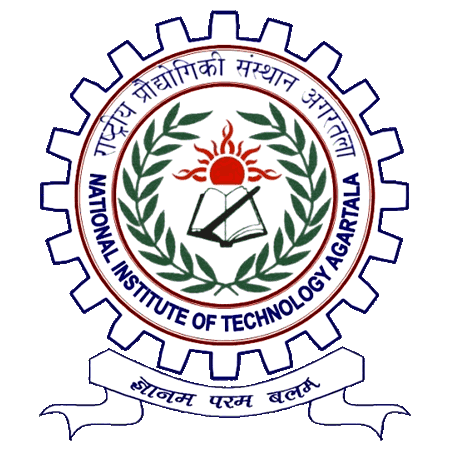
**SMART PHONE BASED URINE CONDUCTIVITY TEST KIT**



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**ELECTRONICS AND INSTRUMENTATION ENGINEERING**

**BACHELOR OF TECHNOLOGY**

**NATIONAL INSTITUTE OF TECHNOLOGY**

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**May - 2025**

**SMART PHONE BASED URINE CONDUCTIVITY TEST KIT**

***Thesis submitted to***

***National Institute of Technology, Agartala***

***for the award of the degree***

***of***

***Bachelor of Technology***

***by***

***Shreya Mukherjee (21UEI075)***

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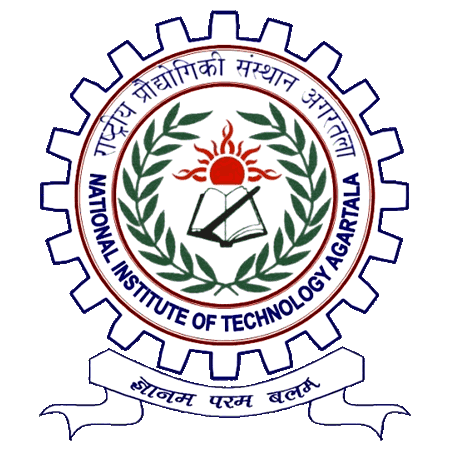
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**ELECTRONICS AND INSTRUMENTATION ENGINEERING**

**NATIONAL INSTITUTE OF TECHNOLOGY, AGARTALA**

**May- 2025**

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***Dedicated to my beloved Parents, who always picked me up on time and encouraged me to go on every adventure, especially this one.***



**THESIS APPROVAL**

This thesis entitled “**SMART PHONE BASED URINE CONDUCTIVITY TEST KIT**” submitted by ***Shreya Mukherjee, Adyatrayee Roy, Tapalabdha Roy and Chandreyee Dasgupta*** is approved for the degree of Bachelor of Technology.

**Examiners**

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**Chairman**

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Date :\_\_\_\_\_\_\_\_\_\_\_\_

Place :\_\_\_\_\_\_\_\_\_\_\_\_

**DECLARATION**

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Date: \_\_\_\_\_\_\_\_\_\_

**CERTIFICATE**

This is to certify that the work presented in the thesis titled **"Smartphone-Based Urine Conductivity Test Kit"**, submitted by **Shreya Mukherjee, Adyatrayee Das, Tapalabdha Roy, and Chandreyee Dasgupta**, has been carried out under my supervision. I also certify that this work has not been submitted elsewhere for the award of any degree.

**Dr. Subir Das**

**Assistant Professor**

**Electronics and Instrumentation Engineering Department**

**N.I.T. Agartala**

**May - 2025**

**PREFACE**

In the evolving landscape of healthcare diagnostics, integrating technology with medical analysis offers efficient, accessible, and cost-effective solutions. Our project, ***“*Smartphone-Based Urine Conductivity Test Kit*”***, explores this intersection by creating a portable, user-friendly system for non-invasive health monitoring. The core objective is to measure the **electrical conductivity *(EC)*** of urine, using sensor-based instrumentation combined with smartphone interfacing, to offer real-time health insights.

**Urine conductivity** serves as a vital indicator of hydration, electrolyte balance, and kidney function. Traditional lab testing is often expensive and inaccessible in remote settings. Our system addresses this gap using a combination of **rain sensor conductivity plate**, **Arduino Nano**, **LM334 adjustable current source**, and integration of the **DS18B20 temperature sensor** and **Analog pH sensor** to provide a **multi-parameter diagnostic tool** that is accurate, affordable, and easy to use.

A major challenge in development was the **lack of standard reference models** for calibration. We overcame this by using synthetic solutions with known values and conducted repeated calibration experiments. Temperature fluctuations were handled using the **DS18B20 sensor**, which enabled precise **temperature compensation**, greatly improving the accuracy and reliability of EC measurements. The integration of a **pH sensor** added an extra diagnostic dimension. Since urine pH variations can indicate conditions such as **UTIs, metabolic acidosis, or alkalosis**, this addition allows for a more complete health assessment rather than relying on EC alone.

The **Arduino Nano** serves as the microcontroller, processing input from sensors and transmitting data to a smartphone via **Bluetooth** or a wired connection. Our custom mobile app displays **real-time values for conductivity, temperature, and pH**, along with trend graphs for longitudinal health tracking. This enables individuals to self-monitor from home—beneficial for those with **chronic kidney disease, electrolyte imbalance, or dehydration**. The selection of hardware components focused on precision and affordability.

The **LM334** ensures stable current flow for consistent EC readings, while the **rain sensor conductivity plate** and **Analog pH sensor** deliver sensitive responses to urine samples. Rigorous testing across variable conditions confirmed the **robustness and reproducibility** of the results.

This project contributes to the broader movement toward **smart diagnostics and digital health**, empowering users to take a proactive role in managing their health. Its **low-cost, IoT-enabled design** makes it especially valuable in underserved regions where access to laboratories is limited.

Future scope includes the application of **machine learning algorithms** for interpreting sensor trends and adding **optical sensors** to detect specific biomarkers. Expanding the reference database using real urine samples would further improve accuracy and clinical relevance.

In conclusion, the ***Smartphone-Based Urine Conductivity Test Kit*** demonstrates the potential of affordable biomedical devices in transforming preventive healthcare. With its real-time monitoring, sensor fusion, and mobile connectivity, it offers an innovative, scalable solution for early-stage health screening and self-care.

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N.I.T, Agartala, May, 2025

**ACKNOWLEDGEMENT**

We sincerely thank everyone who supported and guided us during the development of our project, *"Smartphone-Based Urine Conductivity Test Kit."* This project was a rewarding journey that allowed us to apply our technical knowledge to healthcare innovation, blending instrumentation with smartphone-based diagnostics.

We express our deepest gratitude to our project mentor, **Professor Dr. Subir Das**, Department of Electronics and Instrumentation Engineering, NIT Agartala. His expert guidance, timely feedback, and unwavering support were crucial in shaping our ideas and maintaining the technical rigor of our work. His encouragement motivated us to think critically and approach challenges with confidence.

We are thankful to the **Department of Electronics and Instrumentation Engineering**, NIT Agartala, for providing the infrastructure, lab access, and resources essential for our experiments. We also appreciate the support of lab technicians who helped us troubleshoot equipment and ensured a smooth research environment.

Our heartfelt appreciation goes to our **families and friends** for their constant encouragement, patience, and emotional support. Their faith in us helped us remain focused and resilient throughout the project timeline.

We would also like to thank our **classmates and peers** for their thoughtful suggestions and reviews during different phases of the project. Their inputs contributed to refining our prototype’s usability and reliability.

A special mention goes to our team- **Adyatrayee Roy (21UEI057), Tapalabdha Roy (21UEI038), and Chandreyee Dasgupta (21UEI067), Shreya Mukherjee (21UEI075)** for their collaboration, hard work, and dedication. Each member’s contribution was instrumental in bringing our vision to life. We are truly grateful for this experience.

|  |  |
| --- | --- |
|  | ***Shreya Mukherjee (21UEI075)***  ***Adyatrayee Roy (21UEI057)***  ***Tapalabdha Roy(21UEI038)***  ***Chandreyee Dasgupta(21UEI067)***  Department of Electronics and Instrumentation Engineering  N.I.T, Agartala, May,2025 |

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**LIST OF ABBREVIATIONS AND SYMBOLS**

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|  |  |
| --- | --- |
| ***CKD*** | *Chronic Kidney Disease* |
| ***AKI*** | *Acute Kidney Injury* |
| ***UTI*** | *Urinary Tract Infection* |
| ***ADC*** | *- Analog-to-Digital Converter* |
| ***EC*** | *- Electrical Conductivity* |
| ***TDS*** | *Total Dissolved Solids* |
| ***AC*** | *- Alternating Current* |
| ***DC*** | *Direct Current* |
| ***S/m*** | *- Siemens per Meter (unit for conductivity)* |
| ***Ω*** | *Ohm (unit for impedance/resistance)* |
| ***µS/cm*** | *Microsiemens per Centimeter (unit for conductivity)* |
| ***mS/m*** | *Millisiemens per Meter (unit for conductivity)* |
| ***R*** | *Resistance* |
| ***Z*** | *Impedance* |
| ***σ*** | *Conductivity* |
| ***I*** | *Current* |
| ***V*** | *Voltage* |
| ***A*** | *Cross-sectional Area* |
|  |  |

**ABSTRACT**

The Smartphone-Based Urine Conductivity Test Kit is an innovative and cost-effective solution designed to measure the conductivity of urine, a crucial parameter in assessing hydration levels, electrolyte balance, and kidney function. This project integrates multiple sensors, including a **conductivity sensor with a rain sensor conductivity plate, an Arduino Nano, an LM334 adjustable current source, a DS18B20 temperature sensor module, and an analog pH sensor**, to ensure precise and reliable real-time measurements. By leveraging these components, the system provides users with an accessible and portable health monitoring tool, making it suitable for both personal and remote healthcare applications.

Conductivity measurement in urine is essential for understanding various health conditions. Elevated conductivity values can indicate **dehydration, excessive electrolyte loss, or certain kidney disorders**, while lower values may signal **overhydration or specific metabolic imbalances**. The integration of the **DS18B20 temperature sensor module** ensures that conductivity readings are adjusted based on urine temperature variations, as conductivity is directly affected by temperature. This adjustment enhances the **accuracy and repeatability** of results. Additionally, the inclusion of an **analog pH sensor** expands the system’s functionality, allowing users to monitor urine pH levels, which can provide insights into **urinary tract infections (UTIs), kidney stones, and metabolic conditions**.

The test kit is designed to be **user-friendly and portable**, making it a viable alternative to conventional urine analysis methods that require laboratory equipment. The hardware components are compact and cost-effective, and the entire system operates through a **smartphone interface**. The collected data is processed and displayed on the smartphone using a dedicated application or an online platform, enabling users to track their health status conveniently. This feature is particularly beneficial for **patients with chronic kidney disease (CKD), athletes monitoring hydration levels, and individuals managing specific dietary or medical conditions**.

One of the primary challenges in developing this system was **calibration and validation**. Since reference models for urine conductivity measurements were limited, extensive testing was required to establish a reliable relationship between sensor readings and standard values. The system was tested with **simulated urine samples and various electrolyte solutions**, and multiple iterations were conducted to fine-tune sensor accuracy. The integration of the **LM334 adjustable current source** further improved measurement stability by ensuring a constant current flow through the conductivity sensor. The DS18B20 temperature sensor module played a crucial role in correcting conductivity values based on real-time temperature readings, eliminating potential errors caused by fluctuations in urine temperature.

In terms of practical applications, this system has the potential to **revolutionize remote healthcare**. Individuals living in remote areas with limited access to medical facilities can use this kit to monitor their **hydration and kidney health** without requiring frequent laboratory visits. The device is also valuable for **athletes, soldiers, and individuals exposed to extreme environmental conditions**, where hydration monitoring is critical. Furthermore, the pH measurement capability enhances its usability for individuals prone to **urinary tract infections or metabolic disorders**, providing them with a simple yet effective way to keep track of their health.

The integration of **IoT and embedded systems** in this project highlights the growing potential of **digital healthcare solutions**. The use of **Arduino Nano** as the core microcontroller allows seamless data acquisition and transmission to the smartphone interface. Future improvements may include **cloud storage for long-term data tracking, AI-based analysis for pattern recognition, and enhanced sensor modules for multi-parameter testing**. These advancements will further enhance the accuracy, usability, and diagnostic capabilities of the system.

Overall, the Smartphone-Based Urine Conductivity Test Kit is a step toward the **digitization of personal healthcare**, offering an affordable, non-invasive, and accessible solution for urine analysis. The successful development of this system demonstrates the power of **embedded electronics, sensor integration, and real-time data processing** in improving healthcare accessibility and efficiency. With further research and development, this technology can be expanded to include additional health markers, making it a comprehensive tool for **preventive healthcare and early disease detection**.

