ZZZ-Mate

Pulse-Driven White Noise Generator

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Introduction

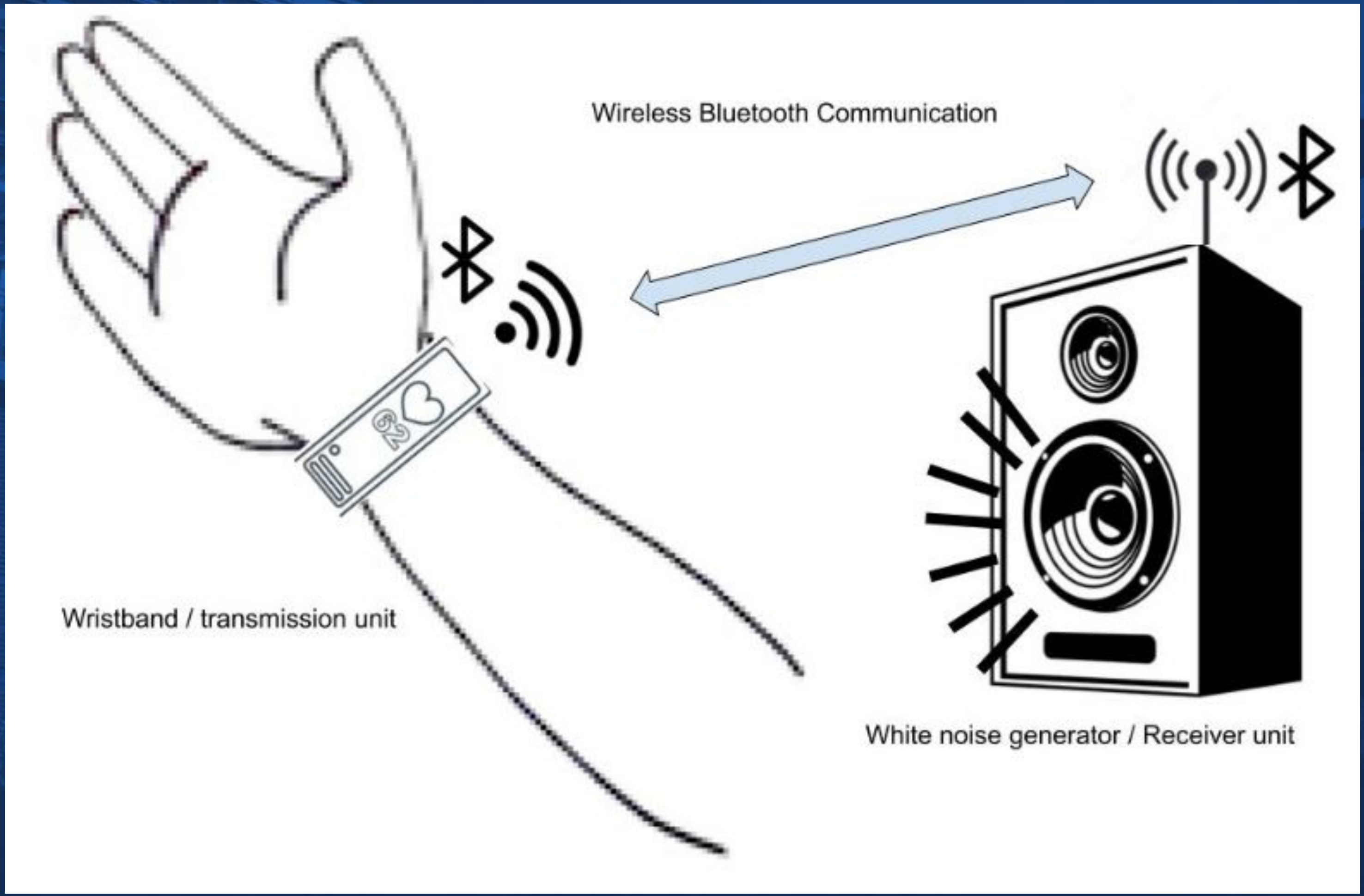
Problem

- Sleep deprivation is an oncurring issue in the world
- White noise machines on market are not variable in output volume
- High volume white noise machines can lead to hearing damage
- Continuous signal overstimulates brain’s auditory cortex

