DEVELOPMENT BOARD

HELIKE UA-E3010 | USER MANUAL

U SOUND

Helike is a development board for assessing multiple USound MEMS speaker-based products for rapid prototyping. The evaluation board is designed to function in three modes — standalone, as USB audio device (UAC 2.0) or as an extension board to a Raspberry Pi platform with 40 Pin GPIO interface. Helike also contains a set of amplifiers to drive two MEMS speakers and two electrodynamic speakers along with multiple supply options.

FEATURES

- Standalone mode (SD card playback)
- USB Audio Device (UAC 2.0)
- Raspberry Pi platform via I2S interface
- Multiple supply options, depending on the availability and application
- Compatible with several USound audio products
- 2 x MEMS amplifiers
- 2 x electrodynamic speaker amplifiers
- Digital audio equalizer
- Dynamic compression algorithm for MEMS
- SD-Card slot
- Joystick for playback control

Helike UA-E3010 | User manual
Released in November 2020
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1. OVERVIEW

MEMS speakers offer a series of advantages compared to traditional electrodynamic speakers. The Helike development board enables evaluation of USound MEMS speakers and the following USound extension kits:

Extension kits	Description	Connector
Dione Maxi UY-R3020	Bendable MEMS speaker array with external amplifier board	Dione Maxi connector
Dione Mini Coming soon UY-R3010	Bendable MEMS speaker array with integrated amplifiers, extendable	Dione Mini connector
Carme 3.0 UJ-R1030	Speaker box designed for testing the performance of MEMS speakers	2.54 mm header from MEMS amp
Sentia 2.0 Coming soon UE-R3020	In-ear earphones using MEMS speakers	2.54 mm header from MEMS amp
Danube 5.0 UAM-R2050	Audio module combining a MEMS tweeter and an electrodynamic woofer in a 2-way system	2.54 mm header from MEMS and electrodynamic amp
Carme 4.0 Coming soon UJ-R1040	Speaker box designed for testing the performance of round MEMS speakers	2.54 mm header from MEMS amp

Table 1: Helike compatible USound products and the corresponding connectors

2. REQUIRED ADDITIONAL PARTS

The Helike development board is delivered with a micro SD-card that can be used to store filter coefficients and audio files for reproduction. Note that the micro SD-card is empty when delivered, and the user must place the desired files (media, filter coefficients).

Depending on which of the above products will be tested, the corresponding extension kit must be acquired separately.

3. PCB LAYOUT

Figure 1 and Figure 2 show the component placement on the PCB.

