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Institute of Electrical and Electronic Engineering

MSc in Computer Engineering

EE529 Embedded Systems

Embedded Systems Project

Real-time Data Logger with an Alarm Clock

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1 Introduction

Embedded systems stand at the core of modern technological advancements, seamlessly integrating hardware and software to fulfill dedicated functions across diverse applications. Acknowledged for their robust functionality within larger systems, embedded systems play a crucial role in enhancing the efficiency and performance of electronic devices. The coordination of hardware and software components in the design of embedded systems emphasizes the vital need for a comprehensive understanding of both domains. This core principle is central to the Embedded Systems design, employing ARM Cortex architecture and the MSP432 microcontroller. It is a logical continuation of prior academic pursuits, including Advanced Digital Systems Design, Microprocessor Systems Design, and Computer Architecture. The integration of these foundational courses has provided us with the essential theoretical background and practical skills required for conceptualizing, designing, and implementing such systems. The overarching goals of this course extend beyond theoretical comprehension, placing significant emphasis on the imperative acquisition of hands-on experience. This practical exposure is crucial for navigating the intricate interplay between hardware and software to effectively address real-world and real-time complexities.

Within the vast array of applications in embedded systems, data loggers stand out as highly prevalent, offering essential capabilities for ongoing monitoring, recording, and analysis of data. These devices serve as indispensable instruments across diverse industries, aiding in fault detection, diagnostics, and the streamlining of maintenance processes. Additionally, data loggers play a key role in enhancing operational efficiency by identifying trends and patterns for process optimization. Their crucial function in ensuring adherence to quality control and industry standards is undeniable.

In this report, we will explore our initiatives to create a real-time data logger integrated with an alarm clock and serial communication. This undertaking serves as a tangible representation of the principles and competencies gained throughout our academic journey, encapsulating the core essence of embedded systems in effectively tackling real-world challenges.

2 Project Description

This project focuses on the development of a real-time data logger using the MSP432 microcontroller, given the following specifications:

- Capturing digital data (in Volts) from three sensors: Potentiometer, temperature sensor, and light sensor.
- Setting a real-time data reading, synchronized with a Real-Time Clock (RTC).
- Implementing a user interface through a keypad and LCD by adding a function to set RTC date and time (e.g., 13/12/2023 13:34) by pressing the * (star) key.
- Enabling users to set an alarm time (hours and minutes) by pressing the # (hash) key.
- Including a 10-second beeping sound (siren) to alert users to the alarm event.
- Generating a beeping sound at each key press using the onboard speaker.
- Displaying a blinking cursor to indicate the cursor position.
- Using an LED indicator that blinks every second, offering a visual cue of the system's operational status.
- Facilitating communication with a PC through UART (eUSCI A0) at 9600 baud to allow real-time data transmission for monitoring purposes.
- Using 3MHz as the system clock-frequency.

3 Tools

- MSP432P401R Microcontroller
- EduBase-V2 for MSP432 Launchpad: to use the onboard sensors/actuators.
- Code Composer Studio (CCS): to write, compile, debug and build the C program for the project.

4 System Design

In order to meet the specified requirements and effectively implement the desired real-time embedded system, the following steps were undertaken:

4.1 Finite State Machine

We designed a two-states FSM to implement this project, ***idle*** and ***run***:

- ***idle:*** In this state, the system keeps track of the key pressed by the user. When the "*" key is pressed, the updateTime() function is called, reading, displaying, and updating the entered time. On the other hand, pressing the "#" key will configure the alarm interrupt provided by the RTC.
- ***run:*** The "run" state operates for a short duration, updating sensor readings through ADC conversion, displaying readings, date and time on the LCD, and transmitting them to a PC using the UART protocol.

Figure1, shows the states transition of the designed Finite State Machine.

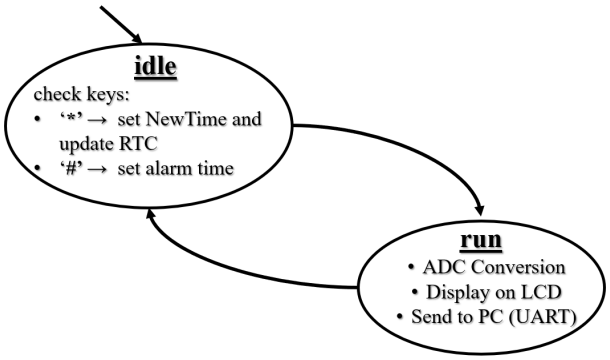

Figure 1: States transition diagram

4.2 Schematic Diagram

The figure below illustrates the pinout and connections between the components used in the Edubase V2 board and MSP432P401R.

