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Smart LED Visualizer

For the applications of an AIoT-Based Power-Saving Audio Visualizer powered up by USB Type-C with 8051/RISC-V Core for the Smart Home & Electric Vehicle Applications

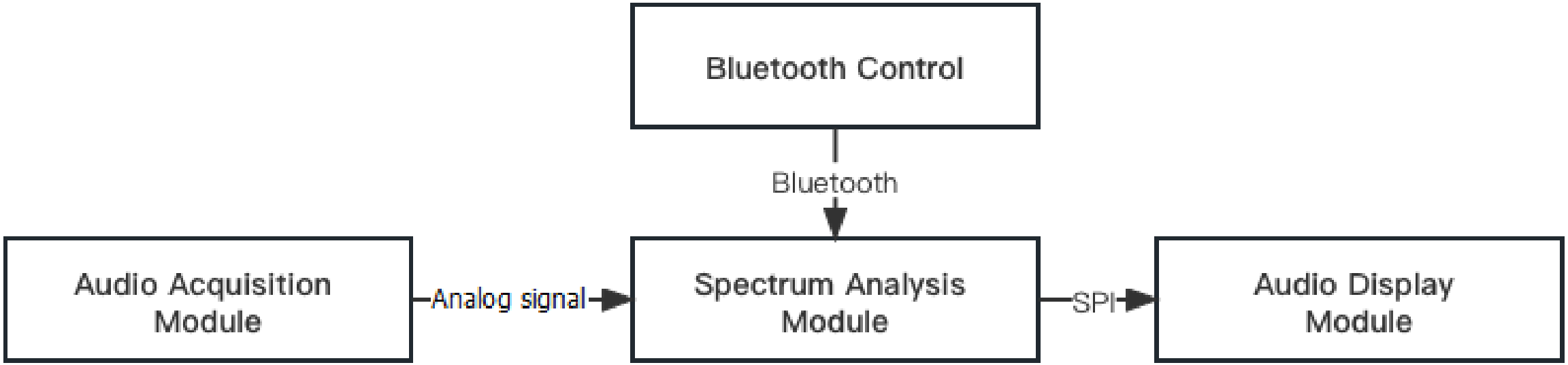
Patent Pending

Rev: Sep 2023

Introduction

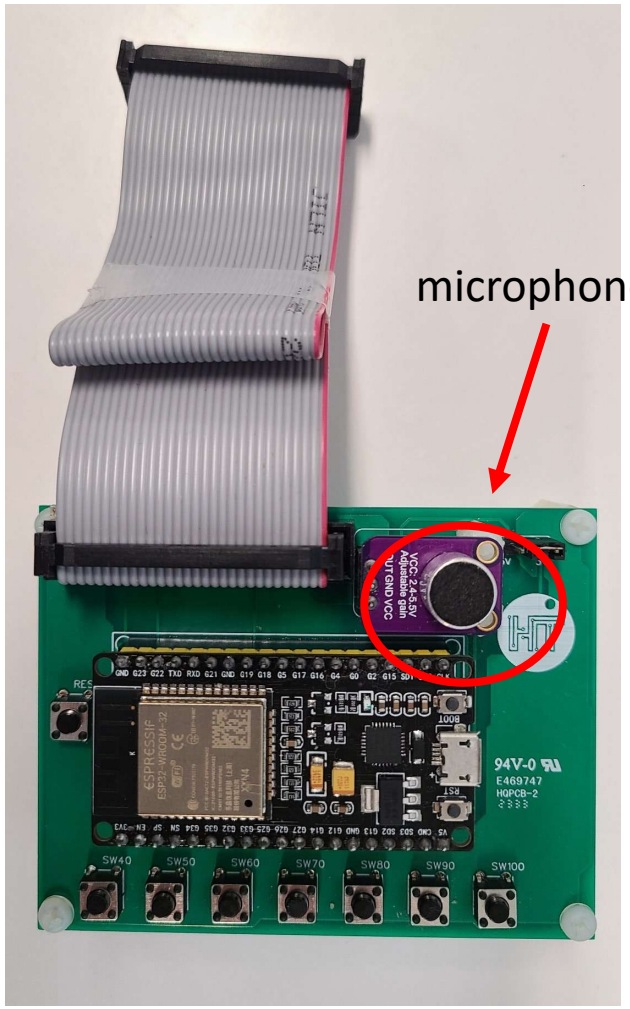
- This article focuses on the implementation of a smart home device.

- The device consists of **four hardware modules,** namely, **the audio collection module**, **the audio processing module**, **the MCU control module**, and **the audio visualization module**.



