BankApp

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GitHub repository

Introduction

What is BankApp?

- BankApp is a hardware-software product that offers various functionalities of a real-world banking application.
- The hardware is centered around a microcontroller, with multiple peripheral devices allowing for a smooth user-system interaction.
- The software is built with efficiency and simplicity in mind, assuring a pleasant experience for the user.

Purpose

- BankApp offers a hardware-software interface that empowers users with a multitude of actions:
  - register in the bank, using a personal card
  - set up a PIN code
  - access to a checking account
  - access to a savings account (with interest gain)
  - add money to the checking account
  - perform payments from the checking account
  - transfer money between checking and savings account
  - add friends
  - send money to friends
  - visualize notifications

Why this idea?

- Because banking doesn't have to be complicated and boring.
- BankApp offers a fun, yet efficient implementation to an ubiquitous need of the modern world: money management.
- With its attractive design and ease of use, BankApp is sure to steal the hearts of world-wide users.

General description

Block scheme

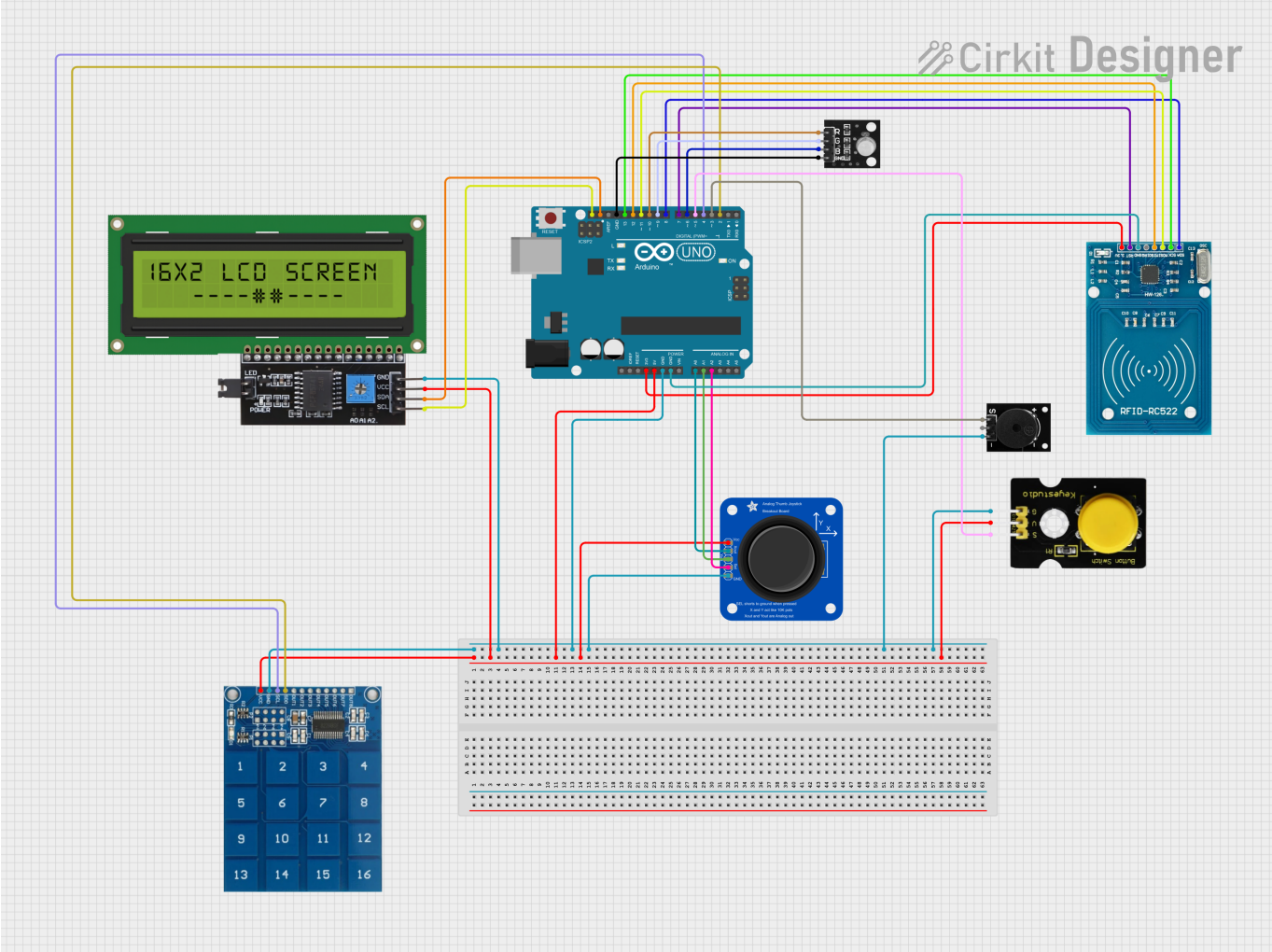
Components and their use

- **Arduino UNO**
  - Uses an ATMega328P microprocessor.
  - Provides just enough memory and computational power for a small-sized, embedded project like this.
  - The engine of the system, controls the whole behind-the-scenes logic of the app.