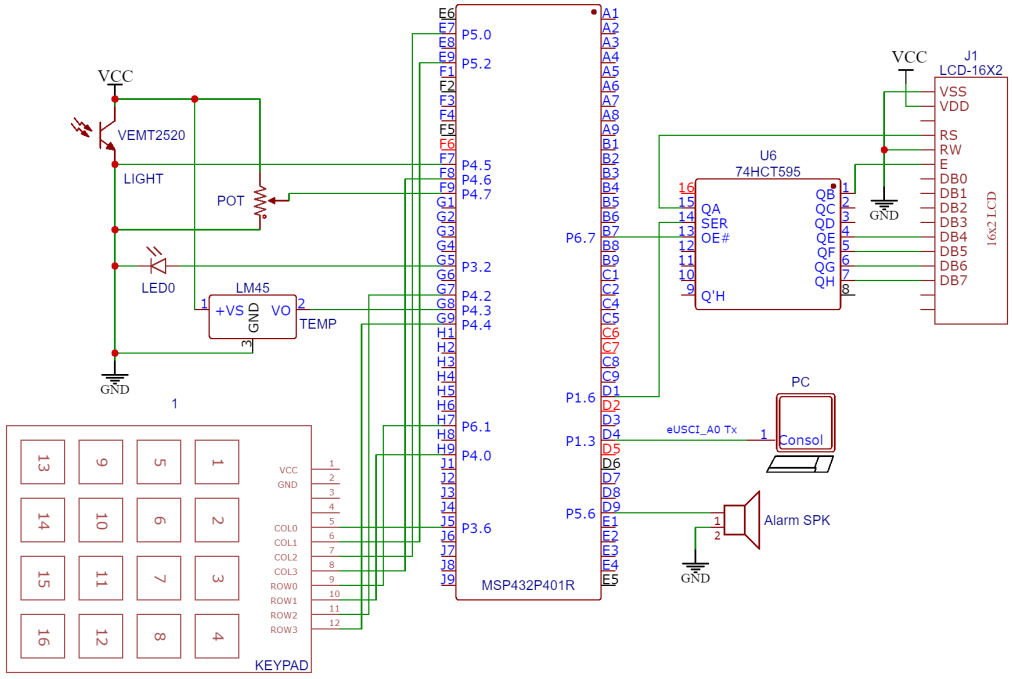

Figure 2: Schematic diagram

5 Implementation & Results

5.1 Source Code

For a detailed look at the code implementation and the associated header files, refer to our GitHub-repository.

5.2 Debugging

Debugging is a critical aspect of software development that involves identifying and resolving errors in the code. In the context of our project, centered around the MSP432P401R microcontroller, debugging is facilitated through a set of tools and features offered by various IDEs, including the one utilized here: CCS.
Here's a brief overview of the features employed:

- **Breakpoints:** Placing breakpoints in the code allows us to pause the program's execution at specific points to inspect variables, registers, and other relevant information.
- **Variables and Expressions Watch:** CCS enables us to monitor the values of variables and expressions in real-time, this helped us to identify unexpected behavior and incorrect values.
- **Registers Views:** Similar to watching variables, checking the registers' values enabled us to inspect the state of hardware registers and memory locations.
- **Stepping Through Code:** we were stepping through the code one line at a time, to trace the program's flow and identify the source of errors.

For example, in order to know what are the different flags and registers that correspond to the RTC-generated interrupts which need to be used in our code, we had to consult the referenced documentation and use the debugging tools mentioned above.

5.3 Results

Our implementation successfully meets several key criteria, affirming its robust functionality within the realm of embedded systems:

- **Integration of Components:** The project effectively integrates the MSP432 microcontroller with a Real-Time Clock (RTC), sensors, LED, LCD, keypad, speaker, and UART communication. This comprehensive approach demonstrates a practical understanding of embedded systems.
- **Real-Time Data Logging:** The inclusion of real-time data logging at one-minute intervals, capturing digital data from three sensors along with a timestamp, is a valuable feature. This not only demonstrates the capability to capture and process data but also provides a timestamp for better analysis.
- **User Interface:** Allowing users to set the RTC date/time using the keypad and providing visual cues with a blinking cursor, in addition to the beeping sound for each key press enhances the user experience.
- **Alarm Functionality:** The incorporation of an alarm feature with the ability to set the alarm time using the keypad is a useful addition to the user. The 10-second beeping sound upon alarm activation adds a practical aspect to the project.
- **Efficient Use of Interrupts:** Configuring three interrupts for second changes, minute changes, and alarm events reflects an efficient use of the microcontroller's capabilities. Placing the interrupt every minute to initiate the conversion of analog channels shows synchronization and optimization.
- **Communication with PC:** The use of UART communication to send data to a PC at 9600 baud demonstrates effective serial communication. This is essential for real-time data transfer and monitoring.

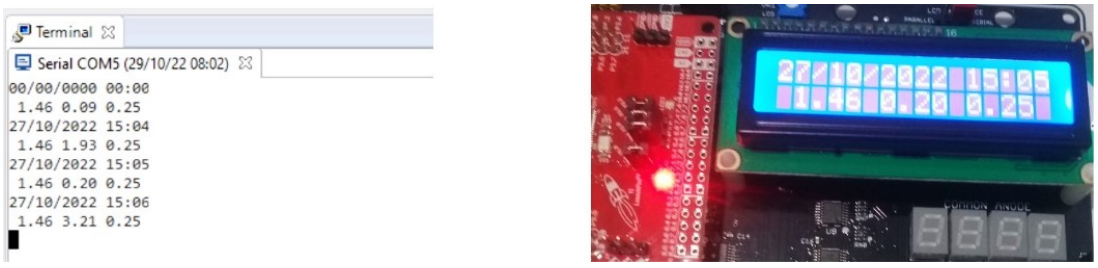

Figure 3: Real-Time data logging

6 Conclusion

In conclusion, our real-time data logger project with the MSP432 microcontroller demonstrates a commendable integration of hardware and software components, which shows a practical understanding of embedded systems as well as its implementation's characteristics that contributed to the project's success. The project's significance resides not only in theoretical understanding, but also in its practical application, which reflects the effective use of embedded systems in real-world circumstances. This work paves the way for further developments in technology and its wide range of uses.

7 References

- MSP432E4 SimpleLinkTM Microcontrollers Technical Reference Manual, 2017.
- EduBase-V2 Trainer User's Guide for TI ARM Launchpad Version 1.13, 2019.
- MSP432® Peripheral Driver Library User's Guid, 2015.
- Jonathan W. Valvano. Embedded Systems: Introduction to ARM®CORTEX M microcontroller, 2014.