Automatic street light controller essay sample

Technology

1. Introduction

Automatic Street Light Control System is a simple and powerful concept, which uses transistor as a switch to switch ON and OFF the street light automatically. By using this system manual works are removed. It automatically switches ON lights when the sunlight goes below the visible region of our eyes. It automatically switches OFF lights under illumination by sunlight. This is done by a sensor called Light Dependant Resistor (LDR) which senses the light actually like our eyes. By using this system energy consumption is also reduced because now-a-days the manually operated street lights are not switched off properly even the sunlight comes and also not switched on earlier before sunset. In sunny and rainy days, ON time and OFF time differ significantly which is one of the major disadvantage of using timer circuits or manual operation.

This project exploits the working of a transistor in saturation region and cut-off region to switch ON and switch OFF the lights at appropriate time with the help of an electromagnetically operated switch. Automatic Streetlight needs no manual operation of switching ON and OFF. The system itself detects whether there is need for light or not. When darkness rises to a certain value then automatically streetlight is switched ON and when there is other source of light, the street light gets OFF. The extent of darkness at which the street light to be switched on can also be tailored using the potentiometer provided in the circuit. Moreover, the circuit is carefully designed to avoid common problems like overload, relay chattering and inductive kick back in relay.

2. Principle

The automatic streetlight control system operates on 12 V DC supply. The automatic streetlight controller has a photoconductive device whose resistance changes proportional to the extent of illumination, which switches ON or OFF the LED with the use of transistor as a switch .

Light dependent resistor, a photoconductive device has been used as the transducer to convert light energy into electrical energy. The central dogma of the circuit is that the change in voltage drop across the light dependent resistor on illumination or darkness switches the transistor between cut-off region or saturation region and switches OFF or ON the LED.

3. Block Diagram & Circuit Diagram

3. 1 Block Diagram

3. 1. 1 Individual Block Explanation

Power supply: AC power supply is stepped down, rectified and filtered to get almost ripple-free DC output for the operation of the circuit.

Light dependent resistor: LDR senses the illumination level and gives the input signal as voltage drop. Amplifier: Darlington circuit amplifies the input current to get maximum current gain. Switch: Relay switch closes or opens electrically and automatically, which is energized or de energized by the Darlington pair.

Street light: Street light is the output of the circuit. In this circuit, it has been replaced by LED

3. 1. 2 Amplification Unit

Darlington pair

In the Darlington configuration, the emitter current of one transistor becomes the base current of the second, so that the amplified current from the first is amplified further by the second transistor. This gives the Darlington pair a very high current gain such as 10000, since the Darlington configuration acts like one transistor with a beta which is the product of the betas of the two transistors. Darlington configuration can be used where high output currents are needed. The Darlington configuration has quite high input impedance. A Darlington pair can be sensitive enough to respond to the current passed by skin contact even at safe voltages. Thus it can form the input stage of a touch-sensitive switch. Darlington Configuration

DC Current gain hFE = hFE1 X hFE2

3. 1. 3 ON OFF control

The circuit is switched ON or OFF by the transistor in saturation region or cut off region respectively, which is controlled by the signal from LDR. The collector current from the transistor toggle between ON or OFF modes. 3. 2 Circuit Diagram

The circuit diagram of automatic street light controller is given below:

The description of all the components used in this circuit is given in chapter 5.

4. Component Description

4. 1 Diode

A diode is a two-terminal electronic component that conducts electric current in only one direction. A semiconductor diode is a crystalline piece of semiconductor material connected to two electrical terminals. A vacuum tube diode is a vacuum tube with two electrodes: a plate and a cathode. The most common function of a diode is to allow an electric current to pass in one direction while blocking current in the opposite direction. Thus, the diode can be thought of as an electronic version of a check valve. This unidirectional behavior is called rectification, and is used to convert alternating current to direct current and to extract modulation from radio signals in radio receivers. When p-type and n-type materials are placed in contact with each other, the junction is depleted of charge carriers and behaves very differently than either type of material. The electrons in n-type material diffuse across the junction and combines with holes in p-type material.

