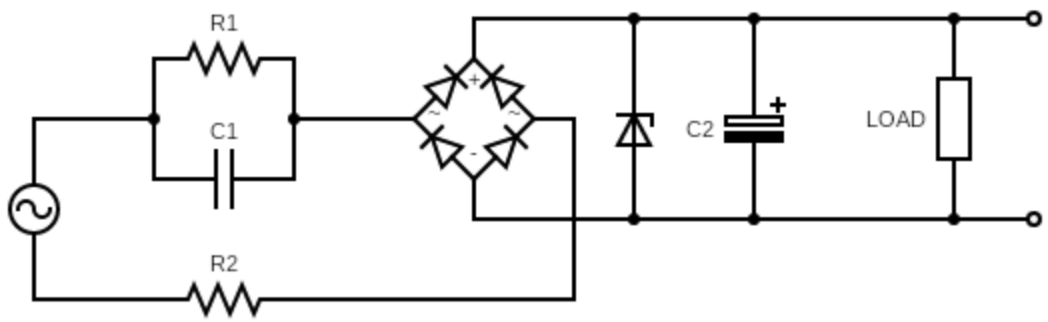
Capacitive Power Supply Circuit (Experiment & Study)

A capacitive power supply circuit is a type of power supply used to convert alternating current (AC) voltage from a mains power source into a lower-voltage, direct current (DC) output. It relies on capacitors to reduce the voltage while also providing a level of filtering and regulation. Capacitive power supplies are often used in low-power electronic devices and applications where simplicity and cost-effectiveness are priorities.



Here are the key equations used to design given circuit:

Reactance of the Capacitor (Xc):

$Xc = 1 / (2\pi fC)$

Where:

Xc is the reactance of the capacitor.

f is the frequency in Hertz (Hz).

C is the capacitance in Farads (F).

Current Calculation (I) in the Circuit:

$I = V / X$

Where:

I is the current in Amperes (A).

V is the voltage in Volts (V).

X is the reactance of the component in Ohms (Ω).

Impedance (Z) Calculation:

$Z = \sqrt{(R^2 + X^2)}$

Where:

Z is the impedance in Ohms (Ω).

R is the resistance in Ohms (Ω).

X is the reactance in Ohms (Ω).

Zener Diode Resistor (R) Calculation:

R = (Vin - Vz) / Iz

Where:

R is the value of the resistor in Ohms (Ω).

Vin is the input voltage in Volts (V).

Vz is the output voltage of the Zener diode in Volts (V).

Iz is the current through the Zener diode in Amperes (A).

Limiting Resistor for an LOAD (R):

R = (Vs - Vf) / If

Where:

R is the value of the resistor in Ohms (Ω).

Vs is the supply voltage in Volts (V).

Vf is the forward voltage drop of the LED in Volts (V).

If is the allowable current through the LED in Amperes (A).

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Certainly, let's perform a step-by-step calculation to determine the current output of the given capacitive power supply circuit using the provided component values.

These calculations are based on a capacitance of 1 μF, a voltage of 230 V, a frequency of 50 Hz, and a resistance of 500 ohms.

Reactance of the Capacitor (Xc):

Xc = 1 / (2πfC)

Xc = 1 / (2π * 50 Hz * 1 x 10^(-6) F)

Xc ≈ 3183.1 Ω

Current Calculation (I) in the Circuit:

I = V / Xc

I = 230 V / 3183.1 Ω

I ≈ 0.0722 A (or 72.2 mA)

In this analysis, we've determined that the this capacitive power supply circuit can deliver a maximum current of 72.2 mA. This level of current output is sufficient for the intended load or application, ensuring that the circuit can meet its power requirements effectively.

