

Triac Power Controller

1. Introduction

The triac power controller is a classic electrical circuit used to control the amount of power that the light bulb is receiving.

Triac control load circuits have been used in apartments since the 1970s for dimming room lights.

The circuit is based on keeping the triac OFF (non-conducting state) for a certain percentage of the AC mains signal half cycle. The load/light bulb is ON when the triac is conducting and OFF when the triac is not conducting. Keep the load/light bulb OFF for a certain percentage of the cycle will reduce the total energy (power*time) that the load is receiving this average power, voltage and current.

2. Circuit

The circuit consists of a triac, diac and a low pass RC filter that is driving the triac control.

You can see the 50 ohm light bulb in the picture below that is the circuit load.

You can see the RC low pass filter supplying current to the triac gate, connected in series with the diac component. The four diodes (including two Zeners) are used to emulate the diac component that is not available in the student edition of the PSpice simulation software

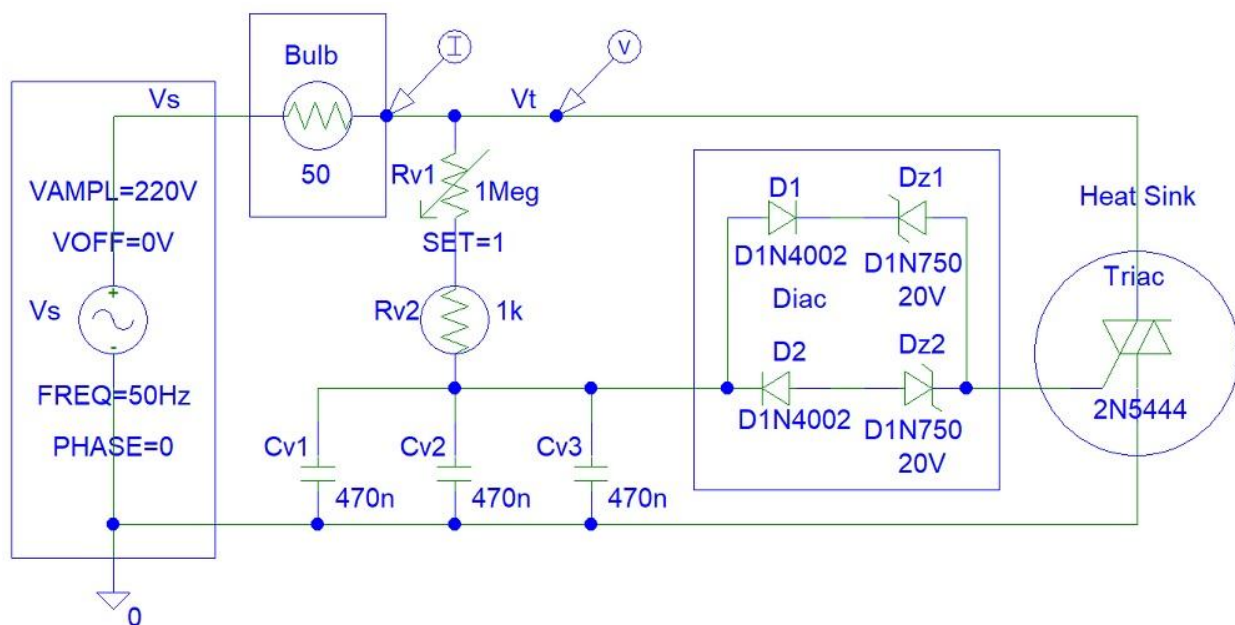


Figure 1: Triac Power Controller Circuit

The triac turns ON and starts conducting when voltage is applied to its gate pin. The triac remains ON even after its gate voltage falls to zero and only turns OFF when the mains power supply input is reversed (because we all know that mains voltage is a polarity changing direction sinusoidal input).

The RC filter is used to provide a delay from 0 seconds to quarter of a period ($1/50 \text{ Hz} = 0.02 \text{ seconds} = 20 \text{ ms}$). At zero delay, the light bulb turns ON immediately and remains ON until the end of half cycle. At quarter cycle delay the light bulb turns ON only half of the time. The longer is the delay, the dimmer will be the light bulb. When you are increasing the delay you are also reducing the signal amplitude, thus preventing the light bulb/load from turning ON. Thus a diac is used to keep the load OFF after quarter cycle if the RC low pass filter filter output amplitude is not sufficiently small and can still turn ON the triac.

I used three 470 nF capacitors in parallel to avoid the use of electrolytic or bipolar capacitors.

This circuit was not tested in practise.

3. Calculating The Time Delay

Those deviations will show that the low pass filter delay cannot exceed the quarter cycle. The capacitor voltage output is equal to:

$$\begin{aligned}V_c &= \frac{V_s/(j\omega C)}{R+1/(j\omega C)} \\&= \frac{V_s}{1+j\omega RC} \\&= \frac{|V_s|}{\sqrt{1+(\omega RC)^2}} \angle -\arctan(\omega RC)\end{aligned}$$

$$\text{Phase} = -\arctan(\omega RC)$$

$$= -\arctan(\omega/\omega_0)$$

$$\text{(Where: } \omega_0 = 1/(R * C),$$

$$2 * \pi * f_0 = 1/(R * C),$$

$$f_0 = 1/(2 * \pi * R * C)$$

f_0 = Maximum filter low pass frequency (Hz)

If a sinusoidal signal input is added to a number then you are shifting the signal backwards. If the sinusoidal signal input is subtracted from a number then you are shifting the signal forwards.

