COST EFFECTIVE NEUTRON COUNTER PLATFORM FOR SOIL MOISTURE ESTIMATION

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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(UGC AUTONOMOUS)
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Sangivalasa, bheemili mandal, visakhapatnam dist.(A.P)

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CERTIFICATE

This is to certify that the project report entitled **"COST EFFECTIVE NEUTRON COUNTER PLATFORM FOR SOIL MOISTURE ESTIMATION"** submitted by **Mr.N.YASWANTH (319126512103), Mr.NASEER SHAIK (319126512040), Mr.K.RAKESH (319126512047), Mr.V.B. LAL MEHAR (320126512L02)** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.

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Project Guide

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ABSTRACT

Water is increasingly becoming a scarce resource. Accurate Soil Moisture (SM) sensing over intermediate geographical scales plays a critical role in efficient use of water for sustainable Agriculture. Recently, the technique of Cosmic Ray Neutron Sensing (CRNS) has emerged as a viable solution. However, the technique has not found widespread use due to high cost of gas filled conventional neutron detectors.

Moreover, the detector is bulky and is prone to damage from mechanical shocks. There is a need to design inexpensive, portable, lightweight and operator friendly neutron counters for large scale deployment of CRNS SM sensors to implement sustainable agriculture. The neutron counter design in the present work is based on the use of low cost semiconductor neutron detectors used in conjunction with a single chip reconfigurable PSoC platform. Neutron detection requires various functions like generation and regulation of high voltage, signal conditioning, pulse discrimination, digital counting, and data communication.

Since, the cost of Neutron counter systems critically hinges on the type of detector used and the level of integration of above functions, the current design with semiconductor detectors and the versatile PSoC platform achieves the required cost effectiveness for the given functionality.

Keywords— Cosmic Ray Neutron Sensing, SM Sensors, Gas filled Detector, PSoC.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Cosmic ray neutron sensors using PIN diodes are widely used in atmospheric and environmental research to detect and measure the flux of neutrons produced by cosmic rays interacting with atmospheric gases. These sensors are based on the principle of ionization, where a neutron entering the detector collides with a nucleus, producing a cascade of charged particles that ionize the semiconductor material in the PIN diode.

The resulting charge is then collected by the electrodes in the diode, generating a current that is proportional to the neutron flux. One of the key advantages of cosmic ray neutron sensors using PIN diodes is their high sensitivity, which allows for accurate measurements even at very low neutron fluxes. They also have a fast response time and low power consumption, making them well-suited for use in remote or inaccessible locations.

The use of cosmic ray neutron sensors has become increasingly important in recent years, as researchers seek to better understand the interactions between cosmic rays, atmospheric gases, and the Earth's surface. These sensors are used in a wide range of applications, including soil moisture measurement, radiation dosimetry, and atmospheric monitoring.

In this project we will explore the theory and application of cosmic ray neutron sensors using PIN diodes. We will describe the materials and methods used in our experiment, present and interpret the results, and discuss the potential impact of this research for atmospheric and environmental monitoring.

1.2 Cost Effective Neutron Sensor

A cost-effective neutron sensor with PIN diode can be achieved by optimizing the design and materials used in the sensor. Some of the key factors that can contribute to the cost-effectiveness of a neutron sensor with PIN diode include:

- **Neutron converter layer:** The neutron converter layer is an essential component of the neutron sensor, and its choice can affect the sensor's sensitivity, energy response, and cost. Materials such as boron or lithium are commonly used as neutron converters, and they offer a good balance between cost and performance.
- **PIN diode:** The PIN diode is the radiation detector in the neutron sensor, and its selection can impact the sensor's sensitivity and noise performance. PIN diodes made of standard silicon are cost-effective and widely available, and they offer good sensitivity and noise performance for most neutron detection applications.
- **Signal processing electronics**: The signal processing electronics used in the neutron sensor can affect the system's noise performance, dynamic range, and power consumption. Simple signal conditioning circuits and low-noise amplifiers can help reduce the cost and power consumption of the system while maintaining good performance.
- **Neutron shielding:** Neutron shielding is necessary to reduce the background radiation that can interfere with the neutron detection signal. Cost-effective materials such as borated polyethylene or concrete can be used for shielding, while still providing good attenuation of the background radiation.
- **Size and weight:** The size and weight of the neutron sensor can impact the installation and transportation costs, as well as the power consumption of the system.

A compact and lightweight design can reduce these costs, while still providing good sensitivity and performance.

Overall, a cost-effective neutron sensor with PIN diode can be achieved by carefully selecting the materials, design, and signal processing electronics used in the sensor. By optimizing these factors, it is possible to achieve a balance between performance and cost, making the neutron sensor an affordable solution for various neutron detection applications.

1.2.1 Conditions for Cost Effective Neutron Sensor

There are several conditions that can make a neutron sensor cost-effective, including:

- **High sensitivity:** A highly sensitive neutron sensor can detect low levels of neutron radiation, reducing the need for expensive and complex detection systems.
- **Low power consumption:** A neutron sensor with low power consumption can reduce the operating costs associated with the sensor, making it more cost-effective in the long run.
- **Compact design:** A compact neutron sensor can reduce the size and weight of the detection system, which can lower transportation and installation costs.
- **Wide dynamic range:** A neutron sensor with a wide dynamic range can accurately detect both high and low levels of neutron radiation, reducing the need for multiple sensors or complex signal processing systems.
- **Low maintenance:** A neutron sensor with low maintenance requirements can reduce the cost and frequency of servicing, making it more cost-effective in the long run.

- **Minimal background interference:** A neutron sensor that is designed to minimize interference from background radiation can improve the accuracy and reliability of the measurements, reducing the need for costly calibration and correction procedures.

- **Use of cost-effective materials:** The use of cost-effective materials, such as standard silicon or plastic scintillators, can reduce the cost of the neutron sensor without compromising its performance.

1.2.2 Advantages of Cost Effective Neutron Sensor

PIN diodes are commonly used for detecting cosmic ray neutrons due to their unique advantages over other types of detectors. Here are some advantages and limitations of using PIN diodes for cosmic ray neutron detection.

Advantages:

- **High Sensitivity:** PIN diodes have a high neutron detection efficiency, which means they can detect even very low neutron fluxes with high accuracy.

- **Fast Response Time:** The fast response time of PIN diodes allows for real-time measurements of neutron fluxes.

- **Low Power Consumption**: PIN diodes require very low power to operate, making them ideal for use in remote or inaccessible locations.

- **Low Noise:** PIN diodes produce low electronic noise, which makes it easier to detect small signals. Simple Operation: The operation of PIN diodes is relatively simple and requires minimal setup, which reduces the potential for experimental error.

1.2.3 Drawbacks

- **Directional Sensitivity:** PIN diodes are sensitive to neutrons coming from a specific direction, which means that they may not be suitable for detecting neutrons that come from all directions. Temperature Sensitivity: The performance of PIN diodes is sensitive to temperature changes, which can affect the accuracy of the measurements.

- **Radiation Damage:** Prolonged exposure to high levels of radiation can damage the PIN diode, leading to reduced sensitivity and accuracy.

- **Crosstalk:** The signal produced by the PIN diode can be affected by other types of radiation or background noise, which can lead to false measurements.

Despite these limitations, the use of PIN diodes for cosmic ray neutron detection remains popular due to their high sensitivity, fast response time, and low power consumption. Ongoing research and development continue to address the limitations of PIN diodes and improve their performance in neutron detection.

1.2.4 Installation and/ Setup

The installation and setup of a cost-effective neutron sensor with PIN diode will depend on the specific application and the design of the sensor. However, there are some general steps that can be followed to ensure a successful installation and setup process:

- **Determine the mounting location:** The neutron sensor should be installed in a location where it can detect neutron radiation without interference from background radiation. The mounting location should also be accessible for maintenance and calibration.

- **Prepare the mounting surface:** The mounting surface should be clean and flat, with no sharp edges that could damage the sensor. The surface should also be able to support the weight of the sensor and any associated mounting hardware.

- **Install the neutron sensor:** The neutron sensor should be installed using the recommended mounting hardware, which may include screws, brackets, or adhesive. The sensor should be securely mounted and oriented to optimize neutron detection.

- **Connect the signal cables:** The signal cables from the neutron sensor should be connected to the signal processing electronics. Care should be taken to ensure proper grounding and shielding of the cables to minimize noise and interference.

- **Calibrate the sensor:** The neutron sensor should be calibrated using a neutron source of known strength and energy. The calibration procedure will depend on the specific sensor design and may involve adjusting the signal processing electronics or applying correction factors.

- **Test the system:** Once the neutron sensor is installed and calibrated, the system should be tested to ensure that it is detecting neutron radiation accurately and reliably. The testing procedure will depend on the specific application and may involve exposing the sensor to a range of neutron radiation levels.

- **Maintain the system:** Regular maintenance and calibration are essential to ensure that the neutron sensor continues to operate accurately and reliably. The maintenance procedures will depend on the specific sensor design and may involve cleaning the sensor, checking the signal processing electronics, and recalibrating the system as necessary.

Overall, the installation and setup of a cost-effective neutron sensor with PIN diode requires careful attention to detail and proper calibration and testing to ensure accurate and reliable performance.

1.2.5 Maintenance

Regular maintenance is essential for ensuring the reliable and accurate performance of a cost-effective neutron sensor with PIN diode. Here are some maintenance activities that should be performed:

- **Cleaning the sensor surface:** The sensor surface should be cleaned regularly to remove any dust, debris, or other contaminants that may interfere with the neutron detection. Cleaning can be done using a soft, lint-free cloth or brush and a mild detergent solution. Care should be taken not to damage the sensor surface or the wiring.

- **Checking the wiring connections:** The wiring connections between the sensor and the signal processing electronics should be checked regularly to ensure that they are tight and secure. Loose connections can cause signal loss or noise and can lead to inaccurate measurements.

- **Checking the signal processing electronics:** The signal processing electronics should be checked regularly to ensure that they are operating correctly. This can be done using a calibration source or by checking the output signal using a digital multimeter or oscilloscope.

- **Recalibrating the system:** The neutron sensor should be recalibrated periodically to ensure that it continues to provide accurate and reliable measurements. The calibration frequency will depend on the specific application and may range from monthly to annually.

- **Checking for damage:** The neutron sensor and associated electronics should be checked for any physical damage, such as cracks or corrosion, that may affect the performance. Any damaged components should be repaired or replaced as necessary.

- **Storage:** The neutron sensor should be stored in a dry, cool, and clean environment when not in use. Exposure to high temperatures or humidity can damage the sensor and degrade the performance. Overall, the maintenance of a cost-effective neutron sensor with PIN diode requires regular cleaning, checking of wiring connections and signal processing electronics, recalibration, and careful storage to ensure reliable and accurate performance over time.

