9028Q2MPi ESS DAC HAT user's guide
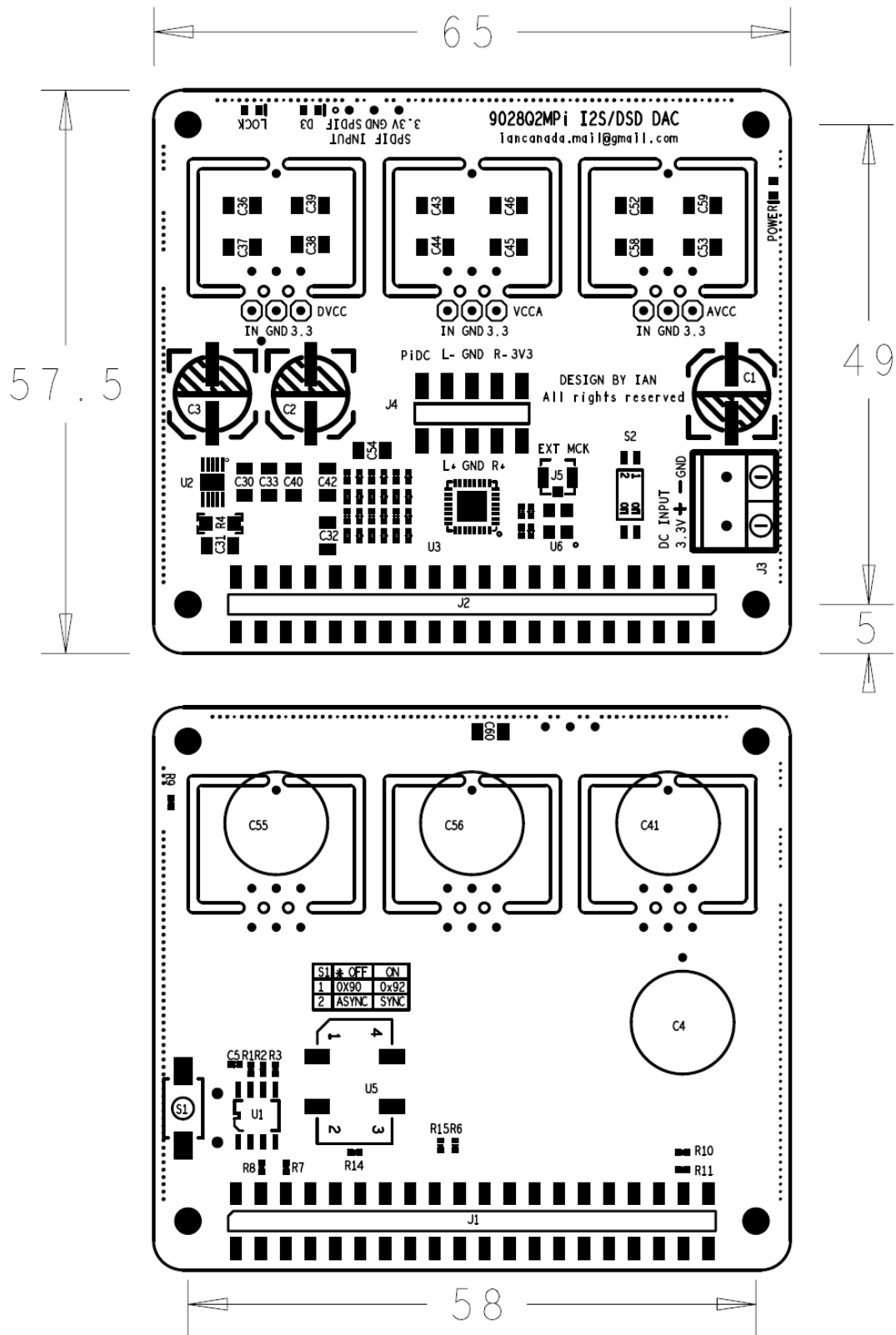
By Ian Jin, Dec 30, 2018 Ver. 1.0a

A. Introduction

9028Q2MPi ESS DAC HAT is an audiophile grade DAC core board for Raspberry Pi. Based on the latest ES9028Q2M SABRE32 reference DAC technologies, it targets the highest possible sound quality and performance for audio DIYers.

