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PORTFOLIO PROJECT REPORT

ENG20009- Engineering Technology Inquiry Project

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Introduction

The advent of microcontroller-based systems has opened new avenues for complex environmental monitoring and data logging. Particularly, the integration of storage mechanisms, command response protocols, and precise timing is pivotal in capturing and preserving the integrity of environmental data. Our project, carried out under the auspices of the Engineering Technology Inquiry Project at Swinburne University of Technology, has been primarily focused on enhancing the efficiency and reliability of data logging through an Arduino microcontroller by addressing three core aspects:

1. **SD Card Read and Write Operations:** Implementing a seamless mechanism for storing environmental data on an SD card allows for extensive data accumulation and analysis. My role involved developing a system that not only logs environmental data efficiently but also ensures data integrity and ease of access for future retrieval and analysis.

2. **Identification Command Response:** Ensuring that our data logging system can communicate effectively with external systems, I worked on the implementation of the SDI-12 protocol's identification command. This feature allows the system to provide vital information about itself, including the device's unique address, which is fundamental for multi-sensor networks and the correct identification of our device in a complex monitoring setup.

3. **Timer Interrupt Management:** To achieve precise timing for sensor readings and data logging, I employed timer interrupts within Arduino's architecture. This approach guarantees that our data is logged at consistent intervals, a crucial requirement for creating a reliable data set that accurately reflects temporal variations in environmental conditions.

The convergence of these three domains forms the bedrock of my contribution to this environmental monitoring project. By meticulously refining the data logging process, establishing robust communication protocols, and ensuring precise timing through interrupts, I have endeavored to elevate the reliability and efficacy of our environmental monitoring system. The following sections will articulate the technical nuances of my work, the challenges surmounted, and the pragmatic solutions developed throughout the course of this project.

This report will elucidate the innovative approaches taken, the underlying technical principles applied, and the practical outcomes of this endeavor. It is my intention to demonstrate that through careful planning, rigorous testing, and continuous refinement, we can significantly bolster the capability of microcontroller-based environmental monitoring systems to serve our growing data-driven needs in ecological assessment and management.

Pseudocode

The pseudocode of the code that I had contributions in is as follows.

```
function Initialize_SD_Card():
    try to open "message.txt" with read/write permissions
    if failure:
        stop and report the error "open failed"
    else:
        close the file

function Setup():
    Initialize_SD_Card()
    Configure_Timer3_Interrupt(forwrite)
    Start_Timer3 with 600000000 microseconds interval

function Loop():
    Call menu()

function forwrite():
    Get current date and time from RTC
    Acquire sensor values by calling senval(1)
    Construct a string message with sensor values and timestamp
    Write the constructed message to the SD card

function sdicom():
    if Serial1 has available data:
        Read a character from Serial1
        if character is less than 1:
            Remove the byte and log "Byte removed"
```

```
    else:
      Process_SDICOM_Commands based on the character

function Process_SDICOM_Commands(character):
  if character is '?':
    Process_Inquiry_Command()
  else if character equals sensor address:
    Process_Sensor_Commands()

function Process_Inquiry_Commands():
  Read the next character
  if it is '!':
    Output the sensor address
  else:
    Log "Incorrect input"

function Process_Sensor_Commands():
  Read the next character
  if character is 'I':
    Process_Information_Command()

function Process_Information_Command():
  Read the next character
  if it is '!':
    Construct and output the information message

function sdiout(data):
  Set digital pin LOW for signal
```

```
  Output data to Serial1
  Wait for half a second
  Set digital pin HIGH
  Wait for a short delay

Function senVal
  Initialize sensor
  Read value from sensor
  If reading is successful
    Return sensor value
  Else
    Return error code or default value
End Function

Function writeSD(fileName, data)
  If SD card is present
    If file with fileName exists
      Open the file in append mode
    Else
      Create a new file with fileName
    End If
    If file is open
      Write data to the file
      Close the file
      Return true // Write success
    Else
      Return false // File open error
    End If
```

```
  Else
    Return false // SD card not present
  End If
End Function

Function readSD(fileName)
  If SD card is present
    If file with fileName exists
      Open the file in read mode
    Else
      Return error // File does not exist
    End If
    If file is open
      Initialize an empty data structure (e.g., array or list)
      While not end of file
        Read line from file
        Add the read data to the data structure
      End While
      Close the file
      Return the data structure // Read success
    Else
      Return error // File open error
    End If
  Else
    Return error // SD card not present
  End If
End Function
```

Risk Assessment

When delving into the intricate task of developing a microcontroller-based environmental monitoring system with an emphasis on SD card interactions and real-time responsiveness, it is imperative to conduct a meticulous risk assessment to ensure the system's reliability and efficiency. The risks involved can be detailed as follows:

Technical Risks:

1. **Timer Interrupt Handling:** The implementation of timer interrupts is a sophisticated operation fraught with the risk of introducing timing conflicts within the system. If not carefully managed, interrupts could potentially preempt critical read/write operations to the SD card, leading to missed data logs or system instability. The technical challenge lies in crafting interrupt service routines that are concise yet efficient, thereby minimizing their overhead on the system's performance. A well-designed interrupt handling mechanism must be put in place to ensure that real-time events are processed promptly without disrupting the ongoing SD card operations.

2. **Concurrency and Synchronization:** Given that the SD card operations are split between two cards—with one dedicated to reading and the other to writing—there exists an inherent risk of concurrency issues. These could arise from simultaneous access attempts to the respective cards, which necessitates the implementation of a robust synchronization mechanism to prevent data corruption or loss.

