Pocket Diagnostics

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CONCEPT OF OPERATIONS

REVISION – Draft
25 January 2018

Concept of Operations
for
Pocket Diagnostics

Team 48

Approved by:

Project Leader Date

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T/A Date

Change Record

Rev.	Date	Originator	Approvals	Description
-	9/15/2024	Pocket Diagnostics		Draft Release

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1. Executive Summary

Diagnostics is an important factor when testing electrical instruments. There is a need for a small portable device that is able to perform these diagnostic functions of multiple bench instruments. The aim of this project is to build a small portable lithium ion battery powered device. This device should connect to a smartphone via bluetooth using the ESP 32 standard. This device should be able to perform the functions of various test bench instruments. Through the established bluetooth connection with the user's mobile device, the device will be able to monitor and record the collected data to the user. The data obtained will be output in the form of displayed waveforms on the user's smartphone device.

The device will be made of three main subsystems, the smartphone application, the firmware and the electronics. The smartphone application will be a cross platform developed application that will be able to report the data collected through user interaction. The firmware consists of writing the programs for the hardware components of the device. The electronics consists of two main parts, the power and controls, and the data acquisition and communication. The power and controls will handle the charging, discharging, and protection of the Li-ion battery. The microcontroller will execute the firmware to control the device's operations. The data acquisition will consist of converting the analog signals to digital signals for processing. All these subsystems will work together to provide the user of the device with the required result.

2. Introduction

2.1. Background

In many undergraduate classes test bench equipment is used to get results like waveforms, frequency response, and logic waveforms to name a few. The Analog Discovery Device is used to replace these different functions and bench equipment for students and private use that cannot have access to that equipment. For students this device is used instead of lab equipment or simulation as a remote option, however it does have its drawbacks. The AD2 uses a wired connection to a device like a laptop or computer; it makes it more difficult to connect wires to GPIO cables while still having connection to the laptop. We intend to introduce a wireless version of this device and possibly remove the requirement for a laptop or computer, replacing it with a cellular device. By using bluetooth connection we are able to create a better space for operation, because most of our student use is with a breadboard it would help the portability of the device.

2.2. Overview

To accomplish this design some new systems must be added and others must be reworked. The first system to be added is WiFi/bluetooth connection which will replace the existing USB connection to a laptop. By adding Wifi/Bluetooth connection we can remove the hassle of connecting to a computer, and we are able to have a portable design. The second system to be added is a new app for devices so that a cellphone can replace the need for a laptop to interpret data. To power this device a source must be used to replace the power supplied by the USB, this will be battery powered. All of the systems described above are going to enhance the original application by creating higher mobility/flexibility, while also creating a better working environment for students when constructing circuits.

2.3. Referenced Documents and Standards

- AD2 Manual: https://digilent.com/reference/test-and-measurement/analog-discovery-2/reference-manual
- ESP32 Software: https://docs.espressif.com/projects/esp-idf/en/stable/esp32/get-started/index.html

3. Operating Concept

3.1. Scope

The Pocket Diagnostics will be able to perform bench instruments' functions; Serial Port Sniffer, I2C and SPI inspection, 16-Channel Logic Analyzer, GPIO interface, and a Signal Inspector. Each of these functions will be made through subsystems that will report to a microcontroller. The microcontroller will be used to take in different inputs from these subsystems and display the results to a cellular device via bluetooth. By creating a more portable device we can help distanced learning students with their work, and improve the overall usage of an Analog Discovery Device.

3.2. Operational Description and Constraints

The battery-powered device that connects to a smartphone via Bluetooth or USB, allowing users to perform various tasks such as monitoring serial communications (RS-232, 485, TTL), inspecting I2C and SPI protocols, capturing digital signals, controlling GPIO pins, and analyzing low-frequency analog signals with a built-in oscilloscope. The smartphone app provides a user-friendly interface for real-time data visualization, configuration, and reporting, thus making the system portable and versatile for debugging and monitoring electronic circuits.
The resulting constraints for this operational description is as follows:

- Battery Life: Limits the usage of the device due to constantly recharging the device.
- Frequency Limitations: Restricted to low frequency signals, therefore unsuitable for high speed systems.
- Smartphone Dependent: Requires a compatible smartphone for control and display.
- Environmental Sensitivity: Prone to issues in performance in varying temperatures, humidity, and/or physical damage.
- Accuracy: Compared to bench top instruments, the ADC resolution and sampling rate for our device will not match.

3.3. System Description

- Smartphone Application: This subsystem will display the data obtained through a cross platform developed smartphone application that interacts with the instrument. This subsystem will also obtain the data collected wirelessly through the use of bluetooth.
- Firmware: This subsystem will consist of developing the firmware to handle the analog to digital conversion for data acquisition. It will manage the GPIO pins and the serial ports. This subsystem will consist of the code that connects the hardware applications with the software applications.
- Power and Controls: This subsystem will handle charging, discharging, and protecting the Li-ion battery. It will convert the battery voltage to the required levels

for different components. Through the use of a microcontroller, the firmware will be executed to control the device’s operations.

