Internet of Things and Cyber Physical Systems

ECE 510

Project Progress Update

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Summary

The primary focus and aim of project **NerG** is to tap into the under and un-utilized energy sources from around everyday surrounding and to make big impact with compounded multiple small efforts put together in the bigger picture and in the long run, contribute as a substantial unit to a Smart Energy grid of a Smart City or Smart Ecosystem.

The **NerG** project in its alpha stages such as right now, will be implemented through a minimalist ideology where the focus is on the strengthened establishment of the core concept of energy harvesting through unconventional means to be able to collectively contribute towards a Smart energy grid.

The immediate use case that **NerG** will be focusing on is to enable through its functionality, a proof of concept of harvest of energy through the process of conversion. This will be demonstrated either through a module of lighting system or stepping up of the harvested power to be consumed in charging an electronic gadget.

Technical Specifications

The goal of the NerG project is to support a smart energy grid by utilizing underutilized energy sources found in everyday contexts. This section describes the technical requirements that drove our system's design and implementation, emphasizing attainable objectives given our time and talent restrictions.

Core Concept and Scope

The main idea of NerG is the unorthodox collection of small amounts of energy. To ensure simplicity and functionality, we have used a simple approach for our proof of concept. The main goal is to show that energy harvesting is feasible using doable and simple techniques, such the suggested attachment to the door's hinge movements.

Mechanism for Energy Harvesting

Our idea produces power by harnessing mechanical energy from the environment, such as little motions. We chose this strategy because it is easy to understand and implement, which will enable us to complete the system's development and testing in the allotted time. Because piezoelectric materials are readily available and have an easy to apply design, we use them for this purpose.

Power Output Specifications

Our energy harvesting system is designed to produce electricity in the milliwatt (mW) range, which is a small output. For small-scale uses, such as charging a low-power electronic device or lighting an LED, this power level is adequate. Our desired output voltage ranges from roughly 3.3V to 5V, which is suitable for an array of tiny electronic components.

Energy Storage and Management

Considering capacitors can quickly charge and discharge, they are a good choice for intermittent power sources when it comes to storing gathered energy. We choose capacitors with a 1000µF capacity for demonstration purposes. These capacitors offer a short-term storage option with the ability to deliver power spikes as required.

Control System and Monitoring

A microcontroller (such as the Arduino Uno), selected for its simplicity and ease of programming, serves as the foundation of the control system. In addition to controlling energy flow and power output monitoring, the microcontroller also performs basic data logging functions. The system is equipped with sensors that monitor the surrounding environment and maximize energy collection.

Modularity and Expandability

Given that of the modularity of our design, we can integrate and expand our energy harvesting modules in the future. Because of its modular design, our system may be easily expanded or changed without requiring a whole rebuild, allowing it to be tailored to a variety of settings and needs.

Communication and Data Logging

By utilizing Bluetooth modules, the system may transmit data to a mobile device or central hub and has basic communication capabilities. This feature makes it possible to remotely check system status and energy harvesting performance. Data logging is used to capture environmental factors and power production, giving insights into the effectiveness and performance of the system over time.

Safety and Reliability

A key element in our design is safety. We make sure that all components are used within their stipulated ratings and provide overvoltage protection. Proper assembly processes and the selection of sturdy components are key factors in enhancing reliability.

Prototype Specifications

- **Power Output:** 3.3V to 5V, up to 50mA
- **Storage:** Capacitors, up to 1000μF
- **Microcontroller:** Arduino Uno
- **Communication:** Bluetooth
- **Sensors:** Basic environmental sensors (e.g., temperature, light)

- **Display:** OLED display for real-time monitoring

Segments of the Project

Hardware Description

A full description of the hardware components utilized in the NerG project may be found in this section. The emphasis is on ease of assembly, simplicity, and functionality in line with the time and scope of our project.

