Scientific Report

Design of a Simple RLC Rectifier for an LED Circuit

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Abstract—This project investigates the design of a basic RLC rectifier to convert a low-frequency AC generator output into a usable DC supply for a parallel LED circuit. Using available components, the rectifier is constructed with a diode, inductor, and smoothing capacitor, followed by current-limiting resistors to ensure safe LED operation. The resulting circuit effectively reduces ripple and maintains LED current below the specified limit.

Keywords—*computational physics, RLC rectifier, LED circuit, AC–DC conversion, current limiting*

1. Introduction

1.1. Background

LED circuits require a stable DC supply and strict current control to operate safely. However, many practical power sources, such as low-frequency generators, provide AC outputs that must be rectified and filtered before use. An RLC rectifier offers a simple method for converting AC to DC while reducing ripple through the combined effects of a diode, inductor, and capacitor. This project applies these principles to design a rectifier capable of powering a parallel network of LEDs within their safe operating limits.

1.2. Objectives

- To design and analyze a basic RLC rectifier using available components.
- To convert a 5 V_{rms}, 20 Hz AC source into a usable DC output.
- To ensure each LED receives sufficient voltage while keeping current below 20 mA.
- To determine appropriate resistor, inductor, and capacitor values for safe and efficient operation.

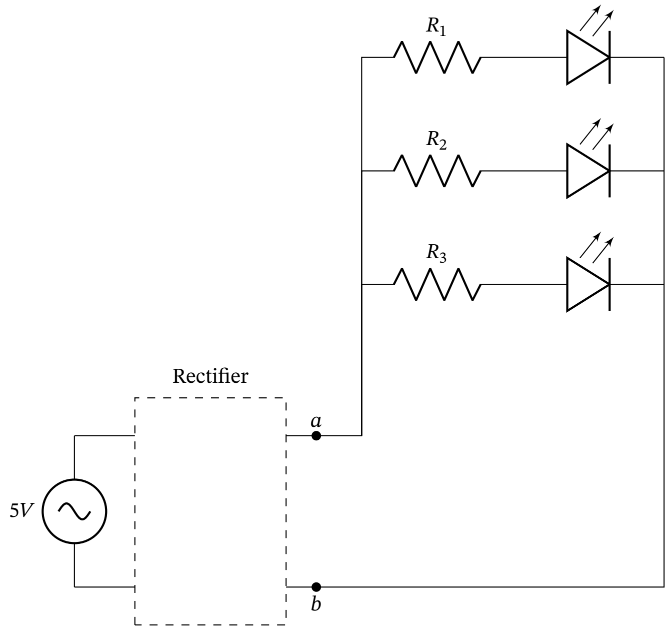
2. Method

2.1. Circuit Case

This project designs a basic RLC rectifier to supply a parallel network of three green LEDs, each requiring a forward voltage of 2 V and limited to a maximum current of 20 mA. Because the LEDs are modeled without internal resistance, external resistors are used for current limiting. The LED network is connected to the rectifier output at nodes a and b. The AC generator provides 5 V_{rms} at 20 Hz, and all components, including the source, are assumed to have an internal resistance of 0.1 Ω.

No	Component	Value
1	Resistor	3 Ω
2		24 Ω
3		36 Ω
4		100 Ω
5		130 Ω
6		220 Ω
7		510 Ω
8	Capacitor	1.0 μF
9		3.3 μF
10		22 μF
11	Inductor	2 μH
12		5.1 μH
13		2 mH
14		400 mH

Figure 1. Components Table



2.2. Component Calculations

Generator Peak Voltage

Since the generator output is given in RMS form, the peak voltage is computed as:

$$V_{\text{peak}} = V_{\text{rms}}\sqrt{2} = 5\sqrt{2} \approx 7.071 \text{ V}.$$

This peak voltage determines the maximum possible forward voltage applied to the rectifier and LED network during each conduction cycle.

LED Branch Resistors

To ensure that each LED does not exceed the maximum current of 20 mA, we select appropriate current-limiting resistors R_1, R_2, R_3 for the three parallel LED branches. Using Ohm's Law:

$$R = \frac{V_{\text{peak}} - V_{\text{LED}}}{I_{\text{max}}}.$$

Substituting $V_{\text{LED}} \approx 2$ V and $I_{\text{max}} = 20$ mA, the required resistance is:

$$R = \frac{7.071 - 2}{0.020} \approx 254 \ \Omega.$$

From the available components in the table, the closest safe standard value is 220 Ω, which is selected for all three LED branches.

Inductor and Capacitor Selection

To construct a basic RLC rectifier, we include an inductor in series with the rectifier output and a capacitor across nodes a and b. Following the guideline to maximize filtering capability, we select the largest available values from the component table:

- Inductor: $L = 400$ mH
- Capacitor: $C = 22\ \mu$F

These components help reduce current ripple and improve rectifier smoothing at the low operating frequency of 20 Hz.