Thus the time delay is negative of the phase:

$$\textit{Time Delay} = \arctan(\omega * R * C) * T/360^\circ$$

(Where: T = Period (seconds))

$$= \arctan(\omega/\omega_0) * T/360^\circ$$

An inverse tangent function cannot output a number above the magnitude of |90| degrees with inputs above zero (because phase calculations are not assuming the existence of the third quadrant in a circle).

4. Simulations

Maximum output ($R_{v1} = 0 \text{ ohms}$):

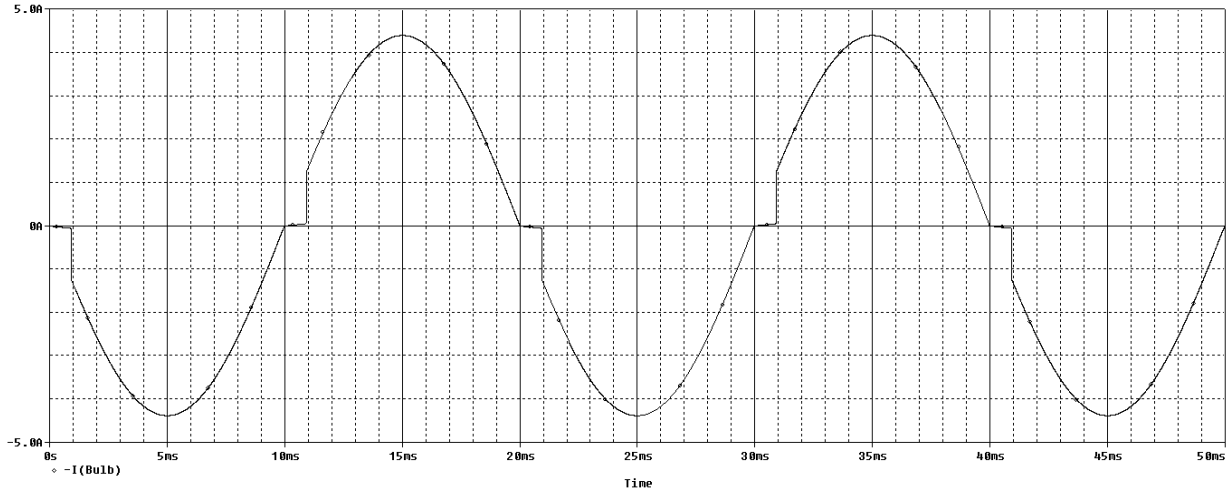


Figure 2: Load Current Simulations

Minimum output ($R_{v1} = 1 \text{ Megohms}$):

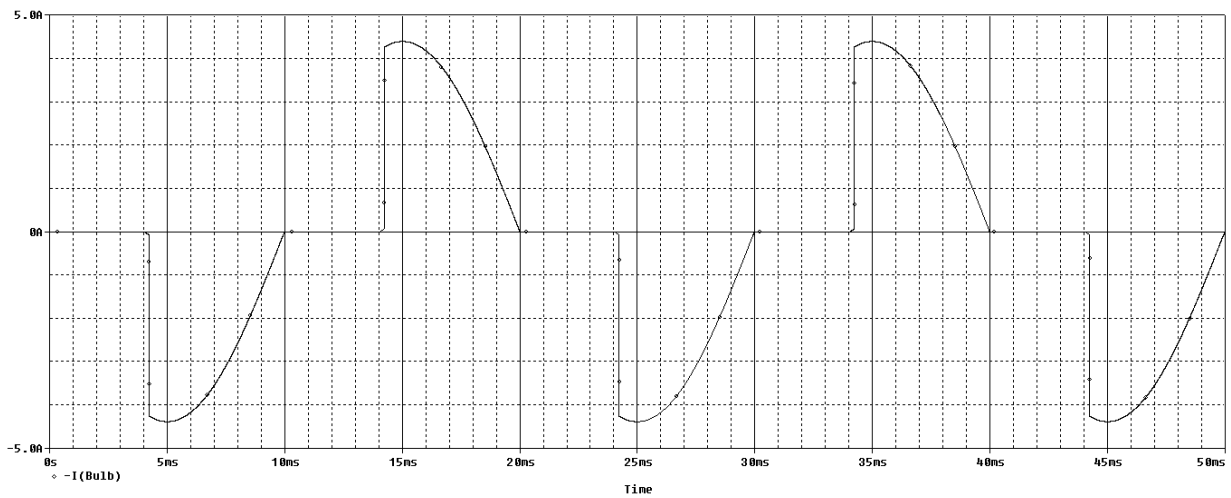


Figure 3: Load Current Simulations

5. Conclusion

Because the RC circuit is a low pass filter, it is thus possible to eliminate the need for a diac or the need for phase delay calculations. You can simply reduce the maximum low pass frequency (f_0) by increasing the variable resistance value or the capacitor value, thus preventing the current from entering the gate of the triac and keeping the light bulb OFF.

Other applications include turning ON in the dark lights when the low pass filter capacitor is replaced with a photodiode that switches from short circuit (when light is applied to its surface) to open circuit (in the dark) and thus turns ON the light bulb by supplying voltage to the triac.

6. References

1. <https://www.animations.physics.unsw.edu.au/jw/RCfilters.html>
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