EEL3926L Week 3 Laboratory: Regulator Prototype

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February 15, 2026

1 Introduction

The objective of this laboratory was to prototype and verify the 3.3 V and 5.0 V regulator circuits designed in WEBench. The circuits were assembled on a breadboard, and key performance metrics such as output voltage (V_{out}), load regulation, efficiency, and output ripple were measured and analyzed.

2 3.3V Regulator Analysis

2.1 Verification and Measurements (Steps a–e)

- LED Resistor (R_{LED}): 98.9 Ω
- Output Voltage (No Load) (V_{out}): 3.324 31 V
- LED Forward Voltage (V_F): 2.033 V

$$I_{LED} = \frac{V_{out} - V_F}{R_{LED}} = \frac{3.32431 - 2.033}{98.9} = 0.01306\,\text{A} \tag{1}$$

2.2 Load Testing and Power Analysis (Steps f–j)

- Load Resistance (R): 100 Ω
- Output Voltage (Loaded): 3.263 V
- Measured Load Current (I_{res}): 0.032 A

$$I_{out} = I_{LED} + I_{res} = 0.01306 + 0.032 = 0.04506\,\text{A} \tag{2}$$

$$P_{out} = I_{out} \cdot V_{out} = 0.04506 \times 3.32431 = 0.1498\,\text{W} \tag{3}$$

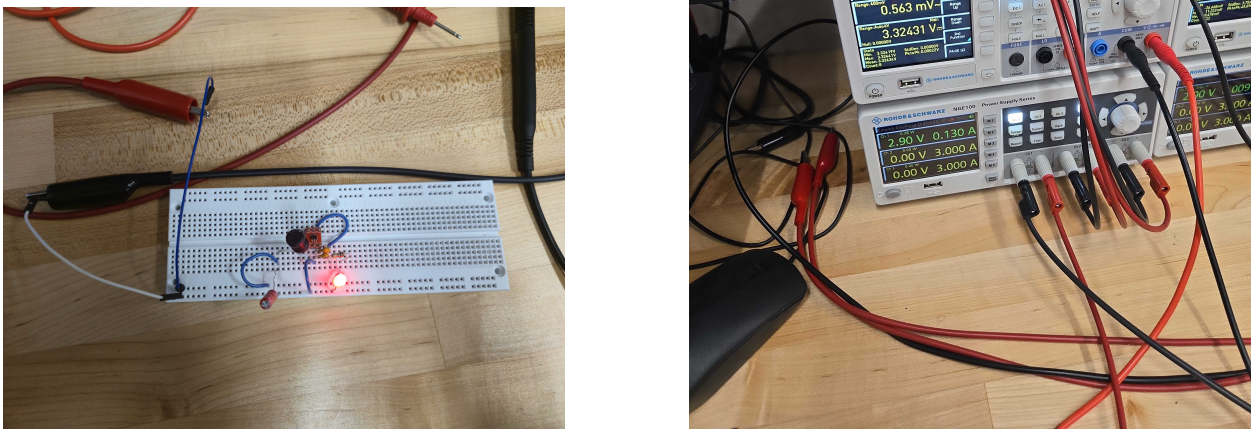
- Input Voltage (V_{in}): 2.9 V
- Input Current (I_{in}): 0.055 A

$$P_{in} = V_{in} \cdot I_{in} = 2.9 \times 0.055 = 0.1595\,\text{W} \tag{4}$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{0.1498}{0.1595} \times 100 \approx 93.92\% \tag{5}$$

2.3 Output Ripple

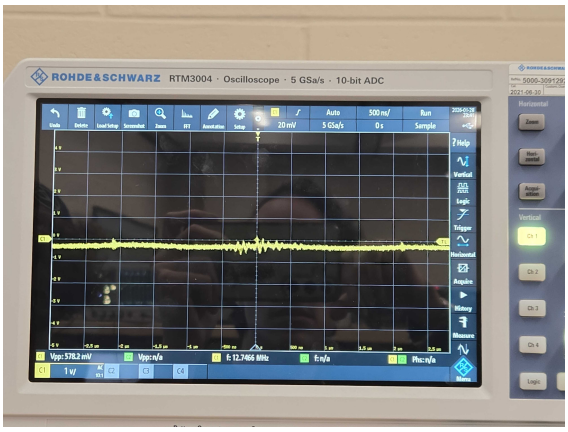
- Peak-to-peak ripple voltage: $\approx 870\,\text{mV}_{\text{pp}}$
- Switching frequency: $\approx 12.746\,\text{MHz}$



(a) 3.3V Circuit

(b) Voltage Measurements

Figure 1: 3.3V Regulator Circuit and Measurements



(a) Output Ripple (Oscilloscope)

