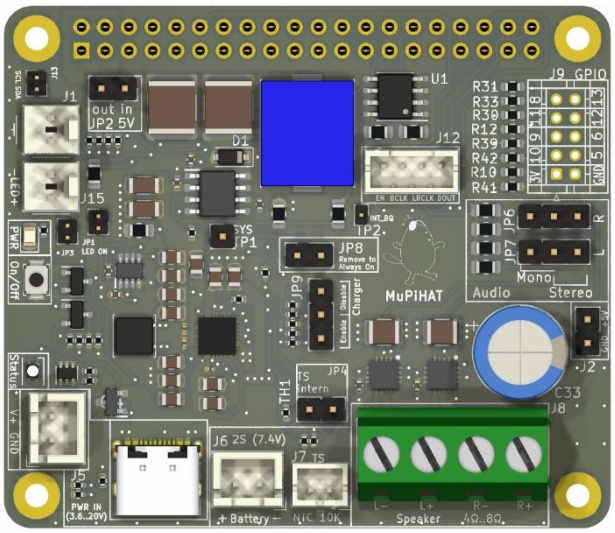
Raspberry Pi – Audio & Power Supply HAT designed for MupiBox

MuPiHAT – Raspberry Pi HAT

Audio Amp – Power Management – Battery Charger

The MupiHAT is one single RPI Hardware-Attached-on-Top (HAT) embedding all functions needed to build a battery supplied Music Player – ideally for building a MuPiBOX (www.mupibox.de) with smallest footprint

- Wide Power Input Range 3.6V to 20V via USB-C or PinHeader
- Supplies the Raspberry Pi
- Fully integrated charger for Lithium Batteries with Protection Features
- On/Off Shim Function Push-Button Power-On and clean RPI shutdown
- 2 x 3 W Class-D Audio Amplifier 4-8 Ohm Speakers
- 8 GPIO via PinHeader for connecting auxillaries or LEDs



Born to be used as an *All-in-One HAT* to support easy Plug & Play Hardware for building up the Kids Music Player ***MupiBox*** (www.mupibox.de) or any other similar device, it features Audio Amplifier, On-Off Controller, Battery Charger and GPIO extensions.

The ***Audio Amplifier*** is built of two times the tiny MAX98357A digital pulse-code modulation (PCM) input Class D amplifier, configurable either as single Mono or Stereo amplifier with up to 2 x 3W Output Power for use with 4Ω or 8Ω speakers.

The ***On-Off Controller*** handles a clean power-up and power down by usage of LTC2954 Push Button On/Off Controller with Interrupt signal to the Pi for triggering shut-down and Kill signal from the Pi when shut down is completed. One onboard Push-Button is mounted and any external Push-Button can be connected on a pin header. The pin header provides also an GPIO output to drive an LED.

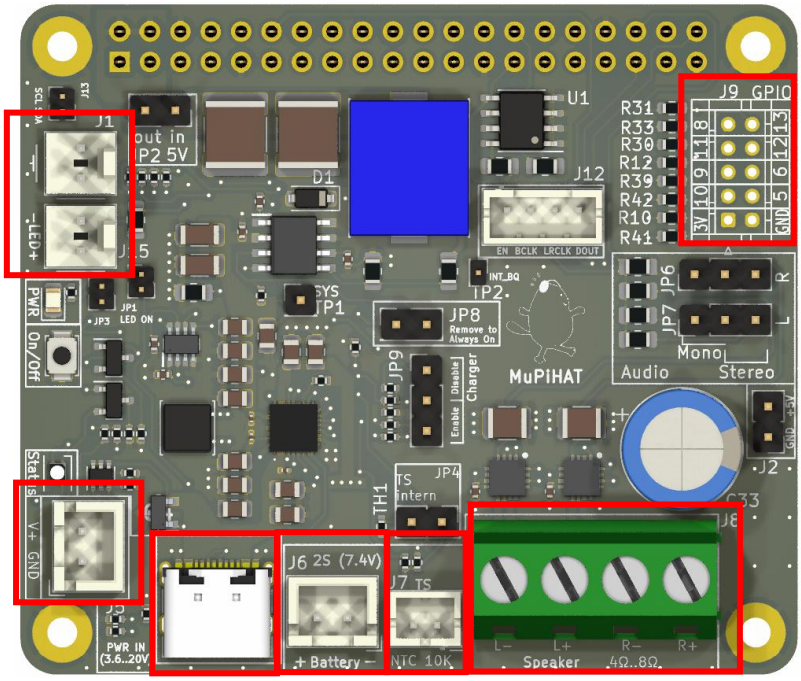
The ***Battery Charger*** is based on TI BQ25792 chip features fully integrated switch-mode buck-boost charger for 1-4 cell Li-ion batteries and Li-polymer batteries, fixed to 2-cell (2S) on MuPiHAT.
The Battery Charger works with a wide range of power input sources and delivers a regulated system power which is converted into 5V supply for the HAT and the Raspberry Pi.