1.2.6 Tips for Successful Cost Effective Neutron Sensor

- **Choose the right neutron converter material:** The choice of neutron converter material is critical for achieving optimal sensitivity and energy response. Be sure to select a material that is well-suited for the application and neutron energy range of interest.

- **Optimize the detector geometry:** The detector geometry, including the thickness of the neutron converter layer and the size of the active detector area, can have a significant impact on the sensitivity and performance of the neutron sensor. Experiment with different geometries to find the optimal design for your application.

- **Use high-quality signal processing electronics:** The quality and performance of the signal processing electronics can greatly impact the sensitivity and accuracy of the neutron sensor. Choose high-quality components and ensure that they are properly configured and calibrated.

- **Regularly calibrate the system:** Regular calibration of the neutron sensor is essential for maintaining accurate and reliable measurements. Use a reliable calibration source and follow the recommended calibration procedure.

- **Protect the sensor from environmental factors:** Environmental factors such as temperature, humidity, and radiation can affect the performance of the neutron sensor. Protect the sensor from these factors by using appropriate shielding and environmental controls.

- **Minimize background noise:** Minimizing background noise is essential for achieving optimal sensitivity and accuracy. Use appropriate shielding and noise reduction techniques to reduce the impact of background noise on the sensor output.

- **Follow proper maintenance procedures:** Regular maintenance, including cleaning, checking wiring connections and signal processing electronics, recalibration, and careful storage, is essential for ensuring the reliable and accurate performance of the neutron sensor over time.

1.3 Comparison to other Methods

- **Scintillation detectors:** Scintillation detectors use a material that emits light when struck by neutrons to detect neutrons. They can detect a wide range of neutron energies, but are typically more expensive than PIN diode detectors.

- **Gas proportional detectors:** Gas proportional detectors use a gas-filled chamber to detect neutrons. They are highly sensitive and can detect both thermal and fast neutrons, but are typically more expensive and require a high-voltage power supply.

- **Solid-state detectors**: Solid-state detectors, such as silicon detectors, can detect neutrons using the recoil nucleus produced when a neutron collides with a nucleus in the detector. They are highly sensitive and can detect a wide range of neutron energies, but are typically more expensive than PIN diode detectors.

Compared to these other methods, cost-effective neutron sensors with PIN diodes offer several advantages:

- **Low cost:** PIN diode detectors are relatively inexpensive compared to other neutron detection methods.
- **Compact size:** PIN diode detectors are compact and lightweight, making them easy to use and transport.
- **High sensitivity:** PIN diode detectors are highly sensitive and can detect thermal and fast neutrons.
- **Low power consumption:** PIN diode detectors require minimal power, making them ideal for portable and battery-powered applications.However, compared to some other methods, such as gas proportional detectors and scintillation detectors, PIN diode detectors have a lower efficiency for detecting neutrons. This means that they may require longer measurement times or larger detector sizes to achieve the same level of sensitivity as these other methods. Additionally, PIN diode detectors may be more susceptible to noise and interference from background radiation, which can reduce their sensitivity and accuracy.

CHAPTER 2

HARDWARE REQUIRED

2.1 COMPONENTS REQUIRED

- Cockroft-Walton Voltage Multiplier
- PIN diode
- A Low Noise CMOS Charge-Sensitive Preamplifier
- Power Bank Circuit
- Americum 241
- HDPE board
- RF Coaxial Coax Adapter Sma Male To Bnc Cable

2.2 Cockroft-Walton Voltage Multiplier:

2.2.1 About Cockroft-Walton Voltage Multiplier:

The Cockroft-Walton voltage multiplier is an electronic circuit that can be used to generate high DC voltages from a low AC input voltage. It was first developed in the 1930s by John Cockroft and Ernest Walton, who used it to generate high voltage for particle accelerators. The Cockroft-Walton voltage multiplier is a type of voltage multiplier circuit that uses a series of capacitors and diodes to multiply the input voltage.

The circuit works by charging capacitors in parallel with the input voltage during the positive half-cycle of the AC input, and then discharging them in series during the negative half-cycle. This results in a DC output voltage that is a multiple of the input voltage. The basic Cockroft-Walton voltage multiplier circuit consists of a series of stages, each consisting of a diode and a capacitor.

The diodes are arranged in a ladder-like configuration, with the anodes of each diode connected to a capacitor and the cathodes of the diodes connected to each other. The output voltage is taken from the top of the ladder, where the highest voltage is developed. The output voltage of a Cockroft-Walton voltage multiplier can be calculated using the formula:

Vout = n * Vin * sqrt(2) Where Vout is the output voltage, Vin is the input voltage, and n is the number of stages in the voltage multiplier. The Cockroft-Walton voltage multiplier has several advantages, including its simplicity, low cost, and high voltage output.

It is commonly used in applications such as particle accelerators, X-ray generators, and high voltage power supplies. However, the Cockroft-Walton voltage multiplier also has some limitations. It is not very efficient, as some of the input power is lost in charging and discharging the capacitors. Additionally, the voltage multiplier can be prone to breakdown and arcing, which can damage the diodes and capacitors. To address these issues, modern voltage multiplier circuits may include additional components such as resistors, inductors, and voltage regulators.

2.2.2 Schematic diagram

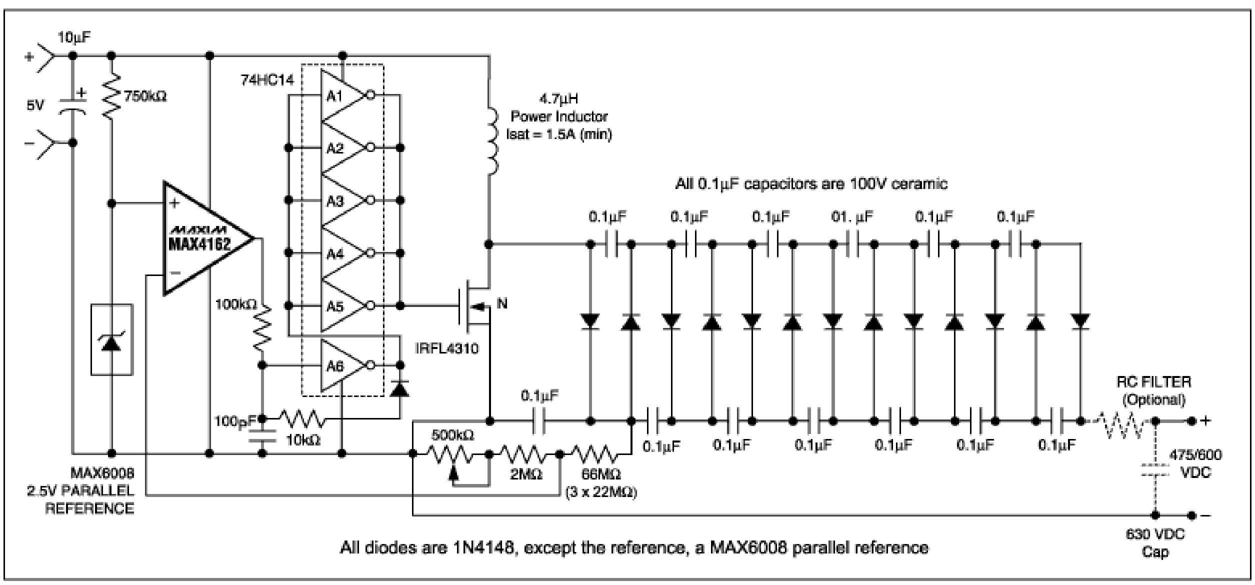


Fig 2.1- Cockroft-Walton voltage multiplier circuit

2.2.3 Power Requirement

The power requirements for a Cockroft-Walton voltage multiplier depend on several factors, including the number of stages in the voltage multiplier, the input voltage, and the output voltage.

The input power required for a Cockroft-Walton voltage multiplier can be calculated using the formula: Pin = Iin * Vin Where Pin is the input power, Iin is the input current, and Vin is the input voltage. The input current for a Cockroft-Walton voltage multiplier is determined by the charging current for the capacitors in each stage. The charging current is determined by the capacitance of the capacitors and the frequency of the input AC voltage.

The higher the capacitance and frequency, the higher the charging current. The output power of a Cockroft-Walton voltage multiplier can be calculated using the formula: Pout = Iout * Vout Where Pout is the output power, Iout is the output current, and Vout is the output voltage. The output current for a Cockroft-Walton voltage multiplier is determined by the load connected to the output. The load can be a resistive load, such as a high-voltage capacitor or an ionization chamber, or a reactive load, such as a particle accelerator or X-ray generator. The higher the load, the higher the output current

2.2.4 Working of Cockroft-Walton Voltage Multiplier

- The Cockroft-Walton voltage multiplier is a type of voltage multiplier circuit that uses capacitors and diodes to produce high DC voltages from a low AC input voltage. The circuit is named after its inventors, John Cockroft and Ernest Walton, who first developed it in the 1930s for use in particle accelerators.

- The basic working of the Cockroft-Walton voltage multiplier can be explained as follows:

- The circuit consists of a series of stages, each consisting of a capacitor and a diode. The diodes are arranged in a ladder-like configuration, with each stage adding the voltage of the previous stage to the output voltage.

- Initially, the capacitors in each stage are uncharged, and the AC input voltage is applied to the first stage.

- During the positive half-cycle of the AC input voltage, the first capacitor charges to the peak voltage of the AC input voltage. The diode connected to the capacitor conducts, allowing the capacitor to charge to the voltage of the previous stage. At the same time, the diode connected to the previous stage blocks the flow of current, preventing the charge from discharging.

- During the negative half-cycle of the AC input voltage, the first capacitor discharges through the second diode, which conducts in the reverse direction. The second capacitor then charges to twice the voltage of the first stage, as the voltage of the first capacitor is added to the voltage of the AC input voltage. The process continues for each subsequent stage.
- The output voltage is taken across the last capacitor in the ladder, which can reach several times the peak voltage of the AC input voltage.

- Overall, the Cockroft-Walton voltage multiplier is a simple and effective way to generate high DC voltages from low AC input voltages. It is commonly used in particle accelerators, X-ray generators, and other high-voltage applications.

2.2.5 Cockroft-Walton Voltage Multiplier Specifications & Features:

The specifications and features of a Cockroft-Walton voltage multiplier can vary depending on the specific application and design. However, some common specifications and features of a typical Cockroft-Walton voltage multiplier include:

- **Voltage multiplication factor:** The Cockroft-Walton voltage multiplier can multiply the input voltage by a factor of n, where n is the number of stages in the voltage multiplier.

- **Output voltage range:** The output voltage of a Cockroft-Walton voltage multiplier can range from a few kilovolts to several megavolts, depending on the number of stages and the input voltage.

- **Input voltage range:** The input voltage of a Cockroft-Walton voltage multiplier is typically in the range of a few hundred volts to a few kilovolts AC.

