FifoPi Ultimate 768KHz PCM/DSD/DoP FIFO user's guide

By Ian Jin, Dec 30, 2018 Ver. 0.9 (draft)

A. Introduction

The digital audio stream consists of two parts: the data and the clock. Usually we don't have any problems with data. However, the clock is not perfect (there are no ideal clocks in the real world); it comes with jitter (or phase noise). Jitter is the main reason why different digital audio sources sound different even when they are played from the same audio stream.

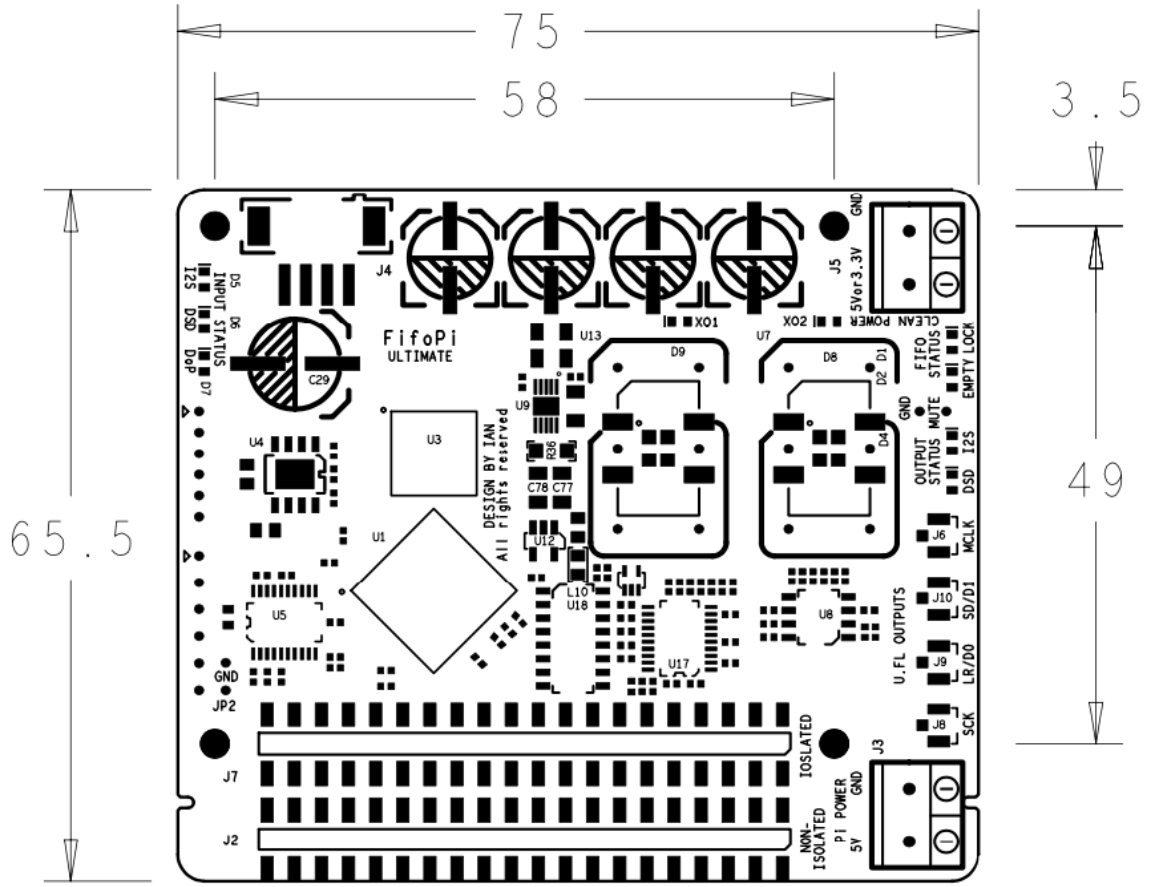
Based on the next generation of Ian FIFO technology, FifoPi Ultimate is an all in one asynchronous PCM/DSD/DoP stereo FIFO solution with built-in isolator and clock board. It is a kind of logic device, which can buffer the digital audio stream, allowing the audio data to pass through while isolating the original clock and replacing it with a new secondary clock. If the new clock has less phase noise than the old one, the digital audio stream after the FifoPi will have less jitter and that will make the DAC or other digital audio device playing the stream sound better. Moreover, the sound quality of the playback will be independent from the digital audio source.

