A10 - Reliability and Safety Analysis

Year: 2024 **Semester:** Spring **Team:** 12 **Project: Microphone Interface**
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Assignment Evaluation: See the Rubric in the Brightspace Assignment

1.0 Reliability Analysis

The components for this analysis are the SMT32F746ZGT6 MCU, LD1117S33TR voltage regulator, and the WM8731 codec.

For the MCU and voltage regulator we will be using the failure rate (per 10^6 hours) formula for microcircuits and microprocessors found inside of the [1]MIL-HDBK-217F handbook:

$$\lambda_P = (C_1 \pi_T + C_2 \pi_E) \pi_Q \pi_L$$

For the codec we will use the formula for digital devices found inside of the same [1]MIL-HDBK-217F handbook:

$$\lambda_P = (C_1 \pi_T \pi_A + C_2 \pi_E) \pi_Q \pi_L$$

For the mean time to failure (MTTF), in years:

$$MTTF = 10^6 / (24 * 365 * \lambda_P)$$

For all components we will keep the three variables constant. The quality factor, π_Q, will be set to 10 since all of these are commercial components. The environmental constant, π_E, will be set to 0.5 due to the device being stationary in a controlled environment. The learning factor, π_L, will be set to 1 since all components have been manufactured for more than 2 years.

1.1 [4]STM32F746ZGT6 MCU

The STM32F746ZGT6 microcontroller is the heart of the device. It is used to communicate with all our components such as the LCD and codec, perform DSP on incoming audio input, and handle user input logic from encoders and buttons. Failure for it to operate normally could result in incorrect communication with connected components and lead to unpredictable behavior for the device. Its failure wouldn't cause any direct harm to users.

Table 1, MCU Analysis

Parameter name	Description	Value	***Comments*** *regarding choice of parameter value, especially if you had to make assumptions.*
C1	Die complexity	.56	32-bit MCU
π_T	Temperature Coeff.	*.98*	85 C worst case temp

C_2	Package Failure Rate	*0.077*	144 pin SMT
π_E	Environmental Constant	*0.5*	Ground-benign
π_Q	Quality Factor	*10*	Commercial Part
π_L	Learning Factor	*1*	More than 2 years in production
λ_P	Failure Rate (per 10^6 hours)	*5.873*	
MTTF	Mean Time To Failure (years)	*19.44*	

The calculated MTTF for the MCU is about 19.5 years, which is certainly long enough for this type of product; however, this number could be improved. Alternatively, we could use a different MCU model with fewer pins to reduce the package failure rate.

1.2 [3]LD1117S33TR Voltage Regulator

The LD1117S33TR voltage regulator will be used to scale down the 5V signal from the USB power supply down to 3.3V to then be delivered to power all our components on board. Failure for this device can lead to an improper voltage being delivered to each of the components, possibly damaging them and killing the device. It does not pose any direct risk to the user.

Table 2, Voltage Regulator Analysis

Parameter name	**Description**	**Value**	***Comments*** *regarding choice of parameter value, especially if you had to make assumptions.*
C1	Die complexity	.01	1-100 Bipolar Transistors
π_T	Temperature Coeff.	*58*	125 C worst case temp for linear (MOS & Bipolar)
C_2	Package Failure Rate	*.00012*	3 pin SMT
π_E	Environmental Constant	*0.5*	Ground-benign
π_Q	Quality Factor	*10*	Commercial Part
π_L	Learning Factor	*1*	More than 2 years in production
λ_P	Failure Rate (per 10^6 hours)	*5.806*	
MTTF	Mean Time To Failure (years)	*196.62*	

In the end the voltage regulator came out to have a very low package failure rate as well as a very high MTTF. The only considerations for improvement would be to install some sort of cooling which would prevent the voltage regulator from reaching its high temperatures and possibly damaging other parts of the device if it fails.

1.3 [2]WM8731 Codec

The WM8731 codec is the input and output source of our device's audio. It samples the incoming analog audio signal and sends it to the MCU via I2S for processing. Failure of this device can either lead to no output or perhaps produce loud noise which could lead to hearing damage for the user if connected to loudspeakers or headphones.