- **Output current range:** The output current of a Cockroft-Walton voltage multiplier can range from a few microamps to several amps, depending on the load and the design of the voltage multiplier.

- **Efficiency:** The efficiency of a Cockroft-Walton voltage multiplier can vary depending on the number of stages, the input voltage, and the load. Typically, the efficiency of a voltage multiplier is in the range of 50-80%, with the remaining power lost as heat.

- **Ripple voltage:** The output voltage of a Cockroft-Walton voltage multiplier may have some ripple due to the charging and discharging of the capacitors. The amount of ripple depends on the frequency of the input voltage and the capacitance of the capacitors.

- **Breakdown voltage:** The Cockroft-Walton voltage multiplier is designed to withstand high voltages, but there is always a risk of breakdown or arcing, especially at high voltages. The breakdown voltage depends on the dielectric strength of the capacitors and the breakdown voltage of the diodes.

- **Size and weight:** The size and weight of a Cockroft-Walton voltage multiplier depend on the number of stages and the power rating. Typically, a voltage multiplier with more stages and higher power rating will be larger and heavier.

- **Safety features**: The Cockroft-Walton voltage multiplier may include safety features such as overcurrent protection, overvoltage protection, and grounding to ensure safe operation and prevent damage to the components.

2.2.6 Applications of Cockroft-Walton Voltage Multiplier

- **Particle accelerators**: Cockroft-Walton voltage multipliers are commonly used in particle accelerators to generate high voltage pulses for accelerating charged particles.

- **X-ray generators**: Cockroft-Walton voltage multipliers are used in X-ray generators to produce high voltages required for ionization of the gas in the X-ray tube.

- **Nuclear physics research**: Cockroft-Walton voltage multipliers are used in nuclear physics research to generate high voltage pulses for ionizing and accelerating atomic particles.

- **Mass spectrometry**: Cockroft-Walton voltage multipliers are used in mass spectrometers to ionize and accelerate particles for analysis.

- **Electrostatic precipitators**: Cockroft-Walton voltage multipliers are used in industrial electrostatic precipitators to generate high voltage for removing particulate matter from the air.

- **Nuclear medicine:** Cockroft-Walton voltage multipliers are used in nuclear medicine for the production of radiopharmaceuticals.

- **High voltage testing:** Cockroft-Walton voltage multipliers are used in high voltage testing of equipment and systems, such as power cables and transformers.

- **High voltage power supplies:** Cockroft-Walton voltage multipliers are used in high voltage power supplies for applications such as electrostatic painting, electrostatic printing, and electrostatic flocking.

2.3 PIN DIODE

2.3.1 About PIN DIODE

- A PIN diode is a type of diode that is commonly used in electronic circuits for various applications such as RF switches, attenuators, and detectors. The name PIN diode is derived from its structure, which consists of three layers: a P-type semiconductor layer, an intrinsic (I) layer, and an N-type semiconductor layer.

- The intrinsic layer is a very lightly doped layer, which makes the PIN diode a high-resistance device. This makes the PIN diode an excellent choice for applications where high resistance is required, such as in RF attenuators.

- The PIN diode also has a larger junction area than a standard PN diode, which makes it capable of handling larger power levels and reduces its noise level. The PIN diode is a type of variable resistor, where its resistance can be controlled by varying the DC bias voltage applied across the diode.

- When no bias voltage is applied, the PIN diode acts as an open circuit. When a forward bias voltage is applied, the PIN diode behaves like a standard diode, allowing current to flow in the forward direction.

- When a reverse bias voltage is applied, the depletion region widens, and the PIN diode becomes highly resistive, allowing only a small leakage current to flow.

Fig 2.2- PIN Diode

2.3.2 Working of PINdiode

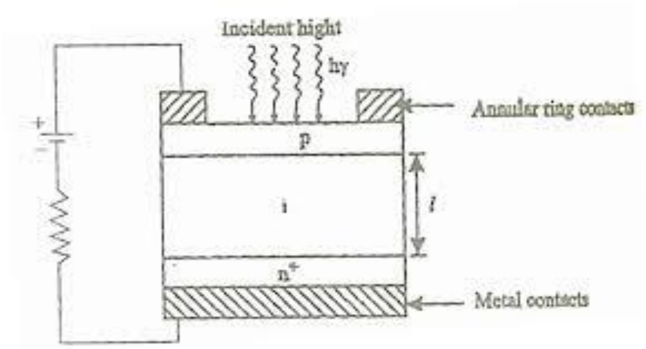


Fig 2.3- Working of PIN Diode

The PIN diode detector used in cosmic ray neutron sensors is a type of semiconductor detector that is based on the principle of ionization. It consists of a thin layer of intrinsic (i-type) semiconductor material sandwiched between heavily doped p type and n-type semiconductor layers.

The p-type and n-type layers act as electrodes that collect the charge generated by the ionization of the intrinsic layer. When a neutron enters the detector, it collides with an atomic nucleus, producing a cascade of charged particles that ionize the intrinsic layer. The resulting charge is then collected by the p-type and n-type electrodes, generating a current that is proportional to the neutron flux.The intrinsic layer in the PIN diode detector is typically made of high-purity silicon, which has a high cross- section for neutron capture and produces a large number of charged particles upon interaction with a neutron.

To improve the directional sensitivity of the detector, it is often coupled with a moderator or shield that is designed to selectively attenuate neutrons from certain directions. The moderator or shield can be made of materials such as polyethylene, paraffin, or boron, depending on the desired energy range of the neutrons being detected. In summary, the PIN diode detector used in cosmic ray neutron sensors is a highly sensitive and efficient neutron detector that is based on the principle of ionization in a semiconductor material. It is often coupled with a directional shield or moderator to improve its directional sensitivity and reduce background noise.

2.3.3 Design Considerations

- **Frequency range:** PIN diodes are commonly used in RF and microwave circuits, so it's important to choose a diode with a frequency range that matches the intended application. Higher frequency circuits require diodes with lower parasitic capacitance and inductance.

- **Power handling:** The maximum power that a PIN diode can handle without damage depends on its size, design, and materials. It's important to choose a PIN diode that can handle the expected power levels in the circuit to avoid damage or failure.

- **Temperature stability:** The performance of PIN diodes can be affected by temperature changes, so it's important to choose a diode with good temperature stability or to incorporate temperature compensation in the circuit design.

- **Biasing:** PIN diodes can be biased in both the forward and reverse directions to control their resistance and capacitance. The choice of biasing direction depends on the intended application and the desired level of attenuation or switching speed.

- **Circuit configuration:** The performance of a PIN diode is influenced by the surrounding circuit components, such as matching networks, transmission lines, and biasing circuits. It's important to carefully design the circuit layout and choose appropriate components to optimize the diode's performance.

- **Reverse recovery time:** The reverse recovery time of a PIN diode is the time it takes for the diode to recover its blocking state after the reverse bias voltage is removed. A shorter reverse recovery time is generally desirable for high-speed switching applications.

- **Package type:** The package type of a PIN diode can affect its performance, particularly at higher frequencies. Surface-mount packages are commonly used in high-frequency applications, while through-hole packages are often used in lower-frequency circuits.

2.3.4 Performance Specfications of PIN diode

- Forward current (If): Up to 1 A
- Reverse voltage (Vr): Up to 200 V
- Reverse current (Ir): Up to 10 µA
- Breakdown voltage (VBR): Typically between 50 and 200 V
- Resistance (Rd): Typically between 1 and 100 Ω
- Capacitance (Cd): Typically between 1 and 100 pF
- Reverse recovery time (trr): Typically between 10 and 100 ns
- Power handling capacity: Up to several watts

2.3.5 Applications of PIN DIODE

PIN diodes have a wide range of applications in electronics and telecommunications. Some common applications of PIN diodes include:

- **RF Switches:** PIN diodes are commonly used as RF switches in wireless communication systems. Their fast switching speed and low insertion loss make them ideal for use in applications such as cell phone base stations, satellite communications, and radar systems.

- **Attenuators:** PIN diodes can also be used as variable attenuators in RF and microwave circuits. By varying the bias voltage applied to the diode, its resistance and capacitance can be controlled to adjust the attenuation level.

- **Photodetectors:** PIN diodes can be used as photodetectors in fiber optic communication systems. When light is incident on the diode, it generates a current that can be detected and used to transmit data.

- **RF Limiters:** PIN diodes can also be used as RF limiters to protect sensitive components in a circuit from high-power signals. The diode is biased in the reverse direction, and when a high-power signal is incident on the diode, it begins to conduct and limits the amplitude of the signal.

- **Voltage-controlled Oscillators (VCOs):** PIN diodes can be used to control the frequency of VCOs by varying the capacitance in the resonant circuit. This is commonly used in applications such as phase-locked loops (PLLs) and frequency synthesizers.

- **Power Dividers:** PIN diodes can be used in power divider circuits to split an RF signal into multiple outputs. By varying the bias voltage applied to the diode, the amount of signal that is routed to each output can be controlled.

2.4 Power bank circuit

2.4.1 About Power bank circuit

A power bank circuit is an electronic circuit that is designed to store electrical energy in a battery and provide it as a power source for portable electronic devices such as smartphones, tablets, and laptops. The circuit typically consists of a rechargeable battery, a protection circuit, and a boost converter. The rechargeable battery is the main component of a power bank circuit. The battery can be a single cell or multiple cells connected in series or parallel depending on the required output voltage and current.

Lithium-ion (Li-ion) batteries are commonly used in power banks due to their high energy density and low self-discharge rate. The protection circuit is necessary to prevent overcharging, over-discharging, and short circuits of the battery. It consists of a charge controller, a discharge controller, and a voltage regulator. The charge controller controls the charging process of the battery to prevent overcharging, while the discharge controller prevents over-discharging. The voltage regulator ensures that the output voltage of the power bank is stable and does not exceed the maximum voltage of the connected device.

The boost converter is used to boost the voltage of the battery to the required output voltage of the device. It works by converting the DC voltage of the battery to a higher voltage level using an inductor and a switching circuit. Power bank circuits can be designed with different output power ratings, depending on the required output voltage and current of the device. The capacity of the battery also determines the runtime of the power bank, which is the amount of time it can provide power to the device before it needs to be recharged.

Power bank circuits are commonly used in portable electronic devices, especially smartphones and tablets, where they provide a convenient and portable source of power for extended use. They can also be used in outdoor activities such as camping, hiking, and travel, where access to electrical outlets may be limited.

2.4.2 Component list

- **Battery**: The battery is the main component of the power bank circuit, and it can be a single cell or multiple cells connected in series or parallel depending on the required output voltage and current. Lithium-ion (Li-ion) batteries are used in power banks due to their high energy density and low self-discharge rate.

- **Protection circuit:** The protection circuit is necessary to prevent overcharging, over-discharging, and short circuits of the battery. It consists of a charge controller, a discharge controller, and a voltage regulator.

