BRAC UNIVERSITY
Inspiring Excellence

Electrical and Electronic Department

Electronic Devices and Circuits II

EEE207

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Term Project - 1

<u>Group 10</u>

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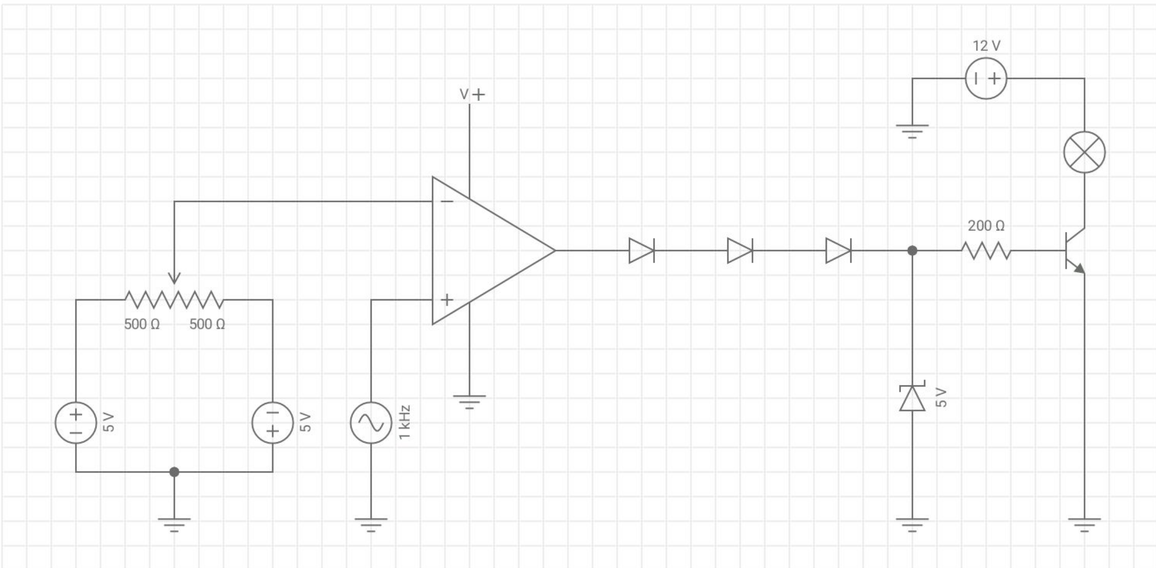
Objective

Design two dimmer circuits that are able to vary the intensity of a lamp from 10% to 90% of its full intensity. One circuit for 12V 18W DC lamp and the other circuit is for 220V 100W AC lamp.

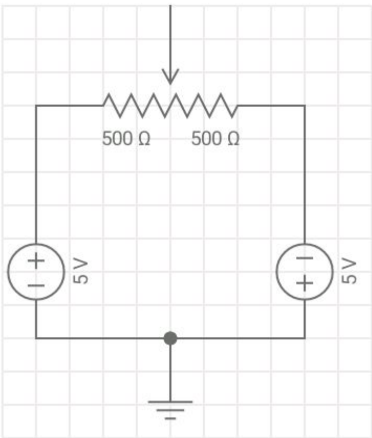
Circuit 1



Design Methodology

The circuit consists of three sections - variable DC supply, operational amplifier and switching circuit. The circuit is designed for a DC lamp rated 12V 18W. The variable DC supply can vary output voltages ranging from -5V to 5V. The variable DC supply is connected to the inverting terminal of the op amp. A sinusoidal AC supply of amplitude 5V is connected to the non-inverting terminal of the op amp. In the op amp the power supply, *V-* is connected to the ground and the power supply, *V+* is 12V. The output of the op amp is then connected to the switching circuit made using the BJT.

Designing the variable DC supply



The variable DC supply is made by connecting two 5V sources to a potentiometer. The positive terminal of one source is connected to one side of the potentiometer and the negative side of another source is connected to the other side of the potentiometer. This allows us to vary the supply from 5V to -5V.

Designing the Operational Amplifier

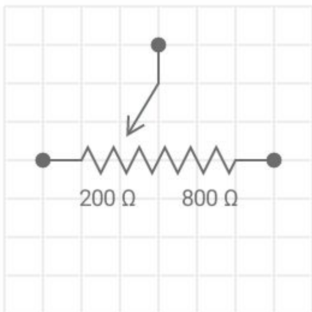
Here the op amp is used in an open loop connection. The non-inverting terminal of the op amp is connected to the AC supply and the inverting terminal is connected to the variable DC supply. The power supply, *V*- is connected to ground and power supply, *V*+ is 12V. If the DC supply voltage is higher than the AC supply voltage, the output is V_{sat}- = 0V + ΔV (where ΔV is the internal voltage drop of the op amp) and if DC supply voltage is lower than the AC supply, then output V_{sat}+ = 12V - 2V = 10V is produced. The result is a pulsating signal from the op amp which varies from V_{sat}+ *to* $V_{sat.}$-. By varying the input on the interverting terminal, the variable DC supply, we can control the duty cycle output of the op amp.

