Medication Adherence Monitoring in Resource-Limited Settings

The Need For Improved Treatment Outcome – Innovations and Health.
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Project Goals

- Building a working prototype that solves a real-world healthcare problem using resource-constrained computing.
- A low-power healthcare solution, with offline capabilities, small-data AI models, efficient edge computing, and limited computing environments.

Description

- The project is about building a medication adherence reminder device.
- The primary aim is to provide solutions to medication nonadherence which has been a persistent cause of treatment failure most especially among the elderly and those in rural underserved communities with limited resources.

Analysis Of Available Variety Of Technology Applications For Monitoring Medication Adherence

- Monitoring of patient medication adherence is a global challenge because of the absence of *gold standard* methods for adherence measurement and this has been one of the reasons why medication nonadherence has been a persistent cause of concern for healthcare professionals.

- Available Variety Of Invented Technology For Solving Medication Nonadherence Problem include:
  - electronic pill bottles or boxes
  - ingestible sensors
  - electronic medication management systems
  - blister pack technology
  - patient self-report technology
  - video-based technology
  - motion sensor technology

Analysis Of Available Variety Of Technology Applications For Monitoring Medication Adherence

- Strength
  - Most technologies were able to provide real-time monitoring of medication-taking behaviors
  - Technologies like electronic pill bottles or boxes have discrete design and small size
  - objective medication adherence monitoring ability
  - acceptance among patients
- Weaknesses and Identified Constraints
  - relied on proxy measures of medication adherence.
  - Successful implementation of these technologies in clinical settings has rarely been reported.
  - these devices cannot directly confirm ingestion of medications, raising concerns toward their medication adherence monitoring accuracy
  - possibility of sensor retention within the body are considerable limitations of some of these technologies like the motion sensor technology as well as potential risks to patient health and safety.
  - Most of these technologies are expensive and not feasible in resource limited settings.