- **Boost converter**: The boost converter is used to boost the voltage of the battery to the required output voltage of the device. It works by converting the DC voltage of the battery to a higher voltage level using an inductor and a switching circuit.

- **Input connector:** The input connector is used to connect the power bank to a charging source such as a USB port or a wall adapter.

- **Output connector:** The output connector is used to connect the power bank to the device being charged, and it may include one or more ports with different output voltages and currents.
- **Switches:** The switches are used to turn the power bank on and off, and they may include a battery level indicator that shows the remaining charge of the battery.
- **Resistors and capacitors:** Resistors and capacitors are used in the protection circuit and boost converter to control the charging and discharging of the battery and to smooth out the output voltage.
- **Inductor:** The inductor is used in the boost converter to store energy and to smooth out the output voltage.
- **Diodes:** Diodes are used in the boost converter to control the flow of current and to prevent reverse current flow.
- **ICs:** Integrated circuits (ICs) such as voltage regulators and charge controllers are used in the protection circuit and boost converter to regulate the voltage and current of the battery and to control the charging and discharging process.
- **PCB**: Printed circuit board (PCB) is used to connect all the components of the power bank circuit and to provide a stable platform for the circuit.

2.4.3 Schematic diagram

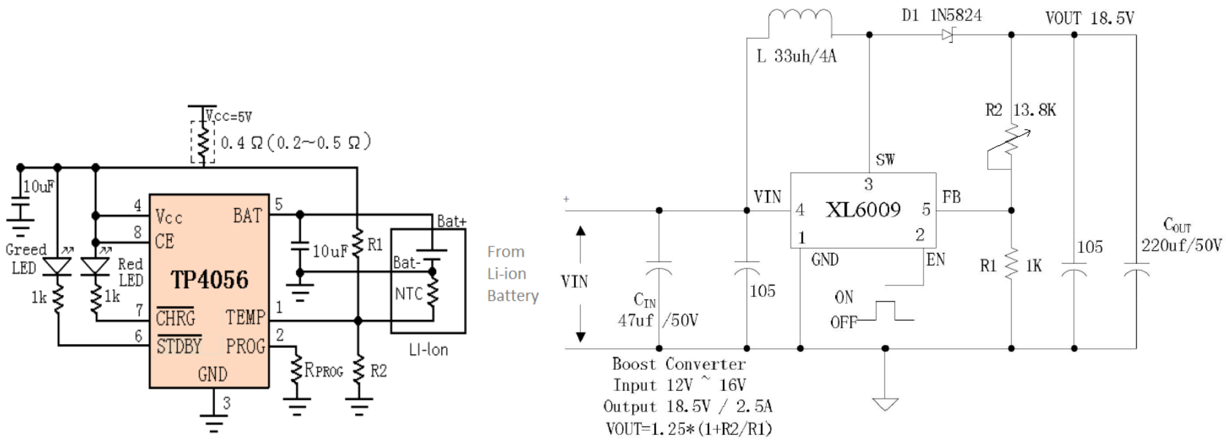


Fig 2.4-Block Diagram of TP4056 Charging Module

A schematic diagram for a power bank circuit is a graphical representation of the circuit's components and their connections. It is used to show the flow of electricity in the circuit and how the different components are connected to each other.

The power bank circuit's schematic diagram serves as a blueprint for building the circuit and is essential for troubleshooting and repair. It provides a visual representation of the circuit's design, making it easier to understand and modify.

2.4.4 Working of Power Bank Circuits

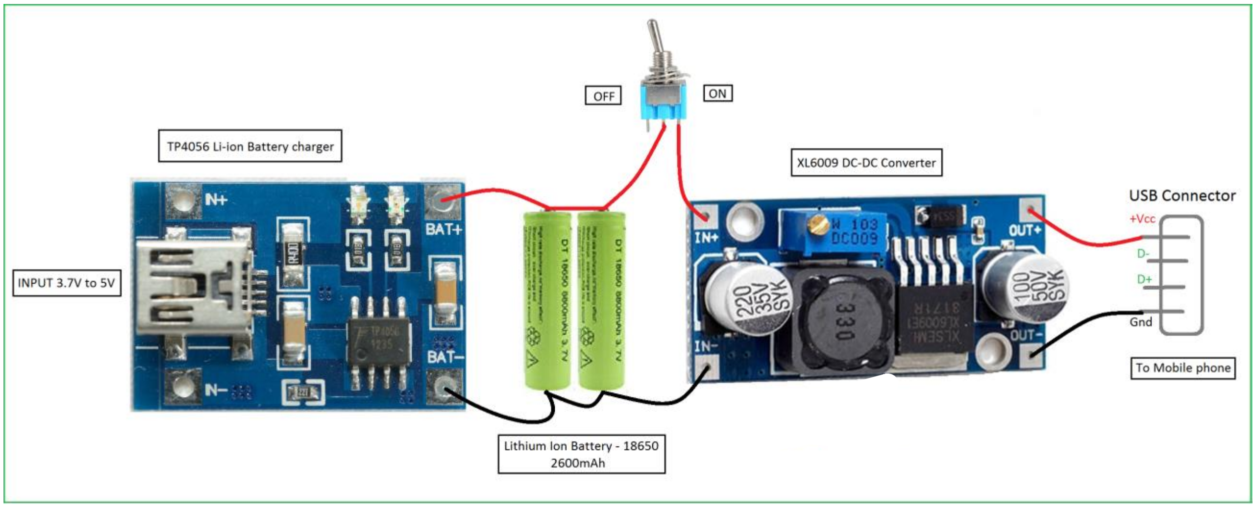


Fig 2.5-Dual Power Supply

- A power bank will be designed which can provide a 5V/4A power output. The power bank will be constructed using a 3.7V Li – ion battery and will have a charger circuit built using TP056 IC and power booster circuit at the output.

- The Li-ion battery will store the charge and then battery will be used to supply power to the devices. For storing the charge, the Li-ion battery first itself needs to be charged using a charger circuit for which TP056 IC is used. This IC is commonly used for charging the Li-ion batteries.

- The IC is specially designed to charge a single 3.7 V Li-ion battery and can provide maximum charging current of 1A.

- The mobile phones and most of the electronic gadgets need 5V to power up but the Li-ion battery will provide a maximum voltage of 4.2 V. Therefore, a power booster circuit will be needed which can amplify the output power to 5V.

- For amplifying the power stored in the battery XL6009 regulator IC is used which will boost the DC power from the battery to a regulated 5V DC. The XL6009 provides maximum 4 A current at the output (as per its datasheet). Therefore, the power bank designed in this electronics project will provide an output power of 5V / 4 A.

2.4.5 Specifications of Power bank circuit

Components Name	Specification	Quantity
DC source	5V	-
Battery	3.7V Li-ion	1
Battery charger controller	TP4056	1
Voltage regulator	XL6009	1
Resistance R1,R2, R_{prog}	10k	3
R3	0.4 ohm	1
R4	4.1k	1
R5	1.3k	1
Capacitor C1, C2	10uF	2
C3, C4	1uF	2
Cin	220uF, 35V	1
Cout	100uF,50V	1
LED D1,D2	General purpose	2
Diode D3	SS34	1
Inductor L1	47uF	1

2.4.6 Applications of Power Bank Circuits

- **Mobile devices** : Power bank circuits are commonly used to charge mobile devices such as smartphones, tablets, and laptops. They provide a portable and convenient source of backup power for these devices.

- **Portable speaker :** Portable speakers require a power source to operate. Power bank circuits can be used to power portable speakers, providing a portable and convenient way to listen to music or other audio.
- **Outdoor activities :** Power bank circuits can be used to power electronic devices during outdoor activities such as camping, hiking, and backpacking. They provide a portable and convenient source of backup power for electronic devices such as flashlights, GPS devices, and radios.
- **Emergency backup power :** Power bank circuits can be used to provide emergency backup power in the event of a power outage or other emergency situation. They can power critical electronic devices such as medical equipment, communication devices, and lighting.
- **Remote sensing :** Power bank circuits can be used to power remote sensing equipment, such as weather stations, environmental monitoring equipment, and scientific instruments. They provide a portable and reliable source of power for these devices.
- **Robotics :** Power bank circuits can be used to power robotic devices, such as drones and other unmanned vehicles. They provide a portable and convenient source of power for these devices, allowing them to operate for longer periods of time without the need for external power sources.

2.5 Charge-Sensitive Preamplifier

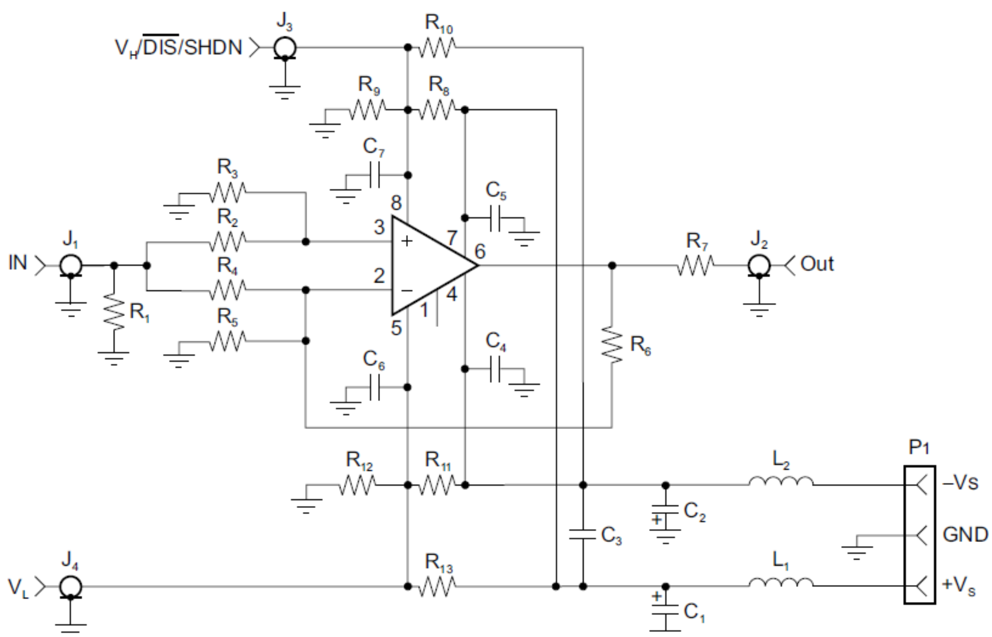
2.5.1 Overview on Low Noise Charge-Sensitive Preamplifier

Low Noise Charge-Sensitive Preamplifier is an electronic circut designed to amplify small electrical charges produced by sensors or detectors. These preamplifiers are commonly used in applications such as radiation detectors, X-ray imaging systems, and particle detectors. Charge-sensitive preamplifiers work by converting the charge signal generated by the sensor or detector into a voltage signal. The preamplifier typically consists of a feedback capacitor, a feedback resistor, and an amplifier stage.