Table 3, Codec Analysis

Parameter name	**Description**	**Value**	***Comments*** *regarding choice of parameter value, especially if you had to make assumptions.*
C1	Die complexity	25	1 to 1000 elements
π_T	Temperature Coeff.	*.98*	85 C worst case temp
C_2	Package Failure Rate	*.013*	28 Pin QFN
π_E	Environmental Constant	*0.5*	Ground-benign
π_Q	Quality Factor	*10*	Commercial Part
π_L	Learning Factor	*1*	More than 2 years in production
π_A	Device Application Factor	*1*	All digital applications.
λ_P	Failure Rate (per 10^6 hours)	*245.065*	
MTTF	Mean Time To Failure (years)	*4.65*	

The failure rate for the codec is very high and the MTTF is just short of 5 years. While our product is not essential to function for more than a couple years, it won't have good longevity if the codec is prone to fail within 5 years of use. It is possible that the model derived from the handbook is not appropriate for this component and there was some issue with the accuracy of the calculation. To improve the longevity of the codec, we can implement cooling to reduce the operating temperatures.

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

Our schematic consists of 6 major blocks: power, MCU, control, SWD, codec, and LCD connector. The criticality levels can be broken up to low, medium, and high. Where high is capable of serious damage such as burns or hearing loss, medium just produces uncomfortable levels of audio but not severe enough for hearing loss, and low is only capable of incorrect logic or shutting down the device without posing any health risks for the user. The acceptable failure rate for high criticality is 10^{-9}, for medium 10^{-7}, and low 10^{-6}.

3.0 Sources Cited:

[1] "Military Handbook Reliability Prediction of Electronic Equipment" Department of Defense. Washington DC. MIL-HDBK-217F, Dec. 2, 1991.

[2] "Portable Internet Audio CODEC with Headphone Driver and Programmable Sample Rates WOLFSON MICROELECTRONICS plc." Accessed: Mar. 30, 2024. [Online]. Available: https://www.mouser.com/datasheet/2/76/WM8731_v4_9-1141834.pdf

[3] "LD1117 Adjustable and fixed low drop positive voltage regulator Datasheet -production data Features," 2020. Accessed: Mar. 30, 2024. [Online]. Available: https://www.st.com/content/ccc/resource/technical/document/datasheet/99/3b/7d/91/91/51/4b/be/CD00000544.pdf/files/CD00000544.pdf/jcr:content/translations/en.CD00000544.pdf

[4] "This is information on a product in full production. STM32F745xx STM32F746xx," 2016. Accessed: Mar. 30, 2024. [Online]. Available: https://www.st.com/content/ccc/resource/technical/document/datasheet/96/ed/61/9b/e0/6c/45/0b/DM00166116.pdf/files/DM00166116.pdf/jcr:content/translations/en.DM00166116.pdf

