Towards a Low Cost, Microcontroller-Based Class-D Audio Amplifier

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Presenter's Resume

Timm Bostelmann received his engineer's degree in computer engineering from the FH Wedel (University of Applied Sciences) in 2008. Since then, he is employed at FH Wedel as a research assistant in the field of embedded systems.

Motivation

DIY Backpack Speaker

Amplifier Requirements

- High efficiency (low power consumption)
- Good audio quality
- Low cost
- Wireless connectivity
- Ideally DIY

Exemplary Existing Solution

TAS5630B based WONDOM AA-AB32192

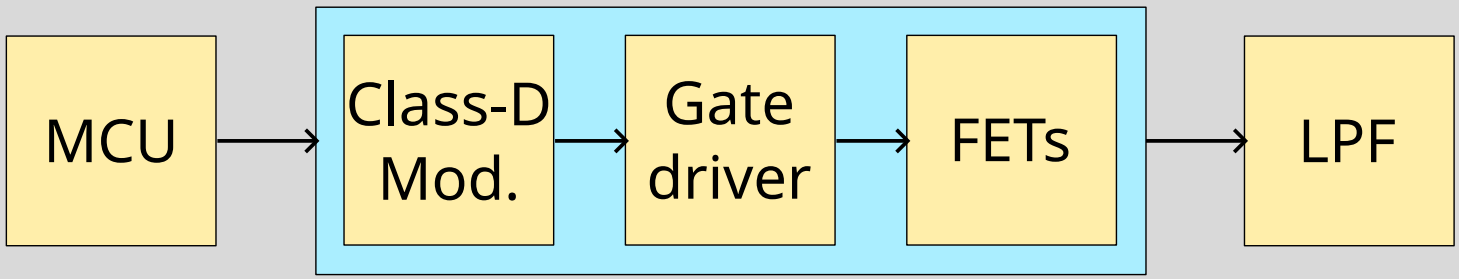
- Power supply voltage 25 V to 48 V
- Idle Power: 4.8 W
- Efficiency at high power: 91 % to 96 %
- Switching frequency: 400 kHz
- THD+N = 1 % @ 246 W, 4 Ω

Problems

- 4.8 W dominates for “idle listening”
- Internal switching transistors
  (no replacing, no tinkering)
- Extra cost for class-D IC
- Not DIY