B. Highlighted Features and Specifications

- Up to 384KHz 16/24/32 bit PCM, native DSD512, and S/PDIF support.

- Jumper selectable asynchronous and synchronous clock mode.

- 50MHz internal asynchronous clock or external synchronous clock range from 22.5792MHz to 98.3040MHz.

- Works with either external ESS controller or possible Linux driver.

- All register settings can be programmed through the ESS controller or possible Linux driver.

- To eliminate the ground loop and EMI noise, ESS controller or Linux driver can work in isolated mode when FifoPi or IsolatorPi is integrated in system.

- Raw balanced current output makes it much suitable to work with different kind of external I/V solutions. Compatible external I/V stage board can be directly plugged on top of it. Third party I/V stage boards can also be used through the adapter PCB.

- 403 Ohm low output impedance.

- Ready for 3.3V ultra capacitor power supply or LifePO4 battery power supply.

- It is also possible to power AVCC, DVCC and VCCA separately.

- Can automatically switch between PCM, DSD and S/PDIF.

- DIY friendly with a lot of modding and upgrading options.

C. Layout and Dimensions (in mm)

65

57.5

49

5

9028Q2MPi I2S/DSD DAC
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SPDIF INPUT
3.3V GND SPDIF D3
LOCK

POWER

C36 C39
C37 C38
IN GND 3.3 DVCC

C43 C46
C44 C45
IN GND 3.3 VCCA

C52 C59
C58 C53
IN GND 3.3 AVCC

PiDC L- GND R- 3V3

DESIGN BY IAN
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C3 C2 C1

J4

C54

EXT MCK
L+ GND R+

U2 C30 C33 C40 C42
C31 R4
C32

U3 J5 U6 S2

DC INPUT
3.3V + - GND

J3

J2

58

S1 * OFF ON
1 0X90 0x92
2 ASYNC SYNC

C55 C56 C41

C60

C4

C5 R1 R2 R3

U5
1 4
2 3

U1

S1

R15 R6

R10
R11

R8 R7 R14

J1

D. Getting start

1. Plug the 9028Q2MPi ESS DAC HAT on top of RaspberryPi;

2. Plug the I/V board on top of 9028Q2MPi;

3. Plug the ESS controller into GPIO connector J2 (unless have ES9028Q2M Linux driver);

4. Connect 3.3V low noise DC power to J3 (ultra capacitor or LifePO4 battery direct is preferred);

5. Power the Raspberry Pi (with player software installed) as usual. 9028Q2MPi and I/V stage can be powered at same time or before.

6. In the player's setup manual, select general I2S DAC (for hardware based volume control from ESS controller), or PCM5122 compatible DAC (such as Hifiberry DAC+) if you need additional hardware volume control from player UI. Restart the player if it is required.

7. Adjust volume to 0dB or other suitable level at the first time of use. Enjoy the music.

E. Connectors

J3: DC power input
A 3.3V DC power supply must be connected to this 2-pin 5.0mm terminal for the ES9028Q2MPi to operate. Any low noise linear 3.3V power supply is good for this DAC HAT. But direct 3.3V ultra capacitor power supply or LifePO4 battery power supply would be preferred for best possible sound quality. It consumes around 50mA average current with 50MHz MCLK. Generally use a supply that provides 100mA as a minimum.

J5: External MCLK input in u.fl coaxial cable socket
This connector connects to external MCLK signal through u.fl coaxial cable when it's running at synchronized clock mode. Please keep this connector unconnected at asynchronous mode (default).

J4: Fully balanced ES9028Q2M raw output connector
To connect to external I/V stage board.

PIN number	Descriptions
1	NC
2	Pi5V, internally connected to Raspberry Pi GPIO PIN2 and PIN4.
3	L+, Left positive current output
4	L-, Left negative current output
5	GND
6	GND
7	R+, Right positive current output
8	R-, Right negative current output
9	NC
10	AVCC,ES9028Q2M AVCC 3.3V voltage rail

S/PDIF input

To connect to optional optical S/PDIF receiver or other S/PDIF receiver in 3.3V LVTTL logic level.