The BQ25972 is controlled via I^2C enabling the software to get full control of battery management and status acquisition, such as monitoring supply and battery voltage, drawn current and charger status.

Eight ***GPIO***s are available on a pin header with series resistors to protect the Raspberry Pi.

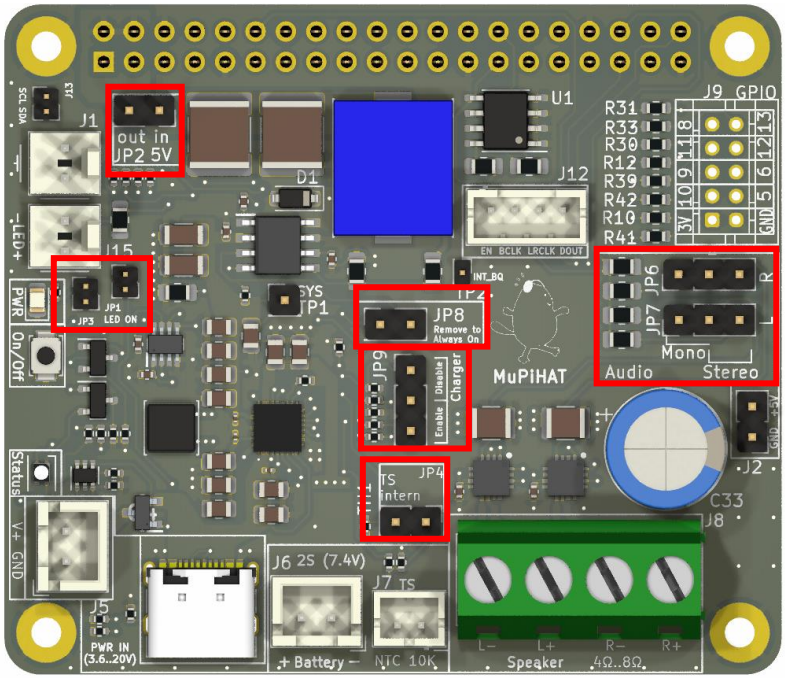
Connectors

Connector	Function	Connector Type	Remark
J1 **J15**	Push Button LED	1x2P x 2.54mm, Molex KK, 0022232021 1x2P x 2.54mm, Molex KK, 0022232021	Push to Power On RPI Push short to shut down Push >6sec to hard switch-off Connect LED of Push Connector
J2	5V Output	1x2P x 2.54mm (not assembled)	
J4	USB-C Power IN	USB Type C	3.6V to 20 V 5V recommended
J5	Power IN	JST XH Type, B2B-XH-A, 1x02P 2.50mm Vertical	3.6V to 20 V 5V recommended Reverse Polarity Protected
J6	Battery Power	JST XH Type, B2B-XH-A, 1x02P 2.50mm Vertical	7.4 V (2-cell in series) Protected Cells recommended
J7	Battery Thermal Sensor	JST PH Type, B2B-XH-A, 1x02P 2.00mm Vertical	Thermal Sensor (NTC 10K) Input for Battery Pack Overheat Protection Not needed is JP4 set
J8	Speaker	1x4P Screw Terminal 5.08mm, DB128L-5.08-4P	Connect 4Ohm or 8Ohm Speaker
J9	GPIO	JST PHD Type, B10B-PHDSS, 2x05P 2.00mm	8 GPIO from RPI 3.3V + GND
J10	Raspberry PI Connector	Pin Socket 2x20S 2.54mm	RPI 40Pin Connector
J12	*I2S*	*I2S – Audio / Digital Lines*	*Test Connector to sniff I2S*
J13	*I2C*	*I2C – SDA/SCL*	*Test Connector to sniff I2C*