3.1. TOP LAYER

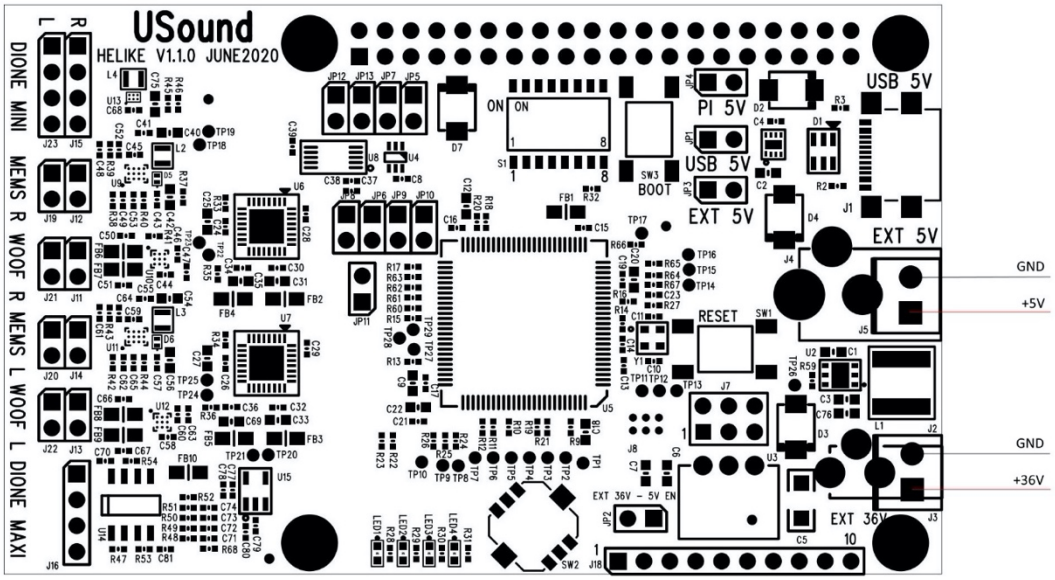

Figure 1: Component placement on the top layer of the PCB

3.2. BOTTOM LAYER

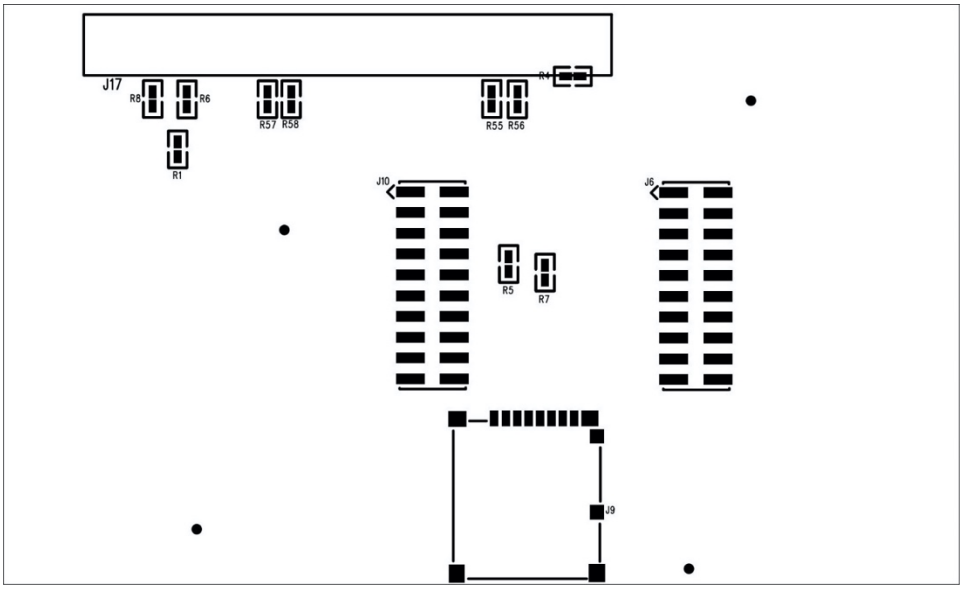

Figure 2: Component placement on the bottom layer of the PCB

4. SUPPLYING THE HELIKE BOARD

The Helike board has four supply options for the microcontroller and its peripherals: USB, 5V external, 36 V external and 5 V via Raspberry Pi header. The used supply input depends on the user's preference and the used output device. Figure 3 shows the block diagram of the supply lines in the Helike development board.

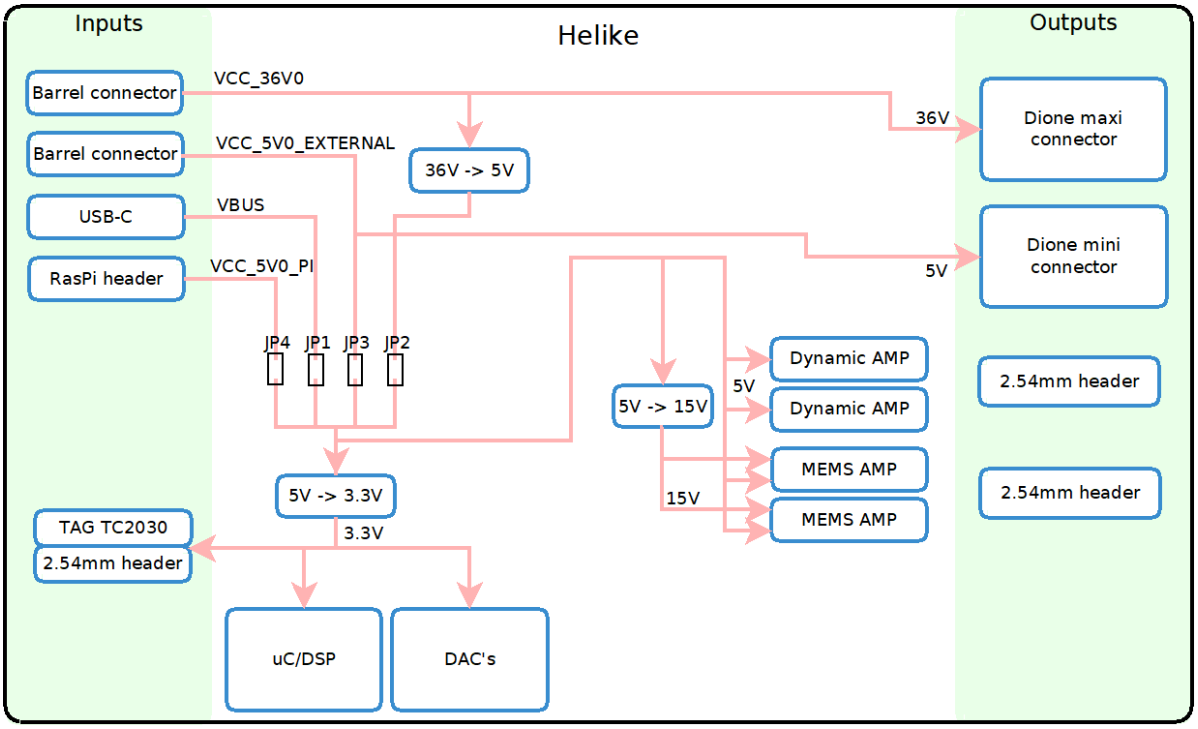

Figure 3: Helike supply block diagram

Jumpers JP1, JP2, JP3 and JP4 are used to select the power supply. Note that only one of these jumpers should be set exclusively.

