SCIENTIFICA

eMUSIC MiniBoard

User Guide

Issue: Second Version
Revision: 2.5a

Reference: eMUSIC MiniBoard -UG-Rev
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Revision History

The following table shows the revision history for this document.

Date	Version	Revision
2018/03/28	1.0a	Initial release. Limited distribution.
2018/05/22	2.0a	After the changes done in the PCB. Now, eMUSIC MiniBoard v2.
2018/05/24	2.1a	Small corrections: • Figure 14 caption. • Table 5 includes the GND to LV change in header P2 of v2.
2018/06/18	2.2a	Error in section 3.2. MISO and MOSI signals were wrong (pins 7 and 9).
2018/12/18	2.3a	Details on SiPM connector for ease of mezzanine design.
2019/01/25	2.4a	Software basic procedure information added.
2019/02/11	2.5a	Software procedures reviewed. Mezzanine boards descriptions.

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1 Introduction

1.1 Overview

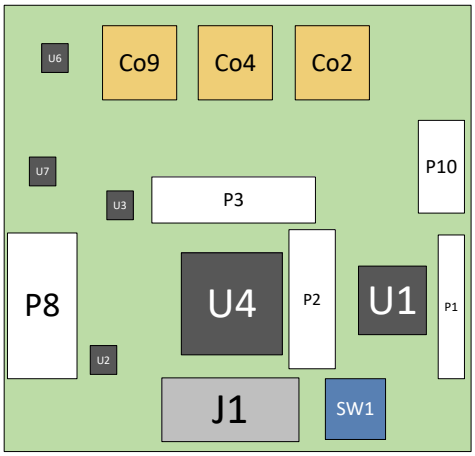
The eMUSIC MiniBoard v2 is a general-purpose evaluation board based on eMUSIC chip, an 8-channel readout ASIC for SiPM arrays. It can be connected to 8 SiPMs through a high-density connector, and the outputs of the chip can be easily monitored via the MCX connectors provided. The flexible design of the board allows to customize it to the user needs: outputs can correspond to either the individual channels (pure analog or binary discriminated, configurable via SPI protocol), or the analog summation of these channels in two different gains (high and low). These summation outputs can be either differential or single ended.

Besides the different output possibilities, this eMUSIC chip itself also has several configuration parameters accessible via SPI protocol. All outputs present two different gain configurations. The ASIC contains a tunable Pole-Zero cancellation providing output signals with less than 10ns FWHM. Note that the PZ can be also bypassed if the shaping is not needed. All channels and blocks can be power-off. As configurability level may vary according to users' needs, this board allows many levels of configuration.

It is important to highlight that the board does **not** include any HV module. This voltage must be externally generated.

1.2 Block Diagram

The block diagram of the board is shown in Figure 1. Block names and locations match with their location in the PCB.



U1: ATmega328P microcontroller.

U2, U3: 5V and 3.3V power regulators, respectively.

U6, U7: +5V and -5V power regulators, respectively, for single ended conversion

U4: eMUSIC chip.

J1: SiPM array readout connector with HV.

P1: UART connector: configuration via microcontroller.

P2: eMUSIC SPI connector: allows external control.

P3: eMUSIC outputs connector: channels, sum & fast or.

P8: Power supply connector: LV and HV.

P10: Expansion bus connected to the microcontroller.

Co4: eMUSIC SE sum differential negative output.

Co2: eMUSIC SE sum differential positive output.

Co9: eMUSIC SE HG sum.

NOTE: *depending on specific uses needs, some of the depicted connectors or pin headers may not be mounted.*

Figure 1: eMUSIC MiniBoard v2 Evaluation Board block diagram.

1.3 Board Features

The eMUSIC MiniBoard Evaluation Board features are listed here. Detailed information of these features is provided in Chapter 3.

- 8-channel SiPM readout over 20-pin connector with HV.
- MCX outputs (the pattern is also compatible with SMA and LEMO connectors):
  - 2 differential outputs (high gain) with the sum of the channels
  - Single-ended with the sum of the channels (high gain)
- Header connector including 8 single ended, HG and LG differential and fast OR trigger output.
- Configuration over SPI with 14-pin connector (P2).
  - Microcontroller is bypassed in this mode.
- External reset can be applied by power on/off boards.
- Configuration over UART with 6-pin connector (P1).
- Non-volatile ASIC configuration: EEPROM.
  - 100,000 write/erase cycles.
- Plug & Play: a microcontroller loads factory calibration at startup.
- Power supply can be shared between a group of N boards.

1.4 Board Specifications

1.4.1 Dimensions

- Width: 50 mm (1.97 in.)
- Length: 45 mm (1.77 in.)
- Thickness: 1.6 mm (0.063 in.)

Notes:

- A 3D model of this board is available.
- The schematic of the board is available.
- The layout of the board is available.

1.4.2 Environmental

- Operating temperature: 0ºC to +45ºC
- Storage temperature: -25ºC to +60ºC
- Humidity: 10% to 90% non-condensing

1.4.3 Operating Voltage

- +LV: +6.5 V_{DC}
- -LV: - 6.5 V_{DC}
- HV: Please follow the instructions of the selected SiPM datasheet.

2 Board Setup and Configuration

2.1 Board Component Location

Figure 2 and Figure 3 show the eMUSIC MiniBoard v2 component locations. Each numbered component is keyed to Table 1. Table 1 identifies the components and links to a detailed functional description of the components and board features in Chapter **¡Error! No se encuentra el origen de la referencia.**.

IMPORTANT: Figure 2 *and* Figure 3 *is for visual reference only and might not reflect the latest revision of the board. (This user guide documents eMUSIC MiniBoard v2 Rev. 2.0 and later.)*

IMPORTANT: *There could be multiple revisions of this board. The specific details concerning the differences between revisions is not captured in this document. This document is not intended to be a reference design guide and the information herein should not be used as such. Always refer to the schematic of the specific eMUSIC MiniBoard v2 version of interest for such details.*

CAUTION! *Electrostatic discharge (ESD) can cause board damage. Wear an anti-static bracelet when handling the board or when plug-in the SiPMs.*

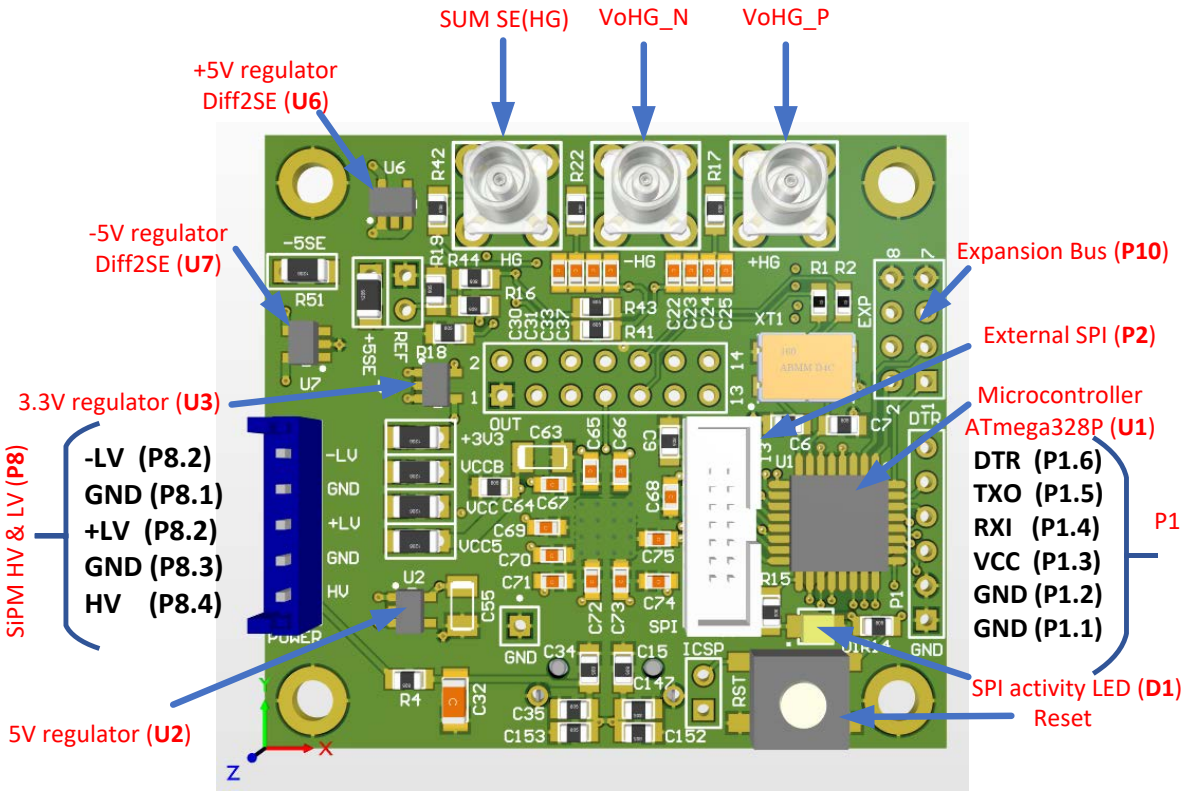


Figure 2: eMUSIC MiniBoard v2 top components location.

