International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 12 Dec. 2025, pp: 526-531 www.ijaem.net ISSN: 2395-5252

PC-based Operational Amplifier Tester for Improved Efficiency

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Date of Submission: 15-12-2025 Date of Acceptance: 31-12-2025

ABSTRACT: Operational amplifiers (op-amps) are fundamental components in analog electronic systems and require pre-use verification to ensure reliability and functionality. Traditional op-amp testing approaches are often characterized by complex circuitry and time-consuming manual procedures, especially in laboratory environments where multiple devices are to be validated. This study presents a PC-based embedded system architecture designed to enhance the efficiency and accuracy of op-amp testing processes. The proposed system integrates a microcontroller-based embedded platform with a graphical user interface (GUI) developed in XAML/C#. Test data is transmitted between the microcontroller and the PC through serial communication, with the microcontroller managing signal generation, data acquisition, and result validation. The system computes closed-loop voltage gain, as a key performance metric and automatically classifies the device under test (DuT) as functional or faulty. By streamlining the testing process into a single connection setup, the solution significantly reduces manual labour and error-prone configurations. This innovation is particularly beneficial to laboratory technologists, enabling quick and reliable assessment of op-amp ICs prior to deployment in academic or industrial experiments.

KEYWORDS: Op-amp, Test, PC, Algorithm, NodeMCU ESP8266, Application

I. INTRODUCTION

Operational amplifiers (op-amps), like all other electronic components, require functional verification before deployment in electronic circuits. This necessity arises from the fact that components may appear physically intact while being electrically defective. While discrete components can be readily tested using standard instruments such as digital multimeters, most integrated circuits (ICs), particularly analog ICs like op-amps, do not lend themselves to such simple testing methods. Traditionally, the functionality of op-amps is determined by integrating them into operational circuits and observing their performance. This process is both time-consuming and cumbersome, especially when testing a large number of devices, due to the requirement of additional passive components for proper configuration and operation. Moreover, this approach becomes increasingly laborious in laboratory environments where numerous devices must be tested for educational or prototyping purposes.

Op-amp evaluation typically involves the measurement of several key parameters such as input and output impedance, open-loop voltage gain, slew rate, and Common Mode Rejection Ratio (CMRR). According to [1], faults in analog ICs are generally categorized into two types: catastrophic faults, which result from physical damage and render the device non-functional, and parametric faults, which arise from variations in internal parameters, causing the device to function with reduced performance. Devices affected by catastrophic faults fail completely, while those with parametric faults may operate sub-optimally, thereby affecting circuit reliability.

[2] compiled various testing methodologies for op-amp characterization, including oscillation-based methods, servo feedback systems, self-loop testing, and neural network-based analysis. The first three approaches are generally accompanied by complex circuitry, whereas the neural network-based approach, though theoretically promising, requires a large training dataset; one that scales with the number of parameters involved. Collectively, these methods are rigorous and time-intensive, limiting their applicability in routine testing scenarios.

In practical laboratory settings, especially in academic institutions, the goal is often limited to determining whether an op-amp is functionally operational. For such applications, confirming the closed-loop voltage gain of the op-amp is often sufficient. This gain is determined by the configuration of the input and feedback resistors connected to the inverting terminal of the device under test (DuT). The actual gain observed when the op-amp is powered and supplied with an input signal is compared to its theoretical value. If the measured gain closely approximates the expected value, the device can be considered functional for basic experimental use.

From the foregoing, it is evident that the primary challenges in conventional op-amp testing are circuit complexity and extended testing time. To address these limitations, this study proposes the use of a computer-based automated test system [3]. The system comprises a microcontroller circuit interfaced with a personal computer (PC). Both the PC and the microcontroller are programmed to execute a sequence of tasks: apply a test signal to the op-amp, capture the output, compute the closed-loop voltage gain, and deliver a verdict regarding the functionality of the DuT.

The proposed system reduces the testing process to a single wire connection and automates the evaluation, significantly simplifying the task. This approach is particularly advantageous for laboratory technologists who are responsible for verifying op-amp functionality before issuing them to students for experimentation. By eliminating the need for repeated manual configurations and complex test setups, the system enhances efficiency and reliability in op-amp testing workflows.

II. METHODOLOGY

This study adopts a design and implementation methodology to develop a PC-based system for efficient testing of operational amplifiers (op-amps). The methodology consists of hardware development, embedded software implementation, and system validation. The design aims to simplify the op-amp testing process, minimize manual intervention, and provide automated test analysis through a PC-based user interface. The block diagram of the proposed system is shown in Figure 1.