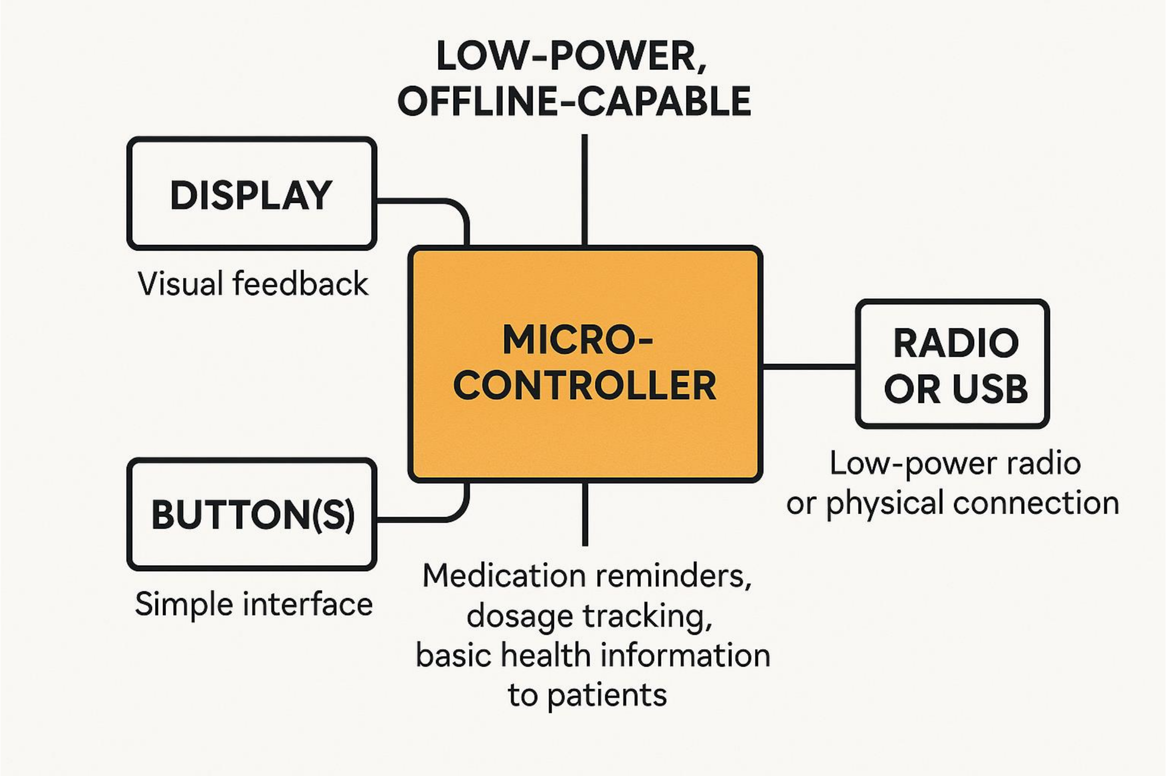
Alternative Design Explorations

- a low-power, offline-capable mobile application designed for resource-constrained environments.
- a mobile app that provides medication reminders, dosage tracking, and basic drug information, all while operating offline.
- a medication reminder device that involves a low-power, offline-capable microcontroller for long battery that provides medication reminders, dosage tracking, and basic health information to patients.

Final Decision (Standard Being Adopted)

- A medication reminder device that involves a low-power, offline-capable microcontroller for long battery that provides medication reminders, dosage tracking, and basic health information to patients.

Final Decision (Standard Being Adopted)



Final Decision (Standard Being Adopted)

- **Components Description**
- **A microcontroller is the brain, managing everything and spending most of the time in sleep mode for battery saving.**
- **RTC wakes the MCU when it's time to remind the user.**
- **Display (e-ink or segmented LED) shows medication reminders and health info with very low power usage.**
- **Buttons provide a simple interface for users to confirm medication taken or navigate basic info.**
- **Memory stores medication schedules and logs usage for later syncing.**
- **Low-Power Radio (like Bluetooth Low Energy or Sub-1 GHz) sends data wirelessly to healthcare providers.**
- **USB Port offers an alternative wired method to sync data.**

Final Decision (Standard Being Adopted)

- **Benefits and Advantage over Other Available Technologies**
- **Extremely Low Power Consumption**
- **Battery lasts months or years**, not days.
- No need for frequent recharging—ideal for elderly users or areas without reliable electricity.
- Enables **always-on** monitoring without draining power.
- **Offline Capability**
- Works **without internet or cellular connectivity**.
- Reliable in **remote or rural areas** with poor network infrastructure.
- No risk of **cloud service outages** or **data privacy breaches via internet**.

Final Decision (Standard Being Adopted)

- **Cost-Effective**
- Components like low-power microcontrollers (e.g., ARM Cortex-M0, ESP32 in low-power mode, etc.) are **inexpensive**.
- **No subscription fees** for cloud storage or app integration.
- Affordable for **low-income or public health programs**.
- **Easy to Use**
- Simple interfaces like **buttons, beepers, LED indicators, or e-ink displays**.
- Designed for **non-tech-savvy users**, such as elderly or visually impaired patients.
- Doesn't require smartphone literacy or app installations.

Final Decision (Standard Being Adopted)

- **High Reliability**
- Fewer points of failure compared to app-based or connected solutions.
- Immune to issues like software updates, phone crashes, or app permissions.
- Functions even in emergencies or disaster zones without digital infrastructure.
- **Portable and Discreet**
- Small, lightweight form factor; can be integrated into pillboxes or wearable devices.
- Non-intrusive and discreet compared to phones constantly buzzing or showing notifications.

Final Decision (Standard Being Adopted)

- **Customizability**
- Fully programmable for **individualized reminder schedules**, dosage tracking, and alerts.
- Can be adapted with features like vibration, audio cues, or display messages.
- **Enhanced Data Privacy**
- No internet connection means **no external data transmission**.
- Ideal for privacy-sensitive users or organizations with strict data protection policies.
- **Durable and Robust**
- Minimal moving parts or exposed electronics.
- Can be made **weatherproof**, **dustproof**, or **shock-resistant** for harsh environments.

