Solar Piezoelectric System

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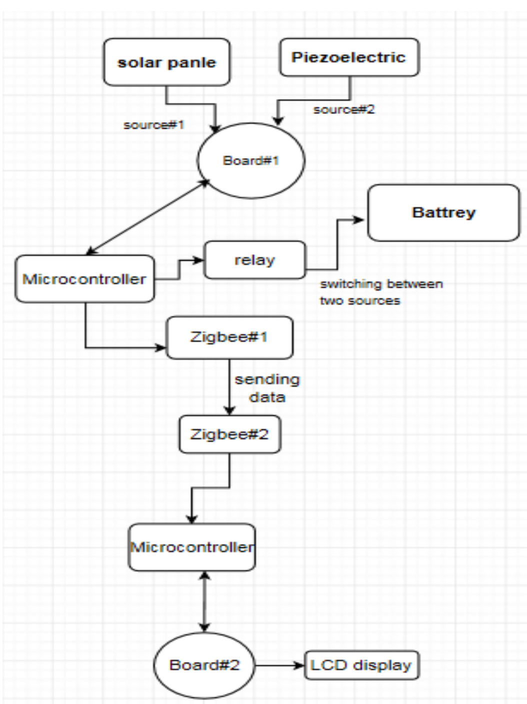
Abstract-- the Solar & Piezo Dual Charging project aims at charging a 12VDC Battery with the help of a Solar Panel and few piezoelectric transducers. With the help of Solar energy and footsteps on the transducer energy can be generated to charge the battery. The system smartly switches between these two energy sources and lets the battery to charge through the source which would provide adequate amount of power to charge the battery at any instant. A relay is used for the switching purpose. This power generating board is connected through wireless communication using Zigbee protocol to transfer charging information to another board that would monitor the process of charging. This board will have an LCD that will display the information related to charging to the user who wishes to monitor the charging process. Both side boards will have an ATmega family microcontroller for controlling purposes.

I. Introduction

HIS project is to advance the use of free energy. The solar Tpiezoelectric system is collecting two energy sources. The solar panel is connected on top of the piezoelectric. The energy is taken from the sun's rays through the solar panel and from the compression through the piezoelectric. Then we use a relay to switch between the two sources. Finally the energy is stored in a battery.

II. System Diagram



III. Main Equipment Requirements

A. *Hardware Requirements:*

- Piezo Sensor x 6
- 10W Solar Panel
- 12V Battery x 1
- 1000uF Capacitor x 1
- Atmega328 Microcontroller x 2
- Zigbee Module Pair x 1
- LCD

B. *Software Requirements:*

- MC Programming Language: C
- Arduino Compiler

IV. Solar Panel System

Solar panels are devices that convert light into electricity. They are called "solar" panels because most of the time, the most powerful source of light available is the Sun, called Sol

by astronomers. Some scientists call them photovoltaics which mean, basically, "light-electricity."

A solar panel is a collection of solar cells. Lots of small solar cells spread over a large area can work together to provide enough power to be useful. The more light that hits a cell, the more electricity it produces. So spacecraft are usually designed with solar panels that can always be pointed at the Sun even as the rest of the body of the spacecraft moves around, much as a tank turret can be aimed independently of where the tank is going.

A. *Solar Panel Specifications:*

- Related power: 10W
- Voc: 20.6V
- Vop: 17.3V
- Short circuit current (Isc): 0.69A
- Short circuit current (Isc): 0.69A
- Working current (Iop): 0.58A.
- Output Tolerance: ±3%
- Temperate coefficient of (Isc): (010+/-0.01)%/℃
- Temperate coefficient of Voc: - (0.38 +/-0.01)%/ ℃
- Temperate coefficient of power Voc: -0.47%/℃

- Temperature range: -40℃to +80℃
- Frame: Heavy duty aluminum
- Kind of connection: waterproof junction box, can be customized
- Guarantee of power: 90% within 10 years 80 within 25 years
- Kind of glass and its thickness: Low Iron, high transparency tempered glass of 3.2mm
- SLA Battery Voltage: 12V
- Dimensions: 13.2 x 8.1 x 0.7 inches