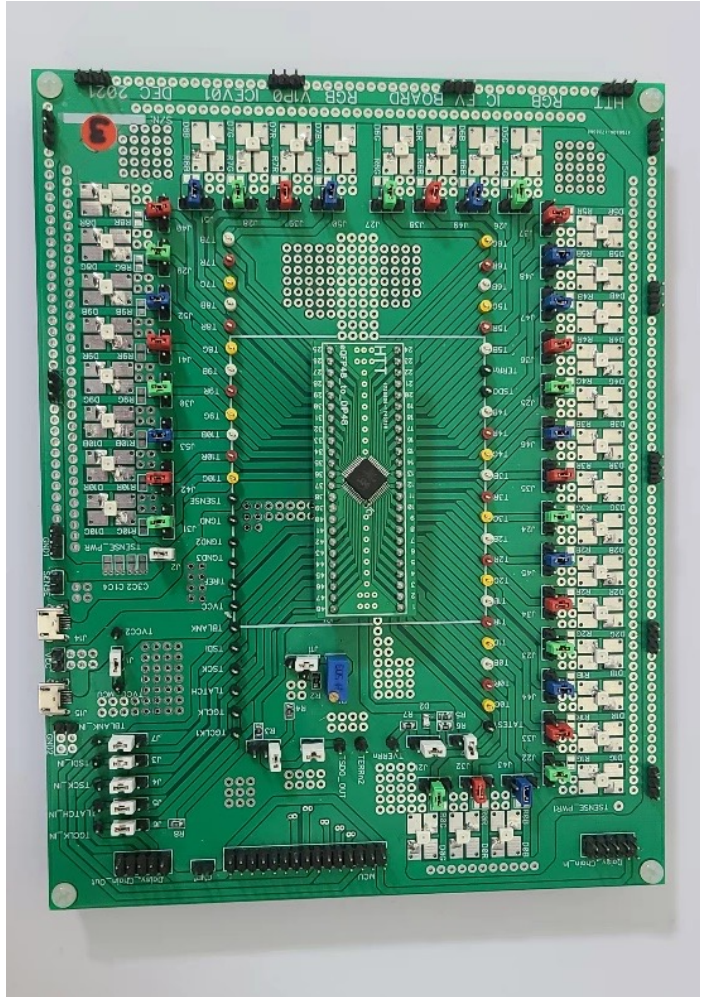
Audio Acquisition Module

- This module receives the **audio signals** and transmits them to the **MCU**.
- The module consists of a condenser **microphone** for sensitive **sound detection** and an amplifier circuit.
- The output of the module is analog. Then, it is converted into digital output by the MCU.
- The digital output is activated when the sound intensity reaches a specific threshold, to be adjusted by means of a potentiometer on the transducer.
- The analog output voltage varies with the input sound intensity.



Audio Display Module

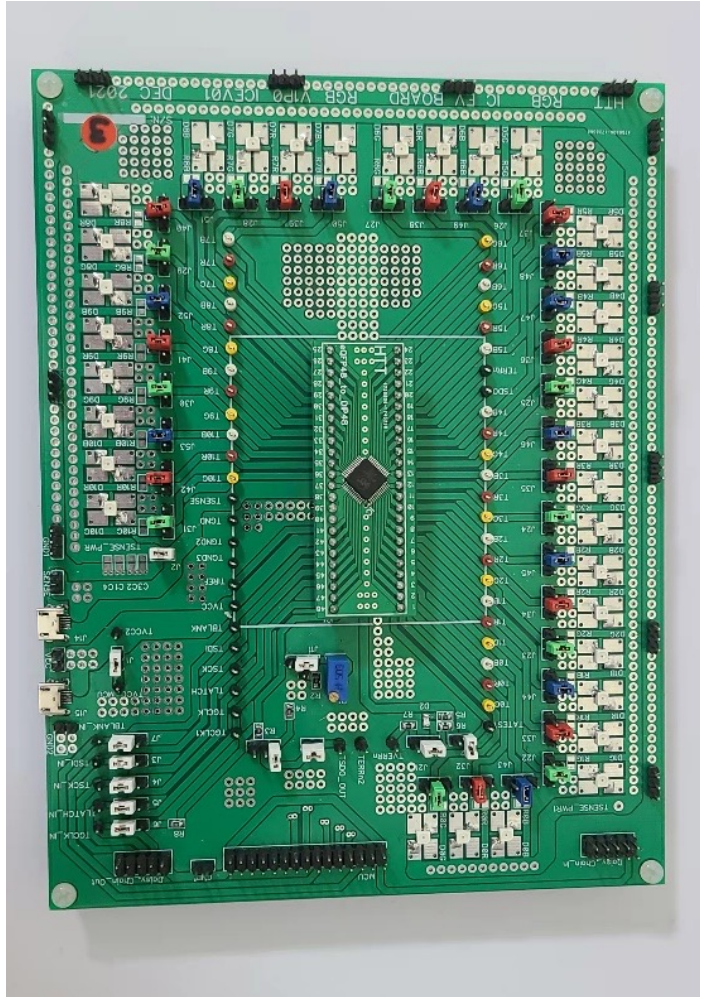
- This module is named as an **RGB** board.
- We want to use a RGB board to **convert the invisible audio to a visible signal**.
- The RGB board has 11 groups of LEDs, each group consisting of red, green, and blue LEDs.
- The RGB board has a 24-channel constant-current-sink output and supplies an output current of up to 50mA adjusted by an external resistor.