- **LCD 16×2 with I2C module**
  - Communicates by I2C with the microcontroller.
  - The main source of information and feedback provided to the user.
  - Displays all menus and actions.
- **MFRC522 Card scanner**
  - Communicates by SPI with the microcontroller.
  - The user scans the card here, when prompted.
- **Dual-axis Joystick, with push-button**
  - Gets analog input from the user, which is then converted to digital data.
  - Used to navigate between menus and as an OK/Confirm button.
  - The push-button needs debouncing.
- **TTP229 Capacitive keyboard (16 keys)**
  - Used to input the PIN code and money sums.
  - No debouncing needed.
  - 10 is used as 0
  - 11 is used as backspace
- **Red Push-button module**
  - Used as a Back/Cancel button.
  - Needs debouncing.
- **Passive buzzer module**
  - Commanded by the microcontroller via PWM.
  - Provides acoustic feedback to the user.
- **RGB LED module**
  - Provides visual feedback to the user.

Hardware Design

Components scheme

Created using Cirkit designer.



Electrical schematic

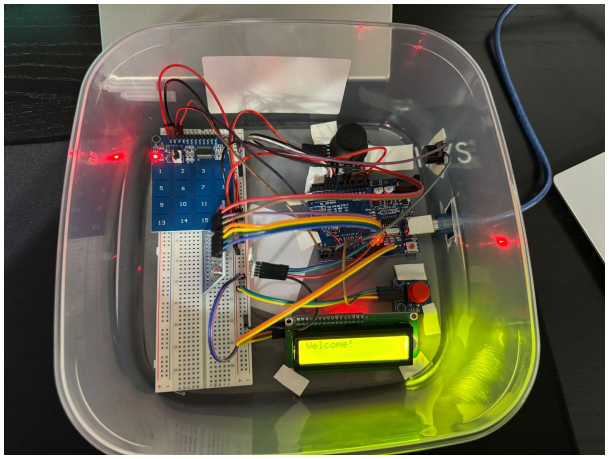
Created using **Autodesk Fusion360**.

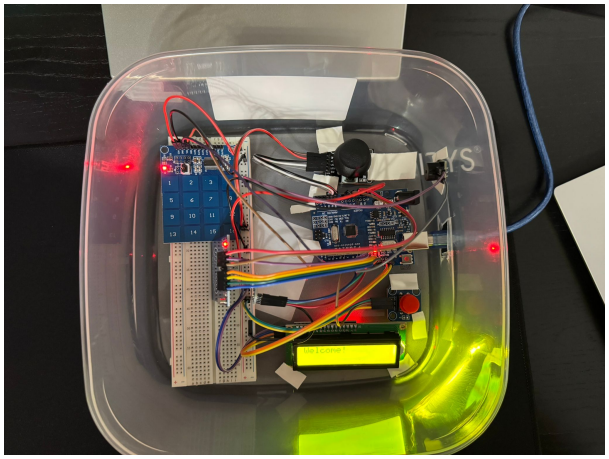
Bill of Materials

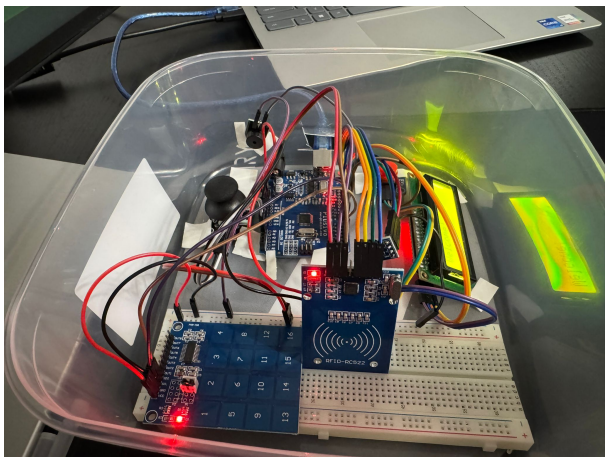
Component	Link to Vendor	Datasheet Link
Arduino Uno (ATmega328P)	Vendor Link	Datasheet
Capacitive touch (TTP229)	Vendor Link	Datasheet
LCD I2C 16×2	Vendor Link	Datasheet
Card scanner (MFRC522)	Vendor Link	Datasheet
Dual-axis Joystick	Vendor Link	Datasheet
Passive buzzer	Vendor Link	Datasheet
Red Push-button module	Vendor Link	Datasheet