Energy Harvesting Unit

The Gear headed generator is the main part of our energy collecting device. A gearhead generator is a device that combines a generator with a gearhead mechanism to convert mechanical energy into electrical energy efficiently at different speeds. The gearhead (gearbox) adjusts the rotational speed of the input shaft, often reducing a high-speed, low-torque input to a lower-speed, higher-torque output. This configuration is particularly useful for applications where the mechanical input varies in speed or force

- Component: 24V 20 rpm Gear headed Motor.
- Specifications: 67 mm in length, up to 10V in voltage output (depending on stress)

Energy Storage

Given that capacitors charge and discharge quickly, we use them to store the captured energy. For our intermittent power generation, capacitors offer a suitable interim storage solution.

- Component: Electrolytic Capacitors
- Specifications: 1000μF of capacitance and 25V of voltage rating

Control System

The Arduino Uno microcontroller is at the heart of the control system. The Arduino Uno is the preferred model due to its small size, ease of programming, and extensive library and support availability.

- Component: Arduino Uno
- Specifications: ATmega328P microcontroller with 14 digital I/O pins and a 5V operational voltage

Connectivity

We employ a Bluetooth module to facilitate data exchange and remote monitoring. This makes it possible for us to send data for additional analysis to a central hub or mobile device.

- Component: HC-05
- Bluetooth Module Specifications: Operating Voltage: 3.3V-5V, Bluetooth Protocol: V2.0+EDR

Sensors

Basic sensors are part of the system to keep an eye on the surroundings and maximize energy collection. Real-time data is provided by these sensors, which are linked to the Arduino Uno.

- Component: DHT11 Temperature and Humidity Sensor
- Specifications: Temperature range: 0–50°C; Humidity range: 20–90%; Operating Voltage: 3.3V–5V

Display

The real-time performance data of the system is displayed on an OLED display. This covers environmental factors, storage state, and power output.

- Component: 0.96-inch OLED Display
- Specifications: I2C interface, 128 × 64-pixel resolution

Assembly and Integration

The parts are put together on a breadboard to facilitate testing and prototyping. The capacitors, which are connected to the Arduino Uno, are connected to the piezoelectric disks. The Arduino is further connected to the sensors and display, and the Bluetooth module is set up to transmit data.

System Layout

- Energy Harvesting Unit: Strategically positioned piezoelectric disks that absorb vibrations.
- Storage: The harvesting unit-connected capacitors
- Arduino Uno Control System: Monitoring data and energy flow

- Sensors: DHT11 offers data on the surroundings
- Display: OLED displaying system performance in real time
- Connectivity: Data transmission to a mobile device from the HC-05

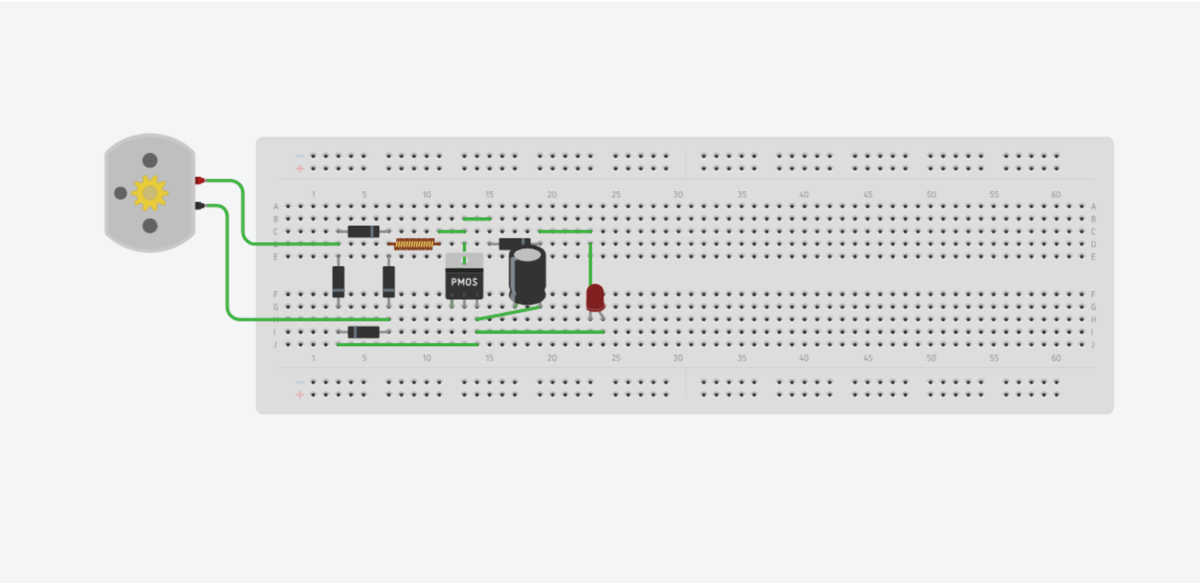


Figure 1: Proposed Actual Hardware Representation.

