Abstract

This circuit explains the light intensity control of night lamp using LEDS. The element which is used for sensing light in the circuit is the light dependent resistor. The resistance of the light dependent resistor depends on the light incident on it. If the intensity of light incident on it is more, then the resistance of the circuit decreases. If the intensity of light incident on it decreases, then the resistance of the device increases. We are making use of this property of the light dependent resistor to detect the light and thereby operate the LEDs. We are arranging five light emitting diodes in an array such that a single LED is in series with a resistor and five such series LEDs are arranged in parallel.

Acknowledgement

Throughout the course of our project we received advice and assistance from many members of staff at Maseno University. We would like to thank and acknowledge the following people for their guidance:

Our academic supervisor, Mr. J. Alwala, for his continual support throughout the school

year. Significantly his help with the circuit implementation of the project which saved us many frustrated hours.

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Introduction

We turn ON the lights in our houses and offices manually. We need to turn ON the lights only when it is dark. So, here our circuit will be turning on the light automatically (basically domestic lights) when its dark.

This circuit helps us to turn on the lights automatically depending upon the surroundings. Some people may forget to turn off the light in the morning, which leads to wastage of electricity as well as money, hence this circuit helps us to overcome this problem.

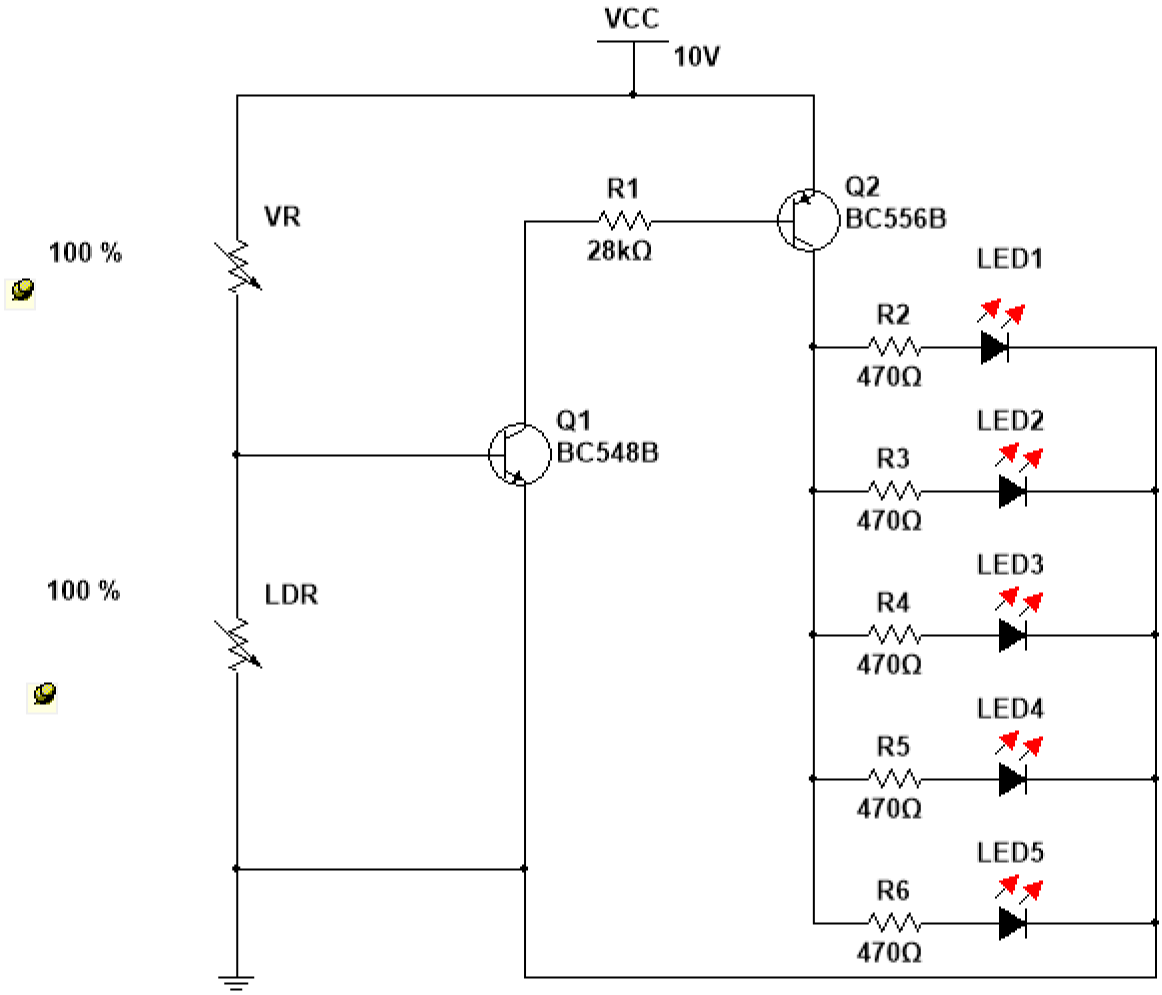
Background

Auto Night Lamp Using LEDs is a circuit which turns ON the LED lights interfaced to it at night time and it turns OFF the lights automatically when it is day. Usage of LEDs is growing day by day due to the advantages they provide compared to the conventional filament bulbs or fluorescent lamps. They provide good quality of white light with a better intensity compared to others. They also consume less power compared to their alternatives.