Impedance (Z) Calculation:

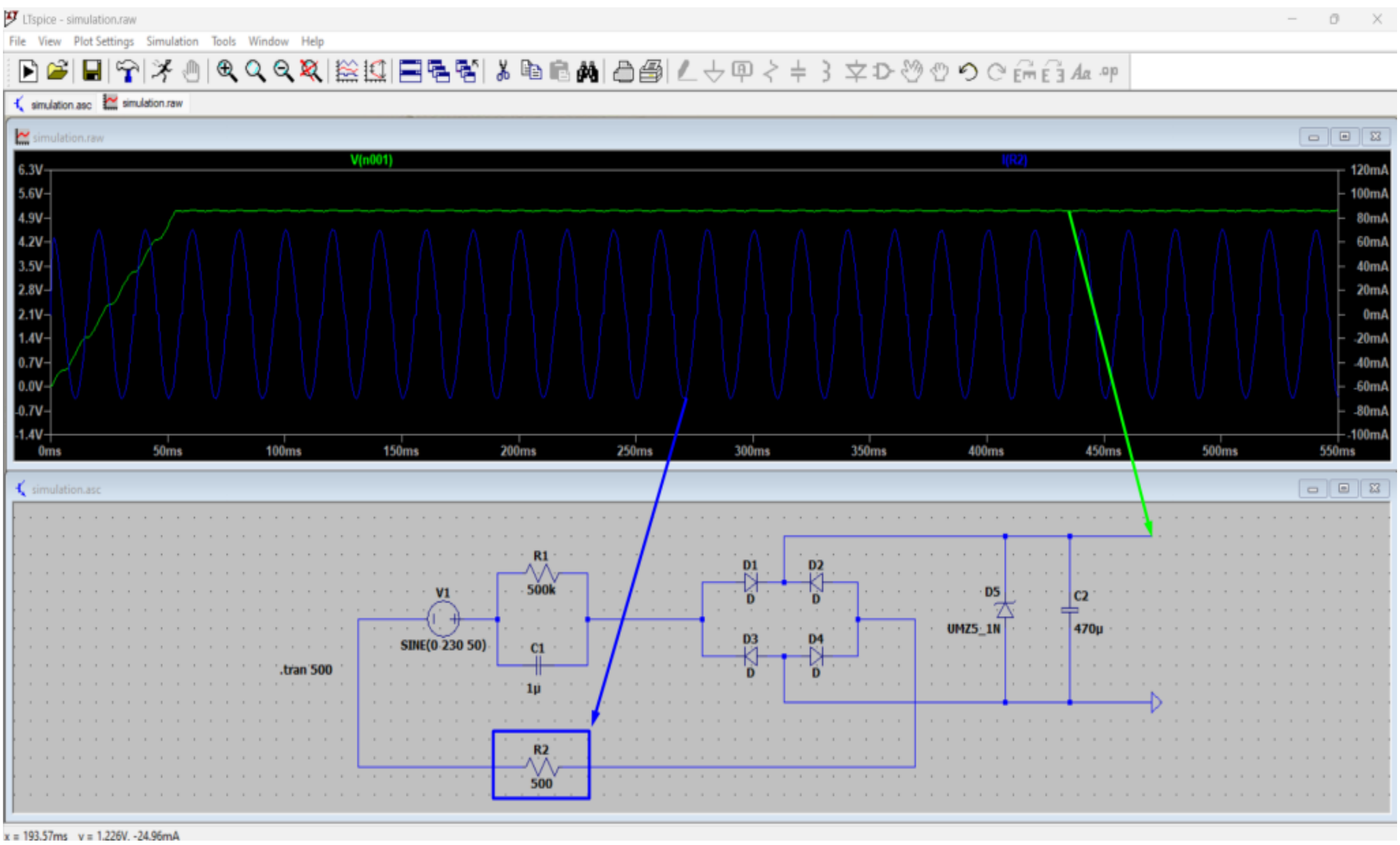
Z = √(R^2 + Xc^2)

Z = √((500 Ω)^2 + (3183.1 Ω)^2)

