ID2802: Open Ended Lab Project

INDIAN INSTITUTE
OF TECHNOLOGY
PALAKKAD

Final Report

Project Topic:

Development of portable biosensor

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1 Introduction

Accurate measurement of current in the microampere range is essential in various biological measurements. It allows for the characterization of electrochemical reactions, the study of biological processes, and the quantification of drug concentrations in biological samples. By measuring such small currents, researchers and healthcare professionals can gain valuable insights into complex biological systems and make informed decisions regarding drug dosing and patient management.

The current method for measuring microampere-level currents relies on the use of an electrochemical workstation. While these instruments provide accurate measurements, they are large, expensive, and not easily portable. Their size and cost limit their accessibility, hindering widespread use and potential applications in point-of-care diagnostics and remote monitoring. Therefore, there is a need for a smaller, portable alternative that can provide comparable accuracy while being more cost-effective and user-friendly.

To address the limitations of the existing instruments, our project focuses on the development of a portable biosensor specifically designed for accurate current measurements in the microampere range. This biosensor incorporates miniaturized electronics, advanced sensing technologies, and innovative signal processing algorithms to achieve precise and reliable measurements within a compact device.

The portable biosensor offers several advantages over traditional instruments for microampere current measurement. Firstly, its compact size makes it highly portable, enabling its use in various settings, including point-of-care applications, remote areas, and field research. Additionally, the cost-effective design of the biosensor makes it more accessible to researchers, healthcare providers, and resource-limited settings. Its user-friendly interface and simplified operation allow for easy integration into existing workflows, minimizing training requirements.

One specific application of the portable biosensor is drug concentration measurement in samples. By accurately measuring microampere-level currents, the biosensor enables the quantification of drug concentrations, facilitating therapeutic drug monitoring and personalized medicine. Its portable nature makes it ideal for real-time monitoring of drug levels in various clinical and non-clinical settings, enabling timely dose adjustments and optimizing treatment outcomes.

2 Literature Review

Biosensors typically produce small electrical outputs, and most of them are amperometric, impedometric, and potentiometric. To measure these small electrical outputs, bench-type source measurement units and impedance analyzers were widely used. [1]

2.1 Means of Error

In low current amplification there should be considered many factors in order to produce the accurate result such as leakage current or burden voltage. The volume of leakage current or burden voltage will affect the voltage amplifier circuit measured that will be corrupting the measurement contrary with theoretical measurement. Hence, it should be as low as possible the value or leakage current or burden voltage. Moreover, incorrect human handling of PCB also were intentionally contaminated before testing, will affect the measurement. This was similarly a potential source contamination resulting from fingerprint, skin oil, and saliva.

2.2 Three Electrode configuration

The three electrode system remedies many of the issues of the two electrode configuration. The three electrode system consists of a working electrode, counter electrode, and reference electrode. The reference electrode's role is to act as a reference in measuring and controlling the working electrode potential, without passing any current. The reference electrode should have a constant electrochemical potential at low current density. Additionally, since the reference electrode passes negligible current, the iR drop between the reference and working electrode (iRU) is often very small. Thus with the three electrode system, the reference potential is much more stable, and there is compensation for iR drop across the solution.

2.3 Biomarker Identification

Table 1: Oxidation Potential of Various Bio markers[**?**]

Bio Marker	Potential V
Glucose	+0.6
Dopamine	+0.65
Ascorbic acid	+0.15
Uric acid	+0.5 V
Adenine	+0.7 V

The range of current observed when applying a specific potential to biomarkers can vary based on several factors, including the concentration of the biomarker, electrode characteristics, and experimental conditions. Typically, in electrochemical experiments involving biomarkers, micro- to milliampere (A to mA) currents are commonly observed. Hence the Bio sensor while identifying this current can detect the concentration of that biomarker in the given sample.

3 Materials and Methods

We would be providing a constant voltage of 0.5-0.7V which corresponds to the oxidation potential of dopamine between the reference electrode and working electrode. This voltage will oxidise dopamine to different quinones. We should measure the output current in microamperes from the counter electrode and working electrode. [2]

3.1 Measuring micro ampere current and calibrating it

Measuring micro ampere current requires careful consideration as there is only low levels of current involved. When working with microampere currents, it is crucial to consider noise sources and minimize any potential interference. Additionally, selecting appropriate measurement instruments or components with low input bias currents and high sensitivity is important to obtain accurate measurements in the microampere range.

