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| Lab 2: Sensor Data Acquisition, Digitizing, Filtering, and Digital I/O |
| ECSE 426 Microprocessor Systems |
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Due: February 23rd 2015

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Lab 2: Sensor Data Acquisition, Digitizing, Filtering, and Digital I/O

# 1. Problem Statement

Data acquisition and signal processing are common operations performed by embedded microprocessor systems. Within the scope of this experiment, we will implement a system which collects data from a temperature sensor and displays the results using LEDs.

# 2. Theory and Hypothesis

## 2.1. Analog-to-Digital Conversion

* Resolution and step sizes
* How to interpret the output of an ADC

## 2.2. Kalman Filter

* What’s a Kalman Filter?
* Meaning of variables
* Choice of values (from Matlab simulation)

## 2.3. Data Interpretation

* Translate to understandable numbers
* Show the equations and values provided in Reference Manual (need reference!!)

## 2.4. Pulse Wave Modulation

* What’s a PWM?
* How does duty\_cycle and period influence the fade-in fade-out effect

# 3. Implementation

The overall system is controlled by a 168MHz system core clock. It is divided of two main components, data processing and visual feedback. The implementation of each is detailed in the following sections.

## 3.1. Data Processing

The data processing component is controlled by the clock operating at a rate derived from the system core clock. This software implemented system clock is called Systick, which counts up to a specific number of pulses before throwing an interrupt. The required sampling frequency of 50Hz is achieved by dividing the system core clock of 168MHz by 50Hz. The Systick interrupt handler will throw an interrupt every 0.02ms and allow one data sample to be taken and processed.

### 3.1.1. Data Acquisition and Digitizing (ADC)

The built in temperature sensor is connected to ADC1 through channel 16. To collect data from the temperature, we initialized the ADC as summarized in table 1.

Table : ADC Initialization Parameters

|  |  |
| --- | --- |
| Initialization Parameter | Value |
| ADC\_Mode | ADC\_Mode\_Independent |
| ADC\_Prescaler | ADC\_Prescaler\_Div2 |
| ADC\_DMAAccessMode | ADC\_DMAAccessMode\_Disabled |
| ADC\_TwoSamplingDelay | ADC\_TwoSamplingDelay\_5Cycles |

The mode is independent since we only needed to use one ADC component. The prescaler is set to div2 because that is the smallest division choice available. DMA Access Mode was disabled since we did not need to use any direct memory accesses. The two sampling delay indicates the amount of cycles to pass between two samples are taken. We chose 5 cycles since that was the highest frequency.

For specific ADC setting, we imposed the following configurations.

Table : ADC Configuration Parameters

|  |  |
| --- | --- |
| Configuration Parameter | Value |
| ADC\_Resolution | ADC\_Resolution\_12b |
| ADC\_ScanConvMode | DISABLED |
| ADC\_ContinuousConvMode | DISABLED |
| ADC\_ExternalTrigConv | ADC\_ExernalTrigConvEdge\_None |
| ADC\_DataAlign | ADC\_DataAlign\_Right |
| ADC\_NbrOfConversion | 1 |

We set the resolution as 12 bits since that was the highest resolution size. We disabled the Scan Conversion Mode since we only needed to do the conversion in a single channel for one sensor. We disabled continuous conversion mode because we did not need a continuous sampling. We set the external trigger conversion edge to none since we are using a software interrupt. We set data align to right because that’s how integers are represented in C. The number of conversions is set to one since we are only doing one conversion per sample.

The channel on which samples are taken is configured as shown in table 3.

Table : Channel Configuration Parameters

|  |  |
| --- | --- |
| Configuration Parameter | Value |
| ADCx | ADC1 |
| ADC\_Channel | ADC\_Channel\_16 |
| Rank | 1 |
| ADC\_SampleTime | ADC\_SampleTime\_480Cycles |

As previously mentioned, the temperature sensor is hardwired to ADC1 over channel 16. Since this is the only used, the value for rank does not matter. We selected 480 cycles as sample time because \_\_\_\_\_\_

Finally, the sampled data taken from the ADC is forwarded to the Kalman filter.

### 3.1.2. Data Filtering (Kalman Filter)

* Mention that the data comes from the ADC

We reused the Kalman filter from Lab Experiment 1, with some changes. Instead of an array of inputs and outputs, each iteration will only pass in a scalar input value and pass back one output value. The parameters that we used for the Kalman filter we determined experimentally (see Section 4.1). The output values are passed as input to the conversion function.

