Homework 11: Reliability and Safety Analysis

Team Code Name: **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 an 8-channel digital audio mixer board. There are 8 input channels, right and left main mix output, and 2 auxiliary mix outputs. To perform all of this, there are a variety of microprocessors communicating with each other. There is one monitoring the channel interfaces, another that is the brain of the operation, and another which actually does all of the digital mixing and calculations. These three are all critical components for reliability. Finally, there is significant current draw on the 5V rail through a linear regulator. This will cause a large amount of heat, which will cause the regulator to fail faster, and is of concern. Another component susceptible to failure is the motorized fader, as it is a moving part that operates by a motor and is belt driven, however this will not be further analyzed due to its failure being mechanical in nature instead of electrical.

2.0 Reliability Analysis

- ADSP-21262 SHARC – This is the processor used to actually perform the calculations and do the digital "mixing" of the different audio inputs. It has 144 pins on it, which increases its chances of failure. Also, since it is a processor, it is a critical component, and we need to know how long we can rely on it before failure. If this component fails, the entire product is useless until replaced.

Parameter name	Description	Value	Comments
C_1	Die complexity	0.56	32-bit/40-bit floating, assumed to be MOS since it is built for speed. Datasheet did not specify type of transistors.
π_T	Temperature coeff.	1.5	From datasheet, T_J is ambient temperature + 65°C. Using 35°C, T_J is 100°C
C_2	Package Failure Rate	0.078	Nonhermetic 144-pin
π_E	Environment Factor	2.0	G_F = "Fixed Ground"
π_Q	Quality Factors	10.0	COTS Equipment
π_L	Learning Factor	2.0	Production Availability 11/13/09, thus not yet in production.
Entire design:			
λ_p	Predicted number of	19.92	

	failures per 10^6 hours		
MTTF	Mean Time To Failure	50,200.80 hours = 5.73 years	

- ARM9 – This is the processor that is fondly referred to as the “brain” of the operation. It takes all of the input information from the ATMega32As, and tells the SHARC what to do with the audio signals, and is comprised of 40 pins. It also directly controls the LCD screen, and processes the user input on the touch screen. Just as the SHARC, if this component fails, the entire product is useless until replaced.

Parameter name	Description	Value	Comments
C1	Die complexity	0.24	32-bit, assumed to be Bipolar as the ARM9 is built for its reliability.
π_T	Temperature coeff.	1.5	Using $T_J = 100^oC$
C_2	Package Failure Rate	0.019	Nonhermetic 40-pin
π_E	Environment Factor	2.0	G_F = “Fixed Ground”
π_Q	Quality Factors	10.0	COTS Equipment
π_L	Learning Factor	1.0	In production >2.0 years
Entire design:			
λ_p	Predicted number of failures per 10^6 hours	3.98	
MTTF	Mean Time To Failure	251,256.28 hours = 26.68 years	

- ATMega32A – This is the processor used for the individual channel interface, comprised of 44 pins. It monitors the user inputs on each channel, and relays information to the Hammer for processing. There are also 10 of these within the package, one for each of the faders, with the main L and R faders being controlled by the same processor. It is not as much of a critical component as the DSP or Hammer, but if it fails, then that particular input channel is no longer usable.

Parameter name	Description	Value	Comments
C1	Die complexity	0.14	8-bit, assumed to be MOS as it is the conservative number.
π_T	Temperature coeff.	1.5	Using $T_J = 100^oC$
C_2	Package Failure Rate	0.022	Nonhermetic 44-pin

π_E	Environment Factor	2.0	G_F = "Fixed Ground"
π_Q	Quality Factors	10.0	COTS Equipment
π_L	Learning Factor	1.0	Assumed in production >2.0 years
Entire design:			
λ_p	Predicted number of failures per 10^6 hours	2.54	
MTTF	Mean Time To Failure	393,700.79 hours = 44.94 years	

- 5V Linear Regulator – It is anticipated that this will be the hottest part within the package. Although it will be connected to a very large heat sink, heat will still be a contributor to device failure. There are actually two of these regulators, one producing 5V output for 5V devices, and another acting as an intermediate step to power the 3.3V and 1.2V regulators. If the 5V rail is not active, then all devices on the channel boards, the Hammer, and the Display will all be unable to function. If the intermediate regulator fails, the SHARC will be unable to function properly.

Parameter name	Description	Value	Comments
C1	Die complexity	.01	Contains 15 bipolar transistors
π_T	Temperature coeff.	16	Using $T_J = 100^oC$
C_2	Package Failure Rate	0.0012	Nonhermetic 3-pin
π_E	Environment Factor	2.0	G_F = "Fixed Ground"
π_Q	Quality Factors	10.0	COTS Equipment
π_L	Learning Factor	1.0	Assumed in production >2.0 years
Entire design:			
λ_p	Predicted number of failures per 10^6 hours	1.624	
MTTF	Mean Time To Failure	615763.55 hours = 70.29 years	

- According to this analysis, the weakest link in the design is the ADSP-21262 SHARC Processor. The failure rate of this processor could be cut in half if it had been in production for more than 2 years. However, the current revision of it has not even gone into production at the time this document was written. The earlier revisions of the chip have been in production for a while, but the samples that we obtained are of the new version, and as such were calculated as being in production for less than 0.1 years. Also, some of the products may have been tested to some sort of MIL-SPEC that was not easily found. I simply assumed a value of 10 because they are all COTS equipment. The type of transistors within the ATMega32A and the SHARC are also unknown, and were assumed to be MOS as this was the conservative number. The final consideration is that T_J was calculated by assuming an ambient temperature of 35°C. This takes into account any heat created by the surrounding air. However, the typical ambient temperature is 25°C, which would decrease the value of π_T. Since the analysis was performed on the critical processors, there are not any design elements that could be modified or improved upon to improve the reliability of the design other than using different processors. Doing this would cause a complete redesign of the entire project, and as such is not a viable option.

3.0 Failure Mode, Effects, and Criticality Analysis (FMECA)

The schematics for the Drink Mixer's multiple boards have been broke down into functional blocks, and can be found in Appendix A. Part 1 is the "brain" Hammer ARM9, part 2 is the DSP, part 3 is the ATMega32As, part 4 is the channel interface peripherals, part 5 is the power supply, part 6 is A/D and D/A, and part 7 is the audio preamp. Many of the possibly failure conditions for each functional block and the possible causes of each are included in Appendix B.

