E-Paper Schedule: A passive, distraction free solution for personal organization

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***Abstract*—This device is a small, low-cost e-paper based schedule viewer. With the goal of being as distraction-free and autonomous as possible, it is configured just once using a Bluetooth connection, after which it uses a Wi-Fi connection to a calendar provider to update its display automatically every hour. To conserve battery, it spends most of its time in deep sleep. As many calendar events as can fit on the display are shown in a minimal, non-distracting format, along with the weather.**

I. Introduction

Many calendar management software suites exist for computers and smartphones, such as Outlook and Google calendar. These multifaceted scheduling solutions offer advanced functionality, including email and video call integration across web-based ecosystems such as Microsoft's 365. While these tools offer powerful features, their use and form can become distracting. This device does not seek to replace these calendar managers, instead working with them to produce a tool for visualizing calendar information in a form more similar to that of a traditional paper diary. The device is a small, portable, low cost display capable of displaying calendar events without user interaction or distraction. Such a device and its benefits have not yet been realized in a product purchasable today. The system is designed for manufacturing, where a circuit board implementation of the device has been designed, ordered, and tested in a prototype.

II. Related Work

Electrophoretic display (EPD) technology moves charged particles with electric fields, and is the basis for e-paper displays. These displays are high contrast, low power, backlight-free and capable of retaining their image without power. EPDs are most commonly used in e-books, public transport information updates, logistics, industrial sensor readouts, and increasingly as updateable price tags in supermarkets.

With aims very similar to that of this project, Hodges et al. [1] outlines a concept smartphone flip cover with an integrated e-paper display on the inside. Such a display would be used to visualize key information at a glance such as device screenshots, tickets, shopping lists and weather reports, and consume a negligible amount of the smartphone's battery. The display was touch-enabled for basic interactions.

III. Prototype

A. First Prototype

The prototype's display shows the current date, month and hour, the current temperature, chance of rain and weather condition in the form of an icon, and a list of events for the current and upcoming days.

This first prototype uses a Wesmos C3 Pico development board, chosen due to its small size and low power ESP32-C3 chipset. This was combined with the Waveshare 2.9 inch EPD

Fig. 1. First prototype

Fig. 2. All of the prototype's components fitted inside the 3D printed case

Module, which allows for writing display data using SPI (Serial Peripheral Interface). A 100mAh LiPo (Lithium Polymer) battery provides the power, and the development board's USB-C port and charge circuitry allows for charging and reprogramming the board. These components were connected by hand-soldered wires. A case was designed using the free online modelling tool from tinkercad.com and was printed in two halves using PLA plastic and an Ender 3 3D printer.

The firmware is written in C++ using the Arduino IDE, with power management, Bluetooth Low Energy and Wi-Fi communication, timekeeping, event parsing, display commands and use of a weather API combined to create an autonomous system.

To allow users to setup the device, a webpage is used which uses the Web Bluetooth API to

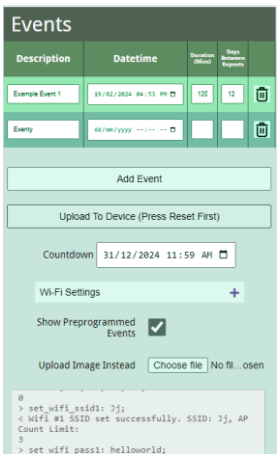

Fig. 3. Screenshot from the setup webpage on Android.

communicate with the device. The device is only reachable via Bluetooth for a brief period after pressing the reset button, allowing for long battery life. The webpage allows users to configure their Wi-Fi Access Point credentials and create a list of events to send to the device.

B. Second Prototype – Design for Manufacturing

After creating the first prototype, a second was designed with focus on creating a PCB (printed circuit board) to consolidate as many components and circuits into a single board as possible. This allows for scaling up the creation of these devices, while simultaneously lowering the size and cost of components.