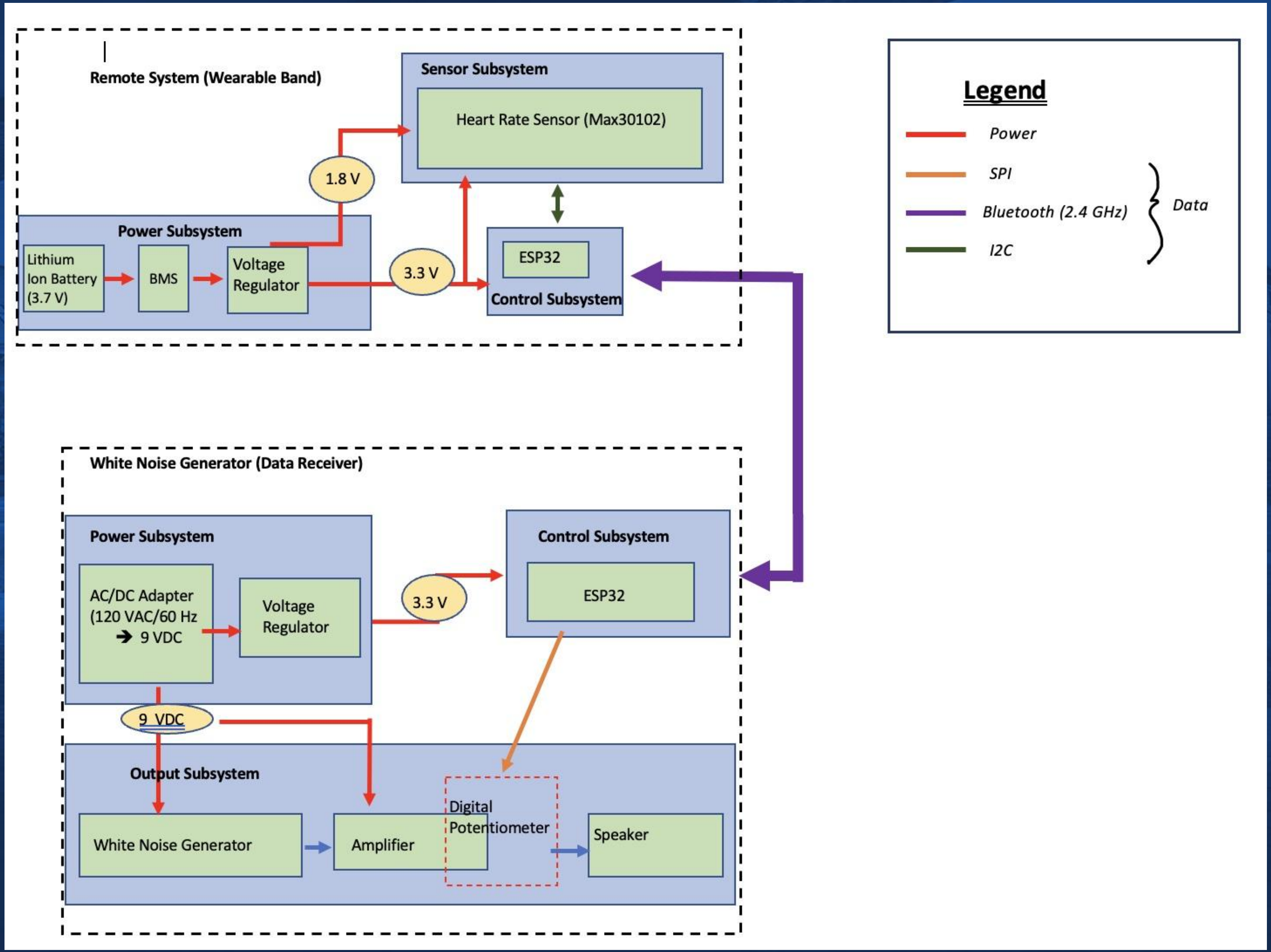
Solution

- A variable white noise generator that can support users according to each stage in their sleep cycle
- Decrease volume as user transitions to deeper sleep
- Use pulse rate measurements to identify the user’s sleep stage
- Use bluetooth connection to communicate with the white noise generator and change the volume accordingly

High Level Design



Block Diagram

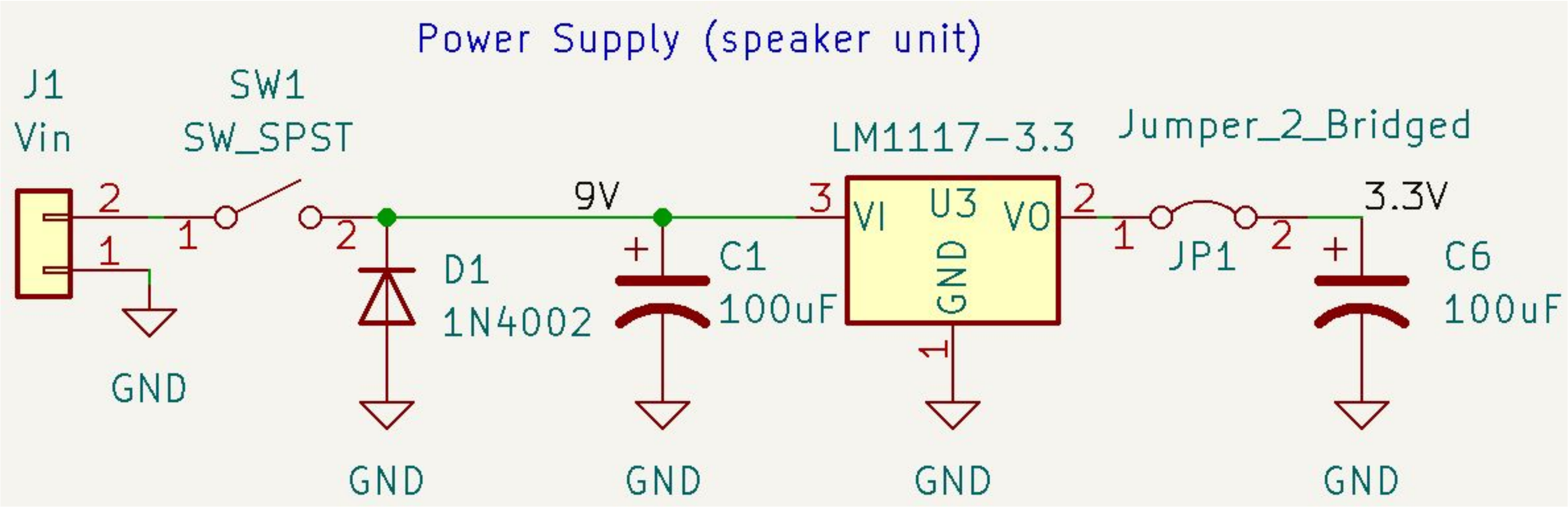


High Level Requirements:

- **Average heart rate measurement (BPM)** measured over the course of five minutes must be within ±5% tolerance against a third party pulse measurement device
- The **output volume is proportional with user's heart rate**. The output will range from 0 to 46dB with ±5dB tolerance based on the user's current sleep stage identified using their real time heart rate
- Battery life of the wristband device must be at least **7.5 hours**