Audio Display Module

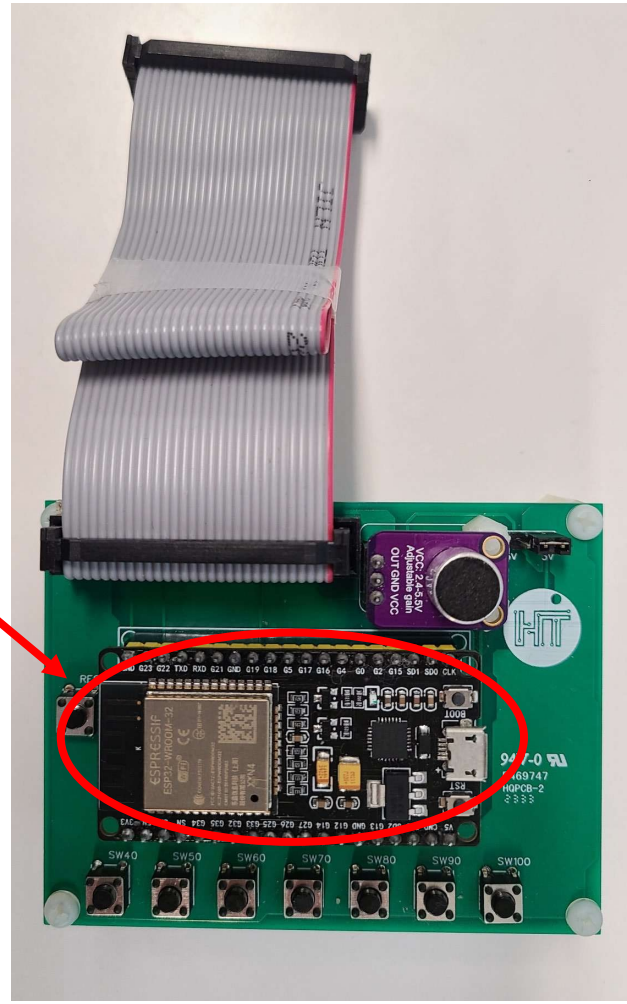
- The number of “**on**” **LEDs** and their **brightness** are determined by the threshold interval by comparing the **FFT results** obtained from the ESP32/RISC-V based MCU.

- This will create a changing **light pattern** corresponding to the **loudness** and **pitch** of the **audio signal**.



Spectrum Analysis Module

- The **ESP32 MCU** was selected to process spectrum analysis.
- It is integrated with an RF antenna, a Bluetooth module, a power amplifier, low-noise amplifiers, filters, and a power management module.
- This study uses ESP32's built-in master-slave integrated Bluetooth module for remote control of the RGB light mode with a mobile phone.
- **MATLAB** is used as a tool to analyze the audio signal in the frequency domain.



Spectrum Analysis Module

- **RISC-V** based MCU can be another choice.

- With a license-free, sanction-free RISC-V CPU core, the speed, flexibility and simplicity of this system can be improved.

https://www.techrepublic.com/article/risc-v-what-it-is-and-what-benefits-it-can-provide-to-your-organization/

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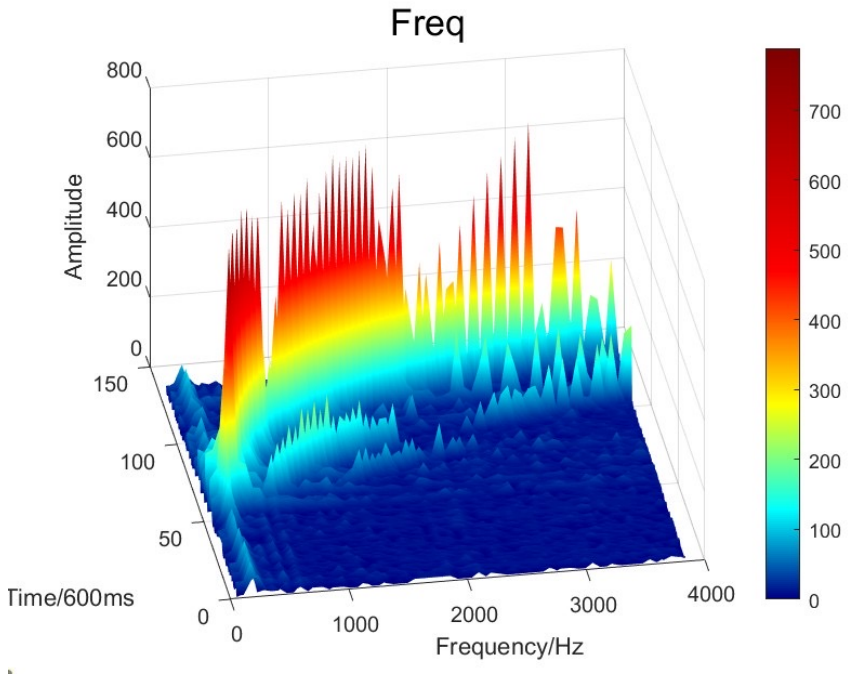
Design of Spectrum Analysis Module

- In this module, a fast Fourier transform, which uses a base 2 logarithm and is provided by the Arduino fix_ftt library, is applied to the original signal to obtain the frequency domain characteristics of the audio signal.
- We use MATLAB to analyze frequency domain of the audio signal.
- This picture shows the feature of a **special audio signal** which sound frequency is changing gradually from 0 Hz to 4000 Hz to analyze.