PIN number	Descriptions
1	SPDIF input
2	GND
3	3.3V power, internally connected to J3

40PIN GPIO connectors

PIN#	J1 40 PIN GPIO connector to connect to Raspberry Pi	J2 40 PIN GPIO connector to other HAT on top of DAC
1,17	3.3V from Raspberry Pi	Connected to the same 3.3V PINs of J1
2,4	5V from Raspberry Pi	Connected to the same 5V PINs of J1
6,9,14,20, 25,30,34, 39	GND	GND
3	I2C DA	I2C DA
4	I2C CL	I2C CL
27	ID DA	ID DA
28	ID CL	ID CL
12	SCK input	Connected to same SCK PIN of J1
35	LRCK/D1 input	Connected to same LRCK/D1PIN of J1
40	SD/D2 input	Connected to same SD/D2 PIN of J1
All other PINs	Connected to same PIN of J2	Connected to same PIN of J1

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

F. Jumper settings

Jumper switch S2 is located at top side of PCB.

Jumper Switch S2	OFF (default)	ON
1	Asynchronous clock mode.	Synchronous clock mode Must have synchronous external MCLK connected to J6 when set at on position
2	I2C address: 0x90	I2C address: 0x92

G. LED indicators

LED	Descriptions	Notes
D2	LOCKL	Lit when left ES9028Q2M DAC U2 is locked to input music signals
D7	POWER	Lit when this DAC HAT is powered

H. Ways to improve sound quality

Run DAC with synchronous clock

It was confirmed that running this DAC with synchronous clock has better sound quality than the default asynchronous mode.   The following steps are needed to switch to this synchronous clock mode:

1. Install a FifoPi between Raspberry Pi and this ES9028Q2M ESS DAC (see FifoPi user's manual for configuration details).
2. Connect the MCLK signal from FifoPi to this DAC by an U.FL coaxial cable. Cable length should be as short as possible.
3. Set pin1 of jumper switch to 'ON' position.
4. Choose a pair of really nice XO for FifoPi according to personal preference. Those XOs will be very important to the sound quality and sound style.
5. Set DPLL bandwidth to lowest level 1 for both PCM and DSD in ESS controller setting manual.

Now, the ESS DAC already has the MCLK that is synchronous to the music signal. So you can enjoy the better quality music from this ESS DAC HAT at synchronous clock mode.

Furthermore, it's also possible to try the true SYNC mode by stopping the DPLL of ESS DAC while works in synchronous mode. To do so, you will need another two more steps:

1. At "Normal/True SYNC mode" setting page, select "True SYNC with DPLL stopped".
2. Set both PCM bandwidth to "No band width 0".

However, this true SYNC mode is not perfect for ES9028Q2M DAC. It supports PCM format only. DSD and DoP are not supported. And MCLK has to be 128FSR. Also lock LED will keep lit if this mode is enabled. It cannot be

guaranteed to work properly if conditions are not met.

Make the ESS controller running isolated from DAC

ESS controller itself has a micro-processor. It could generate EMI noise that impacts the sound quality of DAC. Running it at isolated mode will eliminate all electronic connections between ESS controller and DAC thus stops the noise from being injected into DAC. Much cleaner DAC ground plan will be expected under this configuration.

It's very easy to run the ESS controller at isolated mode. The only thing needs to do is to plug it onto the non-isolated GPIO connector of FifoPi or IsolatorPi.

Power DAC directly from a 3.3V ultra capacitor power or LiFePO4 battery power

To improve the power supply performance, it is highly recommended to use 3.3V ultra capacitor power or LiFePO4 battery power directly to J3 for this DAC. Any LDO or regulator will degrade the performance of passive power supply.

Power voltage rails separately

It is possible to power the three voltage rails separately. To do so, we need to break the three decoupling network daughter boards from the DAC PCB first by using a side cuter. Then feed three independent 3.3V power supplies to PINs of DVCC/GND, VCCA/GND and AVCC/GND.   3.3V ultra capacitor power and LiFePO4 battery power supply are always preferred.