Software Description

A complete explanation of the software elements and programming logic utilized in the NerG project is given in this section. The program is made to oversee data gathering, energy harvesting, and communication, guaranteeing effective system functioning and monitoring. The primary program structure, the development environment selection, and the specific functionality are all essential to the project's success.

Development Environment

The Arduino Integrated Development Environment (IDE) is used by the NerG project for development and debugging. The Arduino IDE's user-friendly interface and wide library support make it a popular option for both novices and experts. It makes creating, assembling, and uploading code to Arduino microcontrollers simple. The ease of use and dependability of the Arduino IDE make it a perfect platform for our project, especially considering our limited resources and time.

The IDE is compatible with a variety of operating systems, including Windows, macOS, and Linux, so it won't interfere with our unique installations. Moreover, the

Arduino IDE's robust online community and comprehensive documentation greatly lower the learning curve and offer a wealth of resources for troubleshooting.

Main Program Structure

The NerG project's basic program structure is made to manage a variety of functions, such as data collection, data transfer, data display, energy harvesting, and initialization. The C/C++ program is structured into a few functions that carry out distinct duties. To guarantee continuous functioning, these functions are called within the main loop.

The functions and roles of each software component are described in depth in the sections that follow.

Initialization

Considering it sets up all the parts and configurations needed for the system to work properly, the initialization step is very important. This include initializing sensors, defining pin modes, configuring the display, and connecting to the Bluetooth module.

The microcontroller is set up to communicate with the different sensors and output devices during initialization. For example, the DHT11 sensor is configured to begin gathering environmental data, and the OLED display is setup to guarantee that it can display data in real-time. To facilitate data transmission to a mobile device or central hub, the Bluetooth module is also initialized.

The initialization phase establishes the groundwork for the program's next phases by making sure that every component is prepared to function as intended.

Energy Harvesting Logic

The NerG project's fundamental idea is energy harvesting logic. It entails controlling the capacitors' charging as well as reading the output from the generator. When mechanical stress is applied, such as vibrations or tiny motions, piezoelectric sensors produce an electrical charge. After then, capacitors are used to collect and store this electrical charge.

The output from the generator is frequently checked by the microcontroller. The system interprets an increase in sensor output over a certain threshold as a sign that there is enough mechanical stress to produce useful electrical energy. The capacitors are then charged by the microcontroller using this energy.

The generator analog readings are read during this operation, and the quantity of energy produced is subsequently calculated by processing the data. Even with tiny and irregular mechanical inputs, the system guarantees a steady supply of gathered energy by routinely monitoring and storing energy.

Data Collection

Given data collecting offers insights into the ambient factors that impact energy harvesting, it is a crucial component of the NerG project. The DHT11 temperature and humidity sensor is one of the sensors that the system uses to gather data. This information aids in comprehending the outside variables affecting the energy harvesting process's efficiency.

For instance, the DHT11 sensor detects both humidity and temperature. The effectiveness of generator can be greatly impacted by external factors; therefore, these readings are crucial for maximizing the system's performance. Additionally, the gathered data is utilized to track and evaluate the system's overall performance.

At regular intervals, the microcontroller gathers data from the sensors and saves it for further examination. The system's efficiency can be increased by using the ongoing data collection to spot trends and make wise judgments.

Data Display

The OLED display is used to show system performance data in real time. It displays important data like the quantity of energy harvested, the state of energy storage, and meteorological parameters like humidity and temperature.

Users can continuously monitor the system's operation thanks to the display's real-time updates. This real-time data is essential for determining how well the energy harvesting process is working and for making any necessary modifications. The OLED panel is the best option for our project because of its excellent contrast and low power consumption.

The display is controlled by the microcontroller, which sends data to it on a regular basis to keep the information on it up to date. The OLED display improves user interaction and makes troubleshooting simpler by giving a visual depiction of the system's performance.

