Development of a Modernised Software Platform for an Educational Robot

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1 Introduction

In 48540 Signals and Systems, a robot platform called the "Maze Rover" is used to teach signal and control theory concepts to Electrical Engineering students. This robot is built on an obselete 16-bit microcontroller platform called "ModCon", and a replacement is under development. The new platform ("ModCon 2.0") is built on a Freescale Kinetis 32-bit microcontroller, which provides vastly improved performance.

This project demonstrates the reimplementation of the Maze Rover's embedded software on the ModCon 2.0 platform using the C99 programming language.

Development used a Freescale Kinetis TWR-K70F120M development board. This board is designed to integrate into the Freescale Tower System (as seen in Figure 1), which provides a modular system for development of embedded projects. In this project, an Analog Interface Board developed by a previous student was used as a tower peripheral.

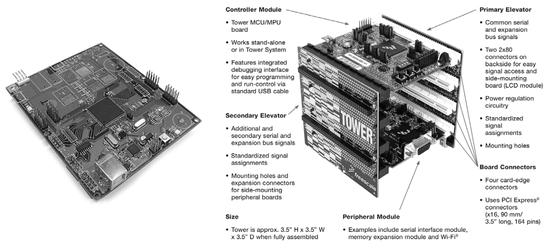

Figure 1: Previous-generation ModCon Controller (left) and the Freescale Tower System (right) [Freescale Semiconductor, 2012]

2 Project Goals

The goal of this project was to completely reimplement the functionality of the existing Maze Rover firmware on a prototype of the ModCon 2.0 platform. At a high level, this included communications functionality related to modulation and demodulation of signals, and the implementation of a motor controller. This required the implementation of a Hardware Abstraction Layer providing:

- SPI and UART interfaces
- Analog input and output
- Periodic timers
- Low level drivers i.e. clock generator, interrupt controller, General-Purpose I/O

3 Code Quality

Prior to commencing software development for this project, a literature review was conducted examing code quality and its applicability in an embedded software project. Quality code was defined to be Stable, Maintainable, and Portable. Research discovered the common sources of error when using C, and methods for reducing their impact. Coding standards from embedded software expert groups such as MISRA and the Barr Group were reviewed. The results of the research were synthesised into an extensive Embedded Software Coding Standard.

4 Communications

The Maze Rover is capable of simulating the generation of amplitude-modulated waveforms, and the demodulation of such waveforms using a coherent demodulator. Demodulation requires the recovery of the carrier oscillator used in modulation, and this is performed using a digital phase-locked loop with a voltage-controlled oscillator (VCO) and discrete phase shifter.

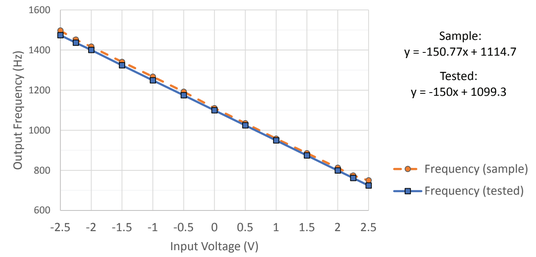

Figure 2: Performance of the Voltage Controlled Oscillator compared to a reference Maze Rover unit using identical parameters

This functionality was ported (by adapting the original source) to the new platform, and demonstrated fully functional. The performance of the VCO is compared to a reference Maze Rover unit in Figure 2, and the output of the demodulator is shown in Figure 3.

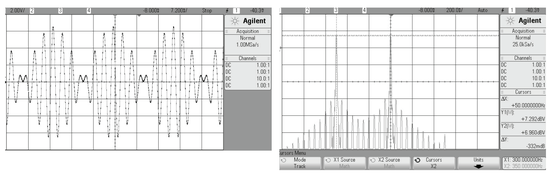

Figure 3: Demodulation shown in Time (left) and Frequency (right) domains. Message signals at 300Hz and 350Hz visible (see cursor measurements at bottom right)

5 Control Systems

As prototype Maze Rover hardware was not available, a substitute control task was performed using the Quanser MAGLEV apparatus. A control framework was developed, modelled on that used on the ModCon in Introductory Control. The control task (levitating a steel ball as seen in Figure 4) was performed successfully using a PID-form controller derived by state-space methods.

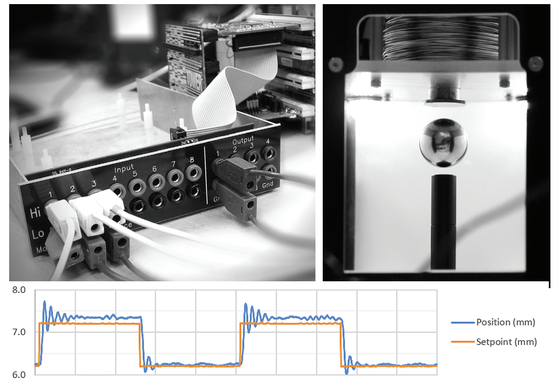

Figure 4: Prototype hardware configuration (left), the MAGLEV system under succesful control (right), and the controlled MAGLEV system response to a 1mm step input (bottom)

6 Conclusion

The project has met its core goals. A hardware abstraction layer for the ModCon 2.0 has been developed. The suitability of the resulting platform for use in a Maze Rover replacement has been demonstrated by porting the Maze Rover's communications functionality and performing a complex control task.

References:
Freescale Semiconductor, 2012. TWR-K70F120M Tower Module User's Manual Rev. 1.1. [Online]
Available at: http://cache.freescale.com/files/microcontrollers/doc/user_guide/TWRK70F120MUM.pdf