The Circuit Components

COMPONENTS	RATINGS	QUANTITY	MODEL
Transistors	BC548B (NPN) BC556B (PNP)	1 1	BK206 F906
Resistors	470Ω 2MΩ 28KΩ	5 1 1	Generic
Breadboard		1	B-204
Potentiometer (Variable Resistor)	10kΩ	1	Generic
DC Power Supply	10V		HY3005D-3
Light Emitting Diode	10MΩ-100Ω	1	Generic
Led Bulbs (Yellow)	Vf = 1.83V @ 20mA Luminous intensity is 200mcd(millicandela)	5	Standard 5mm
Jumper Wires		Several	

The Circuit Diagram



The Working Principle

The transistors are used in saturation mode. They are used as electronic switches in this mode. The transistor BC548 is a general purpose NPN transistor which is used to further switch the LEDs. The transistor BC556 is a PNP transistor which basically switches the LEDs on and off depending on the its base current value which is varied by the Light Dependent Resistor(LDR). The Light Dependant Resistors are used as photosensitive devices in this circuit.

The entire circuit along with the LEDs is powered by a 10V DC power supply. The 10kΩ variable pot(resistor) in series with the LDR forms a voltage divider. By varying the pot value, we can change the sensitivity of the LDR.

LDR will have a high resistance when there is no light around it. This helps to turn on Q1(NPN). Once Q1 is ON, the voltage across the collector and the emitter will become LOW. This make the transistor Q2(PNP), to turn ON.

When LDR (Light Dependent Resistor) is in light, the resistance of LDR is very low. As a result, base of the transistor Q1 becomes high. As a result, LED's which are connected to Q2 turns OFF.

When the circuit is in dark, the resistance of LDR is in order of mega ohms(10M). Now the base of the transistor becomes low, as a result transistor Q1 causes the transistor Q2, to be ON, which thereby switches LED's to ON state.

In this circuit transistor Q1 switches states of the transistor Q2 and effectively the LED's, based on the supply as well as light conditions. The output of LDR is connected to the base of transistor Q1 to switch the transistor based on the light conditions. The collector terminal of the transistor Q1 is connected is to the base of transistor Q2 to switch LED's according to the conditions.

There are 3 major parts of this circuit system

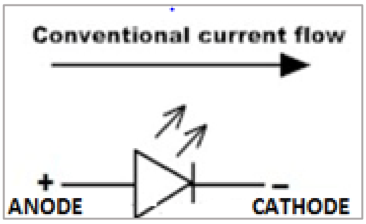
1. The Voltage Divider Bias Circuit
2. The Sziklai Connection Circuit/Complementary Darlington Circuit
3. The Load Circuit(The LEDs)

The LEDs

Leds converts electric current into illumination (or light). The LEDs are placed in the circuit at a distance of about 1cm so that the lighting is well distributed in the focus area.

A led consist of two principle elements of a semiconductor i.e.

- Positively charged P-type holes
- Negatively charged N-type electrons

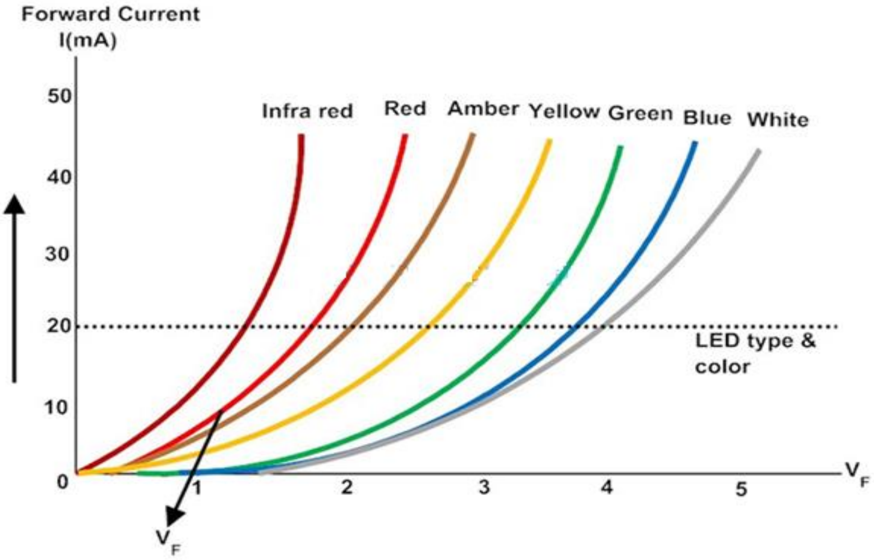


When the positive P side of the diode is connected to power supply, and the N side to the ground, thus the connection is forward bias, which allows current to flow throughout the diode(LED).