Appendix A: Schematic Functional Blocks

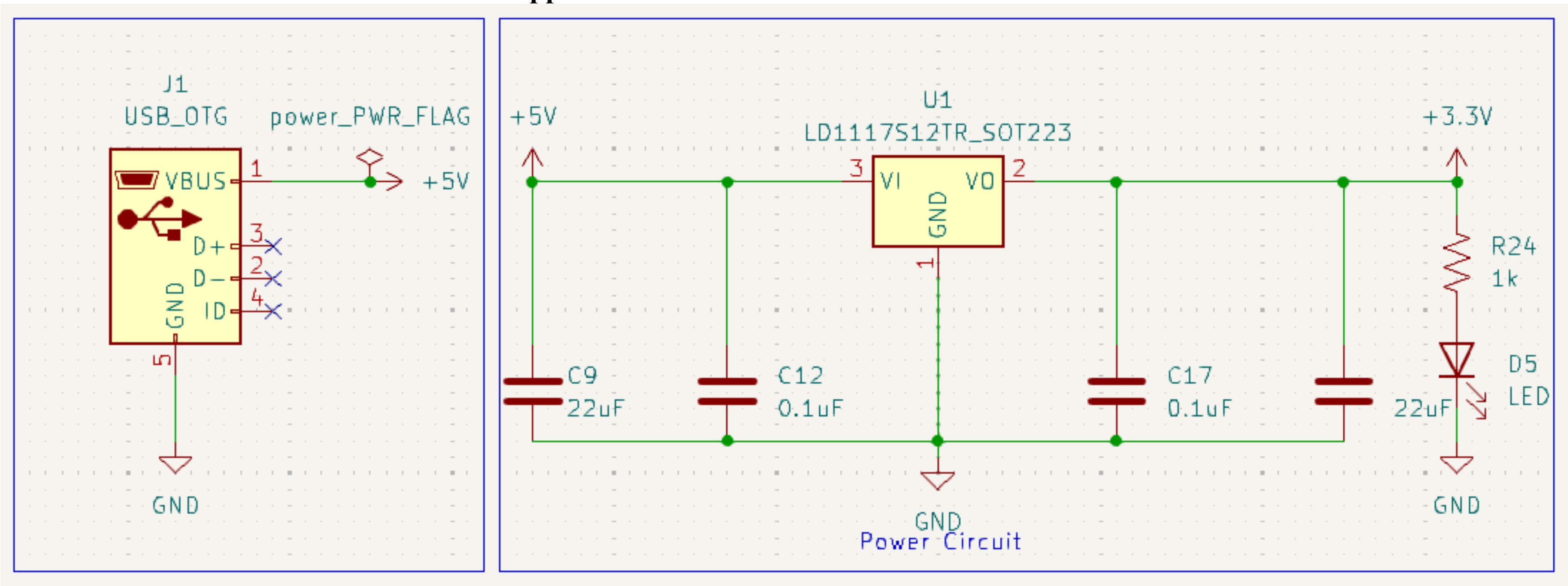

Figure 1, Power Circuit

