CE4920 PROJECT 1

SUMMARY:

In previous courses, students have studied the concepts of embedded systems design including microcontrollers, the basic embedded systems model, sensors, actuators, and signal conditioning circuits. Programs written in Assembly or C have been used to monitor and control the embedded system. While microcontrollers are an important part of the embedded systems industry, improvements in integrated circuit density have allowed companies to produce advanced and feature-rich programmable devices that engineers can use to custom-design a complete system on a single chip (PSOC). This reduces the size of the designed product because many chips are combined into one.

In Embedded Systems 4, students extend their skills by learning how to configure and program custom PSOC designs for the Cypress Semiconductor PSOC5 architecture. PSOC5 provides an ARM Cortex M5 processor and a robust suite of peripheral devices. Students will also extend their skills by writing their own operating system for the PSOC5 architecture to control process behavior. Finally, students will explore using an off-the-shelf operating system for system control.

The CE4920 laboratory is divided into three multi-week projects. Each project consists of milestone goals that progress the student toward the final project system. The first laboratory project is a rehabilitation product used after heart attacks. It is the control system of a cardio-fitness treadmill that uses heart rate to control the speed of a DC motor.

DEFINITIONS:

*A **programmable system-on-a-chip** (PSOC) is a single-chip solution that combines a CPU with blocks of analog and digital peripheral devices that can be selected for inclusion in a design.*

*A **field-programmable gate array** (FPGA) is a digital device that allows gate-level designs to be routed in the available memories and multiplexer logic arrays. FPGAs generally do not include arrays of analog components.*

A PSOC is similar to a soft-core processor running in an FPGA but has the added advantage of analog circuitry such as op-amps, filters, and mixers available to the user. In some sense, the PSOC is an evolution of the microcontroller based embedded system that extends integration to the analog components that normally would reside on the system mother-board.

SYSTEM DESCRIPTION

The system is a heart rate monitor that controls the speed of a DC motor driving the track of a treadmill. The system adaptively changes jogging or walking speed based on the user's heart rate and the exercise profile chosen at system startup.

REQUIREMENTS:

1. The system identifies power-up with music and text.
2. The system must allow the user to wake it up and select an exercise profile.
3. The system must use heart rate to control the speed of a DC motor.
4. The system must provide a stop request.

USE CASES

1. Power On Reset

    A. The user applies power or resets the system.
    B. The system initializes.
    C. The system announces initialization with music and a welcome message.

2. Start Request

    A. The user requests treadmill start.
    B. The system identifies the request.
    C. The system presents an exercise profile menu.

3. Profile Selection

    A. The user selects a profile from the profile selection menu.
    B. The system gradually increases motor speed until the profile is reached.

4. Heart rate changes more than 10%

    A. The system identifies a significant heart rate change.
    B. The system adjusts the motor speed according to the selected profile.

SPECIFICATION OF SYSTEM INPUTS AND OUTPUTS

1. System Inputs

   A. The user starts the treadmill using a capacitive touch slider.
   B. The use chooses an exercise profile using two capacitive touch buttons.

2. System Outputs

   A. The system uses an LCD panel to display text to the user.
   B. The system uses a piezo-speaker to generate sound.
   C. The system uses a pulse width modulated GPIO pin to control the DC motor driving the treadmill gear train.
   D. The system uses a USB interface to send heart rate logs to a computer.
   E. The system recreates the heart beat signal as a test point on a GPIO pin.

SYSTEM FUNCTIONAL SPECIFICATION

The system uses software written in C. The main control function is a finite-state machine. Interrupts are used when appropriate.

1. The system initializes at power-on reset.
   (RESET STATE)

   A. System variables are initialized to appropriate starting values.
   B. System peripheral devices are initialized.
   C. Interrupts are enabled if appropriate.
   D. The system displays a welcome message on the LCD panel.
   E. The system plays a minimum 5 second musical welcome song.
   D. The system blanks the LCD panel and enters the wait state.

2. The system responds to a left-to-right finger swipe as a wakeup command.
   (WAIT STATE)

   A. Incorrect finger swipes are ignored.
   B. A correct finger swipe wakes the system.
   B. The LCD panel presents an exercise profile menu after wakeup.
   C. The system waits for an exercise profile to be chosen.
   D. The system blinks the user selection four times after selection.
   E. The system transitions to the monitor state.

3. The system ramps up motor speed after exercise profile selection.
(RAMPUP STATE)

    A. A gradual ramp up occurs over 8 seconds.
    B. The system ignores heart rate during the ramp up.
    C. The system stops the ramp at the exercise profile setting.

4. The system monitors heart rate and adjust motor speed.
(MONITOR STATE)

    A. The system samples the heart beat signal and identifies the beat peak.
    B. Heart rate is calculated.
    C. Heart rate is output through the USB port if connected to a monitoring PC.
    D. If a 10% change in heart rate is identified then the motor speed is adjusted according to the selected profile.
    E. The system remains in the monitor state until stop is requested.

5. The system receives a stop request.
(STOP)

    A. The user commands the treadmill to stop.
    B. The system decreases treadmill speed over 2 seconds.
    C. The system returns to the wait state.

6. Supplemental information

    A. The heart rate profile algorithms would normally be described in this section of the requirements and specifications document.
    B. In CE4920, students may design their own unique heart rate behavioral profiles. For example, perhaps a 10% increase in heart rate results in a treadmill slowdown by 10%. Similarly, a 10% decrease in heart rate might result in a treadmill speedup by 10%.

LCD USER INTERFACE REQUIREMENTS

1. Welcome

   A. The system fills the top row with square blocks at 0.1s intervals.
   B. The system centers the phrase "Welcome to" on the top line after block fill.
   C. The system centers the phrase "My Treadmill" on the bottom line.
   D. The system blanks the display after the power-up music plays.

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DELIVERABLES

1. **Demonstrate** system milestone goals to Dr. Meier by the stated due dates.
2. **Submit** final design documentation at the end of the project.

MILESTONE	DUE
Startup, music, text, wait, profile selection	Week 2
Analog signal conditioning, heartbeat peak detection, heart rate calculation	Week 3
Waveform acquisition and DAC recreation.	Week 4
USART transmission	Week 5
Motor control	Week 6
PROJECT DEMONSTRATION AND DOCUMENTATION SUBMISSION	Week 6