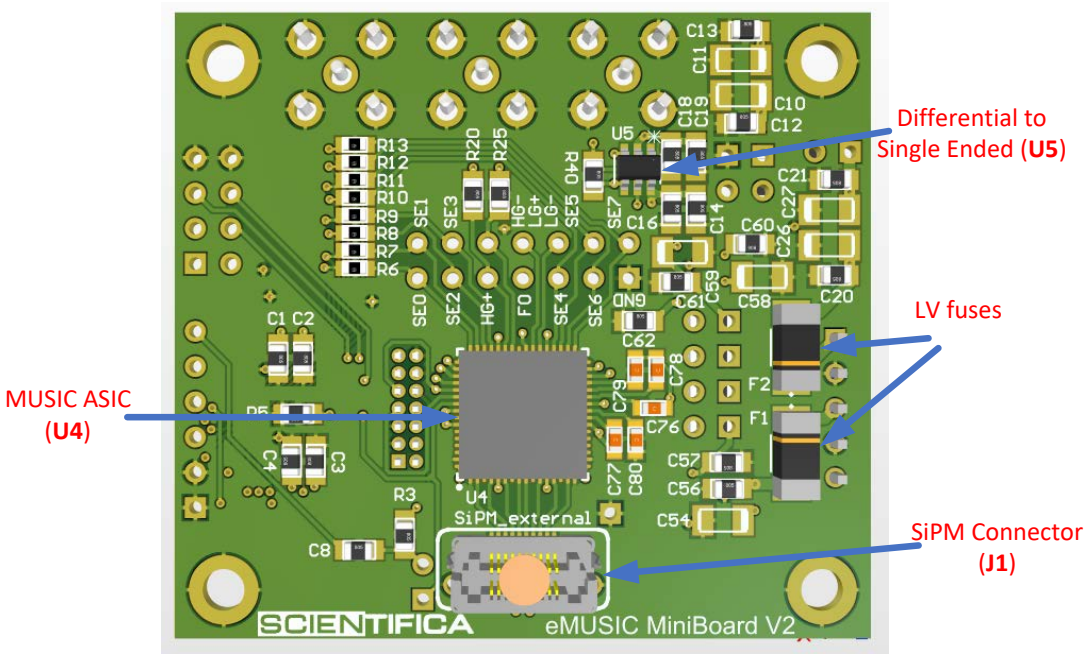


Figure 3: eMUSIC MiniBoard v2 bottom components location.

Ref. Des.	Feature / Component	Notes
U1	8-bit microcontroller with EEPROM	Microchip ATmega328P-AU
U2	Linear voltage regulator 5V (150 mA max.)	Microchip MIC5225-5.0YM5-TR
U3	Linear voltage regulator 3.3V (500 mA max.)	Microchip MIC5219-3.3YM5-TR
U4	eMUSIC 8-channel ASIC	Scientifica MUSIC8R1
U5	Differential to single-ended voltage converter	Texas Instruments LMH6703
U6	Linear voltage regulator +5.0V (150 mA max.)	MIC5225-5.0YM5-TR
U7	Linear voltage regulator -5.0V (100 mA max.)	MIC5270-5.0YM5-TR
J1	SiPM array readout connector with HV and GND	Samtec LSHM-110-02.5-L-DV-A-S-K-TR
D1	SPI activity LED	LED
P1	UART connector	2.54 mm. pitch
P2	eMUSIC SPI connector	CnC Tech. 3220-10-0100-00
P3	eMUSIC outputs pin header connector	2.54 mm. pitch
P8	Power supply connector: LV and HV	JST Sales America Inc B5B-EH-A(2.50 mm .pitch)
P10	Expansion bus connected to the microcontroller	2.54 mm. pitch
HG	eMUSIC channel / differential sum outputs SMA connector	Rosenberger 32K10K-400L5
±HG	eMUSIC single-ended sum outputs SMA connector	Rosenberger 32K10K-400L5

Table 1: eMUSIC MiniBoard v2 Components.

2.2 Board Usage Profiles

The following section aims to show the user the different ways in what the eMUSIC MiniBoard can be employed. It covers from a simple plug & play application to very specific applications where chip parameters need to be periodically modified.

The connectivity diagrams depicted herein are orientative, and in no case a limiting factor for any other possible application not covered in the examples.

2.2.1 Plug & Play Profile

This is the simplest way to use eMUSIC MiniBoard. User do not need to interact with the internal ASIC configuration. The microcontroller will dump the calibration from its internal EEPROM (non-volatile memory) two seconds after the board has been switched on. Then, the board LED (D1) will blink for less than a second and finally, the board will be ready.

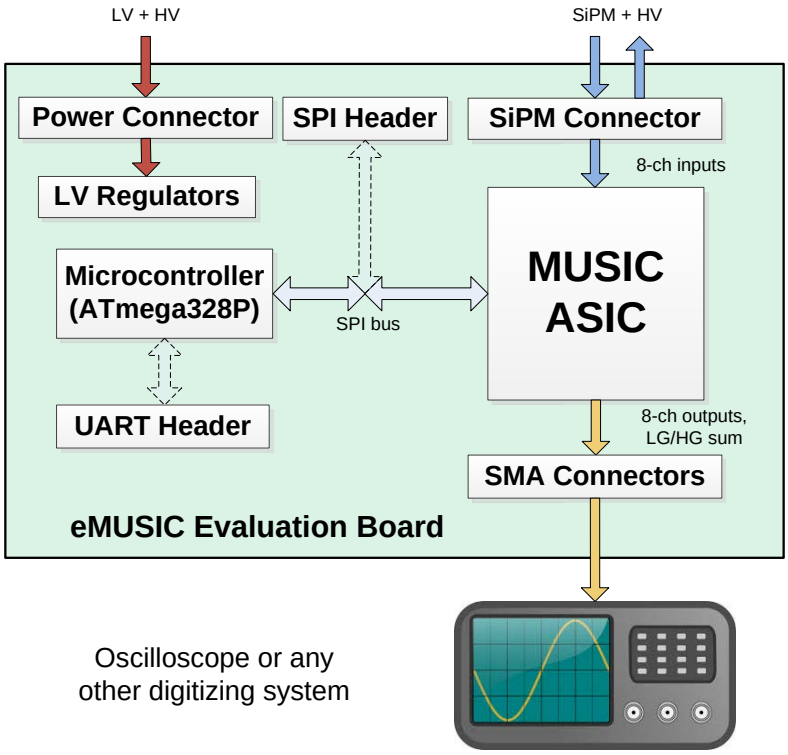


Figure 4: eMUSIC MiniBoard v2 Plug & Play Profile simplified block diagram.

2.2.2 Limited Programmability Profile (UART)

In this mode user can modify eMUSIC MiniBoard v2 configuration over UART interface, using the ATmega328P microcontroller as a bridge (see Figure 5). Moreover, the non-volatile configuration stored into the EEPROM can also be modified. The eMUSIC MiniBoard v2 Evaluation Board needs to be connected to an external UART to USB board (FTDI FT232RL USB). This auxiliary board can be connected to a PC running a 64-bit Windows or Linux operating systems. Table 2 shows the Operating Systems Software Compatibility List.