Final Decision (Standard Being Adopted)

- **Ideal for Integration with Other Passive Devices**

Can easily interface with:

- E-ink displays for ultra-low-power feedback
- BLE radios for occasional syncing
- Sensors for compliance tracking (e.g., opening the pill compartment)

Tools and Technologies Used

- Artificial Intelligence (AI)
- Internet of Things (IoT)

 - Sensors

 - Wireless Communication

- Cloud Storage

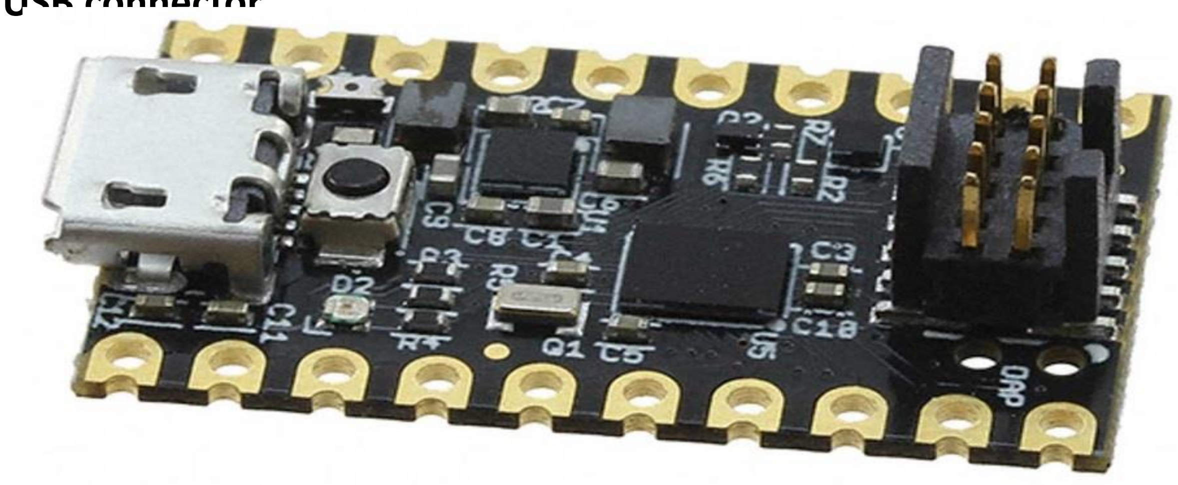
-for more info…List location or contact for specification (or other related documents)

Tools and Technologies Used

- **Microcontroller**

- **Low-Power MCU (Microcontroller unit) Module (MAX32625PICO style)**

- **MAX32625PICO—32-bit Cortex-M4 microcontroller with 512 kB Flash, low-power modes, onboard button and USB connector**