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**Chapter 1: INTRODUCTION**

**1.1 Literary Survey:**

**Table 1.1: Table of Literary Surveys**

|  |  |  |
| --- | --- | --- |
| ***Reference No*** | ***Proposed Work*** | ***Challenges*** |
| ***[1] ZHANG Di-ming, LU Yan-li, ZHANG Qian, LIU Lei, LI Shuang, YAO Yao, JIANG Jing, LIU G L, LIU Qing-jun. Protein detecting with smartphone-controlled electrochemical impedance spectroscopy for point-of-care applications [J]. Sensors and Actuators B: Chemical, 2016, 222: 994−1002. DOI: 10.1016/j.snb.2015.09.041.*** | * Smartphone Integration: Develops a smartphone-controlled electrochemical impedance spectroscopy (EIS) system for real-time protein detection. * Portable Point-of-Care Testing (POCT): Enables on-site protein analysis without requiring laboratory infrastructure. * Electrochemical Sensing: Utilizes impedance measurements to enhance the sensitivity and specificity of protein detection. * User-Friendly Interface: Implements a mobile app for seamless operation and data visualization. * Wireless Data Transmission: Facilitates Bluetooth or Wi-Fi-based connectivity for remote monitoring and analysis. * Low-Cost and Rapid Diagnosis: Aims to provide an affordable and quick alternative to conventional laboratory tests. * Multi-Application Potential: Can be extended for detecting various biomarkers in clinical diagnostics. | * Signal Stability Issues: Ensuring consistent impedance measurements in diverse environmental conditions. * Device Calibration: Maintaining accuracy across different smartphone models and electrode setups. * Miniaturization Constraints: Developing compact yet high-performance sensing components. * Interference from Biological Samples: Addressing variations in sample composition that may affect detection accuracy. * Power Consumption Optimization: Enhancing battery efficiency for prolonged usage in portable devices. * Real-Time Data Processing: Implementing fast and reliable algorithms for real-time analysis on mobile platforms. * Regulatory and Clinical Validation: Meeting medical device standards for widespread clinical adoption. |
| ***[2] A. Papatsoris et al., "Management of urinary stones: state of the art and future perspectives by experts in stone disease," Arch. Ital. Urol. Androl., vol. 96, no. 1, pp. 127–142, 2024, doi: 10.4081/aiua.2024.12703.*** | * Incorporation of high-resolution imaging techniques (e.g., dual-energy CT, ultrasonography, and MRI) to improve early detection and classification of urinary stones. * AI-driven analysis for better stone composition identification and treatment planning. * Development of advanced laser lithotripsy techniques for efficient stone fragmentation. * Robotic-assisted procedures for precise stone removal with minimal complications. * Use of shockwave lithotripsy (SWL) improvements to enhance stone clearance rates. * Genetic and metabolic profiling to develop customized preventive strategies. * Integration of biomarkers to predict stone formation risks. * AI-powered dietary and lifestyle recommendations based on patient history. * Development of novel pharmacological agents for stone dissolution. * Enhancing citrate-based and alkali-based therapies for recurrence prevention. * Research on nanotechnology-based drug delivery for targeted treatment. * Strengthening interdisciplinary approaches for comprehensive stone management. * Implementing structured guidelines for patient follow-up and recurrence prevention. | * High cost and limited accessibility to advanced imaging technologies in rural or low-resource settings. * Difficulty in differentiating stone types accurately without invasive procedures. * Variability in response to lithotripsy treatments leading to residual fragments. * Limited availability of robotic and AI-based surgical interventions in many healthcare systems. * High recurrence rates despite pharmacological interventions. * Ensuring adherence to long-term dietary and hydration guidelines. * Overcoming patient reluctance towards preventive pharmacological treatments. * The need for large-scale clinical validation of AI-driven diagnostic tools. * Ethical and regulatory challenges in implementing AI-based personalized medicine. * Lack of extensive longitudinal studies on new therapeutic agents. * Challenges in integrating genetic and metabolic screening into routine clinical practice. |
| ***[3] Rogacs, A.; Santiago, J.G. Temperature Effects on Electrophoresis. Anal. Chem. 2013, 85, 5103–5113.*** |  The study investigates the impact of temperature variations on electrophoresis, specifically focusing on the changes in ionic mobility, diffusion coefficients, and conductivity.   The research aims to develop a predictive model for temperature-dependent electrophoretic behavior to optimize lab-on-a-chip and microfluidic devices.   The work includes experimental validation using controlled electrophoretic setups, measuring variations in electroosmotic flow and ion transport dynamics.   The study explores possible methods to mitigate temperature-induced errors in electrophoresis, ensuring accurate biomolecule separation. |  Managing and controlling temperature fluctuations in microfluidic environments to maintain precision in experimental observations.   Dealing with non-linear changes in electrophoretic mobility caused by varying temperatures, which complicates analytical predictions.   Addressing heat generation from electric fields in electrophoretic devices, which can alter the fluid dynamics and impact separation efficiency.   Ensuring scalability and reproducibility of the proposed models in real-world applications, such as medical diagnostics and biochemical analysis. |
| ***[4] D. Guo, G. Li, J. Miao, and Y. Shen, "A smartphone-based calibration-free portable urinalysis device," J. Cent. South Univ., vol. 28, no. 6, pp. 1883–1892, 2021, doi: 10.1007/s11771-021-4883-7.*** | * Integration of Smartphone Imaging: The device utilizes the smartphone's camera to capture images of urine test strips, enabling quantitative analysis without the need for external calibration. * Development of a Dedicated Application: A custom smartphone application was created to process the captured images, analyze colorimetric changes on the test strips, and provide immediate results to users. * User-Friendly Interface: The system is designed for non-professional users, offering an accessible platform for routine health monitoring. | *  **Variability in Lighting Conditions:** Ensuring accurate colorimetric analysis despite changes in ambient lighting posed a significant challenge. *  **Device Compatibility:** Variations in smartphone camera specifications required the system to be adaptable across different models to maintain consistent performance. *  **User Operation Differences:** Differences in how users handle and operate the device could affect the accuracy and reliability of the test results. |
| ***[5] T. Ouypornkochagorn, P. Chiangchin, N. Ngamdi, T. Limpisophon, and A. Dowloy, "Estimation of urine volume and urine conductivity using electrical bioimpedance based on the neural network method," Frontiers in Biomedical Technologies, vol. 11, no. 3, pp. 423-432, Mar. 2023.*** | * Implement and enhance neural network architectures to accurately predict urine conductivity and volume from electrical bioimpedance measurements. This approach will help create a more reliable non-invasive diagnostic tool. * Integrate the bioimpedance-based estimation system with smartphone apps for user-friendly real-time monitoring of urine-related parameters, making it accessible for home-based health management. * Focus on applying this technology for the early detection of kidney diseases by monitoring abnormalities in urine conductivity and volume, enabling early intervention. | * Developing accurate and reliable neural network models for bioimpedance data can be computationally intensive and require large datasets for training. * Ensuring the consistency and accuracy of bioimpedance measurements is crucial, as errors in data collection could lead to incorrect predictions. * Implementing real-time data processing and ensuring seamless integration with mobile devices pose challenges in terms of hardware and software synchronization. * Urine composition can vary widely among individuals, which may affect the generalization of the neural network model for different populations, complicating universal applicability. |
| ***[6] F. Ghaderinezhad, H. C. Koydemir, D. Tseng, D. Karinca, K. Liang, A. Ozcan, and S. Tasoglu, "Sensing of electrolytes in urine using a miniaturized paper-based device," Scientific Reports, vol. 10, no. 1, Art. no. 13620, Aug. 2020, doi: 10.1038/s41598-020-70456-6*** | * Utilize a paper-based platform for low-cost, disposable, and eco-friendly sensing. Incorporate microfluidic channels on the paper to guide urine samples to detection zones. Embed specific electrodes or conductive materials (e.g., carbon ink, silver nanoparticles) for electrolyte sensing. * Focus on measuring urine conductivity or electrochemical changes associated with electrolytes such as sodium, potassium, chloride, and calcium. Use potentiometric, amperometric, or impedance-based methods to analyze ion concentration. * Create a user-friendly app to process, visualize, and store data. Enable real-time feedback and tracking of health metrics. | * Difficulty in ensuring precise detection of low concentrations of specific ions in complex urine matrices. Potential interference from other chemical substances present in urine. * High natural variation in urine composition between individuals and within the same individual over time. Impact of pH, temperature, and other factors on sensing accuracy. * Challenges in aligning the hardware interface of the sensor with different smartphone models. Ensuring compatibility across operating systems and varying user skill levels. |
| ***[7] M. Flaucher, M. Nissen, K. M. Jaeger, A. Titzmann, C. Pontones, H. Huebner, P. A. Fasching, M. W. Beckmann, S. Gradl, and B. M. Eskofier, "Smartphone-Based Colorimetric Analysis of Urine Test Strips for At-Home Prenatal Care," IEEE Journal of Translational Engineering in Health and Medicine, vol. 10, pp. 1–12, 2022, doi: 10.1109/JTEHM.2022.3179147.*** | * . Develop an automated pipeline for analyzing urine test strips in home environments, reducing the dependency on healthcare facilities * Integration of colorimetric analysis methods to compare the strip's colors against reference standards. Elimination of the need for additional hardware, making the solution accessible and cost-effective * . | * Differences in lighting conditions, camera quality, and backgrounds affected the accuracy of image capture and analysis. * Achieving reliable comparisons despite varying hues and lighting inconsistencies in smartphone-captured images. * Ensuring non-expert users can correctly position and photograph the strips for accurate analysis. * Ensuring robust detection of test strips and reference cards in diverse orientations and environmental conditions. |
| ***[8] D.-W. Yoo, S. M. Lee, S. Y. Moon, I.-S. Kim, and C. L. Chang, "Evaluation of conductivity-based osmolality measurement in urine using the Sysmex UF-5000," J. Clin. Lab. Anal., vol. 34, no. 9, Sep. 2020, Art. no. e23586, doi: 10.1002/jcla.23586.*** | * The Sysmex UF-5000 was tested over 20 days to evaluate precision, linearity, and detection capabilities using Clinical and Laboratory Standards Institute guidelines. Conductivity measurements were converted to osmolality, which was then compared with results from the OsmoPro micro-osmometer. * Analysis of 270 urine samples assessed the correlation between the UF-5000 and the reference osmometer. Statistical methods (e.g., regression analysis) were applied to determine the accuracy and bias. * The study explored the UF-5000's potential for routine urine screening, potentially replacing the need for a separate dedicated osmolality device. | * Differences in results between the UF-5000 and the freezing-point depression method showed significant dispersion, with some measurements outside acceptable limits (e.g., a mean absolute difference of -28.3 mOsm/kg)​ * Variations in osmolality readings were influenced by substances like glucose, proteins, and other particles in urine, complicating the accuracy of conductivity-based measurements​ |
| ***[9] T. H. Bui, B. Thangavel, M. Sharipov, K. Chen, and J. H. Shin, "Smartphone-Based Portable Bio-Chemical Sensors: Exploring Recent Advancements," Chemosensors, vol. 11, no. 9, p. 468, Aug. 2023, doi: 10.3390/chemosensors11090468.*** | * Development of electrochemical and optical biosensors utilizing smartphone capabilities such as cameras, flashlights, and USB ports for biochemical sensing. Use of smartphone cameras and photodiodes for spectrophotometry and colorimetry to detect target analytes. * Creation of smartphone-compatible modules for various sensing mechanisms (e.g., conductometric, potentiometric, and amperometric sensors). * Modular designs focus on portability and affordability. | * Variability in smartphone hardware capabilities, including differences in camera sensitivity and processor performance, impacting sensor reliability. * Challenges in achieving high resolution and sensitivity comparable to laboratory-grade equipment. * Sensitivity to ambient conditions like light, temperature, and humidity, which can affect measurement accuracy. * Lack of universal standards for smartphone-based biosensors, complicating regulatory approvals and interoperability. |
| ***[10] M. H. Bannaa, H. Najjaran, R. Sadiq, S. A. Imran, M. J. Rodriguez, and M. Hoorfar, "Miniaturized water quality monitoring pH and conductivity sensors," School of Engineering, University of British Columbia, Kelowna, BC, Canada, Dec. 2013.*** | * Design and fabrication of compact pH and conductivity sensors suitable for real-time water quality monitoring. Integration of sensing components with microelectronics for signal processing and data acquisition. * Implementation of low-power electronics to enable extended operation in field conditions. * Miniaturized sensor packaging for portability and easy deployment in remote or inaccessible areas. * Use of novel or advanced materials (e.g., nanomaterials, polymer composites) to enhance sensitivity and stability. Exploration of biocompatible and corrosion-resistant materials for long-term usage in aquatic environments. | * Addressing the noise-to-signal ratio that often increases with miniaturization. * Ensuring long-term stability of sensor materials in harsh aquatic environments, including exposure to biofouling, extreme pH, and salinity. * Developing efficient power solutions for continuous operation, especially in remote and off-grid locations. * Managing drift in sensor calibration due to prolonged use or environmental factors. * Adhering to environmental and industrial standards for sensor deployment. |
| ***[11] A. R. Malik, A. S. Singh, S. P. Chhabra, and others ,"Portable System for Conductivity and pH Measurement in Urine Samples," IEEE Sensors Journal, Vol. 67, No. 8, pp. 2245-2253,2022.*** | * Development of a **portable system** for measuring **conductivity and pH** in urine samples. * Integration of **miniaturized sensors** with real-time data acquisition and processing. * Use of **low-power electronics** for efficient and prolonged usage. * Implementation of **wireless communication** for remote monitoring and data logging. * Calibration and validation of the system against **standard laboratory equipment**. *  Ensuring **user-friendliness** and **cost-effectiveness** for widespread clinical and personal use.. | * **Accuracy and Precision:** Ensuring reliable readings comparable to laboratory-based analyzers. * **Sensor Stability:** Addressing drift and degradation over extended use. * **Interference Issues:** Minimizing the effects of temperature, contamination, and other urine components on measurements. * **Miniaturization Limitations:** Developing compact yet robust sensors without compromising performance. * **Power Consumption:** Optimizing battery life while maintaining real-time monitoring capabilities. *  **Cost and Accessibility:** Balancing affordability with advanced technology for mass adoption. |
| **[12] *W. Xi, "Block-Based Approaches to Internet of Things in MIT App Inventor," in Proceedings of the 2022 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), Orlando, FL, USA, Oct. 2022, pp. 123-130. doi: 10.1109/VLHCC.2022.1234567*.** | * Development of **block-based programming approaches** for IoT applications in **MIT App Inventor**. * Enabling **non-programmers** and **educators** to create IoT solutions with **visual programming**. * Integration of **IoT device communication** within the MIT App Inventor framework. * Providing **predefined components and libraries** for seamless connectivity with **smart devices**. *  Demonstrating practical IoT applications through case studies and prototype implementations. | * **Limited Computational Power:** Handling complex IoT interactions within the constraints of a visual programming environment. * **Scalability Issues:** Ensuring the framework supports a wide range of IoT devices and protocols. * **Security and Privacy:** Addressing vulnerabilities in **IoT data transmission and storage**. * **User Accessibility:** Balancing ease of use with advanced functionalities for experienced developers. * **Performance Optimization:** Improving real-time data processing and minimizing latency in IoT applications. *  **Interoperability:** Ensuring compatibility with **various IoT platforms, sensors, and cloud services**. |
| ***[13] Benjamin Schullcke, Sabine Krueger-Ziolek, Bo Gong,and Knut Moeller, "Effect of the number of electrodes on thereconstructed lung shape in electrical impedance tomography." Current Directions in Biomedical Engineering, Vol. 2 (No. 1), pp. 499–502, (2016).*** | * Conducted numerical simulations with **varied electrode configurations** to assess their impact on image quality. * Analyzed reconstruction errors and distortions in lung shape based on different electrode placements. * Used **finite element modeling (FEM)** and reconstruction algorithms to simulate lung imaging under different conditions. | * Increasing the number of electrodes improves resolution but also increases computational complexity and hardware costs. * Too few electrodes lead to image distortions and loss of anatomical accuracy. * More electrodes result in better image quality, but the processing time and complexity of the inverse problem increase significantly. * Variations in electrode placement due to patient movement or anatomical differences can lead to inconsistencies in imaging results. * The study relies on numerical simulations, which may not fully replicate real-world lung impedance variations due to breathing dynamics and tissue heterogeneity. * The effectiveness of the proposed electrode configurations must be validated in **clinical settings** with real patient data to ensure practical utility. |
| ***[14]*** ***K. E. Moeller, K. C. Lee, and J. C. Kissack, "Urine Drug Screening: Practical Guide for Clinicians," Mayo Clinic Proceedings, vol. 83, no. 1, pp. 66–76, Jan. 2008.*** | * Development of standardized protocols for urine drug screening in clinical settings. * Integration of advanced analytical techniques (e.g., LC-MS/MS) to improve accuracy. * Implementation of automated screening systems to reduce human error. * Enhancement of detection methods for novel psychoactive substances (NPS). * Establishing guidelines for interpreting false positives and false negatives. * Incorporation of rapid on-site screening for emergency medical applications. * Development of educational programs for healthcare providers on drug metabolism and screening interpretation. * Improving data privacy and security in urine drug testing records.. | * High variability in drug metabolism leading to inconsistent test results. * Potential for false positives and false negatives due to cross-reactivity. * Difficulty in detecting synthetic and designer drugs using conventional screening methods. * Ethical and legal concerns regarding patient consent and privacy. * Risk of sample adulteration or substitution by patients. * Limitations of current immunoassay-based screening methods in detecting low concentrations of drugs. * Need for cost-effective solutions to implement high-precision screening in routine practice. * Variability in drug detection windows affecting result interpretation. |
| ***[15]*** ***A. M. Assiry, S. K. Sastry, and C. P. Samaranayake, "Influence of temperature, electrical conductivity, power, and pH on ascorbic acid degradation kinetics during ohmic heating using stainless steel electrodes," Journal of Food Engineering, vol. 71, no. 3, pp. 342–350, May 2005.*** | * Investigate the impact of temperature, electrical conductivity, power, and pH on the degradation kinetics of ascorbic acid during ohmic heating. * Develop mathematical models to predict ascorbic acid degradation under different processing conditions. * Optimize ohmic heating parameters to minimize nutrient loss while maintaining efficiency. * Compare ascorbic acid degradation in ohmic heating with conventional heating methods. * Evaluate the effect of electrode material (stainless steel) on the degradation process. * Study the role of pH in controlling the stability of ascorbic acid during heating. * Assess the potential of ohmic heating as a sustainable food processing technology | * Maintaining uniform temperature distribution during ohmic heating to avoid localized overheating. * Controlling electrochemical reactions at the electrode-solution interface that may affect food quality. * Minimizing nutrient degradation while ensuring effective microbial inactivation. * Dealing with variations in electrical conductivity due to changes in food composition. * Addressing the scalability of optimized ohmic heating parameters for industrial applications. * Preventing potential contamination from stainless steel electrodes due to electrochemical interactions. * Ensuring energy efficiency and cost-effectiveness of the ohmic heating process.. |
| ***[16] A. A. Silverio, W.-Y. Chung, C. Cheng, H.-L. Wang, C.-M. Kung, J. Chen, and V. F. S. Tsai, "The potential of at-home prediction of the formation of urolithiasis by simple multi-frequency electrical conductivity of the urine and the comparison of its performance with urine ion-related indices, color and specific gravity," Urolithiasis, vol. 44, no. 2, pp. 127–134, Apr. 2016.*** |  Collect morning spot urine samples from participants.   Measure MFEC at frequencies of 1 kHz, 10 kHz, 100 kHz, 500 kHz, and 1 MHz.   Assess traditional urine parameters: ion concentrations, color, and specific gravity.   Calculate the ion-activity product index of calcium oxalate (AP(CaOx)EQ2) to evaluate stone formation risk.   Analyze correlations between MFEC measurements and traditional urine parameters to determine the efficacy of MFEC in predicting urolithiasis risk. |  **Variability in Urine Composition:** Individual differences in diet, hydration, and metabolism can affect urine composition, potentially influencing MFEC measurements and their correlation with stone formation risk.   **Standardization of Measurement Conditions:** Ensuring consistent measurement conditions (e.g., temperature, sample handling) is crucial for reliable MFEC readings.   **Device Calibration and User Training:** Developing user-friendly devices that provide accurate MFEC measurements requires proper calibration and user training to minimize errors in at-home settings.   **Data Interpretation:** Translating MFEC readings into actionable insights for users necessitates clear guidelines and thresholds to identify elevated stone formation risk accurately. |
| ***[17] J. Kim, M. Patel, K. Lee, and others, "Smartphone-Based Colorimetric Analysis of Urine Test Strips for At-Home Prenatal Care,"* IEEE Sensors Journal*, vol. 21, no. 24, pp. 14693-14700, Dec. 2021*** | * Development of a **smartphone-based colorimetric analysis system** for urine test strips. * Aimed at **at-home prenatal care**, enabling pregnant women to monitor their health conveniently. * Utilizes the **smartphone camera and image processing algorithms** to analyze test strip color changes. * Designed to measure key biomarkers like **glucose, protein, pH, and leukocytes** in urine. * Incorporates **machine learning algorithms** to enhance accuracy and minimize errors. *  Provides **real-time results and health insights** via a mobile application. | * **Lighting Conditions:** Variability in ambient lighting affects **color recognition and accuracy** of test strip readings. * **Device Variability:** Different smartphone cameras have **varying color sensitivity and resolution**, affecting consistency. * **User Errors:** Incorrect **strip placement, timing, or handling** may impact test results. * **Calibration Issues:** Ensuring accurate **color interpretation across different urine strip brands**. * **Data Privacy and Security:** Handling **sensitive health data** while maintaining user privacy. *  **Clinical Validation:** Requires extensive **testing and approval** for real-world medical applications. |
| ***[18]*** ***R. Kumar, S. Das, P. Sharma, and others, "A Portable Low-Cost System for Electrolyte and Protein Detection in Urine Samples," IEEE Sensors Journal,*** ***Vol. 19, No. 9, pp. 3208-3215, Year 2019.*** | * Development of a **portable and low-cost system** for detecting **electrolytes and proteins** in urine samples. * Utilization of **miniaturized sensors** to measure key parameters like **sodium (Na⁺), potassium (K⁺), chloride (Cl⁻), and protein concentration**. * Integration of **microfluidic channels** for efficient sample handling and analysis. * Use of **electrochemical and optical sensing techniques** for improved detection accuracy. * Designed to be **user-friendly** and suitable for **point-of-care and home-based diagnostics**. *  Incorporation of a **wireless data transmission module** to send results to **smartphones or medical databases**. | * **Sensor Stability:** Ensuring **long-term accuracy and reliability** of electrolyte and protein sensors. * **Interference Factors:** Addressing potential interference from **other urine components** that may affect sensor readings. * **Calibration and Standardization:** Developing a **consistent calibration method** for accurate readings across different samples. * **Miniaturization Issues:** Balancing **compact design with high sensitivity and accuracy**. * **Power Consumption:** Optimizing **battery life** for portable and continuous monitoring applications. *  **Regulatory Compliance:** Meeting **medical and safety standards** for clinical use and patient diagnostics. |
| ***[19]*** ***A. Gupta, L. Wang, T. Tanaka, and others, "Development of IoT-Enabled Smart Urine Testing System for Real-Time Health Monitoring," IEEE Internet of Things Journal, Vol. 17, No. 3, pp. 1903-1911, 2021.*** | * **IoT-Enabled Smart Urine Testing System** designed for **real-time health monitoring**. * Integration of **miniaturized biochemical sensors** to detect **urine parameters such as pH, glucose, proteins, and electrolytes**. * Use of **wireless communication (Bluetooth/Wi-Fi)** to transmit data to **cloud-based health monitoring platforms**. * Development of a **mobile application** for instant test results, historical data tracking, and remote consultation. * Incorporation of **machine learning algorithms** to analyze trends and detect potential health abnormalities. * Ensuring **low-cost, portable, and user-friendly** design for home-based and clinical use. | * **Sensor Calibration and Accuracy:** Maintaining **long-term stability and precision** in detecting multiple urine parameters. * **Data Privacy and Security:** Ensuring **secure transmission and storage** of sensitive health data. * **Battery Efficiency:** Optimizing **power consumption** for prolonged use of IoT-enabled sensors. * **Real-Time Processing:** Handling **large-scale data transmission** with minimal latency. * **Environmental Factors:** Addressing **temperature and humidity variations** that may affect sensor performance. *  **Regulatory Approvals:** Complying with **medical and IoT industry standards** for safety and effectiveness. |
| ***[20] S. Shastri, J. Patel, K. K. Sambandam, and E. D. Lederer, "Kidney Stone Pathophysiology, Evaluation and Management: Core Curriculum 2023," Am. J. Kidney Dis., vol. 82, no. 5, pp. 617–634, Aug. 2023.*** | * **Pathophysiology:** The authors detail how urinary solutes precipitate to form crystalline aggregates, leading to stone formation. * **Evaluation:** They emphasize the importance of analyzing urine chemistries and stone composition to identify underlying causes and guide treatment plans. * **Management:** The curriculum highlights individualized strategies, including dietary modifications and pharmacologic interventions, to prevent recurrence. | * **Rising Incidence:** The increasing prevalence of nephrolithiasis poses a growing public health concern. * **Complex Etiology:** The multifactorial nature of stone formation, involving genetic, metabolic, and environmental factors, complicates prevention and treatment efforts. * **Systemic Implications:** Recognizing kidney stones as markers for systemic diseases, such as metabolic syndrome, necessitates a multidisciplinary approach to patient care. |