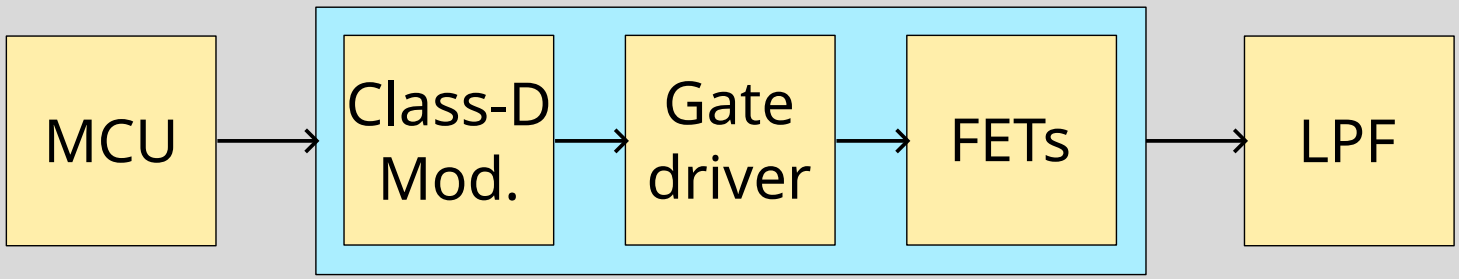
Approach

Classic – custom class-D IC

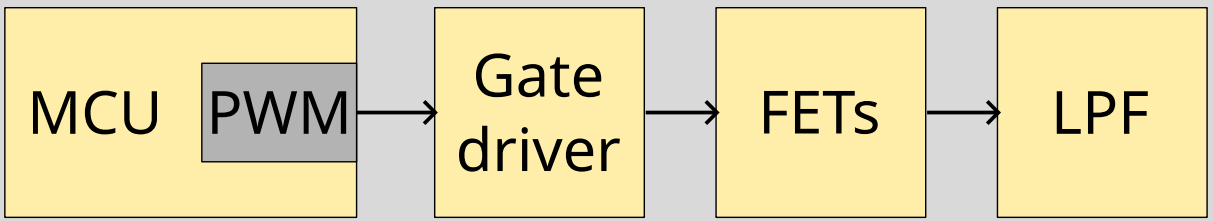


Approach

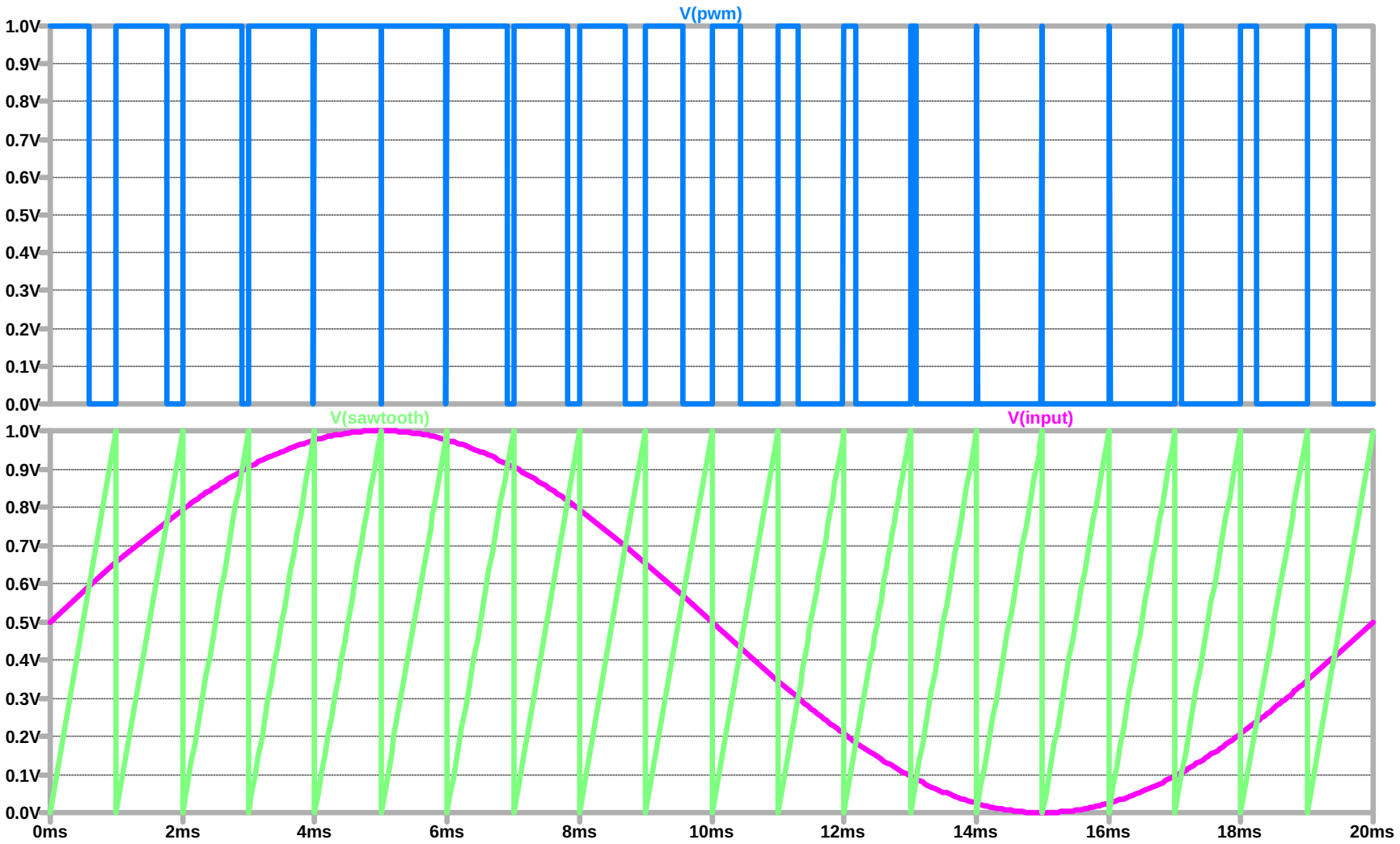
Classic – custom class-D IC



Simple – direct PWM generation



PWM


V(pwm)
1.0V
0.9V
0.8V
0.7V
0.6V
0.5V
0.4V
0.3V
0.2V
0.1V
0.0V
V(sawtooth)
V(input)
1.0V
0.9V
0.8V
0.7V
0.6V
0.5V
0.4V