Z ≈ 3212.2 Ω

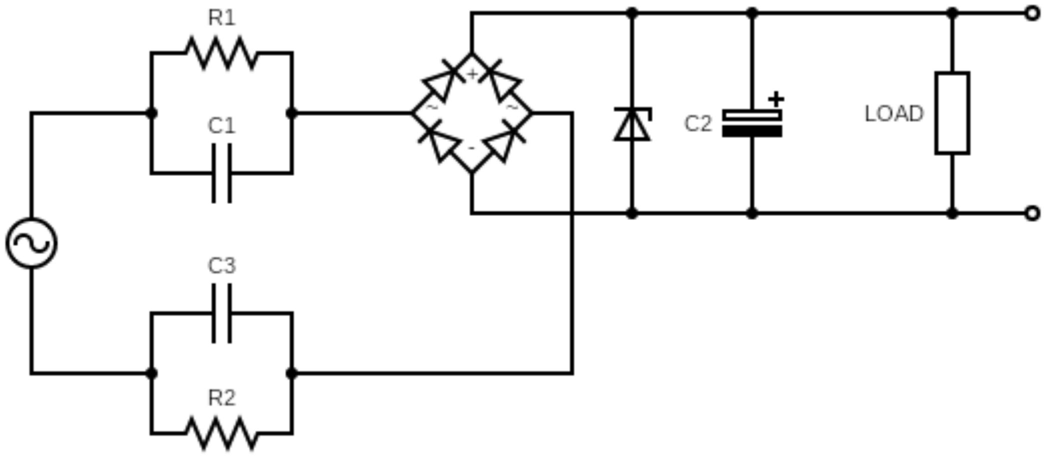
An impedance of 3212.2 ohms indicates the combined resistance to the flow of AC current in the circuit, taking into account both the resistive and capacitive components. This value offers valuable insights into the circuit's behavior when subjected to AC conditions.

Let now simulate this circuit and component value on LTSpice to see how correct our calculation is;

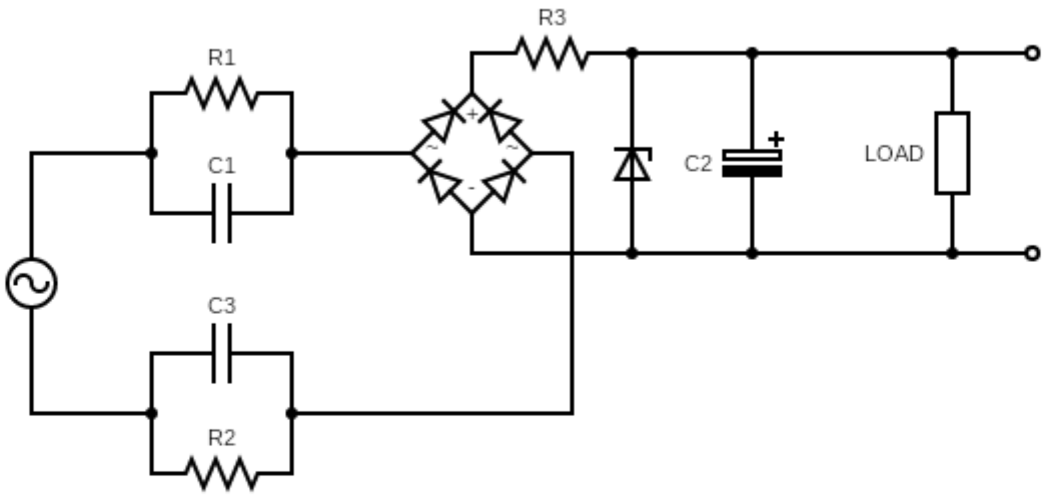


After prototyping, I encountered a significant problem with the circuit: resistor R2 get overheated and eventually burned out due to its low wattage rating of 1/4 watt. To address this issue immediately, I made modifications to the design to eliminate the need for the resistor altogether.

Take a look at this diagram,



I attempted another iteration of the experiment by replacing the resistor with an additional capacitor, acknowledging that relying on chance, much like tossing a coin, is not a dependable approach, particularly in engineering. In this second trial, I introduced several modifications, as illustrated in the revised diagram. The adjustments were made in an effort to refine the experimental setup and address the shortcomings observed in the initial attempt. The iterative nature of these experiments allows for continuous learning and improvement, moving away from a reliance on chance and towards a more methodical and informed approach to achieve a robust and reliable outcome.



In conclusion, the rapid experiment conducted to assess the reliability of the capacitive power supply circuit within the context of the broader project revealed that the experiment was not conducted with a well-structured and systematic approach. The trial served as an initial exploration rather than a comprehensive study, and the experiment lacked the meticulous planning and employment of proper components and equipment. It was a rapid attempt to draw preliminary conclusions about the feasibility of using a capacitive power supply for the project. Despite the less-than-ideal execution, the experience gained from this rapid trial will inform future endeavors, fostering a more thoughtful and comprehensive approach to understanding and designing power supply circuits in subsequent projects. The intent is to revisit and refine the design in future iterations to enhance its reliability and performance.