To determine the reliability of the entire system, three different degrees of criticality have been defined. Any failure that concerns the safety of the operator or any bystanders is defined as being a high criticality failure with an industry standard rate of $\lambda_p < 10^{-9}$. This type of failure could result in direct injury to the user, and may also cause further damage to the product and its components. Some examples of this may be power supply failures, shorts causing fires, or audio levels being turned up so far that they cause hearing damage to those near the output speakers. The other types of failure that have been defined are medium and low criticality failures. These are not determined by a value of λ_p, but rather by the consequence of the error. Failures of this type will not cause injury, but may cause parts of the device to not work or cause a nuisance. Examples of a medium criticality failure would include the touch screen malfunctioning, or the DSP or ARM9 not working properly. A low criticality failure would be something similar to a single RPG not working properly, or the LED bar graph indicator on the channel not working properly, or the On/Off button not working. These simply serve as an inconvenience to the user, and may cause dissatisfaction to the user. For a more complete list of failures, please refer to Appendix B: FMECA Worksheet.

4.0 Summary

The purpose of this document is to provide an analysis of the reliability and safety of the drink mixer. Each of the different microprocessors contained within the product were critically analyzed, and their mean time to failure was calculated. It was also determined that the weakest link in the product is the ADSP-21262 SHARC Processor, with the highest failure rate. The schematic has been broken up into several different functional blocks, and each of these blocks analyzed for critical failures. Each of these critical failures has then been looked at and a probable cause determined, along with its severity and consequences. It has also been determined that there are incredibly few possibilities of an error or malfunction that could cause harm to the user or bystanders. As a result of this, almost any error that would occur is simply a nuisance or functionality error.

List of References

[1] "ATMega32A Datasheet." ATMEL. http://www.atmel.com/dyn/resources/prod_documents/doc8155.pdf. Accessed: 8 November 2009.

[2] "LM78XX Series Voltage Regulators." National Semiconductor. http://www.datasheetcatalog.org/datasheet/nationalsemiconductor/DS007746.PDF. Accessed: 8 November 2009.

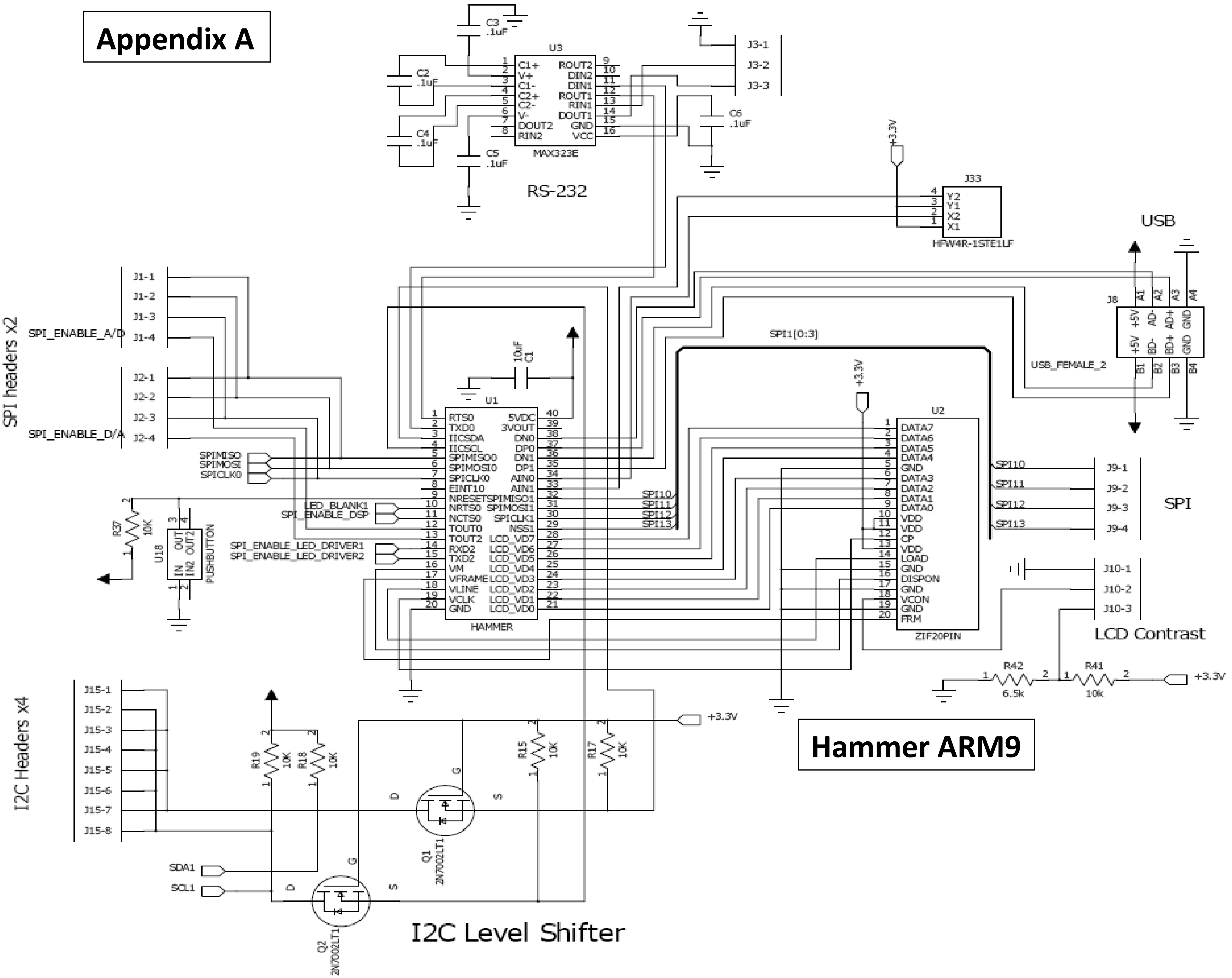
[3] "SHARC Embedded Processor." ANALOG DEVICES. http://www.analog.com/static/imported-files/data_sheets/ADSP-21261_21262_21266.pdf. Accessed: 8 November 2009.