The feedback capacitor is charged by the input signal, and the feedback resistor is used to control the gain of the preamplifier. The amplifier stage amplifies the signal and provides output to the next stage of the electronic circuit. Low noise charge-sensitive preamplifiers are designed to amplify small electrical charges with high precision and low noise levels.

They typically employ techniques such as shielding, low-noise components, and careful layout to minimize noise and interference from external sources. The performance of a charge-sensitive preamplifier is typically characterized by parameters such as input impedance, gain, bandwidth, noise figure, and power consumption.

2.5.2 Schematic diagram



Schematic for DEM-OPA-SO-1A

Fig 2.6-Block Diagram of OPA-SO-1A

2.5.3 Pin configuration and functions

6 Pin Configuration and Functions

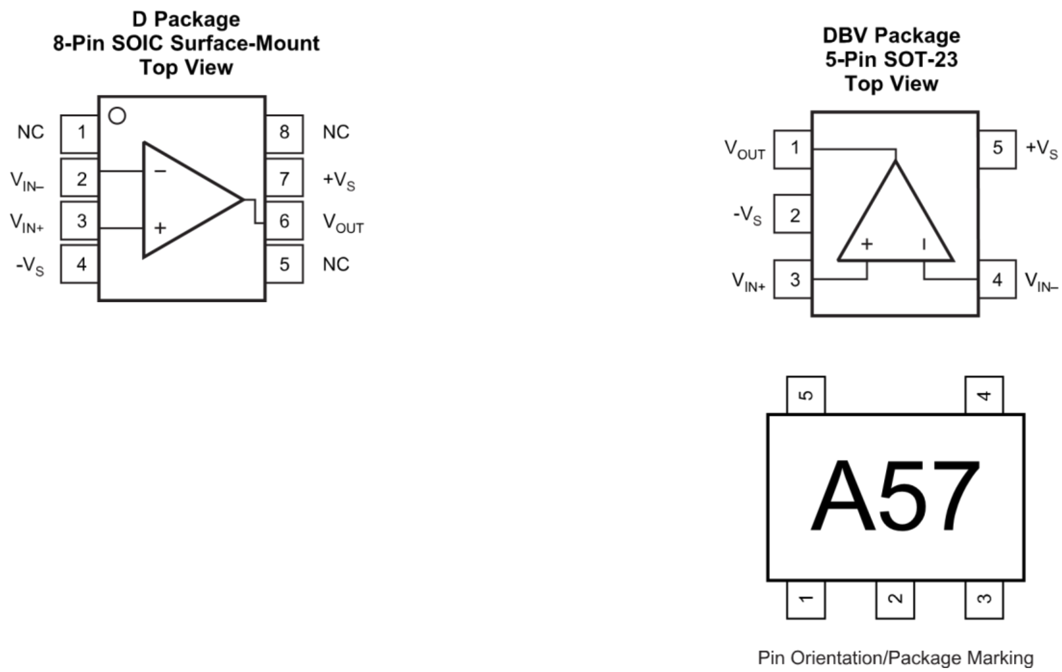


Fig 2.7- 6 Pin Configuration

2.5.4 Working of Charge-Sensitive Preamplifier

A Low Noise Charge-Sensitive Preamplifier works by converting the small electrical charges produced by sensors or detectors into voltage signals that can be further processed by downstream electronic circuits. The preamplifier consists of several stages that work together to amplify and shape the input signal. The input stage of the preamplifier typically consists of a feedback capacitor and a feedback resistor.

When a charge is applied to the feedback capacitor, it creates a voltage difference across the capacitor that is proportional to the input charge. The feedback resistor is used to control the gain of the preamplifier, and the input impedance of the preamplifier is determined by the capacitance of the feedback capacitor. The amplified signal from the input stage is then passed on to the amplifier stage, which is typically implemented using a low-noise operational amplifier. The amplifier stage amplifies the signal to a level suitable for further processing by downstream electronic circuits.

To minimize noise, the amplifier stage is usually designed to have a high input impedance and low output impedance. The output stage of the preamplifier provides a buffered output signal that is free from the high-frequency noise and interferences that may have been picked up by the input stage.

The output stage typically consists of a buffer amplifier that is designed to have a low output impedance and can drive long cables or other loads. Overall, a Low Noise Charge-Sensitive Preamplifier is designed to provide high-precision amplification of small electrical charges with low noise and high bandwidth. The performance of the preamplifier is influenced by various factors such as the input impedance, gain, bandwidth, noise figure, and power consumption, which need to be optimized for specific applications.

2.5.5 Specifications of Charge-Sensitive Preamplifier

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA656	SOIC (8)	2.90 mm × 1.60 mm
	SOT-23 (5)	4.90 mm × 3.91 mm

DEVICE	V_S (V)	BW (MHz)	SLEW RATE (V/µs)	VOLTAGE NOISE (nV/√Hz)	AMPLIFIER DESCRIPTION
OPA656	±5	230	290	7	Unity-Gain Stable FET-Input
OPA657	±5	1600	700	4.8	Gain of +7 stable FET Input
OPA659	±6	350	2550	8.9	Unity-Gain Stable FET-Input
LMH6629	5	4000	1600	0.69	Gain of +10 stable Bipolar Input
THS4631	±15	210	1000	7	Unity-Gain Stable FET-Input
OPA857	5	4750	220	—	Programmable Gain (5 kΩ / 20 kΩ) Transimpedance Amplifier

Features

• 500 MHz Unity-gain Bandwidth unity-gain stable

• Low Input Bias Current: 2 pA

• Low Offset And Drift: ±250 µV, ±2 µV/°C

• Low Distortion: 74-dB SFDR at 5 MHz

• High-Output Current: 70 mA

• Low Input Voltage Noise: 7 nV/√Hz

2.5.6 Applications of Charge-Sensitive Preamplifier

- A Low Noise Charge-Sensitive Preamplifier is commonly used in a variety of scientific and industrial applications, where it is essential to amplify small electrical charges with high precision and low noise levels. Some of the typical applications of a Low Noise Charge-Sensitive Preamplifier include:

- Radiation detection: Charge-sensitive preamplifiers are widely used in radiation detection applications such as nuclear physics, medical imaging, and environmental monitoring. In these applications, charge-sensitive preamplifiers are used to amplify the small electrical charges produced by radiation detectors.

- X-ray imaging: X-ray imaging systems require high sensitivity and low noise preamplifiers to detect the small electrical charges produced by X-ray photons. Charge-sensitive preamplifiers are used in X-ray imaging applications to amplify the electrical charges produced by the X-ray detector.

- Particle detection: Particle detectors such as gas detectors and solid-state detectors require high sensitivity and low noise preamplifiers to detect the small electrical charges produced by charged particles. Charge-sensitive preamplifiers are commonly used in particle detection applications to amplify the signals from the detectors.

- Mass spectrometry: Mass spectrometry is a technique used to identify and quantify chemical compounds in a sample. Charge-sensitive preamplifiers are used in mass spectrometry applications to amplify the electrical charges produced by the ions in the sample.

- Ionizing radiation measurement: Charge-sensitive preamplifiers are used in ionizing radiation measurement applications to amplify the small electrical charges produced by radiation detectors such as Geiger counters, ionization chambers, and proportional counters.

2.5.7 Limitations of Charge-Sensitive Preamplifier

A charge sensitive preamplifier (CSP) is a specialized electronic circuit that amplifies the small electrical signals generated by charged particles or photons in detectors such as photomultiplier tubes and semiconductor detectors. While CSPs are widely used in particle physics experiments and radiation detection applications, they also have some limitations, including:

- **Noise**: CSPs are sensitive to various types of noise, including thermal noise, shot noise, and flicker noise. These noises can limit the accuracy and resolution of the signal measurement and affect the detection sensitivity.

- **Signal distortion**: CSPs can introduce signal distortion due to the finite bandwidth of the amplification circuit. This can lead to a loss of signal information, distortion of the signal shape, and non-linearities in the response. 3. Charge collection effects: CSPs are susceptible to charge collection effects, which can occur when the detector collects a large number of charges in a short period. These effects can cause the CSP to saturate or even damage the detector.

- **Temperature dependence**: The performance of CSPs can be sensitive to temperature changes, which can affect the gain, noise, and signal response.

- **Power consumption**: CSPs typically require a high supply voltage, which can lead to high power consumption and heat dissipation. This can be a significant issue for portable or battery-operated devices.

2.6 AMERICUM 241

Physical and Chemical Properties: Americium 241 is a radioactive metal that has a silver-white appearance. It has a half-life of 432 years and emits alpha particles and gamma rays. Americium 241 is highly reactive and can form compounds with other elements such as oxygen, chlorine, and nitrogen.

- **Uses:** Americium 241 has a few practical uses, such as in smoke detectors and as a neutron source for scientific research. It can also be used as a radiation source for industrial radiography.

- **Health Effects:** Americium 241 is a highly toxic substance that can cause severe health effects if not handled properly. It can enter the body through inhalation, ingestion, or skin contact and can cause radiation sickness, cancer, and other long-term health problems. The level of risk depends on the amount of exposure, duration of exposure, and the route of entry.

- **Safety Precautions:** Handling Americium 241 requires proper safety precautions to minimize the risk of exposure. These precautions include wearing protective clothing, using proper ventilation, and handling the material with specialized tools and equipment. Disposal of Americium 241 is subject to strict regulations and must be done in accordance with federal, state, and local guidelines.

- **Regulations:** The use, storage, and disposal of Americium 241 are regulated by various government agencies, including the Nuclear Regulatory Commission and the Environmental Protection Agency. Regulations cover issues such as handling, storage, transportation, and disposal of Americium 241 to ensure public safety and protect the environment.

2.7 HDPE (High-density polyethylene)

HDPE stands for High-density polyethylene. It is a type of thermoplastic polymer that is commonly used in the manufacturing of a wide range of products such as plastic bottles, pipes, toys, and containers. HDPE is known for its high strength-to-density ratio, which makes it a durable and versatile material that can withstand high impact and resist corrosion. Some of the key properties of HDPE include:

- **Chemical resistance:** HDPE is highly resistant to chemicals, including acids, bases, and solvents.

- **Moisture resistance:** HDPE is impermeable to moisture, making it an excellent material for applications that require water or moisture resistance.

- **UV resistance:** HDPE is resistant to UV radiation, which makes it suitable for outdoor applications.

- **Flexibility:** HDPE has a high degree of flexibility, which makes it easy to mold and shape into various forms.

- **Recyclability:** HDPE is a recyclable material, and it can be recycled into new products multiple times without losing its properties. Due to its properties, HDPE is widely used in various industries such as packaging, construction, agriculture, and automotive. It is a cost-effective material that offers excellent performance, durability, and versatile.