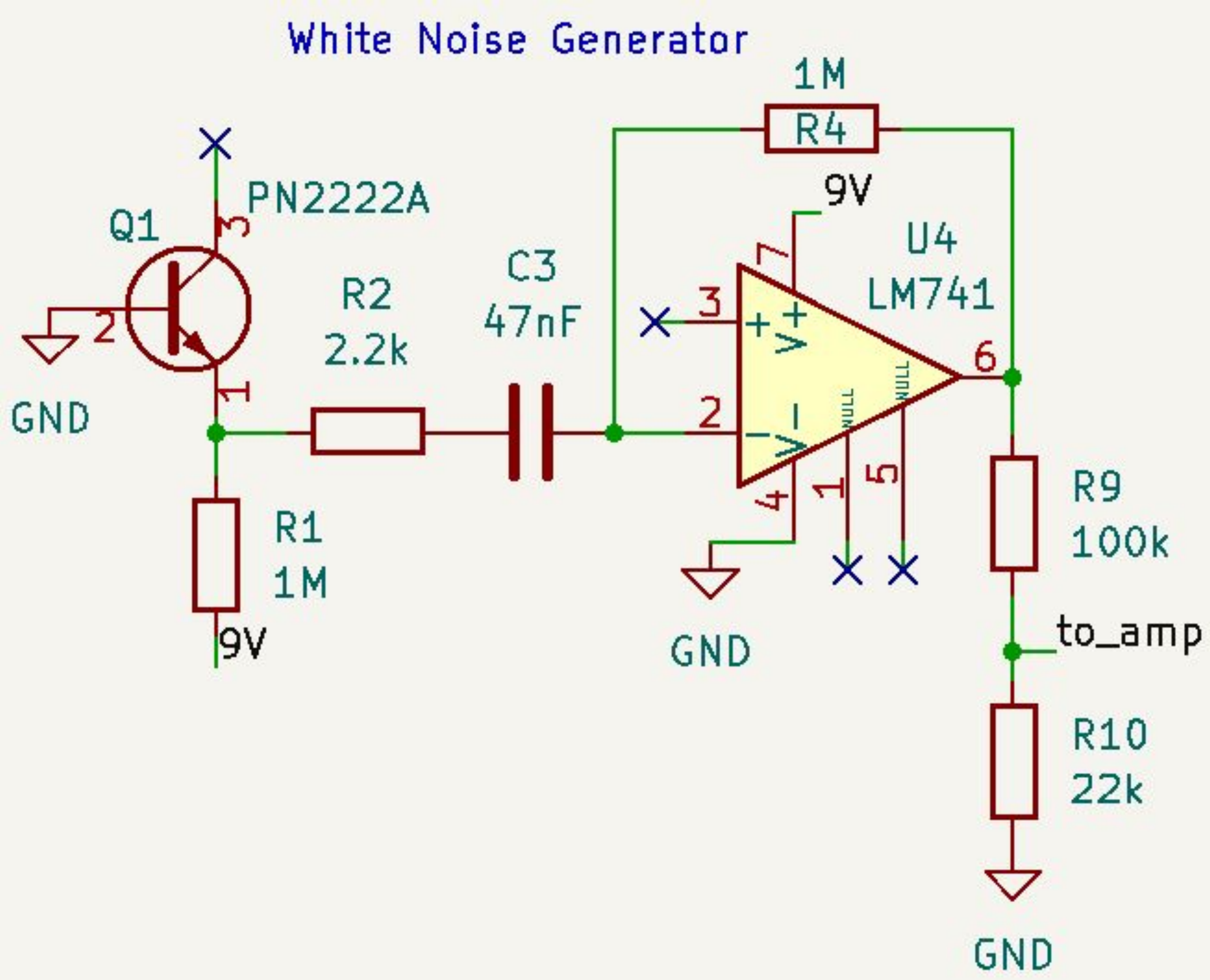
White Noise Generator

Power Subsystem



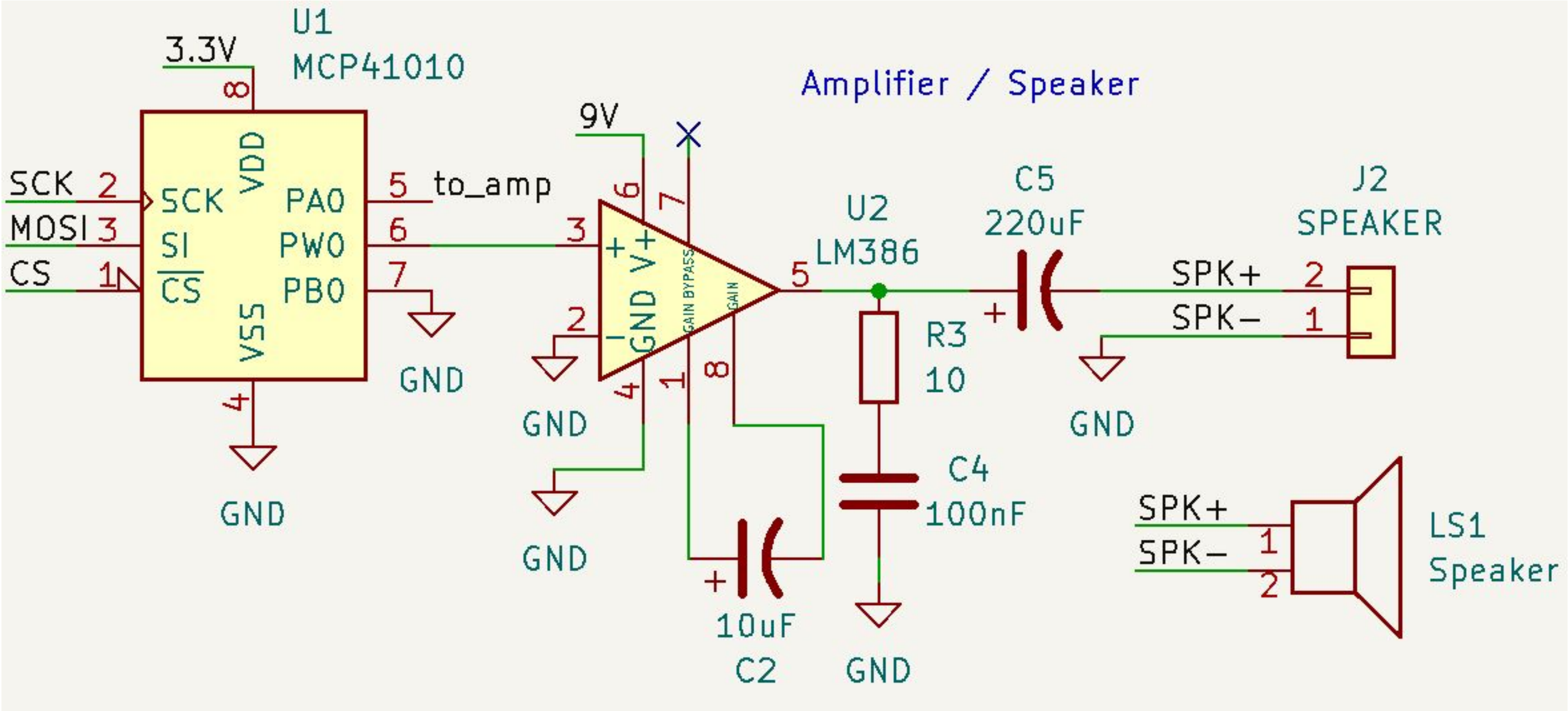
- 9V/1A power supply
- Reverse polarity protection diode (1N4002)
- 3.3V Voltage Regulator (LM1117-3.3)