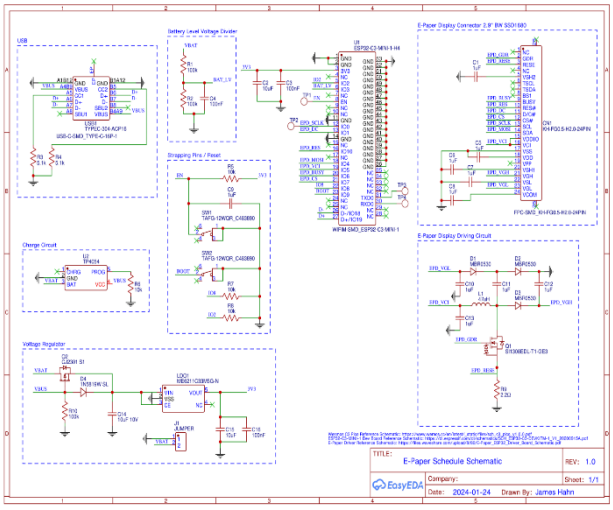

Fig. 4. The second prototype's schematic

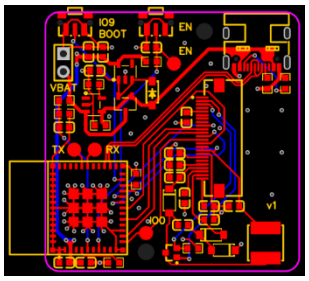

Fig. 5. Routing of ordered PCB with top and bottom layers visible. Copper fills have been hidden for clarity.

Fig. 6. The second prototype

As the main focus of the second prototype was to create a functional PCB able to match all of the first prototype's capabilities, only a rudimentary 3D printed case was constructed. Achieving this prototype involved creating a schematic and PCB layout using the free online tool available at easyeda.com. This tool also allowed for the browsing and importing of components from the electronic supplier LCSC, and exporting of PCB design files to JLCPCB for fabrication, surface mount assembly and delivery. This tight integration allowed for quick design and manufacturing, however it somewhat constrains the design to one component supplier and manufacturer.

IV. Next Steps

While neither prototype is currently capable of connecting to online calendar providers, allowing users to paste in a link to their existing online calendar during setup is the goal. This online calendar will be periodically downloaded in its entirety and saved in the microcontroller's onboard flash memory. As long as the device continues to be powered, it will display and move forward through the calendar's events with time, even without an internet connection to update the calendar.

To elevate this project to a commercial standard, a revision to the PCB needs to be created, and an enclosure for the PCB based prototype must be designed with software more capable than TinkerCAD. Exact battery specifications and a battery supplier must be determined, and samples of all components will be ordered and assembled into a final design.

V. Responsible Innovation

The purpose of this device is to provide value to users by eliminating the distracting elements of existing scheduling solutions. This can be particularly useful for people who have trouble managing attention, such as those with ADHD.

To maintain confidentiality of users private calendar link and events, encrypted and authenticated communication via HTTPS will be used. Encryption will also be used for communication that takes place during Bluetooth configuration. The most dangerous component of the device is the battery, and while many overseas manufacturers are able to create cheap batteries that meet the device's requirements, only certified components will be used in the device.

To reduce the likelihood of devices becoming e-waste, the device will be designed to operate independently of any central server, being configurable with any calendar provider that supports the iCalendar format including Google, Outlook and iCloud. An offline mode exists, giving users the option to manually add calendar events using the setup page. The setup page can also be downloaded by users and ran offline indefinitely.

VI. Author Bio

This device was inspired by the Embedded Systems course at Lancaster University, where I was able to experiment with their e-paper displays. I am motivated by opportunities to design and implement novel systems that provide value to people in unique ways.

I enjoy creating holistic projects that integrate hardware, software and enclosure design via 3D printing. I have created two other projects that accomplish this, including a Raspberry Pi Pico powered foldable game console [2], and a tiny Raspberry Pi Zero powered computer in a box [3].

VII. Acknowledgements

I am incredibly grateful for the time, assistance, enthusiasm, and funding generously provided by Joe Finney and Steve Hodges of the School of Computing and Communications at Lancaster University, without whom this project would not have been possible. The device was originally created for my Third Year Project at Lancaster University, and portions of the

text in this paper have been taken from the report submitted for that project.

VIII. REFERNCES

[1] Hodges, S., Scott, J., Chen, N., Taylor, S., Helmes, J., Wright, P., Walker, L., Trim, N., Grosse-Puppendahl, T., Knierim, P., Wood, G. & Denney, T. (2018). *Enhancing Smartphone Productivity and Reliability with an Integrated Display Cover*. Unpublished paper presented at the Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers. Singapore, Singapore

[2] https://github.com/james1236/pico-foldable

[3] https://github.com/james1236/microboy