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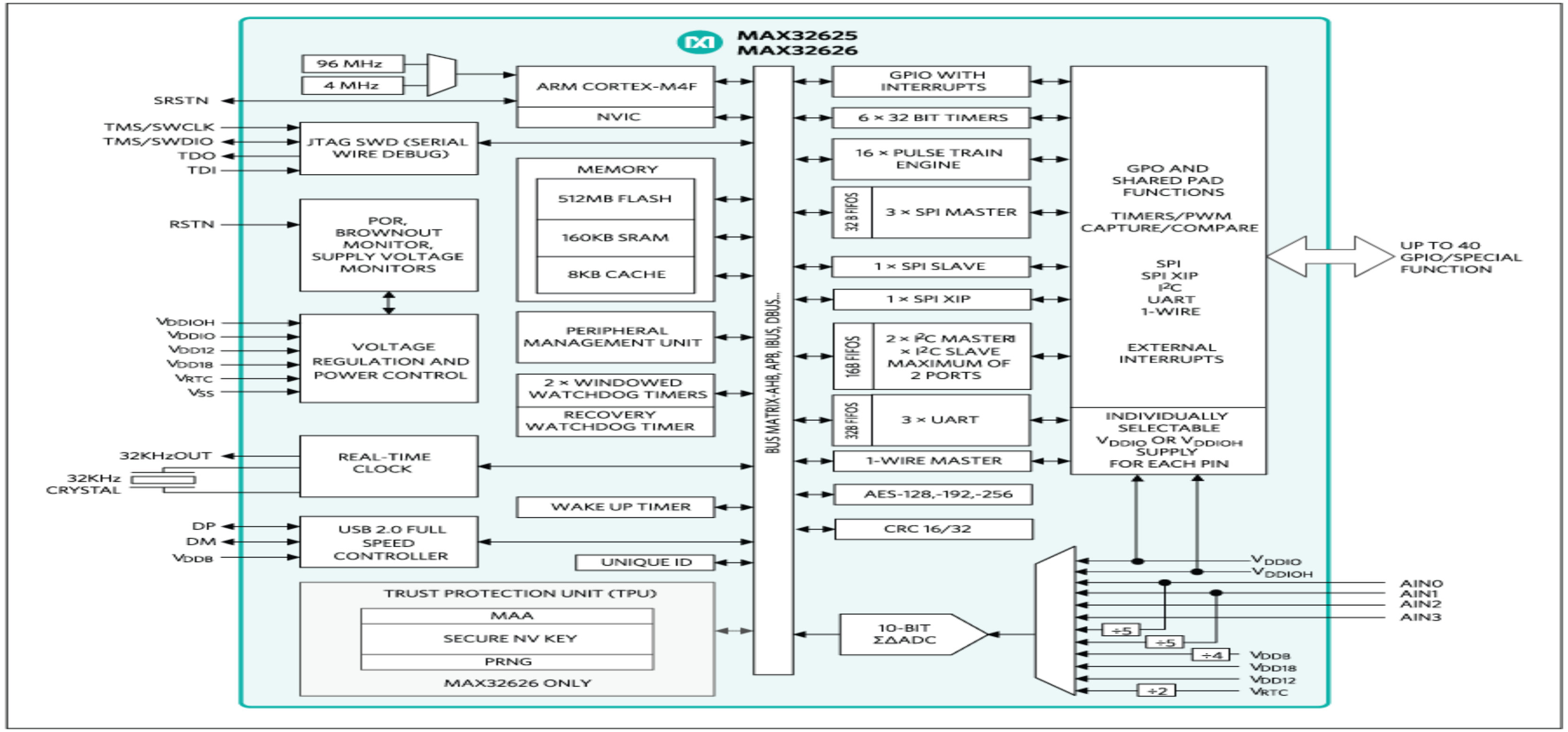
Tools and Technologies Used

- **Components of the Microcontroller Unit (MCU)**

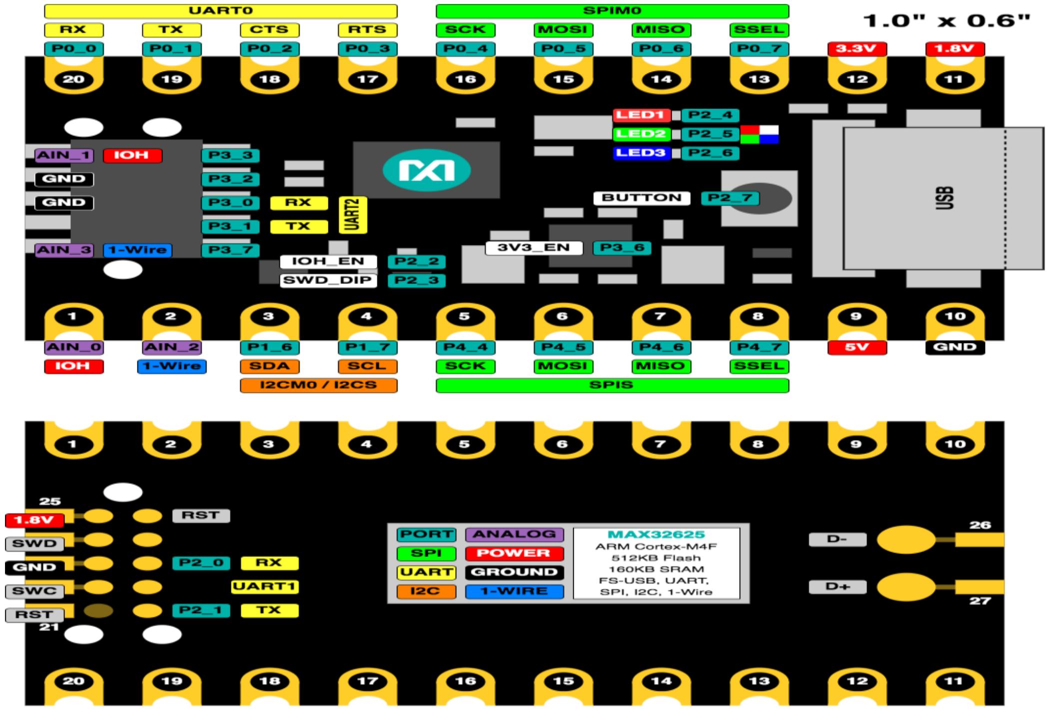
- **MAX32625PICO block schematic showing power regulators, USB interface, GPIO, and power-management IC (PMIC) connections**