CHAPTER 3

METHODOLOGY

3.1 Cost Effective Neutron Sensor

3.1.1 Cosmic Rays

- Cosmic rays are high-energy particles that originate from outside the solar system and travel through space at nearly the speed of light.

- They consist of a mixture of protons, electrons, and atomic nuclei, with energies ranging from a few million electron volts to hundreds of billions of electron volts. When cosmic rays interact with the Earth's atmosphere, they collide with atoms and molecules in the air, producing a cascade of secondary particles, including neutrons.

- The production of neutrons in the atmosphere is primarily due to the interaction of cosmic rays with nitrogen and oxygen atoms. In the first step of this process, a cosmic ray particle collides with a nitrogen or oxygen atom, causing it to break apart into several charged particles, including protons, neutrons, and other particles.

- The neutrons produced in this process have high energies and are known as "fast neutrons."The fast neutrons produced in the atmosphere can further interact with other atmospheric gases, such as hydrogen and oxygen, to produce slower-moving or "thermal" neutrons.

- These thermal neutrons can then be detected by instruments such as cosmic ray neutron sensors using PIN diodes.

3.1.2 Working of pin diode

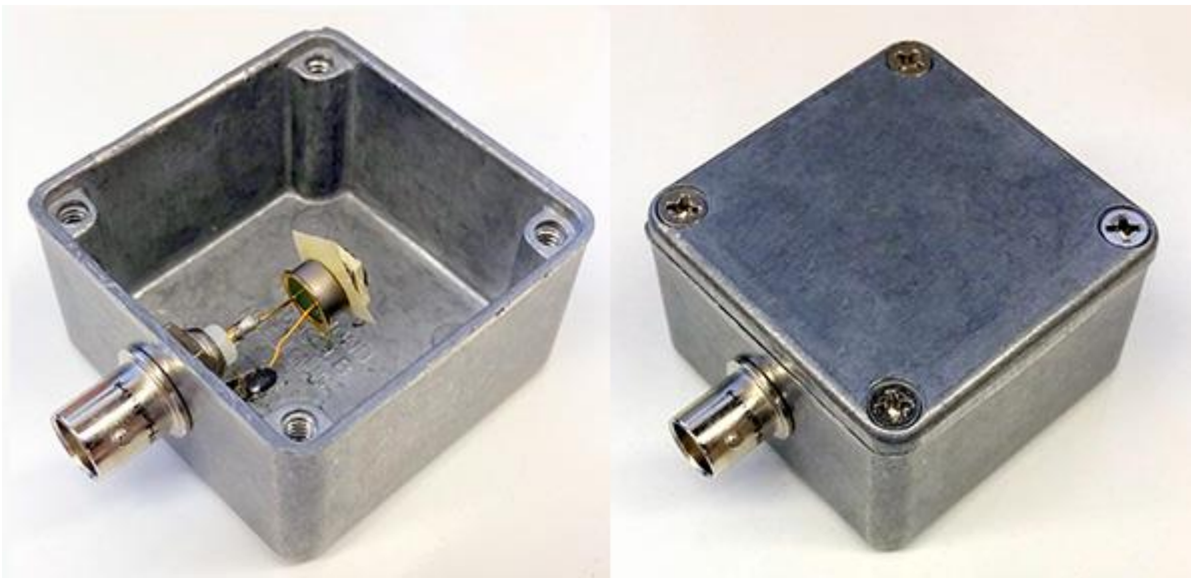
The PIN diode detector used in cosmic ray neutron sensors is a type of semiconductor detector that is based on the principle of ionization.

Fig 3.1- PIN Diode Detector

It consists of a thin layer of intrinsic (i-type) semiconductor material sandwiched between heavily doped p type and n-type semiconductor layers. The p-type and n-type layers act as electrodes that collect the charge generated by the ionization of the intrinsic layer. When a neutron enters the detector, it collides with an atomic nucleus, producing a cascade of charged particles that ionize the intrinsic layer. The resulting charge is then collected by the p-type and n-type electrodes, generating a current that is proportional to the neutron flux.

The intrinsic layer in the PIN diode detector is typically made of high-purity silicon, which has a high cross- section for neutron capture and produces a large number of charged particles upon interaction with a neutron.To improve the directional sensitivity of the detector, it is often coupled with a moderator or shield that is designed to selectively attenuate neutrons from certain directions. The moderator or shield can be made of materials such as polyethylene, paraffin, or boron, depending on the desired energy range of the neutrons being detected. In summary, the PIN diode detector used in cosmic ray neutron sensors is a highly sensitive and efficient neutron detector that is based on the principle of ionization in a semiconductor material. It is often coupled with a directional shield or moderator to improve its directional sensitivity and reduce background noise.

3.1.3 Working of Charge Sensitive Preamplifier



3.2 Working Principle of Charge Sensitive Pre Amplifier

Cosmic ray neutron sensors using pin diodes typically consist of a detector module, electronics, and data acquisition system. The detector module usually includes a silicon pin diode that serves as the radiation detector.

The pin diode is a type of semiconductor detector that is sensitive to ionizing radiation, such as cosmic rays and neutrons. The detector is usually surrounded by a layer of moderator material, such as polyethylene, to slow down and thermalize fast neutrons, making them more detectable. The electronics typically include a preamplifier and shaping amplifier to amplify and shape the signal from the detector. The electronics also usually include a discriminator that sets a threshold for the signal, allowing only signals above a certain amplitude to be counted.

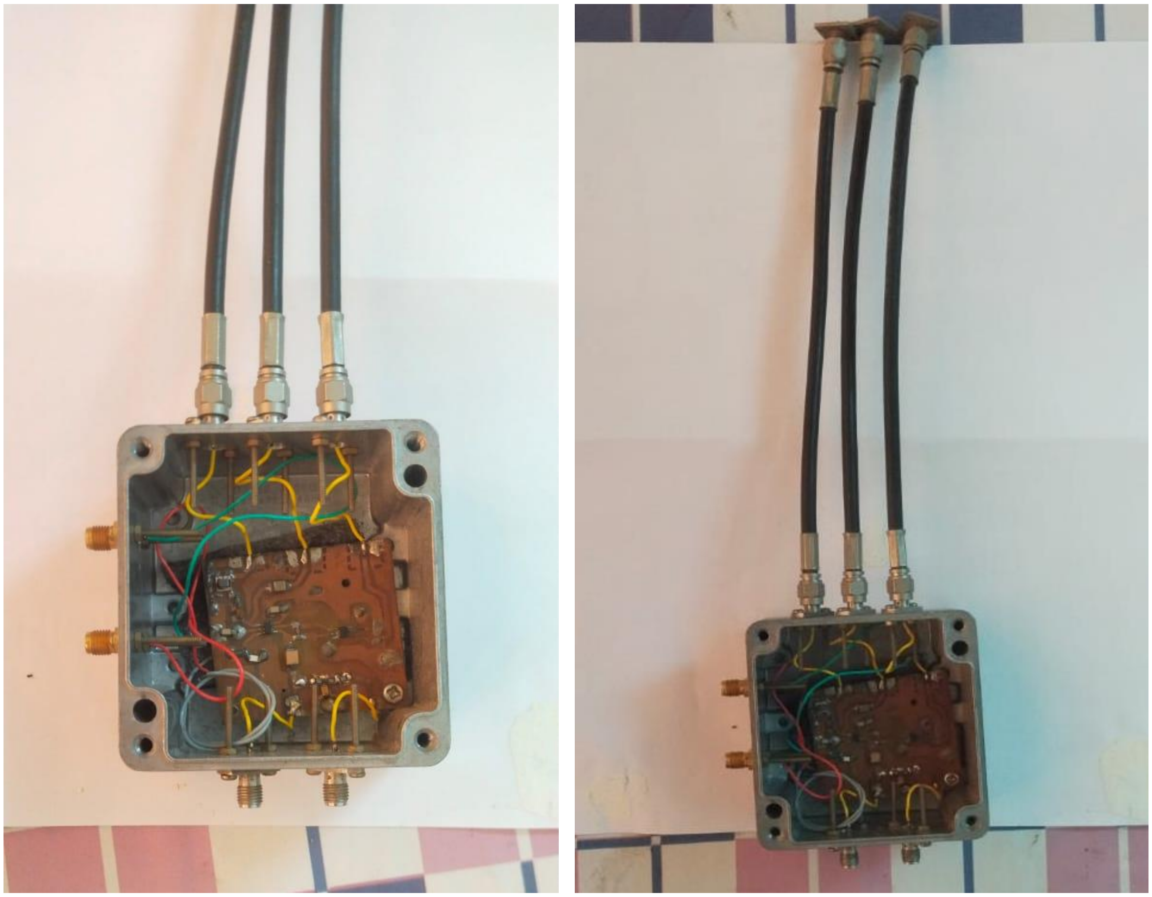


Fig 3.2.1- Charge Sensitive Preamplifier

The data acquisition system typically includes a computer or microcontroller that receives the signals from the electronics and processes them into meaningful data.

The system may also include a user interface for configuring the sensor and displaying the data in real-time. To acquire data using a cosmic ray neutron sensor, the sensor is placed in the desired location and turned on. The sensor typically operates continuously, measuring the radiation flux in the surrounding environment.The data acquired by the sensor can include counts of cosmic rays and neutrons over a certain time period, as well as other statistical measures such as the mean and standard deviation of the counts.

This data can be used to study the flux of cosmic rays and neutrons in the environment, as well as their interactions with matter. In summary, a cosmic ray neutron sensor using a pin diode typically consists of a detector module, electronics, and data acquisition system. The sensor operates

continuously to measure the radiation flux in the surrounding environment, and the data acquired can be used to study the properties of cosmic rays and neutrons.

3.1.4 Working of Power Bank Circuit

A power bank will be designed which can provide a 5V/4A power output. The power bank will be constructed using a 3.7V Li – ion battery and will have a charger circuit built using TP056 IC and power booster circuit at the output.

- The Li-ion battery will store the charge and then the stored charge in the battery will be used to supply power to the devices. For storing the charge, the Li-ion battery first itself needs to be charged using a charger circuit for which TP056 IC is used. This IC is commonly used for charging the Li-ion batteries.

- The IC is specially designed to charge a single 3.7 V Li-ion battery and can provide maximum charging current of 1A.

- The mobile phones and most of the electronic gadgets need 5V to power up but the Li-ion battery will provide a maximum voltage of 4.2 V. Therefore, a power booster circuit will be needed which can amplify the output power to 5V. For amplifying the power stored in the battery XL6009 regulator IC is used which will boost the DC power from the battery to a regulated 5V DC.

- The XL6009 provides maximum 4 A current at the output (as per its datasheet). Therefore, the power bank designed in this electronics project will provide an output power of 5V / 4 A.