The used output device dictates the power consumption of Helike. Check Table 2 to see which output device can be used in conjunction with which power supply and the limits that apply.

Supply/Device	VBUS USB-C (3A @5 V)	VCC_36V0 from barrel connector	VCC_5V0_EXTERNAL from barrel connector	VCC_5V0_PI RasPi header
Dione Maxi	No	Yes [1]	No	No
Dione Mini	No	No	Yes [2]	No
Carme 3.0	Yes [3]	Yes [3]	Yes [3]	Yes [3]
Sentia 2.0	Yes [4]	Yes [4]	Yes [4]	Yes [4]
Danube 5.0	Yes [5]	Yes [5]	Yes [5]	Yes [5]
Carme 4.0	Yes [6]	Yes [6]	Yes [6]	Yes [6]

Table 2: Helike supplies and compatible products

1) The copper lines of VCC_36V0 are dimensioned for currents of 2A. One Dione Maxi sound stripe — in conjunction with an Amalthea amplifier, has a worst-case current consumption of 275mA (20 kHz). Providing that the power supply can source sufficient current, up to seven Dione Maxi sound stripes can be attached to the outputs.

2) The copper lines of VCC_5V0_EXTERNAL are dimensioned for currents of 10A. Dione Mini has a worst-case current consumption of 900mA (per segment, 20 kHz). Providing that the power supply can source sufficient current, up to ten Dione Mini segments can be attached to the outputs. In a typical use case, the current drawn by one Dione Mini segment should not exceed 21 mA.

3) A Carme 3.0 speaker box has a worst-case current consumption of 180 mA (20 kHz). Providing that the power supply can source sufficient current, up to eight Carme speaker boxes can be attached to the outputs (four per amplifier).

4) Up to two Sentia 2.0 earphones can be connected to Helike.

5) Up to four Danube 5.0 audio modules can be connected to Helike.

6) Up to four Carme 4.0 can be connected to Helike.

For high current applications (>2A on VCC_5V0_External and >2.5A on VCC_36 V) replace the respective coaxial connectors with screw terminals. The respective THT holes are in place underneath the barrel connectors. TE Connectivity PN 282836-1 are recommended.

4.1. USB SUPPLY

To supply the Helike PCB via the built in USB-C connector, set a jumper to location JP1. Ensure that no jumper is set at JP2, JP3, or JP4.

The Helike PCB is configured as USB slave device with a current draw of up to 3A. When using the USB supply scheme, ensure that the host device (computer, phone, power bank...) can supply this current.

4.1. EXTERNAL 36 V SUPPLY

The Helike PCB can be supplied externally with a voltage of 36V on the barrel connector J4. JP2 needs to be set to select this supply. An onboard DCDC converter is used to provide the suitable voltages to the microcontroller and peripherals.

The 36V external supply is intended for use in conjunction with the Dione Maxi output device. The necessary Amalthea amplifier can then be directly supplied with power via the Dione Maxi output connector (J16).

4.1. EXTERNAL 5 V

The 5V external supply is activated by setting jumper JP3 and connection the supply on connector J2. Using this supply is mandatory when Dione Mini is used as output device.

4.1. 5 V SUPPLY FROM EXPANSION HEADER

5V can be supplied from the RaspberryPi expansion header (J17 Pin 2 and 4). This is achieved by setting jumper JP4. A minimum current of 500mA is required.

5. AUDIO INPUT CONFIGURATION

The Helike evaluation board has two input configuration options:

In **standalone mode** the I2S clocks are generated by the STM32 microcontroller and audio signals can be input via the USB-C connector (soundcard) or by reading audio files from an SD card.

In **slave mode**, the input comes from a RaspberryPi or another I2S source and is forwarded by the STM32 microcontroller to the DAC converters.

5.1. STANDALONE MODE

The standalone mode is selected by setting the DIP switch S1 position 8 (S1-8) to OFF. In standalone mode, the STM32 is the master on all I2S clocks and the SD-card or the USB input can be selected as audio sources.

To use the standalone mode, the jumpers and solder bridges must be set according to Table .