Jumper Settings

Connector	Function	Default Configuration	
JP1	Enable Status LED	Closed	Open to Disable LED
JP2	5V Power to RPI	Closed	Open to cut power to RPI
JP3	Enable Power LED	Closed	Open to Disable LED
JP4	Internal Thermal Sensor	Closed	Open to use external Battery Pack Thermistor
JP6	Mono/Stereo Right	See Audio Configuration	
JP7	Mono/Stereo Right	See Audio Configuration	
JP8	On/Off Shim Enable	Closed	Open to Disable On/Off Shim Function and always have 5V Enabled
JP9	Charger Enable/Disable	Enabled	Set to Enable or Disable Battery Charger. If no battery pack is connected, set to DISABLE



Electrical Characteristics

Absolute Maximum Ratings

Operation beyond the following rating may destroy the function and in bears a safety risk.

		Min	Max	Unit
Voltage range (with respect to GND)	Connector J4 (USB-C Power In)	3.6	20	V
	Connector J5 (2P Power In)	3.6	20	V
	Connector J6 (Battery)	-0.3	8.7	V
Temperature	Ambient Temperature	-10	65	°C

Raspberry-PI - Pin Out

MuPiHAT	Raspberry	NAME	PIN		NAME	Raspberry	MuPiHAT	
		3.3V	1	2	5V		5.0 V Supply	GPIO
I2C.SDA	*I2C, SDA1*	GPIO 2	3	4	5V		5.0 V Supply	ON_OFF
I2C.SCL	*I2C, SDL*	GPIO 3	5	6	GND			AUDIO
KILL_N	*GPCLK0*	GPIO 4	7	8	GPIO 14	*UART_TXD*		I2C/Battery
		GND	9	10	GPIO 15	*UART_RXD*		HAT EEPROM
INT_N		GPIO 17	11	12	GPIO 18	*PWM0*	BCLK	Power
INT_BQ_N		GPIO 27	13	14	GND			
		GPIO 22	15	16	GPIO 23			
3.3V		3.3V	17	18	GPIO 24			
GPIO	*SPI_MOSI*	GPIO 10	19	20	GND			
GPIO	*SPI_MISO*	GPIO 9	21	22	GPIO 25		LED_POWER	
GPIO	*SPI_CLK*	GPIO 11	23	24	GPIO 8	*SPI_CE0_N*	GPIO	
-		GND	25	26	GPIO 7	*SPI_CE1_N*		
EEPROM_SDA	*I2C_SDA*	ID_SD	27	28	ID_SC	*I2C_SCL*	EEPROM_SCL	
GPIO		GPIO 5	29	30	GND			
GPIO		GPIO 6	31	32	GPIO 12	*PWM0*	GPIO	
GPIO	*PWM1*	GPIO 13	33	34	GND			
LRCLK		GPIO 19	35	36	GPIO 16		AUDIO_EN	
		GPIO 26	37	38	GPIO 20			
		GND	39	40	GPIO 21		DOUT	

Raspberry Pi Configuration

The following modifications need to be done within */boot/config-txt*

```
#-------I2C-------------
dtparam=i2c_arm=on
dtoverlay=max98357a,sdmode-pin=16
```