Figure 2: 3.3V Output Ripple Analysis

3 5V Regulator Analysis

3.1 Verification and Measurements (Steps a–e)

- LED Resistor (R_{LED}): $199.38\,\Omega$
- Output Voltage (No Load) (V_{out}): $5.007\,\text{V}$
- LED Forward Voltage (V_F): $2.85\,\text{V}$

$$I_{LED} = \frac{V_{out} - V_F}{R_{LED}} = \frac{5.007 - 2.85}{199.38} = 0.010796\,\text{A} \tag{6}$$

3.2 Load Testing and Power Analysis (Steps f–j)

- Load Resistance (R): $200\,\Omega$
- Output Voltage (Loaded): $4.856\,\text{V}$
- Measured Load Current (I_{res}): $0.022\,\text{A}$

$$I_{out} = I_{LED} + I_{res} = 0.010796 + 0.022 = 0.032796\,\text{A} \tag{7}$$

$$P_{out} = I_{out} \cdot V_{out} = 0.032796 \times 5.007 = 0.16421\,\text{W} \tag{8}$$

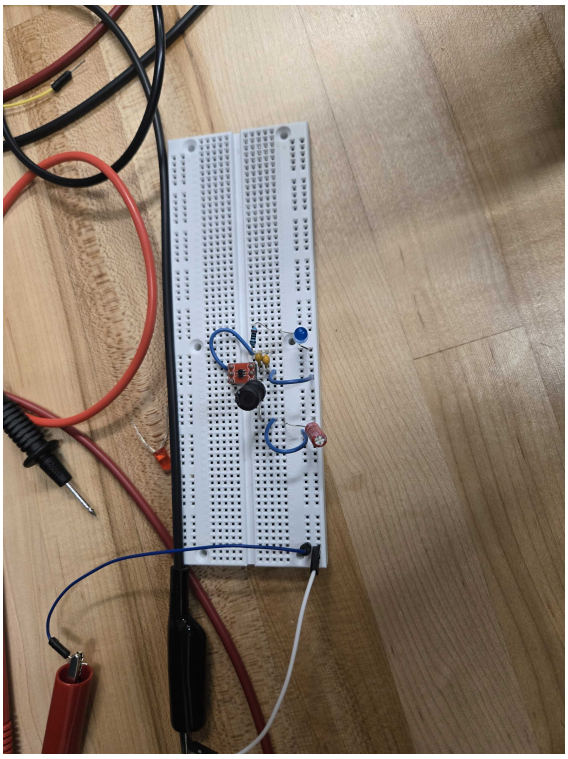
- Input Voltage (V_{in}): $2.9\,\text{V}$
- Input Current (I_{in}): $0.062\,\text{A}$

$$P_{in} = V_{in} \cdot I_{in} = 2.9 \times 0.062 = 0.1798\,\text{W} \tag{9}$$

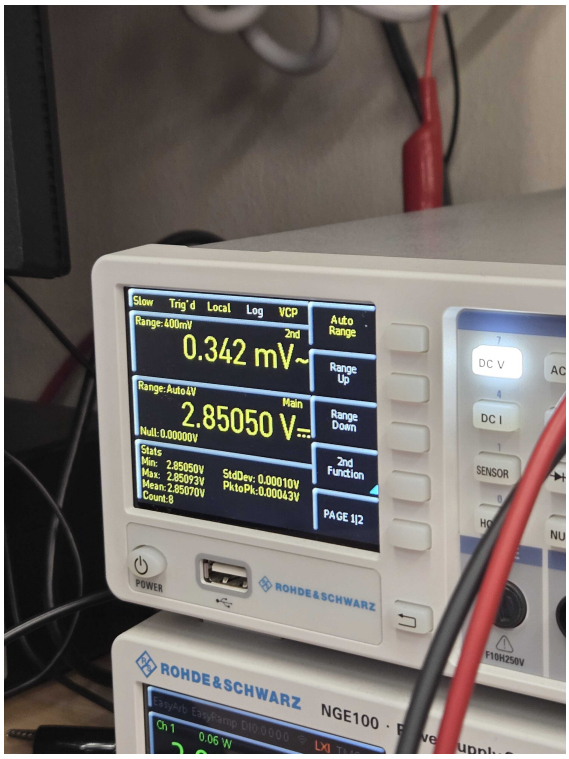
$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{0.16421}{0.1798} \times 100 \approx 91.33\% \tag{10}$$

3.3 Output Ripple

- Peak-to-peak ripple voltage: $\approx 3.6848\,\text{V}_{\text{pp}}$
- Switching frequency: $\approx 74.58\,\text{MHz}$