B. *Solar Overall Circuitry*

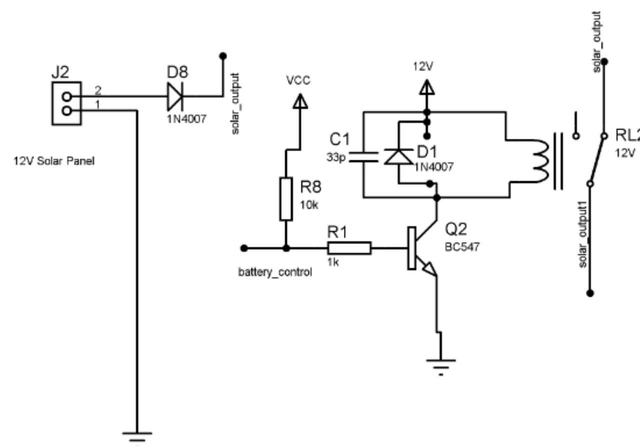


Figure 1 - Solar Circuit

This circuit diagram shows the connection of the solar system. J2 present the input of the solar panel where it produce 12 volts and attach a diode to make sure no current goes back to the source. Likewise, the battery control is connected to the microcontroller that switches the BJT and completes the path of the circuit through the diode. Then, the relay switches at 12 volts source. Since the capacitor that is parallel with the relay coil (C_1) has the potential difference of 12 volts, it will switch on.

V. Piezoelectric System

Piezoelectricity, also called the piezoelectric effect, is the ability of certain materials when subjected to mechanical stress or vibration generates an AC voltage. The most common piezoelectric material is quartz. Certain ceramics, Rochelle salts, and various other solids also exhibit this effect.

A piezoelectric transducer comprises a "crystal" sandwiched between two metal plates. When a sound wave strikes one or both of the plates, the plates vibrate. The crystal picks up this vibration, which it translates into a weak AC voltage. Therefore, an AC voltage arises between the two metal plates, with a waveform similar to that of the sound waves. Conversely, if an AC signal is applied to the plates, it causes the crystal to vibrate in sync with the signal voltage. As a result, the metal plates vibrate also, producing an acoustic disturbance.

A. *Piezoelectric Specifications:*

- Resonant frequency 4600 Hz
- Resonant impedance 250 Ohm
- Max input voltage 20 Vp-p
- Plate material Brass
- Operation temperature -20 ~ +70 C
- Storage temperature -30 ~ +80 C

B. *Piezoelectric Overall Circuitry*

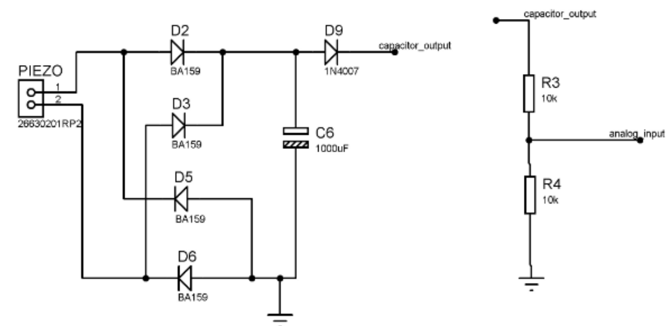


Figure 2 – Piezoelectric Circuit

From the figure above, the piezoelectric diagram starts with piezoelectric elements on the left of the diagram, connecting six piezoelectric in series to increase the input voltage. 1 and 2 present the input AC voltage that is coming from the piezoelectric. Since, the storage is DC, full wave rectifier is used. The energy generated from the piezoelectric cannot dump it in the battery directly because it generate small amount of energy. The solution of this issue is to use storage (C6 capacitor) that the potential difference of the storage is higher than the battery, so it can charge it. To insure that energy does not go back, a diode (D_9) is added.

Also, to measure the voltage inside the temporally storage, R_3 and R_4 presented as voltage sensor and it is connected to the microcontroller.