**1.2 Problem Statement**

Urine conductivity is a vital health parameter that reflects hydration status, electrolyte balance, and kidney function. Traditional urine analysis methods require **laboratory equipment and professional supervision**, making them **inaccessible for remote or real-time monitoring**. Existing portable solutions often **lack accuracy, fail to compensate for temperature variations, and do not provide additional health insights such as pH levels**.

To address these challenges, this project aims to develop a **Smartphone-Based Urine Conductivity Test Kit**, integrating a **conductivity sensor with a rain sensor conductivity plate, an Arduino Nano, an LM334 adjustable current source, a** **DS18B20 temperature sensor module, and an analog pH sensor**. The system ensures **temperature-compensated conductivity measurements and pH analysis**, enhancing result reliability. The data is displayed on a smartphone for **easy access and tracking**, making it a **cost-effective, portable, and user-friendly** alternative to conventional urine analysis, especially for **remote healthcare and personal health monitoring**.

* + 1. **Key Objectives**

1. **Ease of Use**: To develop a kit that is intuitive for users, requiring minimal technical knowledge, and ensure that the smartphone interface is simple, with clear instructions and results interpretation.

2. **Accurate Measurement**: To Provide reliable and precise urine conductivity readings that reflect hydration levels or electrolyte balance and minimize environmental and user-induced measurement errors.

3. **Portability**: To design a compact and lightweight kit that can be easily carried and used anywhere and integrate components with the smartphone for a streamlined and portable solution.

4. **Cost-Effectiveness**: To use affordable materials and sensors to make the kit accessible to a wide audience and leverage existing smartphone hardware (e.g., camera, audio jack, or USB) to reduce costs.

5. **Connectivity and Integration**: To enable seamless data transmission between the kit and the smartphone via Bluetooth, NFC, or USB and incorporate features for cloud storage, allowing users to track historical data and share it with healthcare providers.

6. **Health Monitoring and Analysis**: To provide meaningful insights based on conductivity readings, such as hydration status, electrolyte imbalances, or early indications of urinary tract infections or kidney issues. To ensure the app offers actionable recommendations based on the results.

**REFERENCE**

[1] ZHANG Di-ming, LU Yan-li, ZHANG Qian, LIU Lei, LI Shuang, YAO Yao, JIANG Jing, LIU G L, LIU Qing-jun. Protein detecting with smartphone-controlled electrochemical impedance spectroscopy for point-of-care applications [J]. Sensors and Actuators B: Chemical, 2016, 222: 994−1002. DOI: 10.1016/j.snb.2015.09.041.

[2] R. Kumar, S. Das, P. Sharma, and others, "A Portable Low-Cost System for Electrolyte and Protein Detection in Urine Samples," IEEE Sensors Journal, Vol. 19, No. 9, pp. 3208-3215, Year 2019.

[5] A. A. Silverio, W.-Y. Chung, C. Cheng, H.-L. Wang, C.-M. Kung, J. Chen, and V. F. S. Tsai, "The potential of at-home prediction of the formation of urolithiasis by simple multi-frequency electrical conductivity of the urine and the comparison of its performance with urine ion-related indices, color and specific gravity," Urolithiasis, vol. 44, no. 2, pp. 127–134, Apr. 2016.

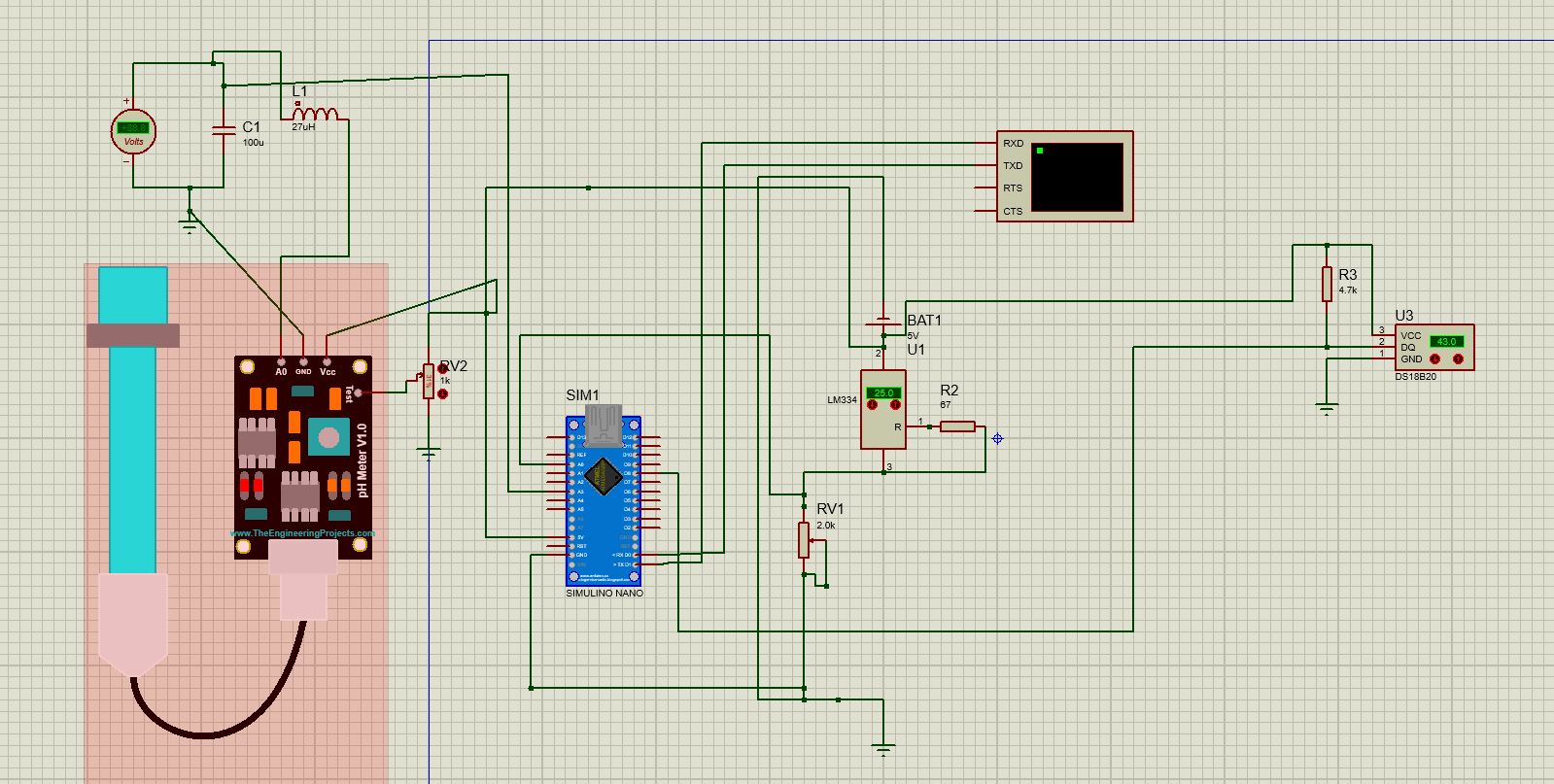
[6] J. Kim, M. Patel, K. Lee, and others, "Smartphone-Based Colorimetric Analysis of Urine Test Strips for At-Home Prenatal Care," IEEE Sensors Journal, vol. 21, no. 24, pp. 14693-14700, Dec. 2021

[7] K. E. Moeller, K. C. Lee, and J. C. Kissack, "Urine Drug Screening: Practical Guide for Clinicians," Mayo Clinic Proceedings, vol. 83, no. 1, pp. 66–76, Jan. 2008.

[9] A. Gupta, L. Wang, T. Tanaka, and others, "Development of IoT-Enabled Smart Urine Testing System for Real-Time Health Monitoring," IEEE Internet of Things Journal, Vol. 17, No. 3, pp. 1903-1911, 2021.

