Homework 3: Design Constraint Analysis and Component Selection Rationale

Team Code Name: The "Drink Mixer" Group No. 2

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Evaluation:

SCORE	DESCRIPTION
10	***Excellent*** *– among the best papers submitted for this assignment. Very few corrections needed for version submitted in Final Report.*
9	***Very good*** *– all requirements aptly met. Minor additions/corrections needed for version submitted in Final Report.*
8	***Good*** *– all requirements considered and addressed. Several noteworthy additions/corrections needed for version submitted in Final Report.*
7	***Average*** *– all requirements basically met, but some revisions in content should be made for the version submitted in the Final Report.*
6	***Marginal*** *– all requirements met at a nominal level. Significant revisions in content should be made for the version submitted in the Final Report.*
*	***Below the passing threshold*** *– major revisions required to meet report requirements at a nominal level.* ***Revise and resubmit.***

* *Resubmissions are due within* ***one week*** *of the date of return, and will be awarded a score of "6" provided all report requirements have been met at a nominal level.*

Comments:

1.0 Introduction

The “Drink Mixer” is a digital audio mixer with individual input equalizer control as well as master output control. The goal of this project is to create a great sounding board with low noise and effects processing capability. Some of the constraints with this project involve a high bandwidth constraint for mixing 8 channels of audio together simultaneously. This puts a limit on what kinds of DSP processors we can use as well as what kind of A/D / D/A converters we can use. With motorized faders, custom designed pre-amplifiers, and several digital components there are a lot of design issues to consider and adjust for throughout project development. In the project we will be interfacing a micro-controller for each channel to perform small user interface tasks. These micro-controllers will be interfaced with a main processor devoted to coordinating tasks with all the other 8 processors, as well as adjusting settings on the DSP controller. While it is possible to accomplish a lot of these tasks on one heftier processor, we believe that by separating the user interface tasks from the sound processing, we can increase the reliability of audio conversion and reduce any types of possible hiccups in the system.

Project Success Criteria Include:

- **An ability to digitally mix audio and adjust individual levels**
- **An ability to adjust individual equalizer settings for the input channel**
- **An ability to add an effect to a channel (i.e. delay / reverb)**
- **An ability to save and load scene settings (from flash or EEPROM)**
- **An ability to display amplitude of output signal**

2.0 Design Constraint Analysis

In this report several design constraints will be considered. These constraints include channel processors, main processors, and digital signal processors. It will also cover information regarding selection of the best A/D Converters as well as D/A Converters. Due to the use of multiple micro-controllers in the project each section will be split up by subsections to discuss the individual requirements for each set of micro-controllers.

2.01 Computational Requirements

Individual Channel Controller

The primary tasks of these micro-controllers do not entail large amounts of computational requirements. The primary purpose of each chip is peripheral management including rotary pulse switches, motor driven faders, and buttons.

Digital Signal Processor

The digital signal processor will have to be capable of processing 8 channels of audio input at 24bits and 44kHz. These calculations could be enormous depending on FIR filter detail as well as post processing effects. Based on filter designs and testing in MATLAB we have determined that the optimal filter detail will be 64th order. This means that 8*64 * 44100 = 22.6 million floating-point calculations per second will have to be performed on the digital signal processor at a bare minimum.

Primary Interface Micro-controller

The primary user interface micro-controller will require fewer calculations, most of which will be generating new filters and sending that information to the DSP.

2.02 Interface Requirements

Individual Channel Controller

The individual channel micro-controllers will be doing most of the user interface management for the main channel interfaces. This particular sound board design is different in that rather than having 6 potentiometers to maintain there is one rotary pulse generator and a series of push buttons to select which property is being edited. It was discussed that one button could be used to toggle through the different actions but it would present usability issues with the operator and reduce the speed at which a property could be adjusted. This micro-controller will also have to be able to interface with the primary micro-controller to notify it of value changes as well as change channel values if the primary controller instructs it to do so. This becomes useful when using scene control or switching output modes for fader control. In order to accomplish all these tasks this micro-controller will have to interface via I^2C with the primary controller and SPI for the LCD display control.

Primary Interface Micro-controller

The primary micro-controller will be required to interface over I^2C to all other micro-controllers for control management. The SPI bus will be used to interface with the SHARC DSP processor. The SPI Channel will also be used to interface with the supported Ethernet controller. This Ethernet controller is not in the PSSCs and is strictly being built onto the board for future upgradability in the area of remote control of system. The display uses the ARM9's built in display controller requiring 12 pins.