Tools and Technologies Used

- **Components of the Microcontroller Unit (MCU)**

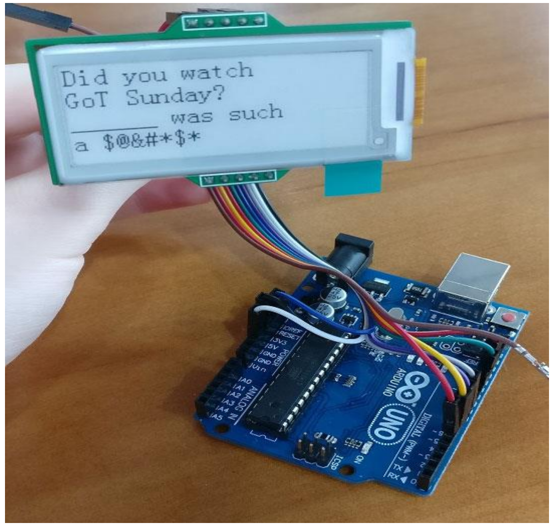
- **MAX32625 functional block diagram, illustrating CPU core, memory, SPI, UART, USB, and power rails**



Tools and Technologies Used

- **Small Display Module (e-ink)**

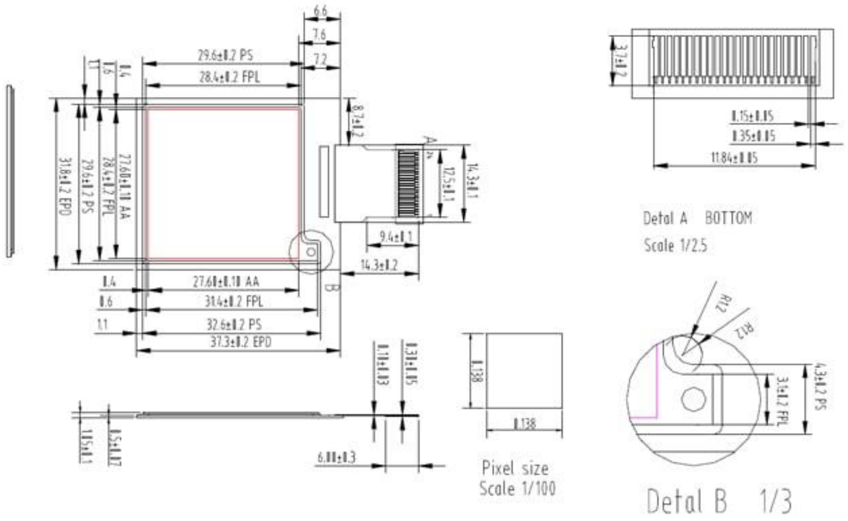
- **2.9" e-ink panel with SPI interface, ultra-low power retention (only consumes power during refresh)**