C. *Relay of Piezoelectric*

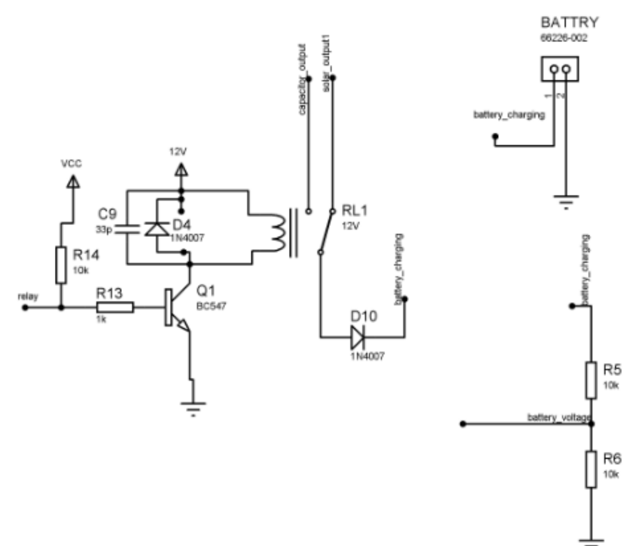


Figure 3 – Piezoelectric Relay

From figure 3, it shows the switching system of the piezoelectric. After the capacitor reaches 15 volts, the microcontroller read the voltage from the voltage sensor then sends the signal to switch the relay to the battery side and it takes 2 seconds. The capacitor discharged when the path is connected to the battery, where it transfers the energy from the capacitor to the battery. Also, the capacitor will be left with around 9 volts after discharging.

D. *AC/DC Convertor (Rectifier)*

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), current that flows in only one direction, a process known as rectification. The output from the transformer is fed to the rectifier. It converts A.C. into pulsating D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification. In positive half cycle only two diodes (1 set of parallel diodes) will conduct, in negative half cycle remaining two diodes will conduct and they will conduct only in forward bias only.

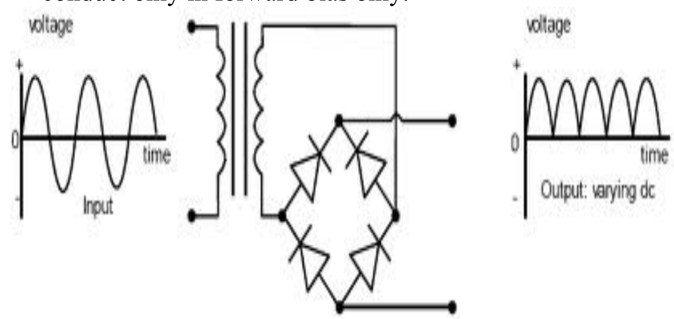


Figure 4 - Rectifier

E. *Filter and Temporary Storage*

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage.

The capacitor would store 15 V instead of transferring the energy to the battery.

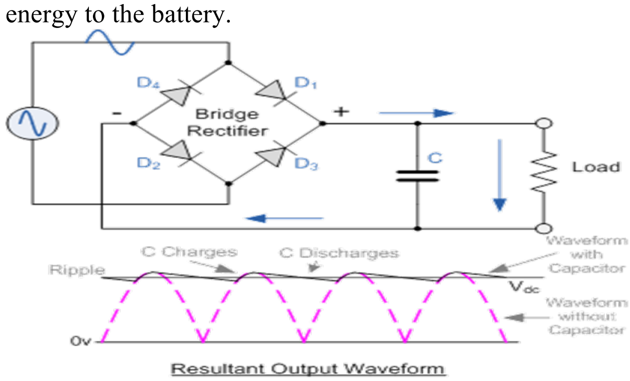


Figure 5 – Rectifier Output Waveform

VI. Wireless Communication

Wireless communication system is one of the requirements of this project. The basic idea of this part is to have two boards that are connected wirelessly to transmit data. Likewise, there are transmitter and receiver board, both boards have a Zigbee connected to an Atmega 328 microcontroller.