Majority and minority charge carriers of P side and N side combine with each other and neutralise charge carriers at the depletion layer of the PN junction. The combination produces energy in the form of photons.

Hence, Light will be emitted from the LED when its P-N junction is forward biased.

LED I-V Characteristic



- At low forward voltages, the driving current of the diode is dominated by the non-radiative recombination current due to recombination of charge carriers across the length of the LED chip.
- At higher forward voltages, the diode driving current is dominated by the radiative diffusion current.
- Even at larger voltages than the usual, the diode current is limited by the series resistance.
- The diode should never reach to reverse breakdown voltage for a short duration of time since permanent damage of the diode may occur.

Controlling of LED Light Intensity

- Intensity of light emitted by a led is controlled by the current flowing through it in the following ways:
- As the current across it varies, the brightness of light can be controlled.
- If a large amount of current is allowed to pass through the diode, led light glows much better than usual.
- If the current exceeds its maximum value, the intensity of light increases further and cause the led to dissipate heat.
- The forward current limit set for designing the RED led is 20mA.When the current required is very less there may be chances of turning off the led.

In our Circuit We Are Using A red LED with the following ratings:

- ✓ Wavelength 610-645
- ✓ DC Forward Voltage Drop(Vf) 1.8V-2.2V
- ✓ Maximum Current 20mA
- ✓ Luminous intensity 150-200mcd

Calculating The Light Intensity

- 1 lux at 1 meter = 1000mcd no matter what the angle of viewing.
- 1 feet=0.3048 meter
- 1 lux=93mcd at one ft.
- 1 lux=1 lumen/square meter

Luminous Intensity is a measure of how bright the LED can get. The unit mcd, is *millicandela*. This LED (Red LED) has a maximum intensity of 200 mcd, which means it's just bright enough to get your attention but not quite flashlight bright. Thus, It would make a good indicator.

*Illuminanc*e is a measure of how much luminous flux is spread over a given area. A given amount of light will illuminate a surface more dimly if it is spread over a larger area, so illuminance is inversely proportional to area when the luminous flux is held constant.

Luminous flux is measured in *lumen*, while luminous intensity is measured in *lumen per steradian*, also called a *candela*. The brightness of LEDs is measured in *millicandela* (mcd), or thousandths of a candela.

For example, a 2000 mcd 30° LED puts out just as much light as am 8000 mcd LED with a 15° viewing angle.

Light meters measure luminous flux, when luminous flux strikes a surface, the surface is said to be illuminated. The intensity of illumination, analogous to the intensity of electromagnetic radiation (which is power per unit area) is the luminous flux per unit area, called the illuminance, denoted by E. The unit of illuminance is the lumen per square meter, also called the lux thus:

$$1 \text{ lux} = 1 \text{ lm/m}^2 = 1 \text{ cd/m2}$$

Examples of illuminance provided under various conditions are:

Illuminance (lux)	Surfaces illuminated by
0.0001	Moonless, overcast night sky (starlight)
0.002	Moonless clear night sky with airglow
0.05–0.36	Full moon on a clear night
3.4	Dark limit of civil twilight under a clear sky
20–50	Public areas with dark surroundings
50	Family living room lights
80	Office building hallway/toilet lighting
100	Very dark overcast day
250	Classes
320–500	Office lighting, Study Library, Show Rooms, Laboratories
400	Sunrise or sunset on a clear day.
1000	Overcast day; typical TV studio lighting
10,000–25,000	Full daylight (not direct sun)
32,000–100,000	Direct sunlight

In conclusion our circuit has a total of 5 LEDs, which in total will produce 1000 mcd in a very dark environment, we can estimate that this Is 1 lux.

Determining the value of the current Limiting resistors.

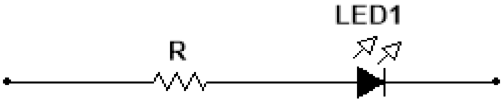
A resistor is used in series with an LED to keep the current to a specific level called Characteristic Forward Current, Therefore, it protects the LED from the excess current flow.

If the voltage source(Vs) is equal to the voltage drop(Vf) of a led, no resistance is required.

Analysing a series connection, Kirchhoff's circuit law tell that the sum of the voltage drops across a circuit is zero. Therefore, the resistor voltage must be equal to the voltage source minus the voltage drops of the LEDs.

To determine the current limiting resistor value, we need 3 things:

1. I =LED forward current in Amps
2. Vf=LED forward voltage drop in volts
3. Vs=Supply voltage



The equation is give as:

$$R = \frac{Vs - Vf}{I}$$

Taking the LED specification from the datasheet and substituting, we get;

$$\frac{10V - 1.83V}{0.02A}$$

$$= 408.5\Omega \;\; approx\ taking\ standard\ 470\Omega$$

Since we want a standard resistor value we will use 470Ω as the value of the current limiting resistor.

