Technical Specification
Embedded DSP Eurorack Synthesizer Module

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Basis

This technical specification is based on the Requirements Specification for the Embedded DSP Eurorack Synthesizer Module. It describes the concrete technical implementation of the defined requirements and specifies how the system shall be realized, tested, and accepted.

Introduction

This document describes the technical design and implementation details of a Eurorack-compatible embedded DSP synthesizer module based on an STM32H7 microcontroller.

Requirements

All functional and non-functional requirements defined in the Requirements Specification are binding. This document defines the technical measures and design decisions used to fulfill these requirements.

Development Environment

- STM32CubeMX for MCU configuration and peripheral setup
- CMake-based build system
- ARM GCC toolchain
- Visual Studio Code as the primary development environment
- SWD-based flashing and debugging
- FreeRTOS as the real-time operating system

Functional Description

The system acquires audio data via an external audio codec, processes the data in real time using DSP algorithms executed on the MCU, and outputs the processed audio signal through the same codec. Control inputs and user interface elements modify DSP parameters and system behavior during operation.

Scope of Delivery

- Assembled Hardware Revision 2 PCB
- Firmware source code including build configuration
- Audio codec drivers and DSP framework
- Project documentation

Testing

Testing is performed on both module and system level and includes:

- Hardware bring-up and power integrity verification

- Audio loopback tests (input routed directly to output). With calibrated signal generator and oscilloscope

- Verification of control inputs and user interface elements

- Long-term stability and real-time performance testing

Acceptance

Acceptance is performed jointly with the customer based on this specification and all documented, mutually agreed changes. Successful acceptance requires fulfillment of all acceptance criteria defined in the Requirements Specification.

Implementation

Mechanical Design

- Eurorack-compatible PCB dimensions (Derived from **IEC 60297** / **DIN 41494**, originally designed for Eurocards in 3U/6U rack systems.)

- No dedicated front panel is designed

- Mechanical mounting compatible via frontpanel with Eurorack rails - frontpanel is mounted on the PCB via washers on jack sockets and mounting holes in slide-potentiometers.

- Since the frontplate is not in scope of the project, the module will not be mountable yet.

Electrical Design

- STM32H7 microcontroller as the central processing unit.

- External audio codec connected via I2C and digital audio interface.

- Eurorack-compatible input and output signal conditioning:

  - All inputs (Audio, CV, and Gate) are protected against maximum Eurorack signal levels (-10 V to 10 V).
  - Gate inputs: protection implemented via transistor circuits.
  - CV inputs: rail-guarded op-amp circuits to prevent overvoltage to MCU ADCs.
  - Audio inputs: appropriate attenuation and diode-based protection. to protect audio codec's analog inputs.
  - Audio inputs: are AC-coupled to further protect the audio codec's ADCs from overvoltage.

- PCB stack and power/signal routing designed to minimize noise interference on analog signals.

- Power regulation:

  - 5 V buck converter for WS2812 LEDs.
  - 3.3 V LDO and 1.8 V LDO to ensure clean power delivery and stable analog reference.

Firmware Design

- Modular and layered firmware architecture utilizing C

- FreeRTOS-based task scheduling and primitives.

- Audio Engine with DMA-driven audio input and output

- Dedicated real-time DSP processing tasks

- Usage of CMSIS-DSP library where applicable

- Dedicated interfacing tasks to handle lower-priority interfacing vs high-priority audio processing.

- Custom Audio Codec drivers for TLV320AIC3204, controlled via I2C

Interfaces

- Stereo Audio input and output via 3.5mm mono Jack sockets each

- 2 Control voltage inputs, 1 V/Oct input , and 4 gate inputs via ADC and GPIO via 3.5mm mono Jacks

- SWD interface for programming and debugging

- 4 Slide potentiometers to control the device's DSP and playback functionality, read via ADC on the MCU

- 2 Push buttons to control playback modes.

- 4 WS2812 RGB LEDs

User Interface

- Faders for continuous parameter control

- Buttons for discrete user actions

- RGB LEDs for visual feedback

Data Storage

- Internal RAM used for audio buffers

- No persistent mass storage required

- Optional storage of calibration data in non-volatile memory on MCUs internal flash.

Functional Workflows

- System boot and peripheral initialization

- Continuous audio acquisition

- Real-time DSP processing

- Audio playback

- Concurrent handling of control inputs and user interface updates

Additional Information

The system architecture is designed to allow reuse and extension for future MCU-based Eurorack modules.

Work Packages and Milestones

Work Packages

ID	Description
P1	Hardware bring-up and validation
P2	Audio Codec I2C driver implementation
P3	Audio subsystem implementation
P4	DSP framework development
P5	Control interface: Gate inputs
P6	Control interface: CV inputs
P7	Control interface: V/Oct input
P8	Integration of control interface with audio subsystem
P9	User interface: slide potentiometers readout
P10	User interface: button readout
P11	User interface: WS2812 RGB LED implementation
P12	Integration of user interface with audio subsystem
P13	System integration and testing

Milestones

ID	Description
M1	Hardware validated and operational
M2	Audio and DSP functional
M3	Control and user interface fully integrated
M4	System acceptance