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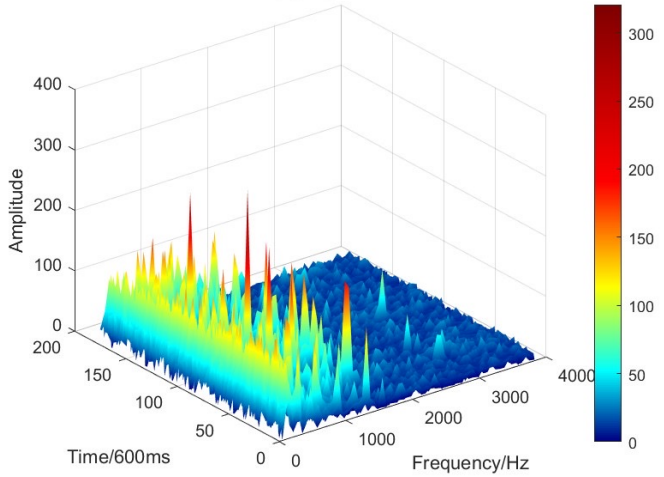
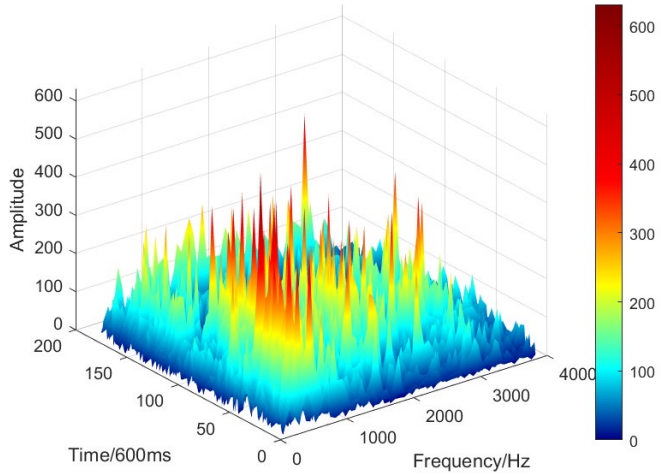
Design of Spectrum Analysis Module

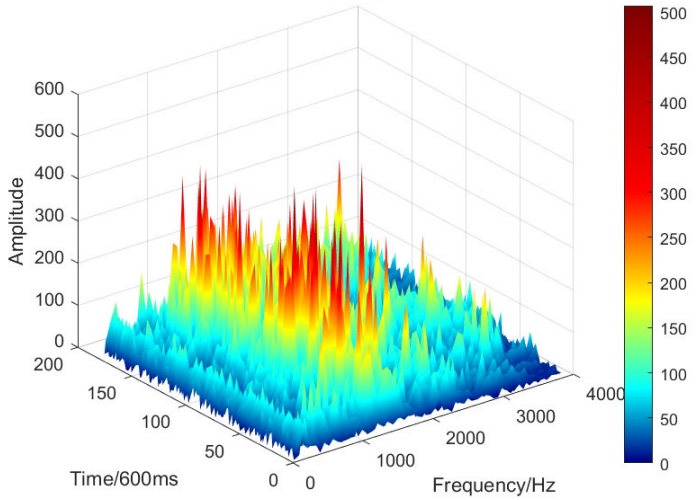
- Following pictures shows different kinds of music's features.
  - **Classical music** mainly distributes at low frequencies.
  - **The drum music** distributes in the whole frequency scale.
  - **Rock music** mainly distributes in the mid and high frequency.



Classic



Drum



Rock

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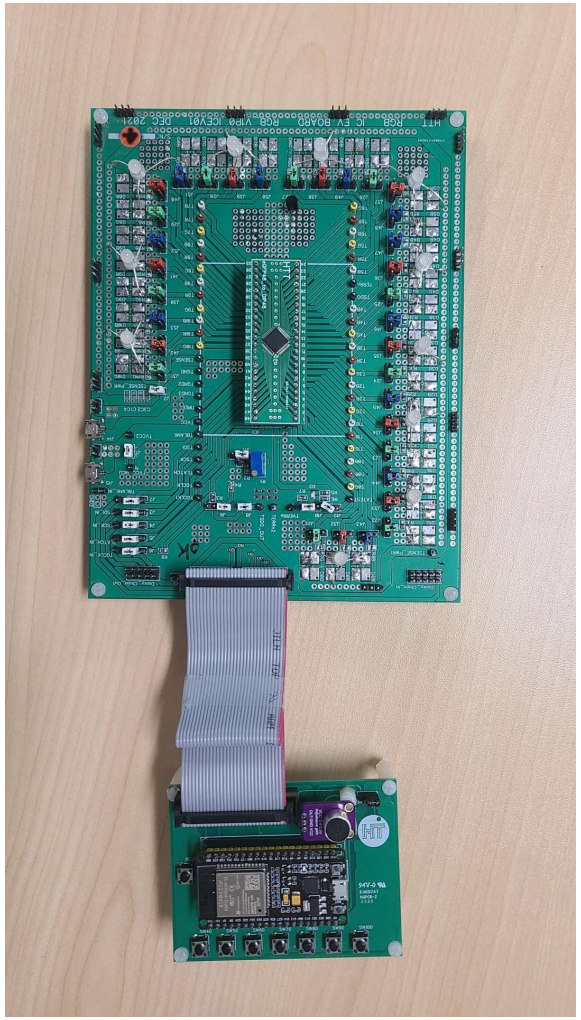
Design of Spectrum Analysis Module

- By utilizing those **music's feature**, we can create different **RGB LED light pattern** according to the music frequency and amplitude.
- The **amplitude** could be used to adjust the brightness of the RGB LED.
- The **frequency** could be used to adjust the light pattern.