White Noise Generator Subsystem



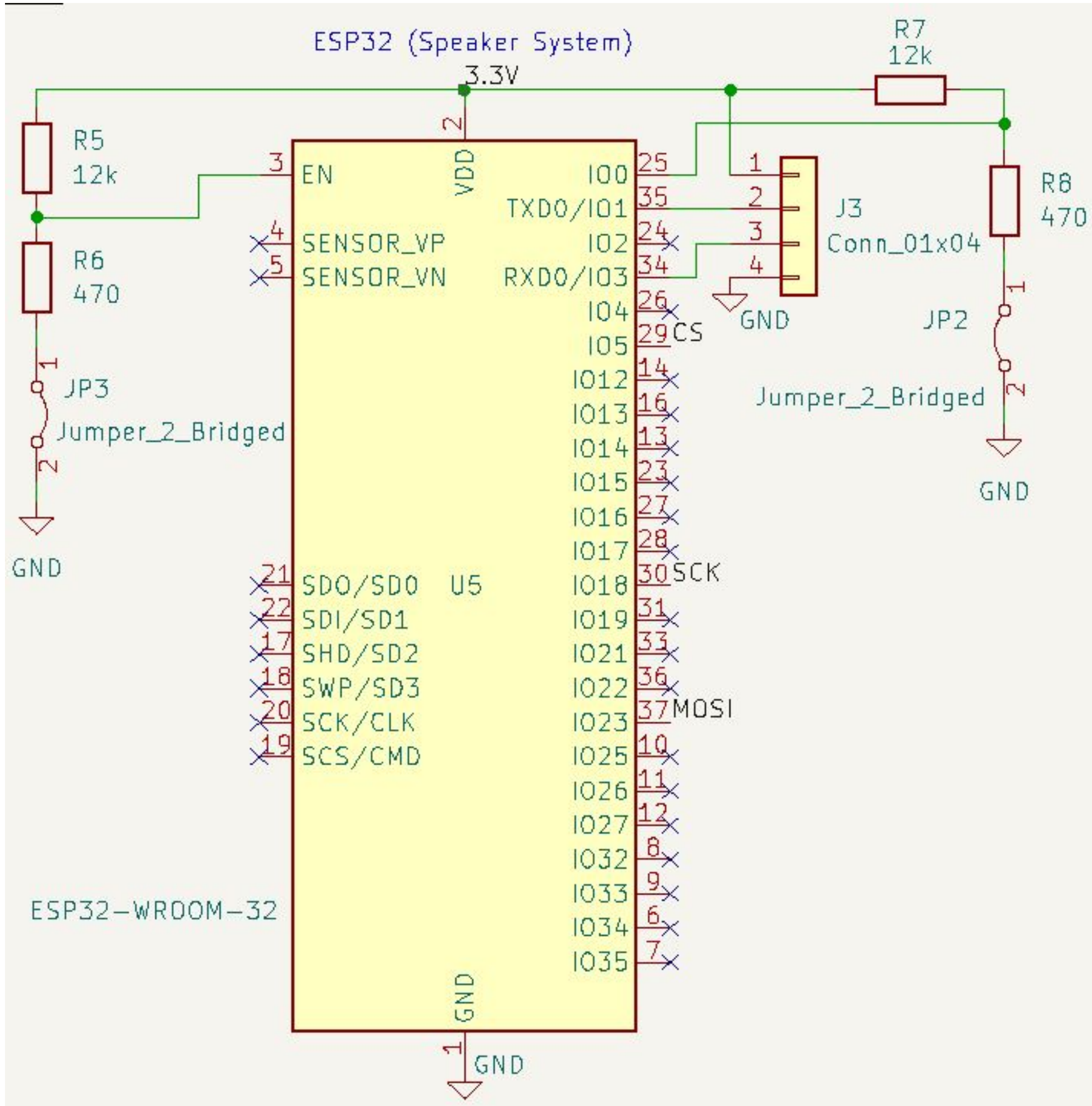
- NPN BJT (2N2222) producing "zener shot noise"
- Opamp (LM741) amplification
- Output attenuation with voltage divider