0.3V
0.2V
0.1V
0.0V
0ms
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
18ms
20ms

Microcontroller Selection

Comparison

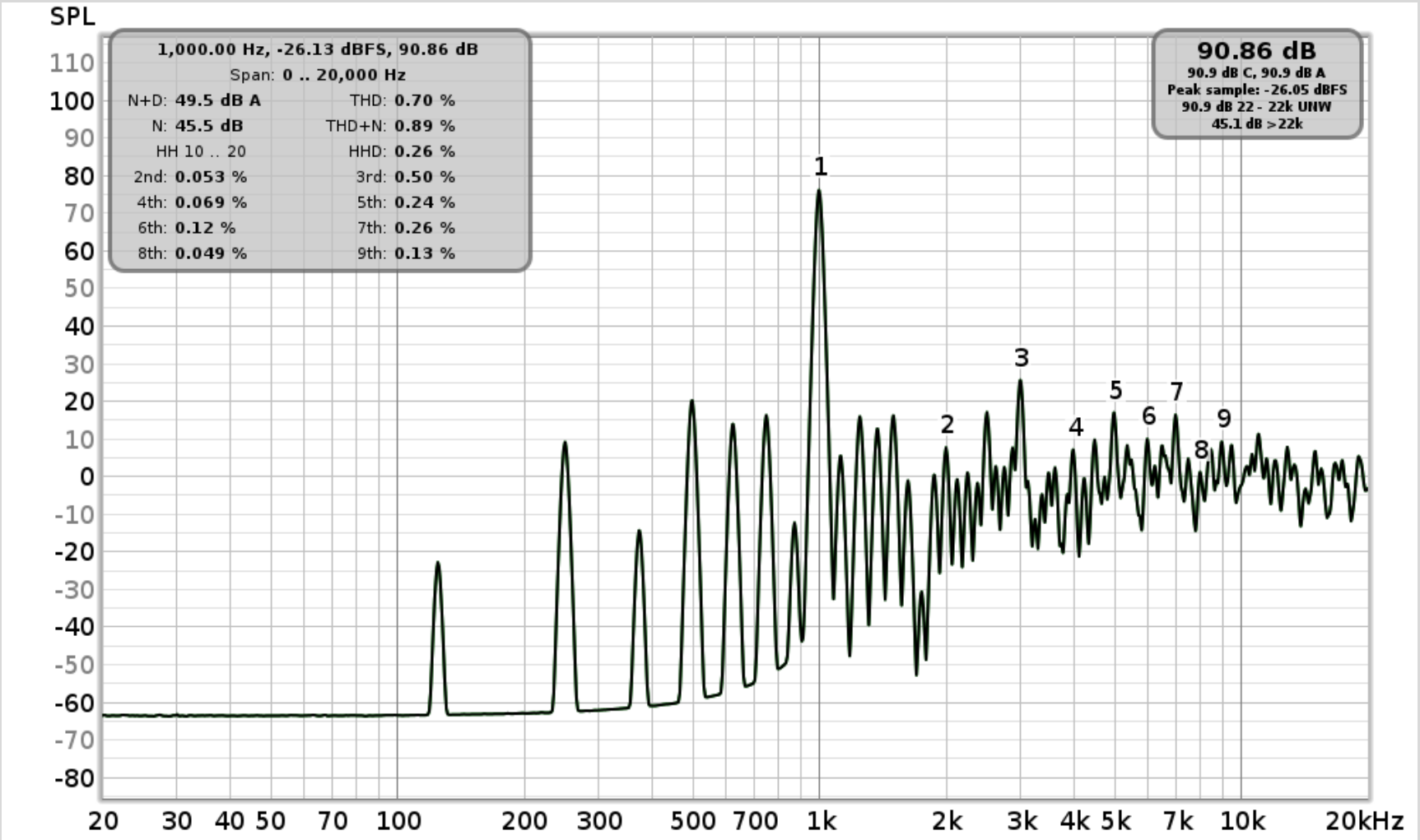
MCU	Clock	PWM clock	Power consumption
ESP32	240 MHz	80 Mhz	0.1 W
TEENSY 4.1	600 MHz	150 Mhz	0.5 W
STM32H723	550 MHz	275 Mhz	0.266 W
STM32H7A3	280 MHz	280 Mhz	0.17 W
STM32WB55	64 MHz	64 Mhz	0.175 W