The region of the p-type material near the junction takes on a net negative charge because of the electrons attracted. Since electrons departed the N-type region, it takes on a localized positive charge. The thin layer of the crystal lattice between these charges has been depleted of majority carriers, thus, is known as the depletion region. It becomes nonconductive intrinsic semiconductor material. This separation of charges at the p-n junction constitutes a potential barrier, which must be overcome by an external voltage source to make the junction conduct. The electric field created by the space charge region opposes the diffusion process for both electrons and holes. There are two concurrent phenomena: the diffusion process that tends to generate more space charge and the electric field generated by the space charge that tends to counteract the diffusion p-n junction in thermal equilibrium with zero bias voltage applied Equilibrium, forward and reverse biased conditions in a p-n junction

When the diode is forward biased, the positive charge applied to the P-type material repels the holes, while the negative charge applied to the N-type material repels the electrons. As electrons and holes are pushed towards the junction, the width of depletion zone decreases. This lowers the barrier in potential. With increasing forward-bias voltage, the depletion zone eventually becomes thin enough that the electric field of the zone can't counteract charge carrier motion across the p–n junction, consequently reducing electrical resistance. The electrons which cross the p–n junction into the P-type material will diffuse in the near-neutral region. Therefore, the amount of minority diffusion in the near-neutral zones determines the amount of current that may flow through the diode.

p-n junction in thermal equilibrium with zero bias voltage applied. Under the junction, plots for the charge density, the electric field and the voltage When the diode is forward biased, the positive charge applied to the P-type material repels the holes, while the negative charge applied to the N-type material repels the electrons. As electrons and holes are pushed towards the junction, the width of depletion zone decreases. This lowers the barrier in potential. With increasing forward-bias voltage, the depletion zone eventually becomes thin enough that the electric field of the zone can’t counteract charge carrier motion across the p–n junction, consequently reducing electrical resistance. The electrons which cross the p–n junction into the P-type material will diffuse in the near-neutral region. Therefore, the amount of minority diffusion in the near-neutral zones determines the amount of current that may flow through the diode.

p-n junction under forward and reverse bias When the diode is reverse biased, the holes in the p-type material and the electrons in the n-type material are pulled away from the junction, causing the width of the depletion zone to increase with increase in reverse bias voltage. This increases the voltage barrier causing a high resistance to the flow of charge carriers thus allowing minimal electric current to cross the p–n junction. The increase in resistance of the p-n junction results in the junction to behave as an insulator. The strength of the depletion zone electric field increases as the reverse-bias voltage increases. Once the electric field intensity increases beyond a critical level, the p-n junction depletion zone breaks down and current begins to flow.

Forward and reverse bias characteristics of a diode a nd it’s circuit symbol A Zener diode is a type of p-n junction diode that permits current not only in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as Zener knee voltage. By contrast with the conventional device, a reverse-biased Zener diode will exhibit a controlled breakdown and allow the current to keep the voltage across the Zener diode close to the Zener voltage. The Zener diode’s operation depends on the heavy doping of its p-n junction allowing electrons to tunnel from the valence band of the p-type material to the conduction band of the n-type material.

In the atomic scale, this tunneling corresponds to the transport of valence band electrons into the empty conduction band states as a result of the reduced barrier between these bands and high electric fields that are induced due to the relatively high levels of doping on both sides. The breakdown voltage can be controlled quite accurately in the doping process. In this project, diode has been as a rectifier in full-wave rectifier circuit. Moreover, it has also been used a safety component to prevent inductive kick back in the reverse bias mode. 4. 2 Light emitting Diode

Light-emitting diodes are elements for light signalization in electronics. The basic principle behind the working of LED is electroluminescence. The Light emitting diode should be forward biased to get the light. In Light emitting diodes, electrons are injected from low work function cathode to the conduction band of the n-type semiconducting material and holes are injected from high work function anode to the valence band ot the p-type semiconducting material. When the electron in the conduction band combines with the hole in the valence band, energy is released. In case of indirect band gap semicondutors, phonon will be released to conserve of both energy and momentum. But in case of direct band gap semiconductor, light will be emitted whose wavelength depends on the band gap of the semiconductor.