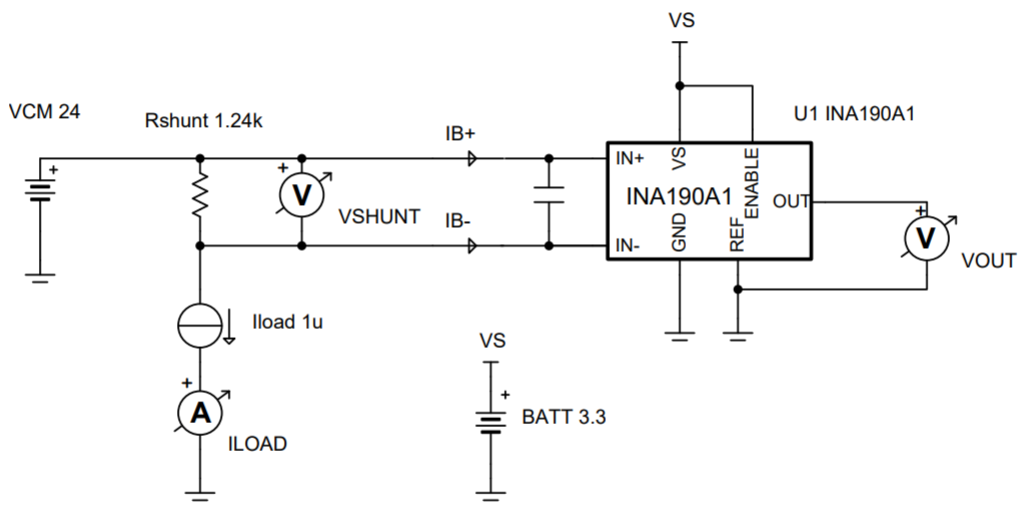

Figure 1: Micro ampere measurement using INA190

We are using INA190, a low-power, voltage-output, current shunt monitor. The low input bias current of the device permits the use of larger current-sense resistors, thus providing accurate current measurements in the microamp range. The low offset voltage of the zero-drift architecture extends the dynamic range of the current measurement. This feature allows for smaller sense resistors with lower power loss, while still providing accurate current measurements.

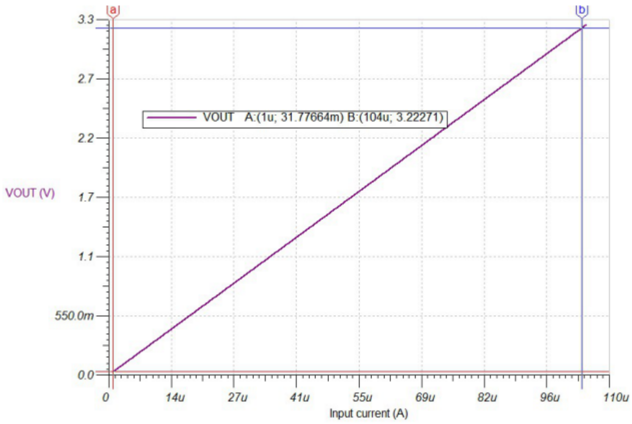

Figure 2: Graph of input current vs Vout

3.2 Milli ampere and milli voltage detection and display using Arduino nano

The output from INA190 comes as milli volts. So we should develop a circuit to measure this milli volts and display it in LCD display. We have used INA219 a zero-drift, bidirectional current/power monitor sensor and coupled it with an Arduino nano and an LCD display.

