

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

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- 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**.



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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.





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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.



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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**.



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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.





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ESP32

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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- 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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- 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.



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- 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.





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

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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.



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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**.





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Power module

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.

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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.



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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%.





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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



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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.



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Application

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.



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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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