[4] "Hammer Board." http://www.elinux.org/Hammer_Board. Accessed: 8 November 2009.

[5] MIL-HDBK-217F. United States Department of Defense. 2 January 1991.

[6] Dudash, Pete. Homework 11: Reliability and Safety Analysis, Two Wheel Deal. 4 April 2008.

Appendix A



RS-232
U3
MAX323E
J33
HFW4R-1STE1LF
USB
J8
USB_FEMALE_2
SPI1[0:3]
SPI headers x2
SPI_ENABLE_A/D
SPI_ENABLE_D/A
U1
HAMMER
U2
ZIF20PIN
SPI
LCD Contrast
R42
6.5k
R41
10k
+3.3V
U18
PUSHBUTTON
I2C Headers x4
SDA1
SCL1
Q1
2N7002LT1
Q2
2N7002LT1
I2C Level Shifter
Hammer ARM9

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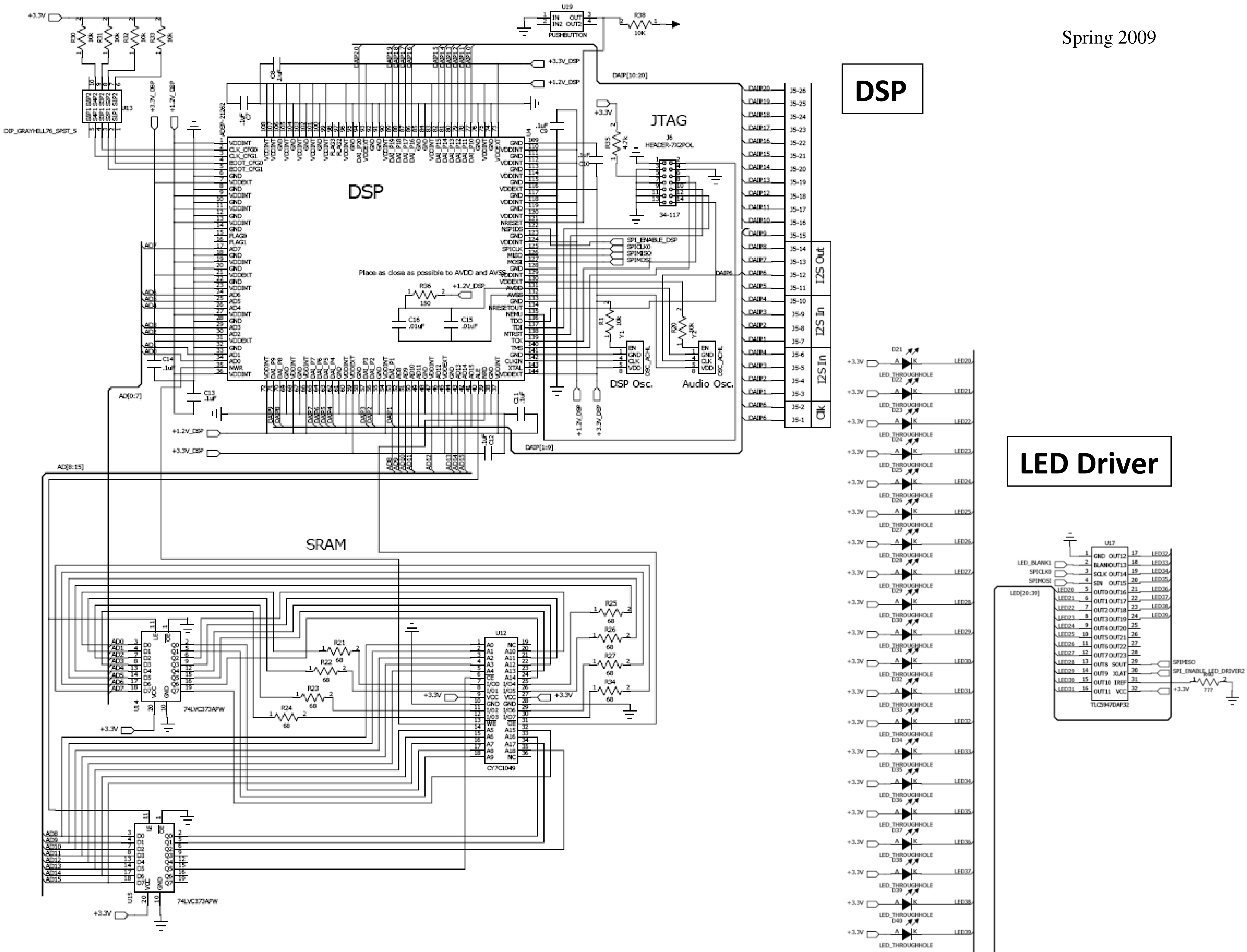
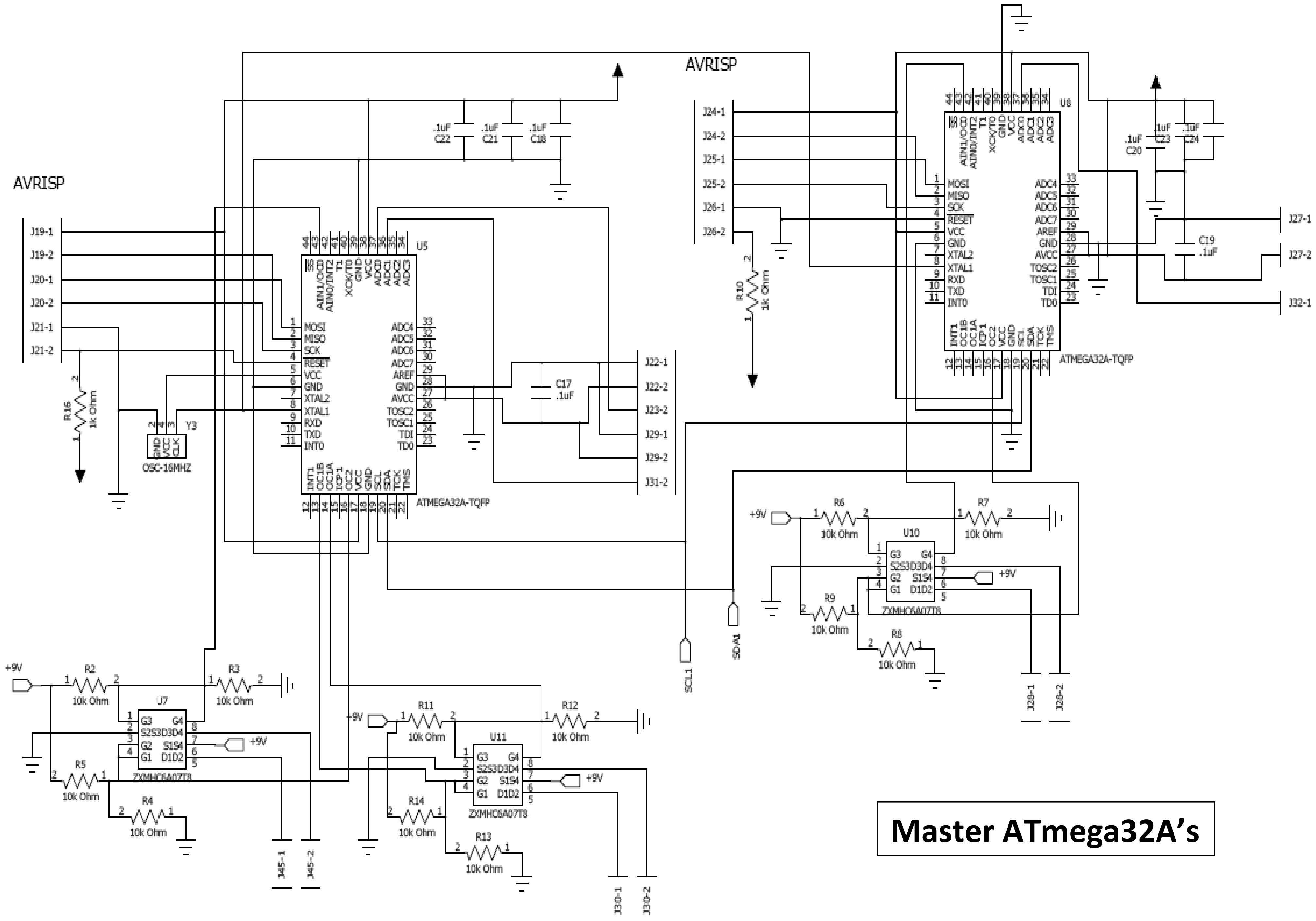
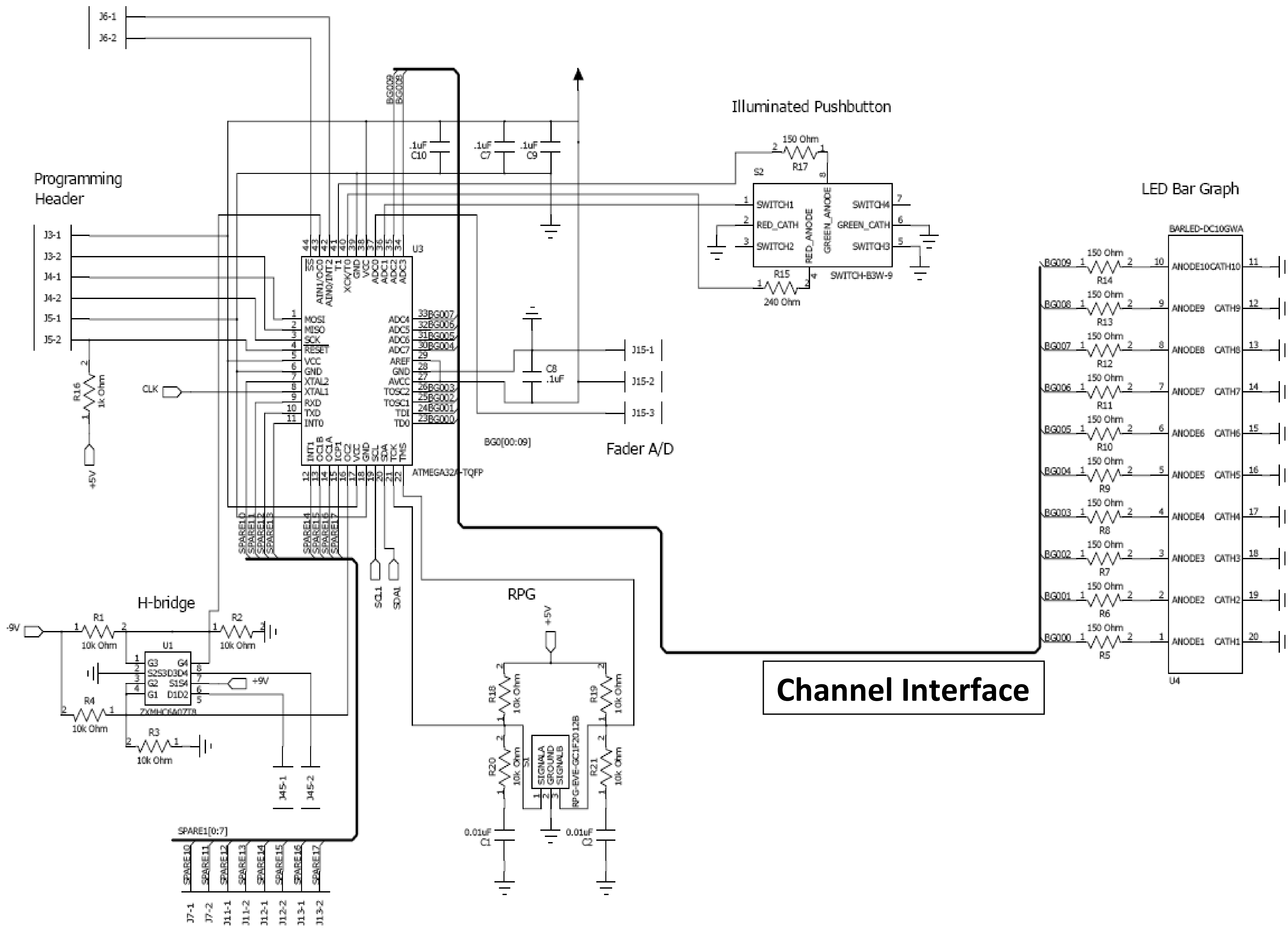


