Bluetooth Audio Rejiggering Instrument (BARI)

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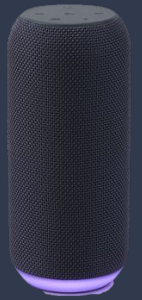
(Group D0)



Use Cases

- Musicians use effects processors to shape the sound of musical signals for increased expression and tonal versatility
- Play with friends, busk at the park
- What if
    - Portable effect box with analog overdrive or distortion, and digital EQ, reverb, modulation
    - w/ Bluetooth speakers => for live performance
    - w/ true wireless (TWS) earbuds => for practice
    - Single device for a full band - microphones, guitars, bass...up to 4 lines at a time

BARI is born!

Signals and Systems
digital and analog effects design

Software Systems
digital effects implementation, UI control, Bluetooth integration

Circuits
amplification, power system, analog effect implementation, I/O, PCB design

Requirements – Operating Condition

SR1. TEMPERATURE
room temperature (+27 C).

SR2. SYSTEM FORM FACTOR
< 5 kilograms
< 15 cm (max dimension)

SR3. SYSTEM COST
production cost for the system at a volume of 10,000 units shall not exceed $100

SR4. BATTERY LIFETIME
> 4 hours at Standard Operating Profile

SR5. SYSTEM VOLTAGE SUPPLY
standard USB-C 5V DC recharge

Requirements – Input & Bluetooth Output

SR6. INPUT CONNECTOR DEFINITION
four XLR or ¼” channels

SR7. INPUT SIGNAL DEFINITION
20 ~ 20 kHz

- “Quiet Mic”: -59 dBV, ZOUT < 500 ohms, balanced;
- “Hot Mic”: -32 dBV, ZOUT < 500 ohms , balanced;
- Instrument: -59 dBV (passive) ~ 1.78 dBV (active, line-level), ZOUT = 10~40 kohms, unbalanced.

SR8. INPUT IMPEDANCE
Balanced and > 10 Zsignal

SR13. BLUETOOTH TRANSMISSION PROTOCOL

- pairing to > 1 device
- Bluetooth 3.0 or higher
- SBC, AAC, or other common codecs, > 250kbps
- Advanced Audio Distribution Profile (A2DP) Bluetooth profile

SR14. BLUETOOTH TRANSMISSION RANGE
> 3 meters stable connection

Requirements – Analog Effects

SR9. PRE-AMPLIFIER OUTPUT
Tunable from -20 dBFS to -2 dBFS

SR10. PRE-AMPLIFIER GAIN FLATNESS
at most +/- 2dB from average in 20 ~ 20 kHz passband

SR11. PRE-AMPLIFIER DISTORTION
introduce total harmonic distortion < -60 dB (carrier)

Technical Challenge:
The pre-amplifier circuit should be able to adjust the input signal amplitude without hurting its quality

SR12. ANALOG OVERDRIVE PERFORMANCE
similar to the output of the simulated Reference Overdrive Pedal, but scale by supply voltage

Technical Challenge:

- For a pure tone with identical input amplitude and an identical gain setting, the Analog Effect shall produce a soft-clipped waveform with magnitude within 2 dB of that of the Reference Overdrive Pedal, and
  - The 2nd and 3rd harmonics of the tone shall be no more than 5 dB less than reference
- frequency characteristic is within 2 dB of reference, over 20 ~ 20 kHz.