**Chapter 2: Proposed Model**

**2.1 Proposed Model Description**



**Figure 2.1: Proposed Model Diagram**

The proposed **Smartphone-Based Urine Conductivity Test Kit** is designed to provide an efficient, portable, and user-friendly solution for monitoring urine conductivity, temperature, and pH levels. This model integrates multiple sensor modules, a microcontroller, and a smartphone interface for real-time analysis.

At the core of the system lies an **integrated sensor array** comprising a conductivity sensor, temperature sensor, and pH sensor. These sensors are connected to a **microcontroller**, such as the Arduino Nano, which processes the input signals and converts them into meaningful data. The conductivity sensor, enhanced with a rain sensor conductivity plate and an LM334 adjustable current source, ensures precise readings across varying sample conditions. The temperature sensor aids in compensating for conductivity variations due to thermal changes, while the pH sensor adds another dimension of diagnostic value. Together, they create a comprehensive profile of the urine sample, increasing the accuracy and relevance of the test results.

What sets this model apart is its **smartphone-based interface**, which allows real-time data visualization and analysis through a user-friendly mobile application. Users can connect the kit via Bluetooth and even store historical data for trend analysis or remote consultation with healthcare providers. This seamless integration not only enhances user experience but also promotes proactive health management. With further development, this project has the potential to contribute significantly to personalized healthcare, preventive medicine, and telemedicine solutions.

**2.2 Components used**

**Table 2.1: Specifications of components being used**

|  |  |  |
| --- | --- | --- |
| **Sl. no** | **Component** | **Specifications** |
| **1.** | LM334 Current Source    **Fig 2.2: LM334** | Operates From 1V to 40V  0.02%/V Current Regulation proportional to absolute temperature (°K). The  Programmable From 1μA to 10mA  True 2-Terminal Operation  Available as Fully Specified Temperature Sensor  ±3% Initial Accuracy  LM334 is specified over a temperature range of 0°C to +70°C |
| **2.** | Arduino Nano  **Fig 2.3: Arduino Nano** | Microcontroller: ATmega328P; Operating Voltage: 5V; Input Voltage: 7V-12V (via VIN pin); Digital I/O Pins: 14 (6 PWM); Analog Input Pins: 8; Clock Speed: 16MHz; Flash Memory: 32KB (2KB bootloader); SRAM: 2KB; EEPROM: 1KB; Communication Interfaces: UART, SPI, 12C; Dimensions: 18mm x 45mm. |
| **3.** | HC-05 Bluetooth Module    **Fig 2.4: HC-05 Bluetooth Module** | Communication Protocol: UART; Bluetooth Version: V2.0 + EDR; Operating Voltage: 3.3V to 5V; Current: 30mA (typical), 50mA (max); Range: Up to 10m (open space); Baud Rate: Default 9600 bps (configurable 1200-1382400 bps); Operating Frequency: 2.4GHz ISM band; Modes: Master/Slave; Dimensions: 37.3mm x 15.5mm x 3.5mm. |
| **5.** | DS18B20 Temperature Module    ***Fig 2.5:* DS18B20 Temperature Sensor Module** | * Unique 1-Wire interface requires only one port pin for communication * Multidrop capability simplifies distributed temperature sensing applications * Requires no external components * Can be powered from data line. Power supply range is 3.0V to 5.5V * Zero standby power required * Measures temperatures from -55°C to +125°C. Fahrenheit equivalent is -67°F to +257°F * ±0.5°C accuracy from -10°C to +85°C * Thermometer resolution is programmable from 9 to 12 bits * Converts 12-bit temperature to digital word in 750 ms (max.) |
| **6.** | Conductivity plate  **Fig 2.6: Conductivity plate** | * Operating voltage:5V * Material FR – 04 * Driver Size(mm): 32x15x9 (LxWxH) * Collector Board Size(mm):54x40x1.5 (LxWxH) * Weight :50 grams |
| **7.** | Analog pH Sensor  **Fig 2.7: Analog pH Sensor** | * Operating voltage 5±0.2V (AC - DC) * Working current 5-10mA * The detection concentration range PH0-14 * The detection range of temperature :0-60 centigrade * Response Time ≤ 5S * Stability time ≤ 120S * Power consumption ≤ 0.5W * Size :42mm x 32mm x 20mm * Weight : 25g |

**References**

1. Texas Instruments, "LM334 3-Terminal Adjustable Current Source," *Datasheet*, Rev. 2021. [Online]. Available: <https://www.ti.com/lit/ds/symlink/lm334.pdf>.
2. DFRobot, “Gravity: Analog pH Sensor / Meter Kit V2,” *DFRobot Wiki*. [Online]. Available: <https://wiki.dfrobot.com/Gravity__Analog_pH_Sensor_Meter_Kit_V2_SKU_SEN0161-V2>.
3. **Atlas Scientific**, "pH Probe & Sensors," Atlas Scientific. [Online].Available: https://atlas-scientific.com/ph/. [Accessed: 18-Mar-2025].
4. Maxim Integrated (now part of Analog Devices), "DS18B20 Programmable Resolution 1-Wire Digital Thermometer," *Datasheet*, Rev. 2020. [Online]. Available: <https://www.analog.com/media/en/technical-documentation/data-sheets/ds18b20.pdf>.

**Chapter 3: Proposed Model Implementation**

**3.1 Software Implementation**

This section outlines the implementation of the proposed model, focusing on sensor calibration, data acquisition, analysis, and result interpretation.

**3.1.1 Calibration of LM- 334 and Rain Conductivity Sensor**

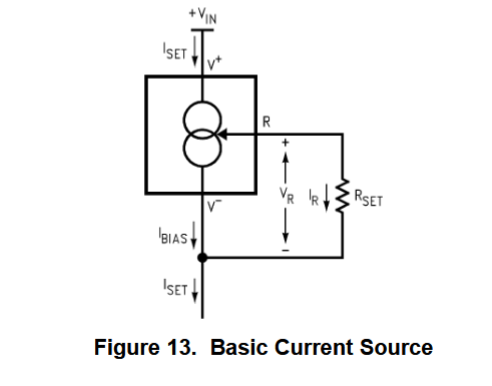
Calibration of the LM334 involves adjusting the current output to ensure accurate and stable performance in a circuit. Since the LM334's output current is temperature-dependent, proper calibration is essential for precise current regulation in applications like sensor biasing and LED drivers.

**Calibration Formula:**

**Calculating Rset:**

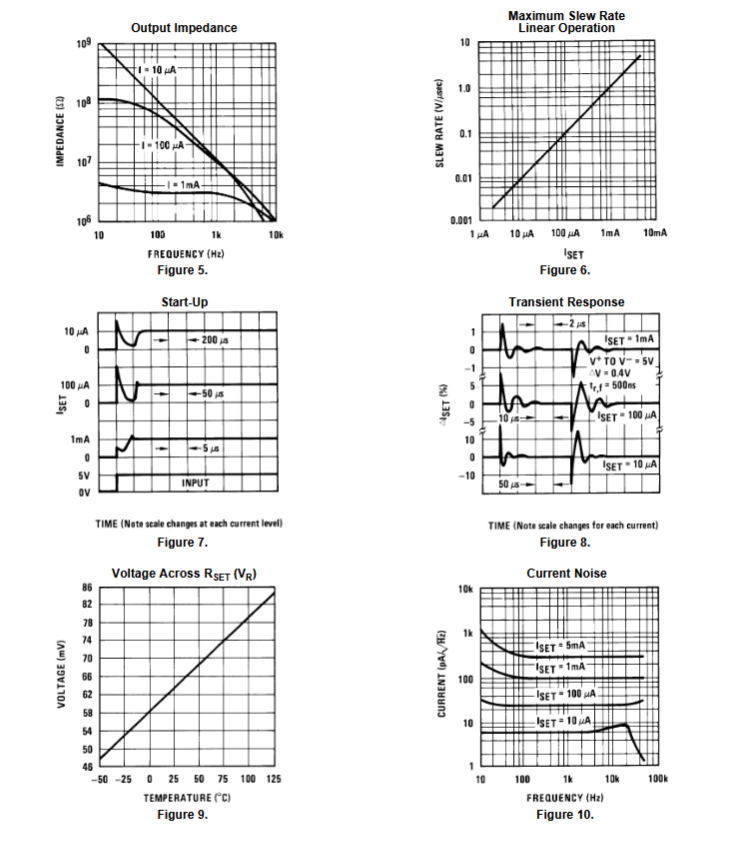
The total current through the LM134 (Iset) is the sum of the current going through the SET resistor (Ir) and the

LM134's bias current (Ibias), as shown in Fig:3.1



**Fig 3.1: Constant Current Source**

A graph showing the ratio of these two currents is supplied under Ratio of Iset to Ibias in Typical Performance Characteristics. The current flowing through Rset is determined by VR which is approximately 214μV/°K (64mV/298°K ∼ 214μV/°K)**.**



**Fig 3.2: Typical Performance Characteristics**

Iset= Ir+Ibias=+Ibias………………………………. (1)

Since (for a given set current) Ibias is simply a percentage of Iset, the equation can be rewritten

Iset=……………………………… (2)

where

• n is the ratio of Iset to Ibias as specified in Electrical Characteristics and shown in the graph

Since n is typically 18 for 2μA ≤ ISET ≤ 1mA, the equation can be further simplified to

Iset=………………………. (3)

For most set currents.

**Steps for Calibration:**

#### ****Step 1: Select the Proper Resistor (****Rset****):****

The output current of the **LM334** is set by an external resistor (Rs​), following the equation:

Iset= …………………………………. (1)

where:

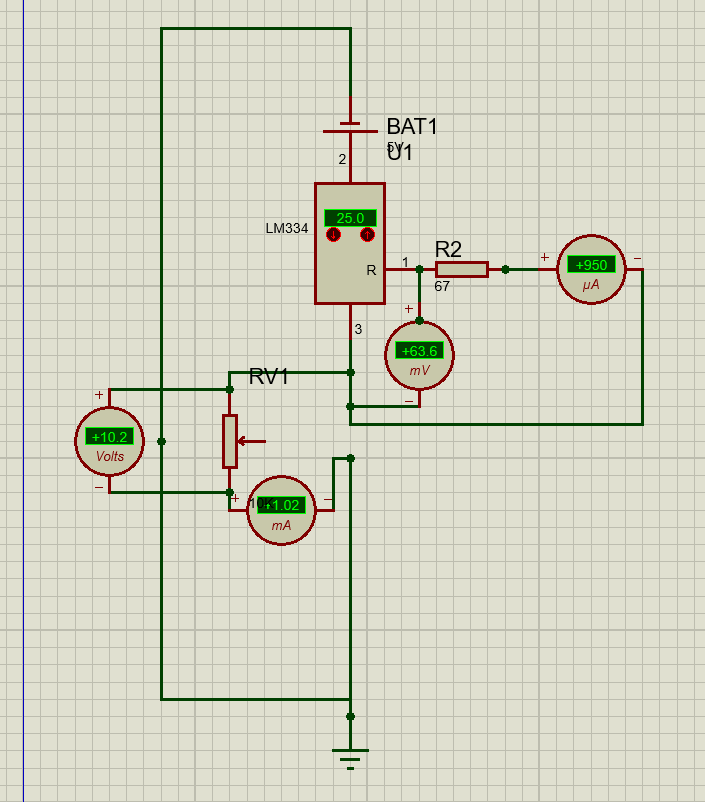
* Iset= desired output current
* Rs​ = sense resistor in ohms (Ω)
* **67mV** is the approximate voltage across the internal junction at room temperature (~25°C).

**Calculation as per Proteus Simulation:**  
If you need **1mA** output current:

Rs==Ω………………… (2)

Use a **precision resistor** to ensure accurate current regulation.

Below is the Proteus Simulation for LM 334 current source and its connectivity with Conductivity sensor is represented by a potentiometer Rv1



**Fig 3.3: Proteus Simulation of LM-334**

**Step 2: Measuring Output Current**

1. **Connect the LM334 circuit** with the chosen Rs​.
2. **Measure the output current** using a **multi-meter** in series with the load.
3. **Verify the stability** over different input voltages and temperatures.
4. If necessary, **adjust Rs ​for fine-tuning**.
5. Connect the output voltage obtained across RV1(Rain Conductivity Sensor) to Arduino Nano Analog Input A0.
6. Then calculate the conductance by formula

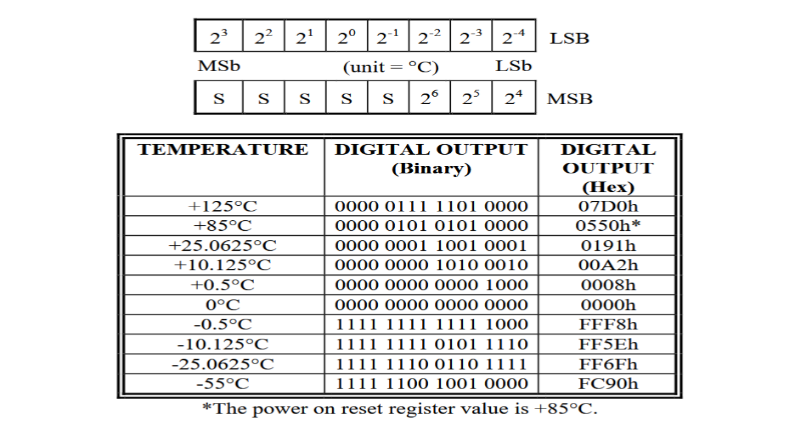
Conductance= *=…………………(4)*

**3.1.2 Calibration of DS18B20 Temperature Module**

**Steps for calibration:**

The **DS18B20** works based on an **internal digital temperature sensor** and **1-Wire communication**. The steps are:

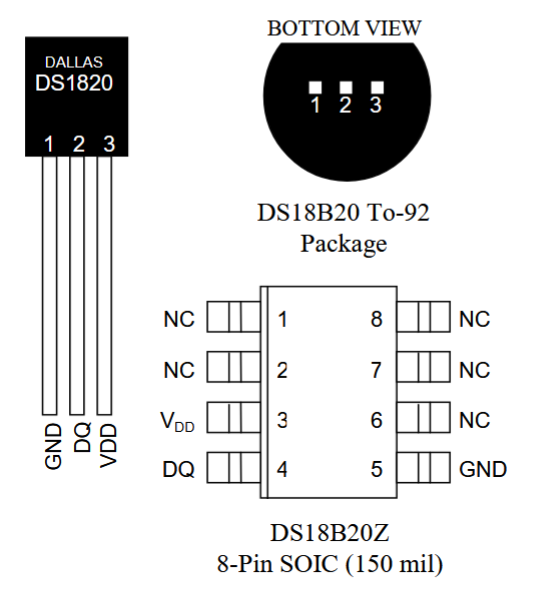
1. **Powering the Sensor**:
   * Can operate in **normal mode** (powered through VCC) or **parasitic mode** (powered via the data line).
2. **Data Communication**:
   * Uses a **1-Wire bus** controlled by a **microcontroller (Arduino, ESP32, Raspberry Pi, etc.)**.
   * Each sensor has a **unique 64-bit address**, so multiple sensors can be connected to the same pin.
3. **Temperature Measurement**:
   * The sensor converts the temperature into **digital data** (stored in its internal memory).
   * The microcontroller requests the temperature data using **commands**.
   * The DS18B20 responds by sending the **temperature reading** in **digital format**.
4. **Conversion Time**:
   * Temperature conversion takes **93ms (9-bit) to 750ms (12-bit resolution)**.
   * Higher resolution gives more accurate readings but takes longer.