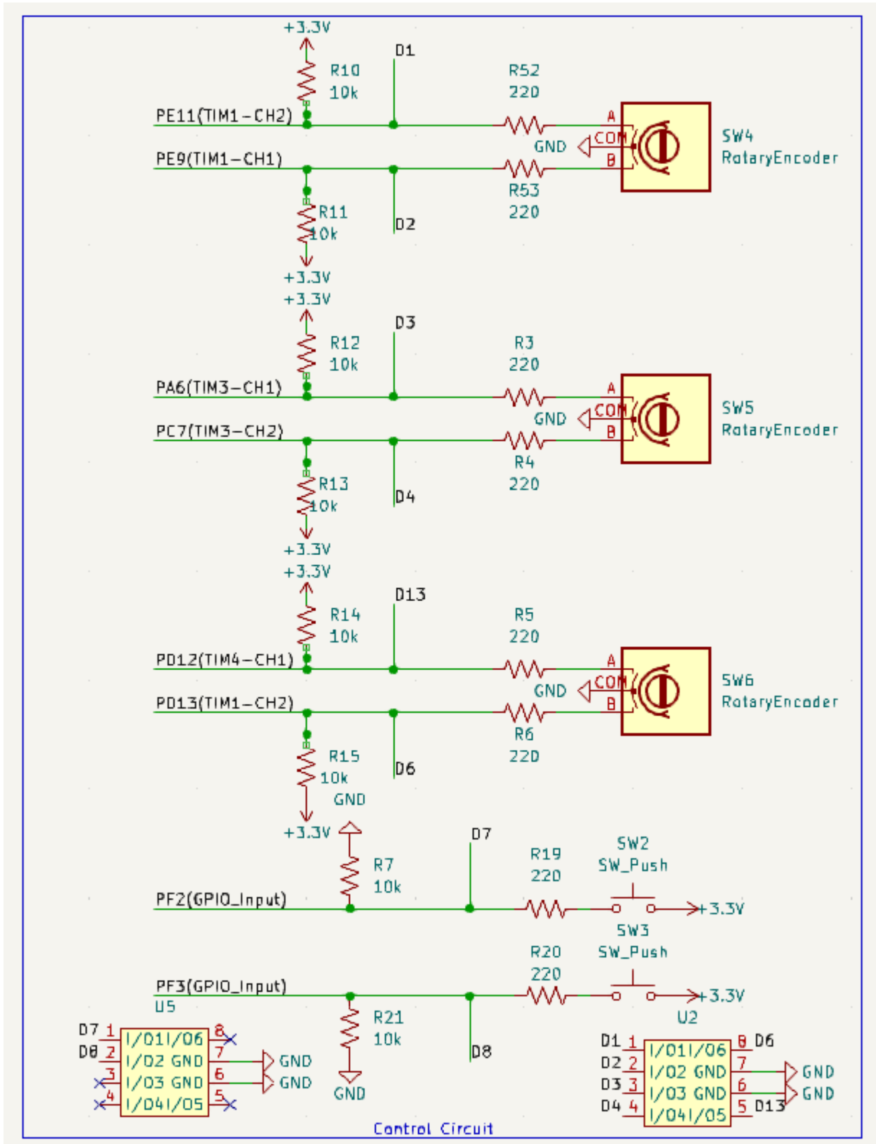

Figure 2, Control Circuit

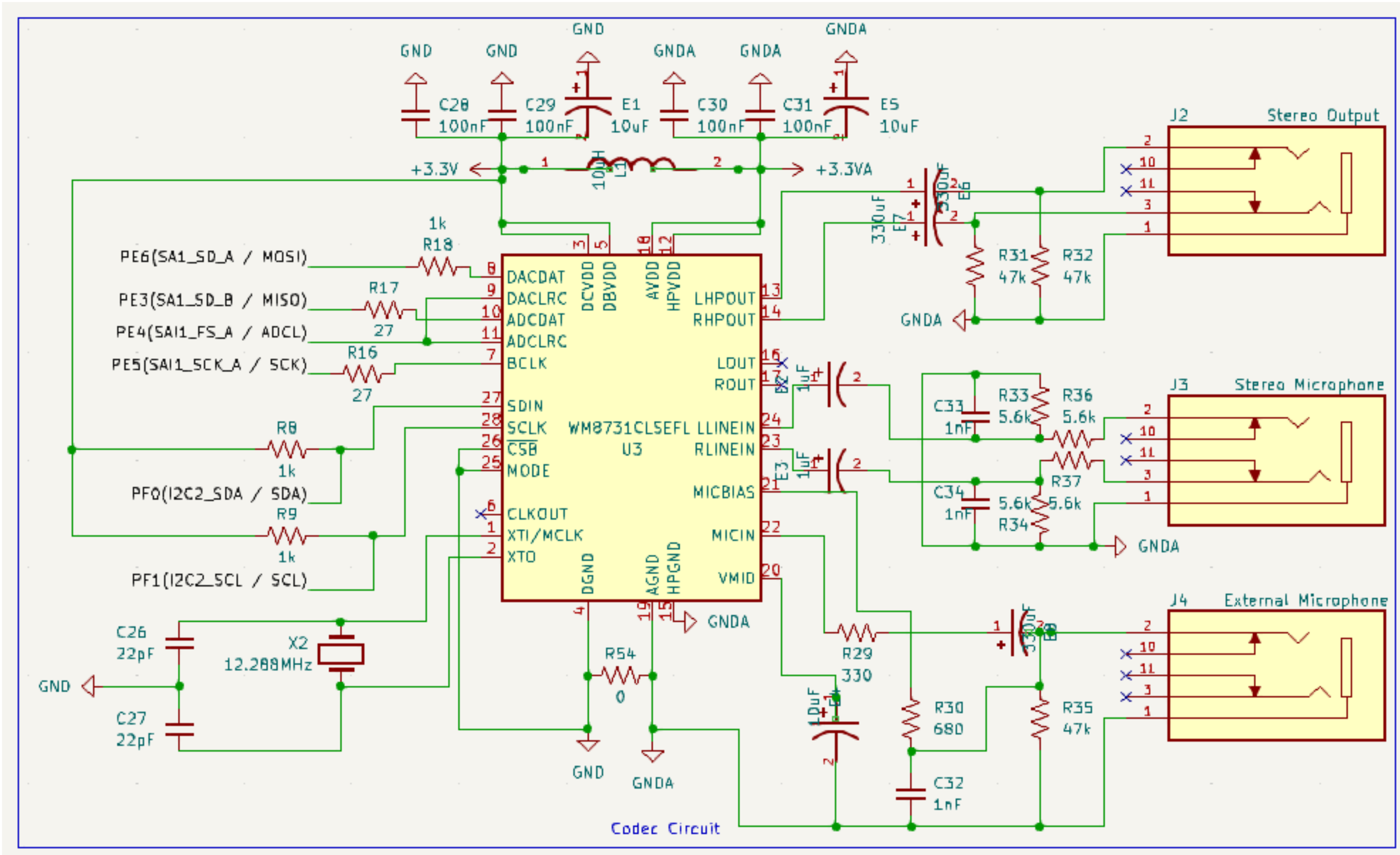

Figure 3, Codec Circuit