Name	Status
JP5	Removed
JP6	Removed
JP7	Removed
JP8	Removed

Name	Status
JP9	Removed
JP10	Removed
JP11	Inserted
JP12	Removed

Name	Status
JP13	Removed
R4	Irrelevant
R5	Irrelevant
R6	Irrelevant

Table 3. DIP switch positions for sampling rate selection.

Name	Status
R7	Irrelevant
R8	Irrelevant

Table 6: Jumper and solder bridge settings for standalone mode

5.1.1. SD-card

To select the SD-card as audio source set the DIP switch S1 position 7 (S1-7) to OFF. Mp3 and WAV files which are stored on the SD-card will be reproduced automatically. Note that the sampling rate of 48 kHz must be set according to the sampling rate that the files provide.

5.1.1. USB input

To select the USB input as audio source, set the DIP switch S1 position 7 (S1-7) to ON. When Helike is connected to a computer via the USB-C connector it will appear in the operating system as a stereo soundcard. Select the soundcard and reproduce audio content from the host device.

5.1. SLAVE MODE

The slave mode is selected by setting the DIP switch S1 position 8 (S1-8) to ON. In slave mode, the STM32 receives I2S audio data and clocks from a source device such as a RaspberryPi.

To use the slave mode, the jumpers and solder bridges must be set according to Table 4.

Name	Status
JP5	Removed
JP6	Removed
JP7	Removed
JP8	Removed
JP9	Removed

Name	Status
JP10	Removed
JP11	Irrelevant
JP12	Inserted
JP13	Inserted
R4	Connected

Name	Status
R5	Connected
R6	Connected
R7	Connected
R8	Connected

Table 4: Jumper and solder bridge settings for slave mode

5.1.1. I2S input

I2S data can be input to Helike via header J17. The pinout matches the RaspberryPi 40 pin header and can be seen in the schematics. Helike expects audio data in I2S format with the following specifications:

- BTCLK = 1.536 MHz
- FSCLK = 48 kHz and the falling edge occurs before the first data bit
- Data must be MSB-first and is strobed on the rising edge of the bit clock

6. OUTPUT CONFIGURATION

Helike supports multiple USound output devices. The full list of compatible devices is shown in Table 1.

Depending on the desired output device, the DIP switches S1-1 thru S1-4 need to be set accordingly. This ensures that the correct filters files are loaded from the SD-card, and hence that optimal sound quality is reached for the corresponding device. Table 5 shows the diff DIP switch position options.

S1-1	S1-2	S1-3	S1-4	SD configuration file	USound Device
Off	Off	Off	Off	N.A	Passthrough (default)
Off	Off	Off	On	config-1.bin	Dione Mini coming soon
Off	Off	On	Off	config-2.bin	Dione Maxi
Off	Off	On	On	config-3.bin	Danube 5.0
Off	On	Off	Off	config-4.bin	Carme 3.0 box
Off	On	Off	On	config-5.bin	Sentia 2.0 coming soon
Off	On	On	Off	config-6.bin	Carme box 4.0 coming soon
Off	On	On	On	config-7.bin	Danube 5.0
On	Off	Off	Off	config-8.bin	Available for user/custom configuration
On	Off	Off	On	config-9.bin	Available for user/custom configuration
On	Off	On	Off	config-10.bin	Available for user/custom configuration
On	Off	On	On	config-11.bin	Available for user/custom configuration
On	On	Off	Off	config-12.bin	Available for user/custom configuration
On	On	Off	On	config-13.bin	Available for user/custom configuration
On	On	On	Off	config-14.bin	Available for user/custom configuration
On	On	On	On	config-15.bin	Available for user/custom configuration

Table 5: DIP switch position for filter selection

6.1. CONFIGURING FILTER FILES

The configuration files config-1.bin thru config-7.bin can be downloaded from the git repository. They contain the optimal filters and compressor settings for the devices mentioned in Table 5.

If an individual filter set is desired, one of the custom configuration files can be selected by setting the switches S1-1 thru S1-4 as shown in Table 5.

Note that for a modified set of filters to be loaded at the startup of Helike, the PCB must be reset. This can be achieved by pressing the “reset” button or by turning it off and on again.

To generate a configuration file, proceed as follows:

6.1.1. Create a .json file

Copy the sample .json file from the git repository and open it in a text editor. The structure of the file is shown in Figure 4: .json file structure.

Use a tool of your choice (e.g. https://www.earlevel.com/main/2013/10/13/biquad-calculator-v2/) to generate a set of biquad filter coefficients and copy them into the editor. The filters use a direct form I implementation.

The first three positions represent the numerator coefficients (feedforward coefficients) while the last two positions represent the denominator coefficients (feedback coefficients).