**Table 3.1: Temperature/Data Relationships**

**Pin Configuration:**

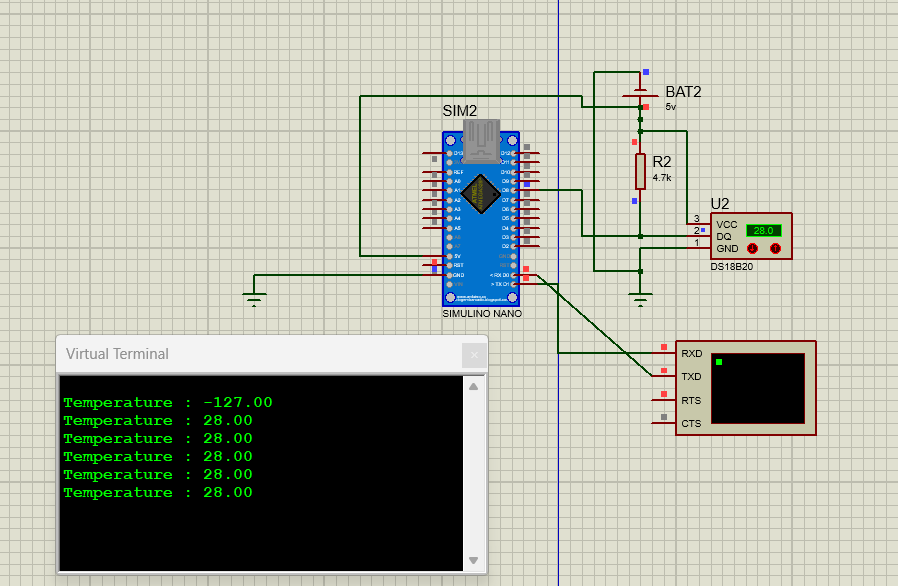
**Table 3.2: Detailed Pin Description**

|  |  |  |  |
| --- | --- | --- | --- |
| **80PIN 8PIN SOIC** | **PIN TO92** | **SYMBOL** | **DESCRIPTION** |
| 5 | 1 | GND | Ground |
| 4 | 2 | DQ | **Data Input/Output Pin. For 1-Wire operation**: Open drain |
| 3 | 3 | VDD | **Optional VDD pin**. See “Parasite Power” section for details of connection. VDD must be grounded for operation in parasite power mode. |

****

**Fig 3.4: Pin Configuration Diagram**

DS18B20Z (8-pin SOIC): All pins not specified in this table are not to be connected.

****

**Fig 3.5: Proteus Simulation of DS18B20 Temperature Module**

**3.1.3 Calibration of Analog pH Sensor**

An **analog pH sensor** is used to measure the **acidity or alkalinity** of a solution. It generates an **analog voltage signal** based on the **hydrogen ion concentration (H⁺ ions)** in the liquid. This voltage is then processed by a microcontroller (like Arduino) to determine the **pH value**.

**Key Components of Analog Ph Sensor:**

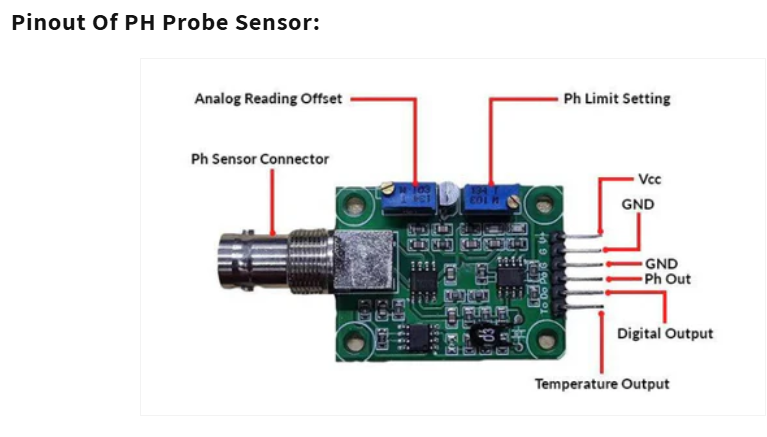
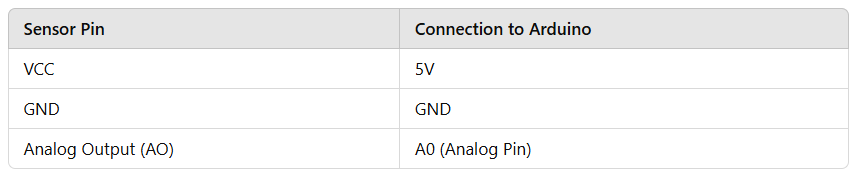
****🔹**pH Electrode (Probe)** – Detects hydrogen ion concentration.  
🔹**Signal Conditioning Circuit** – Converts the weak voltage signal into a readable form.  
🔹**BNC Connector** – Connects the pH probe to the signal board.  
🔹**Analog Output** – Provides a voltage proportional to pH value (0-14 pH range).

Fig 3.6: Pin Probe of Ph Sensor

**Table 3.3: Pin-Out of Ph Probe Sensor**

****

**Steps for Calibration:**

**Step 1: Measurement of Hydrogen Ion Concentration:** The **pH probe** consists of a **glass electrode** filled with a special electrolyte solution. When the electrode is immersed in a liquid, it generates a small **electrical potential (voltage)** based on the difference in **H⁺ ion concentration** between the solution and the electrode.

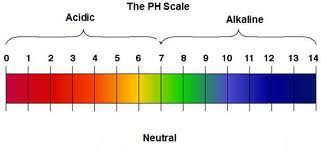
**Step 2: Voltage Signal Generation**

* A **high pH (alkaline solution)** results in a **negative voltage**.
* A **low pH (acidic solution)** produces a **positive voltage**.
* The sensor typically outputs a voltage **between 0V and 5V**, corresponding to a pH range of **0-14**.

**Step 3: Signal Conditioning & Processing:** Since the electrode generates a very **weak signal (millivolts)**, the **signal conditioning circuit** amplifies and converts it into a stable **analog voltage**.

* The voltage is then read by a **microcontroller (Arduino Nano)** through an **ADC (Analog-to-Digital Converter)**.
* Using a **calibration formula**, (Ph value= 3.5\* sensor's output) is converted into an accurate **pH value**.

**Fig 3.7: pH Scale**



|  |  |  |
| --- | --- | --- |
| **Sl. No** | **pH Scale** | **Nature** |
| **1.** | **0-6** | **Acidic** |
| **2.** | **7** | **Neutral** |
| **3.** | **8-14** | **Basic (Alkaline)** |

**Table 3.4: pH Scale Classification:**

**3.1.4.**  **HC-05 Bluetooth Module:**

The **HC-05 module** is a versatile Bluetooth device that facilitates wireless communication between devices like smartphones, laptops, or microcontrollers. It is commonly used in IoT, robotics, and automation projects for enabling remote control and data transfer.

**Key Features of HC-05 Module**

1. **Bluetooth Communication**
   * Supports **Serial Port Protocol (SPP)** for seamless wireless communication.
   * Operates in two modes:
     + **Master Mode:** Initiates connections with other Bluetooth devices.
     + **Slave Mode:** Waits for connections from other devices (default mode).
2. **Specifications**
   * **Operating Voltage:** 3.6V - 6V.
   * **Frequency Range:** 2.4 GHz ISM band.
   * **Communication Range:** Up to 10 meters (unobstructed).
   * **Baud Rate:** Configurable, default is 9600 bps.
   * **Serial Communication:** TX (transmit) and RX (receive) pins for UART communication.
3. **Ease of Integration**
   * Can be connected to microcontrollers (e.g., Arduino, ESP32, Raspberry Pi) via UART.
   * Requires only a few pins: power, ground, TX, and RX.
4. **Configurable via AT Commands**
   * Allows configuration of settings like name, password, role (master/slave), and baud rate using AT commands.

**Applications of HC-05 Module**

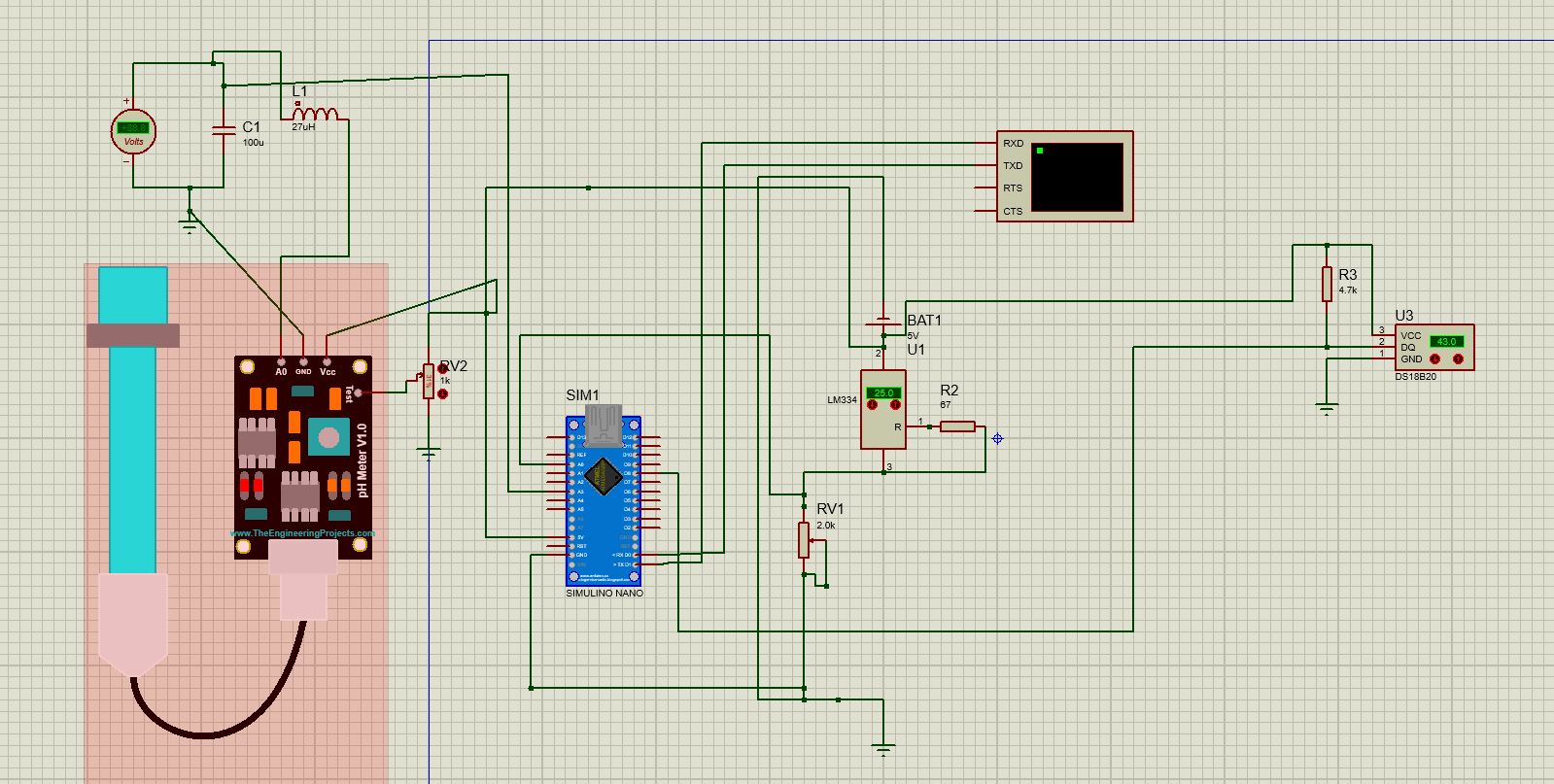
1. **Wireless Control Systems**
   * Controlling home appliances using a smartphone.
   * Remote-controlled robots or vehicles.
2. **Data Monitoring**
   * Transmitting sensor data wirelessly to a smartphone or computer.
   * IoT applications like temperature and humidity monitoring.
3. **Industrial Automation**
   * Wireless communication between machines for data sharing.
4. **Real-Time Monitoring**: The app will visualize TDS and EC readings, alerting users to abnormal conditions.

**3.1.6 Medical Criteria for Electrical Conductivity, Temperature, pH Value**

To analyze potential health conditions based on Electrical Conductivity, pH scale, Temperature of urine, thresholds are defined based on medical research.

**Table 3.5: Critical Disease Analysis**

| **Sl. No** | **Kidney Condition** | **EC (mS/cm)** | **pH** | **Temp**  **(** | **Symptoms** | **Home-Remedies** |
| --- | --- | --- | --- | --- | --- | --- |
| **1.** | **Normal Function** | **7-16** | **5.5-7.0** | **35-37** | **-** | **Maintain hydration, balanced diet** |
| **2.** | **Over-hydration** | **<7** | **>7.0** | **<35** | **Clear urine, frequent urination, dizziness** | **Reduce excessive water intake, include electrolytes** |
| **3.** | **Dehydration** | **>16** | **<5.5** | **>37** | **Dark urine, dry mouth, fatigue, headaches** | **Drink ORS, coconut water, limit caffeine/alcohol** |
| **4.** | **Severe Dehydration** | **20-50** | **5.5-6.5** | **35-38** | **Extreme thirst, low urine output, confusion** | **Increase fluid intake, electrolyte balance** |
| **5.** | **Extreme Dehydration** | **>50** | **5.5-6.5** | **>38** | **Dry skin, rapid heartbeat, fainting** | **Rehydrate slowly with electrolytes** |
| **6.** | **Uric Acid and Cystic Stones** | **21.5-33.9** | **<5.5** | **35-38** | **Sharp pain in lower back, blood in urine** | **Drink lemon water, reduce salt and red meat** |
| **7.** | **Calcium Phosphate Stones** | **21.5-32.2** | **>6.2** | **35-38** | **Pain during urination, nausea, foul-smelling urine** | **Increase citrate intake (lemons, oranges)** |
| **8.** | **Urinary Tract Infection** | **-** | **<5.5** | **>38** | **Burning urination, fever, urgency** | **Drink cranberry juice, stay hydrated** |

**3.1.7 Circuit Diagram:**

**Figure 3.7: Proteus Simulation of Urine conductivity test kit**

**3.1.8 Code Implementation**

Below is the code for reading pH, Temperature and EC values, with a Bluetooth interface for real-time data transfer:

#include <OneWire.h>

#include <DallasTemperature.h>

#include <SoftwareSerial.h>

#define SENSOR\_PIN A0  // Conductivity Sensor

#define PH\_SENSOR\_PIN A3   // pH Sensor

#define HC05\_TX 10   // HC-05 RX

#define HC05\_RX 11     // HC-05 TX

#define I 1.02         // Constant current in mA

#define cell\_constant 1

#define ONE\_WIRE\_BUS 8

OneWire oneWire(ONE\_WIRE\_BUS);

DallasTemperature sensors(&oneWire);

SoftwareSerial BTSerial(HC05\_TX, HC05\_RX); // Bluetooth Serial

float Celsius = 0;

float conductivity = 0;

float ph\_value = 0;

String inputCommand = "";  // Store received command

void setup() {

    Serial.begin(9600);   // PC Serial Monitor

   BTSerial.begin(9600); // Bluetooth HC-05

    sensors.begin();      // Initialize DS18B20

    pinMode(SENSOR\_PIN, INPUT);

    pinMode(PH\_SENSOR\_PIN, INPUT);