Data Transmission

A vital part of the NerG project is data transmission, which allows for system monitoring from a distance. This is made possible via the HC-05 Bluetooth module, which enables data transmission from the microcontroller to a central hub or mobile device. This feature is especially helpful for monitoring the system's performance over time and across many locations.

The microprocessor and the Bluetooth module are set up to exchange data, including the quantity of energy harvested, the state of storage, and the ambient conditions. A coupled device can receive this data and use it to log or display information for further study.

By enabling users to monitor system performance remotely, this feature improves system usability and eliminates the requirement for users to be physically present. Additionally, it offers useful information for system optimization and analyzing the variables affecting system performance.

Main Loop

The core of the program is the main loop, which does the essential operations repeatedly to guarantee ongoing operation. The system carries out duties related to energy harvesting, data gathering, data presentation, and data transmission within this loop.

The loop starts by monitoring the piezoelectric sensors' output and controlling the capacitors' charge. After then, it gathers information from the environmental sensors and shows the most recent data on the OLED display. Lastly, it uses the Bluetooth module to send the gathered data to a device that is paired.

Each function in the main loop is called periodically to guarantee timely updates and continued operation, which is how the loop is built to work effectively. This configuration guarantees the system's continued responsiveness and its ability to monitor and harvest energy in real time.

Detailed Functionality Breakdown

We will divide the features of the software into discrete tasks and explain how each work fits into the larger system to give a thorough grasp of the program.

Management of Energy Harvesting:

- Task: Analyze the generator analog values.
- Description: Depending on the mechanical stress applied, the microcontroller reads the voltage output from the generator. After that, the voltage is examined to ascertain the energy produced.
- Purpose: To capture and store energy efficiently, ensuring continuous power generation.

Energy Storage Management:

- Task: Utilizing the sensor's output to charge capacitors.
- Description: The microcontroller uses the energy it generates to charge the capacitors when the sensor output goes above the threshold. This entails managing energy flow to guarantee effective storage.
- Purpose: To store harvested energy for later use, providing a reliable power source for small electronic devices.

Environmental Data Collection:

- Task: Read data from the DHT11 sensor.
- Description: The DHT11 sensor provides the microcontroller with periodic readings of temperature and humidity data. This information is kept and utilized for optimization and monitoring.
- Purpose: Gain knowledge of how the environment affects energy harvesting efficiency so that modifications may be made with knowledge.

Real-Time Data Display:

- Task: Update system data on the OLED display.
- Description: The OLED display receives data from the microcontroller, which updates it with the most recent data on energy harvested, storage status, and environmental conditions.
- Purpose: To provide immediate feedback on system performance, facilitating monitoring and troubleshooting.

Data Transmission:

- Task: Use Bluetooth to send data.
- Description: The HC-05 Bluetooth module is used by the microcontroller to transmit gathered data to a paired device. Data about the environment, energy levels, and storage conditions are included.
- Purpose: To make it possible for system performance to be remotely monitored and logged, improving usability and offering insightful data for optimization.

Software Optimization and Testing

After the software's first version is created, it goes through extensive testing and optimization. To make sure the system operates as intended; this phase entails operating it under various scenarios. Code is improved and adjusted to meet any problems found during testing.

Optimization Techniques:

- Code Efficiency: Making sure the microcontroller operates the code in an efficient manner, with the least amount of latency and maximum responsiveness.
- Error Handling: To control unforeseen circumstances and guarantee system stability, provide strong error handling.
- Power management: It is the process of optimizing software to consume as little power as possible. This is especially important for energy harvesting projects.

Testing Procedures:

- Unit Testing: Checking that separate functions operate correctly when left alone.
- Integration testing: Verifying that all parts function as intended and that the system integrates seamlessly.
- Stress testing: It is the process of subjecting a system to harsh circumstances to find possible weak points and strengthen resilience.

Documentation and Future Enhancements

To support the product, extensive documentation is written that includes usage guidelines, function explanations, and the code structure. For maintenance and development in the future, this documentation is crucial.