A. *Microcontroller*

The high-performance Atmel 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.

B. *The ATmega328 chip "Microcontroller brain"*

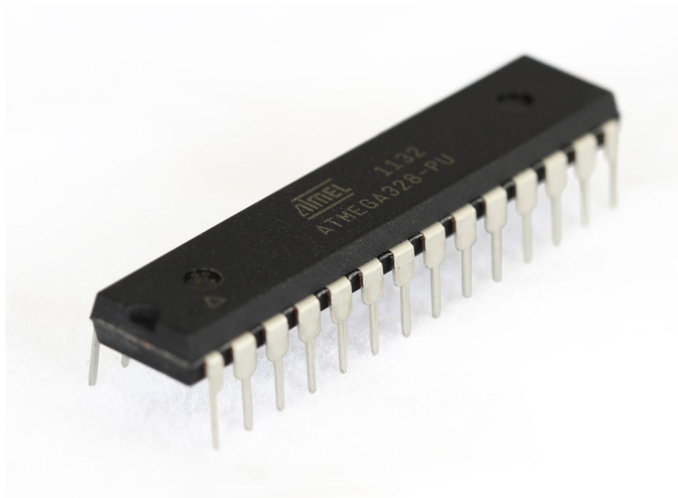


Figure 6 – Atmega 328 Chip

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C. *The ATmega328 Features:*

- Flash:32 KBytes
- EEPROM: 1 KBytes
- SRAM: 2 KBytes
- Max I/O Pins: 23
- Frequency Max: 20 MHz
- VCC: 1.8-5.5
- 10-bit A/D Channels: 6
- Analog Comparator: Yes
- 16-bit Timers: 1
- 8-bit Timer: 2
- Brown Out Detector: Yes
- Ext Interrupts: 2
- Hardware Multiplier: Yes

- Interrupts: 26
- ISP: Yes
- On Chip Oscillator: Yes
- PWM Channels: 6
- RTC: Yes
- Self Program Memory: Yes
- SPI: 1
- TWI: Yes
- UART: 1
- Watchdog: Yes
- Package: Lead Free PDIP 28

D. *Zigbee*

Figure 7 - Zigbee

Zigbee is used to transfer data between the transmitter and receiver PCBs.

ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power wireless M2M networks. The ZigBee standard operates on the IEEE 802.15.4 physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz.

The 802.15.4 specification upon which the ZigBee stack operates gained ratification by the Institute of Electrical and Electronics Engineers (IEEE) in 2003. The specification is a packet-based radio protocol intended for low-cost, battery-operated devices. The protocol allows devices to communicate in a variety of network topologies and can have battery life lasting several years.

E. *Zigbee Features:*

- 3.3V @ 40mA
- 250kbps Max data rate
- 2mW output (+3dBm)
- 400ft (120m) range
- Built-in antenna
- Fully FCC certified
- 6 10-bit ADC input pins
- 8 digital IO pins
- 128-bit encryption
- Local or over-air configuration
- AT or API command set

F. *Transmitter*

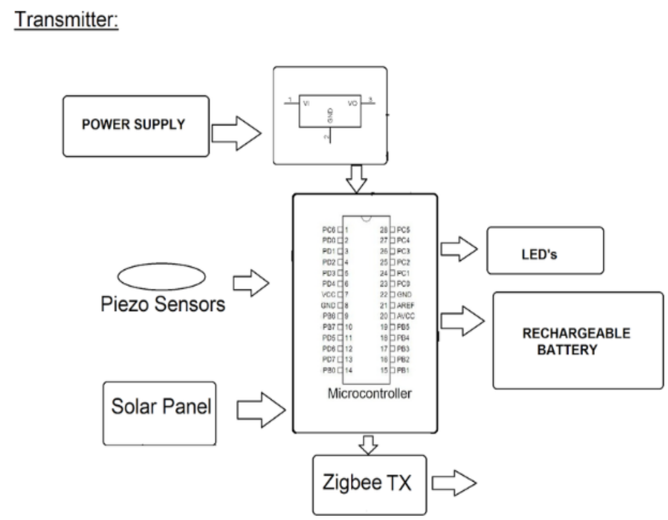

Figure 8 - Transmitter

The figure above shows the transmitter side of the wireless communication. The microcontroller reads the measurement form the capacitor and the battery. Then it will send it to the receiver side.