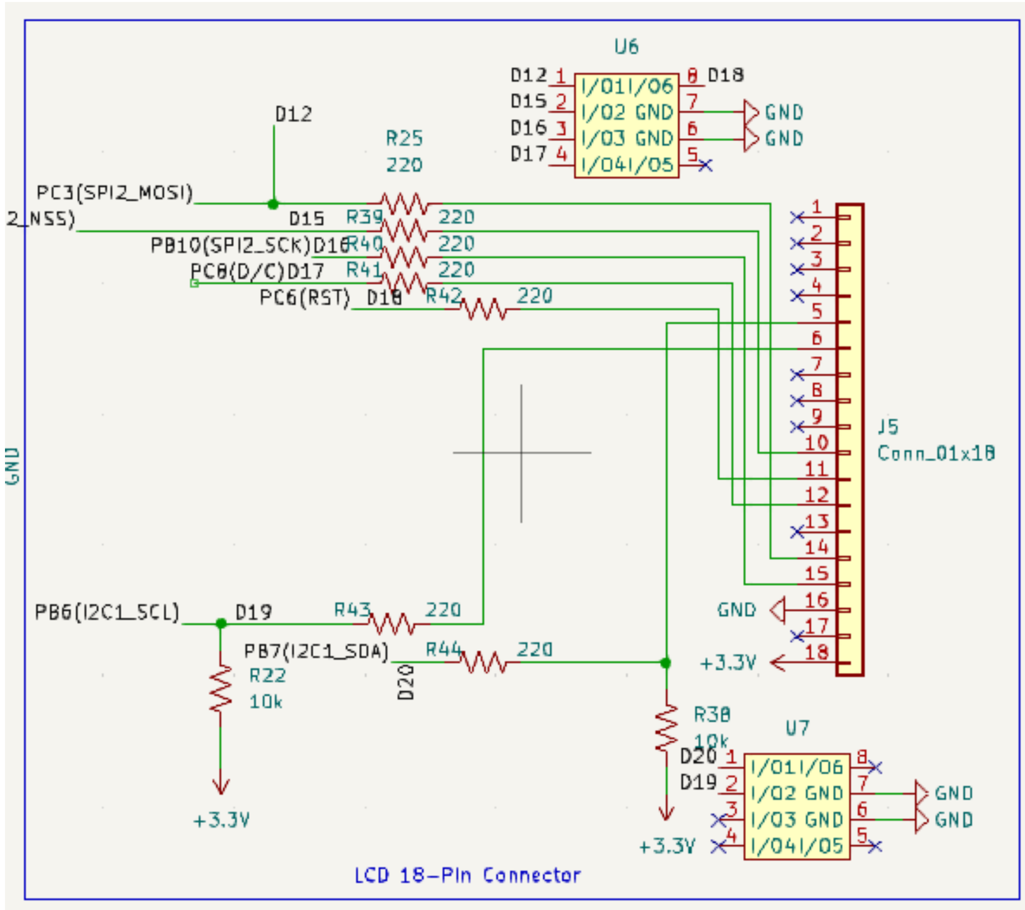

Figure 4, LCD 18-Pin Connector

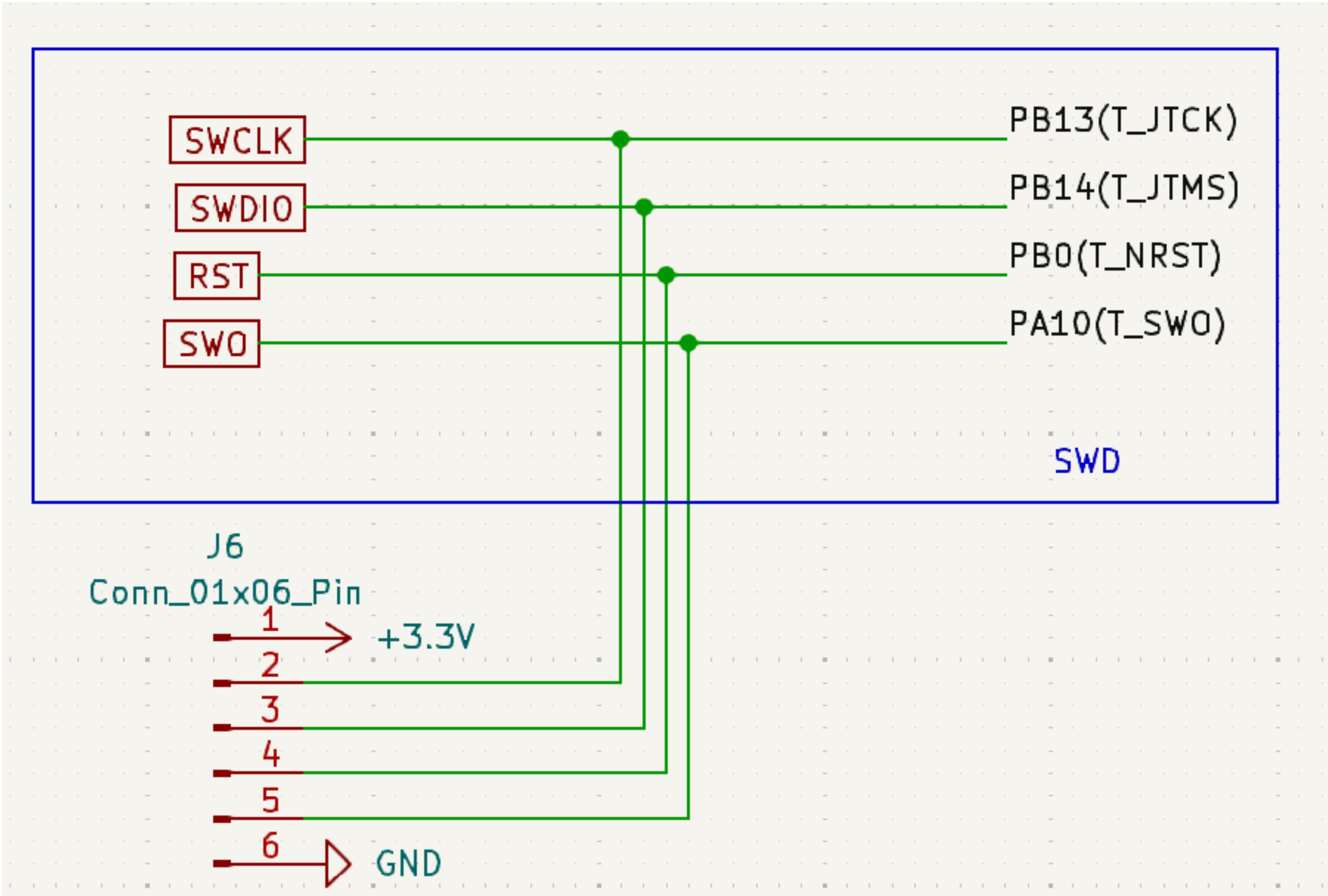
SWCLK
SWDIO
RST
SWO
PB13(T_JTCK)
PB14(T_JTMS)
PB0(T_NRST)
PA10(T_SWO)
SWD
J6
Conn_01x06_Pin
1
2
3
4
5
6
+3.3V
GND

