Heart-Rate Monitor With Micrium uC/OS-II Kernel on the MSP430F5438A Experimenter Board

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ABSTRACT

This application brief takes the low-cost heart-rate monitor solution (based on the LaunchPad with MSP430G2452) one step further by adding multiple tasks and a robust software framework on the MSP-EXP430F5438 Experimenter Board. The uC/OS-II Real Time Kernel from Micrium handles the execution of multiple tasks in order of their priorities: heart-rate monitoring, heart-beat audio output, beats-per-minute (BPM) output on UART, and accelerometer data sampling.

NOTE: The application presented here is for reference design purposes only and is not intended for any life-saving or medical-monitoring use.

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1 Introduction

Complex medical devices and instruments that can perform multiple tasks require a robust framework to minimize the risk of failure. One such robust software framework is the uC/OS-II Real-Time Kernel (RTOS) from Micrium [1].

This report presents a working concept of the uC/OS-II RTOS executing multiple tasks (in order of descending priority): heart-rate monitoring, heart-beat audio output, beats-per-minute (BPM) output on UART, and accelerometer data sampling.

2 Hardware

2.1 MSP-EXP430F5438 Experimenter Board

The MSP430F5438A Experimenter Board (MSP-EXP430F5438) was chosen as the target platform as it has numerous features such as 2-D accelerometer, microphone input, 138x110 dot-matrix LCD, 3.5 mm audio output jack, and RF-EMK headers. Additional details can be found in the *MSP-EXP430F5438 Experimenter Board User's Guide* [2].

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2.2 MSP430F5438A Microcontroller

The MSP430F5438A is a 16-bit ultra-low power MSP430™ microcontroller unit (MCU) with 256KB Flash and 32KB SRAM. Peripherals include 12-bit ADC, 16-bit timers, and USCI modules for SPI or I2C communication. In this application, the DCO is configured to run at 16 MHz and sources SMCLK and MCLK. The internal lower-power 32-kHz source (REFO) sources ACLK.

Additional details can be found in the MSP430F543xA Mixed Signal Microcontroller data sheet [3].

2.3 EKG-Based Heart-Rate Monitor BoosterPack

The low-cost heart-rate monitor solution based on the MSP430 LaunchPad Value Line Development Kit (MSP-EXP430G2) (also called the EKG-Based Heart-Rate Monitor BoosterPack) is used as an analog front end (AFE) to amplify and filter the EKG signal before it is fed to the integrated 12-bit ADC within the MSP430F5438A.

Hardware schematics and design details can be found in *EKG-Based Heart-Rate Monitor Implementation on the LaunchPad Value Line Development Kit Using the MSP430G2452 MCU* (SLAA486) [4].

2.4 Adapter Board

An adapter board acts as a translator between the LaunchPad and the Experimenter Board. It maps the BoosterPack 2x10 header pin out to the appropriate signals on the 24-pin double row Port X.Y header. Appendix A contains the schematic of the adapter board, and Table 1 shows the mapping of the header and port pins.

Table 1. Header Port Pin Mapping

Signal Name	LaunchPad (MSP430G2452) Header		MSP-EXP430F5438 Port X.Y Header	
	Port I/O	Pin Number	Port I/O	Pin Number
VCC	VCC	1	P5.0/P5.1	1, 2
GND	GND	20	GND	8
EKG	P1.4	6	P7.4	4
HAND_LEFT	P1.5	7	P7.6	6
UART_TXD	P1.1	3	P3.4	9
UART_RXD	P1.2	4	P3.5	10
P1_7	P1.7	15	P4.0	13
P2_6	P2.6/XIN	19	P4.5	17
SHUTDOWN	P2.7/XOUT	18	P4.2	15

3 Software

3.1 Micrium uC/OS-II Real-Time Kernel

The uC/OS-II real time kernel from Micrium configures the MSP430F5438A and handles the prioritization of different tasks. The kernel configures the clock sources, I/O ports and pins, timers, ADC, and the LCD peripherals on the Experimenter Board. Instructions on configuring the uC/OS-II RTOS kernel along with code examples demonstrating use of MSP430 low-power modes with low-memory overhead are described in *Optimizing Memory on MSP430 for uC/OS-II* (SLAA506) [5]

3.2 Task 1 (High Priority): Heart-Rate Monitoring (HRM)

The heart-rate monitor task uses the integrated ADC12 (in 10-bit mode) to capture the amplified and filtered EKG output from the AFE on the BoosterPack. Timer_A0 is configured to directly trigger the ADC sampling and conversion (in the background through hardware interrupts). When no contact is detected on the pads, Timer_A0 is sourced from the lower-power ACLK source and samples the hand-detection input at an interval of approximately one second. When hand-detection is triggered, Timer_A0 switches to the more accurate SMCLK (sourced by the DCO) and triggers the ADC at a rate of 60 Hz to collect EKG samples.

When the buffer of 30 samples (approximately 500 ms) is filled, the algorithm processes the new data frame and determines the number of beats-per-minute (BPM). The algorithm initializes the output at 70 BPM (assumes a human subject at rest) and tracks the rate up or down accordingly.

3.3 Task 2 (Medium Priority): Heart-Beat Audio Output

This task uses the 3.5-mm audio jack and the associated TPA301 audio amplifier on the Experimenter Board to play the heart-beat sound. The rate at which the heart-beat is repeated is determined by the BPM result from the HRM algorithm (Task 1).