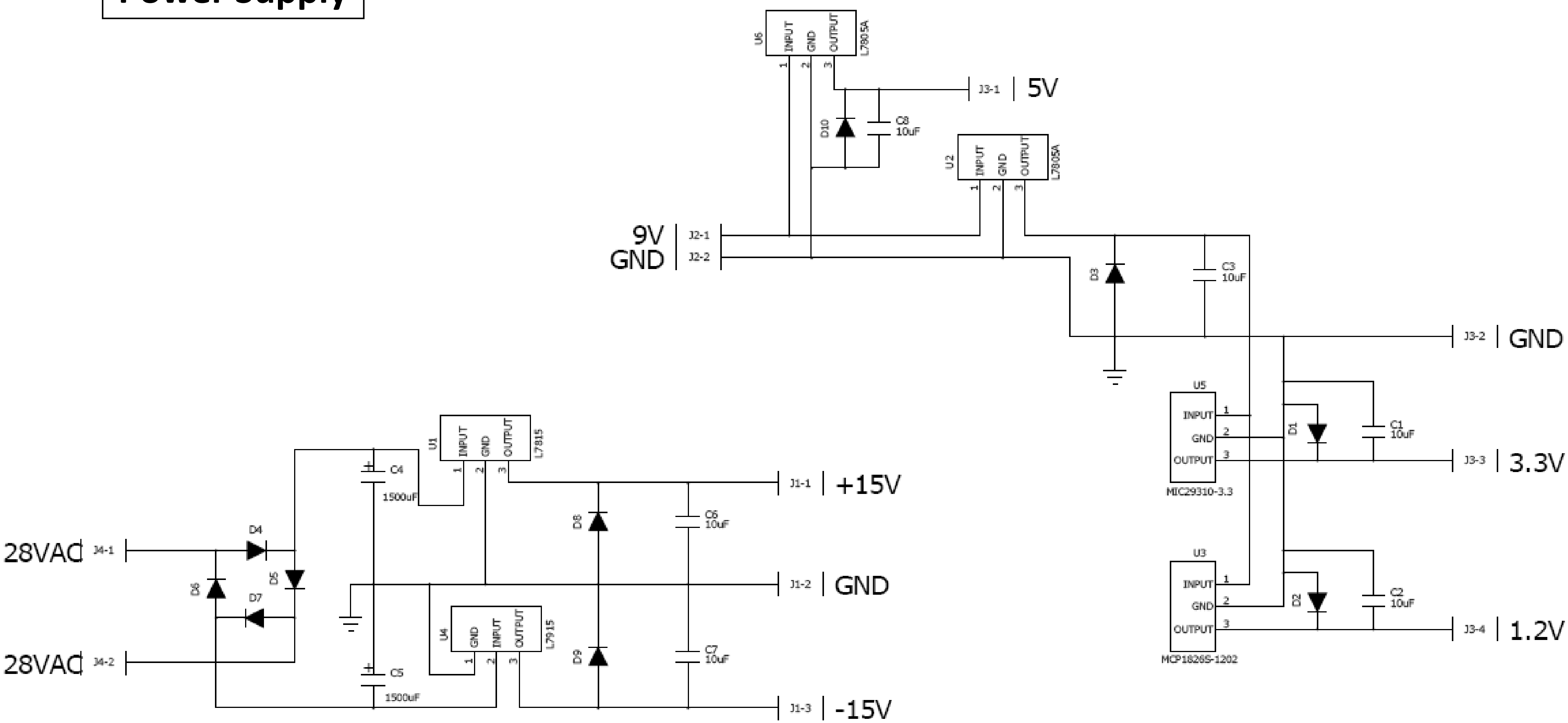
DSP
LED Driver
JTAG
SRAM
DSP Osc.
Audio Osc.
I2S Out
I2S In
I2S In
Clk
Place as close as possible to AVDD and AVSS
74LVC373APW
CY7C1049
TLC5947DAP32
PUSHBUTTON
DIP_GRAYHILL76_SPST_5
HEADER-7X2POL