IMPORTANT: *Special care must be taken when connecting the USB interface board to eMUSIC MiniBoard v2 Evaluation Board. Be sure that DTR and GND pins serigraphy match. Connecting the boards in another way may irreversibly damage the boards. Further details can be found in Section* 0*.*

IMPORTANT: *The microcontroller EEPROM memory has a specified life of 100,000 write/erase cycles, so you may need to be careful about how often you write to it.*

Operating System	Architechture	Compatible
Ubuntu 16.04 LTS	64-bit	Yes
Windows 7	64-bit	Yes
Windows 10	64-bit	Yes

Table 2: Operating Systems Software Compatibility List.

The eMUSIC MiniBoard v2 Evaluation Board can be configured over eMUSIC MiniBoard software, a CLI available *here*. The software allows to configure ASIC via SPI interface: gain, pole/zero, switch on/off channels, sum of channels, etc. It also allows to perform calibrations and store permanently any configuration into the non-volatile memory. Detailed instructions can be found in the Appendix A.

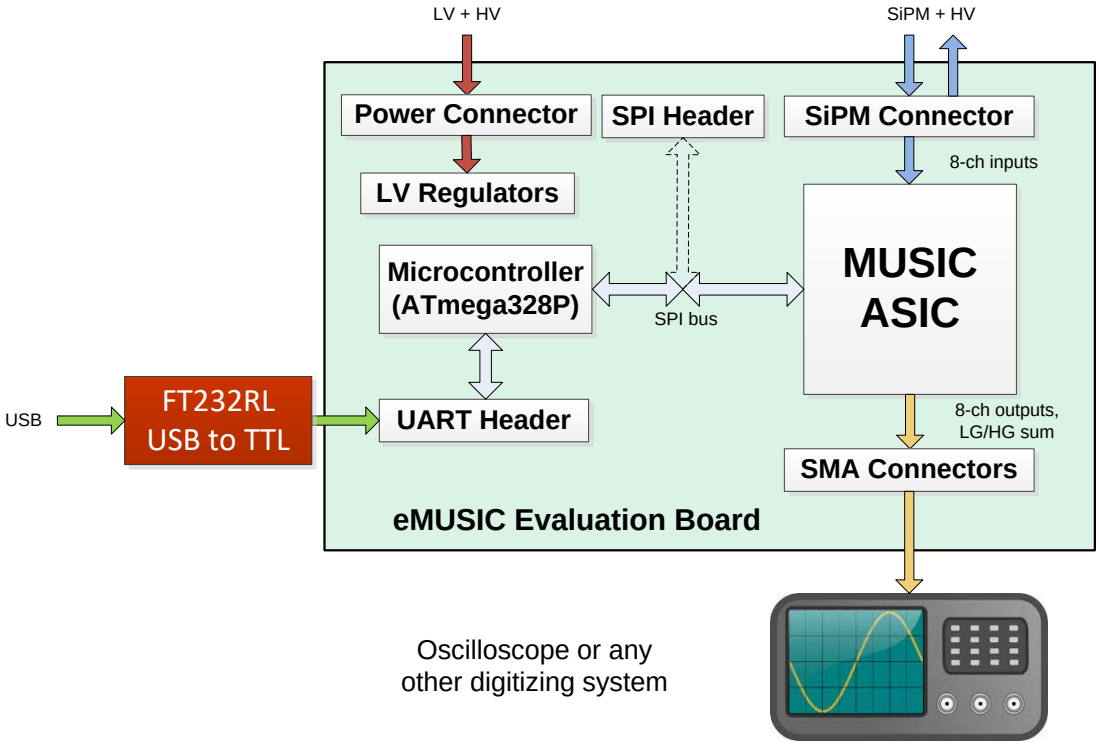


Figure 5: eMUSIC MiniBoard v2 Limited Programmability Profile (UART) simplified block diagram.

2.2.3 Full Programmability Profile (SPI)

In this mode the embedded microcontroller is bypassed and the external master takes control of the SPI bus, and thus the non-volatile configuration dump is disabled. This profile is suitable for applications where periodical reconfiguration of a large number of boards is required. In this mode user has to develop his/her own ASIC control library/driver/API.

User can reset or change any chip parameter by connecting an external SPI master to the pin header provided. Bypass pin must be asserted to claim the SPI bus and power down the microcontroller. More details can be found in Section 3.2.

IMPORTANT: *SPI interface pins, ASIC reset and microcontroller bypass IO standard is 3.3V CMOS. Higher IO voltages may damage the eMUSIC MiniBoard v2 Evaluation Board.*

IMPORTANT: *Wrong ASIC configuration may lead to misfunctioning or even to permanent board damage. Please, be careful when programming the chip and follow carefully the eMUSIC datasheet.*

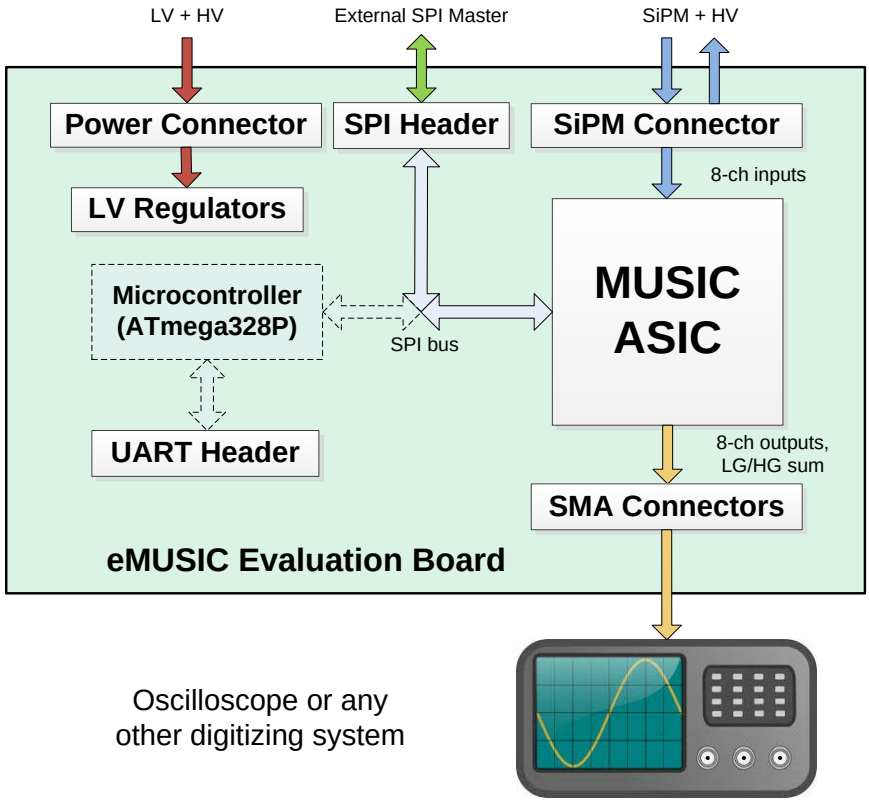


Figure 6: eMUSIC MiniBoard v2 Full Programmability Profile (UART) simplified block diagram.

2.2.4 eMUSIC MiniBoard v2 Outputs

The eMUSIC MiniBoard v2 can have up to 3 simultaneous MCX outputs, and 7x2 pin header (2.54 mm pitch) containing the chip outputs plus the trigger channel fast OR signal.

Signal Name	Output Configuration	Requirement(s)
VoHG+ VoHG-	Differential analog	Co2, Co4 MCx R17, R22 0Ω resistor
VoHG	Single-ended analog	Co9 MCx

Table 3: eMUSIC MiniBoard v2 Evaluation Board Outputs Configuration.

IMPORTANT: *User has to make sure the FT232RL module board power supply jumper (JP1) is connected to +3.3V. Jumper connected to +5V may damage the board.*

3 Board Component Descriptions

3.1 Power supply connectors

The power supply connector mounted on eMUSIC MiniBoard v2 is the B5B-EH-A(LF)(SN) from JST Sales America Inc., a 4-position header connector with 3.96mm pitch (Figure 7). The correspondent female connector models could be the HER-5 and the TE Connectivity AMP Connectors 647466-2.

(a) (b) (c)

Figure 7: Header connector (a), the correspondent receptacle connector (b), and socket contact (c).

Figure 7 shows the layout and Table 4 shows the pin assignment of the power supply connector (P8).

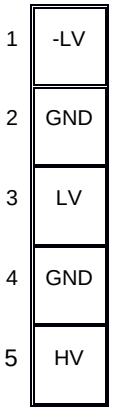


Figure 8: Power supply connector layout.