Output Subsystem



- LM386 power amplifier IC
- Gain of 200 (20log(200) = 46dB)
- Digital potentiometer (MCP41010)

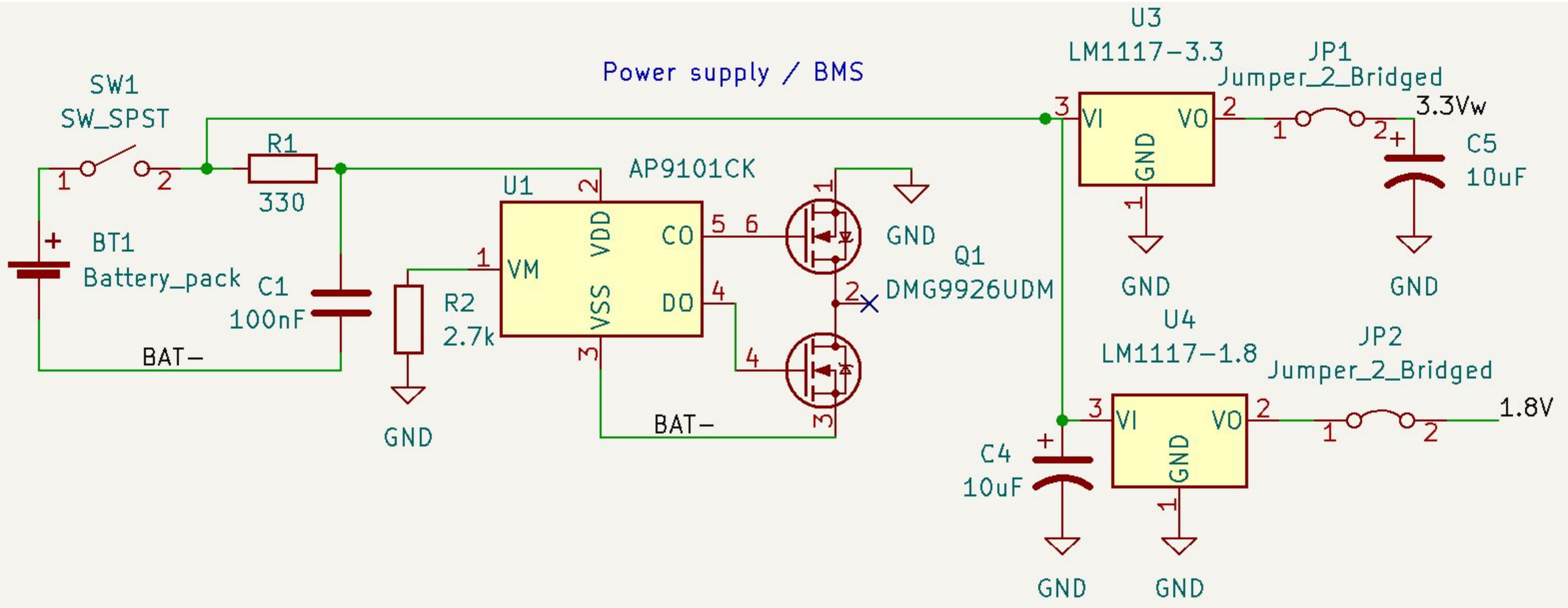
Control Subsystem



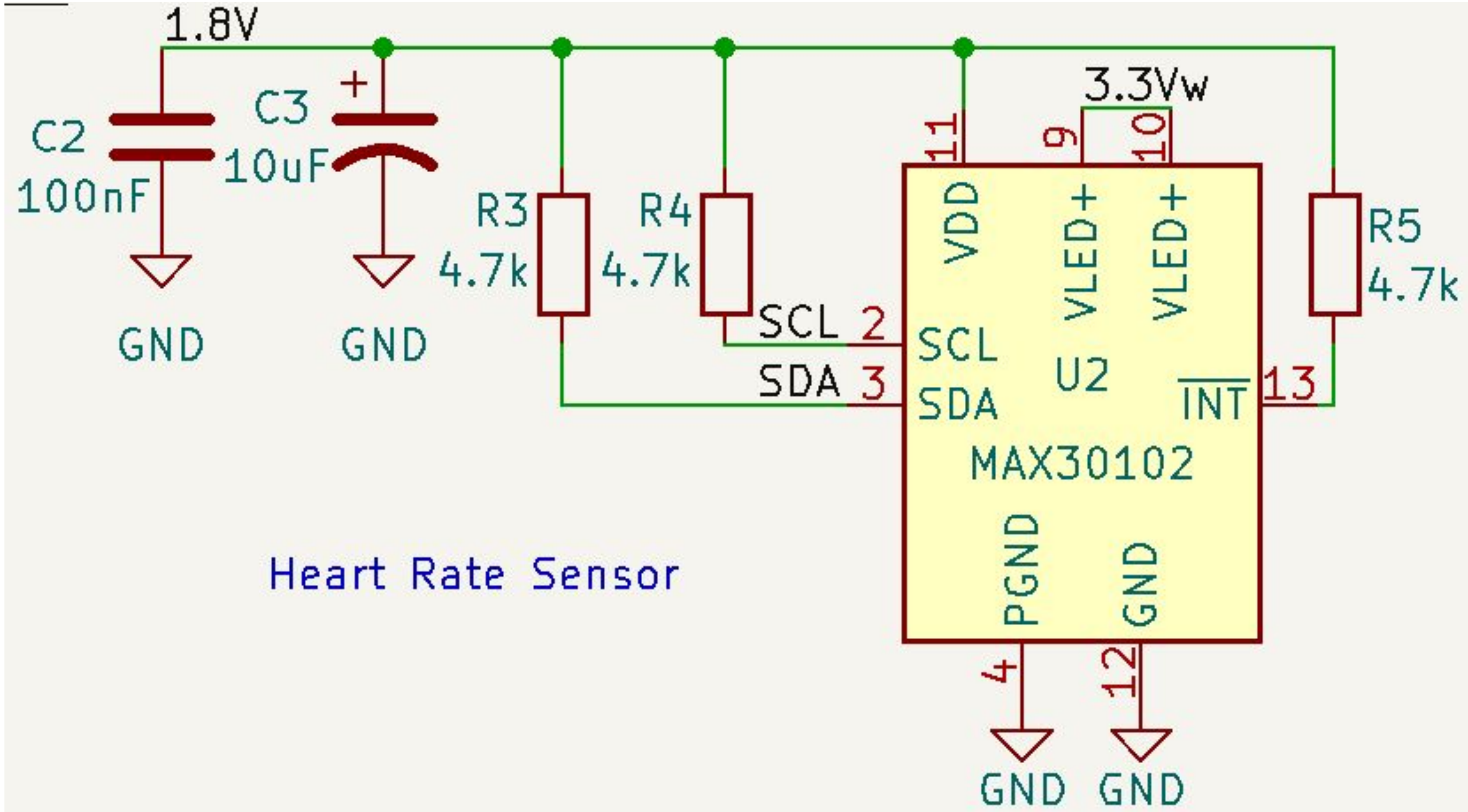
- ESP32 communicates with the digital potentiometer through SPI protocol
- Wirelessly receives heart rate data from wristband ESP32 chip via Bluetooth

Wristband

Power Subsystem

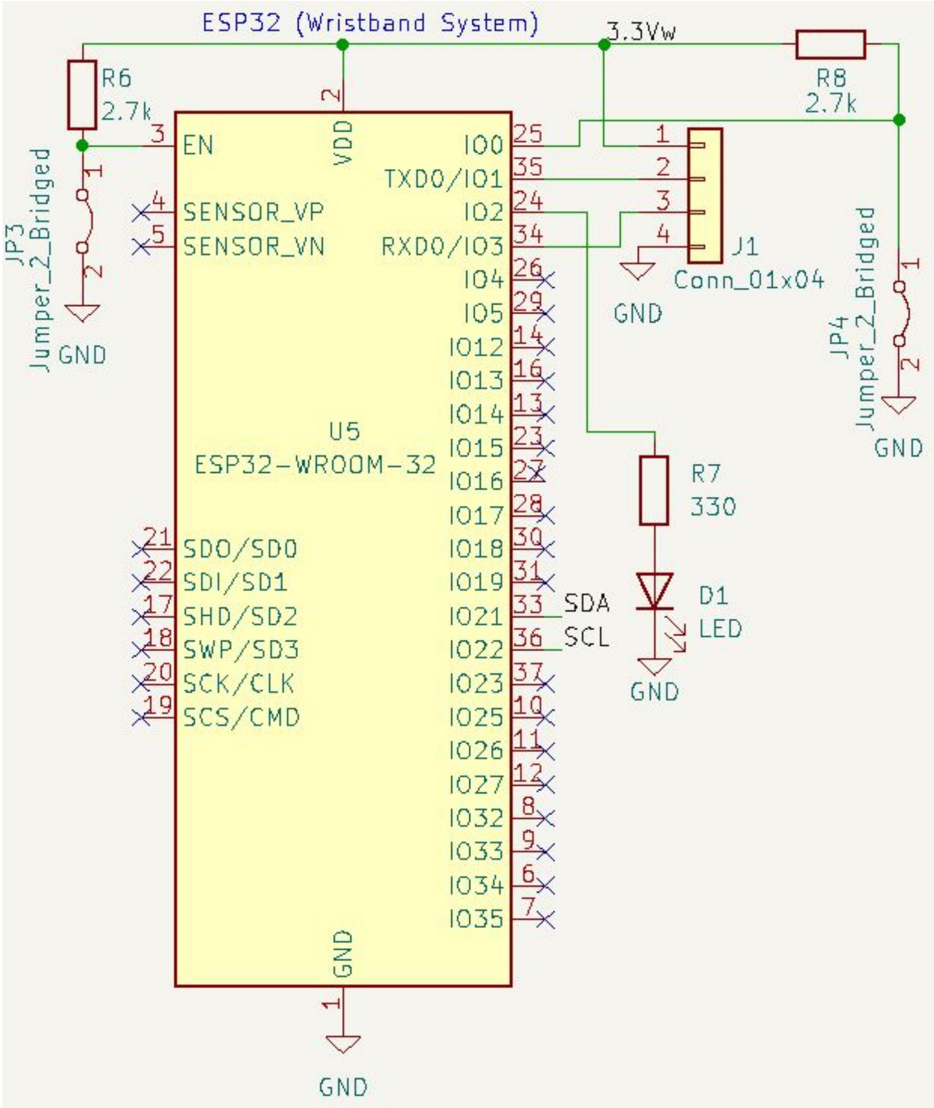


- 3.7V/1100mAh battery
- BMS IC (AP9101C) paired with dual MOSFET (DMG9926)
- 3.3V & 1.8V voltage regulator