- Data Acquisition and Communication: This subsystem will convert the analog signals to digital signals for processing. It will prepare signals for ADC by filtering and amplifying them. Through the use of I2C and SPI interfaces it will be able to handle communication with sensors and other peripherals. The RS-232, RS-485, and TTL serial ports will manage communication.

3.4. Modes of Operations

The Pocket Diagnostics device will have one mode of operation. In this mode the device will be powered by a rechargeable Lithium ion battery and will perform the functions of various bench instruments, such as a logic analyzer. The analog signals will be converted to digital signals and will be communicated to the smartphone application through the use of bluetooth after processing. After the data is obtained by the smartphone application. It will display this data in an easy to understand format for the user of the device.

3.5. Users

Any user that has used an AD2 discovery, or similar device should be well accustomed to the functionality of our device. The only significant difference between our device and an AD2 is the data transfer method from the application on the phone to the pocket diagnostics device and vice versa (bluetooth instead of USB).

3.6. Support

The device will be similar to an AD2 Discovery in functionality, therefore, user manuals regarding the functionality of the device will be applicable to our device. A quick user guide will be provided on the app as well.

4. Scenario(s)

4.1. Device Accessibility

The Pocket Diagnostics device is intended to be interacted with by an android phone app. This means that the user does not need access to a laptop or other device that would be less common to carry on hand.

4.2. Power Outage

The Pocket Diagnostics device is intended to have its own battery. This means that the device can be used to complete work if a sudden power outage occurs or if the area that the device is employed at cannot supply the device with power, like a confined space that isn't intended to have people there for long periods of time (meaning that it wouldn't contain any outlets).

4.3. Bluetooth Communication

The device will use bluetooth to communicate with a phone that has the app installed. This will only require the user to have the GPIO wires necessary to use the device, making the overall setup more portable.

5. Analysis

5.1. Summary of Proposed Improvements

- Portability
  - The device is small and battery powered therefore, compared to bench top instruments, the portability is convenient for everyday users.
- Multi-functionality
  - Combines multiple instruments such as Oscilloscope, logic analyzer, serial port sniffer, I2C/SPI inspector, and GPIO interface into a single device.
- Smartphone integration
  - Since using a smartphone interface for display and control interface, the device promotes readily available hardware for visual and data management.
- Cost efficient
  - Low cost device is more affordable than purchasing individual bench instruments, making it more accessible for students, everyday users, and small labs.

5.2. Disadvantages and Limitations

- Limited Frequency Range
  - Compared to high end oscilloscopes and logic analyzers, our device will be more limited due to being a much smaller device.
- Smartphone Dependant

- The device is solely dependent on a compatible smartphone, so the device will not function without a compatible device. Additionally The smartphone's processing power and screen size will limit the devices functionality.

- Battery Life
    - Since it is battery powered, continuous usage will cause the battery to eventually run out of power and need recharging.
- Environmental Sustainability
    - Due to being portable and battery powered, it will be susceptible to environmental factors such as varying temperatures and physical damage.

5.3. Alternatives

- Dedicated Bench Instruments
    - Trade off: Dedicated bench instruments provide higher accuracy, higher bandwidth, and more advanced features compared to our device. However, they are much larger, less portable, and significantly more expensive. They also require multiple separate instruments for each function (oscilloscope, logic analyzer, protocol analyzer).
- Commercial USB instruments (Analog Discovery 2 and Saleae logic pro)
    - Trade off: These commercial tools are compact, offering similar functions with more refinement. However, they are more expensive than our device, thus not being budget friendly for an everyday college student. They may also have software limitations or locked ecosystems, requiring you to use their software.
- DIY Alternatives (Individual kits)
    - Trade off: One alternative is to build individual kits for each function (oscilloscope, logic analyzer, etc.) using available DIY kits. While this gives flexibility in customization, it would require more work, more space, and a higher total cost than the integrated solution. Additionally, coordinating between different kits for multi-protocol analysis could be cumbersome.

5.4. Impact

- Environmental Impact
    - Battery Usage: The use of Li-ion batteries has environmental concerns, including the sourcing of materials and the eventual disposal of the battery. However, by minimizing the use of disposable batteries and designing the device to be rechargeable, the environmental impact is reduced.
    - Electronic Waste: Since the device replaces multiple bench instruments, it reduces the need for additional hardware, leading to less overall electronic waste.
- Social Impact
    - Accessibility: The system increases accessibility to advanced measurement tools for students, common users, and small labs that cannot afford expensive traditional instruments.
    - Education: It can be a valuable learning tool, allowing students and hobbyists to experiment with digital and analog electronics in a more hands-on, affordable, and convenient way.
- Ethical Concerns

- Responsible Sourcing: Ethical concerns around the sourcing of materials for Li-ion batteries and other electronic components should be considered, as these materials can have significant environmental costs.
- Open Source Design: Releasing the system as an open source project on github, it would promote knowledge sharing and reduce barriers for individuals and organizations to access, thus aligning with ethical principles of openness and collaboration.