Different parts of a Light emitting diode

Radiative recombination in direct and indirect bandgap semiconductor

Cartoon showing radiative recombination in a direct band-gap semiconductor

Schematic diagram of working of an LED Light emitting Diode and its circuit symbol The main advantage of Light emitting diode over other light sources is its increased efficiency. LEDs are available in red, orange, amber, yellow, green, blue and white. Blue and white LEDs are much more expensive than the other colours. We have employed low cost Red LED in our electronic circuit. 4. 3 Light Dependent resistor

A light dependent resisitor is a resisitor whose resistance changes with the intensity of incident light. The working principle of light dependent resistor is photoelectric effect. A light dependent resisitor is made of a high resistance semiconductor. If the energy of the incident light is greater than the band gap of the semiconductor, electron -hole pairs are generated. The photogenerated electron-hole pair transits the device giving rise to photoconductivity. The essential elements of a photoconductive cell are the ceramic substrate, a layer of photoconductive material, metallic electrodes to connect the device into a circuit and a moisture resistant enclosure. Light sensitive material is arranged in the form of a long strip, zig-zagged across a disc shaped base with protective sides. For additional protection, a glass or plastic cover may be included. The two ends of the strip are brought out to connecting pins below the base as shown below. Side view

Top view

Top view and side view of Light Dependent Resisitor The commercial photoconductive materials include cadmium sulphide (CdS), cadmium selenide (CdSe), Lead sulfide (PbS) and Indium antimonide (InSb) etc., There is large change in the resistance of a cadmium selenide cell with changes in ambient temperature, but the resistance of cadmium sulphide remains relatively stable. Moreover, the spectral response of a cadmium sulphide cell closely matches to that of a human eye. Hence, LDR is used in applications where human vision is a factor such as street light control or automatic iris control for cameras. The above mentioned features drive us to opt for CdS based LDR in our electronic circuit for Automatic street light controller.

Light Dependent Resistor and its circuit symbol 4. 4 Full-wave rectifier: The full wave rectifier circuit consists of two diodes connected to a single load resistance (RL) with each diode taking it in turn to supply current to the load. When point A of the transformer is positive with respect to point C, diode D1 will be forward biased and it conducts in the forward direction as indicated by the arrows. When point B is positive (in the negative half of the cycle) with respect to point C, diode D2 will be reverse biased and conducts in the forward direction and the current flowing through resistor R is in the same direction for both half-cycles. As the output voltage across the resistor R is the phasor sum of the two waveforms combined, this type of full wave rectifier circuit is also known as a bi-phase circuit which is shown below. Full-wave rectifier output

4. 5 Capacitor Filter:

The output of the full-wave rectifier will be a rippled DC voltage. In order to obtain a constant DC output voltage, a capacitor is connected across the output of the full-wave rectifier. We have employed an Aluminium Electrolytic type capacitor (100 µF) for our purpose. The property of a capacitor is that it allows ac component and blocks dc component. The capacitor will get charged to the peak voltage during each half-cycle and then will get discharged exponentially through the load while the rectified voltage drops back to zero. Thus, the capacitor helps to fill in the gaps between the peaks. As a result, the actual voltage output from this combination never drops to zero, but rather takes the shape as shown in the figure given below. Full-wave rectifier output after passing through filter

Full-wave rectifier output before passing through filter

Eventhough the output voltage is a not pure dc, but has much less variation in voltage than the unfiltered output of the full-wave rectifier. The extent to which the capacitor voltage drops depends on the capacitance of the capacitor and the amount of current drawn by the load (RC time constant). The two important parameters to consider when choosing a suitable smoothing capacitor are its Working Voltage, which must be higher than the load output value of the rectifier and it’s Capacitance Value, which determines the amount of ripple that will appear superimposed on top of the DC voltage. Moreover, the extent of smoothing is limited by the frequency of the AC voltage and the load current. 4. 6 Relays:

A relay is an electrically operated switch. Most of the relays use an electromagnet to operate a switching mechanism mechanically. Relays are used where it is necessary to control a circuit by a low-power signal with complete electrical isolation between control and controlled circuits or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations. Relays can also be used to protect electrical circuits from overload. In modern electric power systems these functions are performed by digital instruments still called protective relay, which designed to calculate operating conditions on an electrical circuit and trip circuit breakers when a fault is detected.

When an electric current is passed through the coil it generates a magnetic field that attracts the armature and the consequent movement of the movable contact either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing. 4. 6. 1 Single pole single throw Relay:

In Single Pole Single Throw relay, current will only flow through the contacts when the relay coil is energized.