As illustrated in Figure 1, the proposed system architecture comprises both hardware and software components. The PC which hosts the user interface, an embedded device and the module hosting the DuT make up the hardware part. The software subsystem encompasses both the embedded firmware (C/C++) and the application (XAML/C#), both of which control the acquisition, processing, and transmission of test data within the hardware components.

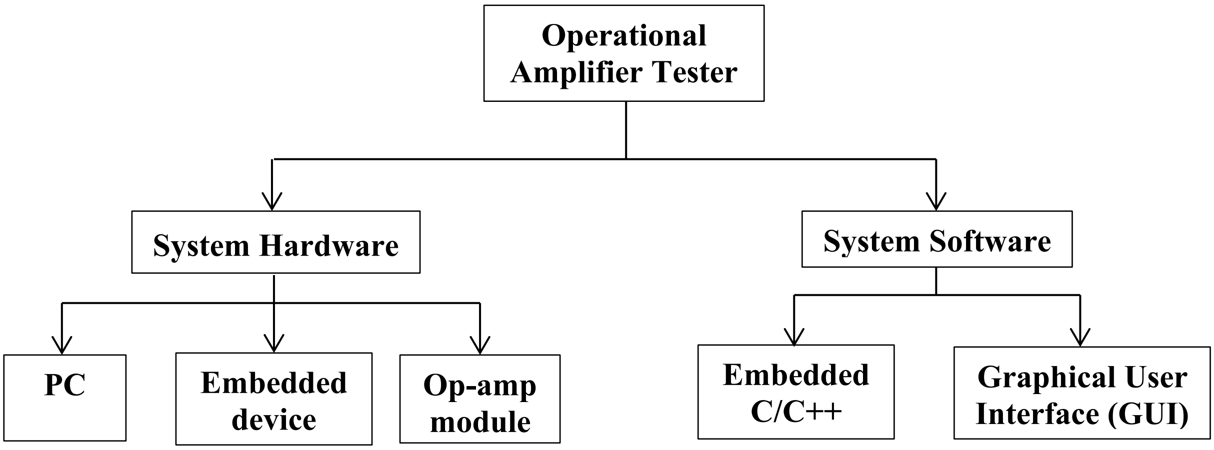

Fig 1: Block Diagram of the PC-Based Op-amp Tester

2.1 Embedded Device

This design makes use of NodeMCU ESP8266 development board (figure 2) from Espressif Technologies [4].
It contains ESP-12N (ESP8266EX) microcontroller. Although, an Arduino UNO can perform a similar function, NodeMCU was preferred because of low cost, lower energy consumption and code security. Furthermore, it comes with a micro-USB port that can provide easier serial communication via a readily available USB cable. The configuration of the microcontroller (MCU) is shown in Figure 3 where port D2 supplies the input signal to the op-amp; port A0 connects to output of the op-amp; D5, D6, D7 connects to the three anodes of an RGB LED. It is powered from VU (V_{cc}) and G (GND)

Fig 2: A Snapshot of ESP-12N Development Board (Courtesy: [4])

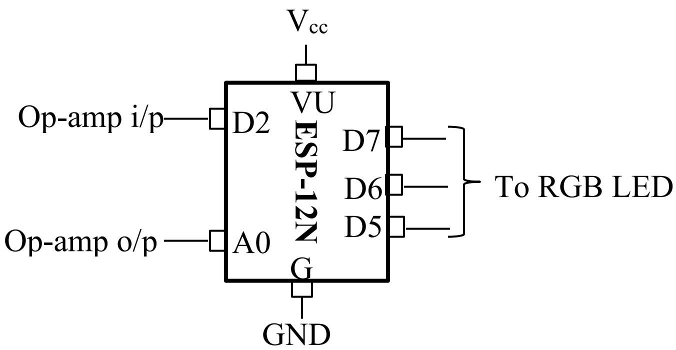

Fig 3: Hardware Configuration of the ESP12-N Module

The parameters of the chip are also specified in table 1.

Table 1: Some Specifications of ESP8266EX IC Chip

Parameter	Specification
Power supply	USB or 5V/3.3V/GND headers
Current consumption	100mA
Operating (I/O) Voltage	3.0V ~ 3.6V
Average operating current	80 mA
Operating temp. range	− 40°C ~ + 125°C

2.2 Graphical User Interface (GUI)

The GUI was designed on the PC to enable the system user input values and view outcomes. It was created as an application using Microsoft's .Net visual Studio IDE that deploys XAML in its design and C# for functionality. XAML is a declarative mark-up language that can build, initialize and set properties of objects that have hierarchical relations in a very simple manner [5]. The designed GUI is shown in figure 5.