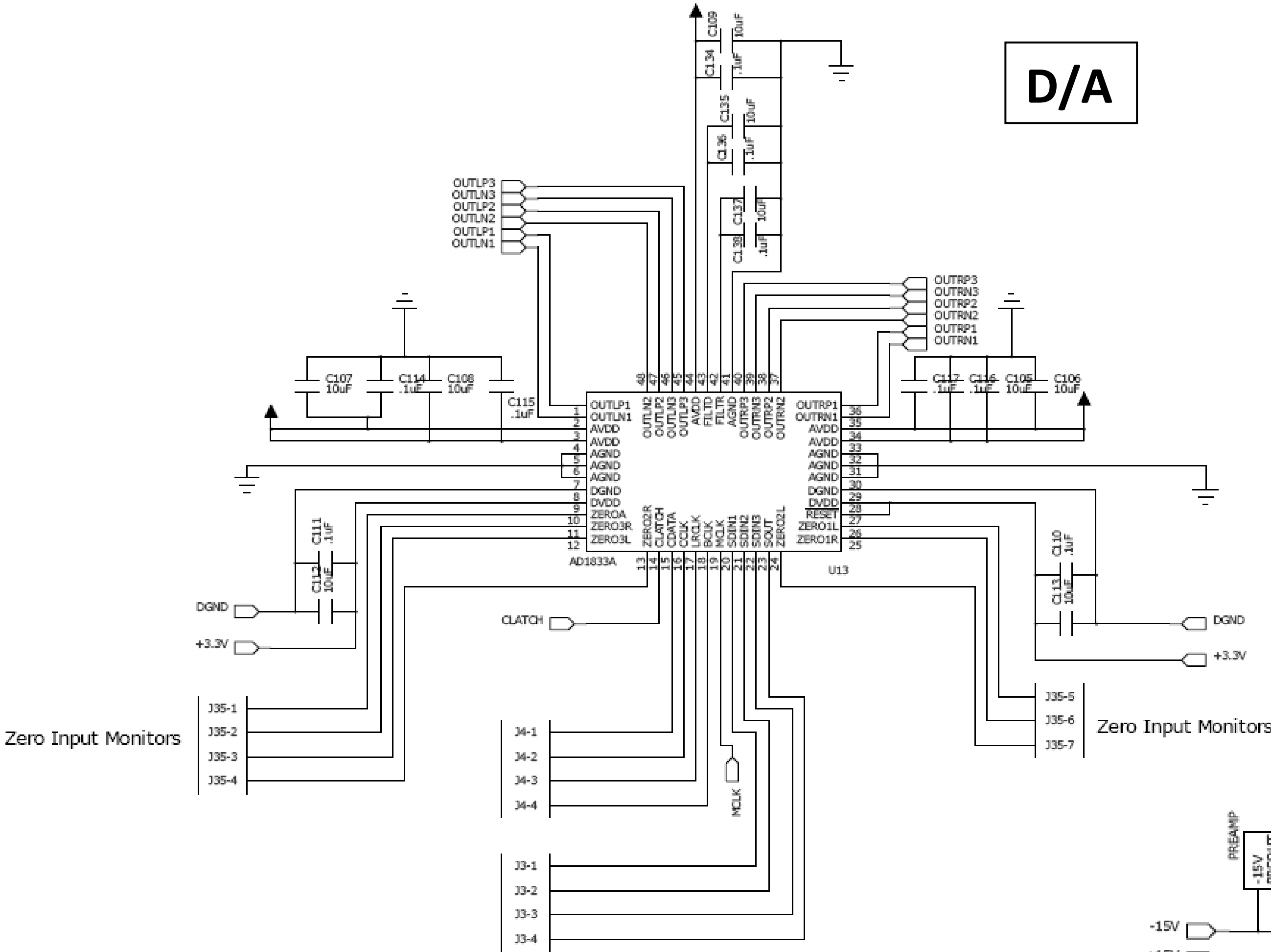
Master ATmega32A's


Programming Header
Illuminated Pushbutton
LED Bar Graph
Fader A/D
H-bridge
RPG
ATMEGA32A-TQFP
SWITCH-B3W-9
BARLED-DC10GWA
ZXMHC6A07T8
RPG-EVE-GC1F2012B
BG0[00:09]
SPARE1[0:7]
Channel Interface