Design of Spectrum Analysis Module

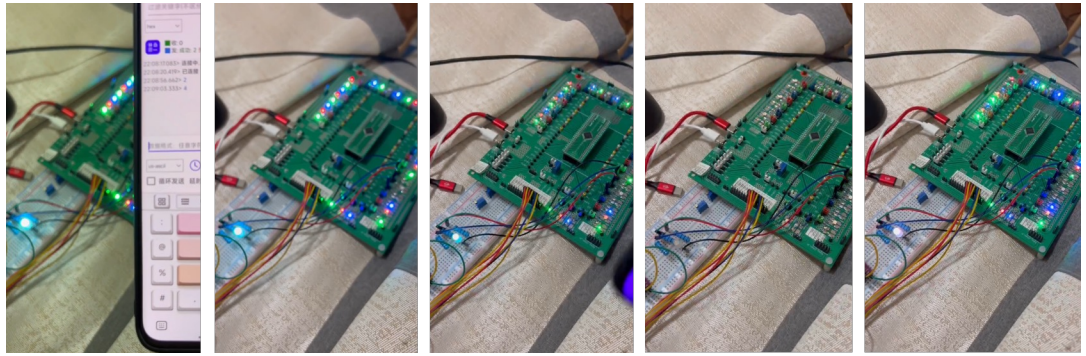
- The **SPI** protocol is used for communication between the spectrum analysis module and the audio display module.

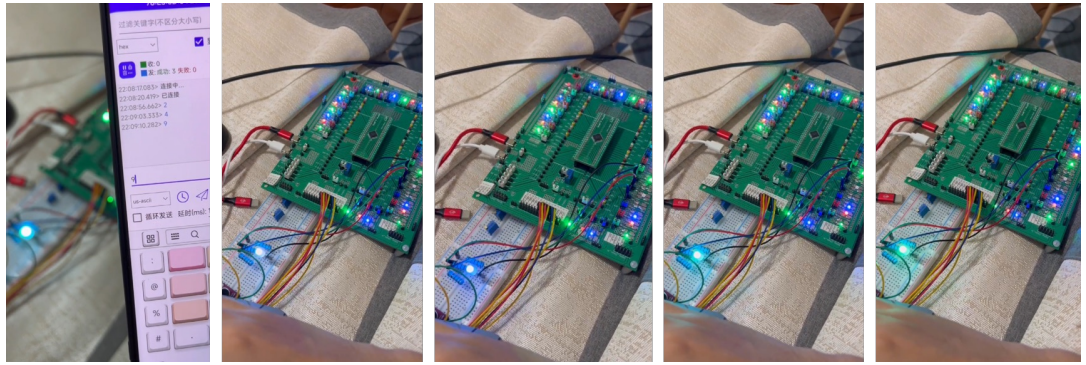
Design of Bluetooth Control

- ***Bluetooth*** *Control*

- In this system, the Bluetooth module is used for remote control.

- The ESP32/RISC-V based MCU is connected to external Bluetooth devices through the Bluetooth Serial Library to realize the remote control of the MCU.