I2C must be enabled. Check if enabled with:

```
ls /dev/i2*
```

You should get:

```
/dev/i2c-1
```

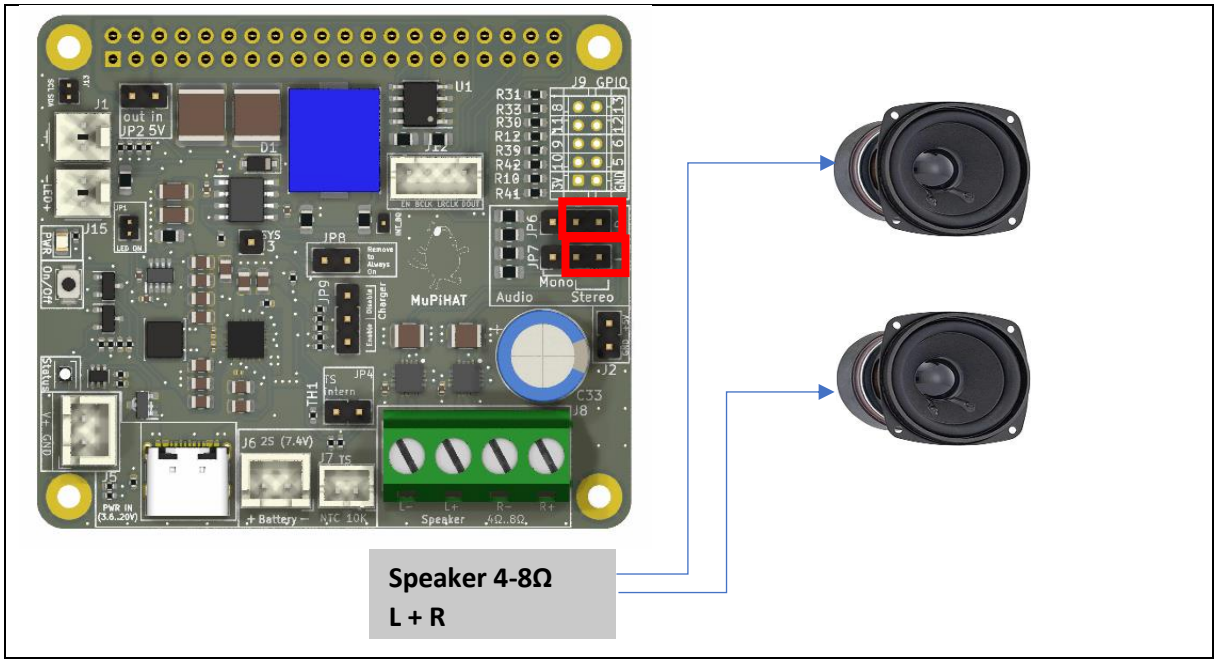
Audio Device

The HAT has two audio amplifiers. It uses the MAX98357A digital pulse-code modulation (PCM) input Class D amplifier, configurable either as single Mono or Stereo amplifier with up to 2 x 3W Output Power for use with 4Ω or 8Ω speakers.

Gain is fixed to 12dB.