PWM frequency

$$f_{\text{pwm}} = \frac{f_{\text{clk}}}{r_{\text{pwm}}} = \frac{80\,\text{MHz}}{1024} = 78125\,\text{Hz} \approx 78\,\text{kHz}$$

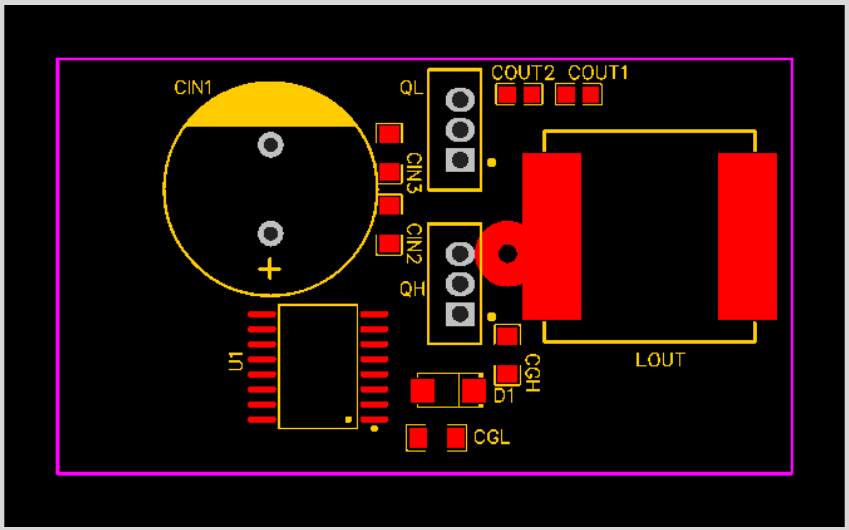
Room Equalization Wizard (REW) Simulation

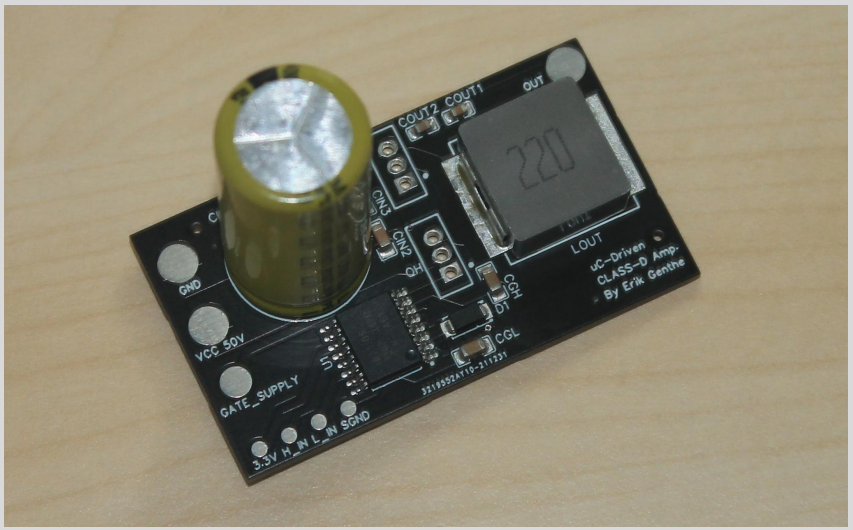
FFT of 1 kHz sine, 10 bit resolution, 78125 Hz