Advantages of LEDs (Why we used LEDs)

1. Small Chip size and low cost.
2. Long life time.
3. High energy efficiency.
4. Flexibility in design.
5. Eco friendly.
6. High switching speed.
7. High luminous intensity.
8. Less affected by damages and radiated heat.
9. More resistant to thermal shock and vibrations.
10. No presence of UV Rays.

Disadvantages of LEDS

1. Ambient temperature dependence of radiant output power and wavelength of the LED.
2. Sensitivity to damages by excess voltage and/or excess current.
3. Theoretical overall efficiency is achieved only in special cool or pulsed conditions.

<u>**The Light Dependent Resistor**</u>

It is a type of photoconductive cell, that vary their electrical property of resistance when subjected to light. Common type of photoconductive material is Cadmium Sulphide(CdS) which is used in LDR photocells.

The photoconductivity in these cells results from light hitting a semiconductor material which controls the flow of current through it. For or a given applied voltage, when the intensity of the light increases, the current also increases.

It uses light energy to control the flow of electrons and therefore the current in them. LDR changes its electrical resistance depending on the presence of light. That is:

- From high value of several thousand ohms in the dark to only a few hundreds of ohms when light is incident on it by creating electron-hole pairs in the material

The peak sensitive wavelength of Cadmium Sulphide material is about 560 nm to 600 nm in the visible spectral range. Characteristics of the LDR we are using are:

- Peak spectral response is 610 nm,
- Darkness resistance is $10M\Omega$
- Illuminated resistance is 100Ω

In the absence of light, the resistance of a light dependent resistor is as high as $10\ M\ \Omega$. In the presence of sunlight, the resistance of a light dependent resistor will fall to 100 Ω. The variation of the resistance of a light dependent resistor over different intensities of light is shown in the below curve:

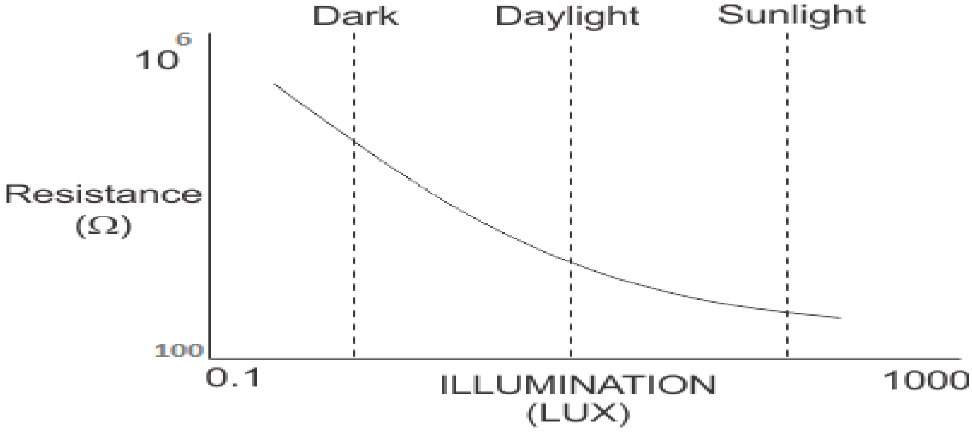
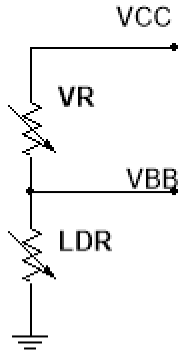


Figure Above Showing the Variation of the Resistance of A LDR Over Different Intensities of Light

As the intensity of the light increases, the resistance of the Light Dependent Resistor decreases and the bias voltage increases. At a certain point determined by the voltage divider network, the bias voltage raises enough to turn the transistor ON.

The sensitivity of the LDR switch is fairly low. To increase the sensitivity of light sensing, few modifications can be applied, that is, we bias it in parallel with the Variable Resistor.

The Variable Resistor/Potentiometer



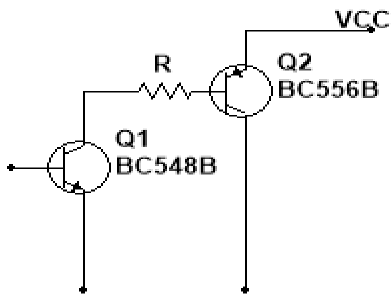
Since the sensitivity of the LDR switch is fairly low, we use the Variable resistor increase the sensitivity of light sensing.

The Variable Resistor and the LDR are connected in a Voltage Divider Bias. The resistors help to give complete control over the voltage and current flowing into the base of the NPN Transistor. In this output of the voltage divider is:

$$\boldsymbol{VBB} = \frac{LDR}{VR + LDR} VCC$$

Ideally VBB is the base supply voltage of the NPN transistor Q1.

The Sziklai Connected Transistors



It is also called a compound transistor, or Complementary Darlington (because it is in contrast to a Darlington arrangement).

It consists of two bipolar transistors just like a Darlington pair, but of opposite polarities, that is one PNP and the other NPN.

The collector of the first transistor(Q1) is connected directly to the base of the second(Q2).