Future Enhancements:

- Advanced Data Analysis: Using environmental data to optimize energy harvesting using machine learning techniques.
- Enhanced User Interface: Creating a mobile application with sophisticated monitoring features and a more user-friendly data display.
- Expanded Sensor Network: Including more sensors to increase data collection and boost system precision.

Components and Materials

This section includes a list of all the parts and supplies needed for the NerG project, along with information on possible sources, quantities, and requirements. The criteria used for selection are conformity with our project's goals, convenience of use, and availability.

Energy Harvesting Components

1. **24V 20 rpm Gear headed Motor**

- Specifications**:** Length 67mm (about 2.64 in), Voltage Output: up to 10V
- Quantity**:** 1
- Estimated Cost**:** $2 per unit

Energy Storage

2. **Electrolytic Capacitors**

- Specifications: Capacitance: 1000μF, Voltage Rating: 25V
- Quantity: 5
- Estimated Cost: $0.50 per unit

Control System

3. **Arduino Uno**

- Specifications: ATmega328P microcontroller, 5V operating voltage
- Quantity: 1

- Estimated Cost: $10 per unit

Connectivity

4. **HC-05 Bluetooth Module**

- Specifications: Operating Voltage: 3.3V-5V, Bluetooth Protocol: V2.0+EDR
- Quantity: 1
- Estimated Cost: $5 per unit

Sensors

5. **DHT11 Temperature and Humidity Sensor**

- Specifications: Operating Voltage: 3.3V-5V, Temperature Range: 0-50°C, Humidity Range: 20-90%
- Quantity: 1
- Estimated Cost: $2 per unit

Display

6. **0.96-inch OLED Display**

- Specifications: Resolution: 128x64 pixels, Interface: I2C
- Quantity: 1
- Estimated Cost: $5 per unit

Miscellaneous Components

7. **Breadboards and Jumper Wires**

- Quantity: 2 sets
- Estimated Cost: $5 per set

8. **Resistors and Capacitors (Assorted Values)**

- Quantity: 1 set
- Estimated Cost: $5 per set

Power Supply

9. **USB Power Supply**

- Specifications: 5V output

- Quantity: 1
- Estimated Cost: $5 per unit

Tools Required

10. Soldering Kit

- Description: Includes soldering iron, solder, and basic tools
- Estimated Cost: $20 per kit