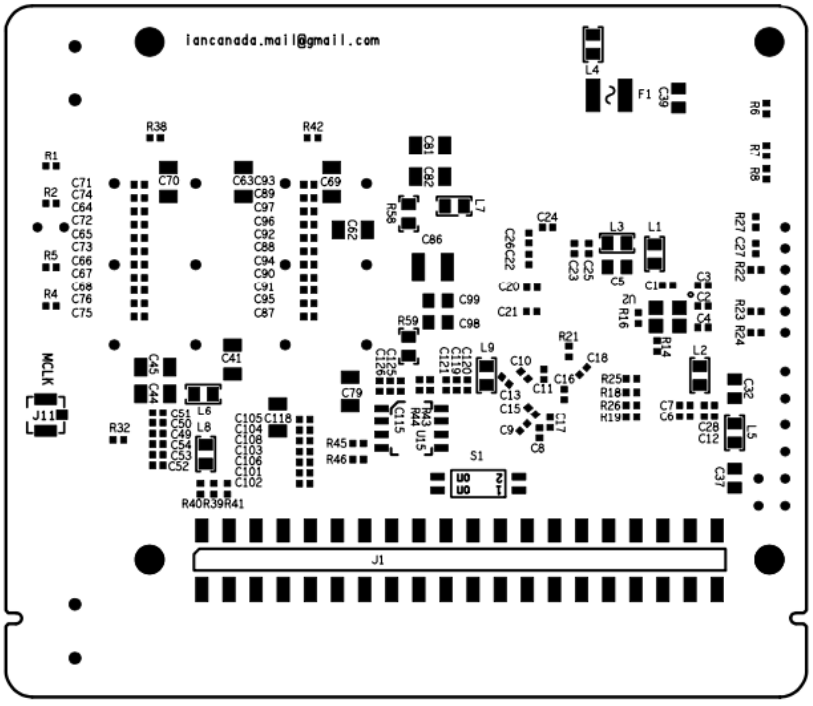
FifoPi is fully compatible with RaspberryPi HAT specifications. It is firmly believed to be one of the most effective solutions to improve sound quality of RaspberryPi based audio applications.

B. Features and Specifications

- All in one FIFO solution with built-in isolator and clock board.
- Up to 768KHz full range PCM format support.
- Native DSD support from DSD64 to DSD1024.
- On-board DoP decoder makes RaspberryPi capable for native DSD play back over GPIO.
- Built-in I2S 16bit to 32bit lossless converter to work with DACs that don't support 16bit I2S format.
- Full rang of XO frequencies supported from 5.6448MHz to 98.3040MHz through a pair of XO sockets.
- Constant delay time for different audio formats and frequencies. Delay time adjustment function is ready for external panel/controller.
- Two isolated DC inputs for both clean power and optional RaspberryPi power from GPIO.
- Additional non-isolated GPIO connector to run DAC controller in isolated mode.
- Works with all RPi DAC HATs and external DACs at synchronized master clock mode to reduce jitter.
- Designed in transparent mode, no Linux driver is required.
- DIY friendly with options and flexibility.

C. Layout and Dimensions (in mm)





D. Getting start

1. Plug the FifoPi on top of RaspberryPi;
2. Plug the DAC HAT on top of FifoPi, or connect to an external DAC through the U.FL connectors;
3. Connect 5V(or 3.3V ultra capacitor/LifePO4 battery direct) to clean DC power to J5;
4. Power ReasberryPi by a 5V DC power from either J3 of FifoPi (into GPIO, recommended) or an USB cable to RPi;
5. Configure DAC HAT as it should be.
6. Enjoy the music.

E. Connectors

J5: Clean isolated DC power input

A 5V-6V DC power supply or 3.3V ultra capacitor/LifePO4 battery direct power supply must be connected to this 2-pin 5.0mm terminal for the FifoPi to operate. It consumes around 100mA average current with normal 45.1584/49.1520MHz XOs. It could be a little bit higher when works with higher frequency XOs. If you use OCXOs or other kind of higher current oscillators, You MUST add the extra current to determine the current output for your power supply. Generally use a supply that provides 200mA as a minimum.

When 3.3V ultra capacitor/LifePO4 battery direct power supply is connected, the internal low noise LDOs will be bypassed automatically.

J3: Optional Raspberry Pi power input

To lower the power supply noise, it's highly recommended to power Raspberry Pi from GPIO through this connector rather than the standard USB power. A 5V 2A DC power is required in this case.

This connector must be kept unconnected if the RaspberryPi USB power is connected.

J6, J11: 2 MCLK outputs in U.FL coaxial cable socket

MCLK output for DAC HAT or external DAC. This signal must be connected if DAC works in synchronized clock mode. The second MCLK output socket is located at the bottom side of PCB.