G. *Receiver*

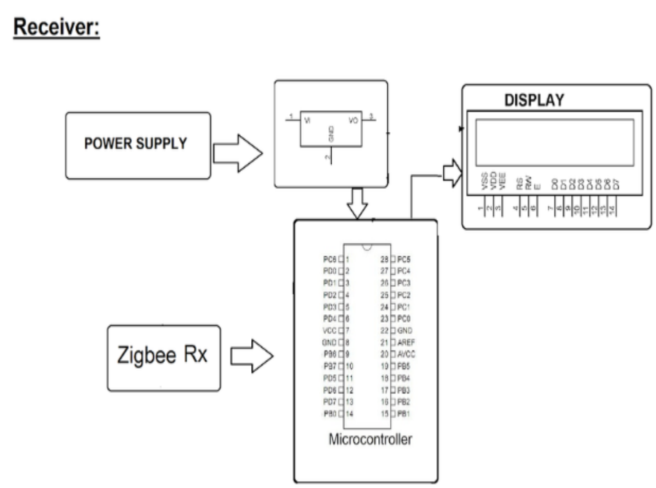

Figure 9 - Receiver

In the receiver side, the data is received by the Zigbee. The Zigbee sends the voltage reading to the LCD to be displayed.

H. *Push-button (Reset):*

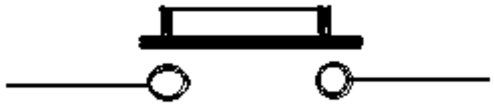

Figure 10 - Reset

A push-button or simply button is a simple switch mechanism for restarting the system. The push button is used in our project to reinitialize the system. Push buttons can be linked together by a mechanical linkage so that the act of pushing one button causes the other button to be released. In this way, a stop button can "force" a start button to be released. This method of linkage is used in simple manual operations in which the machine or process have no electrical circuits for control.

The source of the energy to illuminate the light (LED) is not directly tied to the contacts on the back of the pushbutton but to the action the pushbutton controls. In this way a start button when pushed will cause the process to be started and a secondary contact designed into the operation or process will close to turn on the pilot light and signify the action of pushing the button caused the resultant process or action to start.

VII. Storage

The lead acid battery was picked over the lithium battery because the lead acid is cheaper, safer, and good in high and low temperature.