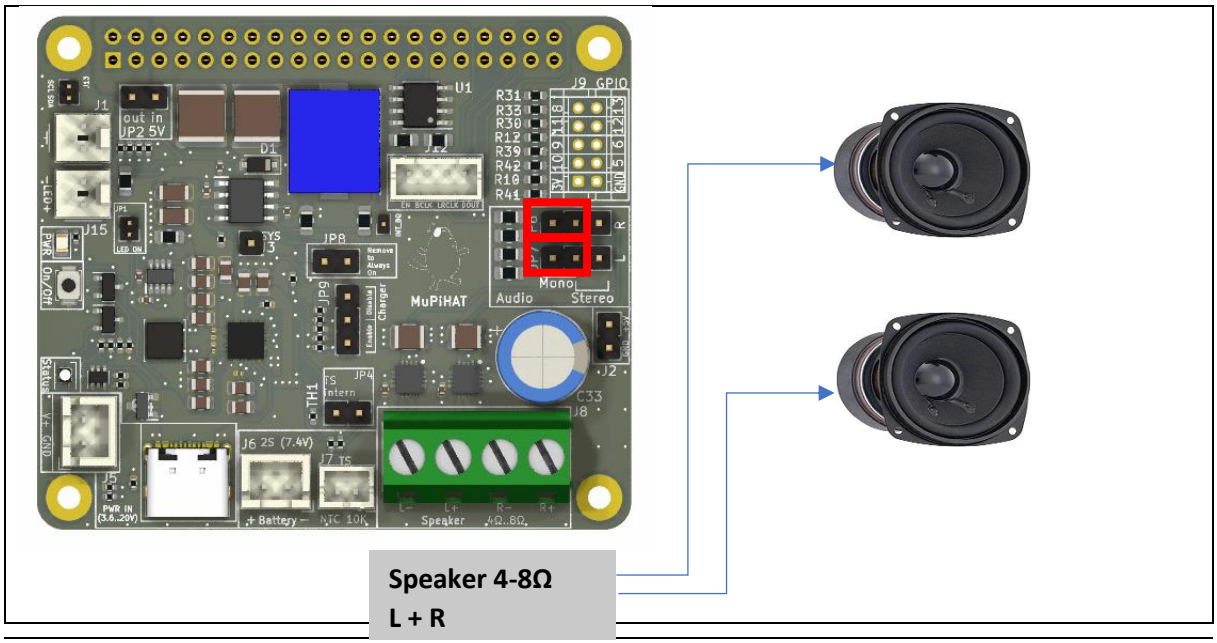
Configuration of Stereo or Mono is done via JP6+JP7.

Stereo Configuration



Mono Configuration

Mono Configuration with one or two speakers is possible.



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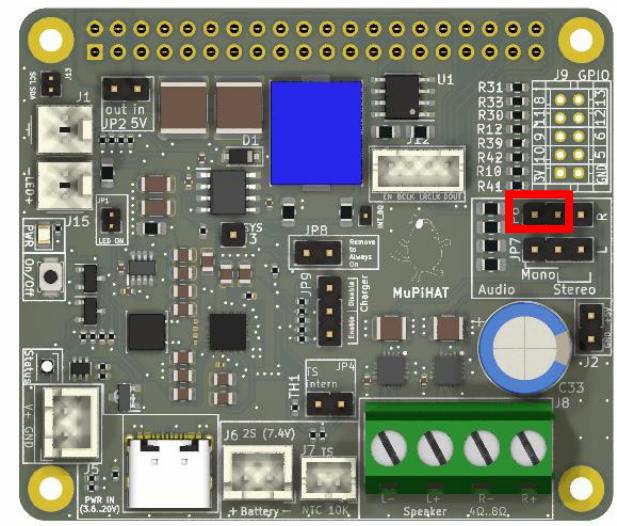


Speaker 4-8Ω
L + R

Battery Charger

The HAT implements a battery charger chip solution from Texas Instruments. The data sheet can be found here on https://www.ti.com/lit/gpn/bq25792. In the following a short description of the charger function as implemented on the HAT is provided.

Safety Considerations

Use of Li-Ion Battery may bear safety risks. The HAT has been designed to consider a reasonable level of safety protection, yet it is only a part of the system and no all combination of HAT + Battery pack can be guaranteed to be safe.

The HAT has following safety protection features implemented:

- Over-Current Protection on BAT input by dedicated PPTC Fuse
- Thermal regulation and thermal shutdown (if external thermistor is properly connected)
- Input/battery Over-Voltage Protection
- Input/battery Over-Current Protection
- Charging Safety Timer

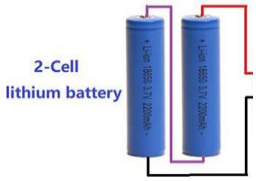
	**The HAT has NO over-discharge protection. It is therefore recommended that Battery / Battery Packs with internal over-discharge protection are used.** **The HAT has NO cell balancing implemented. It is therefore recommended that only Battery / Battery Pack with same type and same properties are used in one pack.**

Compatible Battery Configuration

The Hat is designed to work with 7.4V nominal battery input. Therefore only a 2-cell series of 18650 Li-Ion battery is compatible with the charger.