RGB LED module	Vendor Link	Datasheet

Images







Functionalities

State diagram

- **Notes**:
  - The `LOGOUT` menu can be reached by pressing the `red button` from any menu of the `LOGGED IN` state (i.e. the yellow menus).
  - The `NOTIFICATIONS_SEE`, `SEE_FRIENDS` and `ADD_FRIENDS` menus offer interfaces where the user can navigate between entries.

Usage Guide

General Commands

- Navigation between menus is done by flicking the joystick to the left/right.
- A click on the joystick button is used for selecting a menu or confirming an action.
- A click on the red button is used for cancelling the current action or returning to the previous menu.
- The keyboard does not have a `0` key, so `10` is used as a `0`, while `11` is used as backspace.
- To accept a friend request, the joystick should be flicked up.
- To reject a friend request, the joystick should be flicked down.
- As a welcome bonus, each user starts with 200 in the checking account and 100 in the savings account.
- Buzzer sounds and LED lights accompany the LCD messages as feedback at each step.

State Flow

Start menu

- The device starts with the `Welcome` menu. By flicking the joystick to the left/right, the user can navigate between menus and choose the next action, `Login` or `Register`, by clicking the joystick button. A `Debug` menu is also available.

Register menu

- To `register`, a card should be placed next to the card reader, and then a 4-digit PIN code is required. If the user is already registered, an error message is displayed, else, the user's home menu is accessed.

Login menu

- To `login`, the same steps as for `register` should be followed, with the exception that the validity of the PIN code is checked. Also, if the user has not previously registered, an error message is displayed.

Logged-in menu

- After a successful log-in, the user has access to multiple menus, beginning with the `Hello` menu.
- To the right, the following menus are available: `Main account`, `Economies account`, `Friends`, `Change PIN`.
- To the left, the `Notifications` menu can be found.
- From any of these menus, if the red button is pressed, the `Logout` menu is accessed, where the user is asked to confirm the logout.

Main account menu

- The user can see the sum available in his checking account. From here, he can `add cash`, `make a payment`, `transfer money to the economies account` and `send money to a friend`.
- For each of these actions, a menu asking for the sum shall be accessed. The number must be at most 7-digits long. For each transfer from the account (thus, excluding `add cash`), the existing sum is first checked. If the balance is insufficient, an error message is displayed, and the transaction is aborted.

Economies account menu

- The user can see the sum available in his savings account. Every 15 seconds, a 2% interest is added to this sum.
- The user can `transfer money to the main account`, in a similar way as described above.

Friends menu

- The user can access the `See friends` and the `Add friends` menus.
- If he already sent a friend request to a certain user, or if that user sent a friend request to the current user that has not yet been resolved, the current user cannot send another friend request to that user.

Notifications menu

- There are 3 types of notifications supported: `Friend request`, `Accepted friend request`, `Received money from friend`.
- The latter 2 can be marked as seen by clicking the joystick button.
- For friend requests, the joystick should be flicked up/down to accept/reject it.

Software Design

Background and General details

- The project was developed using the **PlatformIO** extension for VSCode.
- The following **external libraries** were used:
  - `Arduino.h` - from PlatformIO
    - Contains macro-definitions for Arduino pins and basic functions such as `pinMode()` or `tone()`.
  - `LiquidCrystal_I2C.h` - GitHub
    - Used for interfacing the LCD, using the I2C protocol. Provides the `LiquidCrystal_I2C` class, which offers methods for initialization, cursor placing and writing characters.
  - `MFRC522.h` - GitHub

        - Used for interfacing the RFID card scanner, using the SPI protocol. Provides the `MFRC522` class, which offers methods for initialization, card detection and UID reading.
    - `TTP229.h` - GitHub
        - Used for interfacing the TTP229 capacitive keyboard. Provides the `TTP229` class, which offers a non-blocking method for key reading.
- **Novelty elements** - a banking device that uses a joystick as primary navigation method, adding the fun element to the sobriety of a financial app.
- **Laboratories functionalities used**
    - `Lab 0 - GPIO`: The RGB LED is connected to 3 digital GPIO pins of the Arduino, which are set as output.
    - `Lab 2 - Interrupts`: The Watchdog Timer is programmed to generate an interrupt every second (to manage the interest gain times for the savings accounts).
    - `Lab 3 - PWM`: The passive buzzer is controlled using the `tone()` function, which uses PWM behind the scenes.
    - `Lab 4 - ADC`: The Arduino reads analog values from the Joystick - `analogRead(JOYSTICK_VRX_PIN)`.
    - `Lab 5 - SPI`: The Arduino communicates by SPI with the RFID card scanner.
    - `Lab 6 - I2C`: The Arduino communicates by I2C with the LCD.