#Pin(s)	Signal Name	Description
2, 4	GND	PCB ground
1	LV	Voltage range: -6.5 V_{DC}
3	LV	Voltage range: +6.5 V_{DC}
5	HV	SiPM High Voltage. Check selected SiPM datasheet

Table 4 Pin assignment of the power supply connector.

3.2 External SPI interface

The external SPI interface PCB connector is the CNC Tech 3220-10-0100-00, a 10-position header connector (1.27 mm pitch). The correspondent female connector could be the CNC Tech 3230-10-0103-00.

(a) (b)

Figure 9: External SPI connector for PCB (a) and female connector (b).

The eMUSIC chip is compatible with SPI Mode 1 (CPOL = 0, CPHA = 1). Figure 10 shows an example of a read & write and read-only access. Further information can be found in eMUSIC datasheet.

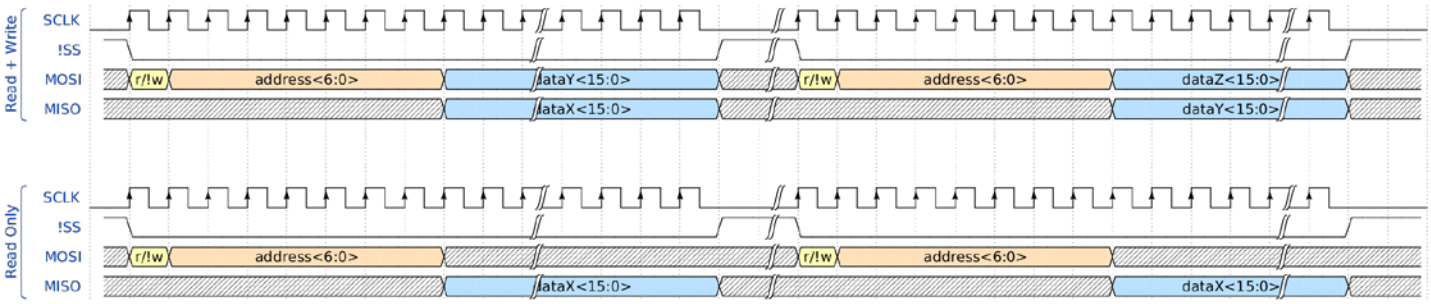


Figure 10: An example of register read+write access (top) and register read only access (bottom).

Figure 11 shows the layout and Table 5 shows the pin assignment of the external SPI interface connector. Special attention must be taken with *bypass* pin (BYP). This pin must be at high level when controlling the ASIC externally. The digital voltage standard is CMOS 3.3 Volts.

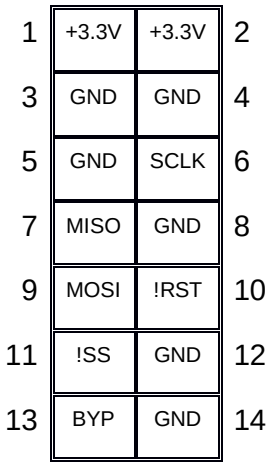


Figure 11: External SPI connector header layout (P2).

#Pin(s)	Signal Name	Description
1,2	LV_3.3V	3.3V
3,4, 5,8,12,14	GND	PCB ground
6	SCLK	SPI interface serial clock. $F_{CLK} \leq 30$ MHz
7	MISO	SPI Master Input / Slave Output
9	MOSI	SPI Master Output / Slave Input
10	!RST	Board reset (active low). It is equivalent to push the reset button (SW1)
11	!SS	SPI Slave Select (active low)
13	BYP	Microcontroller bypass. When asserted (high), the microcontroller powers down and grants the SPI bus to the external SPI master. **Mandatory** for external SPI control

Table 5: Pin assignment for the external SPI connector (P2).

3.3 UART Connector

The user has to use a basic board for the FTDI FT232RL USB to serial IC to work with the microcontroller on the eMUSIC MiniBoard v2 and this board needs to be connected to the eMUSIC MiniBoard v2 P1 connector. The UART connector layout is shown in Figure 12 and pin assignment for the connector is shown in Table 6.

IMPORTANT: *User has to make sure the FT232RL module board power supply jumper (JP1) is connected to +3.3V. Jumper connected to +5V may damage the board.*

IMPORTANT: *Special care must be taken when connecting the USB interface board to eMUSIC MiniBoard v2 Evaluation Board. Be sure that DTR and GND pins serigraphy match. Connecting the boards in another way may irreversibly damage the boards.*

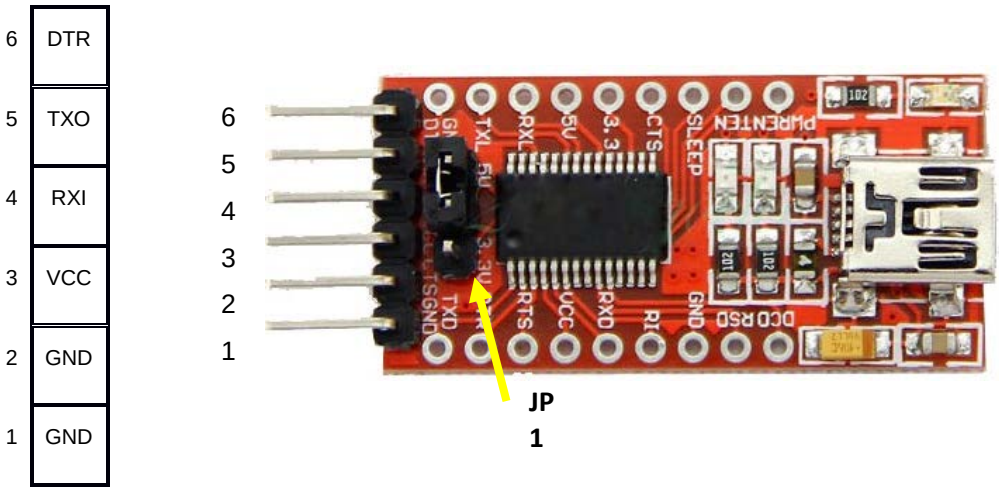


Figure 12: UART connector (P1) layout and PCB picture.

#Pin(s)	Signal Name	Description
1,2	GND	PCB ground
3	VCC	+3.3 V_{DC}
4	RXI	Receive Asynchronous Data Input (USB → eMUSIC MiniBoard)
5	TXO	Transmit Asynchronous Data Input (USB ← eMUSIC MiniBoard)
6	DTR	Data Terminal Ready Control. When asserted, it resets the microcontroller

Table 6 Pin assignment for the UART connector (P1).

3.4 SiPM Readout Connector

The SiPM readout connector is a board-to-board terminal/socket strip, specifically the Samtec LSHM-110-02.5-L-DV-A-S-K-TR.