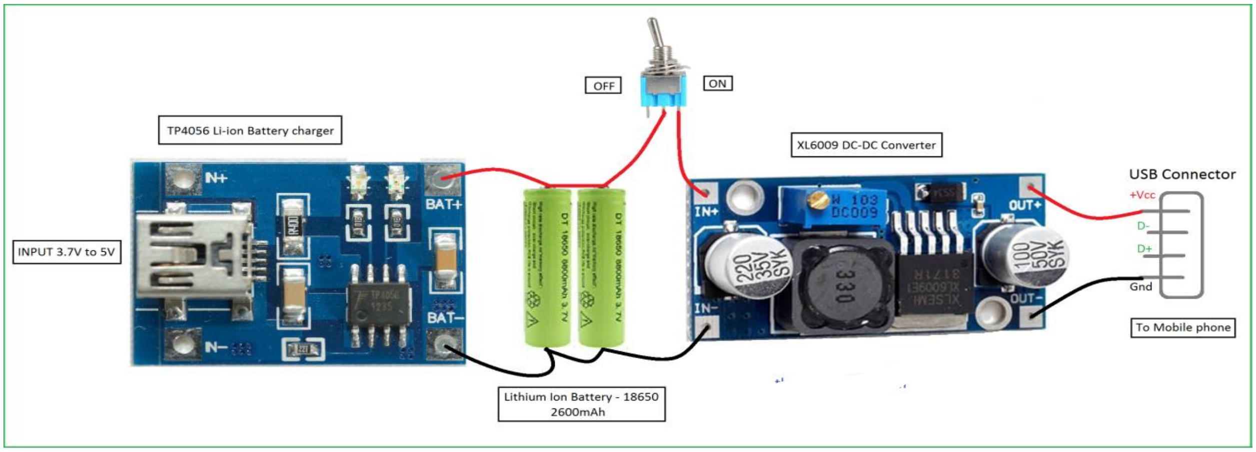


Fig 3.3-Dual Power Supply

A power bank can also be used to power the preamplifier of a cosmic ray neutron sensor using a pin diode. The preamplifier typically requires a low voltage DC power supply, such as 5 volts, to operate. To use a power bank with the preamplifier, a voltage regulator or DC-DC converter may be required to step up the voltage from the power bank to the required voltage for the preamplifier.

The voltage regulator or DC-DC converter can be connected between the power bank and the preamplifier to regulate the voltage and provide a stable power supply to the preamplifier. It is important to ensure that the voltage regulator or DC-DC converter is compatible with the power bank and the preamplifier, and provides a clean and stable power supply to prevent any noise or interference in the data acquisition system.

Overall, using a power bank to power the preamplifier of a cosmic ray neutron sensor can be a convenient and portable solution for field applications or where a stable power source is not readily available. Choose two power banks that can provide the voltage and current required for the positive and negative power supply. Make sure that both power banks have the same output voltage and current rating.Connect one power bank for positive power supply: Connect one power bank to the positive input of the preamplifier.

Use a power cable to connect the positive output of the power bank to the positive input of the charge sensitive preamplifier .Connect the other power bank for negative power supply: Connect the other power bank to the negative input of the preamplifier. Use a power cable to connect the negative output of the power bank to the negative input of the preamplifier.

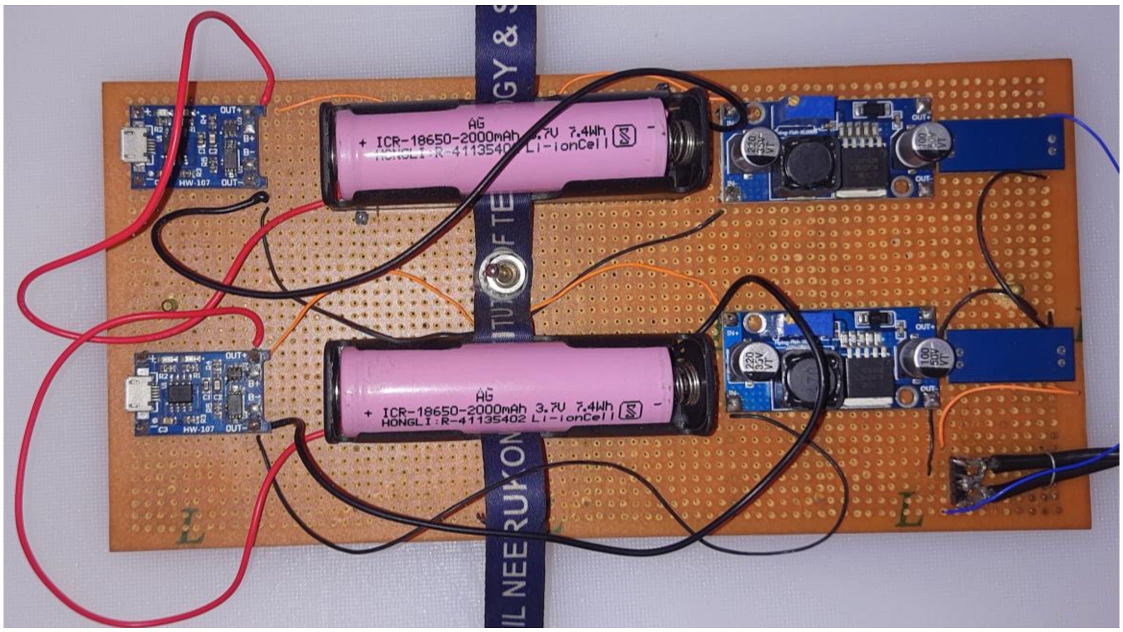


Fig 3.4-Dual Power Supply Hardware Model

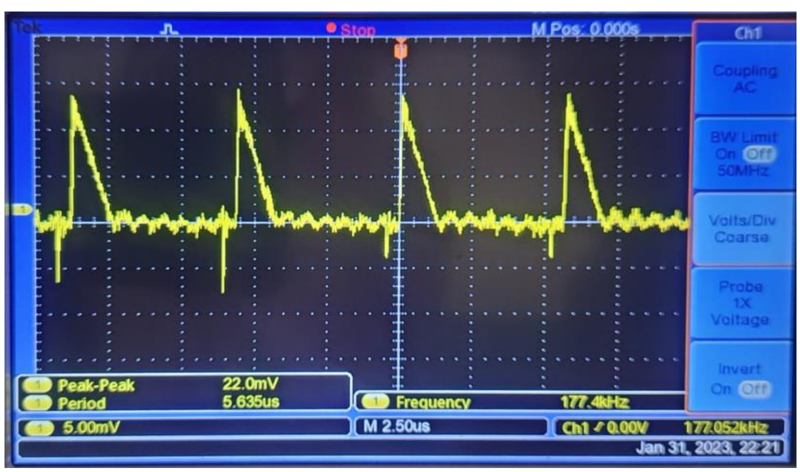


Fig 3.5- Dual Power Supply without Liner Regulator

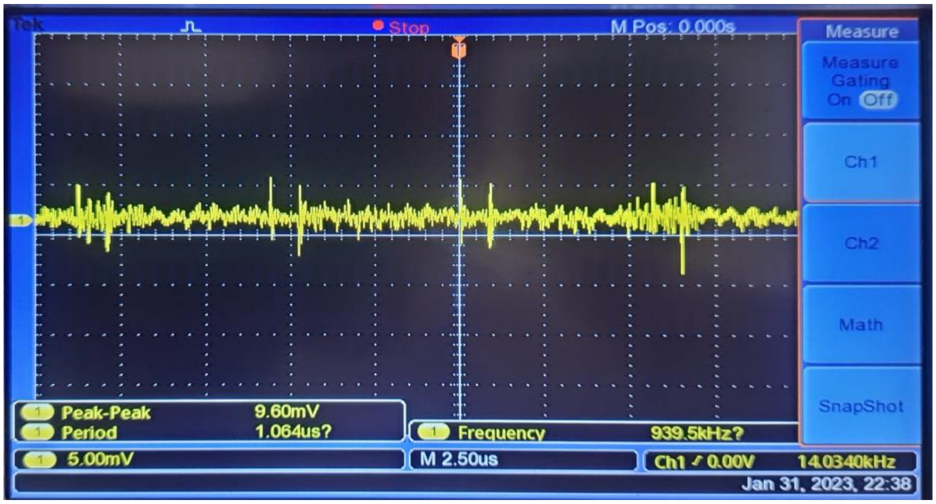


Fig 3.6-Dual Power Supply with Liner Regulator

3.1.5 Working of Americium 241

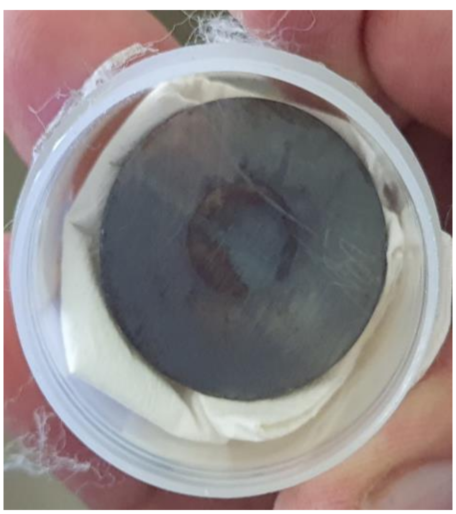


Fig 3.7-Americium 241

In a neutron sensor with a PIN diode, the alpha particles produced by a neutron converter layer interact with the silicon material in the PIN diode, causing ionization and the creation of electron-hole pairs. The electrical current produced by the electron-hole pairs is proportional to the number of alpha particles produced, which is directly related to the number of neutrons detected. The neutron converter layer typically consists of a thin layer of boron or lithium, which can capture neutrons and produce alpha particles through nuclear reactions.

When a neutron is captured by a boron-10 nucleus, an excited state of boron-11 is produced, which decays into an alpha particle and a lithium-7 nucleus. Similarly, when a neutron is captured by a lithium-6 nucleus, an excited state of lithium-7 is produced, which decays into an alpha particle and a helium-4 nucleus. The alpha particles produced by the neutron converter layer have a high energy and a positive charge, which allows them to penetrate through the protective layers of the sensor and interact with the silicon material in the PIN diode.

When an alpha particle interacts with the silicon material, it ionizes the atoms and creates electron-hole pairs. The electron-hole pairs move towards the electrodes in the PIN diode, creating a current that can be measured and used to detect and quantify the number of neutrons that have interacted with the sensor.

The sensitivity of the neutron sensor with a PIN diode depends on the efficiency of the neutron converter layer in producing alpha particles, as well as the ability of the PIN diode to detect and measure the electrical current produced by the alpha particles. The performance of the sensor can be characterized by its sensitivity, energy response, linearity, and other parameters that affect its accuracy and reliability. Proper calibration and maintenance of the sensor are essential for ensuring accurate and consistent measurements.