Tools and Technologies Used

- **Components of E-Ink**

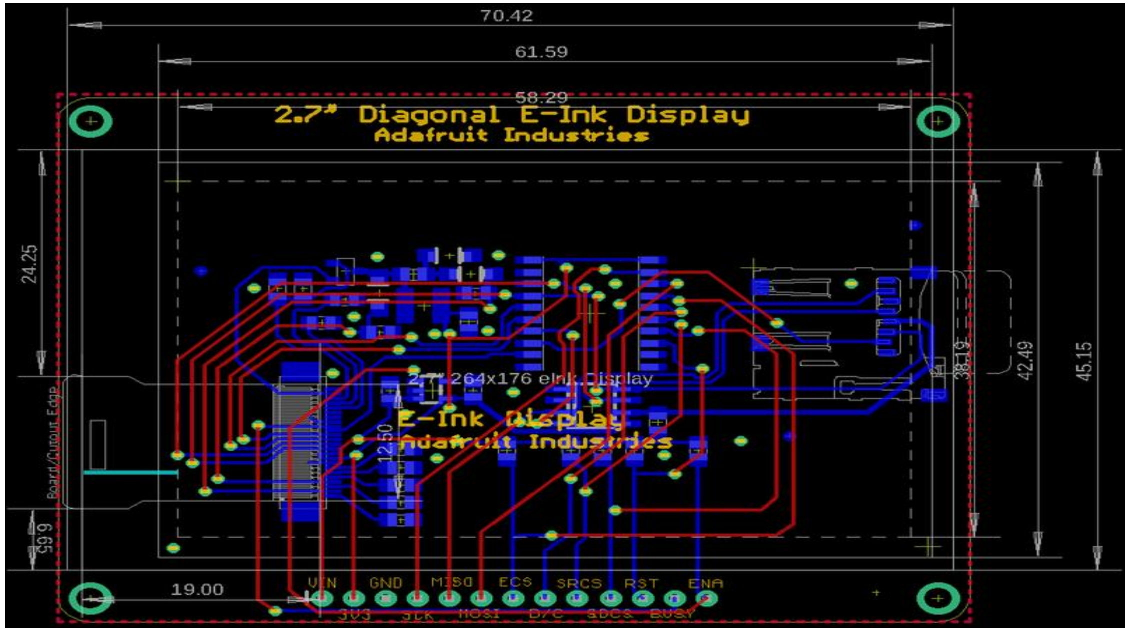
- **E-ink display breakout schematic—shows the SPI interface, boost voltage circuits, and pin labels**



Tools and Technologies Used

- **Components of E-Ink**

- **PCB layout image for e-ink display board or module that communicates over SPI with MCU**