This is the used difference equation:

```
y[n] = b0 * x[n] + b1 * x[n-1] + b2 * x[n-2] - a1 * y[n-1] - a2 * y[n-2]
```

Please note that the coefficients a1 and a2 have to be negated when copying them to the .json file. This is due to the filter implementation.

Figure 4: .json file structure

Additionally, the dynamic range compression of the TPA2011 amplifiers can be set in the .json file.

6.1.2. Convert to .bin file

Once the configuration is completed, copy the content of the .json file and paste it into a json to bson file converter such as https://json-bson-converter.appspot.com/.

Download the .bson file and save it with the file name corresponding to one of the custom filter slots (e.g. config-8.bin).

6.1.3. Place file on micro-SD card

Copy the generated .bin file into the /usound/ folder on the SD-card. Now configure the DIP switches and the filters and DRC configuration will be loaded at the next startup of Helike.

6.2. CARME SPEAKER BOX

Carme 3.0 is a small speaker box that includes a single MEMS speaker. A total of four Carme speaker boxes can be attached to the Helike PCB via Jumpers J12, J19, J11 and J21(2x Left, 2x right).

6.2.1. DIP switch settings

To select the correct filter configuration for Carme set the DIP switches S1-1 thru S1-4 as shown in Table 5. This ensures that the correct filter coefficients are loaded into the audio pipeline.

6.2.2. Speaker attachment

Carme speaker box

The Carme speaker box uses a two-pole cable with a 2 position 2.54 mm female header to interface to Helike. Connect the Carme box to the MEMS L or MEMS R header at the left edge of the PCB. Ensure that the green wire in the Carme Box 3.0 is connected to the first pin shown in Figure 5.

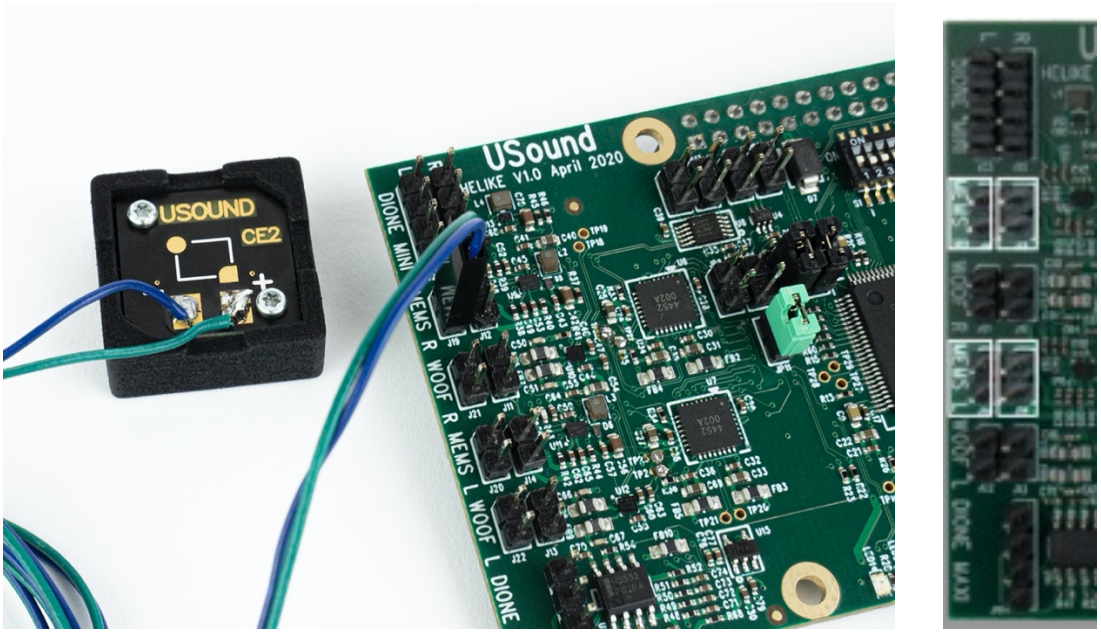

Figure 5: Connection of Carme box to the Helike PCB

Optional woofer

If desired, dynamic woofers can be connected to the woofer outputs. The built in TI TPA2028-D1amplifiers can drive speakers with a nominal impedance of 4Ω or higher.

6.3. FOR DIONE MAXI

Dione Maxi is a sound stripe with 20 MEMS speakers and an external amplifier. The external amplifier that comes with Dione Maxi must be used together with the Helike development board.

6.3.1. DIP switch settings

To select the correct filter configuration for Dione Maxi set the DIP switches S1-1 thru S1-4 as shown in Table 5: DIP switch position for filter selection. This ensures that the correct filter coefficients are loaded into the audio pipeline.