BC548 is an NPN transistor. It has cut-off voltage of 0.7v. NPN transistors are initially open circuited that is when there no base voltage, there is no flow of current from emitter to collector. When the base gets required voltage transistor starts conducting.

Current gain of a Sziklai pair is similar to that of Darlington pair, which is the product of the gains of the two transistors, Q1 and Q2. The BJTs combination can be used as a single high gain transistor.

The combination results in a 3 terminal device that behaves like a single high-current gain transistor. Thus the overall circuit behaves like a transistor of the same polarity as Q1 (input transistor), i.e NPN

The resistor R connected between the two transistors has it improves the turn off time and provide better frequency performance.

Characteristics and Features of Sziklai over the Darlington Pair

- The base turn-on voltage is only about 0.6V or half of the Darlington's 1.2 nominal turn on voltage.
- Only a single base emitter drops between the overall base and emitter of the compound transistor.
- Higher saturation voltage than a Darlington
- Very slightly lower gain than a Darlington.
- Sziklai pair is known to provide a better level of linearity than the Darlington pair which can be advantageous especially in audio applications.

- In view its characteristics Sziklai pair or compound pair finds many uses in circuits in a number of areas, least to mention, audio amplifier outputs, general audio amplifier also in digital switching.

Disadvantages of an Sziklai

- It can saturate only to 0.6V which is a drawback for high power stages

The Transistor Specifications Table

Property	BC548B	BC556B
Hfe(max)	150	460
Hfe(min)	90	150
Ic(max)	0.1	0.1
Pd	1.5	1.5
Vbe(sat)	0.7	-0.7
Vce(sat)	0.09	−0.075

Gain of Sziklai Connection

The beta of both transistors is multiplied together for a new beta. The higher beta allows for much smaller currents to control much large currents on the output (Compared to a single transistor alone).

Gain of Sziklai compound pairs is very nearly the same as that of Darlington. Gain of Darlington is:

$\beta = \beta Q1 . \beta Q2 + \beta Q1 + \beta Q2$

Gain of Sziklai pair is slightly different as there is no individual contribution from Q2 as seen below:

$\beta = \beta Q1 . \beta Q2 + \beta Q1$

Since the terms $\beta Q1$ and $\beta Q2$ on their own can be neglected, we obtain an equation applicable for the Sziklai & Darlington i.e.:

$\beta = \beta Q1 . \beta Q2.$

Finding hfe of Q1, we find the geometric average of the maximum and minimum hfe, whereby:

$Q1hfe = \sqrt{90 * 150} = 116.19$

And for Q2,

$Q2hfe = \sqrt{460 * 150} = 262.68$

Thus the overall gain of the Sziklai connection is given by,

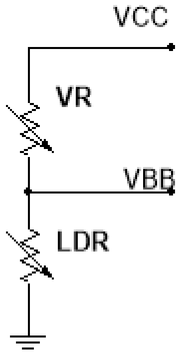
$$\beta = \beta Q1 . \beta Q2$$

$$\beta = 116.19 * 262.68$$

$$\beta = 30520.79 \; is \;\; the \; overall \; gain \; if \;\; sziklai \; a \; pair$$

General Circuit Calculations

From the potential divider bias circuit finding the base current of transistor Q1,



$$\boldsymbol{VBB} = \frac{LDR}{VR + LDR}\, VCC$$

Assuming that its night time, thus taking maximum LDR=10MΩ and maximum VR=10KΩ, while Vcc=10V, then Vbb, will be

$$\frac{10000k\Omega}{10000k\Omega + 10k\Omega}\, 10V$$

Whereby $VBB = 9.99V$

The value of the base resistance Rb is given by VR//LDR, thus:

$$Rb = \frac{LDRxVR}{LDR + VR}$$

$$\frac{10000k\Omega x 10k\Omega}{10010k\Omega} = 9.99k\Omega$$

Finding the base current Ib flowing into Q1,

$$Vcc = IbRb + vbe$$

$$10V = Ib(9990\Omega) + 0.7V$$

$$Ib = \frac{10V - 0.7V}{9990\Omega}$$

$$Ib = 0.931mA$$

Finding the collector current of transistor Q1,

$$hfe = \frac{Ic}{Ib}$$

thus, $Ic = \frac{hfe}{0.931mA}$

and hfe for transistor Q1 (finding geometric average), is

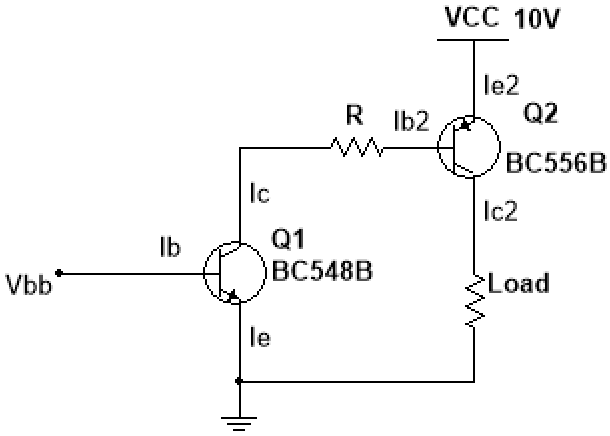
$$hfe = \sqrt{90x150}$$

$$hfe = 116.19$$

thus Ic is,

$$Ic = \frac{116.19}{0.931mA}$$

$$Ic = 124.8mA$$



Finding Rc, for the transistor Q1,

$$VCC = IcRc + Vce$$

$$Rc = \frac{(VCC - Vce)}{Ic}$$

Substituting,

$$Rc = \frac{10 - 0.09}{0.1248}$$

$$Rc = 79.41\Omega$$

Since we have Ic, the $Ic = Ib2$, that is the collector current of Q1, is equivalent to the base current of Q2, thus finding Rb2, for transistor Q2, we get,

$$-VCC = Ib2Rb2 + (-Vbe)$$

$$Rb2 = (VCC - Vbe)/Ib2$$

Substituting,

$$Rb2 = \frac{10 - 0.7}{0.1249}$$

$$Rb2 = 74.46\Omega$$

Finding the load resistance, one LED resistance is given by,

$$LEDr = V/I$$

$$LEDr = \frac{1.83}{0.02A}$$

Where $LEDr = 91.5\Omega$

But since there is a resistor in series for each parallel connection then, Total Resistance for one Serial connection is,

$$Total\ Resistance\ across\ a\ series = 91.5\Omega + 470\Omega = 561.5\Omega$$

Since there are 5 parallel resistances then,

$$Total\ Resistance/Load\ Resistance = Reciprocal\ of\ (1/561.5\Omega\ * 5) = 112.3\Omega$$

Thus, $Rc2 = Load\ Resistance = 112.3\ \Omega$

Finding $Ic2$:

$$-VCC = Ic2Rc2 + -Vce$$

$$Ic2 = \frac{(VCC - Vce)}{Rc2}$$

Substituting,

$$Ic2 = (10 - 0.075)/112.3\Omega$$

$$Ic2 = 88.38mA$$

Finding hfe for Q2,

$$hfe = \sqrt{460x150}$$

$$hfe = 262.68$$

but

$$hfe = \frac{Ic2}{Ib2}$$

thus

$$Ib2 = \frac{88.38mA}{262.68}$$

$$Ib2 = 0.3365mA$$

Finding Rb2 using $Vcc = Ib2Rb2 + Vbe$

$$Rb2 = \frac{10 - 0.7}{0.3365/1000})$$

$$Rb2 = 27641\Omega$$

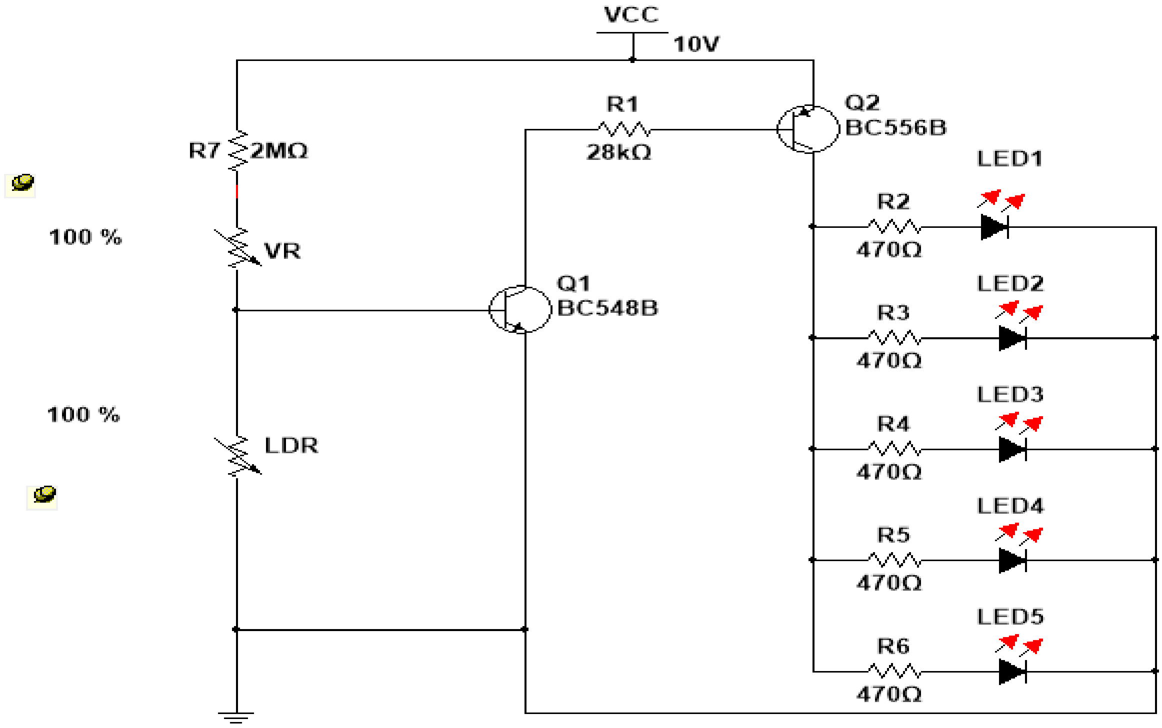
$$Rb2 = 28k\Omega$$

Challenges of the Circuit

Even though we had connected a Variable resistor in parallel with the Light Dependent Resistor in the Potential Divider Bias, the sensitivity of the LED was still quite low, but we found a solution.