MAX30102 Pulse Oximeter / Heart Rate Sensor

Control Subsystem



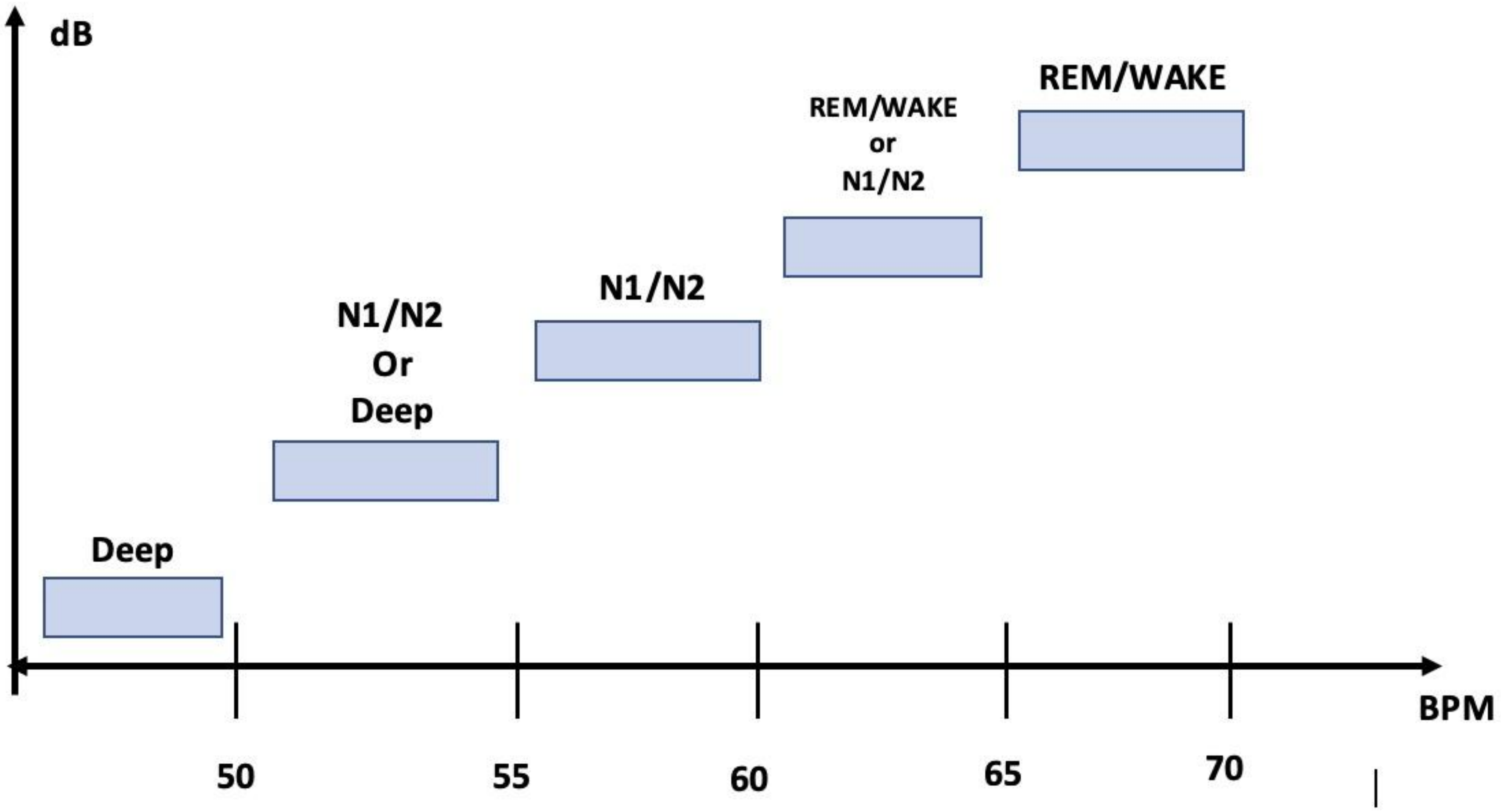
- ESP32 receives heart rate data from the MAX30102 sensor through I2C protocol
- Wirelessly sends heart rate data to white noise generator via Bluetooth
- Both ESP32s are properly programmed to determine the user's current sleep stage

Software Design

Sleep Stage Identification

Volume Range (dB)	Sleep Stage	Heart Rate Range (bpm)
≈ 46	REM/Wake (1)	HRF – (HRF + 5)
≈ 29 – 45	REM/Wake or N1/N2 (1.5)	(HRF - 5) – (HRF)
≈ 14 – 29	N1/N2 (2)	(HRF - 10) – (HRF - 5)
≈ 0 – 14	N1/N2 or Deep Sleep (2.5)	(HRF - 15) – (HRF - 10)
≈ 0	Deep Sleep (3)	(HRF - 20) – (HRF - 15)

Visual Representation

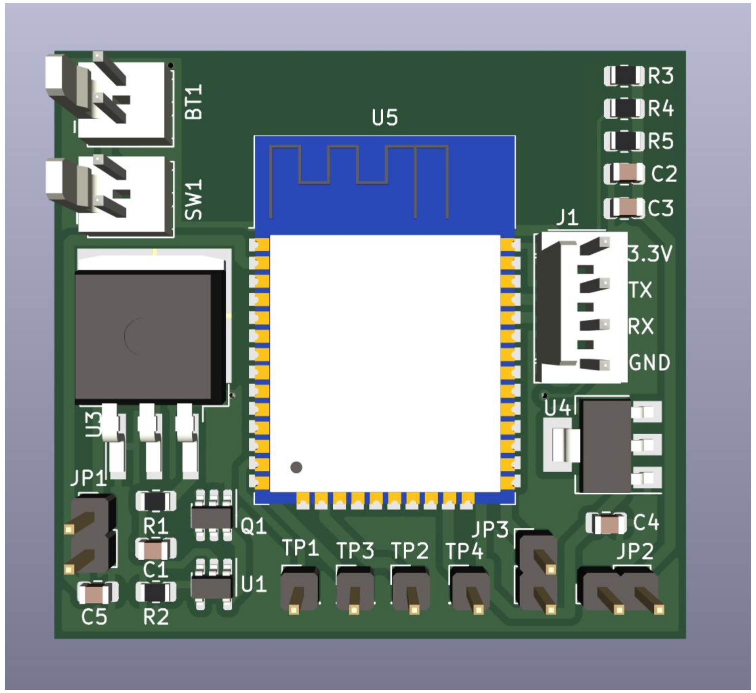


Physical Design

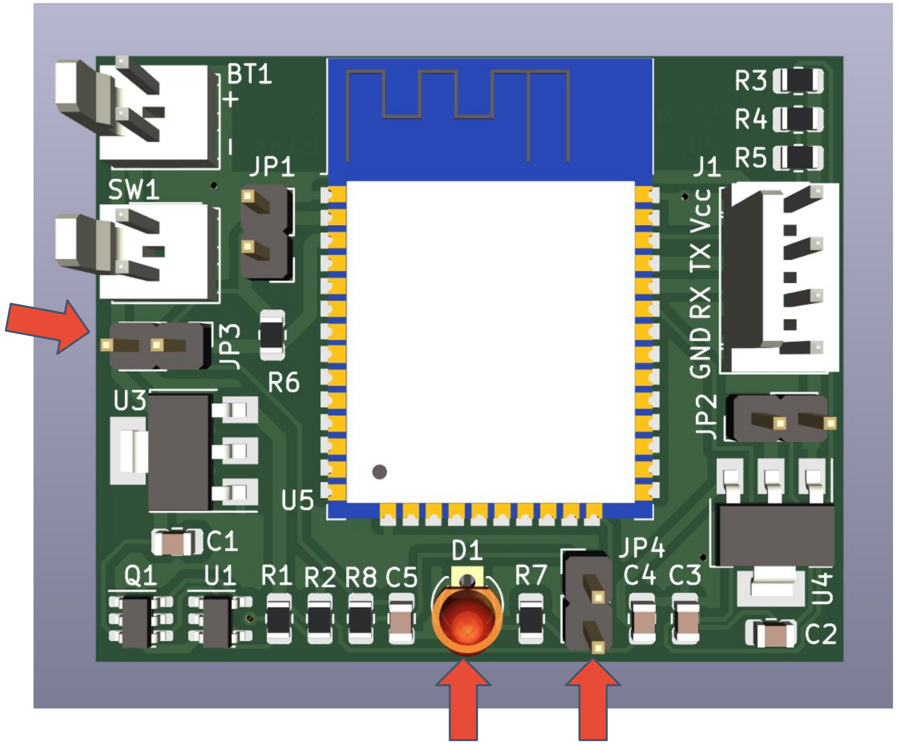
Design Changes:

- Revision on GPIO/SPI connections
- Implementation of pull-up resistor and jumper pins
- Revision of amplifier circuit using voltage divider
- Refined, smaller PCB design

Wristband PCB Design Changes:

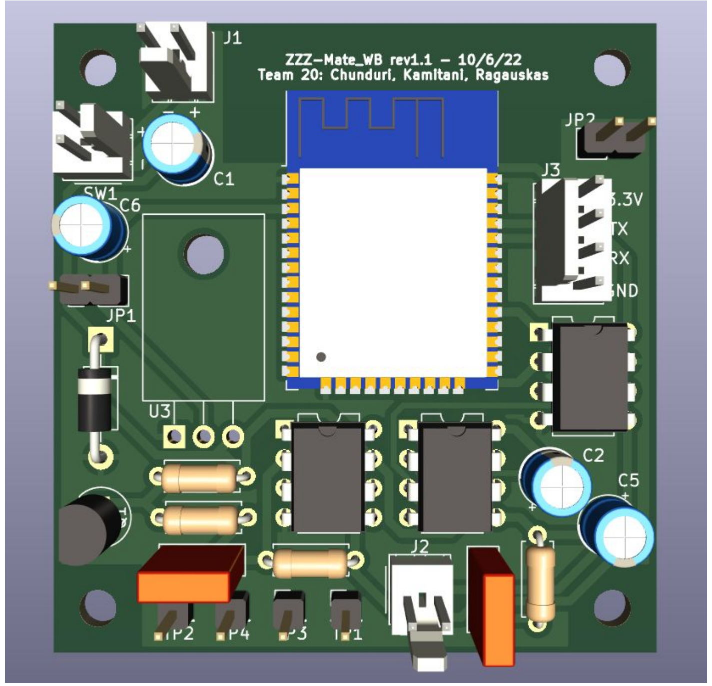


Version 1 Wristband PCB

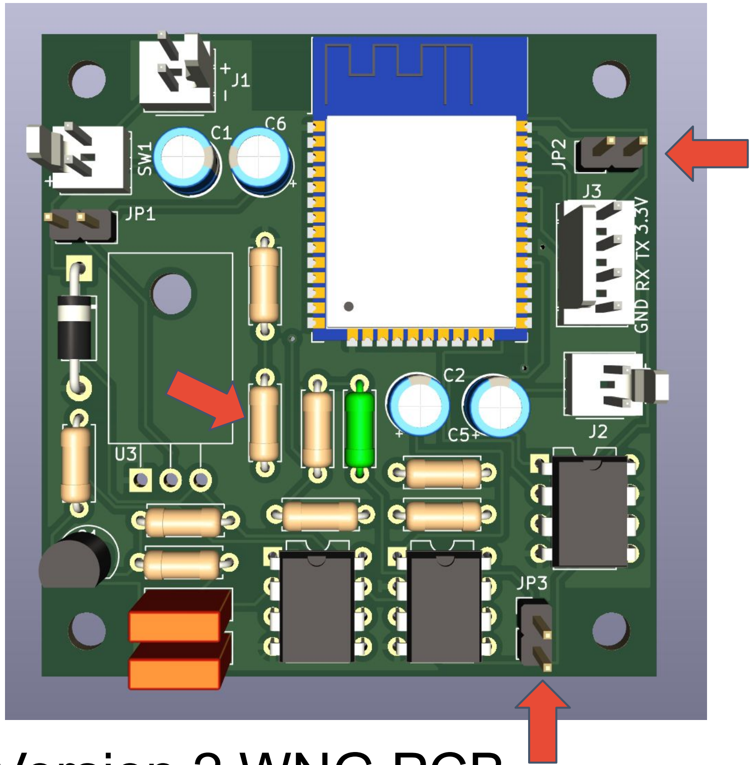


Version 2 Wristband PCB

White Noise Generator PCB Design Changes:



Version 1 WNG PCB



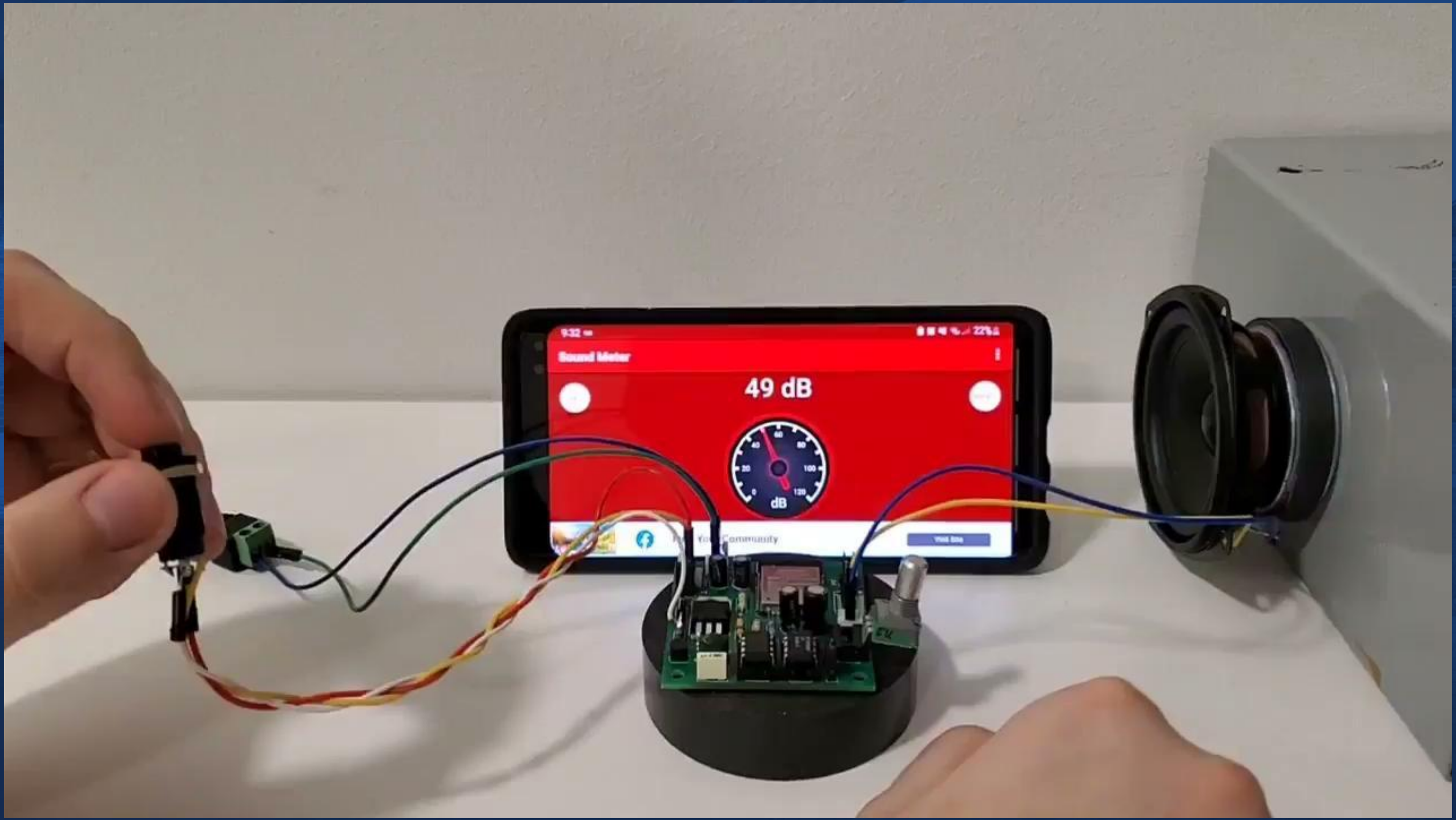
Version 2 WNG PCB

Success and Demonstration

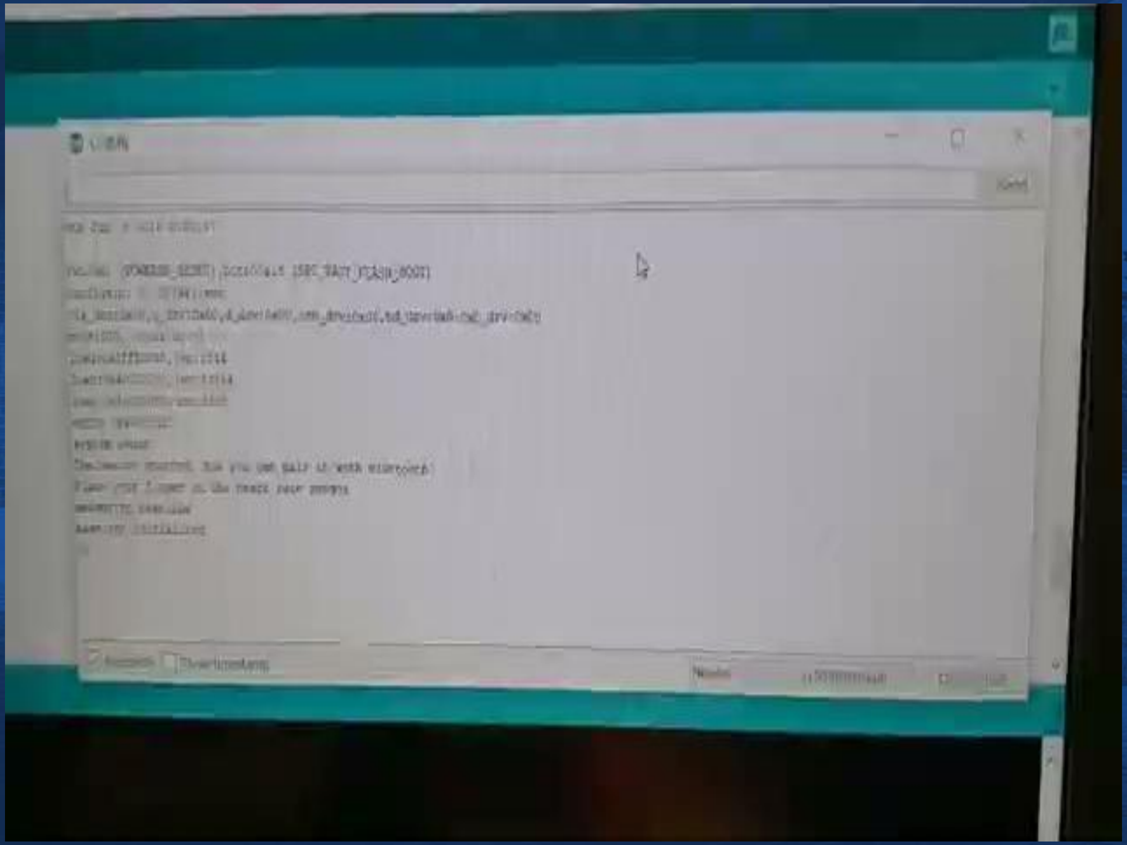
Success

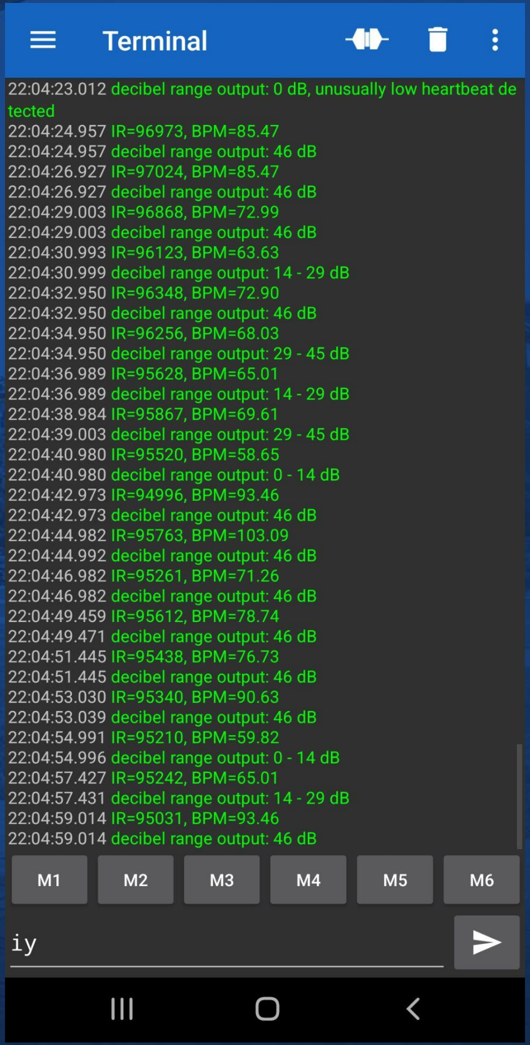
- White noise generation
- Heart rate data collection
- Established connection between ESP32 and cell phone
- Successful software implementation

White Noise Generator



Sleep Stage Identification





Conclusion and Next Steps

Conclusion

Challenges

- Part sourcing and PCB ordering
- Hardware inconsistencies
- Not breadboarding entire systems before PCB designing
- Lack of sufficient research before PCB designing

What We Learned

- Importance of extensive research in R&D
- PCB development using KiCAD
- Debugging procedure using various equipments
- Prototyping using breadboard
- Ordering excess amount of parts and PCBs at an early stage

Next Steps

- Integrate all the components successfully onto two PCBs
  - Make the wristband wearable with an enclosure attached to a band
  - Enclose the white noise generator PCB and speaker into one white noise device
- Add motion sensor and microphone to the design to provide more accurate sleep stage identification

Questions?

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