Reliability and Safety Analysis (Spring 2020)

Team:8
Project: Audio Beamer
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Assignment Evaluation:

Item	Score (0-5)	Weight	Points	Notes
Assignment-Specific Items				
Reliability Analysis		x2		
MTTF Tables		x3		
FMECA Analysis		x2		
Schematic of Functional Blocks (Appendix A)		x2		
FMECA Worksheet (Appendix B)		x3		
Writing-Specific Items				
Spelling and Grammar		x2		
Formatting and Citations		x1		
Figures and Graphs		x2		
Technical Writing Style		x3		
Total Score				

5: Excellent 4: Good 3: Acceptable 2: Poor 1: Very Poor 0: Not attempted

Comments:
Comments from the grader will be inserted here

1.0 Reliability Analysis

The components in this project that are most likely to fail are the MSP430FR5994 Microcontroller, the AP2127K LDO, & PCM3002 Audio Codec.

The AP2127K LDO is more likely to fail because of its dynamic heating possibilities. The LDO junction temperature can vary on its input voltage which can range from 4.2V-3.4V from the Li-ion cell or 5V from the USB input.
The PCM3002 Audio Codec is responsible for all audio analog-digital conversions and is interfaced with the MCU, an Op-amp & external speakers. It likely to fail because of its complexity.
The MSP320FR5994 has a higher probability of failure mainly due to it being the most complex subsystem on the project.

Assumptions:
MIL-HDBK-217f was referred to model all Failure per million hours & MTTF calculations.
The following formulas were used:

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

$$MTTF = 10^6 / (24 * 365 * \lambda_P) \text{ years}$$

Additionally, some parameters in the failure model were assumed to be constant among all components on the system.
Environmental factor is assumed to be 4.0 as we consider our system to be a mobile device
Quality factor is assumed to be 10 which is a lenient estimate for modern consumer products
Learning factor is assumed to be 1 since all of our components have been on the market for at least 2 years.

MSP430FR5994 - Microcontroller

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.28	*Based on MIL-HDBK-217F for 16 bit MCUs*
π_T	Temperature coeff.	*0.98*	Assuming maximum operating temperature of 85C
C2	Package failure rate	*0.032*	80 pins on MCU
π_E	Environmental factor	*4.0*	*Handbook value for mobile device*
π_Q	Quality factor	*10*	*Commercial part*
π_L	Learning factor	*1*	*MCU has been in production for more than 2 years*
Entire design:			
λ_P	Failure per million hours	*4.028*	

MTTF	*Mean Time To Failure*	*245280 hours*	*Approx. 28 years to failure*

AP2127K-3.3 - LDO

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.02	*Based on MIL-HDBK-217F for 100-300 bipolar transistors*
π_T	Temperature coeff.	*5.6*	Assuming maximum operating temperature of 150C
C2	Package failure rate	*0.016*	5 pins on IC
π_E	Environmental factor	*4.0*	*Handbook value for mobile device*
π_Q	Quality factor	*10*	*Commercial part*
π_L	Learning factor	*1*	*MCU has been in production for more than 2 years*
Entire design:			
λ_P	Failure per million hours	*1.76*	
MTTF	*Mean Time To Failure*	*568181 hours*	*Approx. 64.8 years to failure*

PCM3002 – Audio Codec

Parameter name	**Description**	**Value**	***Comments***
C1	Die complexity	0.08	*Based on MIL-HDBK-217F for CMOS based IC with 3001-10,000 transistors*
π_T	Temperature coeff.	*0.98*	Assuming maximum operating temperature of 85C
C2	Package failure rate	*0.087*	24 pins on IC
π_E	Environmental factor	*4.0*	*Handbook value for mobile device*
π_Q	Quality factor	*10*	*Commercial part*
π_L	Learning factor	*1*	*MCU has been in production for more than 2 years*
Entire design:			
λ_P	Failure per million hours	*4.264*	

MTTF	*Mean Time To Failure*	*234521 hours*	*Approx. 26.8 years to failure*

Summary:
According to my calculations, the system seems to be reliable in the correct operating conditons. Therefore, this means that the device has a decent lifespan. The failure rate is acceptable for a consumer system.
The product's reliabliity can be improved in terms of thermal dissipation for the LDO & audio codec which can run hot. While it is possible to improve reliability, its cost & effort is not justified in making a product last more than at least 26.8 years.