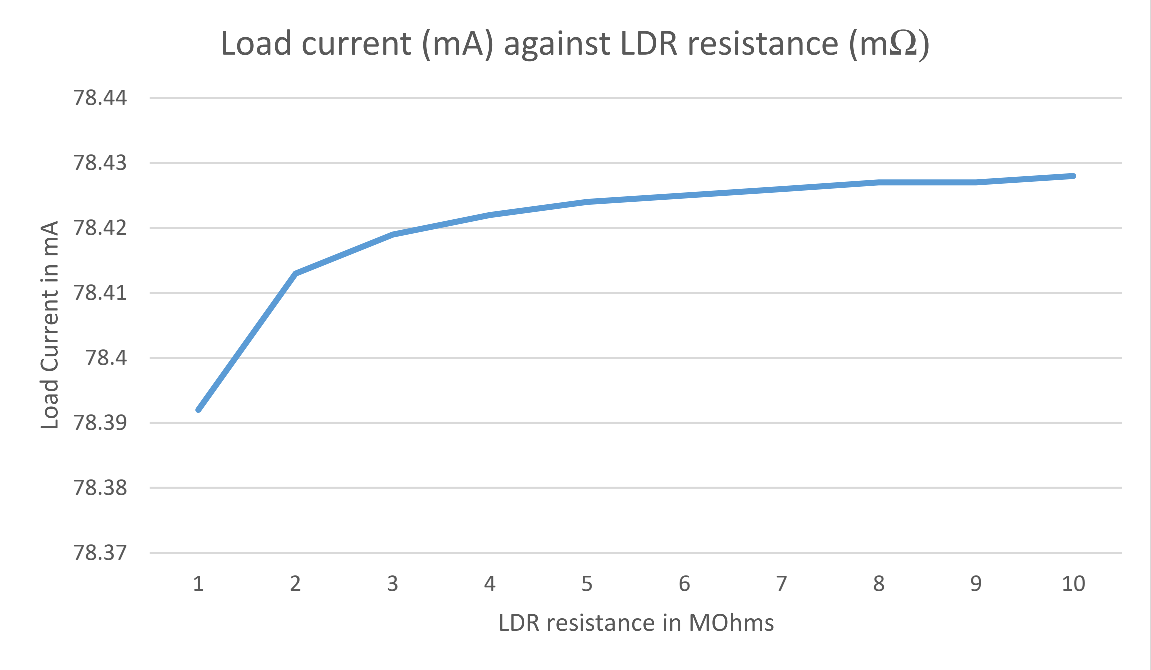
Solution/Modification

We were able to adjust the sensitivity of the LED to better match the ambient environment by connecting the variable resistor in series with a resistor whose value was almost closer to the maximum value of the LDR. As a result we used a $2M\Omega$ Resitor. As shown in the circuit below:



Light dependent resistor has high resistance value in darkness as light illumination on the resistor increases resistance value decreases. The 10 mega ohm Light Dependent Resistor has resistance value ranging from 1000hms to 10 mega ohms. This is connected to the supply through a Variable resistor of 10k resistance in series with a 2 mega ohm resistor.

Graph Showing the Relationship between the LDR Variations and Light Intensities



Load current is current in the Collector Region going into the load of transistor Q2, whereas LDR resistance are the variations of the LDR depending on the surrounding lights.

The value of current determines the brightness of the LEDs, so therefore the higher the LDR resistance(getting darker), the higher the current, and the brighter the LEDs.

How to Operate the Automatic Light Circuit:

- Give the connections according to the circuit diagram.
- Apply the main supply to the circuit, and place circuit in dark, now LED's will glow.
- If you place the circuit in light, then LED's turns OFF.

Demerits of our project plus the solution

Basically, the simple auto night lamp switcher, may turn on the light when it is dark, but the problem comes about when the level of darkness is approaching, the circuit may get successive signals of dark and light with little time intervals. This may cause the circuit to repeatedly turn ON and OFF the lights at a high frequency which can possibly damage our lights within a few minutes or hours. This might happen every time at evening as well as in the morning when the light intensity crosses a value for which our circuit is sensitive and toggles the switch.

Light Activated Switch Circuit Applications:

- This circuit can be used in security applications like when there is darkness on the LDR, it stops lighting.
- This can be used in applications where the light is switched on /off depending on the ambient light

Advantages

1. This is very simple circuit and the cost is also very less.
2. power is saved because the circuit switches the LEDs based on light conditions
3. The main principle of this circuit is to switch ON the light when the LDR is illuminated. The light dependent resistor will have high resistance in darkness and low resistance in the light.