J8: SCK outputs in U.FL coaxial cable socket

SCK output for external DAC. This signal is shared same as bit clock for both PCM and DSD format.

J9: LRCK/D1 output in U.FL coaxial cable socket

LRCK/D1 output for external DAC. This signal is shared by PCM and DSD format. It will be LRCK for PCM or D1 for DSD.

J10: SD/D2 output in U.FL coaxial cable socket

SD/D2 output for external DAC. This signal is shared by PCM and DSD format. It will be SD for PCM or D2 for DSD.

40PIN GPIO connectors

	J7	J2	J1
PIN#	Isolated GPIO to connect to a DAC HAT on top or other analog devices	Non-isolated GPIO to connect a controller or other digital devices	GPIO to connect to Raspberry Pi
1,17	Isolated 3.3V output	3.3V power supply From Raspberry Pi	3.3V power supply From Raspberry Pi
2,4	Isolated power supply output Internally connected to J5 +	5V power supply From/to Raspberry Pi	5V power supply From/to Raspberry Pi
6,9,14,20, 25,30,34, 39	Isolated GND	GND of Raspberry Pi	GND of Raspberry Pi
3	Isolated I2C DA	I2C DA	I2C DA
4	Isolated I2C CL	I2C CL	I2C CL
12	Isolated SCK output	Non-isolated SCK output	SCK Input
35	Isolated LRCK/D1output	Non-isolated LRCK/D1 output	LRCK Input
40	Isolated SD/D2 output	Non-isolated SD/D2 output	SD Input
All other PINs	Unconnected	Connected to the same GPIO PINs of Raspberry Pi	Connected to the same GPIO PINs of Raspberry Pi

MUTE/GND

Isolated MUTE signal. A logic high output means DAC should be muted. This signal is optional. Most of DACs or DAC HATs don't need this signal.

J4: External Display/Control Panel connector

4pin PH2.0mm connector

1	2	3	4
GND	RXd	5V	TXd

Note1: All input/output signals are in LVTTL (3.3V) logic level

F. Jumper settings

Jumper switch S1 is located at bottom side of PCB.

Jumper Switch S1	OFF (default)	ON
1	DoP decoding is enabled	DoP decoding is disabled
2	Output format keeps as same as original input format	Force 16bit I2S format to be converted into 32bit in lossless

Note2: Some DAC, such as ES9038Q2M, has built-in DoP decoder. If you want to use the internal DoP decondr, you will need to disable FifoPi's DoP decoding function. Otherwise, any DoP stream will be converted into DSD format by FifoPi's internal DoP decoder by default. When DoP decoder is disabled, DoP stream will be treated as PCM format

Note3: Some DAC (for example, some ESS DAC) may have problem with16bit i2S format. If that's the case, you will need to enable the internal 16bit to 32bit converter. This converter doesn't impact to DSD/DoP format, or any non-16bit PCM format. It converts 16bit I2S format into 32bit only. But please keep in mind do not use it for 16bit left justified or right justified format. Please also don't enable this 16 to 32 function for ES9028Q2MPi and ES9038Q2MPi DAC HAT,because they support 16bit PCM originally.

G. LED indicators

Group	LED	Descriptions	Notes
Input status	D5	I2S	Lit when PCM format music is received
	D6	DSD	Lit when DSD format music is received
	D7	DoP	Lit when DoP format music is received and converted into DSD format
Output status	D4	I2S	Lit when FifoPi is outputting PCM format
	D3	DSD	Lit when FifoPi is outputting DSD format
FIFO status	D1	LOCK	Lit when McFIFO is locked with the input music stream
	D2	EMPTY	Lit when McFIFO is empty
XO Selection	D9	XO1	Lit when XO1 is selected for current MCLK
	D8	XO2	Lit when XO2 is selected for current MCLK

H. XO oscillators

There are two XO sockets for XO1 (U13) and XO2 (U7). Both or at least one of them must be installed with proper XO. Standard DIP 3.3V clock oscillators with 14- or 8- pin configurations are good for XO1 and XO2. SMT oscillators are also available by using SMT XO adapters.

XO frequencies have to be selected from the following two frequency groups.