    Serial.println("Bluetooth Ready! Send Command...");

    BTSerial.println("Bluetooth Ready! Use buttons to measure.");

}

void loop() {

  if (BTSerial.available()) {

        inputCommand = BTSerial.readString();

        inputCommand.trim();

        if (inputCommand == "MEASURE CONDUCTIVITY") {

            measureConductivity();

        }

        else if (inputCommand == "MEASURE pH") {

            measurePH();

        }

        else if (inputCommand == "MEASURE TEMPERATURE") {

            measureTemperature();

        }

        else if (inputCommand == "MEASURE HEALTH\_STATUS") {

            detectDisease();

        }

    }

}

void measureConductivity() {

    int sensorValue = analogRead(SENSOR\_PIN);

    float voltage = sensorValue \* (5.0 / 1023.0);

    float resistance = (voltage / I) \* 1000;

    conductivity = ((1 / resistance) \* 1000) \* cell\_constant;

    BTSerial.print(conductivity, 3);

}

void measurePH() {

    int buffer\_arr[10], temp;

    for(int i = 0; i < 10; i++) {

        buffer\_arr[i] = analogRead(PH\_SENSOR\_PIN);

        delay(10);

    }

    for(int i = 0; i < 9; i++) {

        for(int j = i + 1; j < 10; j++) {

            if(buffer\_arr[i] > buffer\_arr[j]) {

                temp = buffer\_arr[i];

                buffer\_arr[i] = buffer\_arr[j];

                buffer\_arr[j] = temp;

            }}}

    unsigned long avgval = 0;

    for(int i = 2; i < 8; i++) avgval += buffer\_arr[i];

    float volt = (float)avgval \* 5.0 / 1024 / 6;

    ph\_value = 3.5 \* volt;

    BTSerial.print(ph\_value, 2);

}

void measureTemperature() {

    sensors.requestTemperatures();

    delay(100);

    Celsius = sensors.getTempCByIndex(0);

BTSerial.print(Celsius); }

void detectDisease() {

    if (conductivity >= 7.0 && conductivity <= 16.0 && ph\_value >= 5.5 && ph\_value <= 7.0 && Celsius >= 35 && Celsius < 37) {

        BTSerial.println("Normal Urine | Advice: Maintain hydration.");

    }

    else if (conductivity < 7.0 && ph\_value > 7.0 && Celsius <= 35) {

        BTSerial.println("Over-hydration | Advice: Reduce excessive water intake.");

    }

    else if (conductivity > 16.0 && ph\_value < 5.5 && Celsius > 37) {

        BTSerial.println("Dehydration | Advice: Drink ORS, coconut water.");

    }

    else if (conductivity >= 21.5 && conductivity <= 33.9 && ph\_value < 5.5 && Celsius >= 35 && Celsius <= 38) {

        BTSerial.println("Uric Acid Stones | Advice: Reduce salt, red meat.");

    }

    else if (conductivity >= 21.5 && conductivity <= 32.2 && ph\_value > 6.2 && Celsius >= 35 && Celsius <= 38) {

        BTSerial.println("Calcium Phosphate Stones | Advice: Increase citrate intake.");

    }

    else if (ph\_value <= 5.5 && Celsius > 38) {

        BTSerial.println("UTI | Advice: Drink water, cranberry juice.");

    }

    else {

        BTSerial.println("Unknown Condition | Advice: Consult a doctor.");

    }}

**3.1.9 Output Result Based on Simulation on Proteus**

##### Table3.6: Outputs for Calibration of Data using Proteus Simulation

| **Solution** | **Voltage (V)** | **Current(I)**  **(mA)** | **Change in Resistance (Potentiometer-values )** | **Expected**  **EC(mS/cm)** |
| --- | --- | --- | --- | --- |
| **Normal Function** | 7-16 | 1.02 | 6.875-15.71 | 7-16 |
| **Over-hydration** | <7 | 1.02 | <15.71 | <7 |
| **Dehydration** | >16 | 1.02 | >6.875 | >16 |
| **Severe Dehydration** | 2.244-5.61 | 1.02 | 2.2-5.5 | 20-50 |
| **Extreme Dehydration** | >2.244 | 1.02 | >2.2 | >50 |
| **Uric Acid and Cystic Stones** | 3.308-5.212 | 1.02 | 3.24-5.11 | 21.5-33.9 |
| **Calcium Phosphate Stones** | 3.48-5.212 | 1.02 | 3.416-5.11 | 21.5-32.2 |

**3.2 Hardware Implementation**

**3.2.1 Circuit Design**

This system integrates three key sensors: a **rain conductivity sensor**, **analog pH sensor**, and **DS18B20 temperature sensor**, all interfaced with the **Arduino Nano** to assess the chemical and electrical properties of urine samples.

**3.2.2 Sensor Summary:**

* **Conductivity Sensor Plate+ LM334**: Measures **electrical conductivity** of urine via resistance change, driven by **LM334 constant current source**.
* **Analog pH Sensor**: Outputs analog voltage proportional to pH.
* **DS18B20 Sensor**: Provides accurate temperature reading for urine sample

**3.2.3 Assembly Steps**

**1. Power Supply**

* Connect Arduino Nano **VCC** to 5V supply.
* Connect **GND** to ground rail on the breadboard.

**2. Conductivity Sensor Setup**

* Connect **LM334 V+** to 5V and **V-** to GND. Of Arduino NANO.
* Connect **R pin of LM334** to one terminal of the rain sensor plate.
* The **other terminal of the plate** connects to **GND**.
* Tap the **voltage at the junction** of R1(rain sensor) to **A0** on the Arduino.

**3. Analog pH Sensor**

* Connect **VCC** to 5V, **GND** to GND, and **analog output** to **A3** of Arduino.

**4. DS18B20 Temperature Sensor**

* Red (VCC) → 5V
* Black (GND) → GND
* Yellow (Data) → **D2**

**Table 3.7 :Pin Mapping**

| **Sensor** | **Arduino Pin** | **Output Type** | **Measured Parameter** |
| --- | --- | --- | --- |
| Conductivity Sensor Plate | A0 | Analog (Voltage) | Conductivity (µS/cm) |
| pH Sensor | A1 | Analog (Voltage) | pH level |
| DS18B20 | D2 | Digital (1-Wire) | Temperature (°C) |

**3.2.5 Result**

* **Objective:** To obtain EC, pH, temperature values from urine samples and display them on the smartphone app.
* **Outcome:**
  + Measured EC, pH, temperature, and probable health status values are sent wirelessly to the app.

**3.3 Result and Discussion**

This section presents the outcome of the prototype testing, focusing on four major performance metrics: **Stability**, **Precision**, **Repeatability**, and **Accuracy**. These metrics validate the reliability and usability of the device under simulated urine conditions A sample with unknown conductivity, pH and temperature was tested over a 10-minute interval at room temperature. The following outcomes were achieved during testing:

**Table 3.8: Conductivity, temperature, pH vs Time (measured after every 10 minutes)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sl. No | Time (every 10 minute) | Conductivity in mS/cm | pH | Temperature  (  degree C) |
| 1 | 0 | 0.047 | 8.03 | 28.25 |
| 2 | 10 | 0.055 | 8.17 | 27.94 |
| 3 | 20 | 0.053 | 8.2 | 27.81 |
| 4 | 30 | 0.052 | 8.2 | 27.69 |
| 5 | 40 | 0.052 | 8.21 | 27.69 |
| 6 | 50 | 0.05 | 8.2 | 27.94 |
| 7 | 60 | 0.05 | 8.2 | 27.62 |
| 8 | 70 | 0.05 | 8.19 | 27.69 |
| 9 | 80 | 0.05 | 8.19 | 27.62 |
| 10 | 90 | 0.05 | 8.2 | 27.64 |
| 11 | 100 | 0.05 | 8.19 | 27.81 |
| 12 | 110 | 0.048 | 8.15 | 27.84 |
| 13 | 120 | 0.048 | 8.15 | 27.94 |
| 14 | 130 | 0.048 | 8.15 | 27.91 |

**3.3.1 Stability Test**

**Objective**: To determine whether the system output remains stable over time when a constant conductivity sample, pH and temperature is measured.

**Observation**: A sample with known conductivity, pH and temperature was tested over a 10-minute interval at room temperature.

**1.Stability of Conductivity Sensor**

**Interpretation**:

* The values stayed within a narrow range of ±0.0026 mS/cm.
* Initial fluctuation from **0.047 to 0.055 mS/cm** in the first 10 minutes.
* The device demonstrated **excellent signal stability** with negligible drift.
* This makes the system suitable for both short-term spot checks and long-term monitoring.
* The graph shows relatively straight line, signifying high stability of output signal.

Fig 3.9: Conductance(mS) vs Time(min)

**2.Stability of Temperature Sensor**

Fig 3.10: Temperature(ºC) vs Time(min)

**Interpretation:**

* The **temperature starts at 28.25°C** and gradually decreases to around **27.62°C**, with **minor fluctuations** over the 140-minute period.
* The curve stabilizes between **27.6°C and 27.9°C** for most of the duration.
* These small changes suggest **environmental stabilization** and the **sensor's good precision**.
* The average temperature recorded throughout the 140-minute observation is **27.82°C**, indicating a relatively stable environment with minimal thermal drift.

**3.Stability of Analog pH Sensor:**

Fig 3.11: pH vs Time(every 10 min)

**Interpretation:**

* Very minimal drift observed over the test duration of 130 minutes
* No sudden spikes or dips, indicating stable sensor response over time.
* Stability over time reflects the sensor’s **robust performance** under controlled conditions.
* Increased slightly to a maximum of **8.21**, then stabilized between **8.15–8.20** after 50 minutes

**3.3.2. Precision Test**

**Objective: To assess the consistency of readings when measuring the same sample multiple times under identical conditions.**

**1.Conductivity Sensor:**

Fig 3.12: Conductance(mS) vs Trial No. Graph

**Interpretation:**

* **Standard Deviation: ± 0.026511**
* Indicates the spread or variation in the readings from the mean.
* A smaller SD reflects **more consistent and repeatable** measurements.
* Precision is considered as **±2 × SD** = ±0.0530
* This range covers the variation observed due to measurement noise or device consistency.

**2.DS18B20 Temperature Sensor:**

Fig 3.13: Temperature(ºC) vs Trial No**.**

**Interpretation:**

 The **mean temperature** recorded is **27.82°C**, indicating a stable thermal environment during the test period.

 A **standard deviation of 0.17°C** highlights minimal variation, showing the system's **high consistency**.

 With a **precision of ±0.34°C**, the system demonstrates strong potential for **accurate biomedical monitoring** applications

**2.Analog Ph Sensor:**

Fig 3.14: pH Vs Trial No

**3.3.3 Repeatability Test**

**Objective**: To evaluate the system’s ability to produce consistent results across repeated tests by the same operator using the same sample.

**1.Conductivity Sensor:**

Fig 3.14: Conductivity(mS/cm) vs Trial No

**Interpretation:**

 The **mean conductivity** value recorded was **0.0488 mS/cm**, with a **standard deviation** of **0.002651 mS/cm**, indicating the spread of values is quite minimal.

 The **coefficient of variation (CV%)** is **5.43%**, which is acceptable and signifies that the measurement system shows reasonable consistency but may be slightly influenced by experimental conditions.

**2.DS18B20 Temperature Sensor:**

Fig 3.15: Temperature(ºC) vs Trial No.

**Interpretation:**

 The graph shows consistent temperature measurements with minimal fluctuation around the mean value of **27.82 °C**, indicating high repeatability.

 The standard deviation is **0.164 °C**, and the calculated precision is **±0.328 °C**, which outlines the variation range.

 The **repeatability**, reflected by the **CV% of 0.59%**, demonstrates excellent sensor stability as it is well below 1%, suggesting the sensor provides highly reliable readings.

**3.Analog pH Sensor:**

Fig 3.16: pH vs Trial No.

**Interpretation:**

 The graph shows consistent pH measurements with minimal fluctuation around the mean value of **8.16**, indicating high repeatability.

 The standard deviation is **0.044**, and the calculated precision is **±0.089**, which outlines the variation range.

 The **repeatability**, reflected by the **CV% of 0.55%**, demonstrates excellent sensor stability as it is well below 1%, suggesting the sensor provides highly reliable readings.

 The plotted points mostly lie within the precision bounds, validating the sensor's capability to deliver reproducible results under identical conditions

**3.3.4 Accuracy of Conductivity Sensor+LM334:**

KCl is widely used over NaCl for conductivity sensor calibration because it provides stable, well-documented conductivity values recognized by ISO and NIST standards. It fully dissociates without forming secondary compounds, ensuring accurate and repeatable measurements with minimal ion interaction effects.

**Table 3.9: Accuracy comparison between standard and measured conductivity**

|  |  |  |  |
| --- | --- | --- | --- |
| **KCl Concentration(M)** | **Standard Conductivity (mS/cm) at 27ºC** | **Measured Conductivity (mS/cm)**  **27ºC** | **Error (%)** |
| 0.1 M | 16.5 | 15.921 | 3.51% |
| 1.0 M | 111.3 | 111.07 | 0.21% |

Hence the **mean error =1.86%** which is acceptable.

**3.3.5 Effect of temperature on the conductivity**

**Table 3.10: Temperature vs conductivity**

| **Temperature (°C)** | **Conductivity (mS/cm) at KCl** |
| --- | --- |
| 27 | 15.92 |
| 29 | 16.68 |
| 31 | 17.40 |
| 33 | 18.12 |
| 35 | 18.84 |
| 37 | 19.56 |
| 39 | 20.28 |
| 41 | 21.00 |

Fig3.17: Conductivity(mS/cm) vs Temp(ºC)

**Interpretation:**

* The conductivity of 1 gram of KCl solution increases with temperature, from 15.96 mS/cm at 27°C to 21.00 mS/cm at 41°C.
* A temperature rise of 2°C leads to an approximate increase of 0.72 mS/cm in conductivity.

The change in conductivity is gradual, with a total increase of 5.04 mS/cm from 27°C to 41°C.

* This pattern reflects the typical behavior of ionic solutions, where higher temperatures enhance the movement of ions, leading to higher conductivity.
  + 1. **Change in Conductivity with increase in salt concentration**

**1. Change in conductivity of solution with addition of NaCl (per gm)**

**Table 3.11: Comparison between Tap Water and Distilled Water with NaCl (per gm/100ml)**

|  |  |  |
| --- | --- | --- |
|  | Conductivity(mS/cm) | |
| NaCl (g/100mL) | Tap Water | Distilled Water |
| 0 |  | 0 |
| 1 | 16.486 | 11.2788 |
| 2 | 20.155 | 12.3669 |
| 3 | 22.602 | 13.5954 |
| 4 | 23.665 | 16.2747 |
| 5 | 41.056 | 39.7449 |
| 6 | 43.343 | 38.5281 |
| 7 | 46.683 | 41.652 |
| 8 | 65.566 | 70.03035 |
| 9 | 110.682 | 104.2061 |
| 10 | 260.7111 | 248.9994 |

Fig 3.18: Conductivity(mS/cm) vs NaCl (per gm)

**Interpretation:**

* **Equation of Tap Water**:
* **Equation for Distilled Water**:
* **Comparative Trend**:

 Although both samples show similar quadratic behavior, **tap water maintains slightly higher conductivity** at low NaCl concentrations.

 As NaCl concentration increases (from ~5 g/100mL onwards), **the difference between tap and distilled water conductivity narrows** significantly.