Requirements – Digital Effects

SR15. MINIMUM DIGITAL EFFECTS
any of the following digital effects to any of the four input channels

SR16. EQUALIZATION QUALITY
bass, middle, and treble
+/- 20 dB adjustable, at most +/- 3dB in non-adjusted band

SR17. REVERB WET/DRY RATIO
0% ~ 100% with 10 steps

SR18. REVERB TIME
0~3 s adjustable

SR19. CHORUS MODULATION DEPTH
0~5ms with 10 steps

SR20. CHORUS RATE
0~5Hz with 10 steps

Technical Challenge:
The tunable chorus effect requires implementing a non-trivial algorithm on the uP

SR21. DIGITAL PROCESSING LATENCY
from input to bluetooth send <100 ms

Technical Challenge:
Meeting the latency requirement with limited uP compute power

Requirements – UI

SR22. USER INTERFACE RESPONSE LATENCY
< 100ms

SR23. USER INTERFACE UPDATE LATENCY
(setting takes effect)
< 1s

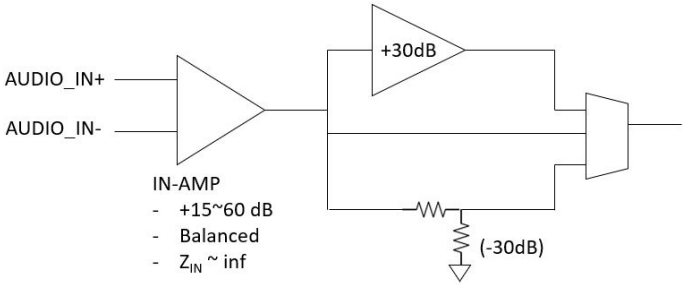
SR24. USER INTERFACE INTERACTION TIME
navigate to any command within 5s

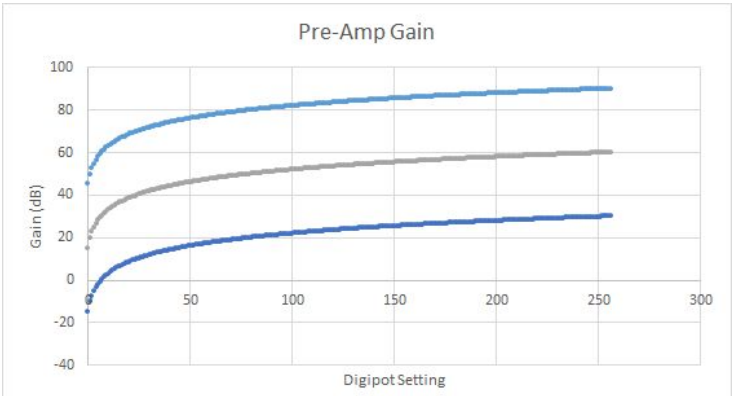
SR25. USER INTERFACE FEEDBACK MECHANISM
The system shall display

- hierarchical menu
  - All settings the user can adjust
  - Highlight menu item that the user is currently interacting with
- current system state