Figure 5, SWD

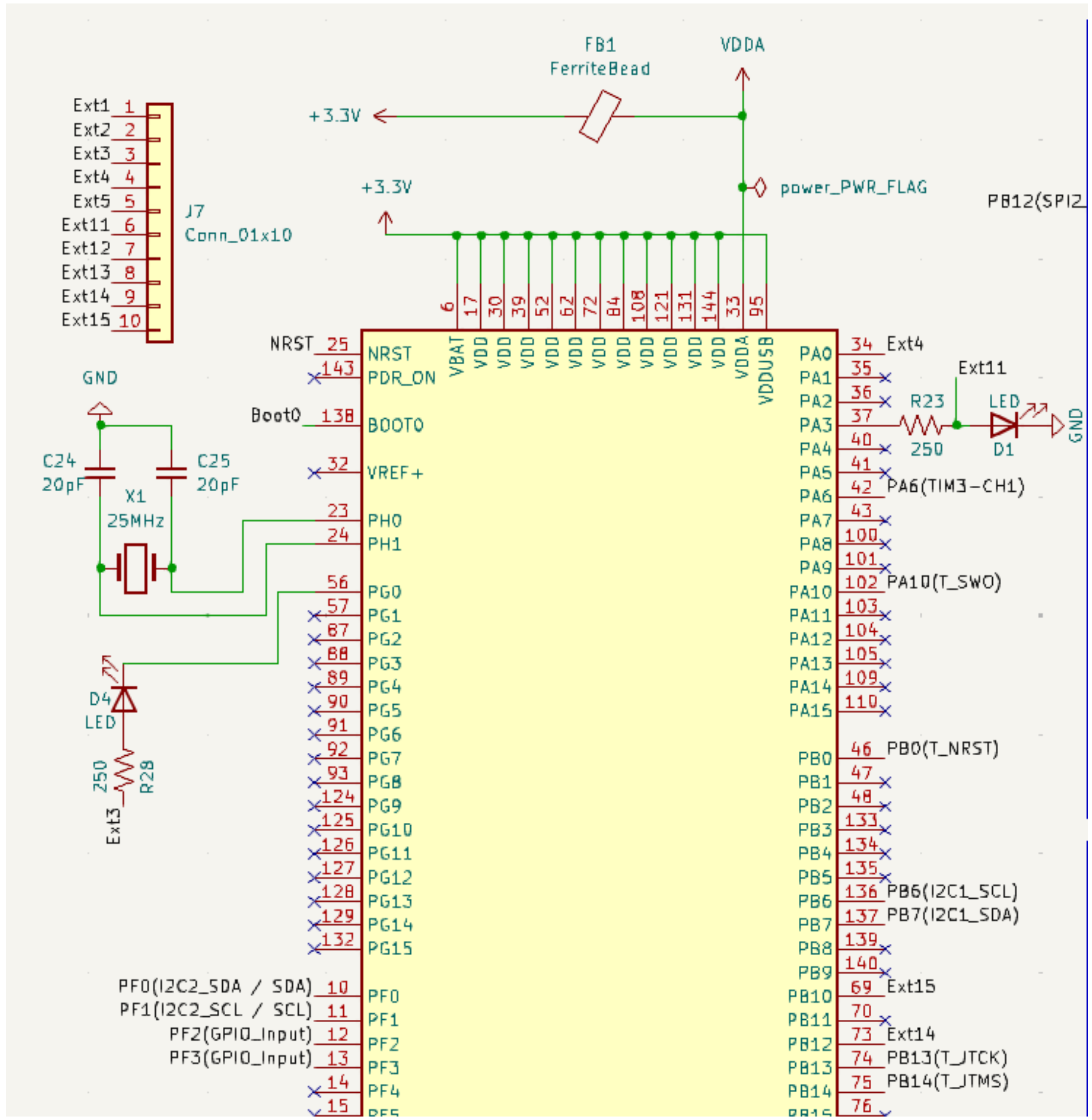

Figure 6.1, MCU (top)