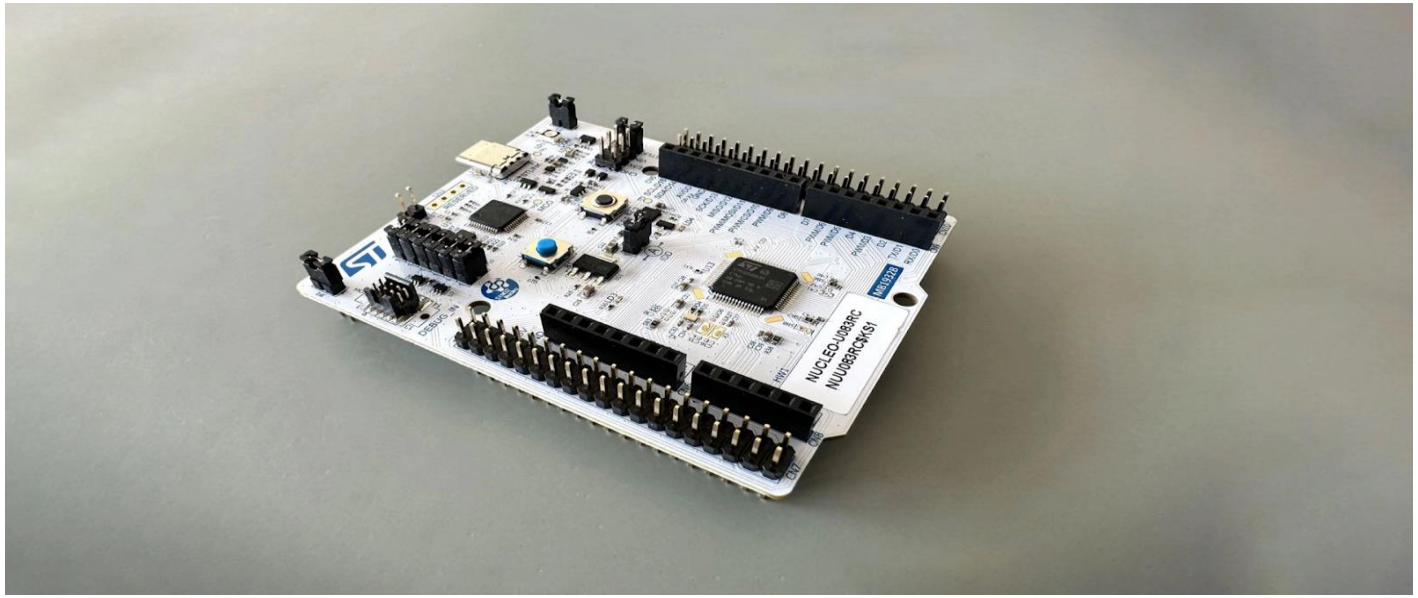
Tools and Technologies Used

- **Battery and Power Management**

- **Coin-cell holder or Li-ion battery connector with power-management IC. Many MCU dev modules include onboard regulator (e.g. MAX14750 in PICO)**

Tools and Technologies Used

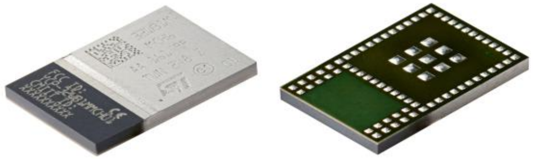
- **Buttons / User Input**



Tools and Technologies Used

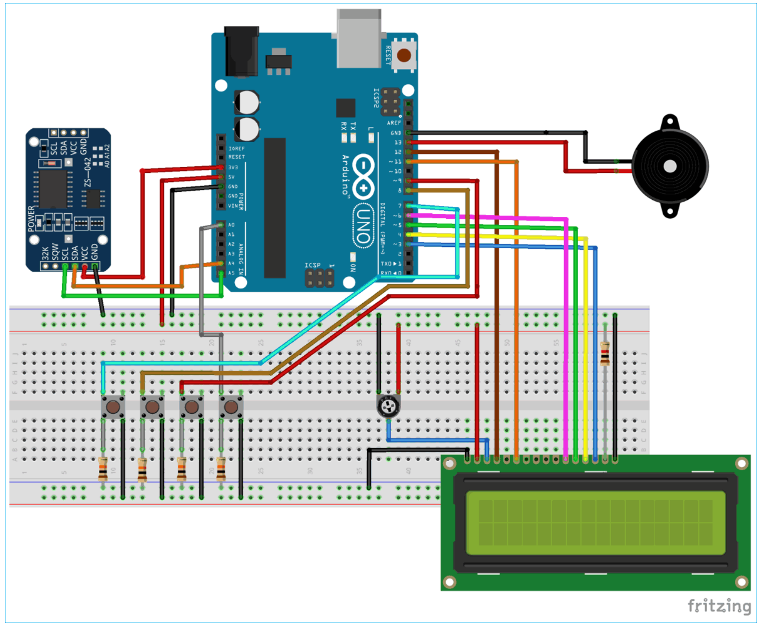
- **Low-Power Radio Module (e.g., BLE)**

- **ST’s STM32WB1MMC module—integrated Bluetooth LE 5.3 radio, dual Arm cores, certified RF, optimized for battery-powered IoT**