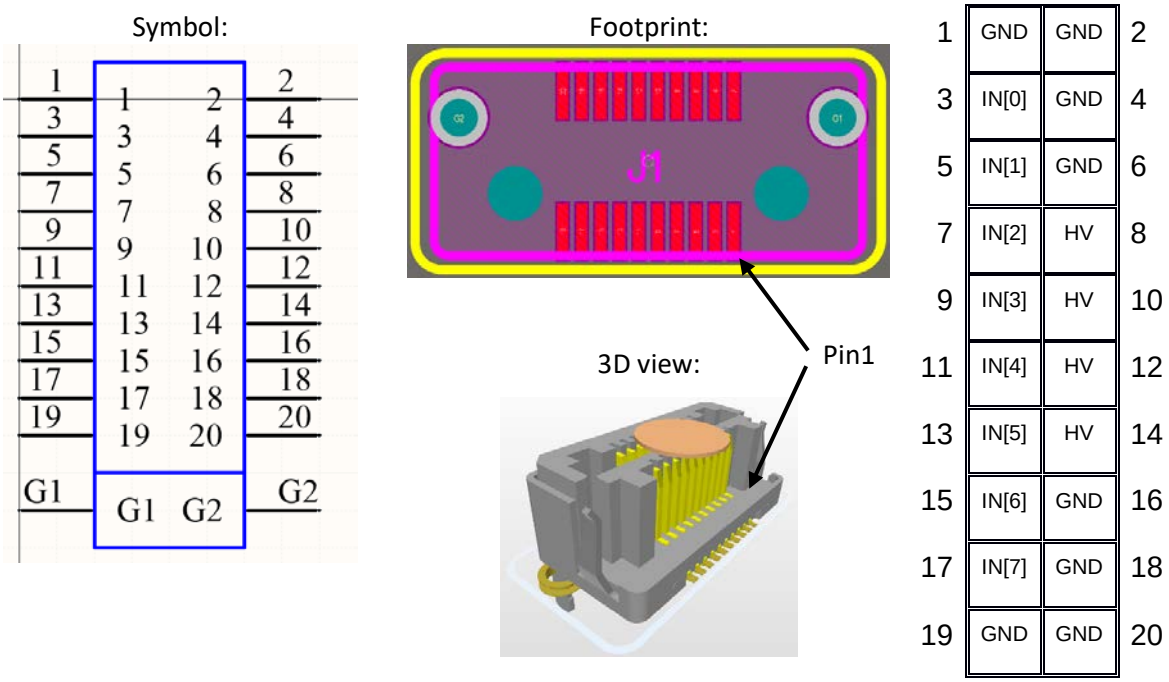


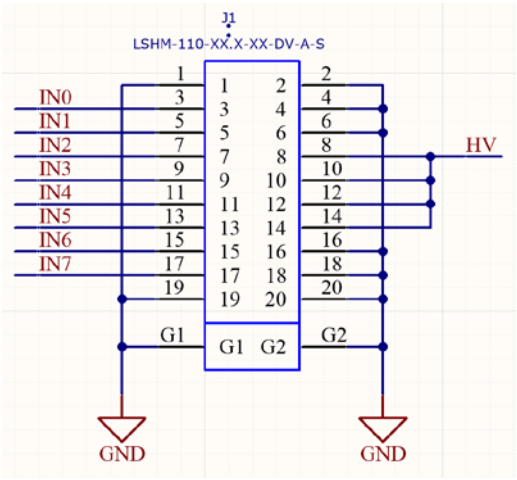
Figure 13: External SiPM connector (Samtec LSHM-110-02.5-L-DV-A-S-K-TR.header layout, J1) schematic design symbol, footprint, 3D view and layout.

#Pin(s)	Signal Name	Description
1,2,4,6,16,18,19,20	GND	PCB ground
3,5,7,9,11,13,15,17	IN[0:7]	SiPM cathodes, ASIC inputs
8,10,12,14	HV	SiPM High Voltage. Check selected SiPM datasheet

Table 7 Pin Assignment for the SiPM Readout Connector (J1).

Figure 13 shows the design of the symbol and the footprint for the SiPM connector.

eMUSIC MiniBoard schematic:



eMUSIC MiniBoard layout (3D view):

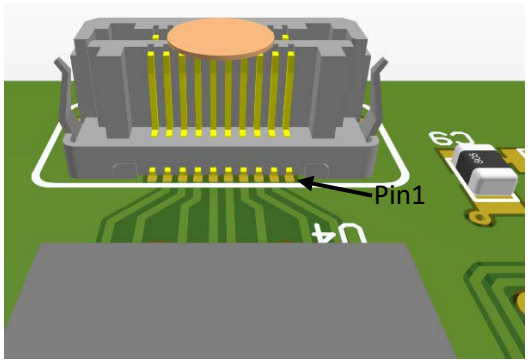
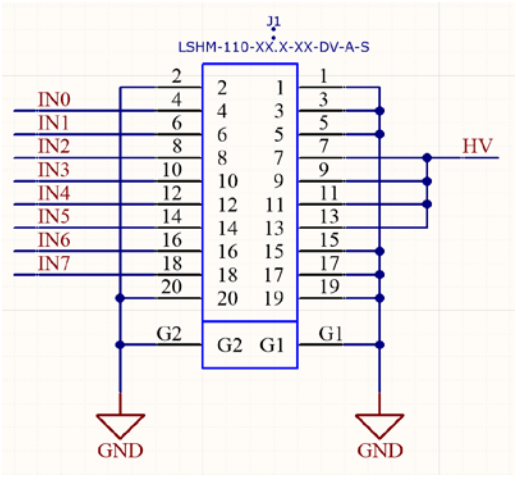


Figure 14: eMUSIC MiniBoard schematic design and 3D view of the layout.

While the connectivity of the eMUSIC MiniBoard is shown in Figure 15, the design at the SiPM mezzanine board is presented in Figure 16.

SiPM mezzanine board schematic:



SiPM mezzanine board layout (3D view):

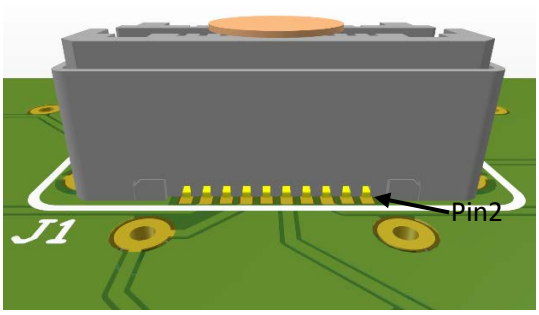


Figure 15: SiPM mezzanine board schematic design and 3D view of the layout.

LSHM Mated connections:

- Existing pin mapping is Pin1, board 1 to Pin2, board 2
- Must keep same Pin1 to Pin2 connectivity between boards

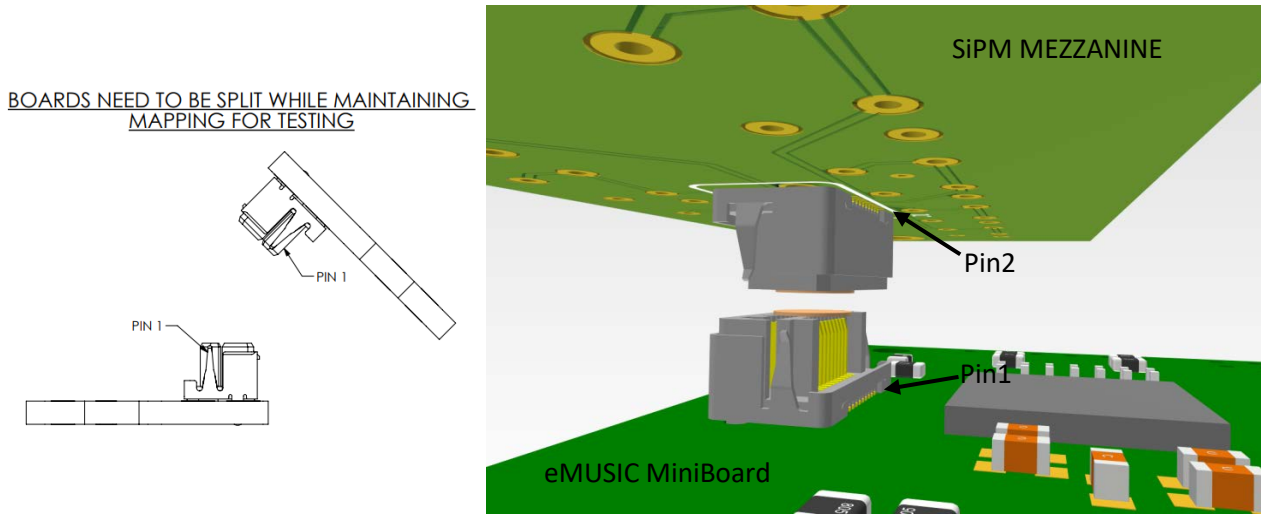


Figure 16: Mating of SiPM connector.

The dimensions needed to design a SiPM mezzanine compatible with the board are presented in Figure 18. For simplicity of the design, the dimensions presented (on the right) are between the pin 1 of the connector and the nearest screw holes. The dimensions on the left are presented respect the ground holes of the connector. Please, take into account that the layout is flipped (and rotated) in Figure 18 because the connector is in the bottom layer.