Physical Risks:

1. **SD Card Durability and Data Integrity:** SD cards are subject to wear and tear due to repeated read/write cycles. This physical limitation poses a risk of data corruption or complete card failure over time, especially when the system is deployed in harsh environmental conditions. Ensuring data integrity requires a mechanism for detecting and correcting errors, as well as a backup strategy for data recovery.

2. **Sensor to SD Card Dependency:** The dual arrangement of sensors and SD cards introduces a layer of complexity in the physical interfacing of these components. The risk here is two-fold: on the one hand, failure of a sensor can lead to gaps in data collection; on the other, an SD card malfunction could result in the loss of valuable data gathered by the sensors. This necessitates a design that includes fault-tolerant features, allowing the system to continue operation even when one component in the pair fails.

In response to these risks, a series of mitigation strategies must be developed and rigorously tested. For the technical risks, this could include implementing preemptive multitasking, where critical tasks are prioritized, and the use of advanced programming constructs that facilitate non-blocking I/O operations. To counteract the physical risks, the system could employ error-checking algorithms and redundant storage solutions, along with regular maintenance checks to replace or repair worn-out components. Regular system audits and real-time monitoring can be invaluable in early detection and rectification of issues, thereby maintaining the continuous operation of the environmental monitoring system.

Reflection on knowledge learned

Reflecting on the journey of developing a microcontroller-based environmental monitoring system has been a significant learning experience that encapsulated the intricacies of embedded system design, particularly the interaction with storage mediums like SD cards and the implementation of real-time processing through timer interrupts.

Firstly, the in-depth exploration of the SPI protocol and its application for SD card communication was enlightening. Understanding the nuances of how microcontrollers communicate with peripheral devices at the byte level expanded my appreciation for the complexity and efficiency of embedded communications protocols. The process of structuring data to be logged, ensuring robust error-handling, and optimizing read/write operations were critical skills honed during this project.

The realization of how essential and challenging it is to manage concurrent processes in a system where timing is crucial was a key takeaway. Delving into the use of timer interrupts and grappling with the need for their precise execution without disrupting the core functionalities of the system was a practical lesson in the importance of real-time operating system principles, even in seemingly simple microcontroller applications.

Moreover, the physical arrangement of the sensors and SD cards illuminated the considerations necessary for reliable hardware design and the importance of considering the physical and electrical limitations of the components. This aspect of the project emphasized the value of a holistic approach to system design, where software and hardware must be seamlessly integrated and cohesively designed.

The risks associated with the project, particularly those surrounding the timer interrupts and SD card operations, highlighted the importance of risk assessment and mitigation strategies in embedded system design. Learning to anticipate potential failures and devising strategies to handle such events proactively has been an invaluable part of my professional development.

In retrospect, the interplay between technical knowledge and practical application has reinforced my understanding of embedded systems. This experience has taught me the vital role of thorough planning, continuous testing, and iterative improvement in developing robust and reliable systems. It has instilled a sense of resilience and adaptability in my approach to problem-solving, knowing that meticulous design and foresight can overcome the challenges posed by complex, real-world applications.

Teamwork reflection

Reflecting on the teamwork aspect of the environmental monitoring system project, it was a journey that significantly underscored the value of collaboration, communication, and the combined strengths of a diverse team in the successful completion of a complex technical project.

Working closely with my teammates, I was able to witness firsthand the power of collective brainstorming when it came to troubleshooting issues with the SD card interface and the timer interrupt mechanism. Each member brought a unique perspective to the table, which was pivotal in overcoming the technical hurdles we encountered. It was a clear demonstration of how a multifaceted problem could benefit from a multidisciplinary approach.

The division of labor was an important strategy that we employed early in the project. By splitting the workload into manageable segments—focusing on SD card operations, sensor readings, and timer management, for example—we could work in parallel, which greatly increased our efficiency. However, the real strength of our team lay in our ability to come together to integrate these separate components into a cohesive system, ensuring interoperability and functional harmony.

Communication was another cornerstone of our teamwork. Regular meetings, clear documentation, and open channels for feedback ensured that everyone was aligned with the project's goals and progress. When difficulties arose with synchronizing the timer interrupts with other tasks, it was the clear and prompt communication between team members that facilitated a quick resolution.

The project also served as a profound learning experience in terms of conflict resolution and the importance of a supportive team environment. There were moments when differing opinions could have led to conflict, but through respectful dialogue and a willingness to consider alternative solutions, we turned potential obstacles into opportunities for learning and growth.

Teamwork within this project was more than just a means to an end—it was a dynamic process that taught us the importance of trust, the benefits of leveraging individual strengths for a common goal, and the irreplaceable value of working together towards a shared vision. It instilled in each of us a deeper appreciation for the synergy that effective teamwork creates and its impact on achieving not just technical success but also personal and professional development.

Conclusion

In conclusion, the development and implementation of the environmental monitoring system project not only achieved its objectives but also provided a wealth of learning opportunities. The successful reading and writing operations to the SD card, the precise response to the identification command, and the effective management of timer interrupts stand as testaments to the technical accomplishments of the project. Despite the initial concerns regarding the technical risks of integrating the timer interrupt and the physical risks involved in the dual operations of the SD card and sensors, the team navigated these challenges with innovative solutions and proactive risk management.

The project's success was greatly amplified by the collective efforts of a dedicated team. Each member's commitment to the project, combined with our shared knowledge and collaborative spirit, allowed us to overcome obstacles and adapt to changing requirements. The experiences gained from this project will undoubtedly serve as a valuable foundation for future endeavors in the field of embedded systems and environmental monitoring.

As we reflect on the project, it becomes clear that the technical skills honed, the risks mitigated, and the lessons learned from teamwork and collaboration are as significant as the project's outcomes. The combination of these elements not only culminated in the successful completion of a complex system but also set a precedent for how teamwork and technical expertise can align to create innovative solutions to real-world problems.