6.3.2. Speaker attachment

Dione Maxi sound stripe

The Amalthea amplifier requires a single-ended input with an input amplitude of 625 mV_{rms}. This output is provided on connector J16 (right channel on Pin 2, left channel on pin 3). Additionally, Amalthea requires a supply voltage of 30-36 V. This can be provided by Helike via the same J16 connector. Note that in this case, supplying Helike with the external 36 V supply is mandatory. The connection diagram of Helike in conjunction with Amalthea and Dione Maxi is shown in Figure 6.

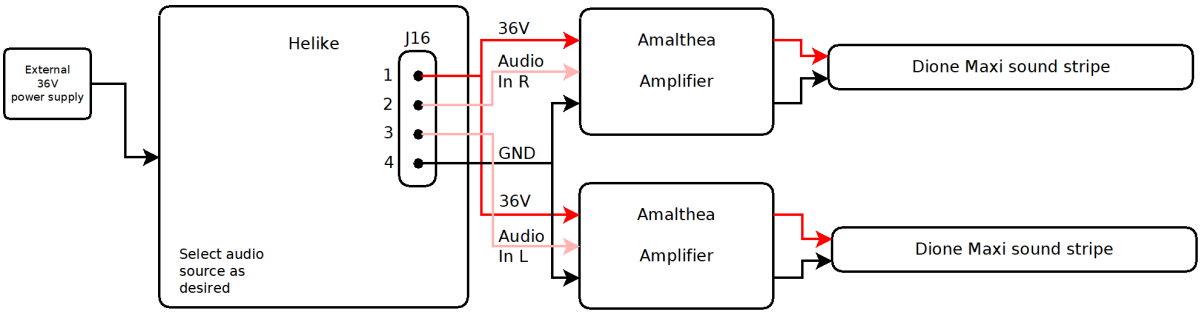

Figure 6: Helike and Dione Maxi connections

Optional woofer

If desired, electrodynamic woofers can be connected to the woofer outputs. The built-in TI TPA2028-D1 amplifiers can drive speakers with a nominal impedance of 4 Ω or higher.

6.4. FOR DIONE MINI

Dione Mini is a sound stripe with 15 MEMS speakers in 3 segments with built in amplifiers. It needs to be supplied with 5 V and requires a balanced input signal. The supply and input signal are provided by the Helike PCB on the Dione Mini connectors (J15, J23). One segment max. current of 900 mA 20 kHz.

6.4.1. DIP switch settings

To select the correct filter configuration for Dione Mini set the DIP switches S1-1 thru S1-4 as shown in Table 5: DIP switch position for filter selection. This ensures that the correct filter coefficients are loaded into the audio pipeline.

6.4.2. Speaker attachment

Dione Mini sound stripe

The Dione Mini requires a balanced input with an input amplitude of 620 mV_{rms}. This output is provided on connectors J15 (right channel) and J23 (left channel). Additionally, Dione Mini requires a supply voltage of 5V. This can be provided by Helike via the same connectors. Note that in this case, supplying Helike with the external 5 V supply is mandatory. The connection diagram of Helike in conjunction with Dione Mini is shown in Figure 7.

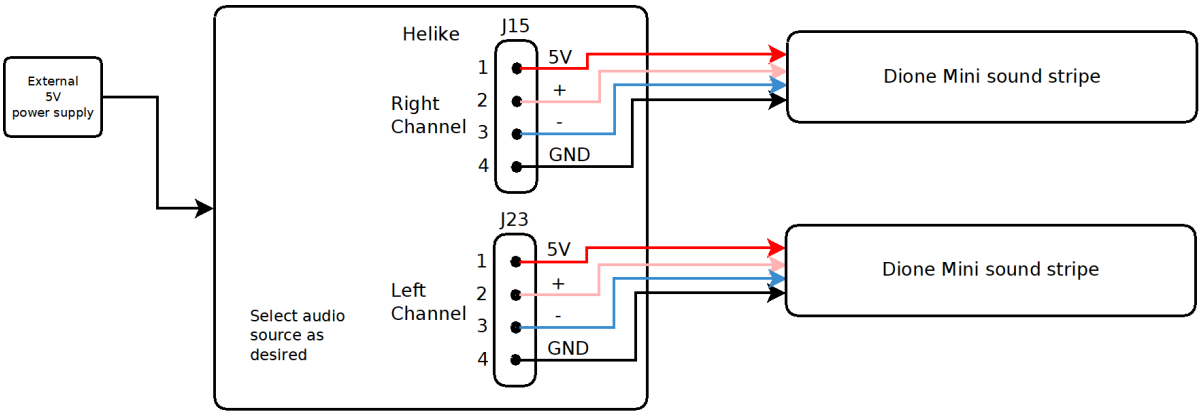

Figure 7: Helike and Dione Mini connections

Optional woofer

If desired, electrodynamic woofers can be connected to the woofer outputs. The built-in TI TPA2028-D1amplifiers can drive speakers with a nominal impedance of 4Ω or higher.