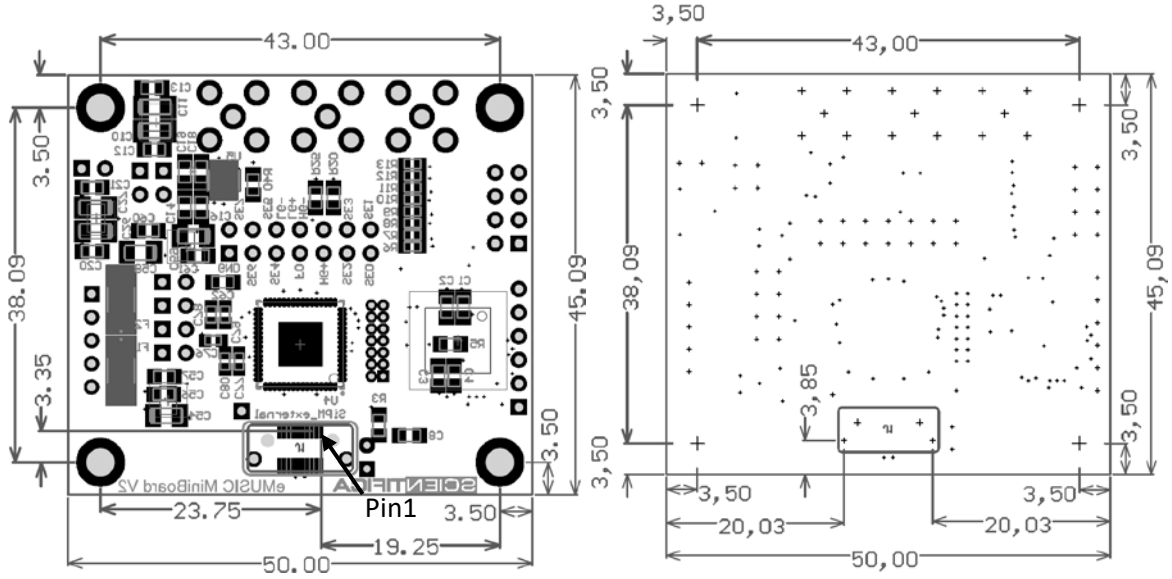


Figure 17: Mechanical dimensions in millimeters over the MiniBoard assembly drawings. It is represented the bottom layer (as seen from the top).

3.5 Microcontroller

The microcontroller has two roles. First, it masters the SPI bus which configures eMUSIC ASIC, and second, it stores the non-volatile eMUSIC configuration. Additionally, these functionalities can be disabled when an external SPI master is connected into the eMUSIC MiniBoard. The microcontroller SPI configuration flow diagram is shown in Figure 19. The flow path can be divided into three modes depending on the *bypass* control signal (see Section 3.2) which grants access to the external SPI bus, and the microcontroller goes into power down state.

- **MODE 1, when *bypass* = '1':**

  When eMUSIC MiniBoard v2 is powered on, microcontroller peripherals are initialized. In the *INIT* state it checks if any external system has asserted the *BYP* control signal. If so, then the microcontroller is powered down and the external SPI master can take control of the eMUSIC ASIC.

- **MODE 2, when *bypass* = '0':**

  When eMUSIC MiniBoard v2 is powered on, microcontroller peripherals are initialized. In the *INIT* state it checks for the *BYP* control signal. If the control signal is at low-level ('0'), the microcontroller will consider that there is no external SPI master present to take control of the SPI bus. In this mode the microcontroller has control over the SPI bus. In this mode there are two functions it performs:

  - **Default Configuration mode**: The controller waits for 2 seconds after power-on or reset. After that, it checks if user has issued any software command. If not, it loads the default calibration file from microcontroller EEPROM which has been previously stored.
  - ***User* Configuration mode***:* If user issues any software command (mini_music_sw) within the 2 seconds after board power-on or reset, then the microcontroller configures the board as per the user configuration. It is important to highlight that the software resets the board automatically by means of DTR line, so user needs not to press reset button with each command.

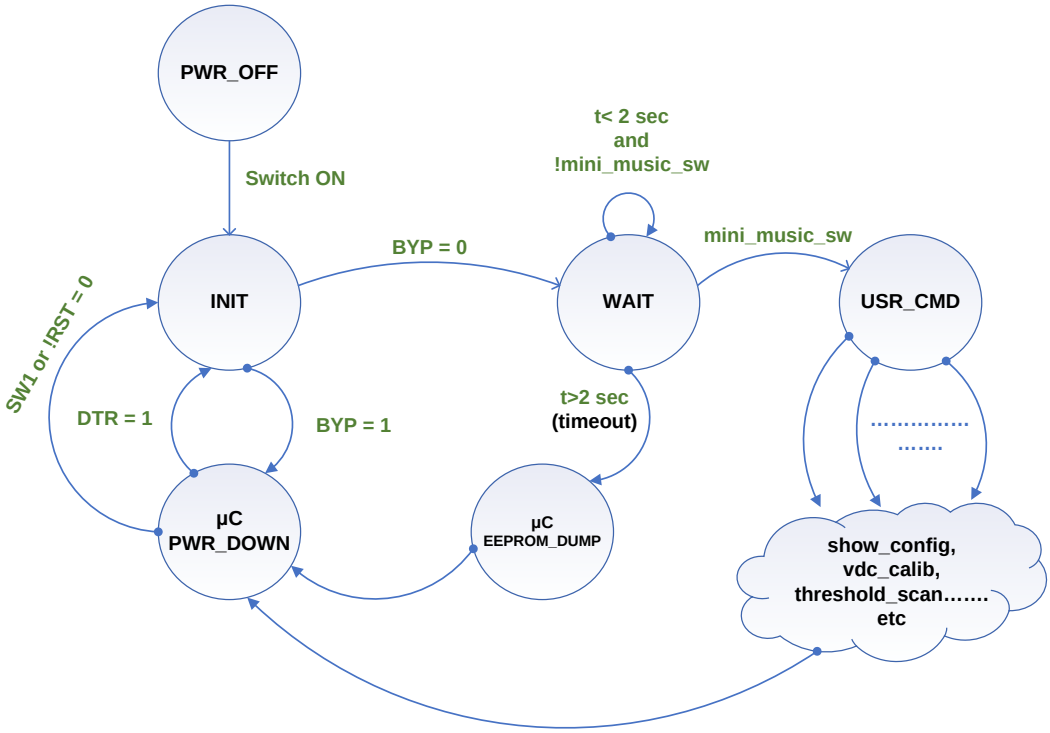


Figure 18: Microcontroller flow diagram.

4 External boards

Two external boards have been designed for connection to SiPM and to access all the eMUSIC signals. They are presented in the following sub-sections.

4.1 Pin to SMA mezzanine board

In the event that more outputs than the sum are required, it is possible to use the P3 (Figure 1). In P3, there is access to all the eMUSIC outputs (Table 8). To make it easier to use a scope, the Pin2SMA mezzanine board can be used (Figure 20).

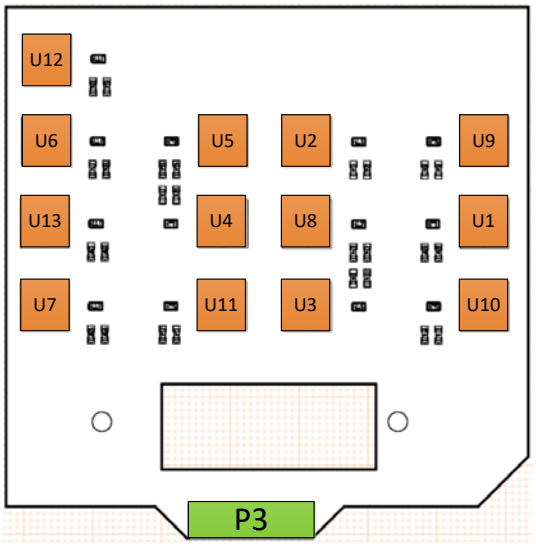


Figure 19: Top view of the Pin to SMA mezzanine board.

Table 8: P3 connector pins.

1	GND	VoSE7	2
3	VoSE6	VoSE5	4
5	VoSE4	VoLG_N	6
7	FastOR	VoLG_P	8
9	VoHG_P	VoHG_N	10
11	VoSE2	VoSE3	12
13	VoSE0	VoSE1	14

The Pin2SMA mezzanine board translates from a standard pin connector to SMA after AC coupling (by 4 capacitors of 100p, 1n, 10n and 100n in parallel). Alternatively, instead of SMA, MCX connectors can be installed.

Table 9: Pin2SMA connector signals.