Implementation details

Modules

pins

- Contains the mappings between Arduino pins and peripheral components pins.

sounds

- Contains various sounds for the buzzer, used as audio feedback for the user after certain actions.

lights

- Contains multiple color schemes for the RGB LED, used as visual indicators of the menus the user is navigating.

wdt_counter

- Controls the Watchdog Timer, by setting it up to generate an interrupt every second.
- It is used as a time-keeper for managing the interest gain of the savings accounts (every 15 seconds, interest is applied).
- It is preferred instead of Timer0/1/2, because these might be controlled by the `millis()` function, which is also used in the project.
- If, at a later time, another configuration of the WDT might be preferred (i.e. interrupt after a time interval), only this module is to be modified, without interfering with other sections that use timers.
- The source file contains a static variable (private to the file) that represents the counter, offering an init and a getter method for outside modules.
- The ISR is rather short and simple, by only incrementing the counter value.

- The live value of the counter can be observed in the debug menu.

debounce

- Offers methods for checking if the joystick is flicked to the right/left/up/down, if the joystick button is pressed and if the red button is pressed.
- In the source file, multiple static variables for debounce handling are used, which must not be accessible from the outside.
- For button debouncing, a generic function is implemented, which is used by specific functions for the two buttons.
- For joystick flicks checking, it is verified if a certain time has passed since the last registered flick, such that there is a delay in the menu navigation system (i.e. the menus do not fall through instantly).

utils

- Contains utility data structures, constants, global variables marked as `extern` and various helper functions.
- The `User` structure is declared here, containing the necessary information each user must posses.
- Functions for keyboard reading, user management, UID card reading and notification handling are specified here.

menus

- The enum class that encodes the menus and the functionality of each menu are described here.

main

- Initializes the global variables, the user database and all the peripheral devices.
- Contains the main loop, which presents the `switch` statement by which the current menu function is chosen

How it works

- The users are stored in a statically allocated array, each of them having a predefined name and UID. Initially, all of them are marked as not registered and have to go through the `register` menu to become active.
- The `main loop` is rather simple: at each iteration, it checks the value of the `curr_menu` global variable via a `switch` and launches the associated routine accordingly. Each such routine then displays its message and enters a `while(true)` loop, waiting for user input.
- The menus communicate with each other by altering the values of the global variables and of the static variables from the `menus.cpp` file.
- The goal was to develop a device as realistic and error-less as possible, so extreme cases are always considered, such that: the user is forced to enter a 4-digit PIN code (is not allowed to submit it until it has 4 digits and cannot input more than 4 digits), the user is always allowed to cancel his current action if he changes his mind, hypothetical error states are checked, sending the system to the ERR0R menu if such a case occurs (i.e. if the current menu is the home page of a user, but there is no user logged in).
- `enum class` have been used for their own namespace feature and for their expressivity compared to numerical constants.

Correctness validation

- Each component was firstly tested alone to validate that the hardware was functional.
- The system as a whole was incrementally tested, after each new feature added.

Optimizations

- Because the maximum number of users is 6, their `registered` status was saved as a single 8-bit variable, using bitwise operations: user i is registered if the i-th bit (from the right) of the variable is 1. If each user had a boolean variable associated for this matter, 6 bytes would have been used in total, instead of 1. Thus, 5 bytes are saved.
- As the available RAM memory is limited, all the menu message strings were stored on the Flash rather than the RAM, via the `F()` macro. Also, variable types from `<stdint.h>` were used, for a better control.
- The notifications are encoded for memory efficiency: the `Notification` struct contains the type (`RecvFromFriend`, `FriendReq`, `ReqAccepted`), the index of the user who sent it and the sum of money sent (used when it is the case).

Results

- The final result is a fully functional, robust device, that encompasses all the proposed features in an intuitive and efficient way, both hardware and software wise.
- Demo on YouTube

Conclusions

- To sum up, this project achieved its goal of getting hands-on experience with embedded design, from wiring up the components all the way to writing efficient and functional software.
- For me, it was a fun experience with satisfactory results, which I will surely cherish in the future!

Bibliography

- MFRC522 setup
- Joystick setup
- TTP229 setup
- LCD setup
- ATmega328P Datasheet
- Button debouncing
- Watchdog timer setup

- C++ enum class

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