Designing the Switching Circuit

In open loop connection op amp produces two outputs only, V_{sat}+ and $V_{sat.}$-. For output $V_{sat.}$-, op amp produces a pulsating signal with a low voltage equal to the internal voltage drop of the op amp as output. Assuming the value of ΔV is 2V, three silicon diodes are added in forward biased orientation. The diode drop of 2.1V (0.7V x 3) would decrease the low voltage output of the pulse to 0V. A zener diode is then connected to the output in parallel. The zener diode has a breakdown voltage of 5V. This ensures that the output pulse of the high voltage of the op amp is never greater than 5V. Therefore, the pulse of 5V high and 0V low reaches the BJT. When the pulse is low, there is no current flowing into the base of the BJT. The BJT then operates in the cutoff region, and thus the lamp turns off. When the pulse is high, there is a current of 21.5 mA flowing into the base terminal and the BJT operates in the saturation region as both EBJ and CBJ are forward biased.This causes a current to flow through from the collector to the emitter terminals, thus turning on the lamp.

Design Analysis

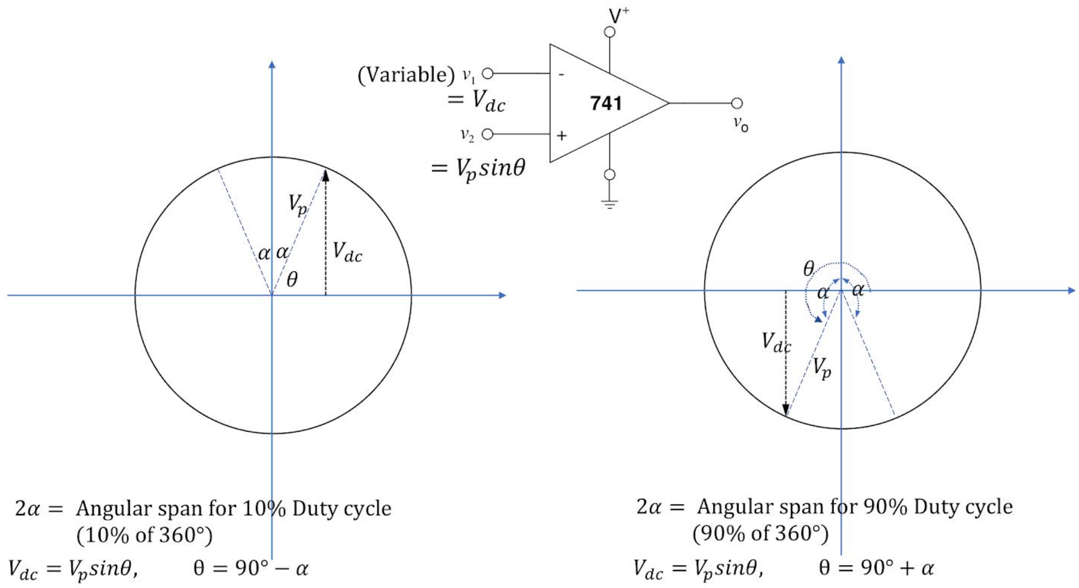
In the variable DC supply, the potentiometer has a total resistance of 1 kΩ. By adjusting the position of the slider, the output voltage is controlled.



For the above setting of the potentiometer, the output would be

$V_1 = 5 - (200 / 1000) \times (5 - (-5)) = 3$ V.

Calculation of Variable DC Voltage level for changing intensity



$$V_{dc} = V_p \sin \theta$$

For 10% Duty Cycle

$$\alpha = (10\% \times 360°) / 2 = 18°$$

$$\theta = 90° - 18° = 72°$$

$$V_{dc} = 5 \sin 72° = 4.76V$$

For 90% Duty Cycle

$$\alpha = (90\% \times 360°) / 2 = 162°$$

$$\theta = 90° + 162° = 252°$$

$$V_{dc} = 5 \sin 252° = -4.76V$$

Here, a Zener Diode is used to limit the high output voltage produced by the op amp since internal voltage drop in the op amp may vary. Therefore we are using a 5V Zener Diode.