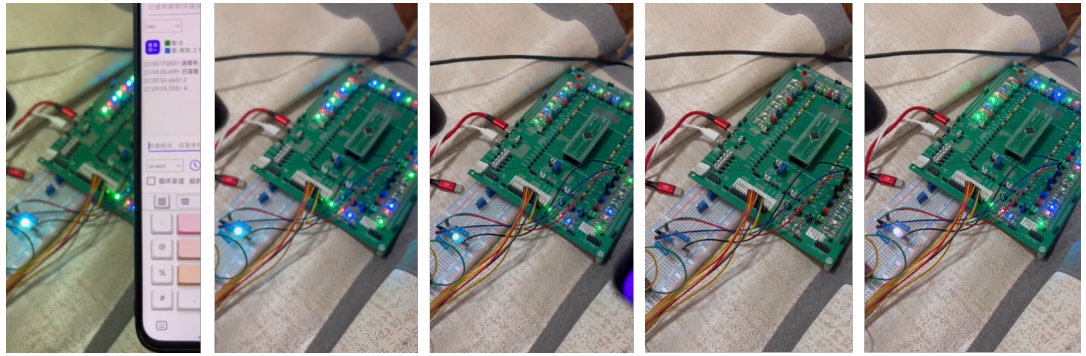


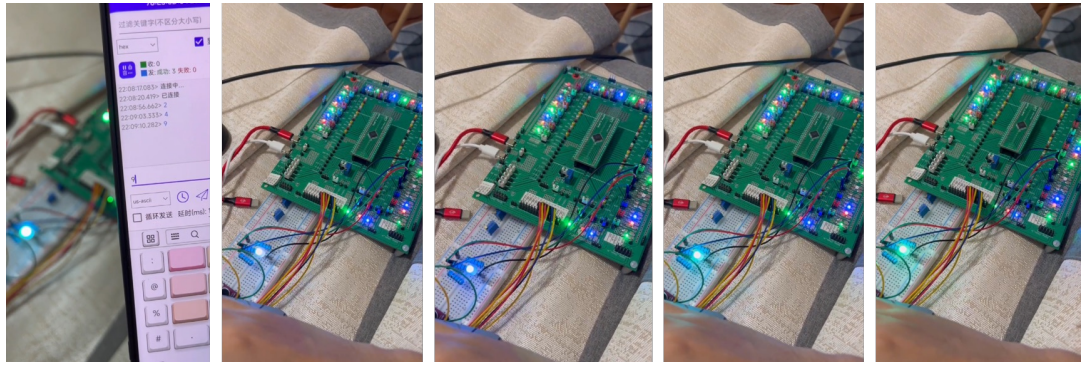
Design of Bluetooth Control

- The system combines Bluetooth, ESP board, audio signal analysis, and the RGB board.

- By using a Bluetooth app, we can send the RGB board a **command**.

- This command can make the RGB board execute the **corresponding function**.





Power module

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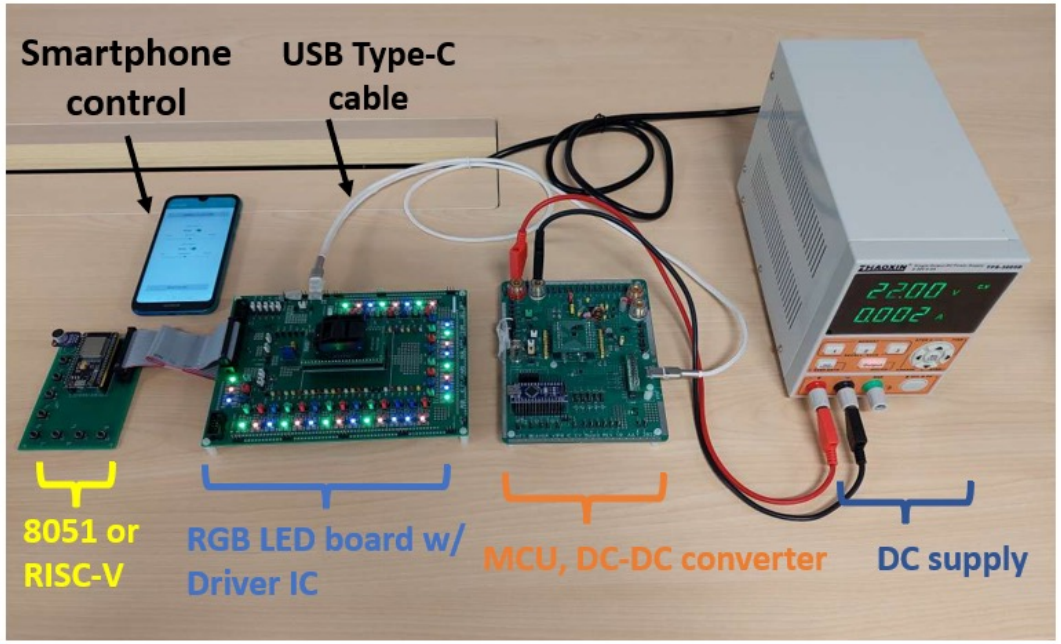
An USB Type-C power source supported by a **DC-DC converter** is used as our power source module to make the system **flexible** and **efficient.**