Try best suitable I/V stage boards and XLR balanced analog output

I/V stage boards are also very important to sound quality. Different I/V solution can play music in different style. Standard op-amplifier I/V stage, transformer I/V stage, OPA861 I/V stage, discrete I/V stage and so on, they all sound differentially. Please choose the best suitable one for this DAC according to personal preference. Also try to use the balanced analog output from XLR connectors on I/V board. In most of the cases, balanced output has better sound quality than the SE output.

Try best suitable register settings

Many of register settings can be programmed form the ESS controller. Such as DPLL bandwidth for both PCM and DSD format, seven preset FIR filters, OSF bypassing, IIR bypassing. Please try the best suitable register settings according to the real listening test. Please see ESS controller user's manual for details.

I. Other options to upgrade

Assemble optional on-board super capacitors

It is possible to assemble some optional small super capacitors to this DAC HAT

Reference	Description	package	Location	Notes
C4	Footprint of optional super capacitor for DC input J3	Dimension 11.5mm Through Hole	Bottom Side of PCB	Rated voltage must be higher than the power supply voltage. Normally 5.5V
C41	Footprint of optional super capacitor for DVCC			
C56	Footprint of optional super capacitor for VCCA			
C55	Footprint of optional super capacitor for AVCC			

Use 3.3V low noise regulators

It is possible to use three 3.3V low noise regulators for DVCC, AVCC and VCCA if don't use 3.3V passive power supply.

To do so, we need to break the three decoupling network daughter boards first from the DAC PCB by using a side cuter. Then assemble three same size low noise LDO boards at the same position. LT3042/LT3045 low noise regulator board would be recommended for this application. DC input voltage (J3) needs to be 5V or higher according to the LDO boards under this configuration.

Upgrade on-board XO

It is possible to upgrade on-board XO with a higher grade low jitter one. Both 50MHz and 100MHz can be used. 100MHz CCHD950 or equivalent is recommended. To do so, we need to remove the old XO U5 first, and then assemble the new XO to footprint U4 at bottom side of PCB.

Note2: No need to upgrade the on-board XO if you run this ES9028Q2M ESS DAC HAT at sync mode with external MCLK.