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

Our project can be broken down into the following functional blocks:
1. Power system
2. Bluetooth communication
3. Audio System
4. Microcontroller

The power system is the only system whose failure could be high critical. The power system is responsible for supplying 3.3V, 300mA to the main system while maintaining Li-ion charge control and supplying battery capacity information to the MCU. There is a PMOS that controls whether USB or the Li-ion battery supplies power to the system. A failure of this PMOS would allow the system to draw current from the battery while it is being charged. This can cause unpredictable battery behavior which can cause a fire from the Li-ion cell which is high critical failure. Otherwise a failure in this system is a medium critical failure. A user can detect a failure when the system no longer powers on.

The Bluetooth communication system is responsible for receiving user customizable parameters from a phone app and pass them to the MCU for the DSP. The RN4020 has good reliability and is widely used in the industry. Shorting of bypass capacitors will effectively short PWR & GND which will damage the Bluetooth IC. A failure of this system is considered low critical. The overall system will work, but the user will not be able to change audio processing parameters, and most likely will not be able to pair the smartphone with our device.

The audio system is responsible for (pre)-amplification of the input signal, audio output & A/D, D/A conversation via an audio codec. Causes for failure in this system include plugging in the wrong audio input/output which can cause the audio codec to sink a large amount of current and damage it. Additionally, a failure of bypass capacitors will short the audio codec or the op amp effectively damaging it. A failure in this system is low critical. The user will be able to identify this failure easily because of the lack of audio output.

The microcontroller may behave unexpectedly when the bypass capacitors get shorted causing overheating. A microcontroller failure would make the entire system unusable and would be considered medium criticality due to unpredictable behavior that could cause a large amount of current to be drawn from the Li-ion cell.

2.1 Levels of Criticality

Low critical failure means that it is a negligible failure. This means that the failure mode is not harmful to the user or destructive of the rest of the board. Low critical failures have a failure rate of 10^{-6}.

Medium critical failures are failures that cause damage the system and may present a potential harm to the user. Medium critical failures are aimed to have a failure rate of 10^{-7} or less.

'High' criticality is reserved for failures that have a high probability of potential harm to the user such as burns. These failures are very unlikely to happen and have a failure rate of 10^{-10}.

3.0 Sources Cited:

1. "MSP430FR5994," 2020. [Online]. Available: http://www.ti.com/lit/ds/symlink/msp430fr5994.pdf [Accessed April 10, 2020].

2. "PCM3002, Burr Brown," 2020. [Online]. Available: http://www.ti.com/lit/ds/symlink/pcm3002.pdf [Accessed April 10, 2020].

3. "AP2127K," 2020. [Online]. Available: https://www.diodes.com/assets/Datasheets/AP2127.pdf [Accessed April 10, 2020].