Digital Signal Processor

The DSP will be required to process up to 8 24-bit audio streams at 96kHz sample rate and simultaneously output to up to 4 24-bit output channels. Support for the I^2C data bus for communicating with the primary controller would be ideal, but not necessary. Other options include SPI and emulated I^2C bus.

2.3 On-Chip Peripheral Requirements

Individual Channel Controller

- 1 8-bit A/D Converter (Fader Readout Control)
- 1 PWM Generator (Fader Motor Drive Control)
- I^2C Bus (For Communication with primary microcontroller)
- SPI (For Transfer of Bits to shift registers to operate small graphical display)
- 8 Pushbutton Inputs
    - Gain Control
    - Low Cut
    - High Gain
    - Mid Gain
    - Mid Frequency
    - Low Gain
    - On/Off
    - Solo
- 2 Rotary Pulse Inputs
    - Reading values from the rotary pulse generator. Used to adjust values in dB.
- 4 output pins for digital gain control of preamplifier

Primary Interface Micro-controller

- 2-pins I^2C Bus
- 3-pins SPI bus x2 (Chip supports 2 SPI channels)
- 2 SPI-Select Pins GPIO (1 Ethernet, 2 DSP)
- 12-pins LCD 7.1” Panasonic TFT Display Interface
- 2-pins A/D Input for Touch Screen
- 2-pins Rotary Pulse Input Pins
- 2-pins RS232 Serial Interface
- 2-pins USB Master Controller (future expansion and firmware updates)
- 2-pins USB Slave Controller (future expansion)

Digital Signal Processor

- 3-pins Serial TDM Input
- 3-pins Serial I2S Output
- 3-pins SPI Interface with Microcontroller and A/D Converters for configuring.

- 10-pins LED Bar Graph of Amplitude Output of Signal (PSSC 5)

2.4 Off-Chip Peripheral Requirements

Individual Channel Controller

- H-Bridge for Motor Drive Control on Fader
- Digitally Controlled Potentiometer for Preamplifier Gain Control.
- Rotary Pulse Encoder
- LCD Graphical Display

Primary Interface Micro-controller

- LCD Color 8-bit TFT Display [1]
- Ethernet Controller
- A/D input with Touch Screen interface.

Digital Signal Processor

- 8 24-bit A/D Converters I^2S / TDM Mode
- 2-4 24-bit D/A Converters I^2S / TDM Mode

2.5 Power Constraints

Most power related constraints involve the need for an extremely low noise power source as well as noise suppression capabilities. This noise suppression will reduce incoming noise in the preamplifiers from potential back EMF from the fader motors as well as various switching noises produced by the digital controllers.

2.6 Packaging Constraints

The mixer console needs to be of an appropriate weight such that it is portable and can be transported safely by one person. To do this, the final package needs to weigh 50 lbs or less. The console also needs to be made of material tough enough to withstand use by Liberal Arts majors. This is because Liberal Arts majors are the people that tend to run mixer consoles. The console shall be laid out such that it is functional with the input channels and faders on the left side, and the master controls, effects, and displays on the right side.

2.7 Cost Constraints

The commercially available product that is most similar to the "Drink Mixer" is the KORG Zero 8. Is has a list price of $2,450 [2]. Because we are only accounting for the development cost of parts, and not labor, this is a price that we should be easily able to beat. We are shooting for a total parts cost around $1000.

3.0 Component Selection Rationale

Individual Channel Controller

The mixer's individual channel microcontroller must run at 16 MHz, have an A/D converter, a PWM channel, at least 10 IO pins (more would enable hardware self-checks), and an I^2C bus. Two possible candidates are Atmel's ATmega32A [3] and Microchip's PIC16F1934 [4]. Both have multiple 10-bit A/D converters, PWM channels, and over 30 I/O pins (when not used for other purposes). The Atmel has slightly more channels for each of these peripherals. Both chips will also run on 5.5 Volts, and are available as both dual-in-line and quad-flat-pack. While the Atmel can run at 16 MHz when used with an external crystal, the PIC has an internal oscillator which is factory calibrated and can run at 32 MHz with 1% error. However, the most important difference between the chips is the Atmel's use of TWI (Two Wire Interface) instead of an I^2C module. However, I^2C libraries exist for Atmel processors, and Chuck Barnett, the lab attendant for ECE477, has past experience with this functionality. Based upon his encouragement, and the confidence that comes from extensive documentation available for the ATmega chipset and compiler, the ATmega32A was chosen for the individual channel microcontroller.

