BL40A1101 Embedded Systems Programming

Final Assignment

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Group Zybo Z-7 Assignment

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SWITCHED MODE POWER CONVERTER SIMULATOR/EMULATOR

1 INTRODUCTION

This embedded system project, designed, and developed as part of our final assignment, demonstrates a comprehensive approach to real-time control of a DC-converter designed and implemented on the ZYBO Z-7 development board. Utilizing a state space model and real-time operating system (RTOS), the project showcases the integration of theoretical electrical engineering principles with practical software engineering knowledge acquired from the lectures and exercises. This report outlines the short description of the implemented solution of a real-time DC-Converter Control System.

2 SYSTEM OVERVIEW

The core of our project is a DC-converter with a PI control system. Utilizing a state space model, the system simulates and manages the operation of a DC-converter, an essential component in power electronics. This simulation is achieved through a combination of software engineering, control theory, and electrical engineering principles.

The program opens in the main menu where the user can choose a mode by pressing the 1st button, or by typing a number between 1 and 2. The modes are configuration mode and modulating mode, and on the board the LEDs light up based on which mode the user is in (Main menu = 0 LEDs, Configuration mode = 1 LED, Modulating mode = 2 LEDs).

In the configuration mode the user can choose the Ki and Kp parameters. When accessing configuration mode through UART, the buttons are disabled. However, when it is accessed by using the buttons, both functionalities work at the same time. There are set ways how the user can exit the configuration mode. When using the UART, the user simply types ‘i’ or ‘p’ to switch between the parameters, and ‘e’ for exit. After choosing a parameter, the user needs to type a number to set it. When the mode is entered the default parameter is Ki. The user can also change the parameters by using the buttons on the board. The user can change the Ki and Kp parameters by pressing buttons 3 and 4 to decrease and increase the value, respectively. The second button on the board is used to change which parameter the user wants to set. As the default is Ki, pressing it once chooses the Kp parameter, and pressing it twice exits the configuration mode.

In the modulating mode the user can change the reference voltage in two ways. First, the user can type a number in the UART to set it. The second way to change the voltage is by pressing the 3rd and 4th button to decrease and increase it, respectively. The user can exit the modulating mode by typing ‘e’ in the UART or by pressing the first button on the board. This throws the user back to the main menu.

The program has 4 tasks implemented with FreeRTOS. The ‘modeSelection’ task is the ‘heart’ of the program. It is used for the main menu, the configuration mode, and the switching between the modes, as the name suggests. It is also used during the modulating mode to take in user input through the UART and the buttons. When the modulating mode is entered, the 3 other tasks are resumed. The first task is used for the calculations, the second task is used to change the LED brightness and color on the board based on the output voltage, and the third task is used to print the output voltage in the UART.

3 FUNCTIONALITIES

1. **Hardware Platform**: **ZYBO Z-7 Board**
    - Central Processing Unit: Dual-core ARM Cortex-A9 processor
    - Programmable Logic: FPGA for custom hardware logic
    - Peripherals: UART interface, physical buttons, LED indicators
2. **Real-Time Control with FreeRTOS**:
    - The system utilizes FreeRTOS, a real-time operating system, ensuring timely and efficient task management (Lecture 10 from the course material.)
    - We have used Semaphores in this project for mutual exclusion in critical sections where shared resourced are accessed.
        - More specifically, we use 'buttonSemaphore' to disable the buttons in configuration mode when it is accessed through the UART.
        - 'u3Semaphore' and 'uRefSemaphore' are used during the modulation to block access to global variables u3 and uRef, respectively.
    - This approach facilitates concurrent processing and precise timing, crucial for real-time control applications.
3. **DC-Converter Control**:
    - At its core, the system simulates and controls a DC-converter using a state space model.
    - We have used a discretized model for digital implementation.
    - It includes a Proportional-Integral (PI) controller, ensuring stable and responsive control of the converter output. This controller is fine-tuned to respond to fluctuations, maintaining system stability and achieving the desired voltage regulation.
    - The output voltage of the converter is compared to the reference voltage, further the role of the PI controller is to minimize the error.
    - The constants Kp and Ki help with the rate at which the system must reach stability.
4. **User Interface and Interaction**:
    - The system allows real-time adjustments and monitoring through UART communication coupled with physical button inputs.

- This interface provides a user-friendly way to switch between configuration, modulation and idling modes, on-the-fly adjustments of key parameters like reference voltage, values of ki and kp, making the system interactive.

5. **Visualization and Feedback**:
    - LED indicators are employed to provide visual feedback on the system status and operating mode.
    - This feature enhances user experience and aids in system diagnostics.

The attached video provides the detailed explanation of the program and its functionalities.

Link to the demonstration video: https://www.youtube.com/watch?v=HlXvMNreUl4