Single pole single throw Relay and its circuit symbol 4. 7 Transistors Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor’s ability to change between these two states enables it to have two basic functions: switching or amplification. Then bipolar transistors have the ability to operate within three different regions: * Active Region – the transistor operates as an amplifier and IC = β IB * Saturation – the transistor is fully-ON operating as a switch and IC = Isaturation * Cut-off – the transistor is “ fully-OFF” operating as a switch and IC = 0 The word Transistor is an acronym, and is a combination of the words Transfer Varistor used to describe their mode of operation way back in their early days of development. There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made.

A transistor is made of a solid piece of semiconductor material, with at least three terminals for connection to an external circuit. The Bipolar Junction Transistor basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labeled as the Emitter (E), the Base (B) and the Collector (C) respectively. Bipolar Transistors are current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing voltage applied to their base terminal acting like a current-controlled switch. The principle of operation of the two transistor types NPN and PNP, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

Bipolar Junction Transistor Configurations Since Bipolar Junction Transistor is a three terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor varies with each circuit arrangement.

* Common Base Configuration – has Voltage Gain but no Current Gain. * Common Emitter Configuration – has both Current and Voltage Gain. * Common Collector Configuration – has Current Gain but no Voltage Gain. 4. 7. 1 NPN transistor configuration

NPN transistor configuration The construction and terminal voltages for an NPN transistor are shown above. The voltage between the Base and Emitter (VBE) is positive at the Base and negative at the Emitter because for an NPN transistor, the Base terminal is always positive with respect to the Emitter. Also the Collector supply voltage is positive with respect to the Emitter (VCE). For an NPN transistor to conduct, the Collector is always more positive with respect to both the Base and the Emitter.

The voltage sources will be connected to an NPN transistor as shown above. The Collector is connected to the supply voltage VCC via the load resistor, RL which also acts to limit the maximum current flowing through the device. The Base supply voltage VB is connected to the Base resistor RB, which again is used to limit the maximum Base current. It is well known that the transistor is a current controlled device since the base current controls the collector current. The transistor current in an NPN transistor is the ratio of these two currents (IC/IB), called the DC Current Gain of the device and is given the symbol β of hFE.

The value of β or hFE can be large up to 200 for standard transistors and this large ratio between IC and IB that makes the NPN transistor a useful amplifying device when used in its active region. Also, the current gain of the transistor from the collector terminal to the emitter terminal, IC/IE, is called Alpha (α), and is a function of the transistor. As the emitter current IE is the product of a very small base current plus a very large collector current, the value of alpha α, is very close to unity, and for a typical low-power signal transistor this value ranges from about 0. 950 to 0. 999.

NPN Bipolar Junction transistor

All the transistors have three state of operation:

OFF state: in this state there is no base current applied or IB = 0. ON ACTIVE state: In this state any changes in IB will cause changes in IC since IC = IB x hFE. This type of state is suitable when we use transistor as a signal amplifier because transistor is said is in the linear state. ON SATURATION state: In this state any changes in IB will not cause changes in IC anymore (not linear) and IC will be nearly constant. This state cannot be used to run the transistor as a signal amplifier since the output signal will be clamped when the transistor becomes saturate.

Transistor in operating state

When transistor is in OFF state, the voltage across collector and emitter terminal is equal to the supplied voltage, which is equivalent to the open circuit. When transistor is in the SATURATION state, the collector to emitter voltage is equal or less than 0. 2 V, which is equivalent to the closed circuit. Here, the OFF state is equivalent to the logical “ 0” and the SATURATION state is equivalent to the logical “ 1“. 4. 7. 2 Transistor as an Amplifier

A voltage or current applied to one pair of the transistor’s terminals changes the current flowing through another pair of terminals. To be more specific, the current applied to the base terminal will be multiplied by the current gain factor of the transistor which known as hFE. Therefore transistor can be used as amplifier. Any small signal applied to the base terminal will be amplified by the factor of hFE and reflected as a collector current on the collector terminal side.

When we operate transistor as an amplifier, we choose the bias voltage VBE and VCE in such a way that the output IC and VCE will swing to maximum value (saturation region) or minimum value (cut-off region) without any distortion when the input IB swing to its maximum or minimum value.