Primary Interface Micro-controller

Tin Can Tools' ARM9 based Hammer [5] was compared against Atmel's AT32AP7000 [6] for the primary microcontroller. Both devices satisfy the on-chip peripheral requirements listed in section 2.3 and support embedded Linux. Although the AT32AP7000 has DSP instructions and a 16-bit stereo audio DAC, no one on the team has any experience in programming the device. Not only do we already have a Hammer in our possession, but we also have experience with programming it. Also the AT32AP7000 has 160 GPIO pins, an unreasonable amount compared to the 30 on the Hammer.

Digital Signal Processor

In the selection for the digital signal processor we chose to compare the Analog Devices ADSP-21262[7] and the Texas Instruments Tms320Dm355Zce270 [8]. The Texas Instruments device operates at 270MHz while the Analog Devices operates at 200MHz. The Texas Instruments is actually built on top of an ARM9 modified core but has very limited on board ram of 32KB. Whereas the Analog Devices is built off a SHARC RISC core and has 2Mb of on board ram. This memory limitation alone will be sufficient for the amount of DSP we will be performing and give us headroom for possible effects. It is also important to note that we have access to the necessary development kits for the SHARC processor and we do not have much in the area of the Texas Instruments DSP.

4.0 Summary

The "Drink Mixer" will use a main processor interfaced with a microcontroller for each channel and a DSP. The main processor will be devoted to coordinating tasks with the individual channel processors, and adjusting settings on the DSP. The individual channel processors will perform user interface tasks specific to each channel, and the DSP will perform audio mixing and effects processing. For the main processor, the ARM9 based Hammer was chosen. The ATmega32A became the individual channel processor, and the DSP will be an SHARC ADSP-21262. With these tools, we will be able to create an audio board with low noise, motorized faders, capability to process effects, and good-sounding output.

List of References

[1] "Hammer LCD 8bit Color STN," Mar. 3, 2009. [Online], Available: http://www.elinux.org/Hammer_LCD_8bit_Color_STN. [Accessed: Sept. 12, 2009].

[2] "Korg Zero8 8-channel Digital Firewire Mixer," [Online], Available: http://www.bananasmusic.com/productdetail.asp/pid_10963/productname_Korg-Zero8-8-channel-Digital-Firewire-Mixer. [Accessed: Sept. 14, 2009].

[3] "ATmega32A," 2009. [Online], Available: http://www.atmel.com/dyn/products/product_card.asp?part_id=4404. [Accessed: Sept. 15, 2009].

[4] "PIC16F1934," Sept. 9, 2009. [Online], Available: http://www.microchip.com/wwwproducts/Devices.aspx?dDocName=en538156. [Accessed: Sept. 15, 2009].

[5] "Hammer," [Online], Available: http://tincantools.com/product.php?productid=16133&cat=0&page=1. [Accessed: Sept 15, 2009].

[6] "Atmel AVR32 32-bit Microcontroller AT32AP7000 Preliminary," Sept. 9, 2009. [Online], Available: http://www.atmel.com/dyn/resources/prod_documents/32003S.pdf. [Accessed: Sept. 15, 2009].

[7] "TMS320DM355 Pricing / Packaging / CAD Design Tools / Samples," [Online], Available: http://focus.ti.com/docs/prod/folders/print/tms320dm355.html#symbols. [Accessed: Sept. 14, 2009].

[8] "ADSP-21262: 3rd Generation Low Cost 32-Bit Floating-Point SHARC DSP," Aug 2009. [Online], Available: http://www.analog.com/en/embedded-processing-dsp/sharc/adsp-21262/processors/product.html. [Accessed: Sept. 14, 2009].

Appendix A: Parts List Spreadsheet

Vendor	*Manufacturer*	*Part No.*	*Description*	*Unit Cost*	**Qty**	*Total Cost*
earthLCD	Panasonic	EDMGRB8KJF	7.8" Color STN Touchscreen LCD	99	1	99.00
Tincan Tools	TincanTools	Hammer Carrier S3C2410A ARM920T	Development Kit and Hammer ARM920t based on Samsungs S3C2410A	239.00	1	239.00
Ebay seismoman	ALPS	RSA0N11M	10k Motorized Faders	3.98	20	87.60
Newark	Analog Devices	AD1871YRSZ	24-bit Stereo A/D Convertor	9.52	4	
Newark	Fairchild Semiconductor	J201	J201 N-Channel JFETS	.112	60	6.37
Digikey	Analog Devices	ADSP-21262SKSTZ200	SHARC ADSP-21262 DSP Processor	30.69	1	30.69
Mouser	Atmel	ATmega32A	AVR 8-bit RISC microprocessor	4.84	8	38.72
Mouser	STMicroelectronics	L9997ND013TR	Dual H-Bridge Driver 7-16V 1.2A	3.00	6	18.00
				TOTAL		**519.38**

Appendix B: Updated Block Diagram