Mono – Left	0x90 (144 decimal)
Mono – Right	0x92 (146 decimal)

When using a controller like fi. the AC1 or AC2 in dual mono mode, remember to set the volume registers on both boards using I2C commands.

Reset
The RESET header (14) is used to reset the DAC if necessary. This is not normally needed even when changing registers.

Analog output specification
Each analog output at 0DBFS is equivalent to a voltage of approximately 92.4% of AVCC in series with 195Ω. So given 3.3VDC AVCC it will be about 3.05Vpp across 195Ω. The output will be DC biased at AVCC/2. This works out to about 16ma peak to peak at each output. The amount of bias current will depend of the voltage of the virtual ground.

In dual mono mode the channel on the DAC which is opposite the selected channel carries the same analog signal but anti-phase as shown in the table below. This allows the use of the IVY-III or Legato as a single differential (balanced) mono channel. Dual mono operation is used to achieve the best dynamic range. If you still need single ended output then you would want to add a high quality BAL/SE converter such as the Ballsie Lite or the Ventus. For more details about the IVY-III or Legato please check their manuals.

Mode	Left Differential Output	Right Differential Output
Stereo	Normal Phase	Normal Phase
Mono – Left	Normal Phase	Anti-Phase
Mono – Right	Anti-Phase	Normal Phase

Appendix: DIP switch settings

Switch	ON	OFF	Comments
1	Stereo mode	Dual mono mode	
2	Dual mono LEFT	Dual mono RIGHT	Has no meaning if switch 1 is ON.
3	Fast	Slow	FIR Roll Off
4	Normal (use with SPDIF/PCM)	50Khz (for DSD)	IIR Bandwidth

The DIP switches (see 9 in the layout) 1 and 2 are used to set the board in a stereo or dual mono configuration.
The other DIP switches configure features. Power need not be cycled after changing these switches. It is suggested you leave these “on” for default operation. The defaults were carefully chosen for best all-around performance. For Stereo SPDIF and PCM the defaults are ideal. For DSD you may want to change the IIR bandwidth switch.

Appendix: Buffalo II specifications

Item	Value
Max. Input signal	32 bit / 400Khz
Input voltage	5 to 5.5V DC
Power usage	±290mA
Power usage with Trident set	±450mA
DAC Output current	16mA
Max. current supplied by I2C header	75mA
I2C voltage	3.3V (5V tolerant)
Output impedance	195Ω
Dynamic range (mono mode)	135dB
THD+N (with IVY3, mono mode)	-120dB
Dimensions	3.3” x 2”

Appendix: Bill of materials for Stereo mode DAC

Description	Amount	Notes
Buffalo II DAC board	1	
I/V output stage: IVY 3 or Legato 3	1	For the Legato 3, use the version with output buffer unless you are certain you don't need a buffer.
Placid power supply	1	
Placid HD BP power supply	1	Multiple units can be connected to a single IVY or Legato output stage
Transformer 9V	1	15VA
Transformer 15V	1	30VA, Dual secondary windings required. Feed each Placid BP power supply with a separate 15V transformer.

Other items required:

- Enclosure
- Connectors for input/output and power
- Internal wiring

Twisted Pear Audio provides several other useful items for your project:

Description	Notes
S/PDIF 4:1 MUX/Receiver Module	Provides multiple inputs for your DAC
USB DAC/Receiver	Basic USB receiver. Supports a maximum of 16 bits / 48 KHz.
TOSLINK Optical Input Module Kit	TOSLINK to SPDIF connection
Volumite controller	Adds volume control to the DAC
Trident regulator combo set	Upgrade power supply option for the DAC board

Appendix: Bill of materials for dual mono mode DAC

Description	Amount	Notes
Buffalo II DAC board	2	
I/V output stage: IVY 3 or Legato 3	2	For the Legato 3, use the version with output buffer unless you are certain you don't need a buffer.
Placid power supply	1	Multiple units can be used fi. to power the left and right DAC boards separately.
Placid HD BP power supply	2	Multiple units can be connected to a single IVY or Legato output stage
Transformer 9V	1	15VA
Transformer 15V	2	30VA, Dual secondary windings required. Feed each Placid BP power supply with a separate 15V transformer.
Ballsie Lite or Ventus (2-channel kit)	1	Required only if you want single ended output.

Note: If using the Trident regulator combo set, use 2 Placid power supplies or even better: use a LCDPS.

Other items required:

- Enclosure
- Connectors for input/output and power
- Internal wiring

Twisted Pear Audio provides several other useful items for your project:

Description	Notes
S/PDIF 4:1 MUX/Receiver Module	Provides multiple inputs for your DAC
USB DAC/Receiver	Basic USB receiver. Supports a maximum of 16 bits / 48 KHz.
TOSLINK Optical Input Module Kit	TOSLINK to SPDIF connection
Volumite controller	Adds volume control to the DAC.
Trident regulator combo set	Upgrade power supply option for the DAC board. Order 2 sets for a dual mono configuration.

Appendix: Tips for a clean and safe setup

- Twist all primary and secondary transformer leads.
- Twist all leads coming from the bridge rectifiers/PSU PCB/buffer caps.
- Clean up the wiring, twist all wires that carry AC current, route them clear of DC/signal wires.
- Clean the boards after soldering with Isopropyl alcohol.
- When using a metal chassis, work with double isolation on all wires carrying high voltage AC current or keep at least 10mm distance between the wire and the chassis.
- Use a fuse. This is easy to do when using a chassis power connector with integrated fuse holder.

Appendix: references

Reference	Link
ESS 9018 datasheet	http://www.esstech.com/products/digitalaudio/Sabre%20PF%20080221.pdf
ESS Sabre family whitepaper	http://www.esstech.com/PDF/sabrewp.pdf
DIY audio Buffalo II thread	http://www.diyaudio.com/forums/twisted-pear/160782-buffalo-ii.html
Official and community manuals	http://www.twistedpearaudio.com/docs/docs.aspx
TPA support forums	http://www.twistedpearaudio.com/forum/default.aspx