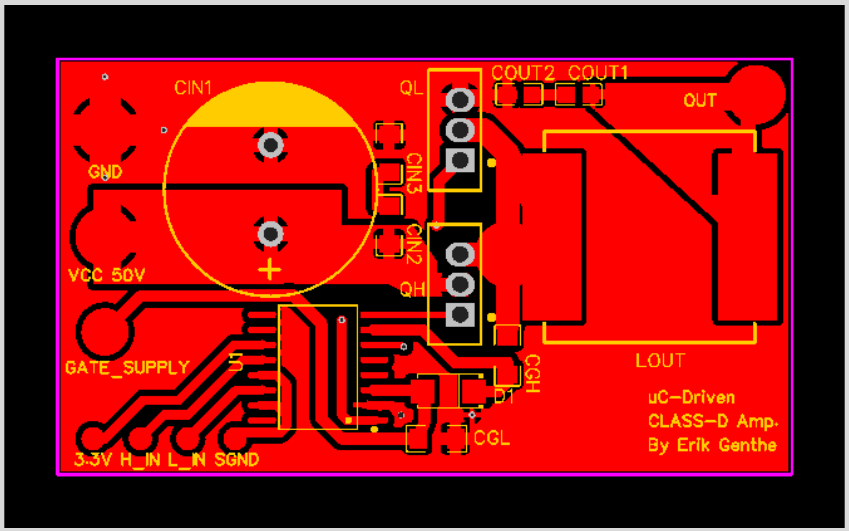


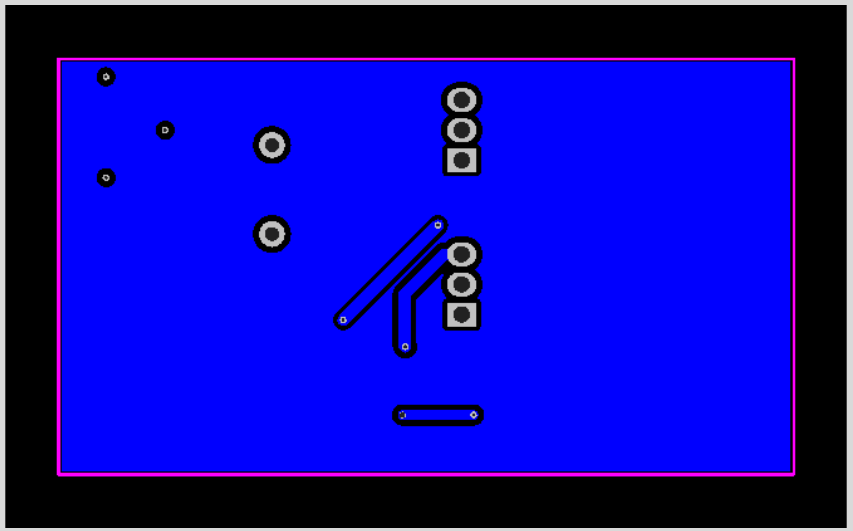
Power Switching Circuit

Layout



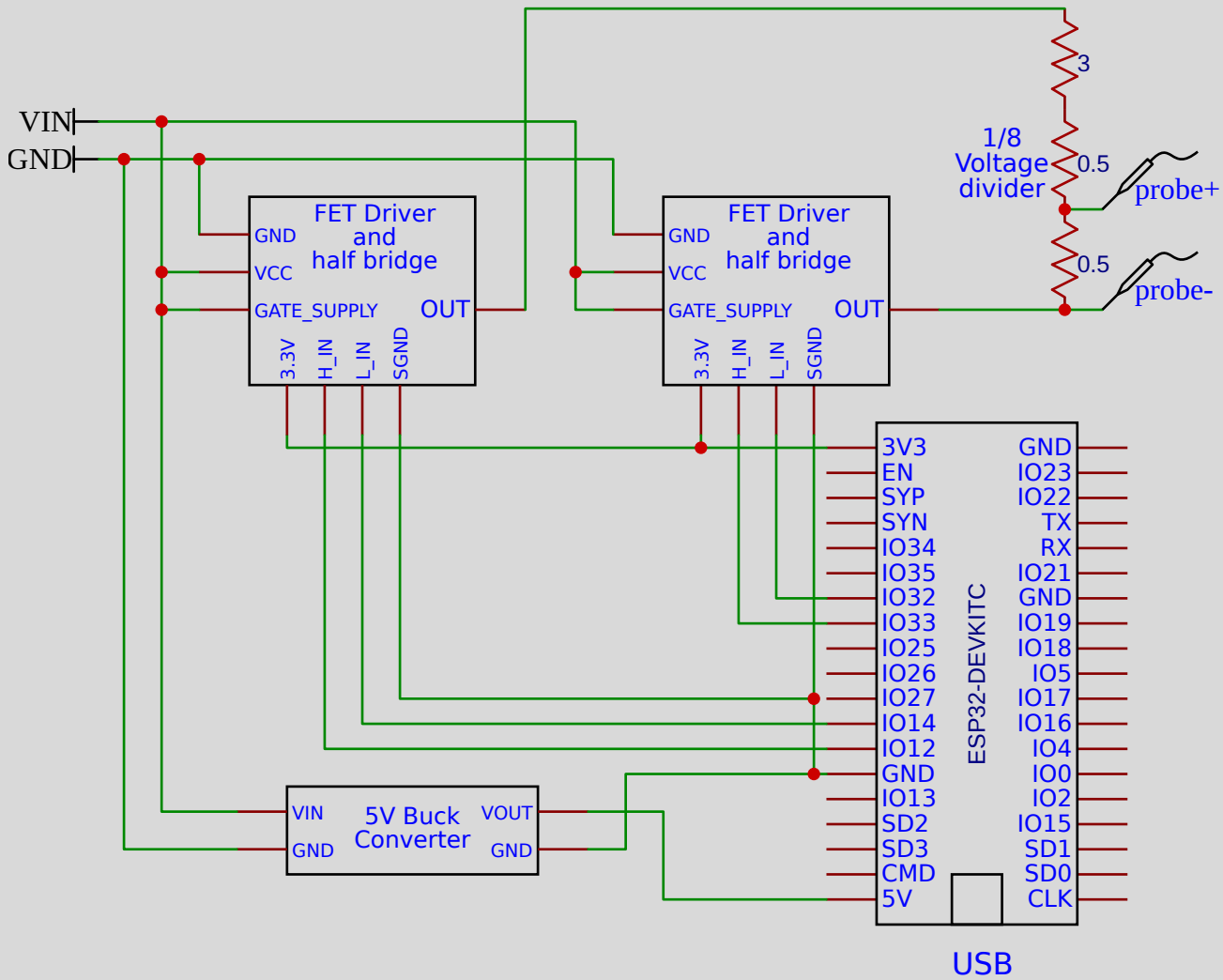






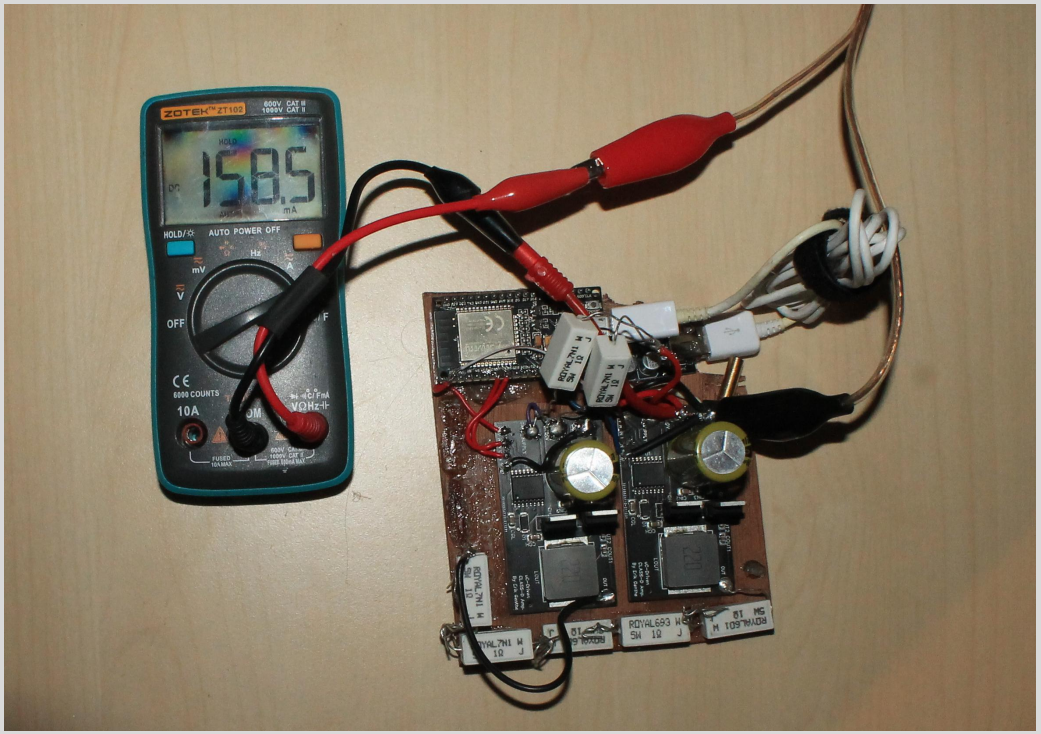
Measurement Setup

Schematic



Idle Power Consumption

Measurement