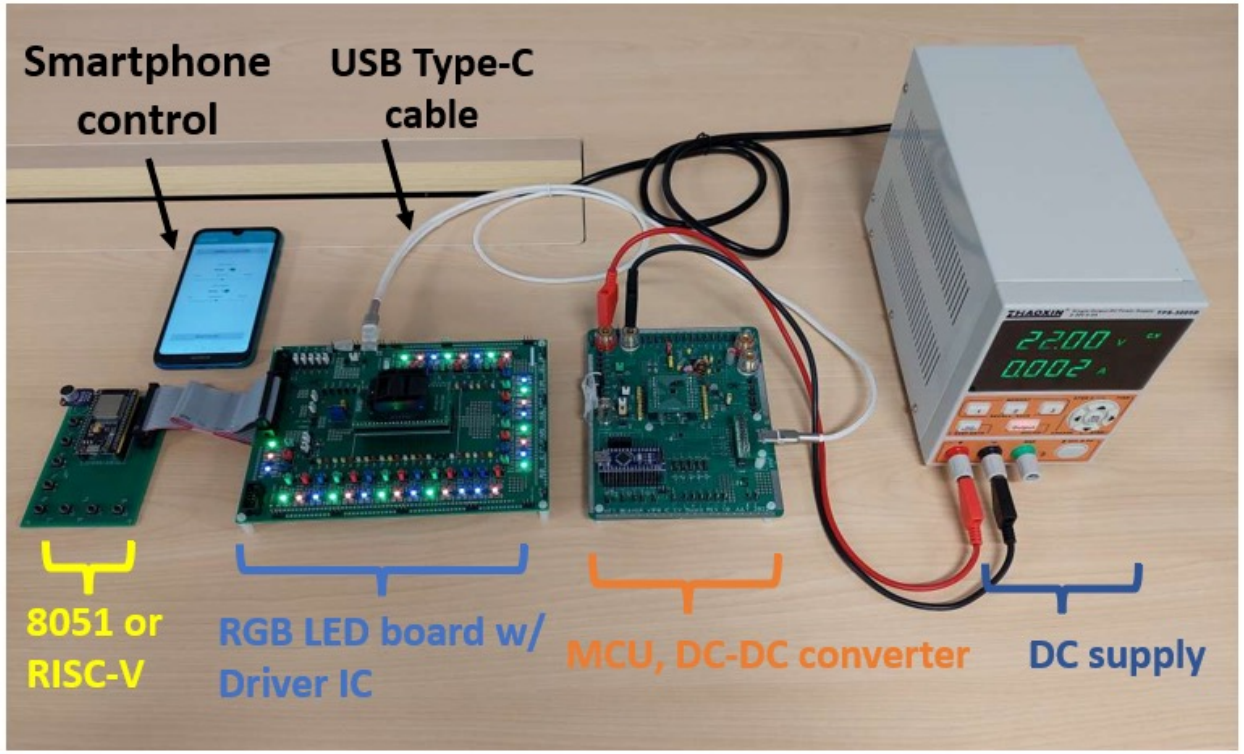
The power delivery process is described below:

- The RGB board operates at a certain voltage and current governed by the changing light patterns.
- The 8051 or RISC-V MCU on the board sends power requests to the power source module with the USB Type-C PD 3.1 protocol.
- The power source module which consists of a protocol MCU and a DC-DC buck converter receives the request and acquires the corresponding power from a DC-supply.
- The protocol MCU can control Vout and Iout precisely using the DC-DC buck converter.
- As a result, the RGB board can have a stable input from the power module.



Power module

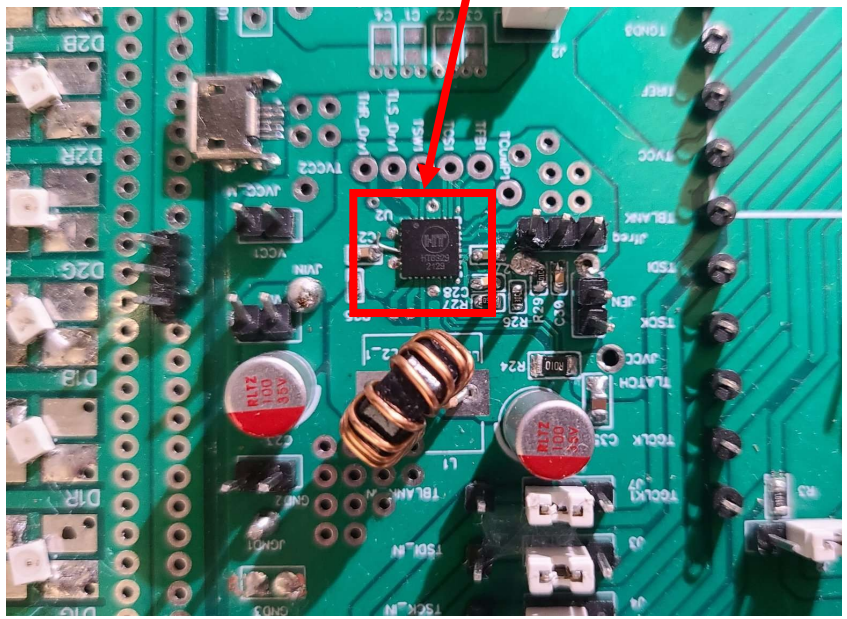
- The whole process can be very **flexible**, **high-speed**, and the **request power range** is very **large**.
- Currently, our RGB is powered by 5V 1A, i.e. power is up to 5W.



Power saving module

- We have developed a DC-DC buck converter for adjusting the power input of our RGB system.
- A power supply provides 20V power and the IC can convert it into 5V to power up our RGB board.
- We measure the power efficiency of it in a RGB LED half-brightness condition.
- Vin of the IC is 12V, and Iin is 0.253A. Pin is 3.036W. Vout is 4.878V, Iout is 0.6A, Pout is 2.9268W.
- **Power efficiency** is Pout/Pin = 96.4%.

DC-DC buck converter



Experimental Results

- The final experimental results are shown below.

- After initializing the system, as the music plays, the **light pattern** on the RGB board changes according to the **rhythm** of the music.

- Meanwhile, the audio volume determines the number of lights. The higher the **volume**, the greater the **number of lights**, up to 11 of the same color. The detection range is between 10dB and 75dB.