Conclusion and Recommendations

- To change the sensitivity of the sensors, we can either increase or decrease the value of the base resistor.
- Premade Sziklai aren't overly good, and its thus recommended to make your own. It is preferable that the PNP transistor Q2, be a power transistor, whereas the transistor Q1 be a small signal transistor so that it feeds into a power transistor. The small signal transistor should have a high beta and enough transmitter current to power the base of the power transistor.
- Since the entire circuit along with the LEDs is powered by a 12V DC power supply. A battery based DC power supply is usually preferred. However, you can use a ac rectified and regulated power supply.
- It's best to use high powered white LEDs in the circuits instead of ordinary LEDs, because the intensity of light produced by these LEDs equals an ordinary fluorescent bulb.
- If the circuit is assembled on the printed circuit board it is best to place the LEDs maintaining a distance of about 1 cm between the LEDs so that the lighting will be well distributed in your room.

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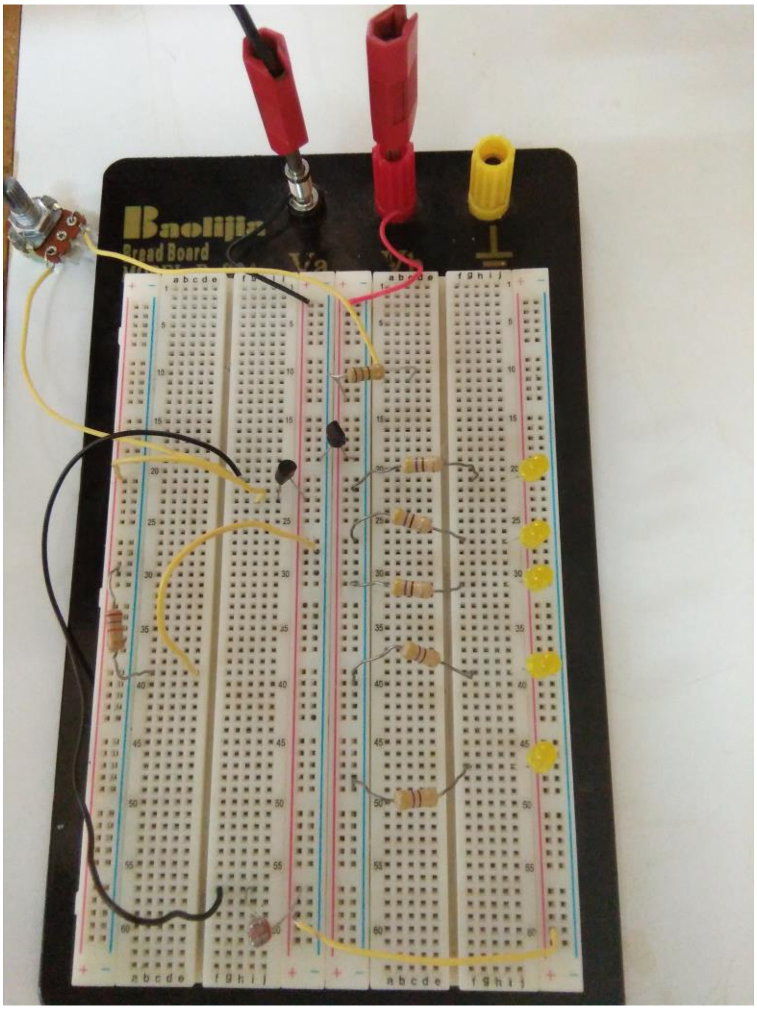
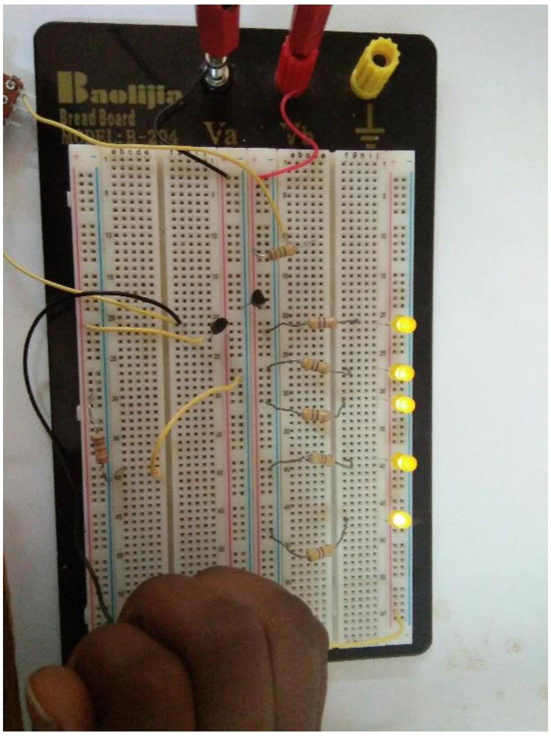
Circuit Diagrams

When subjected to light



<u>When subjected to slight darkness</u>



<u>When subjected to total darkness</u>