Solution Approach

Pre-Amplifier





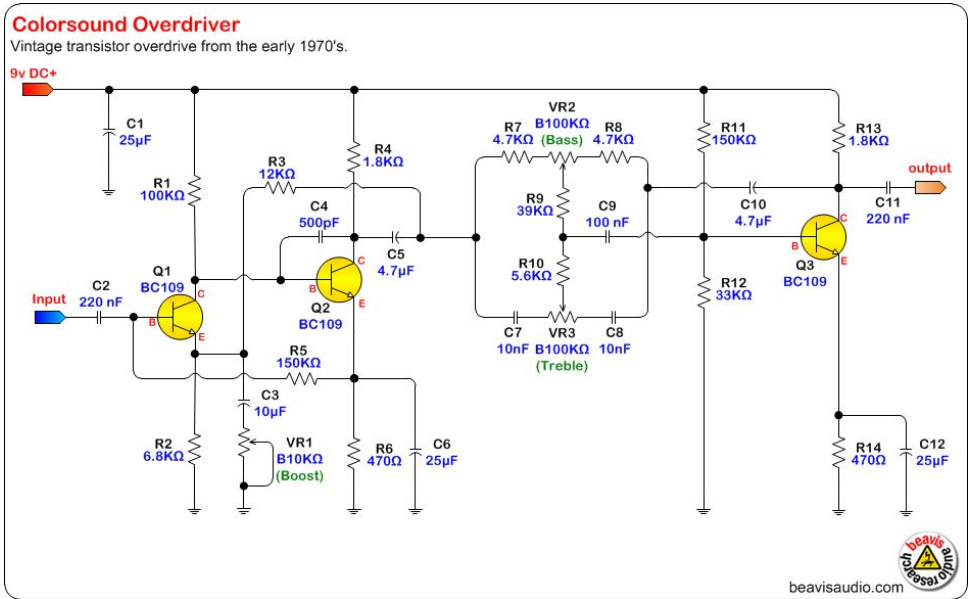
RF Module

BM83 bluetooth module

AAC and SBC codecs; I2S bus

Analog Effect

Colorsound Overdrive (3.3V)

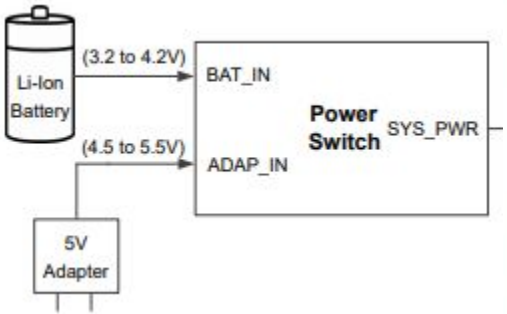


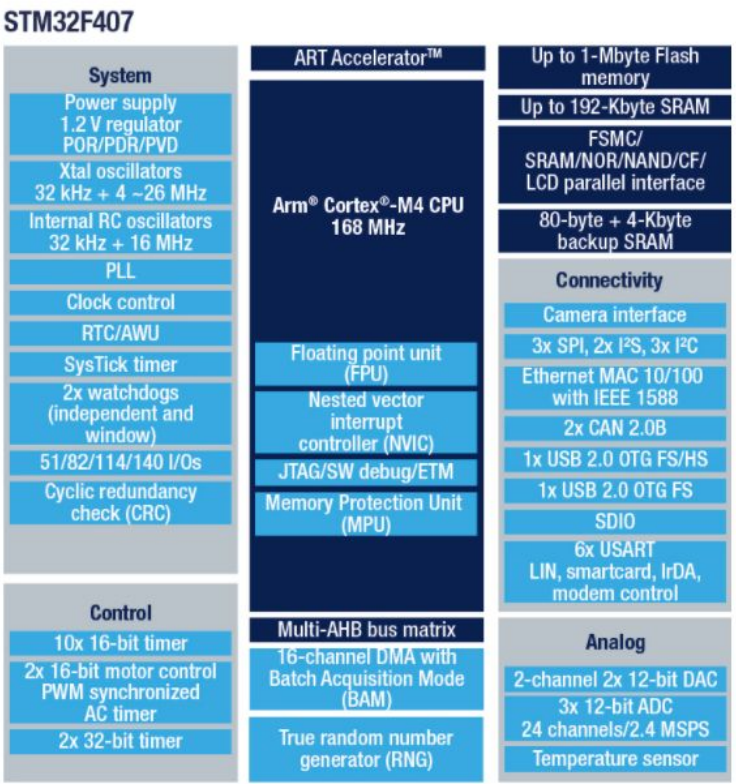
Solution Approach

Power Module

- Battery
- Wall Adapter

BM83's power management module





Microprocessor

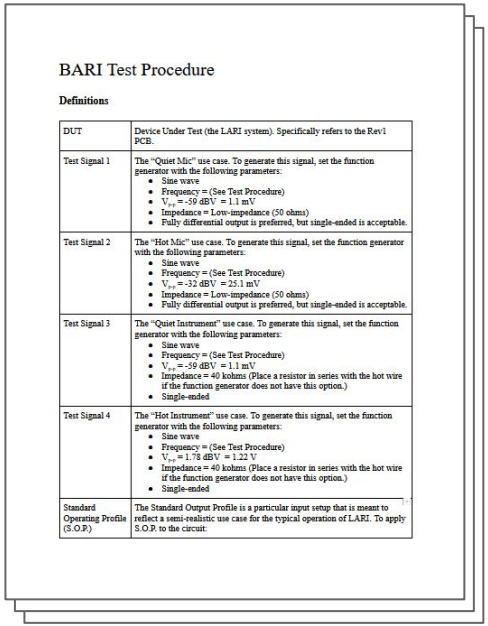
- Signal Processing
- Control

STM32F407VG uP + MCP3464R-E/ST
16-bit 4-channel ADC

User Interface Module

- Output: LCD Display
- Input: Rotary Encoder (w/ button)