#Pin(s)	Signal Name	Description
U1	VoSE1	Single Ended Output Channel 1.
U2	VoSE3	Single Ended Output Channel 3.
U3	VoHG_N	High Gain Diff. Sum Neg.
U4	VoLG_P	Low Gain Differential Sum Pos.
U5	VoLG_N	Low Gain Differential Sum Neg.
U6	VoSE5	Single Ended Output Channel 5.
U7	VoSE7	Single Ended Output Channel 7.
U8	VoHG_P	High Gain Diff. Sum Pos.
U9	VoSE2	Single Ended Output Channel 2.
U10	VoSE0	Single Ended Output Channel 0.
U11	FastOR	Fast OR Trigger Pulse
U12	VoSE4	Single Ended Output Channel 4.
U13	VoSE6	Single Ended Output Channel 6.

4.2 SiPM mezzanine

There is also the possibility to use a SiPM mezzanine which is already prepared with the correspondent connector to the eMUSIC Miniboard (J1 in Figure 1). This connector is already described in section 3.4.

On the bottom side of the board there are female pins at standard distances to be able to plug directly 7 SiPM.

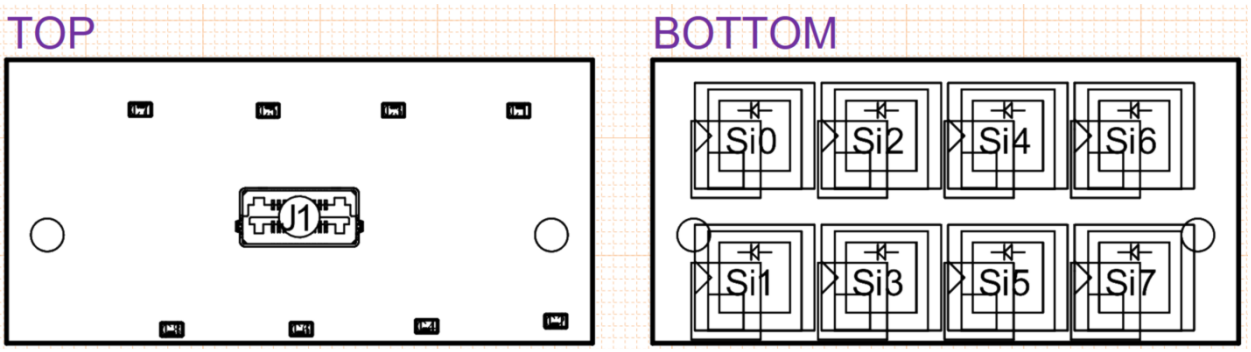


Figure 20: Top and bottom view of the SiPM mezzanine board.

5 Measurement Procedures

5.1 General considerations

This Chapter briefly explains the steps that user needs to follow to perform measurements.

1. Wear an anti-static bracelet to handle the board. The omission of this step may produce permanent damage to eMUSIC ASIC or any other components in the board.
2. Prepare the setup: connect the external boards required for your test. E.g. SiPMs, external SPI, etc.
3. Connect the power supply connector (P8) LV pins to a low-voltage power supply (5 - 6 V_{DC}), and HV pins to a high-voltage power supply.
4. If the board needs to be connected to a PC, a USB cable to an available port on a computer.
5. Configure the electronics (this will depend on the user board usage profile).
6. Use the oscilloscope to measure the different output signals.

IMPORTANT: *Please do not **POWER ON** the board without limiting the LV and HV supply source current.*

a. *Maximum current limit for **LV** supply source is **0.5 A (max.)**.*
b. *Maximum current limit for **HV** supply source is **1 mA (max.)**.*

IMPORTANT: *Please do **not** power the board only from the USB port.*

IMPORTANT: *Please do not turn ON the LV when the **HV** is at 0 V, always make sure that **HV** is at 2V, never lower.*

IMPORTANT: *Never leave the board power ON with **HV** at 0V.*

IMPORTANT: *Please never short circuit the diode **ANODE & CATHODE** pins of the SiPM readout board during any kind of measurements.*

5.2 Analog Summation Readout

The following example shows how to perform summation analog readout with a specific configuration and how to save the current configuration of the ASIC to a file.

1. Connect the power supply and the USB programmer.
2. Configure channels ON and pole zero.
    a. –t: High transimpedance mode (higher gain).
    b. –a: Pole-Zero attenuation is reduction.
    c. –e 0 1 2 3 4 5 6 7: channels enabled.
    d. –u 0 1 2 3 4 5 6 7: channels summed.
    e. --polezero 3 31 –E : Pole zero enabled with values 3 and 31.

    mini_music *config* -t -a -e 0 1 2 3 4 5 6 7 -u 0 1 2 3 4 5 6 7 --polezero 3 31 –E

3. Calibrate for present configuration

    mini_music vdc_calib

4. Another example with a commonly used configuration of the MUSIC ASIC is here depicted.
    a. Configure summation mode for channels: 0 3 6.
    b. Enable the required channels: For example: 0 3 6
    c. Enable the pole zero cancellation with R = 3, C=5 and low attenuation ON.
    d. Enable high transimpedance.

    mini_music config -t -a -e 0 3 6 -u 0 3 6 --polezero 3 5 –E

5. Observe in the oscilloscope the summation readout using pin P11 or the SMAs Co3-Co7.
6. Repeat step 4 to change the current configuration of the ASIC as many times as needed. Note that he enable input might not be the same as the summation outputs. For instance, we might enable all inputs in the 7 SiPM array, but we want only to obtain the summation in the center of the array (channel 3, i.e. SiPM Si4 from board), then the command to configure the ASIC will be:

    mini_music *config* -t -a -e 0 1 2 3 4 5 6 7 -u 3 --polezero 3 31 –E

7. If a preferred configuration for measurements is found, it is recommended to commit the current eMUSIC ASIC configuration to the microcontroller's non-volatile EEPROM memory. Therefore, the eMUSIC ASIC will be automatically configured with desired settings after every board power cycle without the need of dedicated commands.

    mini_music *save_to_eeprom*

5.3 Analog Single Ended Readout

The following example shows how to perform single ended analog readout with a specific configuration. Please, take into account that it can ONLY be performed accessing to the correspondent connector. In our case, we will suppose we can connect a scope to the Pin2SMA mezzanine board.

1. Connect the power supply and the USB programmer.
2. Configure channels ON and pole zero.
    a. –t: High transimpedance mode (higher gain).
    b. –a: Pole-Zero attenuation is reduction.
    c. –e 0 1 2 3 4 5 6 7: channels enabled.
    d. –u 0 1 2 3 4 5 6 7: channels summed.
    e. --polezero 3 31 –E : Pole zero enabled with values 3 and 31.

> **mini_music config** -t -a -e 0 1 2 3 4 5 6 7 --polezero 3 31 –E

3. Calibrate for present configuration

> **mini_music vdc_calib**

4. Observe in the oscilloscope the analog output readout using the SMA external board connected to P13.
5. Repeat step 1 to change the current configuration of the ASIC as many times as needed.
6. If a preferred configuration for measurements is found, it is recommended to commit the current eMUSIC ASIC configuration to the microcontroller's non-volatile EEPROM memory. Therefore, the eMUSIC ASIC will be automatically configured with desired settings after every board power cycle without the need of dedicated commands.

> **mini_music *save_to_eeprom***

5.4 Digital Single Ended Readout

The following example shows how to perform single ended digital readout with a specific configuration. Please, take into account that it can ONLY be performed accessing to the correspondent connector. In our case, we will suppose we can connect a scope to the Pin2SMA mezzanine board.

1. Connect the power supply and the USB programmer.
2. Configure channels ON and pole zero.
    a. –d: digital.
    b. –a: Pole-Zero attenuation is reduced.
    c. –e 0 1 2 3 4 5 6 7: channels enabled.
    d. --polezero 3 31 –E : Pole zero enabled with values 3 and 31.

> **mini_music *config*** -d -a -e 0 1 2 3 4 5 6 7 --polezero 3 31 –E

3. Calibrate for present configuration

> **mini_music *vdc_calib***

4. Use the thresholds and the VBG voltage obtained to reconfigure the ASIC.
    a. Enable the desired channels: For example, 1, 6.

> **mini-music *config*** -e 1 6 -d -b 5 -v 215 214 213 218 211 214 216 215

5. Perform a threshold scan in order to obtain the required thresholds, so the circuit is configured near the transition. Observe that the thresholds depend on the desired configuration of the ASIC and whether the SIPM is switched ON or not.