3.1.6 Working of HDPE

- High-density polyethylene (HDPE) is commonly used as a moderator in neutron sensors with PIN diodes. The HDPE board serves as a moderator to slow down the neutrons and increase their likelihood of interacting with the neutron converter layer in the sensor.

- The slowed down neutrons then interact with the boron or lithium in the neutron converter layer, producing alpha particles that can be detected by the PIN diode. When a fast neutron enters the HDPE moderator, it collides with the hydrogen atoms in the HDPE and loses energy through elastic scattering.

- The scattered neutron then collides with other hydrogen atoms, losing more energy and slowing down even further. This process is repeated until the neutron's energy is low enough to be captured by the boron or lithium in the neutron converter layer. The slowed down neutron then interacts with a boron or lithium nucleus, producing an alpha particle and a recoiling nucleus.

- The alpha particle, being charged and heavy, produces a significant amount of ionization as it travels through the silicon material in the PIN diode, creating electron-hole pairs. The electron-hole pairs move towards the electrodes in the PIN diode, creating a current that can be measured and used to detect and quantify the number of neutrons that have interacted with the sensor. T

- he use of HDPE as a moderator in neutron sensors with PIN diodes allows for a compact and efficient design, as it helps to increase the sensitivity and detection efficiency of the sensor.

- The performance of the sensor with an HDPE moderator can be characterized by its sensitivity, energy response, linearity, and other parameters that affect its accuracy and reliability. Proper calibration and maintenance of the sensor are essential for ensuring accurate and consistent measurements.

3.2 Circuit

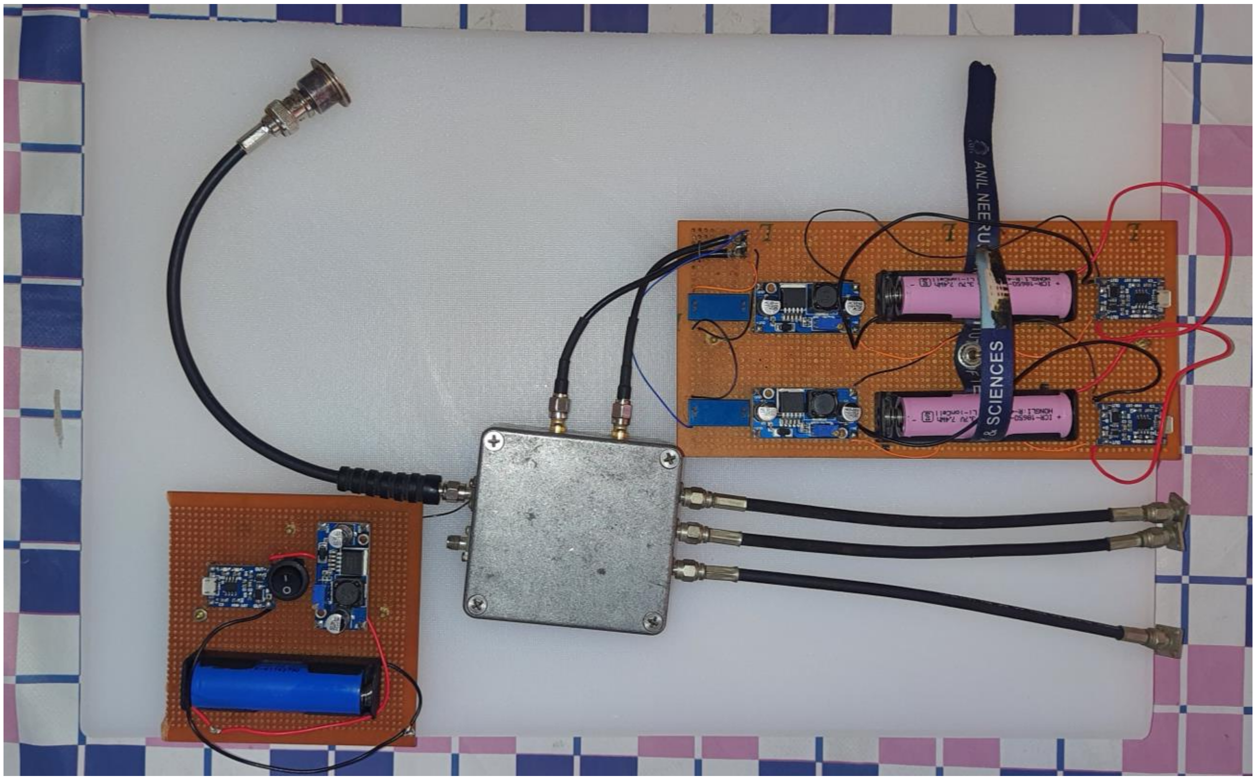


Fig 3.8- Hardware Model of Neutron Counter Flatform

3.2.1 Result

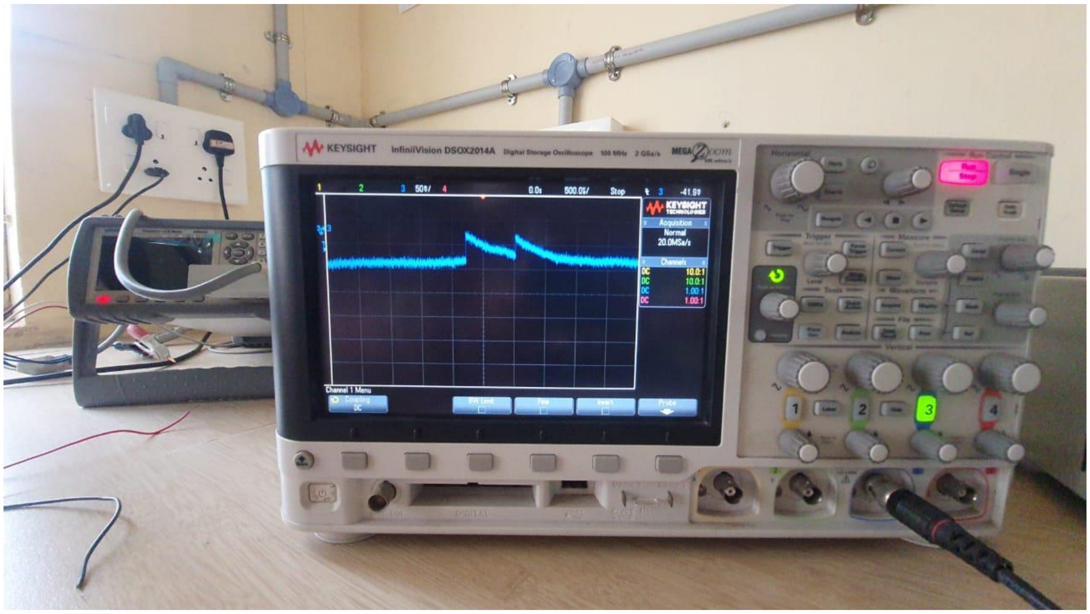


Fig 3.9-Result with Americium 241- Alpha Sourc

3.2.2 ADVANTAGES AND LIMITATIONS OF PROPOSED SOLUTION

PIN diodes are commonly used for detecting cosmic ray neutrons due to their unique advantages over other types of detectors. Here are some advantages and limitations of using PIN diodes for cosmic ray neutron detection.

Advantages:

- **High Sensitivity:** PIN diodes have a high neutron detection efficiency, which means they can detect even very low neutron fluxes with high accuracy.
- **Fast Response Time:** The fast response time of PIN diodes allows for real-time measurements of neutron fluxes.
- **Low Power Consumption:** PIN diodes require very low power to operate, making them ideal for use in remote or inaccessible locations. Low Noise: PIN diodes produce low electronic noise, which makes it easier to detect small signals.
- **Simple Operation:** The operation of PIN diodes is relatively simple and requires minimal setup, which reduces the potential for experimental error.

Limitations:

- **Directional Sensitivity:** PIN diodes are sensitive to neutrons coming from a specific direction, which means that they may not be suitable for detecting neutrons that come from all directions.
- **Temperature Sensitivity:** The performance of PIN diodes is sensitive to temperature changes, which can affect the accuracy of the measurements.
- **Radiation Damage:** Prolonged exposure to high levels of radiation can damage the PIN diode, leading to reduced sensitivity and accuracy.
- **Crosstalk:** The signal produced by the PIN diode can be affected by other types of radiation or background noise, which can lead to false measurements. Despite these limitations, the use of PIN diodes for cosmic ray neutron detection remains popular due to their high sensitivity, fast response time, and low power consumption.

Ongoing research and development continue to address the limitations of PIN diodes and improve their performance in neutron detection. .

3.2.3 Discussions

Future research on PIN diode-based cosmic ray neutron sensors may go a number of different paths, including: The creation of more effective shielding and moderation techniques can increase a sensor's directional sensitivity while lowering its overall effectiveness.To enhance the sensor's overall effectiveness, future research might concentrate on creating more effective shielding and moderation methods.

- **Integration with Other Sensors:** In order to provide a more thorough picture of the environment, cosmic ray neutron sensors using PIN diodes might be connected with other sensors. To give a more full view of the soil moisture levels, they might be combined with soil temperature and humidity sensors, for instance.

- **Development of Wireless Sensor Networks:** Cosmic ray neutron sensors could be used in wireless sensor networks. Miniaturization and Deployment in Remote

- **Areas:** Research could focus on the miniaturization of cosmic ray neutron sensors using PIN diodes, making them more portable and easy to deploy in remote areas. This would enable researchers to collect data in regions that are difficult to access, such as mountainous regions and Arctic regions.

Overall, research on cosmic ray neutron sensors using PIN diodes is still in its early stages, and there is significant potential for future developments in this area. By improving the performance of the sensors and expanding their applications, we can gain new insights into environmental processes and improve our ability to manage and protect natural resources

CHAPTER 4

CONCLUSION

The key findings on the cosmic ray neutron sensor using a PIN diode are as follows:

- The PIN diode detector is an effective neutron detector that is sensitive to neutrons from cosmic ray interactions with the atmosphere.
- The use of a directional moderator or shield can significantly improve the directional sensitivity of the sensor and reduce background noise.
- The sensor is capable of detecting changes in the neutron flux caused by variations in atmospheric conditions, such as precipitation and temperature.
- The sensor can be used to measure the soil moisture content by monitoring the neutron flux attenuation in the soil.The sensor can be deployed in a wireless sensor network for long-term monitoring of soil moisture and other environmental parameters.
- The project demonstrates that the cosmic ray neutron sensor using a PIN diode is a versatile and effective tool for environmental monitoring, particularly for soil moisture content. The sensor is sensitive, accurate, and easy to use, making it suitable for a wide range of applications in agriculture, hydrology, and environmental science.
- Overall, PIN diodes provide a number of benefits over other neutron detection techniques when used for cosmic ray neutron detection. It is a useful tool for applications such as environmental monitoring because it offers high efficiency, low noise, high sensitivity, and directional sensitivity in a small, portable design.

CHAPTER 5

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