6.5. FOR SENTIA 2.0

Sentia 2.0 is an in-ear stereo earphone with one MEMS speaker per side that covers the full frequency range. It can be connected to Jumpers J12, J19, J11 and J21(2x left, 2x right).

6.5.1. DIP switch settings

To select the correct filter configuration for Sentia 2.0 set the DIP switches S1-1 thru S1-4 as shown in Table 5: DIP switch position for filter selection. This ensures that the correct filter coefficients are loaded into the audio pipeline.

6.5.2. Speaker attachment

The Sentia 2.0 earphones can be attached directly to the MEMS speaker outputs which are available on jumpers J12/J19 (right channel) and J14/J20 (left channel). The connection is shown in Figure 8.

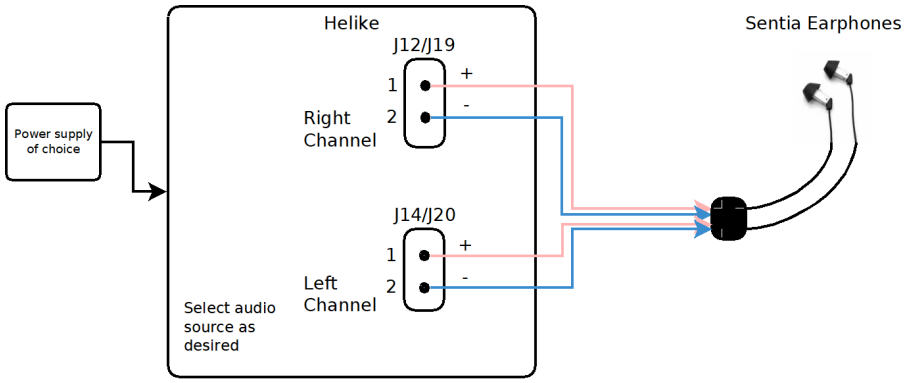

Figure 8: Sentia 2.0 connections to Helike

6.6. FOR DANUBE 5.0

Danube 5.0 is an audio module that includes a MEMS speaker and a woofer for eyewear temples. It can be used in conjunction with Helike, which provides the amplified signals to the drivers.

6.6.1. DIP switch settings

To select the correct filter configuration for Danube 5.0 set the DIP switches S1-1 thru S1-4 as shown in Table 5: DIP switch position for filter selection. This ensures that the correct filter coefficients are loaded into the audio pipeline.

6.6.2. Speaker attachment

Danube 5.0 requires two amplified signals, one for the MEMS speaker and one for the woofer. Helike provides these signals on the jumpers J12, J14, J19 and J20 (MEMS) and on J11, J13, J21 and J22 (woofer). The connection diagram is shown in Figure 9. Up to four Danube 5.0 can be connected to Helike simultaneously if desired.

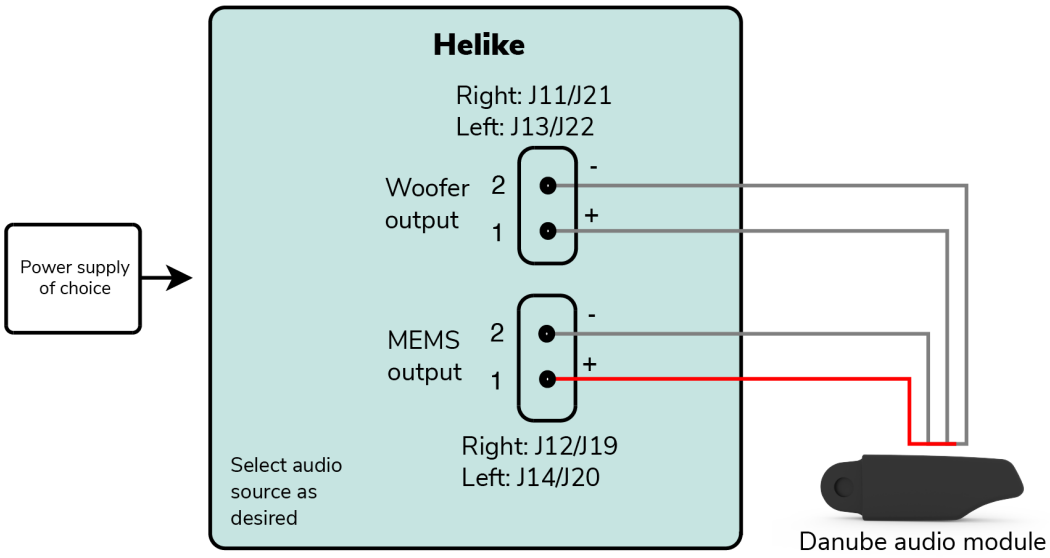

Figure 9: Danube 5.0 connections to Helike

7. INTERFACES

7.1. USER INTERFACES

7.1.1. Joystick

Helike offers a built-in joystick (SW2) that can be used to control the volume. It can also control the playback of files in SD-card read mode. Figure 10 shows the joystick and its pre-configured functions.