> **mini_music *thresholdScan*** -r thScan_results.txt

This command will give an output similar to: -b 5 -v 215 214 213 218 211 214 216 215
Where -b 5 says that the optimum VBG must be set to 5, and the -v followed by those numbers tells a recommended good threshold value to see the digital signal.

6. Use the thresholds and the VBG voltage obtained to reconfigure the ASIC.
    b. Enable the desired channels: For example, 1, 6.

> **mini-music *config*** -e 1 6 -d -b 5 -v 215 214 213 218 211 214 216 215

7. Observe in the oscilloscope the analog output readout using the SMA external board connected to P13.
8. Repeat step 4 to change the current configuration of the ASIC as many times as needed.
9. If a preferred configuration for measurements is found, it is recommended to commit the current eMUSIC ASIC configuration to the microcontroller's non-volatile EEPROM memory. Therefore, the eMUSIC ASIC will be automatically configured with desired settings after every board power cycle without the need of dedicated commands.

> **mini_music *save_to_eeprom***

A. eMUSIC MiniBoard v2 Commands

This Appendix regards to the board usage profile where eMUSIC MiniBoard v2 is configured using the UART interface (see Section 2.2.2).

The list of available commands is the following:

Command	Description
mini_music version	Shows current software version
mini_music read_serial	Reads eMUSIC MiniBoard v2 Serial Number
mini_music reset	Resets eMUSIC ASIC
mini_music show_config [args]	Shows eMUSIC ASIC configuration
mini_music config <args>	Configures eMUSIC ASIC electronics
mini_music config_file <args>	Configures the ASIC from a configuration file
mini_music threshold_scan [args]	Runs a threshold scan of the binary discriminated output
mini_music vdc_calib [args]	Calibrates the V_{DC} of the eMUSIC analog channel outputs
mini_music erase_eeprom	Erases eMUSIC microcontroller EEPROM
mini_music save_to_eeprom	Saves eMUSIC configuration to EEPROM

Table 10: eMUSIC MiniBoard v2 Evaluation Board software commands.

All the above-mentioned commands have the following generic options and they will be omitted in the explanation of the commands:

[-h], [--help] Shows the command help message.

[-P], [--port] Which serial port to use. E.g.: COM4 (Windows), /dev/ttyUSB0 (Linux).

[-l], [--loglevel] Log level (trace, debug, verbose, info, warning, error, fatal, disable).

[-F], [--logformat] Log format ('-' to disable any header).

[-C], [--args_file] File containing the arguments to parse. Same format as the command line flags.

Example User has problems trying to connect with the board and wants to troubleshoot the problem. In this case, we suggest changing the default log level (info) to debug, and specify manually the UART interface number:

mini_music read_serial -l debug -P /dev/ttyUSB0

- **mini_music version:**

Command mini_music version

Returns the git hash corresponding to the software version. In case you need support, please, tell us which version you are using.

Example mini_music version

History Legacy command.

- **mini_music reset:**

Command mini_music reset

Resets the eMUSIC ASIC. After issuing this command, the ASIC will run the original foundry parameters. Thus, the chip may not be properly calibrated. This command has no effect on the microcontroller's EEPROM.

Example mini_music reset

History Legacy command.

- **mini_music show_config:**

Command mini_music show_config [-f <*file_name*>]

Shows eMUSIC configuration. By default, it shows the ASIC configuration, not EEPROM.

[-f] [--dump_file] Dumps the configuration shown in the screen into an output file. When this option is asserted, a path to a writable file name must be provided.

Example This example stores the current ASIC parameters into a file named *good_params.calib*:

mini_music show_config -f ./calib/good_params.calib

History Legacy command.

- **mini_music config_file:**

Command mini_music config_file <-f *file_name*> [-a]

Changes eMUSIC configuration from a file. By default, it applies the configuration to the ASIC, not EEPROM.

[-f] [--file] The path to the configuration file name to be applied.

[-a] [--auto_reload] When provided, eMUSIC ASIC configuration will be updated from the file every time the file changes. This option is suitable when user wants to optimize the performance of the chip by trial and error method. This option is incompatible with *-E* option in order not to stress the EEPROM (it has a finite number of write/erase cycles). In this mode, the application will remain opened, waiting for a change in the configuration file. To exit the application, press CTRL+C.

Example 1 This example loads *music_scratch.txt* into the ASIC every time this file changes:

mini_music config_file -f /tmp /music_scratch.txt -a

History Legacy command.

- **mini_music config:**

Command mini_music config [-d] [-p <R C>] [-t] [-a] [-f] [-g] [-v <vth0>…<vth7>] [-o < voff0>…<voff7>] [-e <ch_list>] [-u <ch_list>]

Changes eMUSIC configuration from the command options provided. By default, it applies the configuration to the ASIC, not EEPROM.

[-d] [--digital] When specified, eMUSIC Single-Ended outputs (VoSE[7:0]) are configured as binary discriminated.

[-p] When specified, eMUSIC Pole/Zero filters are enabled. This command requires two values: R

[--polezero] (from 0 to 7) and C (from 0 to 31).

[-t] **[--hightrans]** When specified, single-ended and differential channels are configured in high transimpedance mode (higher gain). Otherwise, they are configured as low transimpedance.

[-a] **[--lowlad]** When specified, Pole-Zero attenuation is reduced.

[-f] **[--vdcfile]** Specify the eMUSIC Single-Ended VDC calibration file name (*.vdc). This file contains a lookup table with the optimal analog VDC chip parameters for any of the Pole/Zero combinations. If this configuration file is not provided, please, run *vdc_calib* command to calibrate the chip with the optimal parameters for you.

[-g] **[--vbg]** To adjust the bandgap voltage of the comparators when eMUSIC outputs are configured as binary discriminated. Threshold scan test will suggest you the proper configuration of this parameter.

[-v] **[--vthchannels]** To adjust the threshold (per-channel, from 0 to 511) of the discriminator when eMUSIC outputs are configured as binary discriminated. Threshold scan test provides the channels' V_{TH} value where the output comparator commutates from low to high. Using smaller values than the ones shown in the threshold scan, the comparator will be able to detect small signals at the input.

[-o] **[--voffchannels]** Select per-channel the anode input voltage V_{Offset} (from 0 to 511). 8 arguments (one for each channel) are required to use this configuration option.

[-e] **[--chan_enable]** Select the list of eMUSIC channels to enable (0-7).

[-u] **[--sumchans]** The list of eMUSIC channels to be summed (0-7).

Example 1 This example configures eMUSIC in analog mode, with Pole/Zero filter enabled and high transimpedance configuration. Only channels from 0 to 3 are enabled, and the sum output is made from channels 0 and 1:

mini_music config_file -p 5 12 -t -e 0 1 2 3 -u 0 1

Example 2 This example configures eMUSIC in digital mode, with the bandgap voltage to 5 and it will also configure each of the 8-channel thresholds:

mini_music config_file -d -g 5 -v 120 127 122 135 131 124 141 138

History Legacy command.

- **mini_music threshold_scan:**

Command mini_music threshold_scan

Runs a threshold scan of the binary discriminated output. This command only makes sense when eMUSIC outputs are configured as binary discriminated. It performs a sweep of the comparator V_{TH} to find the value where the output channel transition. This test has to be done in absence of signal at the chip input.

Example mini_music threshold_scan

History Legacy command.

- **mini_music vdc_calib:**

Command mini_music vdc_calib

Calibrates the offset of the analog outputs, either single-ended or differential, to maximize the rail-to-rail voltage swing.

Example mini_music threshold_scan

History Legacy command.

- **mini_music erase_eeprom:**

Command mini_music erase_eeprom

Removes the non-volatile configuration. After issuing this command, the non-volatile configuration capability is disabled.

Example mini_music erase_eeprom

History Since software version *aca71eb8*.

- **mini_music save_to_eeprom:**

Command mini_music save_to_eeprom

Commits the current eMUSIC ASIC configuration to the microcontroller's non-volatile EEPROM memory. Thus, eMUSIC ASIC will be automatically configurated with the current settings after every board power cycle or after pressing the reset button.

Example mini_music save_to_eeprom

History Since software version *aca71eb8*.