* Implementation of the filter using previously determined (optimal) variables
* Mention that the data is sent to conversion

### 3.1.3. Data Conversion

* Mention that the data received from the filter needs to be translated in order to be interpreted
* First get the voltage
* Second get the temperature
* Mention that the temperature changes are displayed using LEDs

## 3.2. Visual Feedback

* Independent of the interrupt, can run while data processing is waiting

### 3.2.1. Visual Display (GPIO)

* Mention that when temperature is below the threshold, we display the change
* GPIO configuration (refer to user manual?)

For the GPIO settings we used the following: GPIO\_Pin as GPIO\_Pins 12 to 15 or’d together, GPIO\_Mode as GPIO\_Mode\_OUT, GPIO\_Speed as GPIO\_Speed 100MHz, GPIO\_OType as GPIO\_Otype\_PP, GPIO\_PuPd as GPIO\_PuPd\_NOPULL. We set the pins 12 to 15 since these are the pins hardwired to the LEDs. We set the mode as out since we are writing to the LEDs. We set the speed as 100 MHz since it is the fastest speed. We set the output type as PP and PullUp and PullDown as NOPULL so that \_\_\_\_\_\_\_

* How to track temperature increase and decrease

### 3.2.2. Alarm (PWM)

* Mention that when temperature is above the threshold, we use and alarm
* Increment duty\_cycle by 10% to achieve fade-in fade-out

# 4. Testing and Observations

## 4.1. Terminal Window

* Display intermediate values
  + For Kalman Filter -- Compare against Matlab results
* Know when we passed the threshold

## 4.2. Visual Feedback

* Observe the clockwise/counter-clockwise LEDs
* Observe fade-in fade-out effect beyond threshold

# 5. Conclusion

# References

# Appendix A – Matlab Simulation Results

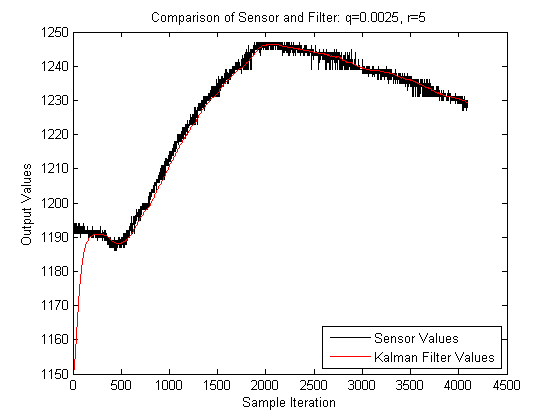


Figure 1: Kalman Filter Parameter q=0.0025, r=5

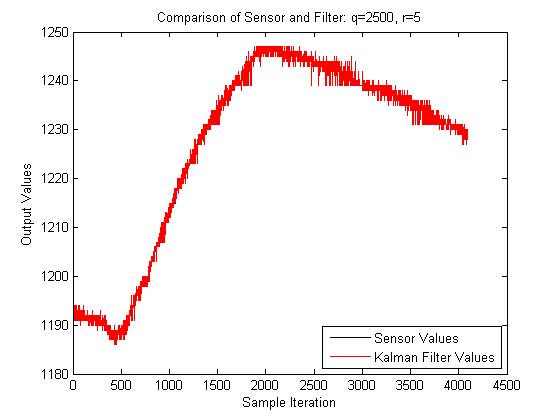


Figure : Kalman Filter Parameter q=2500, r=5

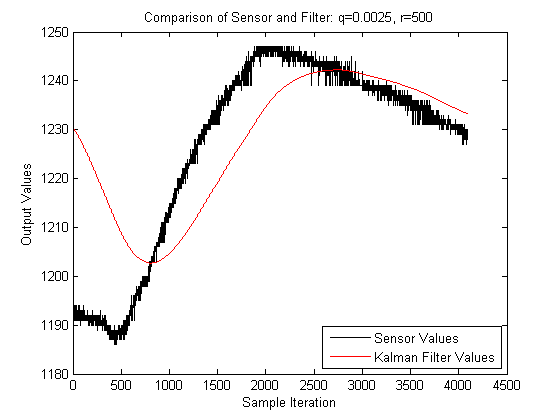


Figure : Kalman Filter Parameter q=0.0025, r=500