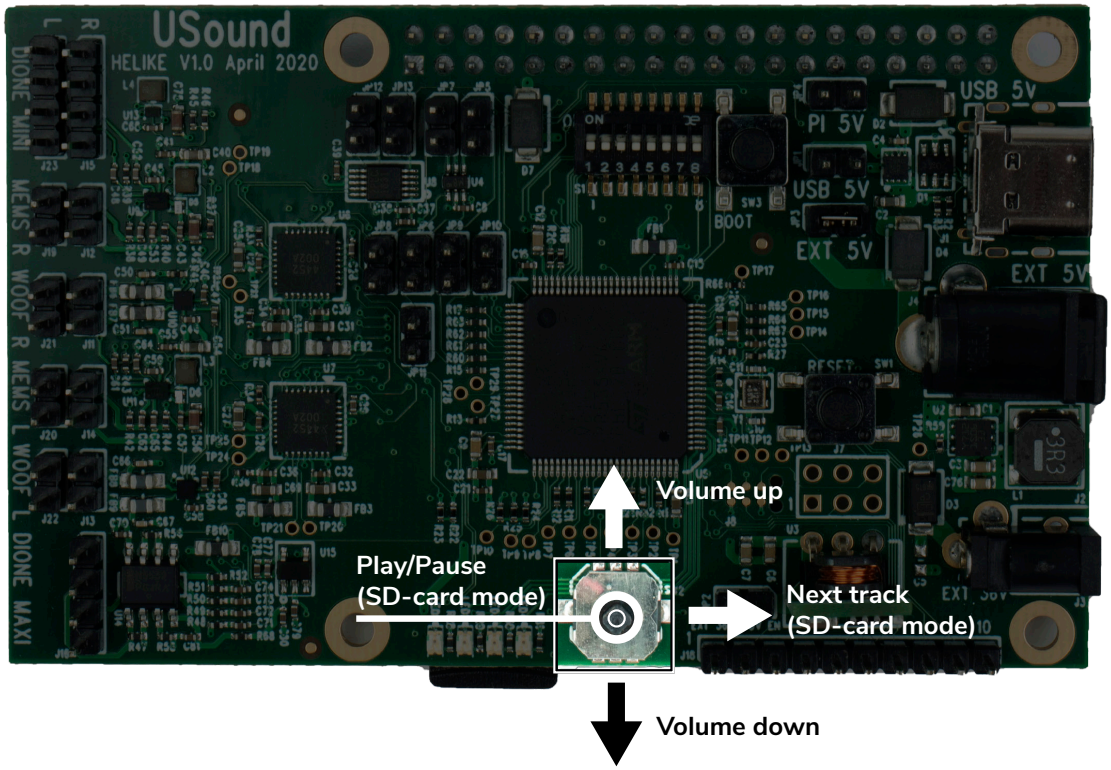

Figure 10: Joystick operation

7.1.2. Buttons

Two tactile buttons are placed on Helike. SW1 resets the microcontroller and can be used to reboot the system. SW3 is used to enter the DFU mode and is necessary for updating the firmware via the USB-C port, for details refer to the Helike firmware programming manual.

7.1.3. LED's

Helike is equipped with four LEDs. Two green (LED1, LED2) and two yellow (LED3, LED4).

- LED1 (green) is blinking when audio frames are sent to the audio engine.
- LED2 (green) is used to indicate volume and mute changes.
- LED3 (yellow) is used to indicate that the SD card is missing.
- LED4 (yellow) is used to indicate I2C communication failures with the DAC and amplifiers.

8. FIRMWARE UPDATE

The firmware of Helike can be updated via a bootloader and the USB-C port or via the SWD interface and an ST-Link programmer.

8.1. UPDATE VIA USB-C PORT

To update the firmware via the USB-C port, a compiled version of the firmware is necessary. Follow the instructions in the **Helike Firmware Programming DFU 0V2** document, to upgrade with this method.

8.2. UPDATE VIA SWD INTERFACE

The SWD interface is intended for programming and debugging the Helike firmware. This interface should be used if the firmware is personalized. The open source software is available from the public git repository under https://github.com/usound-audio/helike

The SWD interface is available on connectors J8 (Tag-Connect LLC, TC2030-IDC style connector) and on J7 (standard 2.54 mm header type).

9. REVISION HISTORY

Created in September 2020

Updated in November 2020

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