Additional Series Load Resistor

To further increase safety and protect against worst-case scenarios (e.g., ideal diode behavior or minimal voltage drops), an additional series resistor R_{load} is inserted before the LED parallel branches. The total series resistance must satisfy:

$$R_{\text{total}} \geq \frac{V_{\text{peak}}}{I_{\text{max}}}.$$

Thus,

$$R_{\text{total}} \geq \frac{7.071}{0.020} \approx 354\ \Omega.$$

Since each LED branch already contains a 220 Ω resistor, the required additional resistance is:

$$R_{\text{load}} = R_{\text{total}} - 220 \approx 134\ \Omega.$$

From the available component values, the closest option is 130 Ω, which is therefore selected as the load resistor. This combination of components satisfies the design constraints while ensuring that LED currents remain safely below the 20 mA limit.

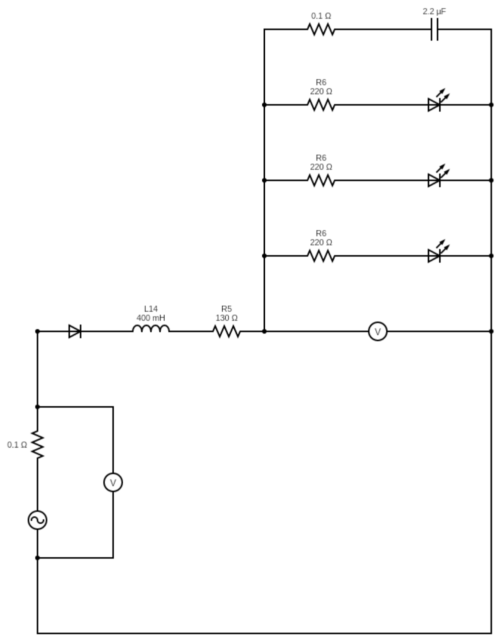


Figure 2. Circuit with RLC Rectifier

Figure 2 presents the final circuit incorporating the RLC rectifier. The rectified and filtered output is supplied to the LED load through the selected series components.

3. Result & Discussion

3.1. Plotting Using PPE

Using the calculated component values, the circuit was implemented in PPE through a CSV file generated in Excel. The grid layout and component placement were arranged to match the schematic in Figure 2. After configuring the component parameters in the CSV file, PPE simulated the rectifier and produced the corresponding voltage and current plots for analysis.

3.2. Plot Results

Ammeter Plots

Figure 3 and the accompanying subplots display the current flowing through each LED branch and the source. The three LED ammeter plots show similar current waveforms, each peaking at approximately 11 mA, which is safely below the maximum allowable LED current of 20 mA. The current drops to zero during each cycle due to the half-wave rectification, resulting in a pulsating waveform consistent with the generator's 20 Hz operation.

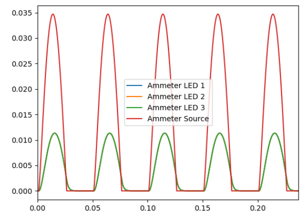


Figure 3. All Ammeters

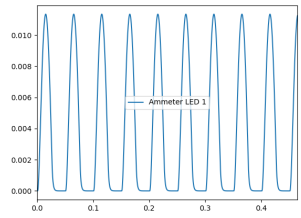


Figure 4. Ammeter LED 1

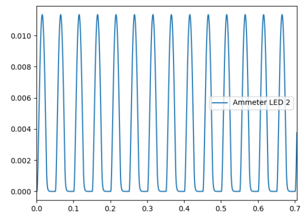


Figure 5. Ammeter LED 2

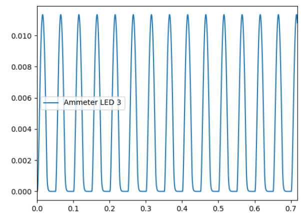


Figure 6. Ammeter LED 3

The combined ammeter plot also illustrates that the source current reaches a higher peak compared to the individual LED branches. This occurs because the total current is the sum of the currents delivered to all load branches as well as the charging current of the smoothing capacitor. The results confirm that the selected resistor and RLC components successfully limit the LED current while maintaining safe operating conditions.

Voltmeters Plot

The voltmeter readings shown in Figure 7 illustrate the voltage at the generator and across the load. The generator voltage plot exhibits a sinusoidal waveform with a peak value near 7.07 V, consistent with the expected peak of a 5 V_{rms} AC source.

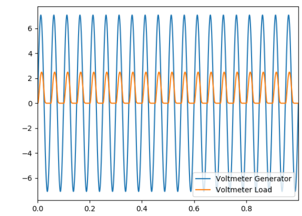


Figure 7. All Voltmeters

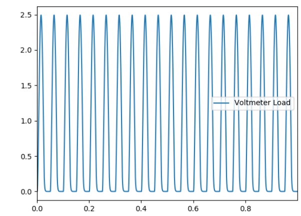


Figure 8. Voltmeter Load

The load voltage, after passing through the diode, inductor, and smoothing capacitor, shows a pulsating DC waveform with significantly reduced ripple. The peak load voltage is approximately 2.5 V, sufficient to forward-bias the LEDs while ensuring that the current-limiting resistors prevent overcurrent. The presence of ripple is expected due to the low rectification frequency (20 Hz) and the moderate value of the smoothing capacitor.

References

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