Design for Test



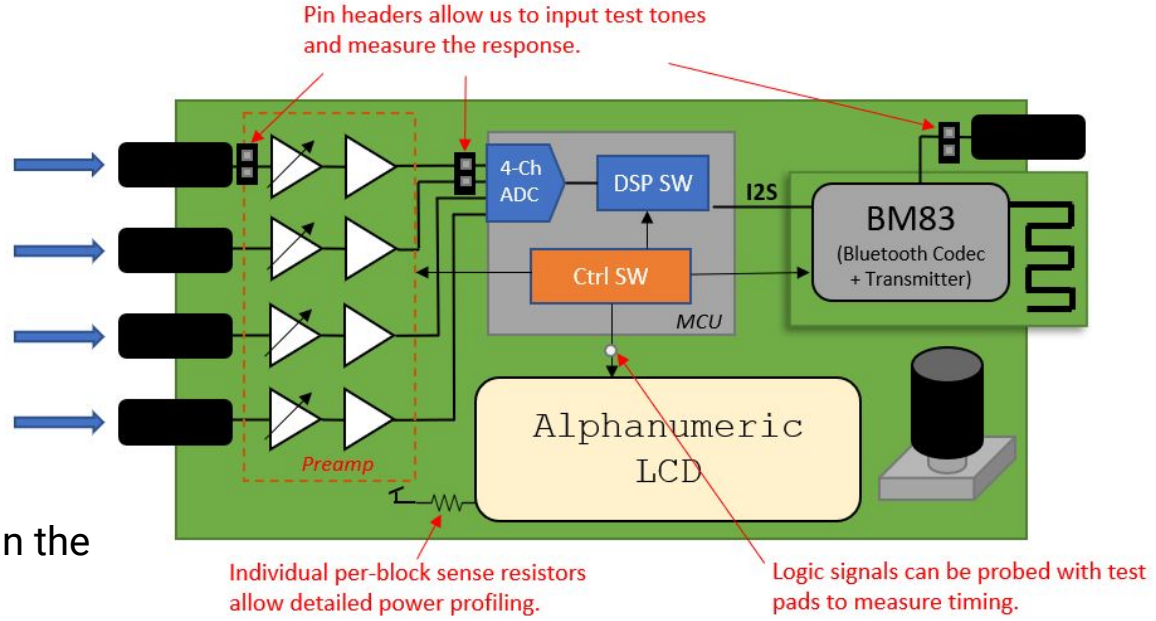
BARI Test Procedure

Definitions

DUT	Device Under Test (the LARI system). Specifically refers to the Rev1 PCB.
Test Signal 1	The "Quiet Mic" use case. To generate this signal, set the function generator with the following parameters: • Sine wave • Frequency = (See Test Procedure) • V_{rms} = -59 dBV = 1.1 mV • Impedance = Low-impedance (50 ohms) • Fully differential output is preferred, but single-ended is acceptable.
Test Signal 2	The "Hot Mic" use case. To generate this signal, set the function generator with the following parameters: • Sine wave • Frequency = (See Test Procedure) • V_{rms} = -32 dBV = 25.1 mV • Impedance = Low-impedance (50 ohms) • Fully differential output is preferred, but single-ended is acceptable.
Test Signal 3	The "Quiet Instrument" use case. To generate this signal, set the function generator with the following parameters: • Sine wave • Frequency = (See Test Procedure) • V_{rms} = -59 dBV = 1.1 mV • Impedance = 40 kohms (Place a resistor in series with the hot wire if the function generator does not have this option.) • Single-ended
Test Signal 4	The "Hot Instrument" use case. To generate this signal, set the function generator with the following parameters: • Sine wave • Frequency = (See Test Procedure) • V_{rms} = 1.78 dBV = 1.22 V • Impedance = 40 kohms (Place a resistor in series with the hot wire if the function generator does not have this option.) • Single-ended
Standard Operating Profile (S.O.P.)	The Standard Output Profile is a particular input setup that is meant to reflect a semi-realistic use case for the typical operation of LARI. To apply S.O.P. to the circuit:

Specific HW and SW policies outlined in the [BARI Test Procedure document](#) (WiP)

DFT Features on the Rev 1 PCB:



Test ↔ Requirement

Battery Lifecycle Test	SR4 (Battery Lifetime)	
System Power Consumption Test	(None, internal specification test)	
Impedance Probe Test	SR8 (Input Impedance)	
Pre-Amplifier Functional Test	SR7 (Input Signal Definition) SR9 (Pre-Amplifier Output)	SR10 (Pre-Amplifier Gain Flatness) SR11 (Pre-Amplifier Distortion)
Analog Effect SPICE Verification Test	SR12 (Analog Overdrive Performance)	
Digital Effect MATLAB Verification Test	SR15 (Minimum Digital Effects) SR16 (Equalization Quality) SR17 (Reverb Wet/Dry Ratio)	SR18 (Reverb Time) SR19 (Chorus Modulation Depth) SR20 (Chorus Rate)
Processing Latency Test	SR21 (Digital Processing Latency)	
User Interface Latency Test	SR22 (User Interface Response Latency)	SR23 (User Interface Update Latency)
Bluetooth Range Test	SR14 (Bluetooth Transmission Range)	
Ease-of-Use Test	SR24 (User Interface Interaction Time)	
All of the above tests:	SR1 (Temperature)	SR5 (System Voltage Supply)
Ensured by Design:	SR2 (System Form Factor) SR3 (System Cost) SR6 (Input Connector Definition)	SR13 (Bluetooth Transmission Protocol) SR25 (User Interface Feedback Mechanism)

2/22	3/1	3/8, 3/15	3/22, 3/29	4/5	4/12
Adam Component selection for Analog Effect	**Tentative: 3/1 Schematic Review**	Mechanical / System Int. Design	**3/22 -> Theoretical Arrival Date for Rev1**	Mechanical Implementation Details	DSP Signal Path Testing
High-level HW architecture	Schematic Revisions & Layout		HW Low-Level Functional Testing		Plan Full-System-Level Test
Start Schematics for Rev 1	Adam to give Design Presentation		Come up w/ Changelog for Rev2?	**Hope to receive Rev2 by 4/12**	Or long-time period tests like battery
	Target Rev 1 Order by 3/5		Rev2 Schematics, Layout --> Order ASAP		
Sam Help w/ prototyping analog effect	Helping w/ Design Presentation	Prototyping DSP Algorithms on the STM32	HW / Peripheral Code low-level imp.	DSP Implementation & Integration	DSP Implementation & Integration
Research and prototype MVP effects	Research and prototype MVP effects	User / Conceptual Design	Unit Testing	DSP Signal Path Testing	DSP Signal Path Testing
				Come up w/ Interim Demo	
Xingran STM32 & BM83 development resources	more on firmware setup	Develop low-level architecture / fn. prototypes	HW / Peripheral Code low-level imp.	DSP Implementation & Integration	DSP Implementation & Integration
Complete very high-level code architecture	define interface/headers	UI (assume LCD library)	Unit Testing	DSP Signal Path Testing	DSP Signal Path Testing
Order STM32 board	**Plan to receive STM32 board**			Come up w/ Interim Demo	
All Budget Definition	Review Design Presentation Slides	Preliminary plans for the enclosure / int.; design review			

4/19: slack time
4/26: Final demo prep, system testing