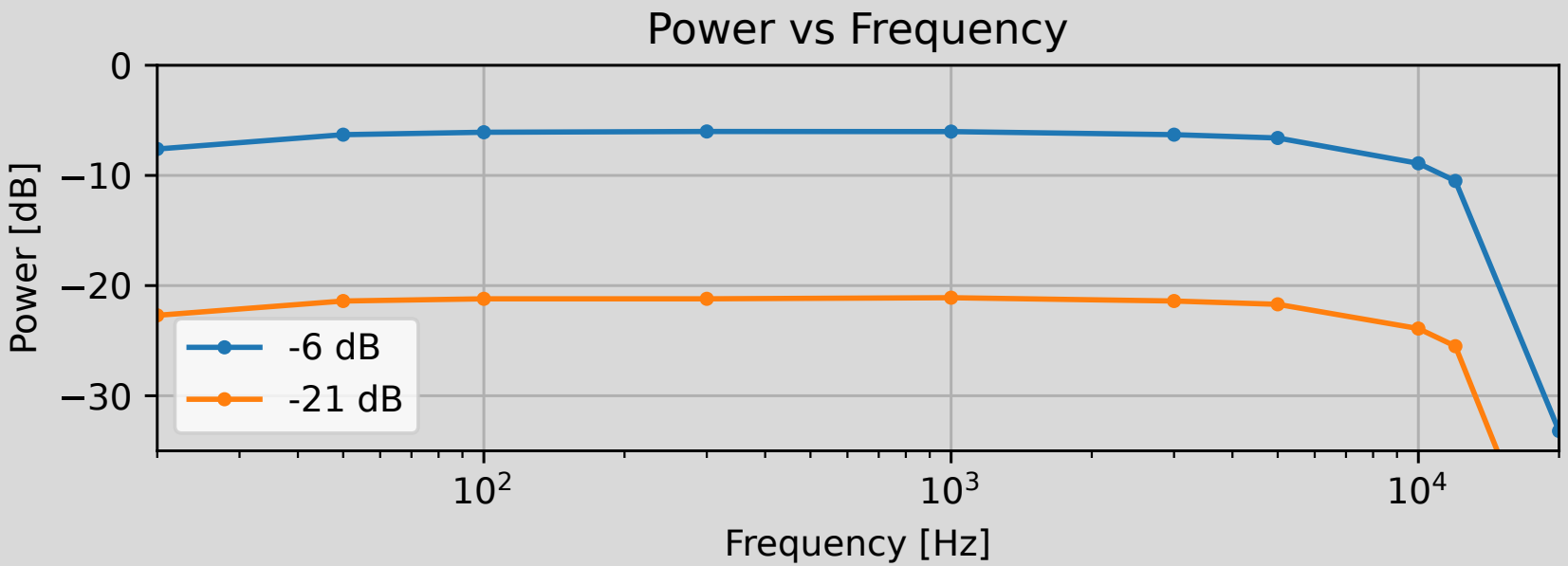


Measurement results

$$P_{\text{idle}} = U \cdot I_{\text{idle}} = 10\,\text{V} \cdot 158.5\,\text{mA} = 1.585\,\text{W} \approx 1.6\,\text{W}$$

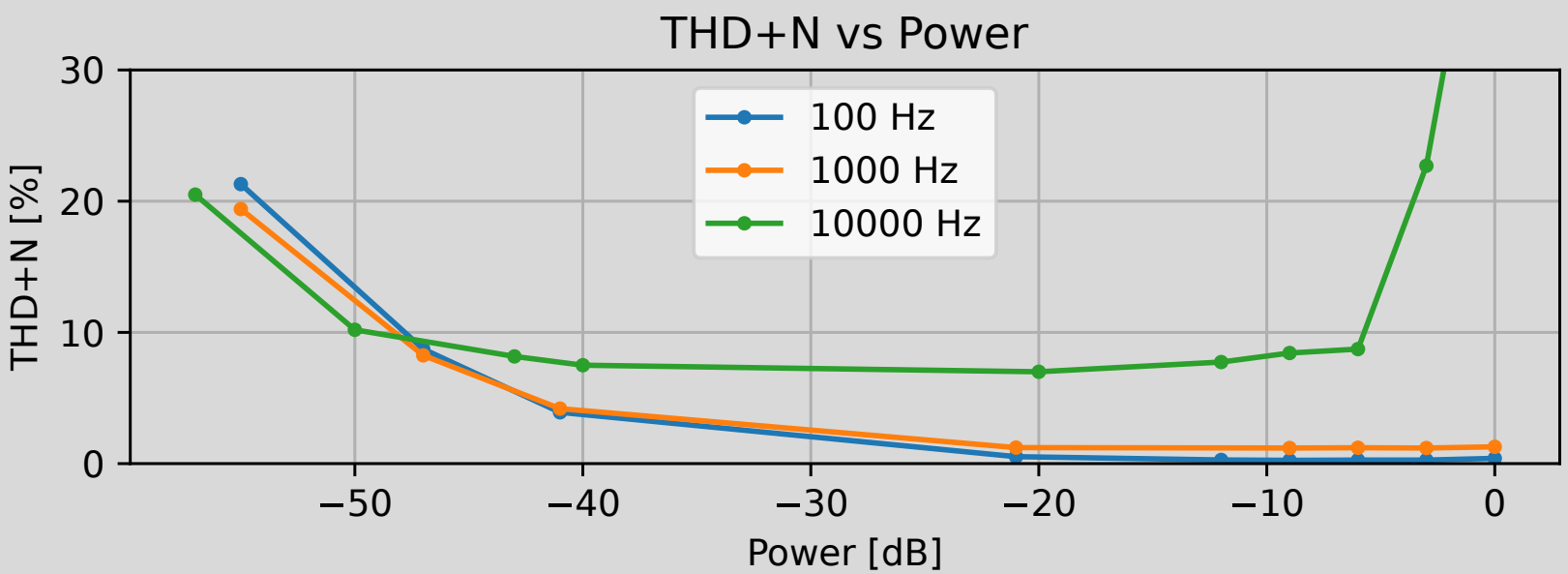
Measurements

Output power over frequency



Measurements

Distortion over output power



Conclusion

- A prototype of a microcontroller-based class-D audio amplifier was engineered and tested
- Simple, customizable DIY setup
- Low idle power of 1.6 W
- Low distortion for low and medium frequencies at low attenuation
- Identified two key problems at high attenuation and high frequencies

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Future work

- Fix high attenuation distortions by using an adjustable voltage source
- Fix high frequency distortions by using a different microcontroller (e.g., STM32WB55)

Thank you for your attention.