Next, we are using a BJT as a switch. To turn on the circuit the BJT has to be in saturation region. We know in order for the BJT to be in the saturation region,

$I_C / I_B < \beta$, where $\beta = 100$

Lamp current, $I_L = I_C = 18 / 12 = 1.5A$

Therefore I_B must be greater I_C / β, where I_C / β, = 1.5A / 100 =15mA

Therefore the I_B(min) is 15 mA. We have to control the value of I_B in order for the BJT to be in the saturation region. I_B is controlled by controlling the value of R_B. We know for the saturation region

$R_B < (V_Z - V_{BE} / (I_C / \beta I_C / \beta))$, where $V_{BE} = 0.7V$

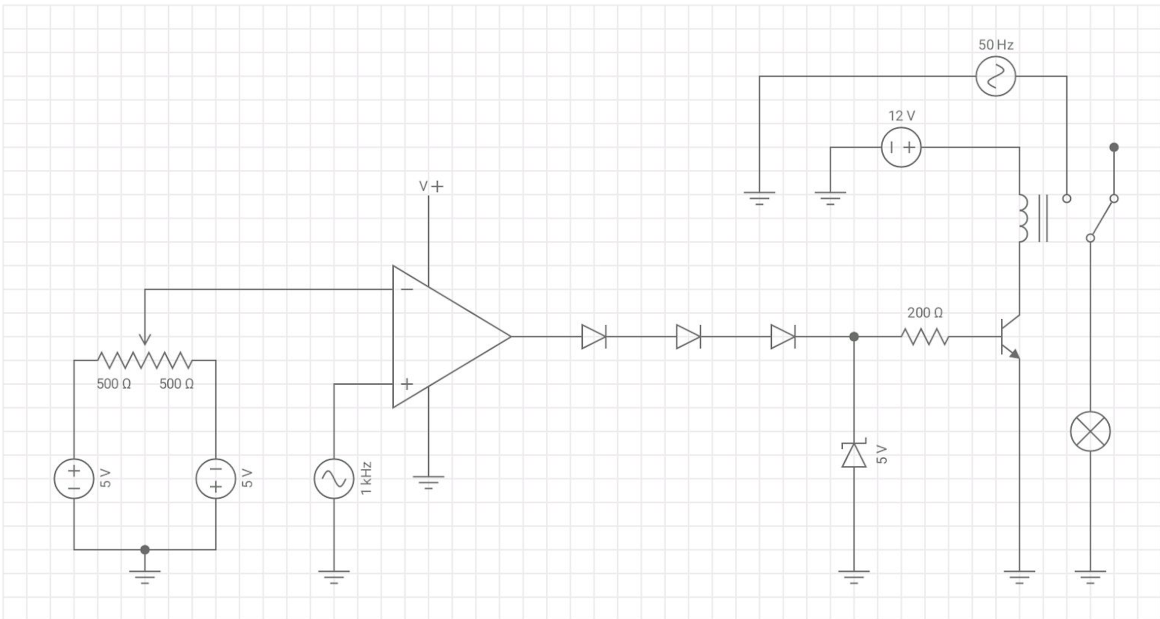
$R_B < (5 - 0.7 / (1.5 / 100)) = 286.67\Omega$

So we have selected R_B as 200Ω. Therefore $I_B = (5-0.7) / 200 = 21.5mA$. For $R_B = 200\Omega$, the I_B is greater than I_C / I_B, thus the BJT is in the saturation region.

We have previously shown that for saturation region, that I_C / I_B must be less than β. Here $I_C / I_B = 1.5A / 21.5mA = 69.77 < \beta$ (100). Therefore we have fulfilled the condition for BJT to be in saturation.

For the cutoff region, the output $V_{sat.}$-, produced by the op amp is equal to ΔV. So to decrease the low voltage output of the pulse to approximately 0V, three silicon diodes are added in forward biased orientation. The diode drop of 2.1V in the 3 diodes (0.7V x 3) would decrease the low voltage output of the pulse to 0V. Therefore no current flows to the BJT and the BJT is in the cutoff region and the switch is off.

Circuit 2



Design Methodology

This circuit is similar to the first circuit. However, since the lamp in this circuit uses AC, a relay is attached to the load of the transistor. The relay would be switched on and off by the transistor. The relay would connect the lamp with a 220V AC supply when switched on.

Designing of the relay

The relay specifications would be chosen such that it will only switch on the lamp when there is a high current flowing through it. The lamp in the DC circuit had a resistance of 8Ω. Therefore, the coil resistance of 8Ω could be used.

Design Analysis

When the pulse is high, there is a current flowing from the collector to the emitter of the BJT. This would cause the relay to activate and the lamp would turn on. When the pulse is low, the current flow in the BJT is stopped and the relay opens the circuit, turning off the lamp.

Comments

The β value of the transistor is assumed to be constant even though the β value is dependent on external conditions such as temperature. Therefore a heat sink is preferred. If the transistor heats up, the beta value will increase. In the first circuit, a huge amount of current is flowing through the transistor. Therefore a higher rating transistor must be used. It has been assumed that the internal voltage drop of the op amp will be constant at 2V. If the value is higher than 2V, more diodes need to be connected.