Figure 11 – Battery

A. *Battery Specifications:*

- Model: EXP 1270
- Voltage 12V
- Amperage 7A

VIII. Board Power Supply

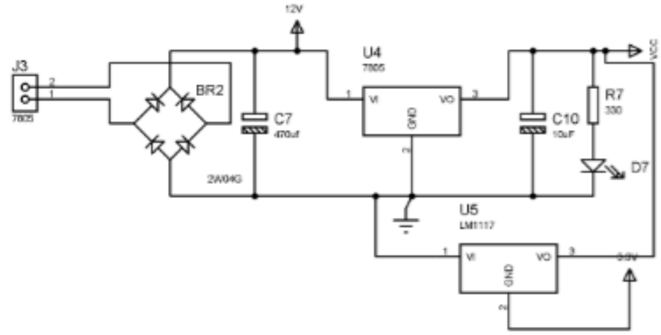

Figure 12 – Power Supply Circuit

The circuit uses standard power supply comprising of a step-down transformer from 230V to 12V and 4 diodes forming a bridge rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470µF to 1000µF. The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant at its pin no 3 irrespective of input DC varying from 7V to 15V. The input dc shall be varying in the event of input ac at 230volts section varies from 160V to 270V in the ratio of the transformer primary voltage V1 to secondary voltage V2 governed by the formula V1/V2=N1/N2. As N1/N2 i.e. no. of turns in the primary to the no. of turns in the secondary remains unchanged V2 is directly proportional to V1. Thus if the transformer delivers 12V at 220V input it will give 8.72V at 160V.Similarly at 270V it will give 14.72V. Thus the dc voltage at the input of the regulator changes from about 8V to 15V because of A.C voltage variation from 160V to 270V the regulator output will remain constant at 5V.
The regulated 5V DC is further filtered by a small electrolytic capacitor of 10µF for any noise so generated by the circuit. One LED is connected of this 5V point in series with a current limiting resistor of 330Ω to the ground i.e., negative voltage to indicate 5V power supply availability. The unregulated 12V point is used for other applications as and when required.

A. *Power Supply Voltage Regulator Features*

- Output Current up to 1A.
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V.
- Thermal Overload Protection.
- Short Circuit Protection.
- Output Transistor Safe Operating Area Protection.

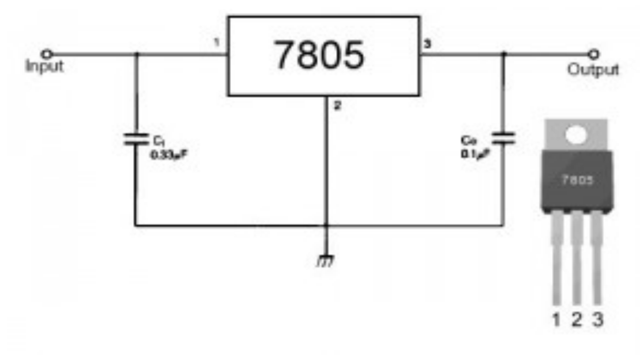

Figure 13 – Voltage Regulator

The LM78XX/LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

B. *Absolute Maximum Ratings*

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V) (for V_O = 24V)	V_I V_I	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range (KA78XX/A/R)	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Figure 14 – Ratings of the Voltage Regulator

C. *Internal Block Diagram*

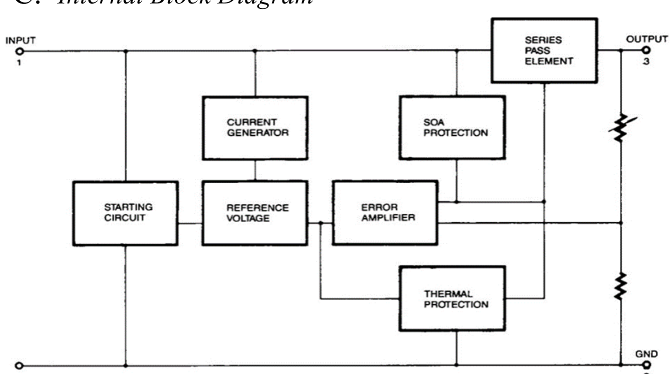

Figure 15 – Block Diagram of Voltage Regulator

D. *LED*

The LED is used in this project to indicate the system is on.

Light Emitting Diodes (LED) the 5 mm cylindrical package is the most common, estimated at 80% of world production. The color of the plastic lens is often the same as the actual color of light emitted, but not always. For instance, purple plastic is often used for infrared LEDs, and most blue devices have clear housings. There are one LED on both PCBs (D7 and D1), where they used to light if the PCB is powered.

IX. Extra Components

- Transistor

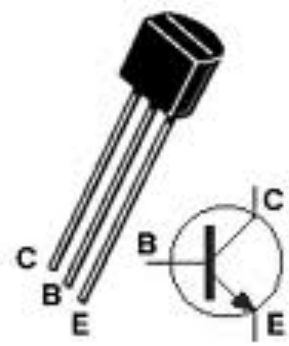

Figure 16 – BC 547 Transistor Pinouts

The BC547 transistor is an NPN Epitaxial Silicon Transistor. The BC547 transistor is a general-purpose transistor in small plastic packages. It is used in general-purpose switching and amplification BC847/BC547 series 45 V, 100 mA NPN general-purpose transistors.