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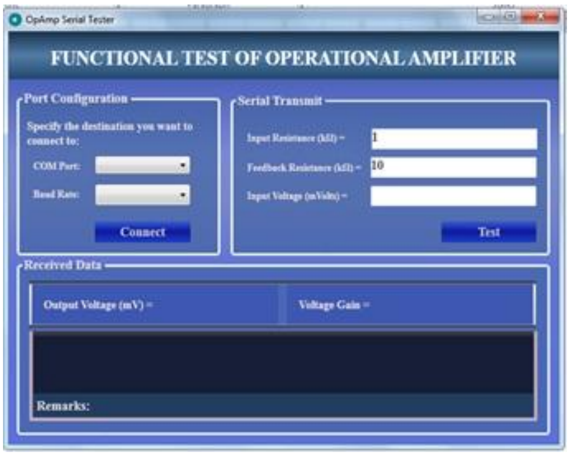

Fig 5: GUI of the Op-amp Tester

Port Configuration enables the determination and selection of PC port in use and baud rate respectively. The Connect textbox establishes communication between the PC and the microcontroller with a baud rate of 9,600bps; Serial Transmit was designed to have fixed values of feedback and input resistances and an input voltage (that must not saturate the op-amp) to be supplied by the user before clicking on "Test". The Received Data are the output voltage, voltage gain, and a remark of the condition of the op-amp which are displayed.

2.1 Microcontroller Software

The program carries out its operation according to the flowchart shown in figure 6. At the start of the process, the controller locates the variables, their initial states and the port configuration with the PC. If hardware communication is established, it obtains control character "1" which represents the baud rate and indicates the status of connection at the GUI. Control character "t" comprises of R_{in}, R_f and V_{in} while "m" represents the test process. On receiving "m", it computes the output voltage and voltage gain represented by "v" and "g" respectively. The results of these computations are received internally and sent to the GUI. Thus, the received data is provided by the microcontroller unit which also gives a remark of the condition of the op-amp.

The complete circuit diagram of the op-amp test system is shown in figure 7.