To measure the millivolts output from the INA190 current sensor and display it on an LCD display, we used the following circuit setup with an Arduino Nano:

Components required:

1. Arduino Nano
2. INA190 current sensor
3. LCD display (16x2 character LCD)
4. Potentiometer (for LCD contrast adjustment)
5. Breadboard
6. Jumper wires

Circuit Connections:

1. Connect the VCC pin of the INA190 to the 3.3V or 5V power supply

2. Connect the GND pin of the INA190 to the ground (GND) of the Arduino Nano. Connect the VREF pin of the INA190 to the reference voltage (VREF) of the Arduino Nano .
3. Connect the OUT pin of the INA190 to an analog input pin (e.g., A0) of the Arduino Nano. Connect the RS, EN, D4, D5, D6, and D7 pins of the LCD display to digital output pins of the Arduino Nano (e.g., D2, D3, D4, D5, D6, D7). Connect the RW pin of the LCD display to ground (GND).
4. Connect the VSS and A (anode) pins of the LCD display to ground (GND). Connect the K (cathode) pin of the LCD display to the backlit LED's cathode pin or ground (GND).
5. Connect the Vo (LCD contrast) pin of the LCD display to a potentiometer's center terminal. Connect one end of the potentiometer to 5V and the other end to ground (GND). Connect the ends of the potentiometer to the VCC and GND pins of the LCD display.

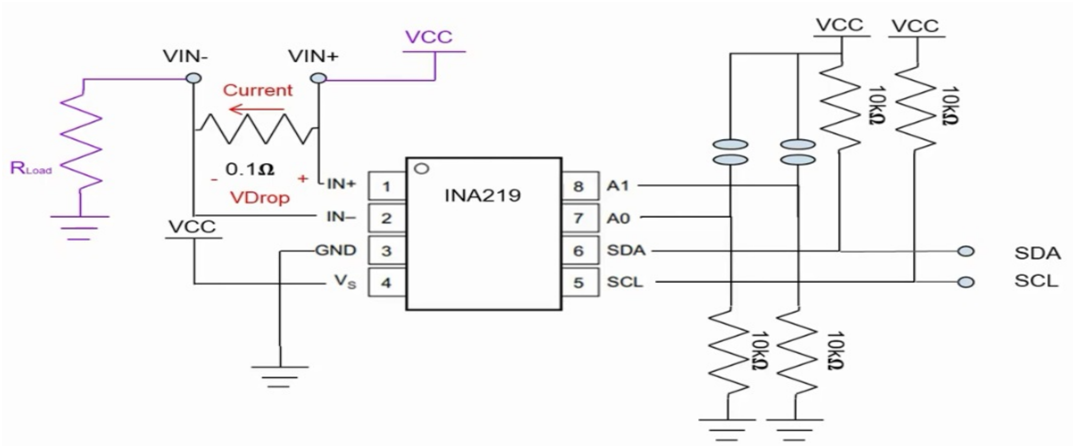

Figure 3: Milli voltage detection using INA219

4 Experiment Results and Discussion

4.1 Simulation of INA190

The INA190 device exhibits the capability to measure current within the range of 1 microampere to 104 microamperes. To verify its performance, we conducted simulations utilizing TINAcloud, a cloud-based simulation platform. The simulations yielded the expected output, indicating the device's reliability and adherence to the specified current measurement range. These results validate the suitability of the INA190 for accurately capturing currents within the stated microampere range.