Power Supply



Spring 2009


D/A
AD1833A
U13
C109 10uF
C134 .1uF
C135 10uF
C136 .1uF
C137 10uF
C138 .1uF
OUTLP3
OUTLN3
OUTLP2
OUTLN2
OUTLP1
OUTLN1
OUTRP3
OUTRN3
OUTRP2
OUTRN2
OUTRP1
OUTRN1
C107 10uF
C114 .1uF
C108 10uF
C115 .1uF
C117 .1uF
C116 .1uF
C105 10uF
C106 10uF
C111 .1uF
C112 10uF
C110 .1uF
C113 10uF
DGND
+3.3V
CLATCH
MCLK
Zero Input Monitors
J35-1
J35-2
J35-3
J35-4
J35-5
J35-6
J35-7
J4-1
J4-2
J4-3
J4-4
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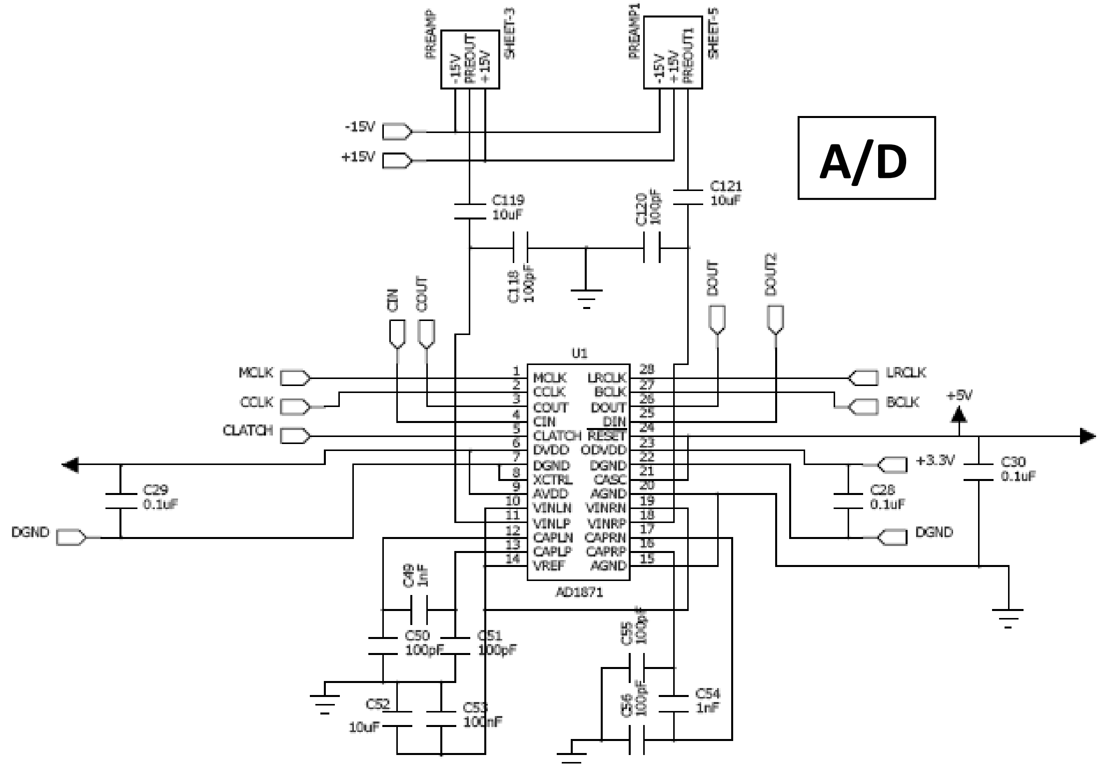
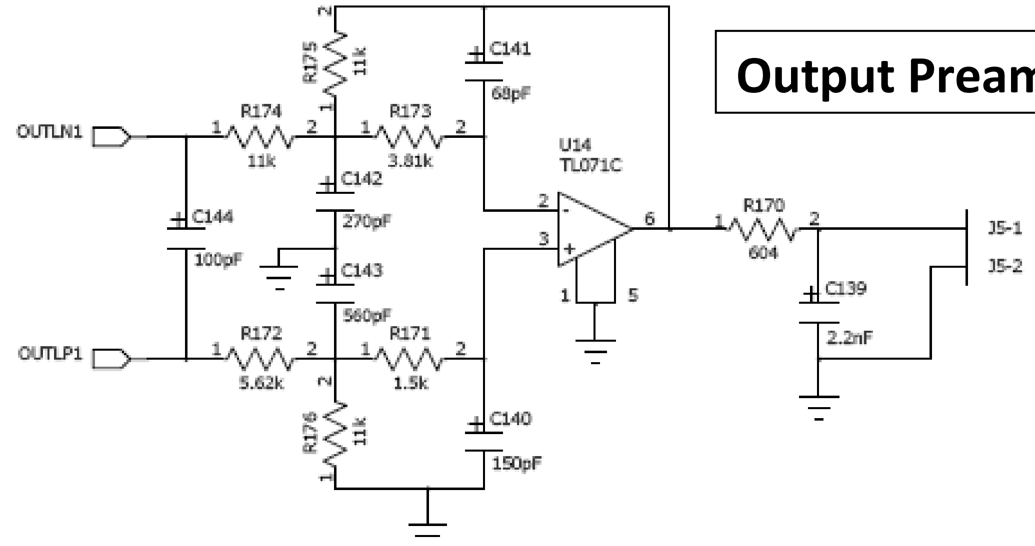
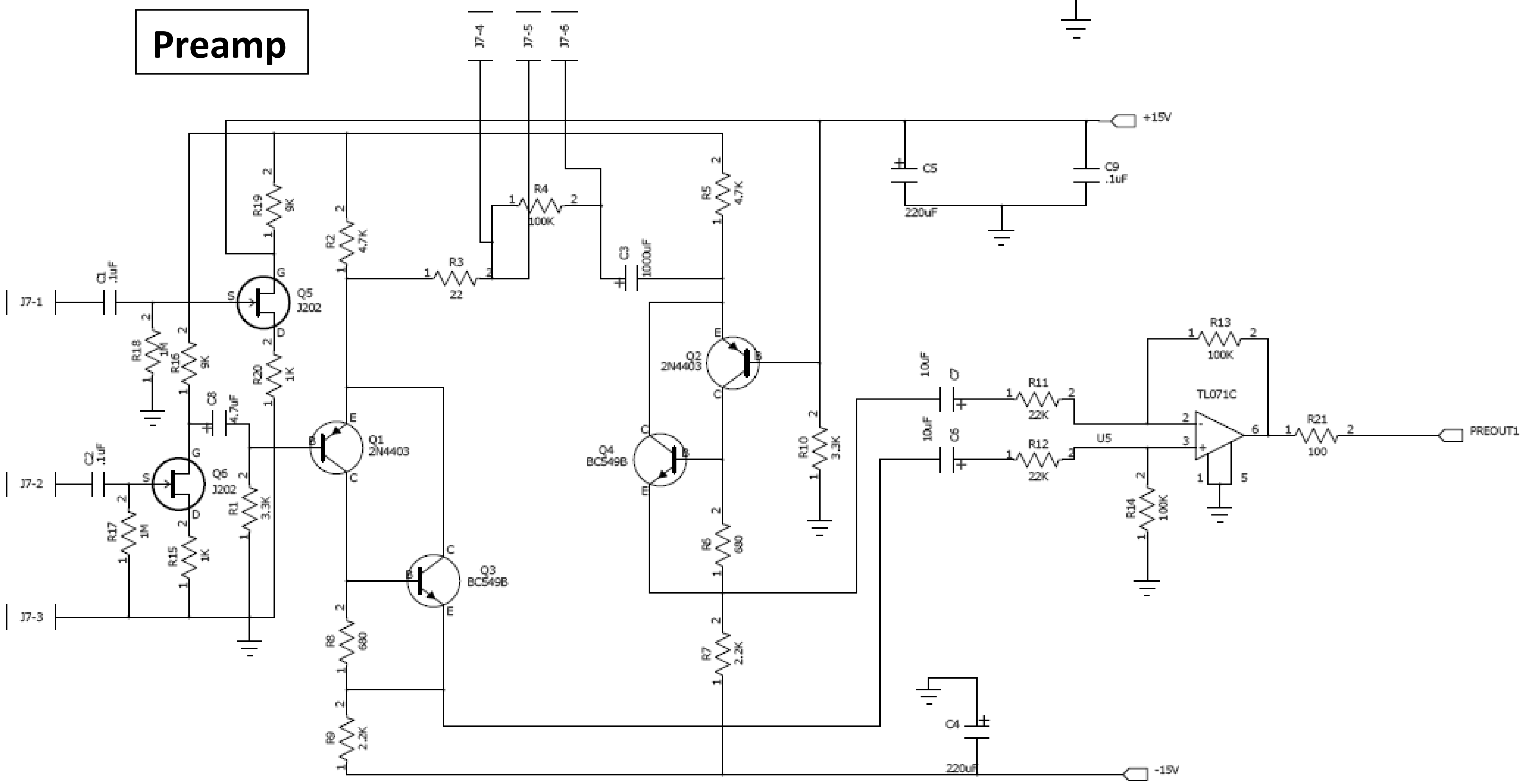
J3-3
J3-4


A/D
PREAMP
SHEET-3
PREAMP1
SHEET-5
-15V
+15V
PREOUT
PREOUT1
C119 10uF
C120 100pF
C121 10uF
C118 100pF
CIN
COUT
DOUT
DOUT2
U1
AD1871
MCLK
CCLK
CLATCH
LRCLK
BCLK
+5V
+3.3V
DGND
C29 0.1uF
C28 0.1uF
C30 0.1uF
C49 1nF
C50 100pF
C51 100pF
C52 10uF
C53 100nF
C55 100pF
C56 100pF
C54 1nF