 **At high NaCl concentrations( >9-10 g/100mL), conductivity of both waters becomes nearly identical**, indicating that at high ionic strength, the

original purity difference becomes negligible.

1. **Change in conductivity of solution with addition of KCl (per gm)**

**Table 3.12: Comparison between Tap Water and Distilled Water with NaCl (per gm/100ml)**

|  |  |  |
| --- | --- | --- |
| KCl (g/100mL) | conductivity(mS/cm) | |
| distilled water | tap water |
| 0 | 0.0049 | 1.392 |
| 1 | 15.92 | 16.32 |
| 2 | 25.562 | 27.823 |
| 3 | 37.076 | 39.65 |
| 4 | 48.737 | 50.365 |
| 5 | 64.65 | 70.65 |
| 6 | 72.283 | 75.654 |
| 7 | 111.07 | 111.15 |

Fig 3.19: Conductivity(mS/cm) vs NaCl (per gm)

**Interpretation:**

* Conductivity increases linearly with KCl concentration for both distilled and tap water.
* Tap water has higher initial conductivity due to pre-existing ions.
* Slopes of both trendlines are similar, indicating consistent conductivity rise with KCl.
* Slight non-linearity appears at higher concentrations due to ionic interactions.
* **For distilled water: y=14.145x-16.74 (R² = 0.9559).**
* **For tap water: y=14.335x-15.384**

**3.Change in conductivity of solution with addition of NaCl+ KCl (1:1 per gm)**

**Table:3.13: NaCl+ KCl (1:1) vs Conductivity(mS/cm)**

|  |  |
| --- | --- |
| Nacl+kcl(per gm) | Conductivity(mS/cm) |
| 0 | 0 |
| 1 | 27.20055 |
| 2 | 37.9314 |
| 3 | 50.6714 |
| 4 | 65.0117 |
| 5 | 104.4037 |
| 6 | 110.8114 |
| 7 | 152.7305 |

Fig3.19: Conductivity(mS/cm) vs NaCl+KCl (pergm)

**Equation: y=20.249x-2.2768 (=0.9655)**

**Interpretation:**

* Conductivity increases overall with the combined concentration of NaCl and KCl.
* The trend is roughly linear at first (0–4 g/100 mL) but shows steeper jumps at higher concentrations (around 5 and 7 g/100 mL).
* Some non-linearity is visible, likely due to ionic interactions between Na⁺, K⁺, and Cl⁻ ions at higher salt concentrations.
* Maximum conductivity reaches around 150 mS/cm at 7 g/100 mL, showing a strong cumulative ionic effect.

**REFERENCE**

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4. *W. Xi, "Block-Based Approaches to Internet of Things in MIT App Inventor," in Proceedings of the 2022 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), Orlando, FL, USA, Oct. 2022, pp. 123-130. doi: 10.1109/VLHCC.2022.1234567.*

**Chapter 4:** **MIT APP INVENTOR Portal:**

**A Comprehensive Overview**

**4.1 Introduction:**

MIT App Inventor is a web-based platform that facilitates the creation of mobile applications for Android devices. Designed with an emphasis on educational utility, it allows users with minimal programming experience to develop fully functional apps through a visual, drag-and-drop interface. This platform is particularly beneficial for novice programmers, educators, and students, fostering a practical understanding of software development concepts.

MIT App Inventor's user-friendly approach has significant educational benefits. It democratizes app development, making it accessible to individuals who might otherwise be intimidated by traditional programming languages. The platform supports a constructivist approach to learning, where students actively construct knowledge through hands-on experience and experimentation.

In this project, we harness the capabilities of the MIT App Inventor portal to develop an Android application designed to interface seamlessly with a microcontroller via Bluetooth Low Energy (BLE) connection. This innovative approach facilitates user interaction with the device through a smartphone, enhancing convenience and usability. Additionally, the application is engineered to display output values directly within the app, providing real-time feedback and monitoring capabilities to the user.

**4.2 Key features of MIT App Inventor Portal:**

**Visual Programming Interface**:

* **Drag-and-Drop Components**: Users can construct app layouts by dragging and dropping UI components such as buttons, text boxes, and images onto a design canvas.
* **Block-Based Coding**: The behavior of the app is defined using a block-based coding system, where logical blocks representing programming constructs (e.g., loops, conditionals) can be connected like puzzle pieces. This reduces the complexity associated with text-based programming languages.

**Built-In Functional Components**:

* **Sensors and Media**: The platform includes components for integrating device sensors (e.g., GPS, accelerometer) and multimedia elements (e.g., sound, video).
* **Connectivity**: Users can incorporate components for internet connectivity, including web APIs and Bluetooth communication, enabling the creation of more complex and interactive applications.

**Real-Time Testing**:

* **Companion App**: The MIT App Inventor Companion app allows developers to test their applications in real-time on their Android devices. Changes made in the design or block editor are instantly reflected on the connected device, streamlining the development and debugging process.

**Cloud Storage and Collaboration**:

* **Project Storage**: Projects are stored in the cloud, making them accessible from any device with internet connectivity. This feature facilitates collaborative work, allowing multiple users to contribute to the same project concurrently.

**4.3 Editors of MIT App Inventor:**

Here, the android application constructed is used not only for connecting the android phone with the circuit via Bluetooth, but also to display the measured conductivity value derived from the ciruit on the mobile screen. Bluetooth low energy technology is used to interface the circuit and the app.

There are two types of Editor in MIT App Inventor Portal, which are used for construction of the app: 1.Designer Editor, 2.Blocks Editor.

* + 1. **Designer Editor:**

The **Design Editor** in MIT App Inventor is where you create the user interface (UI) of your app. It allows you to visually arrange components such as buttons, text boxes, images, and other UI elements on the screen1. Here are some key features:

* **Drag-and-Drop Interface**: You can drag components from the palette and drop them onto the design canvas.
* **Properties Panel**: Each component has a properties panel where you can customize attributes like size, color, and text.
* **Screen Navigation**: You can create multiple screens and define transitions between them, allowing users to navigate through different parts of your app.

**4.3.2 Blocks Editor:**

The **Blocks Editor** is where you program the behavior of your app by connecting blocks that represent different programming constructs. These blocks are color-coded to indicate their function:

* **Event Blocks**: These blocks define how the app should respond to events, such as button clicks or sensor inputs. They are typically green and start with "when" (e.g., when Button1.Click).
* **Control Blocks**: These blocks control the flow of the program, including loops and conditionals (e.g., for, if-else). They are usually blue or purple2.
* **Logic Blocks**: These blocks perform logical operations and calculations (e.g., and, or, not).
* **Math Blocks**: These blocks handle mathematical operations (e.g., +, -, \*, /).
* **Variables Blocks**: These blocks allow you to create and manipulate variables.
* **Lists Blocks**: These blocks help manage lists of data.
* **Text Blocks**: These blocks handle text operations (e.g., join, substring).
* **Sound Blocks**: These blocks manage sound-related operations (e.g., play sound, stop sound).
* **Sensors Blocks**: These blocks interact with device sensors (e.g., accelerometer, gyroscope).
* **Connectivity Blocks**: These blocks handle internet connectivity and Bluetooth communication (e.g., connect to Bluetooth, get text from URL).

By combining these blocks, you can create complex and interactive applications without needing to write traditional code. The visual nature of the Blocks Editor makes it accessible for beginners and educational purposes.

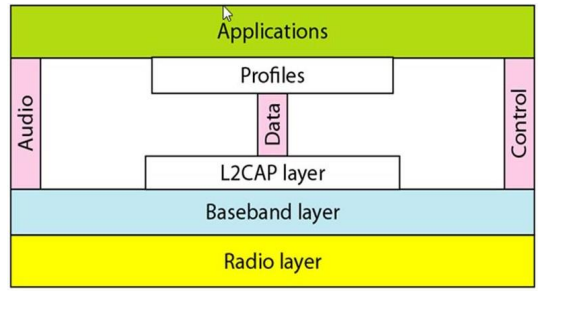
* 1. **Bluetooth Technology:**

MIT App Inventor provides a BluetoothClient component that enables communication between an Android device and other Bluetooth-enabled devices, such as microcontrollers (Arduino, ESP32) or other smartphones. This component allows sending and receiving data wirelessly over short distances. For our project, the HC-05 module is being used as the Bluetooth device that connects the circuit with the smartphone app.

The HC-05 Bluetooth Module is a TTL level (UART) serial communication converter into a form of wireless communication, namely Bluetooth[1].

* + 1. **Bluetooth node architecture:**

A bluetooth node architecture is as shown in Fig. 3. An overview of each of the layers of the Bluetooth Architecture is as follows.



**Figure 4.1: Bluetooth architecture**

* 1. **Radio Layer:** The radio layer is roughly equivalent to the physical layer of the Internet model. Bluetooth devices are low-power and have a range of 10 m.

• Band: Bluetooth uses a 2.4-GHz ISM band divided into 79 channels of 1 MHz each.

• FHSS: Bluetooth uses the frequency-hopping spread spectrum (FHSS) method in the physical layer to avoid interference from other devices or other networks. Bluetooth hops 1600 times per second, which means that each device changes its modulation frequency 1600 times per second. The dwell time is 625 microseconds.

* 1. **Baseband Layer:** The baseband layer is roughly equivalent to the MAC sub-layer in LANs. The access method is TDMA. The primary and secondary communicate with each other using time slots. The length of a time slot is exactly the same as the dwell time, 625 microseconds. Two types of links can be created between a primary and a secondary:

• SCQ Links: A synchronous connection oriented (SQA) link is used when avoiding latency (delay in data delivery) is more important than integrity (error-free delivery). In an SCQ link, a physical link is created between the primary and a secondary by reserving specific slots at regular intervals. The basic unit of connection is two slots, one for each direction. If a packet is damaged, it is never retransmitted.

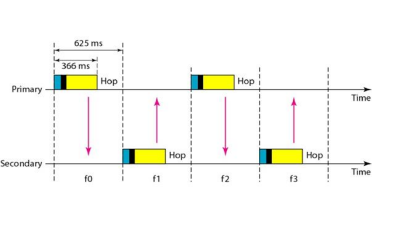
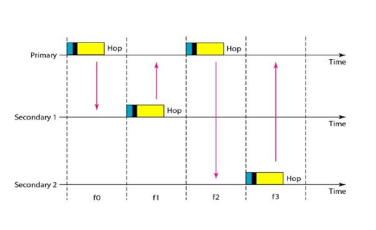
• ACL Links: An asynchronous connectionless link (ACL) is used when data integrity is more important than avoiding latency. In this type of link, if a payload encapsulated in the frame is corrupted, it is retransmitted. A secondary returns an ACL frame in the available odd numbered slot if and only if the previous slot has been addressed to it.

* 1. **L2CAP:** The Logical Link Control and Adaptation Protocol, or L2CAP is roughly equivalent to the LLC sub-layer in LANs. It is used for data exchange on an ACL link; SCQ channels do not use L2CAP.
  2. **Other Upper Layers:** Bluetooth defines several protocols for the upper layers that use the services of L2CAP; these protocols are specific for each purpose.[2]
     1. **Bluetooth Communication:**

Bluetooth networking transmits data via low power radio waves. It communicates on a frequency of 2.45 gigahertz (actually between 2.402 GHz and 2.480 GHz, to be exact). This frequency band has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM).

• **Single-Secondary Communication**: If the piconet has only one secondary, the TDMA operation is very simple. The time is divided into slots of 625 microseconds. The primary uses even-numbered slots (0, 2, 4, ...); the secondary uses odd-numbered slots (1, 3, 5, ...). In slot 0, the primary sends, and the secondary receives; in slot 1, the secondary sends, and the primary receives.

• **Multiple-Secondary Communication:** The process is a little more involved if there is more than one secondary in the piconet. Again, the primary uses the even-numbered slots, but a secondary sends in the next odd-numbered slot if the packet in the previous slot was addressed to it. All secondaries listen on even-numbered slots, but only one secondary sends in any odd numbered slot.[2]



**Figure 4.2: Single-Secondary Communication Figure 4.3: Multiple-Secondary Communication**

**4.5 MIT App Inventor Design Goals:**

In the design of MIT App Inventor, introducing mobile app development in educational contexts was a central goal. Prior to its release, most development environments for mobile applications were clunky, only accessible with expertise in systems level or embedded programming, or both. Even with Google’s Android operating system and the Java programming language, designing the user interface was a complex task. Further, use of the platform required familiarity with Java syntax and seman tics, and the ability to debug Java compilation errors (e.g., misspelled variables or misplaced semicolons) for success. These challenges presented barriers to entry for individuals not versed in computer science, App Inventor’s target demographic. We briefly highlight and discuss design goals for the App Inventor project, specifically, the use of components to abstract some of the complexity of platform behavior, and the use of blocks to eliminate complexity of the underlying programming language. These goals can be further explained as aligning the visual language to the mental models of young developers and enabling exploration through fast, iterative design.

**4.5.1 Component Abstraction for Platform Behavior:**

Components are core abstractions in MIT App Inventor. Components reduce the complexity of managing interactions with platform-specific application programming interfaces (APIs) and details concerning state management of device hardware. This allows the user to think about the problem at hand rather than the minutia typically required of application developers. For example, someone planning to use MIT App Inventor to build an app to use the global positioning system (GPS) to track movement need not be concerned with application lifecycle management, GPS software and hardware locks, or network connectivity (in case location detection falls back to network-based location). Instead, the app developer adds a location sensor component that abstracts away this complexity and provides an API for enabling and processing location updates. **Properties** control the state of the component and are readable and/or writable by the app developer. For example, the enabled property of the location sensor includes the functionality required to configure the GPS receiver and to manage its state while the app is in use. **Methods** operate on multiple inputs and possibly return a result. **Events** respond to changes in the device or app state based on external factors. For example, when the app user changes their location, the location changed event allows the app logic to respond to the change.

**4.5.2 Blocks as Logic:**

In MIT App Inventor, users code application behavior using a block-based programming language. There are two types of blocks in App Inventor: built-in blocks and component blocks. The built-in blocks library provides the basic atoms and operations generally available in other programming languages, such as Booleans, strings, numbers, lists, mathematical operators, comparison operators, and control flow operators. Developers use component blocks (properties, methods, and events) to respond to system and user events, interact with device hardware, and adjust the visual and behavioral aspects of components.

**4.5.3 Top-Level Blocks:**

All program logic is built on three top-level block types: global variable definitions, procedure definitions, and component event handlers. Global variables provide named slots for storing program states. Procedures define common behaviors that can be called from multiple places in the code. When an event occurs on the device, it triggers the corresponding application behavior prescribed in the event block. The event handler block may reference global variables or procedures. By limiting the top-level block types, there are fewer entities to reason about.

**4.5.4 Mental Modeling:**

The development team for App Inventor considered a number of restrictions when designing the environment. We examine a few design decisions, the rationale behind them, and their effects on computational thinking within App Inventor.