A digital copy of the heart-beat sound is stored within the Flash memory of the MSP430F5438A and Timer_B0 is used as a PWM DAC to feed the analog signal to the audio amplifier [2]. As an additional step to minimize the overhead associated with interrupts when using Timer_B0 alone for the PWM DAC, Timer_A1 (which is not utilized by any other tasks) is used. Timer_B0 establishes the duty cycle, and Timer_A1 indicates when the duty cycle should be changed.

3.4 Task 3 (Medium Priority): Beats-per-Minute (BPM) Output on UART

The Experimenter Board has a back-channel UART feature that emulates a virtual COM port over USB (using the onboard TUSB3410) through which data can be accessed on a PC by HyperTerminal program. This task configures the USCI_A1 module to output the beats-per-minute (BPM) result computed by the HRM algorithm (Task 1) on UART. ACLK (32 kHz) is used as the clock source and the baud rate is set to 9600.

3.5 Task 4 (Low Priority): Accelerometer Sampling

The Experimenter Board has a 2D accelerometer on board that provides X- and Y-dimension coordinates for tilt-sensing and other applications. This task also uses the integrated ADC to sample the X- and Y-dimension analog signals and display the resulting conversion values on the LCD.

Figure 1. MSP-EXP430F5438 With HRM BoosterPack Hardware Setup

4 References

1. *uC/OS-II Quick Start Guide* (http://micrium.com/download/QuickStart-MSP-EXP430F5438-uCOS-II.pdf)
2. *MSP-EXP430F5438 Experimenter Board User's Guide* (SLAU263)
3. MSP430F543xA Mixed Signal Microcontroller (SLAS655)
4. *EKG-Based Heart-Rate Monitor Implementation on the LaunchPad Value Line Development Kit Using the MSP430G2452 MCU* (SLAA486)
5. *Optimizing Memory on MSP430 for µC/OS-II* (SLAA506)

Appendix A Adapter Hardware Schematic Diagrams

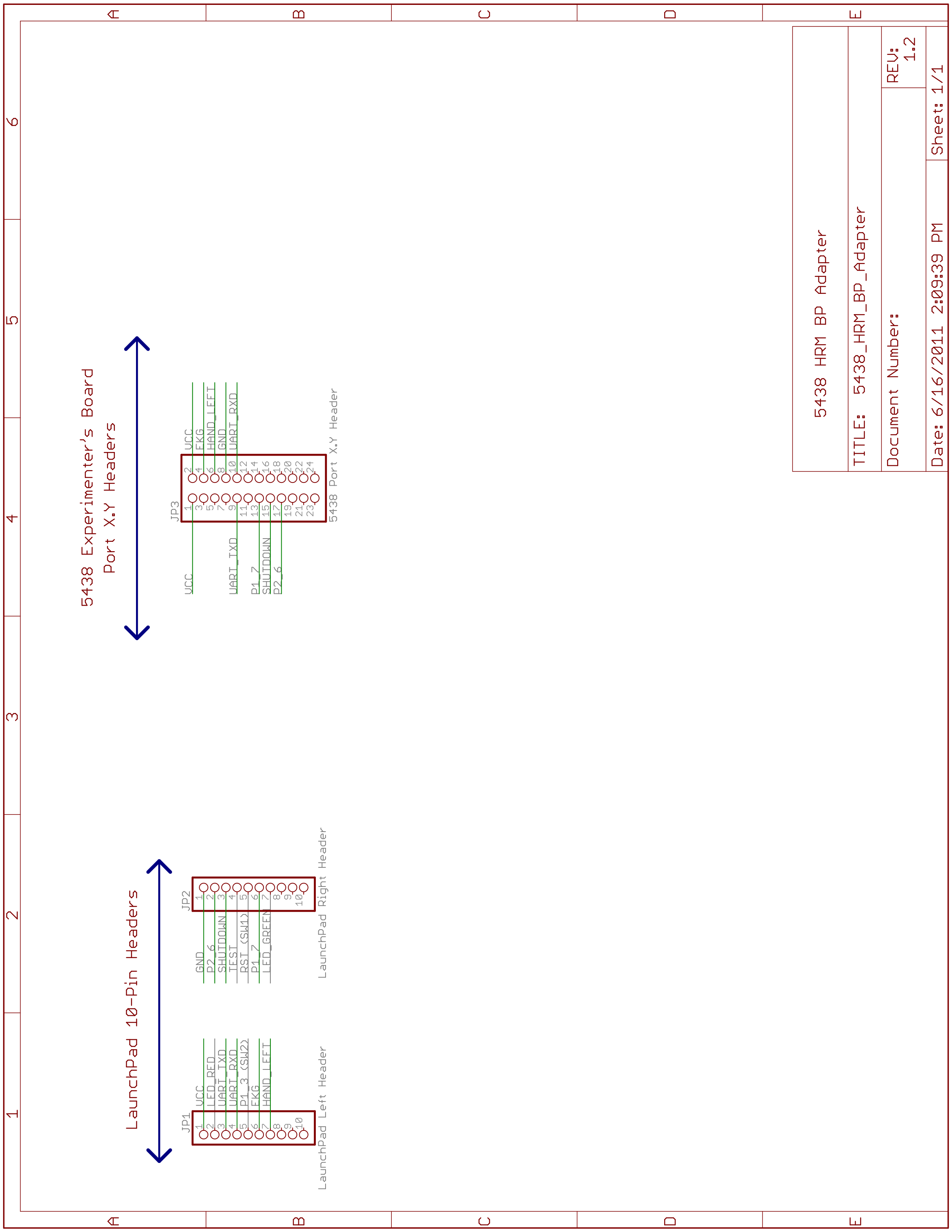

Figure 2. Adapter Board Schematic