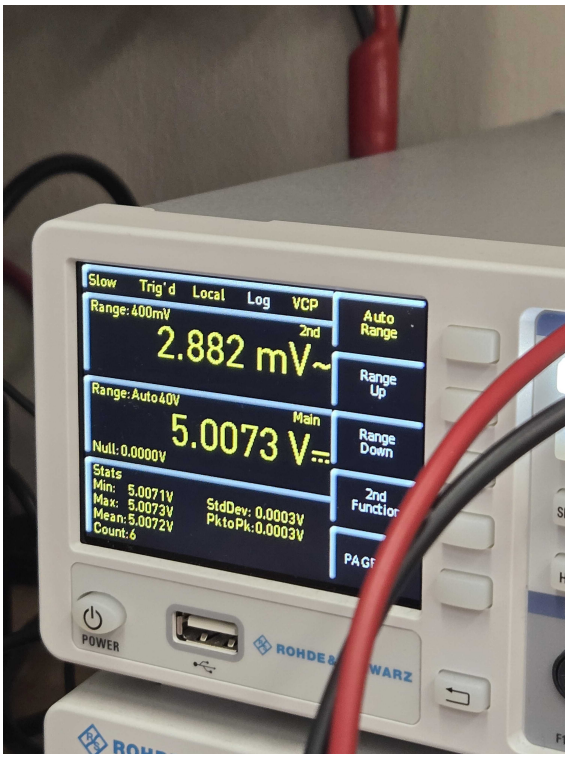


(a) 5V Circuit



(b) Voltage Measurements (Vf)

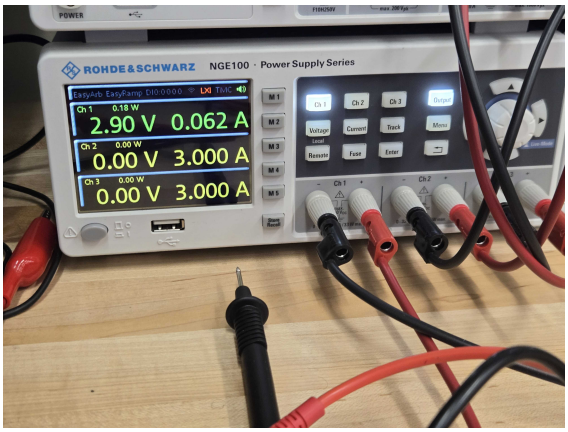
Figure 3: 5V Circuit and Measurements



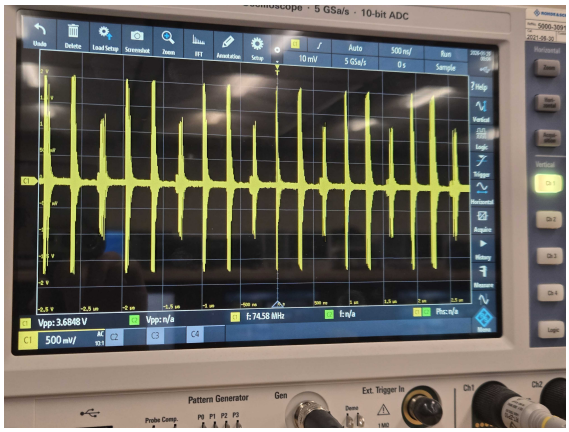
(a) Vout Measurement

(b) Vout with Electronic Load

Figure 4: 5V Output Voltage Measurements



(a) Input Current (Iin)



(b) Output Ripple (Oscilloscope)

Figure 5: 5V Input Power and Output Ripple Analysis

Figure 6: Thermal Image of 5V Regulator Circuit (Procedure 5.0b)

4 Discussion and Questions

4.1 Efficiency Comparison

Both regulators demonstrated high efficiency under load.

- The 3.3V regulator achieved an efficiency of approximately **93.92%**.
- The 5V regulator achieved an efficiency of approximately **91.33%**.

These values are consistent with the expected performance of switching regulators and are close to the efficiencies predicted by WEBench for similar operating conditions.

4.2 Ripple Performance

The measured output ripple for the 3.3V regulator was approximately $870\,\mathrm{mV_{pp}}$ at a switching frequency of about $12.746\,\mathrm{MHz}$. The 5V regulator exhibited a larger ripple of approximately $3.6848\,\mathrm{V_{pp}}$ at a switching frequency of about $74.58\,\mathrm{MHz}$. The increased ripple observed on the breadboard implementation is attributed to wiring inductance, contact resistance, and probe grounding effects during high-frequency measurements.

4.3 What have you learned?

Through this laboratory, I learned the practical process of assembling and testing DC–DC switching regulators. I verified the importance of accounting for parasitic resistances, such as wire and contact resistance, which caused a noticeable drop in V_{out} under load ($3.324\,\mathrm{V} \rightarrow 3.263\,\mathrm{V}$ and $5.007\,\mathrm{V} \rightarrow 4.856\,\mathrm{V}$). Additionally, I gained experience in measuring switching ripple and calculating efficiency from experimental voltage and current data using laboratory instruments.