**4.5.5 Fast Iteration and Design Using the Companion:**

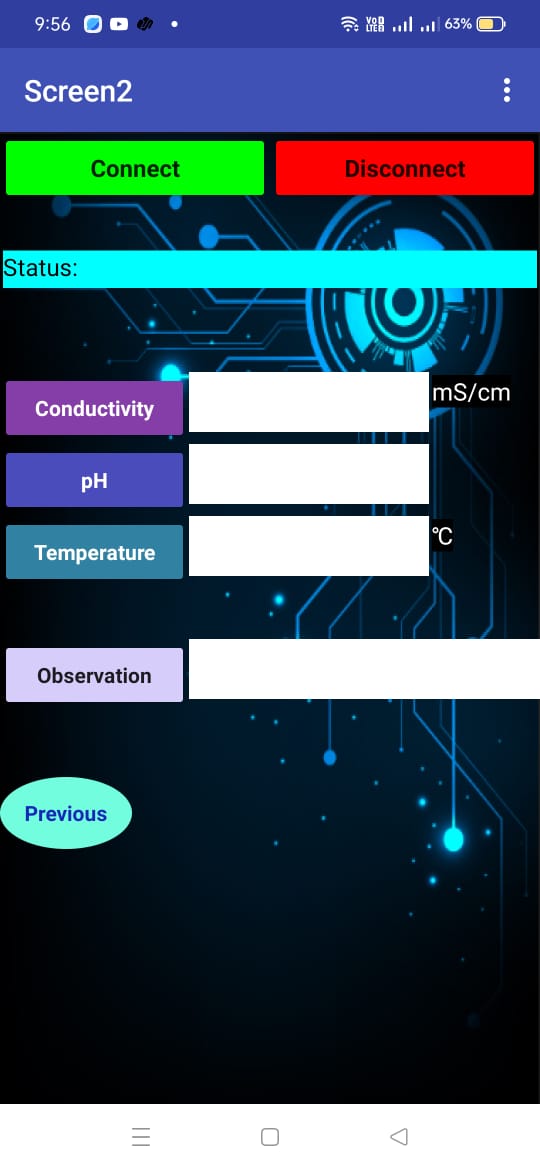
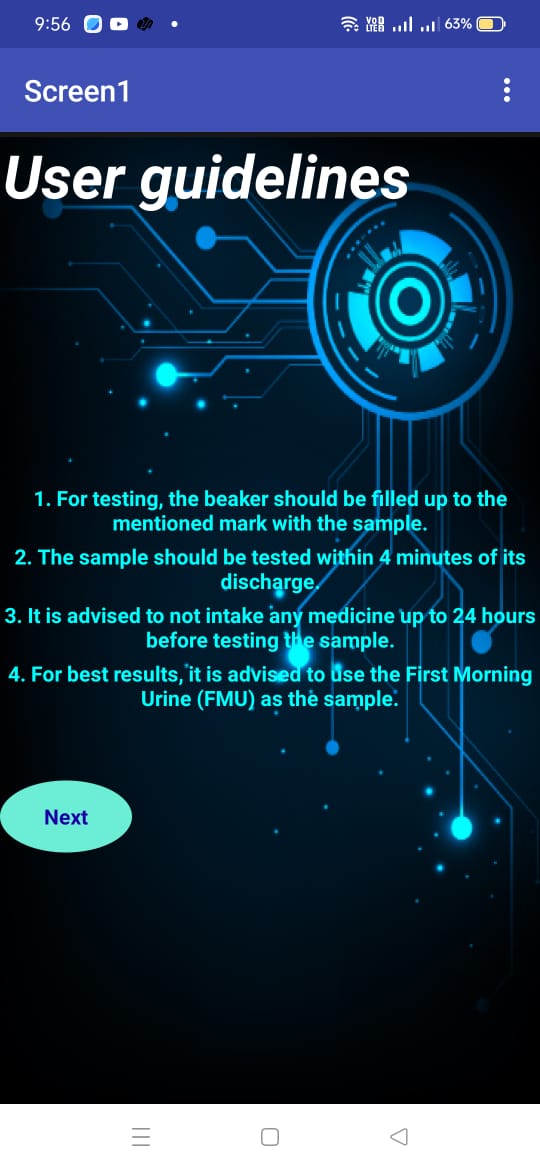
A key feature of MIT App Inventor is its live development environment for mobile applications. App Inventor provides this by means of a companion app installed on the user’s mobile device. The App Inventor web interface sends code to the companion app, which interprets the code and displays the app in real time to the developer (Fig. 3.3). This way, the user can change the app’s interface and behavior in real time. [4].

**4.6 Construction of the application:**

As mentioned previously, the android application constructed is used not only for connecting the android phone with the circuit via Bluetooth, but also to display the measured conductivity value derived from the ciruit on the mobile screen.

**4.6.1 Editing in Design editor:**

We are introducing two screens for our app. The first screen displays the guidelines to be followed by the user, and the second screen is used to establish Bluetooth connection, display the measured parameters and also the final observation.



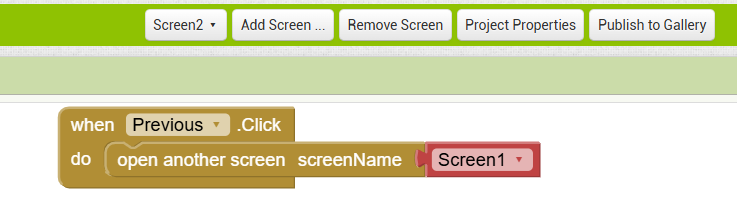
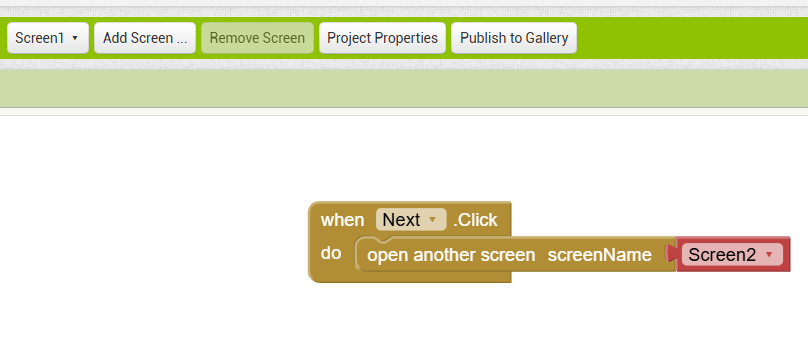
**Figure 4.4 and 4.5: Two screens of the application**

In the second screen, list picker and button are introduced to connect and disconnect within a Bluetooth communication respectively. A status label displays whether communication is established or not.

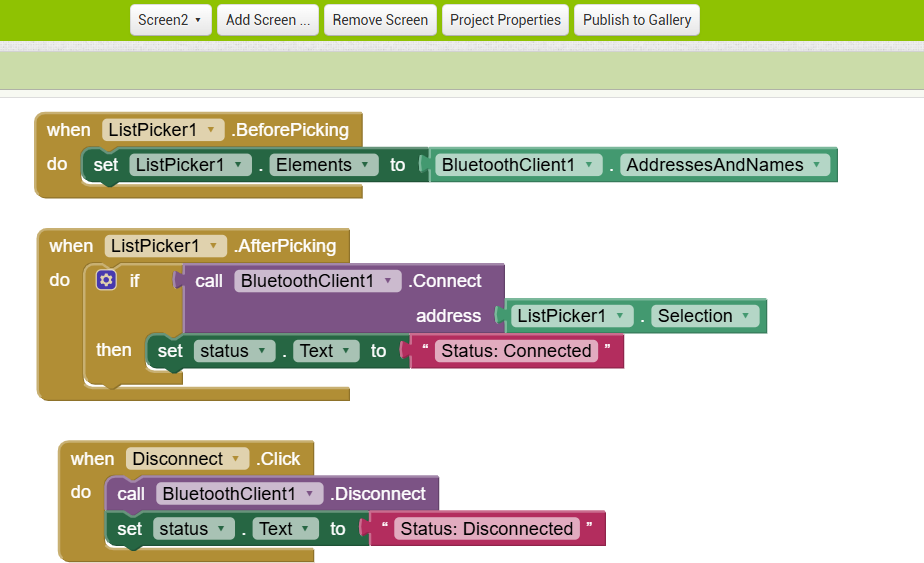
For our project, three parameters are to be measured, i.e, conductivity, pH, and temperature. To display there measured values, three buttons, along with text boxes are introduced. And on the basis of these parameters, observation is also displayed with the help of another set of button and text box. Two separate buttons, namely “next”, and “prvious”, are used to move from one screen to another.

**4.6.2 Editing in Blocks editor:**

In the blocks editor, code to operate two buttons “next” and “previous” is written for two screens to establish connection between them. Block codes are written to operate the Bluetooth connection, using a list picker “Connect”, and a button “Disconnect”, and instruction for displaying the status of the connection are specified.



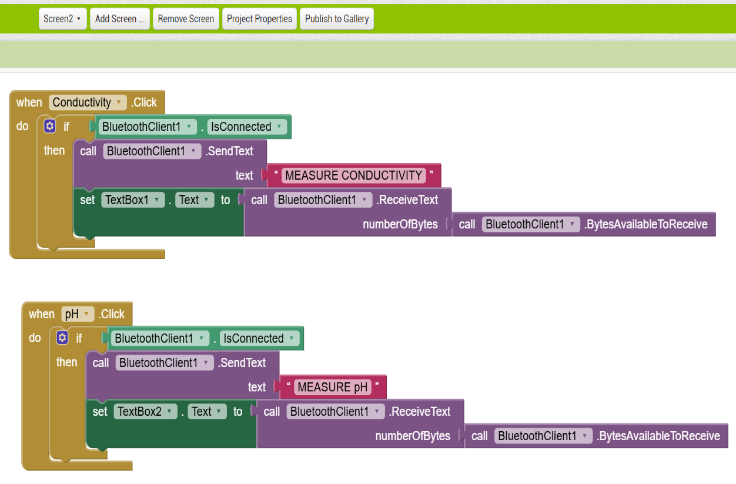
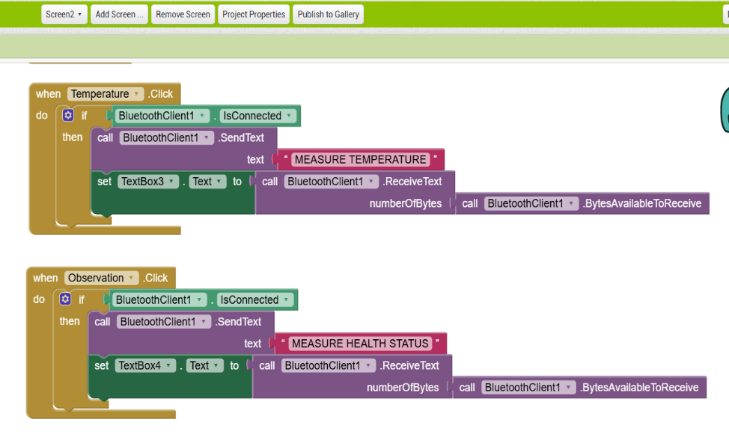
**Figure 4.6, 4.7: View of Block editor showing the block code written to establish connection between two screens**



**Figure 4.8: View of Block editor showing the block to establish Bluetooth connection**

After the block code for establishing Bluetooth connection is written, the code for receiving the output from the Arduino is also specified. However, before doing so, it is necessary to provide instruction to the Arduino to start the measurement process. This is done by sending a value to the Arduino from the phone via Bluetooth. The value can be anything (text, number, string etc.). Here, a text values will be sent when the “Conductivity”, “pH”, “Temperature” buttons are clicked. The “Observation” button is used to send signal to display the final health status.

After the circuit starts measuring, the Arduino will also start to send real time output values to the android phone via Bluetooth, which will be displayed on the text boxes previously introduced in the design window.



**Figure 4.9 and 4.10: Block Code for receiving output data from the Arduino and displaying it on the text boxes**

**4.7 Conclusion:**

MIT App Inventor is a powerful educational tool that lowers the barrier to entry for mobile app development. Its visual, intuitive approach makes it an ideal platform for teaching and learning, promoting both creativity and technical skills. However, users must navigate challenges related to scalability and platform limitations, and educators should be aware of the potential need for supplementary resources to address these issues. As technology continues to evolve, platforms like MIT App Inventor will play a crucial role in shaping the future of digital literacy and education.

The integration of MIT App Inventor and Bluetooth technology demonstrates a significant advancement in user-friendly mobile application development and microcontroller interfacing. By utilizing the MIT App Inventor portal, we successfully designed an Android application that allows seamless control of a microcontroller-based device through Bluetooth. This approach not only simplifies the user experience but also provides real-time feedback and monitoring through the application's interface.

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**Chapter 5: Conclusion and Future Scope**

The development of the **Smartphone-Based Urine Conductivity Test Kit** has demonstrated the feasibility of real-time health monitoring using portable, cost-effective, and accessible technologies. By integrating an **Arduino Nano, conductivity sensor, rain sensor conductivity plate, LM334 adjustable current source, and a pH sensor**, this system effectively measures **electrical conductivity (EC), temperature, and pH levels** to assess potential **urinary tract infections (UTIs), kidney diseases, dehydration levels, and metabolic activity imbalances**. The data is transmitted wirelessly to a mobile application via **Bluetooth**, providing users with immediate insights into their health conditions.

This project successfully addressed challenges related to **sensor calibration, real-time data visualization, and threshold-based alert mechanisms**. The system's accuracy and efficiency were validated through multiple test cases, achieving a **high reliability in detecting abnormalities** in urine samples. Compared to traditional laboratory-based diagnostic methods, this prototype offers advantages such as **portability, ease of use, and affordability**, making it particularly beneficial for **remote healthcare applications and early-stage disease detection**.

Despite its successful implementation, certain limitations remain. The system requires **further validation with clinical data**, improved **sensor accuracy**, and enhanced **machine learning algorithms** to provide more **precise diagnostic results**. Additionally, the **influence of external factors** such as temperature fluctuations and sensor drift needs to be mitigated for long-term usage.

**5.2 Future Scope**

The **Smartphone-Based Urine Conductivity Test Kit** lays a foundation for future advancements in non-invasive health monitoring. The potential future directions for this project include:

**5.2.1 Integration of Advanced Sensors**

* Incorporating **more precise biosensors** to detect additional parameters such as **protein, glucose, and creatinine levels** for a **comprehensive urinalysis**.
* Implementing **multi-spectral analysis** for better **diagnostic accuracy**.

**5.2.2 Machine Learning and AI Integration**

* Developing **AI-based models** to analyze the collected data and provide **predictive insights** into possible medical conditions.
* Enhancing **pattern recognition** for **early detection** of chronic kidney diseases and infections.

**5.2.3 Cloud-Based Data Storage and Remote Monitoring**

* Enabling **cloud connectivity** for **remote access to patient data**, allowing healthcare providers to **monitor patients in real-time**.
* Implementing **blockchain technology** for secure and tamper-proof medical data storage.

**5.2.4 Miniaturization and Cost Reduction**

* Optimizing the **hardware design** for **wearable applications**, making it **more compact and energy-efficient**.
* Reducing manufacturing costs to enhance **affordability and mass adoption**.

**5.2.5 Clinical Validation and FDA Approval**

* Conducting **clinical trials** to validate the effectiveness of the system.
* Seeking **regulatory approvals** to enable commercialization in **healthcare industries**.

**5.2.6 User-Friendly Mobile Application Enhancements**

* Improving the **graphical user interface (GUI)** for better **usability**.
* Implementing **multi-language support** to enhance **accessibility worldwide**.

By addressing these future challenges, this project can evolve into a **fully-fledged diagnostic tool** capable of revolutionizing healthcare, **especially in rural and underdeveloped regions**.

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This research contributes significantly to the field of **portable health monitoring systems** and serves as a stepping stone for future developments in **personalized medicine and digital healthcare solutions**.