AUTOMATED IC CHIP TESTER

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ECE 445 Project Proposal - Spring 2021

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I. Introduction

I.I Objective

A common frustration in ECE 385 is when students find a given IC chip does not work as expected. Testing each chip manually is tedious and time consuming. Students are encouraged to test each chip before using them, but due to the time constraint and complexity of 385 labs, along with the time consumption of unit testing every chip, this advice is rarely followed. Additionally, students often ruin previously working chips without realizing it and are tasked with manually debugging every chip in their circuit.

Our project is targeted towards students by providing a small, portable solution to unit test IC chips quickly and easily. We want to automate the process of chip testing using a database of TI datasheets and a streamlined UI for easy testing. The user would only need to select the chip model number in order for our device to prepare the appropriate signals to each input or power pins. Our internal logic would then analyze the output signal and determine if the chip provides the correct logic.

I.II Background

A number of IC chip testers have been developed in prior years, but these models were not geared towards students as their primary consumers. The Instek GUT-6600A Handheld Digital IC Tester [1], while automated, retails at $600 a device and is too expensive for a student.

If a student in ECE 385 were to unit test a single IC chip, testing would require the equipment and space provided in the dedicated ECE 385 lab. The portability of our device would allow students to immediately test a given IC chip wherever they are located. Additionally, our WiFi-based application would allow ease of viewing on any mobile device the student may have on hand.

I.III Physical Design

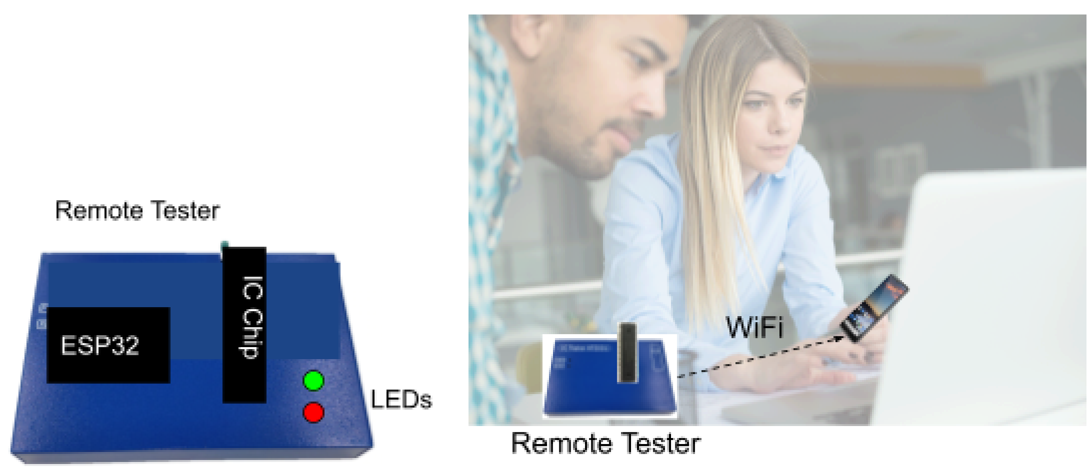

Figure 1: Device physical design

I.V High-Level Requirements

- The device's internal logic must be able to determine if a chip is working properly in under 250 milliseconds.
- The interface between the ESP32 and mobile WiFi device can select from the 18 types of IC chips provided in the ECE 385 standard lab kit and output the correct testing conditions for the chip.
- The voltage regulators must provide the ESP32 Microcontroller with 3.3V and the rest of the components with 5V +/-0.5V.