There are two transistors on the transmitter PCB operating on the relay systems whenever base is high (a signal sent from the microcontroller), then current starts flowing through base and emitter and after that only current will pass from collector to emitter. So that the relay which is connected to collector will switch indicating that transistor is ON.

- Diode “1N4007”

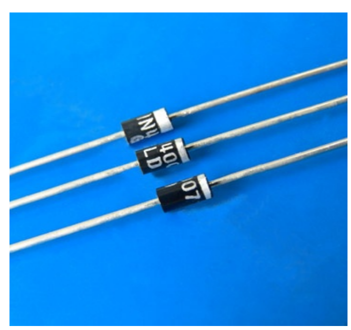

Figure 17 - N4007 diodes

In this project diodes (1N4007) are used in different systems to convert AC into DC which they are used as full wave rectifier, such as in the Piezoelectric harvesting circuit and power supply circuit. Also, it is used to prevent current flow in both directions such as, in the charger controller the diode used to prevent energy to leave the battery.

X. Testing and Results

A. *Solar*

The solar panel testing was measured in three different conditions as shown below. The solar panel was first exposed to the sunlight and we got a maximum voltage. Then half of the solar panel is covered by hand. Finally, the solar panel was measured under a complete shadow.

Conditions	V(DC) Volt	A(Amps)
Max (under sun light)	21.44	0.268
One panel (half shaded)	17.34	0.0074
Under the shade	15.87	0.019

Figure 18 – Solar Measurements

B. *Piezoelectric*

The piezoelectric system was used to charge the capacitor to 15V. The microcontroller's main function is to get the voltage to 15V and then switch the relay to the battery to discharge. The maximum voltage transferred was 12V and the current was 6mA.

C. PCB Hardware Testing

- Continuity test:

  In electronics, a continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".

  Devices that can be used to perform continuity tests include multi meters which measure current and specialized continuity testers which are cheaper, more basic devices, generally with a simple light bulb that lights up when current flows.

  An important application is the continuity test of a bundle of wires so as to find the two ends belonging to a particular one of these wires; there will be a negligible resistance between the "right" ends, and only between the "right" ends.

  This test is the performed just after the hardware soldering and configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering. Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation, then you will hear the beep sound.

- Power on test:

  This test is performed to check whether the voltage at different terminals is according to the requirement or not. We take a multi meter and put it in voltage mode. Remember that this test is performed without microcontroller. Firstly, we check the output of the transformer, whether we get the required 12 V AC voltage.

  Then we apply this voltage to the power supply circuit. Note that we do this test without microcontroller because if there is any excessive voltage, this may lead to damaging the controller. We check for the input to the voltage regulator i.e., are we getting an input of 12v and an output of 5v. This 5v output is given to the microcontrollers' 40th pin. Hence we check for the voltage level at 40th pin. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals is as per the requirement.

XI. Prototype

Six piezoelectric sensors are placed in series under squared hard plastic. Each sensor has foam placed underneath so it gives it more protection from breaking and it also gives more deflection. This way of assembly is to generate more voltage. The Printed Circuit Boards are more efficient as they require no wires. An LED has been placed on the PCB to give a sign of whether or not the board is functioning.

XII. Conclusion

The purpose of this project was to establish the feasibility of a roadside hybrid energy collection/recovery system that can then be used for running nearby street utilities such as lights/signals. The hybrid sources are solar energy (harvested by a commercially available solar cell located next to roadway) and piezoelectric energy (harvested by an array of piezoelectric elements next to the roadway). Each of these systems had its own component level controller. A practical ratio of cost-effective energy recovery from these two sources had been sought in the design of the supervisor controller. It should be possible to monitor system performance via a wireless display located a safe distance from the energy harvesting equipment.

The advantage of this project is that it's environmental friendly. The current roads can be replaced by solar piezoelectric panels to make the roads behave as power generators.

This project can be advanced by making the surfaces of the piezoelectric and the solar panels hard enough for the cars to drive on. The piezoelectric sensors can be attached underneath the solar panel. This way of connection generates more voltage by the piezoelectric.

XIII. References

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