Output Preamp



Preamp



Appendix B: FMECA Worksheet

Table 1 – Hammer ARM9						
Failure No.	**Failure Mode**	**Possible Causes**	**Failure Effects**	**Method of Detection**	**Criticality**	**Remarks**
1A	Micro remains in reset mode	Reset switch is broken and stays in "pressed" state	Microcontroller fails to run program, also cannot reprogram memory	Observation with DMM	Medium	Medium criticality because it disables the functionality of the system
1B	ATMELS and Hammer cannot communicate because Hammer cannot understand 5V logic	I^2C level shifter fried	User interface seems to be working, but audio is not	Observation with DMM and Logic Analyzer	Medium	Medium criticality because it disables the functionality of the system
1C	Contrast is set either all the way up or all the way down	Contrast voltage divider resistor is shorted	Cannot adjust the contrast on LCD	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user
1D	LCD does not receive data	ZIF connector has bent pins or Hammer has burned out pins	LCD will not change the display, but the touch screen works	Observation with Oscilloscope	Low	Low criticality because it is simply a nuisance to the user
1E	Erroneous/Sporadic data sent to the DSP	ARM9 is fried	Audio levels are sporadic. Possibly very high output levels.	Observation with Logic Analyzer	High	High criticality because if levels are too high, they can be harmful when amplified

Table 2 – DSP

Failure No.	**Failure Mode**	**Possible Causes**	**Failure Effects**	**Method of Detection**	**Criticality**	**Remarks**
2A	Micro remains in reset mode	Reset switch is broken and stays in "pressed" state	Microcontroller fails to run program, also cannot reprogram memory	Observation with DMM	Medium	Medium criticality because it disables the functionality of the system
2B	Memory space is too small	SRAM chip burned out	Audio Processing is greatly lagging	Observation with DMM and Logic Analyzer	Medium	Medium criticality because it disables the essential functionality of the system
2C	-If only one side: No power sent to individual LEDs - If both sides: SPI signal not present or sampled incorrectly	-If only one side: LED driver is burned out - If both sides: SPI is not working on DSP	Output amplitude LEDs are not lighting	Observation with DMM and Logic Analyzer	Low	Low criticality because it is simply a nuisance to the user (Although it is one of our current PSSCs, so it is critical)
2D	Erroneous/Sporadic output levels	SHARC is fried	Audio levels are sporadic. Possibly very high output levels.	Observation with Logic Analyzer	High	High criticality because if levels are too high, they can be harmful when amplified

Table 3 – ATMega32A

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
3A	Micro remains in reset mode	Reset jumpers are shorted, thus created an effective "button pressed" state	Microcontroller fails to run program, also cannot reprogram memory	Observation with DMM	Medium	Medium criticality because it disables the functionality of the system
3B	Micro not communicating with ARM9	ATMEL is fried or I^2C not configured properly for that channel	Nothing works on one individual channel	Observation with Logic Analyzer	Medium	Medium criticality because it disables the functionality of the channel
3C	Erroneous/Sporadic information about audio levels is sent to ARM9	ATMEL is fried	Audio levels are sporadic. Possibly very high output levels.	Observation with Logic Analyzer	High	High criticality because if levels are too high, they can be harmful when amplified
3D	PWM is only working on one channel	PWM is disabled or fried	Fader will only move automatically in one direction	Observation with Oscilloscope	Low	Low criticality because it is simply a nuisance to the user.

Table 4 – Channel Interface

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
4A	H-Bridge is not providing power to the fader motor	H-Bridge burned out	Faders don't move automatically	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user.
4B	Channel remains enabled or disabled	On/Off button broken and not creating contact when it is pressed.	Channel audio is not heard and button does not change color when turned on	Observation with DMM	Medium	Medium criticality because it disables the functionality of the channel
4C	LEDs do not light up	LEDs are burned out	LEDs in pushbutton do not light up when they are supposed to	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user.
4D	LEDs do not light up	LEDs are burned out	Some of the LEDs in the bar graph do not light up.	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user.
4E	Square wave is not generating properly	RPG is broken	Levels do not change when RPG is turned	Observation with Oscilloscope or Logic Analyzer	Medium	Medium criticality because it disables the functionality of the channel

Table 5 – Power Supply

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
5A	Excessive current draw, fuses continuously blown	Power rails shorted together	Short causes a blown fuse, burnt out components, or even a fire	Observation with DMM and continuity check	High	High criticality because if power traces are shorted, they can cause a fire
5B	Excessive current draw on regulator	Regulator is blown	Devices on a particular power rail will not power on	Observation with DMM	Medium	Medium criticality because it disables the functionality of the unit
5C	Rectifier circuit is degraded and goes below dropout for regulator, causing a noisy voltage supply	Rectifier diodes or Capacitors are blown	Preamp is noisy	Observation with DMM	Medium/Low	Medium/Low criticality because it is a nuisance to the user, but also degrades the quality of the audio signal.

Table 6 – D/A and A/D						
Failure No.	**Failure Mode**	**Possible Causes**	**Failure Effects**	**Method of Detection**	**Criticality**	**Remarks**
6A	A signal is being passed into the A/D chip, but no signal is coming out.	A/D chip is fried	No audio input to DSP	Observation with DMM and Logic Analyzer	Medium	Medium criticality because it disables the functionality of the unit
6B	A signal is being passed into the A/D chip, but no signal is coming out.	D/A chip is fried	No audio output from DSP	Observation with DMM and Logic Analyzer	Medium	Medium criticality because it disables the functionality of the unit
6C	Reference voltages are noisy and can creates misreads of digital information.	Filter capacitor is blown and open circuited	Audio signal is garbled	Observation with Capacitance Meter	Medium/Low	Medium/Low criticality because it is a nuisance to the user, but also degrades the quality of the audio signal.

Table 7 – Preamps

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
7A	Potentiometer is not changing the voltage divider on the preamp	Gain potentiometer is broken	Gain knob does not change gain	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user.
7B	Missing components add noise to the signal that is very small to begin with	Resistor, capacitor, or transistor is blown	Preamp is noisy	Observation with DMM	Low	Low criticality because it is simply a nuisance to the user.
7C	Op-amp does not pass the signal through	Op-amp is blown	Preamp has no output	Observation with DMM	Medium	Medium criticality because it disables the functionality of the unit