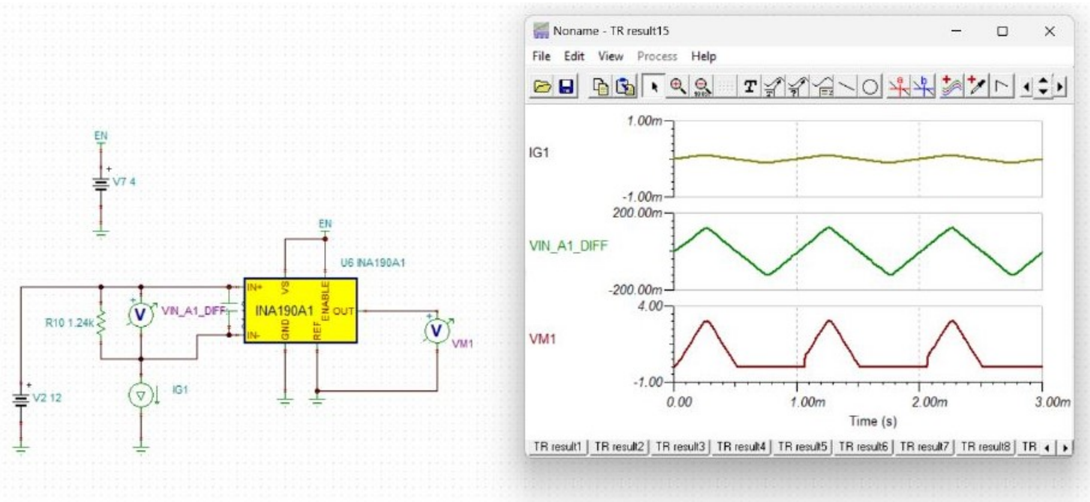

Figure 4: Simulation of INA190 using TINAcloud

4.2 mA Current measurement

The INA 219 was employed to accurately measure a current within the milliampere range, showcasing a precision of +0.8mA. In conjunction with an Arduino nano microcontroller and an LCD display, the measured current was prominently exhibited. This setup allowed for the clear and real-time presentation of the measured current value. The combination of the INA 219, Arduino Nano, and LCD display provided a reliable and user-friendly system for monitoring and displaying milliampere-level currents with a high degree of accuracy.

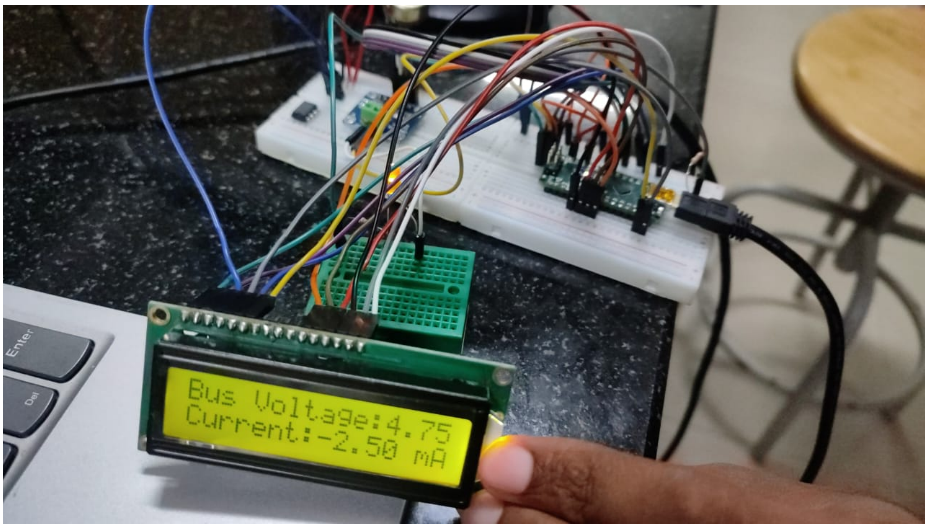

Figure 5: Measuring mA current Using INA219

4.3 Limitations

Given that the INA190 is a surface-mounted IC chip, it may present challenges when it comes to directly testing for errors or faults. Due to its compact design and integration within electronic circuits, troubleshooting and error detection might be more complex compared to other components. However, it is worth noting that certain indirect methods can still be employed to verify the functionality and performance of the INA190.

5 Conclusions and Future Work

The successful measurement of current using the INA219 and the simulation of the INA190 provide promising indications that the INA190 can be utilized to construct a circuit capable of accurately measuring current in the microampere range. By replacing the INA219 with the INA190, it is expected that the circuit will maintain the accuracy and precision required for measuring currents at such low levels. The INA190, known for its suitability in current sensing applications, offers the necessary features to enable reliable and precise measurements within the microampere range. Thus, integrating the INA190 into the circuit holds the potential to establish a robust current measurement system capable of accurately and consistently capturing microampere-level currents.

Future Work:- Further refining and advancing the PCB design for a contamination-free integration of the three-electrode system using the INA190, with the objective of creating a portable biosensor.

References

[1] J. Njagi, M. M. Chernov, J. C. Leiter, and S. Andreescu, "Amperometric detection of dopamine in vivo with an enzyme based carbon fiber microbiosensor," *Analytical Chemistry*, vol. 82, no. 3, pp. 989–996, 2010. PMID: 20055419.

[2] M. N. A. Uda, N. A. Parmin, A. B. Jambek, U. Hashim, M. N. A. Uda, S. N. A. Shaharuddin, and H. Adam, "Nano-micro-mili current to mili voltage amplifier for amperometric electrical biosensors," *IOP Conference Series: Materials Science and Engineering*, vol. 743, p. 012021, feb 2020.