CpE 5170 REAL TIME SYSTEMS

A Real-Time Approach for the Control and Coordination of Multiple Power Electronic Converters with a Single Embedded Processor and Supervisory Control Interfacing Techniques

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Abstract

The project aims to control two dc-dc converters running at two different voltage specifications of 3.3 V and 2.5 V from a common input of 8 V to 15 V at a power rating of 10 W. The aim of the project is to control these two dc-dc converters running at two different frequencies by a **single embedded controller**. The project's conclusions are intended to enhance the designer in assessing the real time performance requirements in a power electronic system which inherently run on hard deadlines, that are not withing the expertise of a typical power electronic engineer. The work primarily aims at scheduling predominantly periodic tasks while also accommodating for aperiodic and sporadic events and how their arrivals can impact the system. The knowledge can be applied in wider scenarios where more complicated supervisory control approaches can be used in power electronic control systems with different types of converters.

1 Literature Review

Real-time systems deal with applications that have firmware and hardware interactions that demand functional, logical and temporal correctness in the firmware to support smooth functioning of the target application, while also accommodating for contingencies, faults and properly utilizing the processing power of the critical computing systems that run the written firmware.

The field of power electronics extensively uses the integration of embedded systems to achieve various control objectives among which the maintenance of a constant output voltage is of prime consideration. To achieve this objective, power electronic converter's are often implemented with a voltage mode control feedback system , which continuously monitors the output voltage of the converter and compensates for deviations.

However, before a converter's controller firmware is written, it is necessary to assess the behavior of the converter's dynamics also known as the small signal dynamics [1–4]. Once the converter's essential transfer functions are known, the digital controller can be designed.

There are numerous methods and algorithms for digitally controlling dc-dc converters [5–7] and function to primarily optimize the time response of the converter.

It is also necessary in critical systems such as power supplies catering to satellites, medical equipment and defense related fields where the health of the power supply is to be continuously monitored [8]. This would require a designer to come up with sensing and failure mode detection algorithms and corrective actions before a catastrophic failure occurs. Literature talks about two kinds of tests for health monitoring, namely, efficiency monitoring [9] and frequency response monitoring [10–12]. Some of the miscllaneous effects of digital control are quantization effects and limit cycling effects [13] which have to accounted for, while designing these supplies.

2 Methodology

2.1 Base design of the converters

The project first starts with a design phase, where two buck converters were designed with two different frequency and voltage specifications for each converter. A PCB is designed for two high-frequency buck converters with the primary buck stage topologies and their ancillary circuitry. Additional protection features such as temperature sensors and over current detection networks are constructed to enable detection of critical faults. The designed PCB and the final version of the built converter are shown in Figure 1 and 2 respectively.

The full features of this Real-Time Operating System are as follows:

1. Control two dc-dc converters in Voltage Mode Control (VMC) at two different frequencies.
2. Each dc-dc controller has its dedicated control law dictated by a digital controller implemented in direct form realization of a tuned controller transfer function
3. Failure mode detection and correction of the following two events:
   (a) MOSFET Over Temperature
   (b) Output Short Circuit
4. Communication with a LINUX terminal (Raspberry Pi) or MATLAB GUI to display messages and enable online variation in control parameters

2.2 Scope of work

This project primarily focuses on scheduling of various types of jobs that enable the operation, control and monitoring of a typical power electronic converter. The various types of jobs in the scope of this application and their dependencies and deadlines are shown in Figure 3 in the Appendix.

Various tasks are categorized based on the following assumptions and reasons:

- MOSFETs can handle overtemperature for an extended time and the job of PWM shutdown can therefore be shifted to a place where considerable slack time may be available for the execution of the task.
- When Under Voltage Lock Out (UVLO) is detected, the gate driver already mutes the PWM to the MOSFETs and arrests the operation. Therefore the job of notifying the user can be again scheduled when the scheduler finds appropriate amount of slack time.
- The controller maintains a constant communication link with the processor and transmits and receives data packets every $1\,\mathrm{ms}$. Therefore it is considered to be periodic.
- The main PWM mapping mechanisms are periodic jobs with hard deadlines running at sampling frequencies of $500\,\mathrm{kHz}$ and $350\,\mathrm{kHz}$