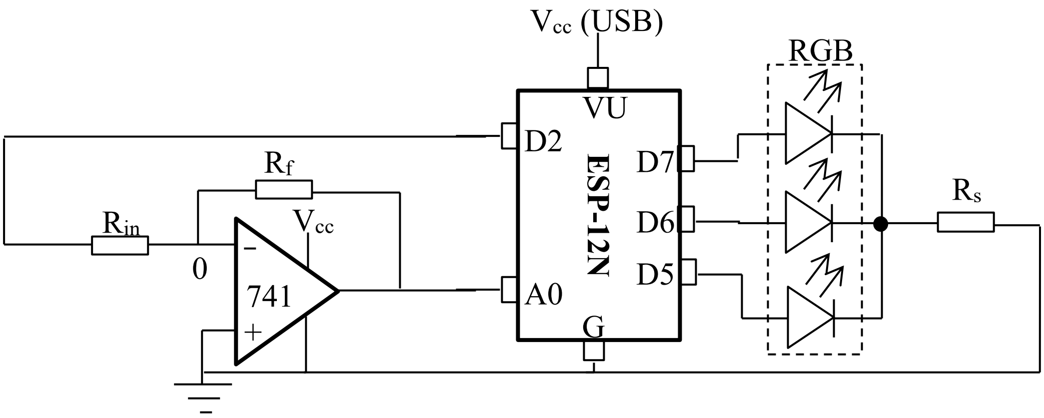

Fig 7: Circuit Diagram of the Op-amp Tester

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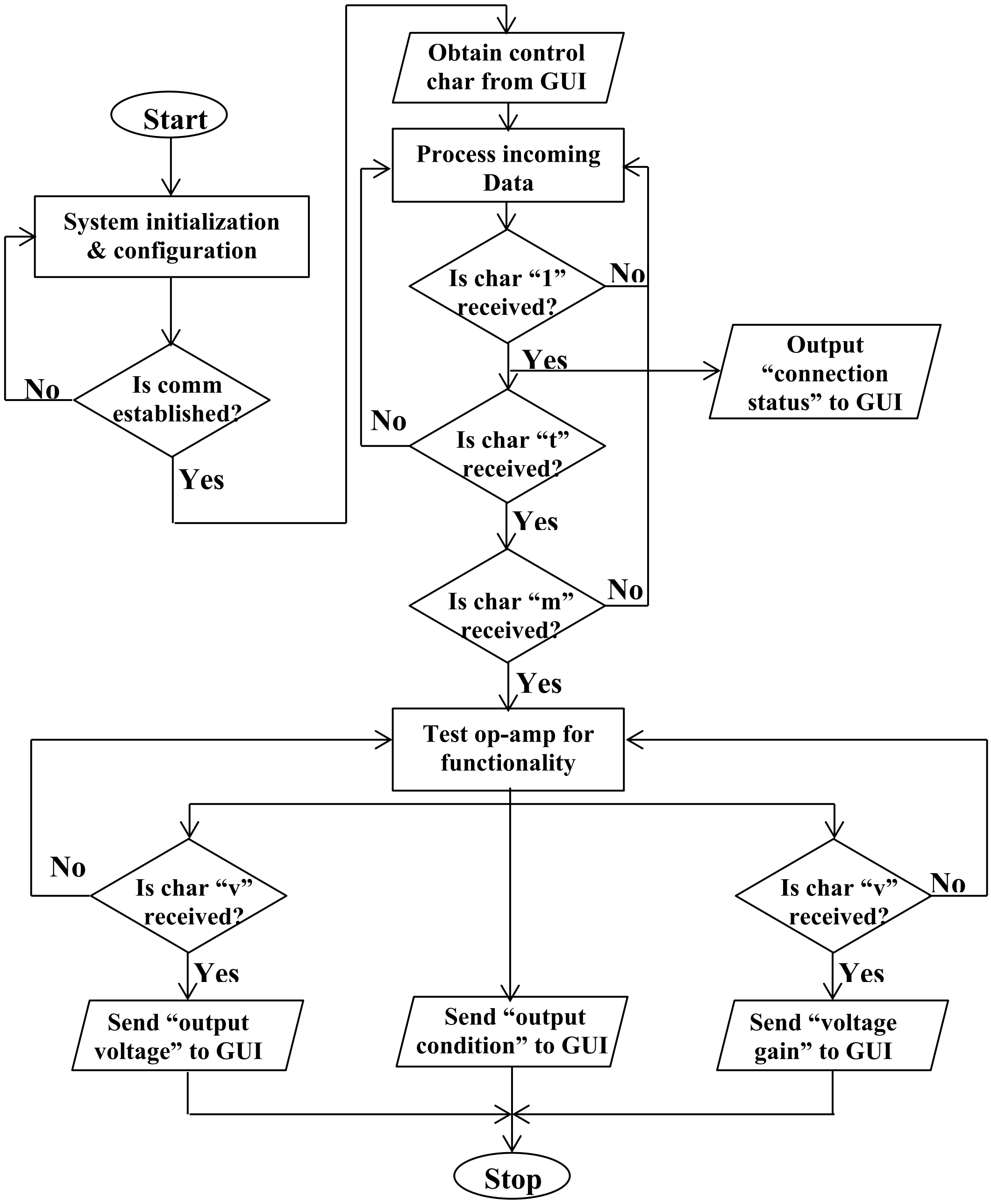

Fig 6: Flow Chart of the Op-amp Tester

III. RESULTS AND DISCUSSION

The design was tested by pluging the DuT into the IC socket in the right order, and with the USB cable connected between the embedded system unit and the PC, open the desktop application and enter the COM port number and the baud rate (9,600). The "connect" button is clicked twice to establish serial communication. The LED displays a blue colour and the input voltage entered and "Test" button clicked. The condition of the op-amp is displayed accordingly. Figure 8 shows the result of the test from a functional op-amp.

From figure 8, a functional op-amp supplied with an input voltage of 200mV produced an output voltage of 2000mV. Hence, a voltage gain of 10 as expected was obtained.in contrast, a faulty op-amp produced the result displayed in figure 9.

Usually, a faulty op-amp would output the same value supplied as input. This design is programmed to give "Nil" for absence of amplification/gain.

Fig 8: Results from a Functional Op-amp

Figure 9: Results from a faulty Op-amp

IV. CONCLUSION

The proposed op-amp test system has been designed and implemented. The results displayed in figures 8 and 9 confirm that the system is capable of checking if an op-amp is functional or faulty which is the sole objective of this work. Factors such as economic application, reliability, efficiency and durability were put into consideration in the course of carrying out this mini-project. It is however important that the user is knowledgeable of the constraints so as to avoid damage of the system or the DuT even before testing it. Further studies on this work can be implemented wirelessly using mobile application since the NodeMCU ESP8266 development board is equipped with in-built wi-fi functionality.

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