A typical capacity achievable with 2 x 18650 (2S1P Configuration) is 7.4V x 3500mA, e.g with XTAR-18650 (https://www.akkuteile.de/lithium-ionen-akkus/18650/xtar/xtar-18650-protected-3-7v-a-3500mah_100633_1234). With this, approximately 4hrs of operation with MuPiBox playing could be achieved with a real-word test.

For longer duration, a 2x2 18650 (2S2P Configuration) is possible as well, e.g. this one: https://www.pollin.de/p/ansmann-liion-akku-2447-3049-2s2p-7-4-v-5200-mah-272279. With this, approximately 8hrs of operation with MuPiBox playing could be achieved with a real-word test.

	**ONLY Li-Ion Configuration with 2-Cell in Series (2S) –> 7.4 V Nominal Voltage** 

Charger Operation

When battery charging is enabled (JP9), the device autonomously completes a charging cycle without host (SW) involvement.

The device charges the battery in five phases: trickle charge, pre-charge, constant current, constant voltage, and top-off trickle charging (optional). At the beginning of a charging cycle, the device checks the battery voltage and regulates current/voltage accordingly.

The STATUS LED indicates the charging status of:

- charging (RED),
- charging complete or charging disabled (GREEN) or
- charging fault (Blinking).

The charger automatically terminates the charging cycle when the charging current is below termination threshold (200mA default).

The device has a built-in safety timer to prevent an extended charging cycle due to abnormal battery conditions.

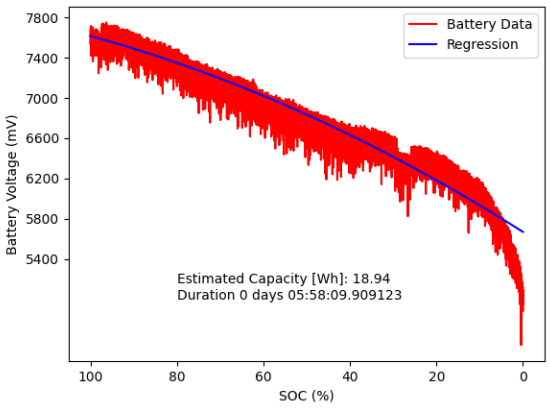
To improve the safety of charging Li-ion batteries, JEITA guideline was released on April 20, 2007. The guideline emphasized the importance of avoiding a high charge current and high charge voltage at certain low and high temperature ranges. The BQ25792 chip follows these guidelines.

Charger Monitoring and State-of-Charge (SOC)

The device has an integrated 16-bit ADC to provide the user with critical system information for optimizing the behavior of the charger.

By monitoring the battery voltage a coarse information of the battery state of charge can be calculated.

Below an example of a real-word test with 2xXTAR Li-ION batteries.



Python Support

A python class and python script is soon available to access the charger IC's I2C registers. With this information of voltages and currents and registers can be accessed. Below an example screenshot:

```
*** Timestamp:  2024-01-07 21:08:05.811387
hat.REG1C_Charger_Status_1:                Fast charge (CC mode)
hat.REG31_IBUS_ADC.IBUS [mA]:              1381
hat.REG33_IBAT_ADC.IBAT [mA]:              172
hat.REG35_VBUS_ADC.VBUS [mV]:              4857
hat.REG37_VAC1_ADC.VAC1 [mV]:              4856
hat.REG39_VAC2_ADC.VAC2 [mV]:              4849
hat.REG3B_VBAT_ADC.VBAT [mV]:              7442
hat.REG3D_VSYS_ADC.VSYS [mV]:              7522
```