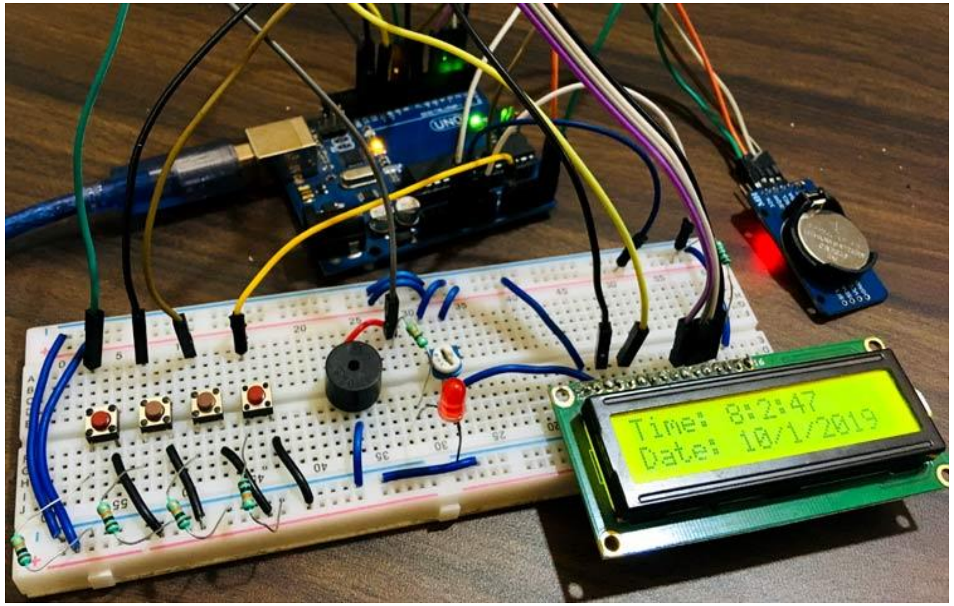
The Medication Adherence Reminder Device – Innovations and Health

- **Circuit-Diagram-Medication-Reminder-Device**



The Medication Adherence Reminder Device – Innovations and Health

- **Medication-Reminder-Device**



Procedures

- **Selection of Device Components**
- **Concept Wiring Flow (Textual Summary)**
- **Integration**

Procedures

- **Selection of Device Components**

- **Selection of a MCU module: The first thing I did was selecting the MAX32625PICO MCU Module. It is capable of coin-cell operation for ultra-low-power applications.**

- **Choosing a display size/type: Secondly, I chose the e-ink display type because of its low refresh power.**

- **Push-Button Input: Thereafter, A push-button is selected for user interaction to wake the MCU from deep sleep.**

- **BLE Radio: Next is the selection of separate UART/SPI-connected radio for syncing reminders or logs.**

- **Battery & power management: Deep-sleep modes are enabled to regulate voltage, and conserve power between reminders.**

Procedures

- **Concept Wiring Flow (Textual Summary)**

Component	Connection Type	MCU (Microcontroller Unit) Interface	Notes
Coin-cell Battery	Power source	→ PMIC → MCU	Ultra-low leakage, USB override
E-Ink Display	SPI bus (+ power)	MOSI, SCK, CS, DC, RESET, BUSY	Low refresh rate, SPI for minimal overhead
Push-Button(s)	GPIO digital input	MCU GPIO	Interrupt-wake capable
BLE Module	SPI or UART bus	MCU peripheral	For occasional sync or logging

Procedures

- **Integration**
- The device set-up began with the MAX32625PICO block as the MCU + PMIC (Power Management Integrated Circuit) core.
- E-ink display module connected via SPI (Serial Peripheral Interface) to MCU for updates, button presses monitoring for user interaction, dosage reminders tracking and visual feedback.
- Push-Button Input wired to a GPIO (General Purpose Input/Output) pin on the MCU for user interaction (e.g., acknowledgment, menu cycling) and de-bouncing enabled to wake MCU from deep sleep on button event.
- Coin-cell battery (e.g. CR2032) powered the PMIC, which supplies regulated voltages thus ensuring deep-sleep modes activation for MCU to conserve power between reminders.
- A deep-sleep and RTC (Real time clock) functionality is incorporated and connected as a separate chip to the MCU via SPI for reminder scheduling even when power is turned off or a device is placed in low power mode.
- Medication schedules and usage data would be stored on a small amount of non-volatile memory and later synced to a healthcare provider's system when connectivity is available via a low-power separate SPI-connected BLE (Bluetooth Low Energy) radio.
- BLE Radio attached to MCU via SPI for syncing data, reminders or logs when needed.

Let us join hands to build groundbreaking, efficient, and scalable technologies that could shape the future of computing in Africa—and beyond.

THANK YOU