XO oscillator frequency group1		Fs supported				
		44.1KHz DSD64	88.2KHz DSD128	176.4KHz DSD256	352.8KHz DSD512	705.6KHz DSD1024
XO Frequencies can be used *	5.6448MHz	√				
	11.2896 MHz	√	√			
	22.5792 MHz	√	√	√		
	45.1584 MHz	√	√	√	√	
	90.3168 MHz	√	√	√	√	√

XO oscillator frequency group2		Fs supported				
		48KHz	96KHz	192KHz	384KHz	768KHz
XO Frequencies can be used *	6.144MHz	√				
	12.2880 MHz	√	√			
	24.5760 MHz	√	√	√		
	49.1520 MHz	√	√	√	√	
	98.3040 MHz	√	√	√	√	√

Note4: XOs have to be selected from two different frequency groups but don't have to be in frequency pair. For example, a 22.5792 MHz XO can work together with a 49.1520 MHz XO.

Note5: XOs can be plug into any of the two sockets (U1, U6) without problem.

Note6: Single XO can also work for music stream that is within supported Fs.

Note7: Only XO with OE (enable/disable function) PIN can be used for dual XO configuration. Single XO configuration doesn't have this limitation.

I. Tips to improve sound quality

XO Selection

FifoPi improves the sound through XO clocks. So, selecting a really nice pair of low jitter XO oscillators is very important. The two XO clock oscillators supplied with the board are just generic ones. It is strongly recommended to replace them with better clocks to boost the sound quality. The CCHD-957 series XO oscillators from Crystek have been tested and found to be a good choice at a reasonable price. OCXOs with better phase noise performance are highly recommended. Trying different clock oscillators for better sound is an interesting experience.

Power direct from a 3.3V ultra capacitor power or LiFePO4 battery power

To improve the power supply performance and lower the phase noise, it is possible to use 3.3V ultra capacitor power or LiFePO4 battery power directly as a clean isolated DC power. To do so, we just need to connect them into isolated DC input terminal J5. The on-board LDOs will be automatically bypassed internally because of the dropout voltage is lower than the minimal voltage which is around 0.3V.

However, if you really want to bypass on-board LDOs physically, you can simple assemble two 0 OHM 0805 jumper resistors or just piece of wires to the footprints of R58,R59, which are located at bottom side of the PCB. Please keep in mind never use power supply other than 3.3V to avoid any damage to FifoPi and XO oscillators if R58 and R59 were shorted.

XO frequency and the sound

For a given Fs, different XO frequency may make DAC sounding slightly different. It was caused by DAC internal logic configuration. For example, to play a 44.1 KHz audio stream at some DAC chip (not all), with 22.5792 MHz (512Fs) and 11.2896 MHz (256Fs) XO installed on socket, I found the sound stage changed a little bit. And 90.3168/98.3040 MHz XOs sound more wonderful to me than the 45.1584/49.1520 MHz. So please try different XO frequencies according to your personal preference.

Potentials of generic XO clock oscillators

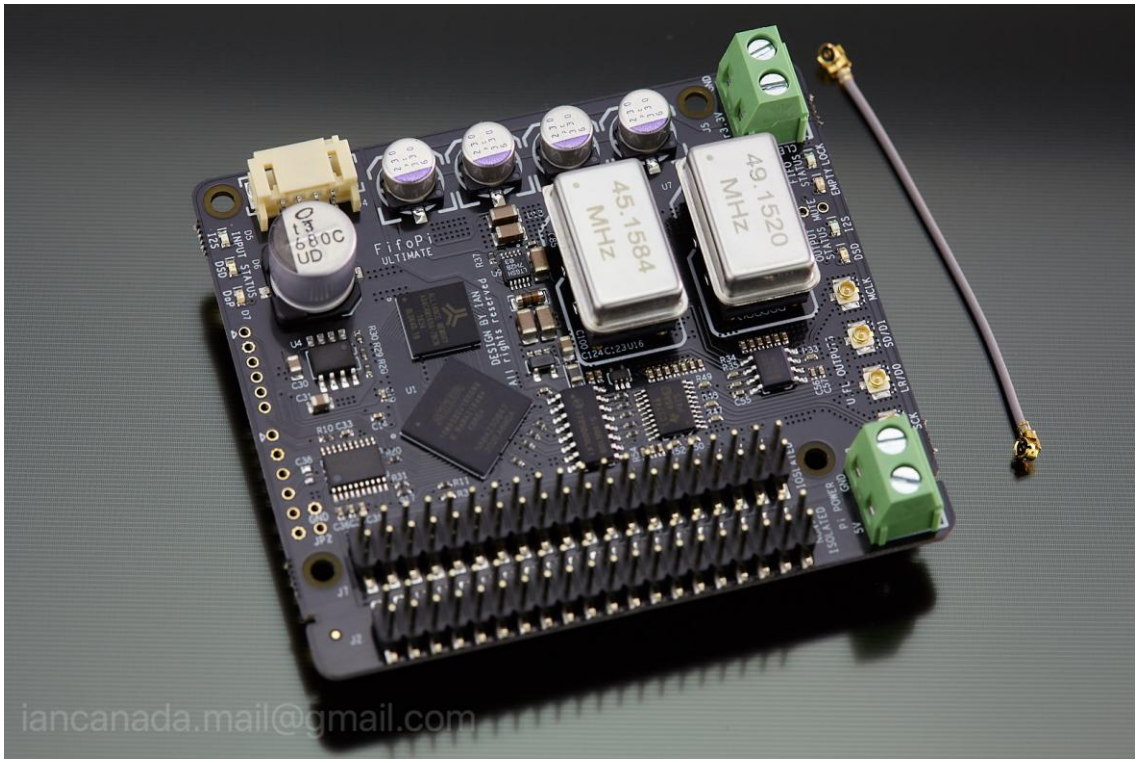
For some generic XO clock oscillators, the internal crystal may not be that bad. The problem is usually that generic oscillators do not have good power supply and driver. In many cases, if fed with a high quality, low noise power supply and interfaced with a low jitter fan-out buffer, they will perform better than originally.

