Module 10

Introduction: Debugging Real-time Systems

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Educational Objectives:

REVIEW C programming arrays
UNDERSTAND how flash memory operates
EXPLORE debugging techniques for real-time systems
LEARN how to generate periodic interrupts using SysTick
INTERFACE bump switches to the robot
DESIGN, BUILD & TEST A SYSTEM
Stores input data into a black-box recorder

Prerequisites (Modules 6, 8, and 9)
- GPIO digital inputs (Module 6)
- Switches and LEDs (Module 8)
- SysTick timer (Module 9)

Recommended reading materials for students:
- Volume 1 Sections 2.7, 6.2, 6.9, 9.1, 9.2, 9.4, and 9.6
  Embedded Systems: Introduction to the MSP432 Microcontroller ISBN: 978-1512185676, Jonathan Valvano, copyright (c) 2017

- Volume 2 Sections 2.4, 3.9, 5.1, 5.4, and 5.7
  Embedded Systems: Real-Time Interfacing to the MSP432 Microcontroller, ISBN: 978-1514676585, Jonathan Valvano, copyright (c) 2017

System verification is an important task when developing embedded systems, especially if the system is to be deployed in safety critical situations. Furthermore, in a **real-time system**, it is not only important to get the correct answer, it is important to get the correct answer at the correct time. **Latency** is the time between when a service is requested and the time when service is initiated. Similarly, **response time** is the time between when a service is requested and the time when service is complete. A real-time system is one that can guarantee a worst-case latency. Alternatively, we can categorize a system as real time if there is an upper bound on the response time.

Some requests occur periodically, and in this module we will use **SysTick interrupts** to execute tasks on a regular basis.

The second component to this module is to develop debugging techniques for real-time systems. **Intrusiveness** is defined as the degree to which the debugging code itself alters the performance of the system being tested. Breakpoints, single stepping, and printf output are high intrusive, and thus not appropriate for debugging real-time systems. Rather we will learn how to dump strategic information into arrays, providing similar observations as the classical printf statement, but in a minimally intrusive manner. For logging, debugging data for long periods of time, we can dump data into the flash ROM of the microcontroller.

In the lab associated with this module, you will interface bump sensors with the microcontroller, see Figure 1. These switches will allow you to know if and where the robot has contacted an obstacle. Data from the line sensor and bump sensors will be collected periodically using SysTick interrupts. Using interrupts to handle the line sensor provides a processor-efficient solution.

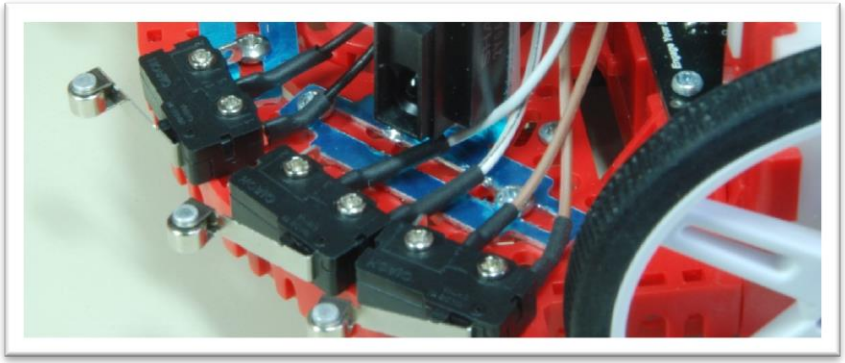

Figure 1. Bump sensors, positioned at the front of the robot.

The basic approach to a system requiring multiple software tasks is to deploy multithreading. One software **thread** is the traditional main program, which runs most of the time. Interrupts will be used to create additional threads. An **interrupt** is a hardware-triggered software execution. In this module, the SysTick interrupt will execute a software task periodically. In Module 13, we will use timers to create PWM outputs. In Module 14, we will use edge-triggered interrupts so a software task is executed immediately if any of the bump sensors are activated.

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