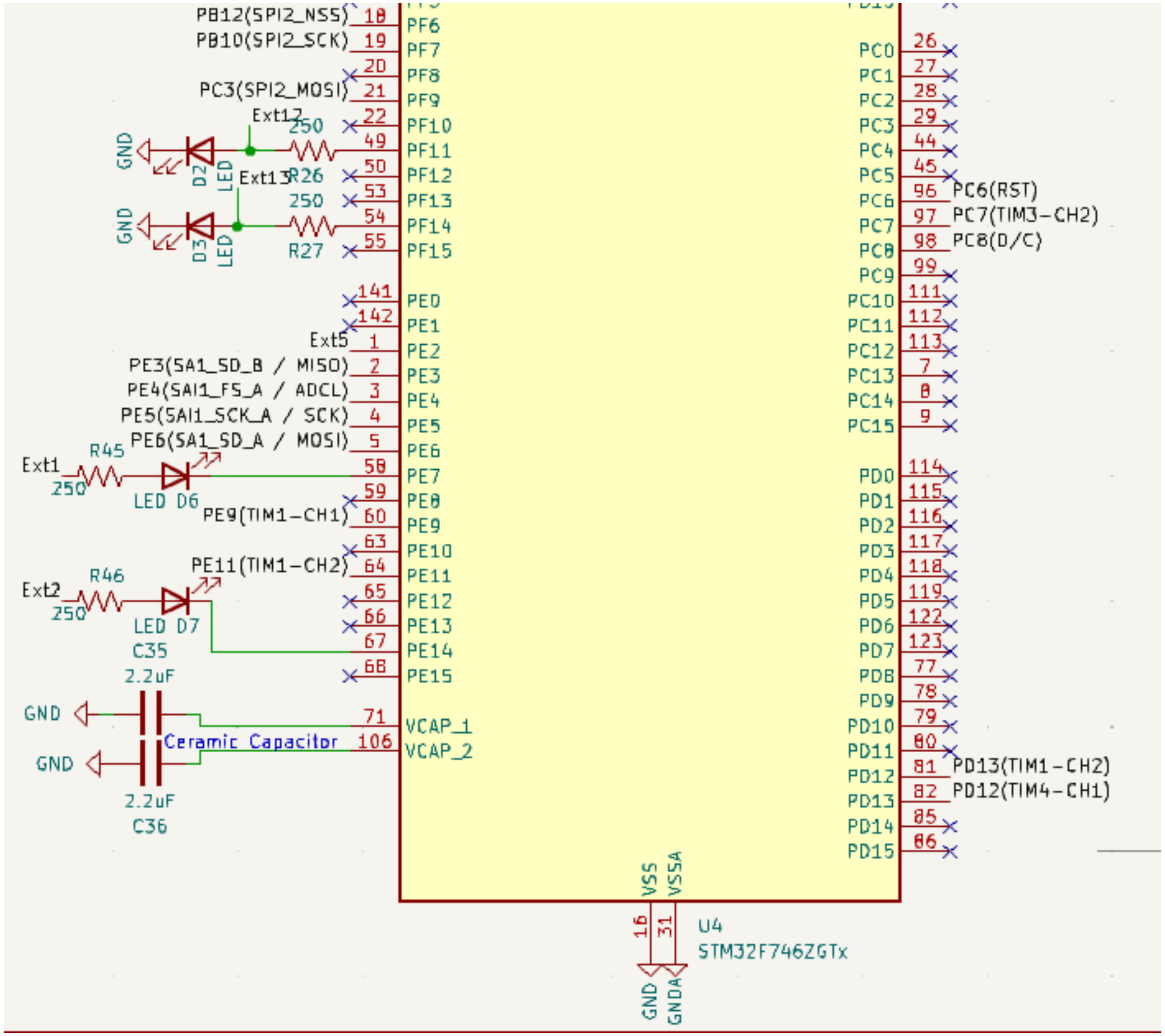

Figure 6.2, MCU (bottom)

Appendix B: FMECA Worksheet

Table 4, Power Circuit

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	No voltage supply	Damaged USB power connector from users jamming it in to strongly	Device is dead	Failure to turn the device on when plugged in	Low	
2	No voltage regulation	Voltage regulator	Overheating and damage to connected components	Smoking, devices do not work as intended	High	

Table 5, Control Circuit

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	No response from button input	Damaged connection from users pressing the buttons too hard	Cannot navigate UI using the buttons	Lack of response from user input	Low	
2	No response from rotary encoder rotation	Natural wear over time	No parameter control from user	Lack of response from user input	Low	

Table 6 Codec Circuit

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	No input/output	Users jamming in the audio jack too strongly into the connector	Lack of input or output when connecting to the jack	Observation	Low	
2	Codec noise filters do not work	Deterioration of components over time	Louder electrical noise coming through with signal	Observation	Low	
3	I2S protocol malfunction	Codec is not synced with the MCU properly due to clock issues	Unpredictable. Possible loud popping or distorted noises which could damage hearing	Observation	High	

Table 7 LCD Connector

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	No LCD display or touch detection	Connection becomes loose or other signals interfere with the signal on the ribbon cable	LCD display does not work or certain artifacts and tearing are present on the display	Observation of the display, inspection of the connection	Low	

Table 8 SWD

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	No power supply	Improper connection or damaged cable	Cannot program the microcontroller	Error when trying to program	Low	
2	No data received	Improper connection or damaged cable	Cannot program the microcontroller	Error when trying to program	Low	

Table 9 MCU

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
1	MCU stops executing instructions correctly	Dip in 3.3 V input	Unpredictable. Frozen program.	Observation.	Low	
2	I2S incorrectly sends out data to codec	Improper software initialization	Codec popping noise	Observation, debugging	Medium	

3	Improper DSP parameters set	Software doesn’t account for safe limits	Extremely loud noise and distortion on output audio	Observation, debugging	High	
4	SPI data is sent incorrectly or too slowly	Software does not properly account for LCD dimensions or sets too slow of a baud rate	No display or lagging in updating UI	Observation	Low	