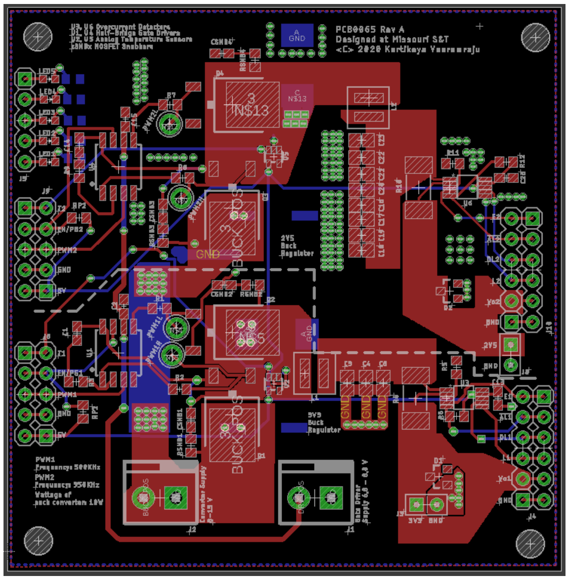

Figure 1: PCB Design

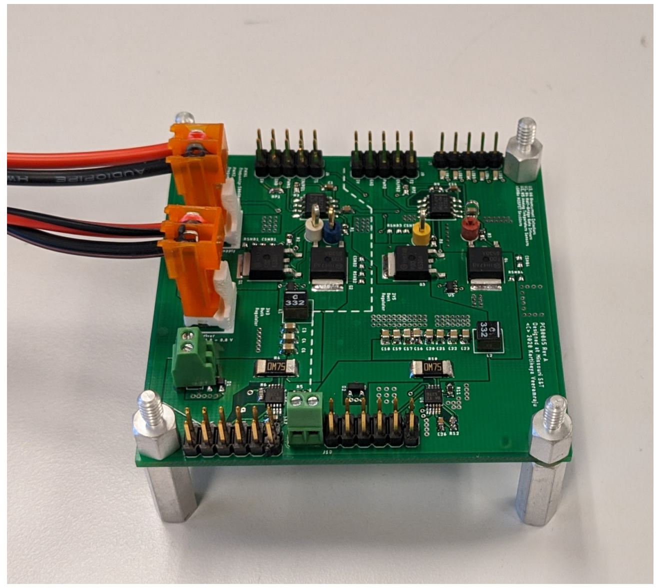

Figure 2: Finished PCB

- The short-circuit conditions are to be cleared within a deadline of $5\,\mu s$ and are therefore considered critical jobs with an unknown release time but a known hard deadline, and therefore are classified as sporadic jobs

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Appendices

A Task Graphs

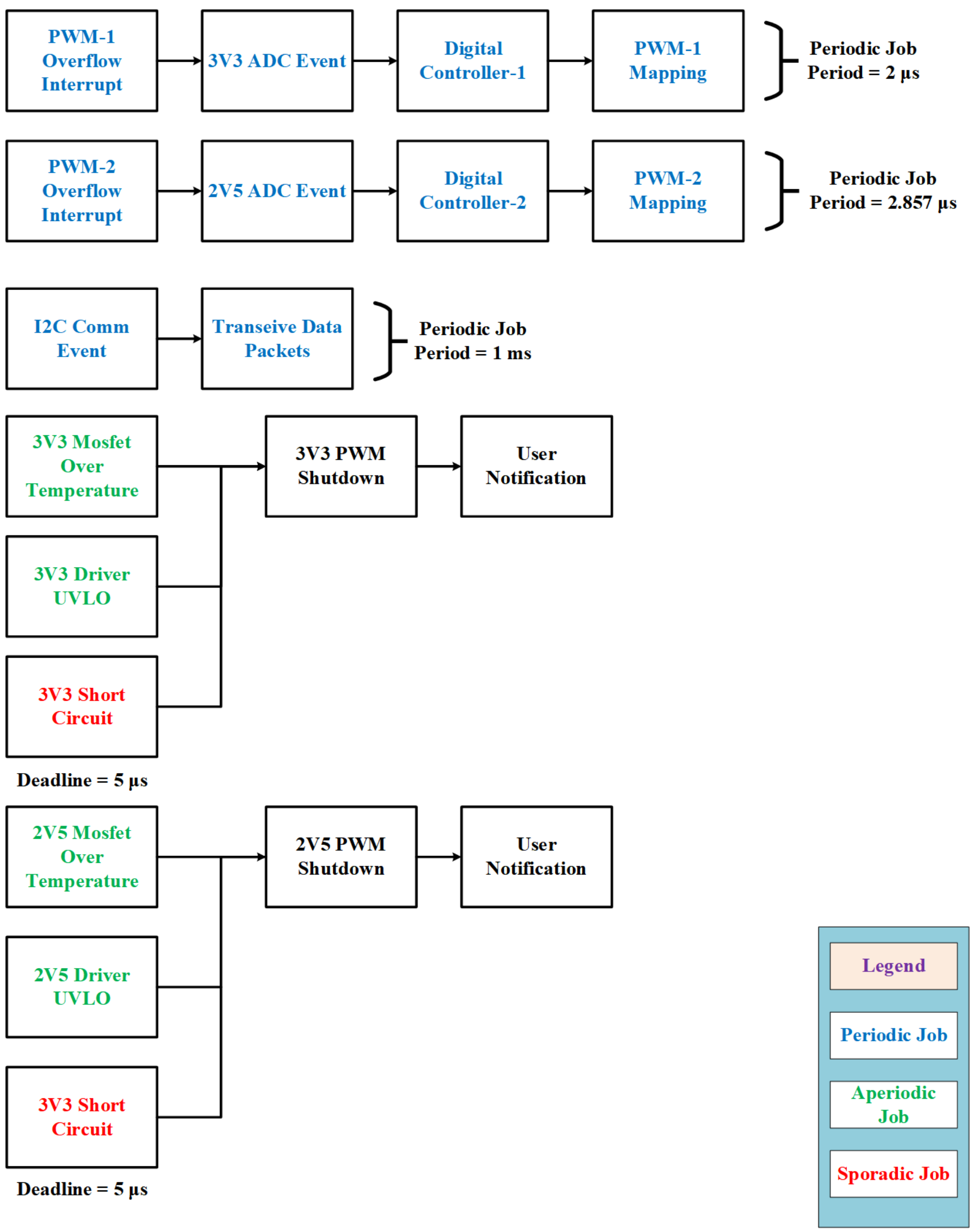

Figure 3: Various types of jobs and their dependencies