XO warm-up time

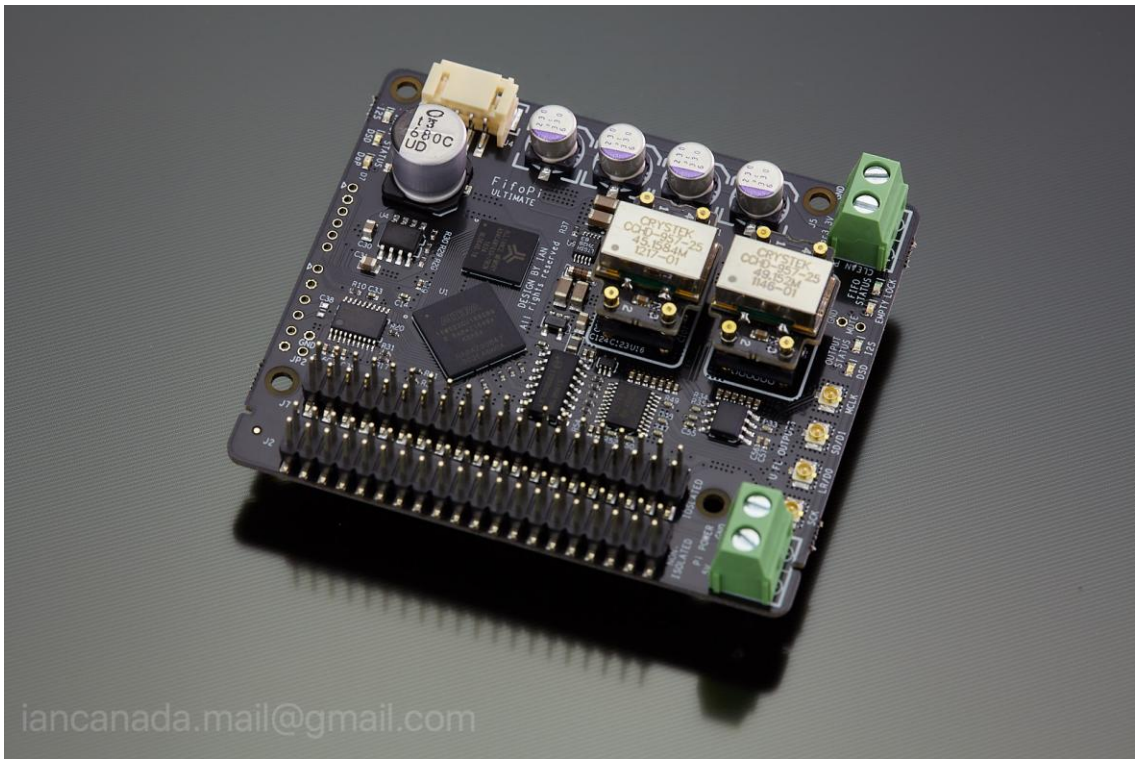
Please keep in mind that all of XO oscillators need warm-up time before really going sweet after power up, from a couple of minutes to half hour (even longer for some of them). So please wait for a while before you making any evaluation.

J. FifoPi picture

1. FifoPi Ultimate



2. FifoPi Ultimate with CCHD975 upgraded



3. FifoPi works with Raspberry Pi