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

Wireless Bluetooth Communication

Wristband / transmission unit

White noise generator / Receiver unit
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)
- NPN BJT (2N2222) producing "zener shot noise"
- Opamp (LM741) amplification
- Output attenuation with voltage divider
- LM386 power amplifier IC
- Gain of 200 (20\log(200) = 46\text{dB})
- Digital potentiometer (MCP41010)
- ESP32 communicates with the digital potentiometer through SPI protocol
- Wirelessly receives heart rate data from wristband ESP32 chip via Bluetooth
Wristband
- 3.7V/1100mAh battery
- BMS IC (AP9101C) paired with dual MOSFET (DMG9926)
- 3.3V & 1.8V voltage regulator
Heart Rate Subsystem

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

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