Typical NPN transistor characteristic curves for CE Amplifier 4. 7. 3 Transistor as a switch

As mentioned above, bipolar transistor has three regions of operation: the cut-off region, the linear or active region, and the saturation region. When using the bipolar transistor as a switch they must be either fully-OFF or fully-ON. When used as a switch, the bipolar transistor is operated in the cut-off region, the region wherein the transistor is not conducting which makes the circuit open so that the applied voltage will be same as the output to make the transistor OFF and saturation region, the region wherein the transistor is in full conducting, thereby closing the circuit so as to get the lowest possible

VCE (i. e. nearly 0. 2 volt) to make the transistor ON. Transistors that are fully ON are said to be in their Saturation region and transistors that are fully OFF are said to be in their Cut-off region. When using the transistor as a switch, a small base current controls a much larger collector load current.

When using transistors to switch inductive loads such as relays and solenoids, a Flywheel Diode is used. When large currents or voltages need to be controlled, Darlington configuration can be used. Transistor switches can be used to switch and control lamps, relays or even motors. NPN transistor as a switch Here, RB resistor is used to control the current on base terminal that make transistor OFF and ON (saturate) and RC resistor is the current limiter for the load. if the load operate with the same voltage as the supplied power (Vcc), the resistor RC can be omitted. In the inductive load circuit, a diode (clamp diode) is connected across the inductive load to protect the transistor again the EMF voltage generated by the inductor component when the transistor is switched on and off rapidly, which is an opposing voltage to the source voltage. Here, the diode will act as a short circuit to the high voltage generated by the inductor component. Any diode which is capable of handling minimum 1 A of current can be used.

6. Working

The alternating current voltage (220 V) is stepped down to (12 V) using a suitable step down transformer. The stepped down AC voltage is rectified to direct current Voltage using a full wave rectifier. To obtain a constant ripple-free DC voltage, a capacitor filter is used across the circuit. In dark, the resistance of light dependent resistor is high. So, the voltage drop across the light dependent resistor is also high. Now the output of the NAND gate N1 is low since both the input signals are high, which makes the switch SW1 to remain open. And now the output from NAND gate N2 becomes high since both the input signals are low. The high output signal from the N2 terminal drives transistor to the saturation region, which makes the collector current IC very high. Finally, the high collector current flowing through the relay, diode, LED and resistor makes the LED glow. When a light of suitable intensity is incident on the light dependent resistor, the resistance decreases and the voltage drop across the light dependent resistor is low.

Now the output of the NAND gate N1 is high since one of the input signal is low and the other one is high, which makes the switch SW1 to close. And now the output from NAND gate N2 becomes low since both the input signals are high. The low output signal from the N2 terminal drives transistor to the cut-off region. In this case, the collector current is not high enough to make the LED glow, since other circuit elements such as relay, diode, LED and resistor are connected in parallel to each other. Thus, by toggling the transistor between cut-off region and saturation region it is possible to switch OFF or switch ON the LED. In this circuit, Darlington pair is employed to increase the collector current. Relay switch is connected in parallel to the LED to protect electrical circuits from overload. The extent of darkness or the intensity of light at which the light should switch ON or OFF can also be tuned by adjusting the potentiometer PR1. The capacitor C3 has been connected parallel to relay to avoid the relay from chattering during twilight threshold levels.

7. Uses of this project

By employing this circuit, energy consumption can be reduced considerably as the light switches ON or OFF automatically in appropriate time. Moreover, errors which occur due to manual operation also can be eliminated completely. The Automatic street light controller unit fabrication is cost-effective with good sensitivity and high reproducibility. Moreover, the construction of the circuit is also simple so that it can be done easily as it involves locally available components. The circuit is designed in such a way that the extent of darkness at which the light has to switch ON or OFF also can be tailored whenever it is needed. It can be used for other purposes like garden lighting, balcony lighting etc.,

8. Conclusion & Scope

Application 1:

The above circuit can be powered from a battery, which can be charged during day time by harvesting the solar energy through a solar cell as shown below:

Battery

Solar cell

Application 2:

The solar energy harvested from sunlight can be stored, inverted from DC voltage to AC voltage using sun tie converter. The AC voltage can be stepped up and given to the electric grid. Photovoltaic array

The AC voltage from the electric grid can be stepped down, rectified and used for powering the circuit. Meanwhile, the street light can also be powered by the A. C. voltage, which is controlled by a relay switch connected to the switching part of the circuit. The above mentioned strategy will enable us to harvest solar energy in an effective way for the operation of the circuit and for powering the street light also.

Solar Street light system with Automatic street light controller A Future perspective

9. Bibliography

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