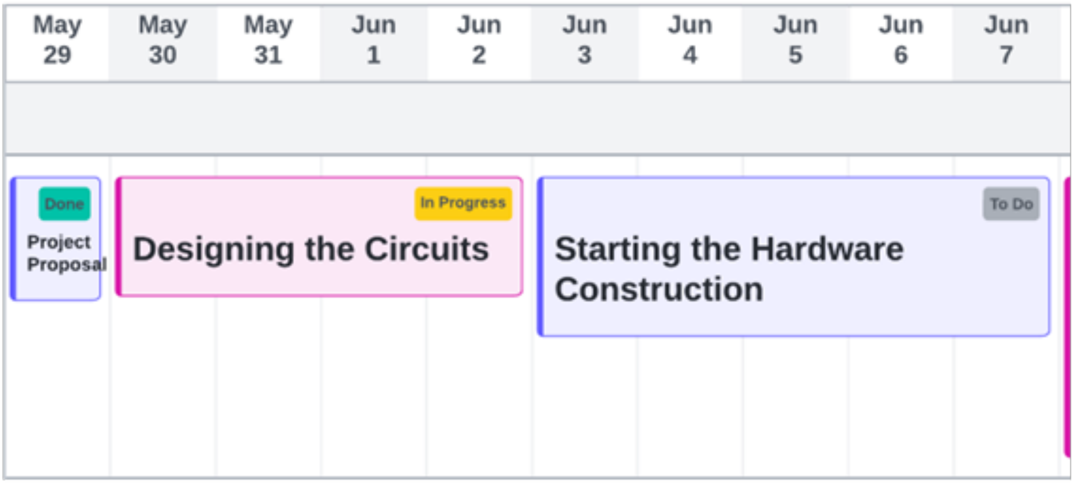
11. Multimeter

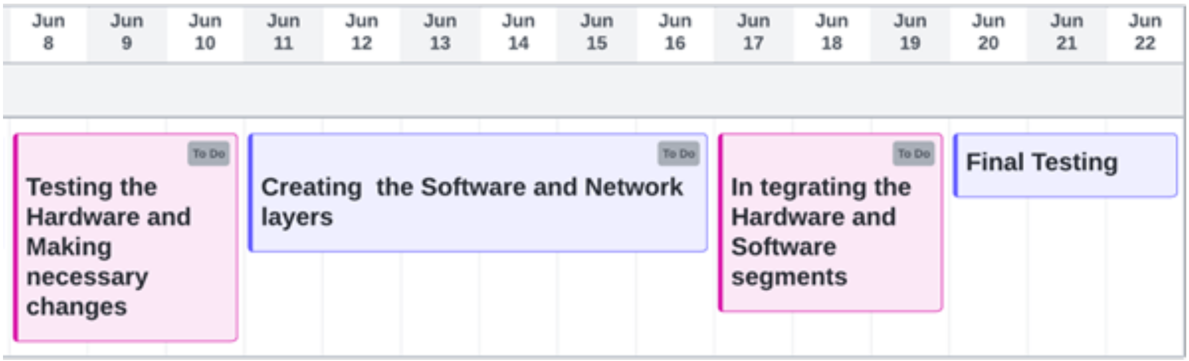
- Description: For measuring voltage, current, and resistance
- Estimated Cost: $10 per unit

Total Estimated Cost

The anticipated total cost of all parts and materials is roughly seventy dollars. However, it is to note that many if not most of these components mentioned above will be available to loan out from the ECE department Laboratory at IIT. Considering the same, the overall anticipated cost might go down even further.

Milestones and Team Member tasks





Work Distribution

Task	Assignee
Project Proposal	Abhilash and Adnan
Designing Circuits	Adnan
Hardware Construction	Abhilash
Testing round #1	Abhilash and Adnan
Network Layer	Adnan
Software Application	Abhilash
Testing round #2	Abhilash and Adnan
Final Testing	Abhilash and Adnan

Conclusion

Proposed Outcomes

The NerG project aims to successfully deliver energy harvesting through unconventional methods within the limited timeframe. The following are the expectations set for the project:

- Successful Energy Harvesting
- Efficient Energy Storage
- Real-Time Monitoring and Data Transmission

Expected Roadblocks

Anticipation and forethought into the expected pitfalls will help in overcoming them without much delay in the process is the main idea behind this section:

- Component Availability
- Technical Limitations
- Time Management

Project Expected Impact

There are numerous possible effects upon successful completion of the NerG project:

- **Educational Value**: The project is meant to help students learn about microcontroller-based systems and energy harvesting.
- **Environmental Benefits**: The project helps to develop sustainable energy solutions by utilizing underutilized energy sources.
- **Basis for Future Work**: Our system's scalable and modular architecture offers a starting point for additional energy harvesting research and development.

Potential Prospects

Although these are main objectives of our project, there are still several areas identified that might use improvement:

- Improved Energy Harvesting: Investigating different energy harvesting strategies, including thermoelectric generators or sophisticated piezoelectric materials, may boost the effectiveness of the system.

- Better Energy Storage: The system's performance would be improved by using energy storage options that are more effective, like supercapacitors or tiny batteries.
- Sophisticated Data Analysis: Depending on the surroundings, energy harvesting could be optimized by putting machine learning algorithms and sophisticated data analysis techniques into practice.
- Expanded Applications: The system's usefulness and impact could be increased by extending its power capacity or incorporating it into a more extensive smart grid architecture.

In Brief

We anticipate gaining actual skills and knowledge in energy collecting by making it informative experience through the NerG project. Notwithstanding to the potential difficulties, we aim to be able to present a proof of concept that demonstrates the potential of underutilized energy sources. We further aim that our work advances the larger objective of developing intelligent and sustainable energy solutions and in establishing the foundation for upcoming advancements.

Through the establishment of attainable objectives and the utilization of accessible resources, we will demonstrate that even minor endeavors can yield noteworthy outcomes when assimilated into a more extensive framework. In addition to improving our technical proficiency, the NerG project's journey is source of motivation to us to keep looking for novel answers to the world's energy problems.

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