- The RGB board light pattern varies with the music played.
  - When the music is playing in a high register, the red LEDs will turn on;
  - When the music is played in a medium register, the green LEDs will turn on;
  - When the music is playing in a low register, the blue LEDs will turn on.

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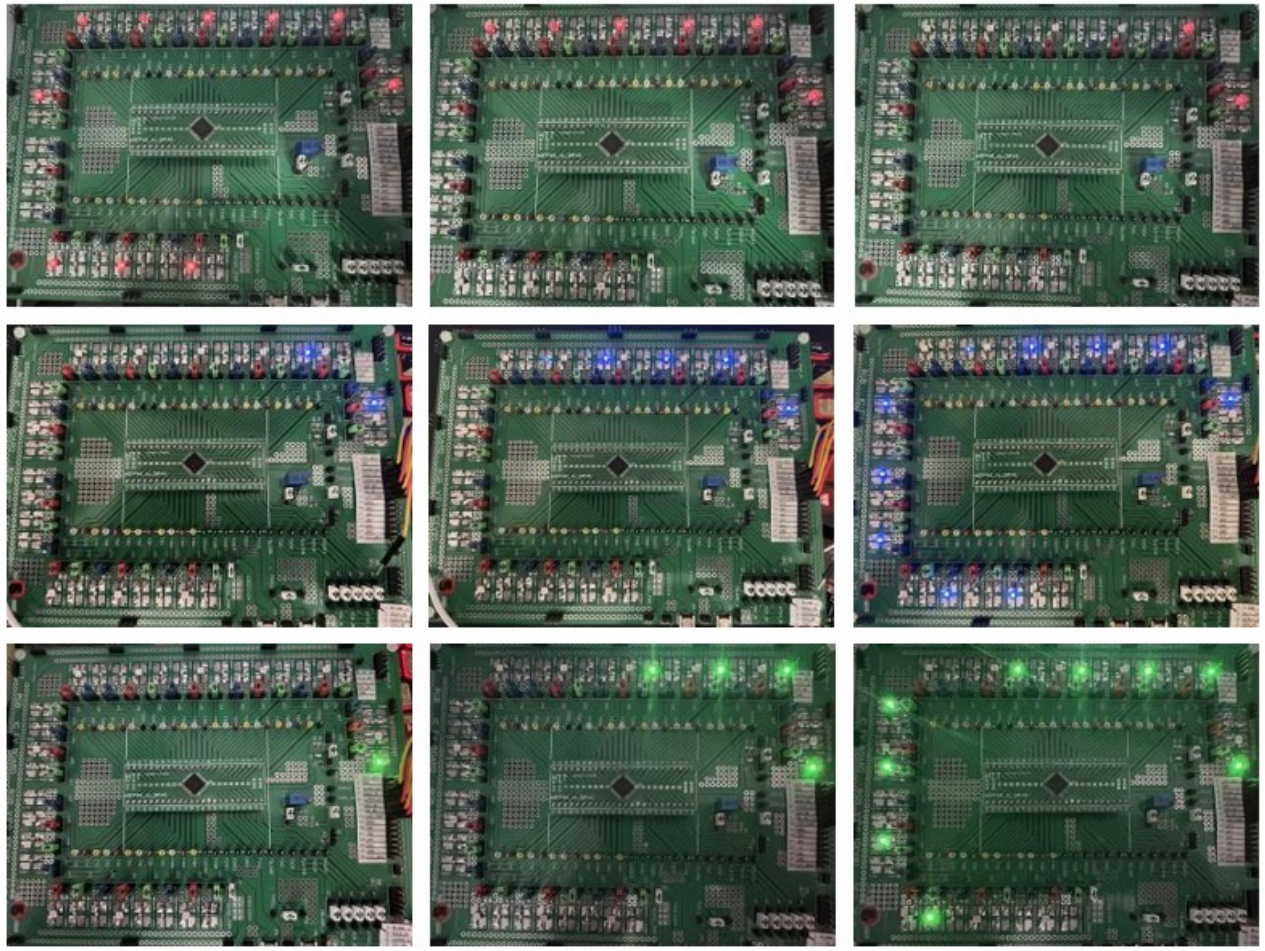
Experimental Results



DISCLAIMER

Application

Smart Home

- The Audio Visualizer can collect and analyze the audio signal in the home and produce corresponding light patterns to adorn the home atmosphere.

- And our power-saving feature will consume less energy and build a green life.

https://www.qh-tek.com/gov/7892

Application

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Car ambient light

- when playing music in a car, the Audio Visualizer could produce corresponding light patterns according to the music, which makes the car more attractive.

https://m.sohu.com/a/304426734_487651/?pvid=000115_3w_a

Conclusion

- In this paper, we proposed an audio visualization system which consists of a MCU and a LED RGB driver board with Bluetooth command control.

- The system can create music-activated lights that vary with the rhythm, pitch and intensity of the ambient music. The audio signal is processed using an FFT algorithm.

- By base-2 logarithm, we calculate a frequency-amplitude array of 64 entries every 20ms. The result is visualized on the RGB board aforementioned.

- The system can be controlled by a Bluetooth device such as a mobile phone. After testing, the system's Bluetooth control and FFT algorithm is stable and usable, and has some application value.

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