II. Design

II.I Block Diagram

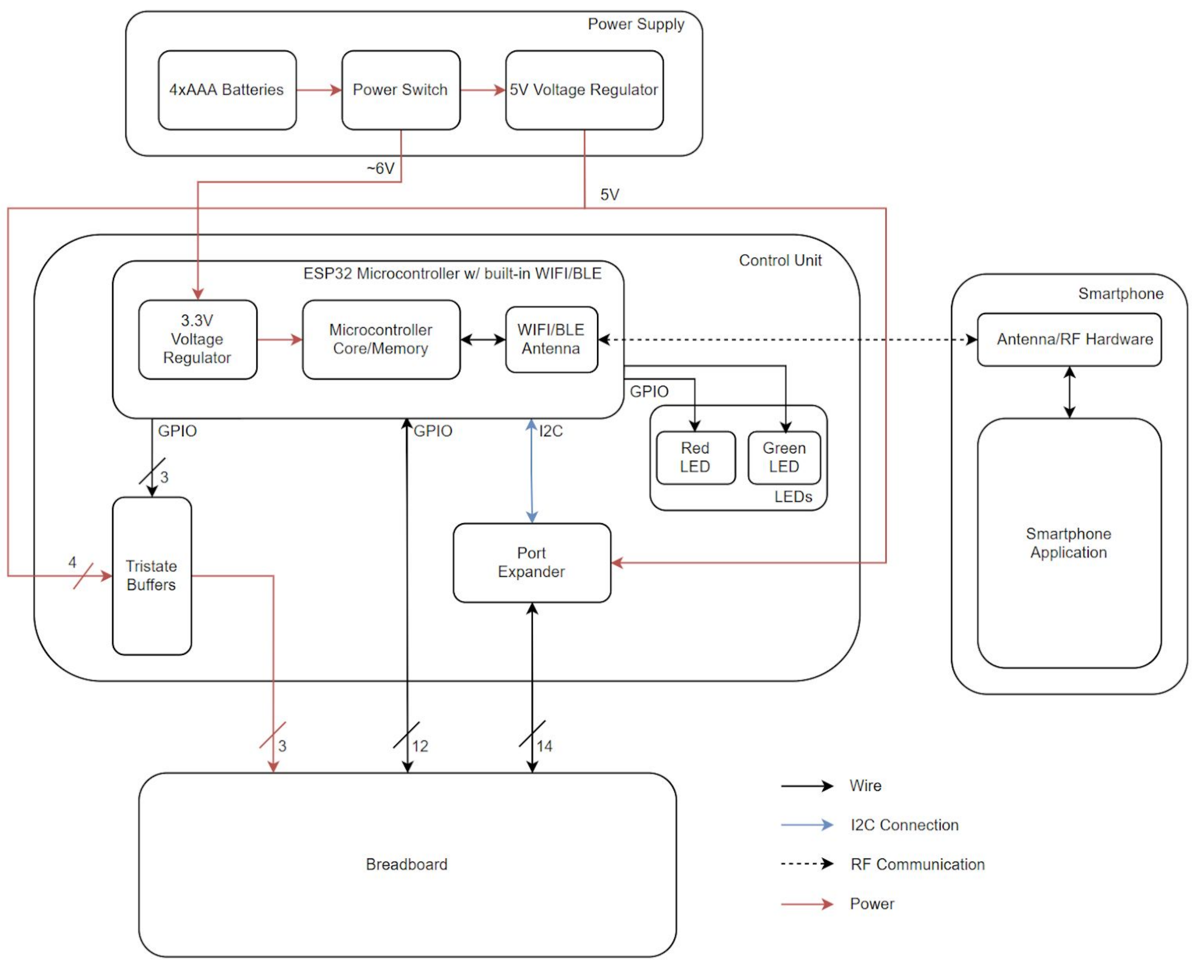

Figure 2: Block diagram

This device requires 4 main subsystems in order to be able to meet the high-level requirements: a power supply, a control unit, a breadboard, and a smartphone. The power supply contains 4 AAA batteries to provide regulated power to the device. The control unit is in charge of executing the test suite for the IC chip under test and does so by providing signals to the breadboard and communicating with the smartphone via WIFI. The breadboard provides an interface for the user to insert the IC chips they wish to test. Lastly, the smartphone allows the user to select from a library of IC chips provided in ECE 385 and communicates this information with the control unit. Together the 4 subsystems can quickly tell the user whether or not their IC chip is functioning properly in a simple UI.

II.II Functional Overview and Block Requirements

II.II.I Power Supply

The power supply subsystem's main purpose is to provide adequate power to our control unit. When powered on, it regulates the voltage to an acceptable level to power the majority of the device's components such as the microcontroller, tristate buffers, and port expanders.

II.II.I.I Battery Cell

Our team chose to use 4 AAA batteries as the main source of power for our project. These batteries will supply a maximum voltage of 6V and an estimated minimum of 5V. These values were chosen based on the operating parameters of the microcontroller and IC chips that will be used for testing purposes. Furthermore, when the batteries no longer function per the requirements, the user can simply replace them with fresh batteries.

II.II.I.II Power Switch

The power switch will control the on or off state for the entire device. This protects the integrity of the device while also indicating to the user when the power is on or off.

II.II.I.III 5V Voltage Regulator

The voltage regulator is expected to draw ~160mA when powered on (tristate buffer: 35mA [2], port expander: 125mA [3]) from the 6V power supply. To ensure adequate operation of our device, our team will require the regulator to support upwards of 300mA.

II.II.I.IV Requirements

Requirement 1: The batteries must output between 5 and 6V while in use.

Requirement 2: The power switch must be able to control the on or off state of the device.

Requirement 3: The 5V voltage regulator must provide 5V +/- 0.5V to the port expander and tristate buffers in the control unit.

II.II.II Control Unit

This subsystem is responsible for proper handling of the WiFi signal as well as the I2C protocol to communicate with the port expander. Moreover, this subsystem includes the ESP32 microcontroller, port expander, tri-state buffers, and LEDS. The WiFi communication allows the user to select what chip they would like to test via a web application and delivers this information to the ESP32-WROOM dedicated receiver.

