UPPSALA UNIVERSITET

Project in Embedded Systems (15 hp)

Project: Embedded signal processing

based on Atmel AVR microcontrollers

Report – Phase 1

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1. Summary

This phase report presents the work done during the period of project phase 1, and a plan for next phase. The embedded devices for digital signal processing are intended to use in the frequencies of up to 50 kHz. The work includes

- Studying the theory on digital filters, and designing methods
- Investigating and determining development kits, and development tools (like IDE, programmer and debugger)

The work is finished on schedule.

2. Theory on digital filters, and designing methods

2.1 Theory on digital filters

A (linear) digital filter (which is related to our present project) can be described by the following difference equation

$$y(n) = b_0 x(n) + b_1 x(n-1) + \cdots + b_M x(n-M) - a_1 y(n-1) - \cdots - a_N y(n-N) \qquad (1)$$

It can be a filter of different types, i.e., low pass, high pass, band pass, band stop and notch. and it can be implemented by an IIR or a FIR.

The frequency properties of the designed digital filter can be characterized and identified with its frequency response (which is easily obtained from *z*-transform)

$$H(\omega) = H(z)\big|_{z=j\omega} = \frac{Y(z)}{X(z)}\bigg|_{z=j\omega} = \frac{b_0 + b_1 z^{-1} \cdots + b_M z^{-M}}{1 + a_1 z^{-1} \cdots + a_N z^{-N}}\bigg|_{z=j\omega} \qquad (2)$$

2.2 Designing methods

The ultimate goal for the designing of a digital filter is to determine the coefficients in Eq. (1) according to the specifications of the desired filter, e.g., bandwidth, cutoff frequencies (lower and upper), pass band, stop band, transition band, phase, and amplitude gain, etc.

For IIR filter design, one can start working with an analog filter template $G(s)$, e.g., Butterworth, Chebyshev, or Bessel, based on the given specifications of digital filters, and then convert the analog filter to the desired digital filter $H(z)$ using bilinear transform,

$$H(z) = G(s)\big|_{s=2f_s\frac{(1-z^{-1})}{(1+z^{-1})}} \qquad (3)$$

For instance, we choose an analog filter template of Butterworth type

$$G(s) = \frac{G_0}{\prod_k^n (s - p_k)/\omega_c} \qquad (4)$$

To design the digital filter with the given cutoff frequency, $\omega_{c,d}$, we can determine ω_c in Eq. (4) with the following relation

$$\omega_c = 2 f_s \tan\left(\frac{\omega_{c,d}}{2 f_s}\right) \tag{5}$$

and then use Eq. (3) to determine the digital filter $H(z)$, in particular, the coefficients of the filter.

3. Development kit and tools

The development kit for the project is the Atmel® UC3-A3 Xplained evaluation kit [2, 3] that has an Atmel® AT32UC3A3256 microcontroller [1] with the following features:

- Atmel® AT32UC3A3256 microcontroller with a 256 KB Flash, and a 66 MHz speed
- High-speed USB interface for transfer data
- 64MBit SDRAM to which data can be read/written
- Up to 8 analog inputs (to ADC)
- 8 ADCs and 2 DACs with the sampling frequency of up to 200 kHz
- RC filter
- 4 LEDs (LED 0 – LED 4) which can be used to show status information
- 4 expansion headers (J1 –J4)
- Footprints for external memory
- Atmel AT45DB series DataFlash® serial flash
- Atmel AT25DF series industry standard serial flash
- 1 Atmel QTouch® slider and 1 QTouch button (SW1) that are detected with the Atmel QTouch library

The features like 32-bit AVR32UC CPU, ADCs, and DACs are necessary and sufficient for embedded DSP. The details on the microcontroller are available in [1].
The IDE (integrated development environment) for programming will be Atmel Studio 6 [4] and the debugger is JTAGICE mkII [5].

4. Conclusion and plan for the next phase

The work planned for the first phase has been finished on schedule, in particular, including

- theoretical study on digital filters and filter designing approaches,
- investigation and selection of hardware & software (development kit, development tools, …)

In the next phase we plan to work on the following framework tasks:

- Analog and digital signal conversion with ADCs and DACs
- Implementation of the algorithms for IIR digital filters

References

[1] Atmel *32-bit AVR® Microcontroller* http://www.atmel.com/Images/doc32072.pdf
[2] Atmel, *AVR32918: UC3-A3 Xplained Hardware User's Guide*, http://www.atmel.com/Images/doc32159.pdf
[3] Atmel, *Atmel AVR32930: UC3-A3 Xplained Getting Started Guide*, http://www.atmel.com/Images/doc32163.pdf
[4] Atmel, *Atmel Studio*, http://www.atmel.com/tools/ATMELSTUDIO.aspx
[5] Atmel, *JTAGICE mkII*, http://www.atmel.com/tools/avrjtagicemkii.aspx