J. ES9028Q2Mpi DAC HAT picture

1. ES9028Q2Mpi DAC HAT
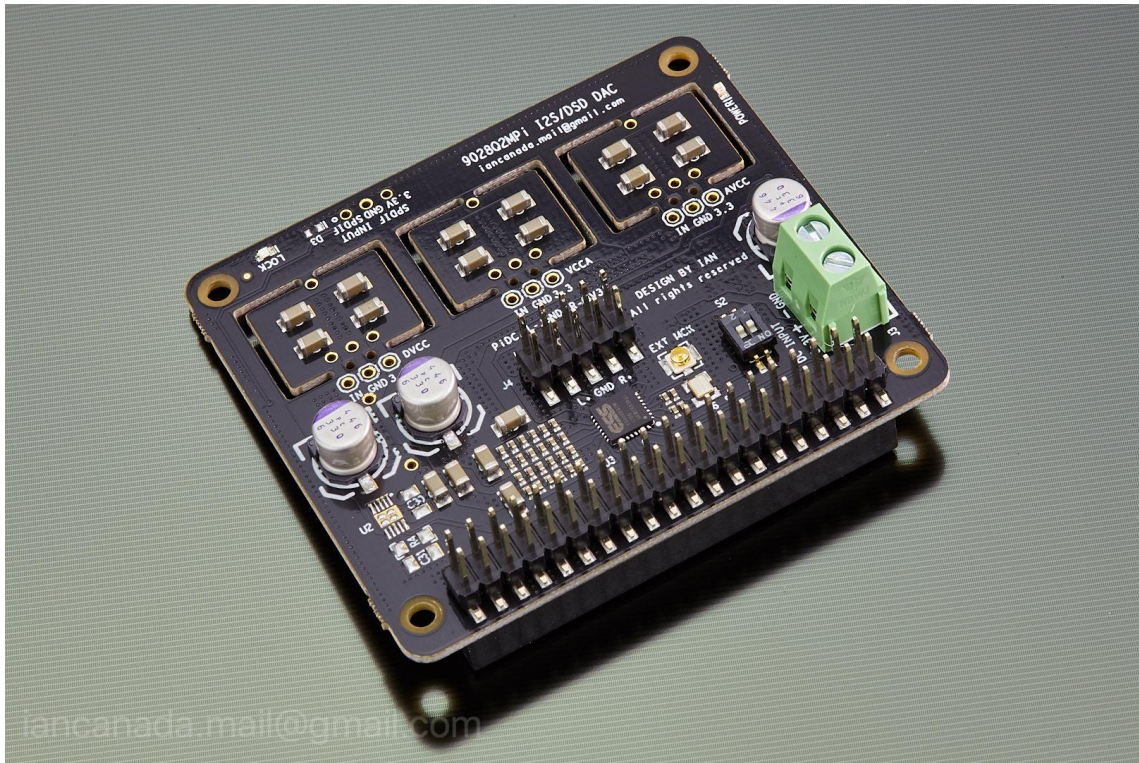
2. Getting start with asynchronous mode (default)

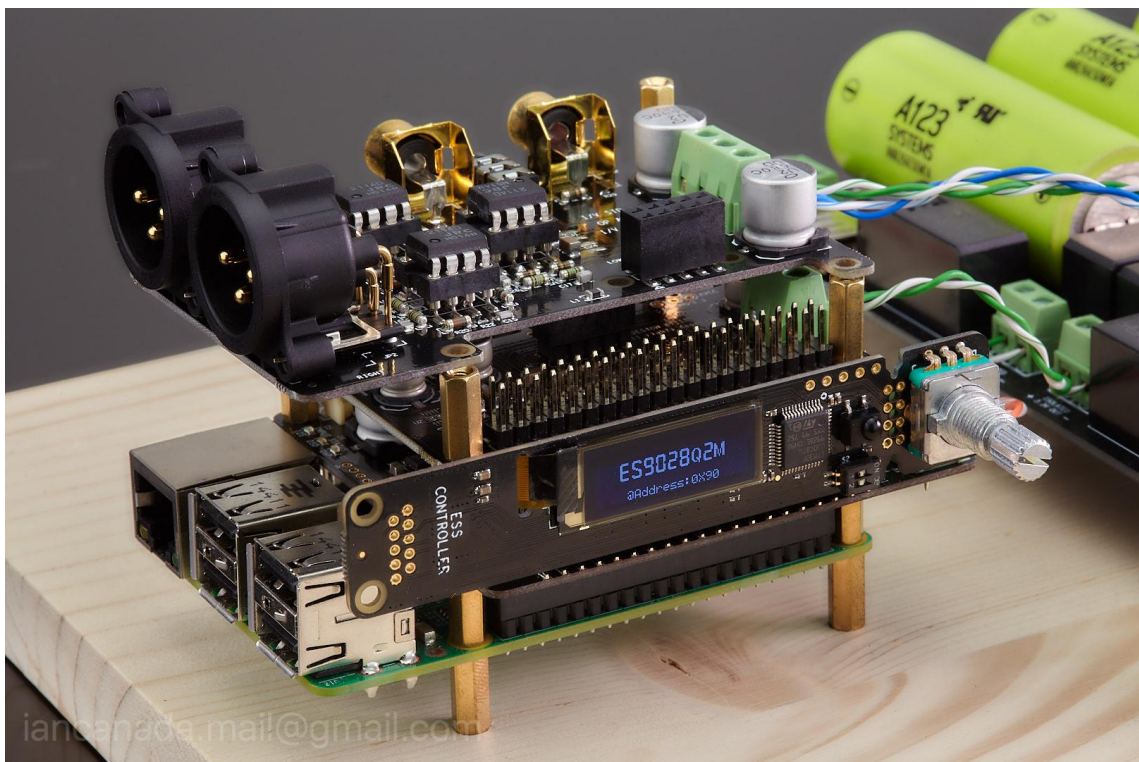   Raspberry Pi + ES9028Q2Mpi DAC HAT + ESS controller + I/V board

3. Run it at isolated asynchronous mode

   Raspberry Pi + IsolatorPi II + (DoP decoder) + ESS controller + ES9028Q2Mpi DAC HAT + I/V board

4. Run this DAC HAT at synchronized mode (highly recommended for best possible sound quality)

   Raspberry Pi + FifoPi + ESS controller + ES9028Q2Mpi DAC HAT + I/V board

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