II.II.II.I ESP-32 Microcontroller

Using the WiFi communication within the microcontroller in this subsystem, the web application can communicate with the dedicated server on our microcontroller so that the user can tell the device what chip they would like to test. Given the data transfer rate of WiFi protocol 802.11n being between 72 to 217 Mbps [4], we can easily satisfy our high level requirement of delivering a result in under 250ms. Moreover, the ESP32 also communicates with the port expander using an I2C bus with an average frequency of 100 kHz [5]. Finally, we will use the dedicated memory on the ESP32 to store the expected output of the IC chip test. If our results match the output, then the chip is working as expected. If not, then we know that the chip is faulty.

II.II.II.II Tristate Buffers

Usually, the standard Vcc pin would be either pin 14 or pin 16, depending on how many pins the IC chip has. However, when this is not the case and the Vcc pin is located elsewhere, we must not send power to the wrong pin or we risk ruining the very chip we wish to test! Therefore, our team decided to include a tristate buffer module that will ensure that the microcontroller sends the proper enable signal to the tristate buffer that will send Vcc to the chip to be tested.

II.II.II.III Port Expander

The port expander allows us to test all of the IC chips that are used in ECE385. This component is a necessity to our design because, based on the available GPIO pins from our microcontroller, we can only send 12 of them to the breadboard for testing purposes. Thus, we are using a port expander to ensure that we have the capability to test IC chips with 16 or potentially more pins.

II.II.II.IV LEDs

The purpose of the red and green LED lights are simply for the user to have a quick visual of whether or not the chip is working properly. If the tested IC chip is functioning properly, the green LED will turn on and stay on until the user is ready to test another chip. Else, if the chip is faulty, the red LED will turn on.

II.II.II.V Requirements

Requirement 1: The microcontroller must be able to accept data from the RF communication corresponding to the selected device to test.

Requirement 2: The microcontroller’s firmware must contain a library of test suites for all 18 chips provided in the ECE 385 lab.

Requirement 3: The microcontroller must be able to control the inputs of the IC chip being tested on the breadboard and compare the outputs to the expected values.

Requirement 4: The results of the tests - working or not working - must be displayed on the LEDs (green indicating a working chip and red indicating a broken chip).

Requirement 5: The tristate buffers must be able to select which pin on the breadboard corresponds to Vcc of the chip under test and provide it with 5V +/- 0.5V.

II.II.III Breadboard

The breadboard is the central testing dock for the user. When the user has selected the IC chip they would like to test, they will place it in a dedicated spot so that the proper signals are sent to the chip. The breadboard for our device is 1.8” x 1.4”, providing enough pin space for the chip.

II.II.III.I Requirements

Requirement 1: The breadboard must be accessible to the user and allow them to insert an IC chip for testing.

II.II.IV Smartphone

The smartphone subsystem will serve as the primary user interface while configuring the device. With the ESP32 chip’s role as the soft Access Point, the smartphone will act as a station (a relationship similar to that of a router and its WiFi client).

II.II.IV.I Antenna/RF Hardware

The connection originating from the ESP32 Web Server will be obtained by the smartphone’s WiFi receiver.

II.II.IV.II Smartphone Application

The smartphone application will offer a button to initiate testing of the IC chip in place and selection from a database of data sheets. Once the testing is complete, the application will display the original chip selection, the findings after testing its output, and an option to test another IC chip.

II.II.IV.III Requirements

Requirement 1: The smartphone app must provide the user with a list of the 18 IC chips provided in ECE 385 and allow them to select which chip they would like to test.

Requirement 2: The smartphone app needs to be able to communicate the user’s chip selection with the microcontroller via WIFI.

3. Ethics and Safety

In electing to design a Web application as opposed to a BLE application, we have a higher potential to be exposed to cyber attacks of malicious intent. According to the IEEE Code of Ethics, Section I, Policy 1, IEEE's promise " … [6] To protect the privacy of others…" plays a role in our attempt to protect the user from a breach of privacy. While we believe the benefits of a WiFi application outweigh that of a BLE alternative, it is our responsibility to not compromise the security of our users. Additionally, it is our responsibility to not abuse the trust of our users by not extracting any data from their device.

Our project has several potential safety hazards. Batteries can be dangerous when used outside of the recommended operating conditions. If a battery is brought to extreme temperatures it can become a fire hazard [7]. We address this issue by only using our project within environments of -18°C to 55°C. Our project also ensures that the power drawn from the batteries is within the safe operating conditions.

In order to work in a safe environment, all group members will follow the CDC recommended safety guidelines surrounding the COVID-19 global pandemic as well as the student guidelines outlined by the University of Illinois [8]. Each group member that is on campus will test a minimum of twice per week, conduct all work virtually unless absolutely necessary, and wear face coverings for any work that must be conducted in person. Additionally, all group members have completed the University's Division of Research Safety laboratory safety training.

References

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[2] Texas Instruments, "High-Speed CMOS Logic Quad Buffer, Three-State", 54HC125 datasheet, Nov. 1997 [Revised Aug. 2003].

[3] Microchip, "16-bit I/O Expander with Serial Interface", MCP23017 datasheet, 2007

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