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

Appendix A: Schematic Functional Blocks

1. Power System

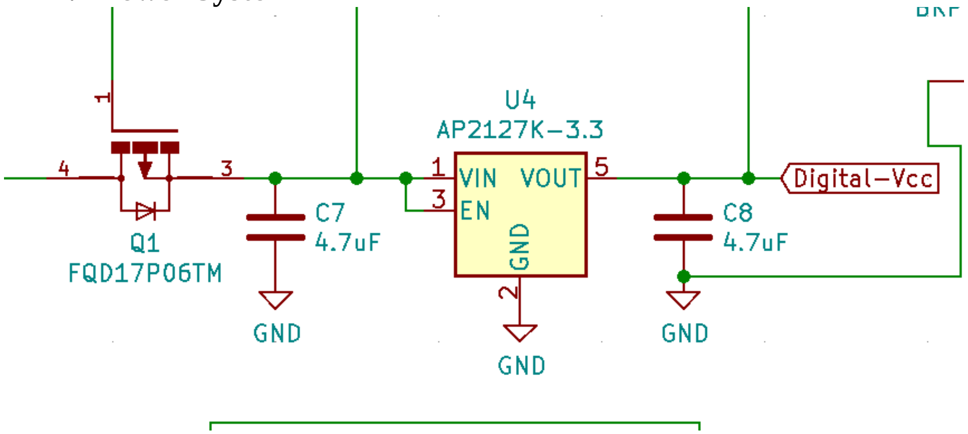

Figure 1: Low Dropout Regulator circuit

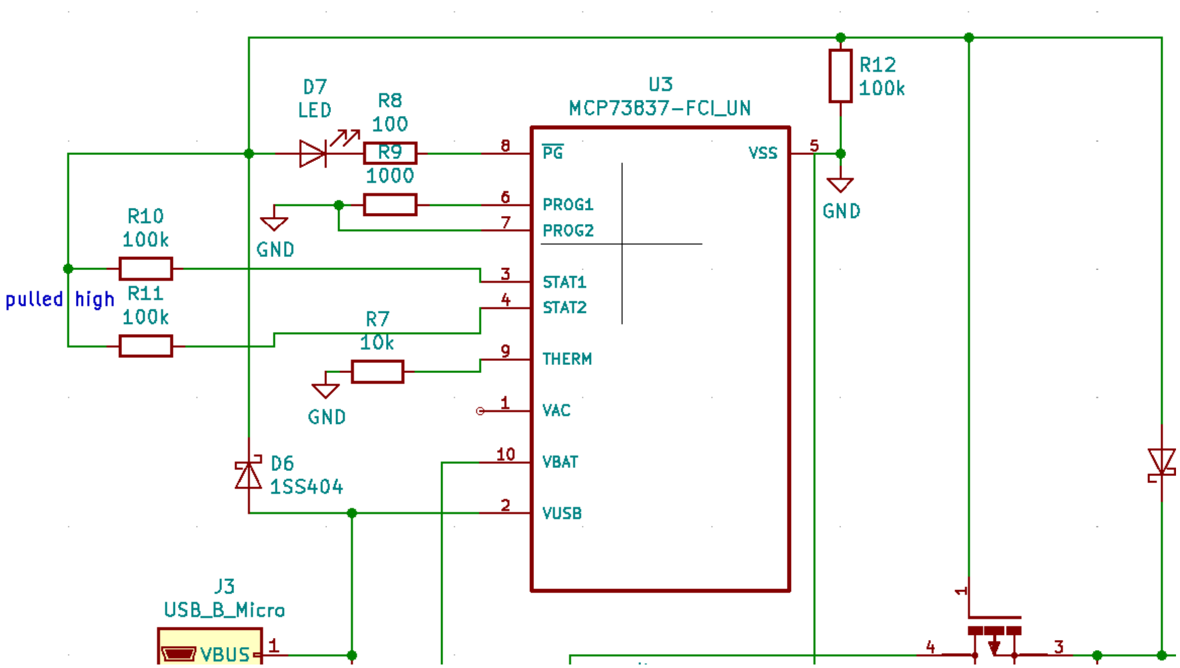

Figure 2: Battery charging circuit

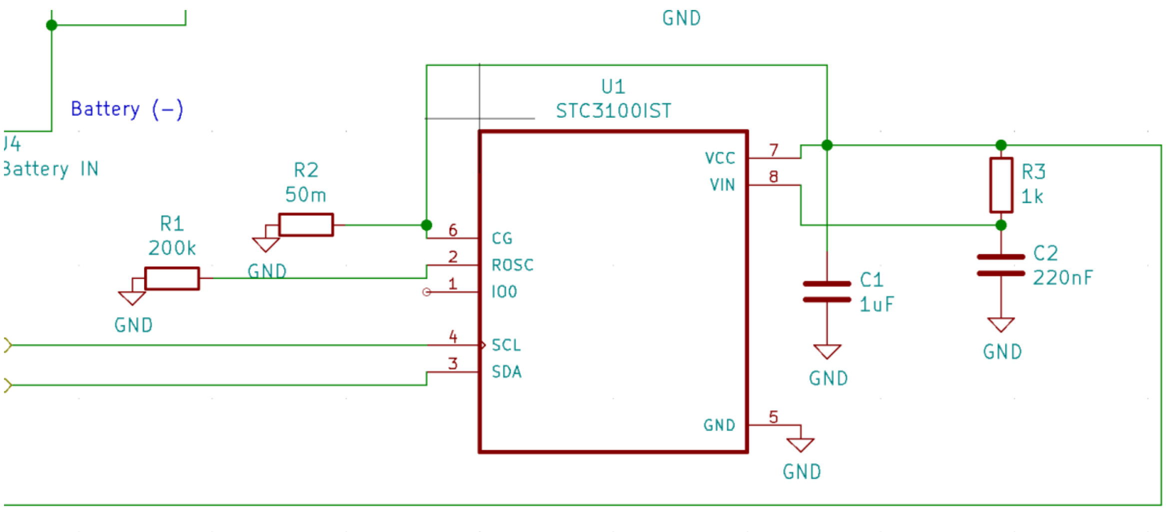

Figure 3: PMIC to calculate battery capacity

2. Audio System

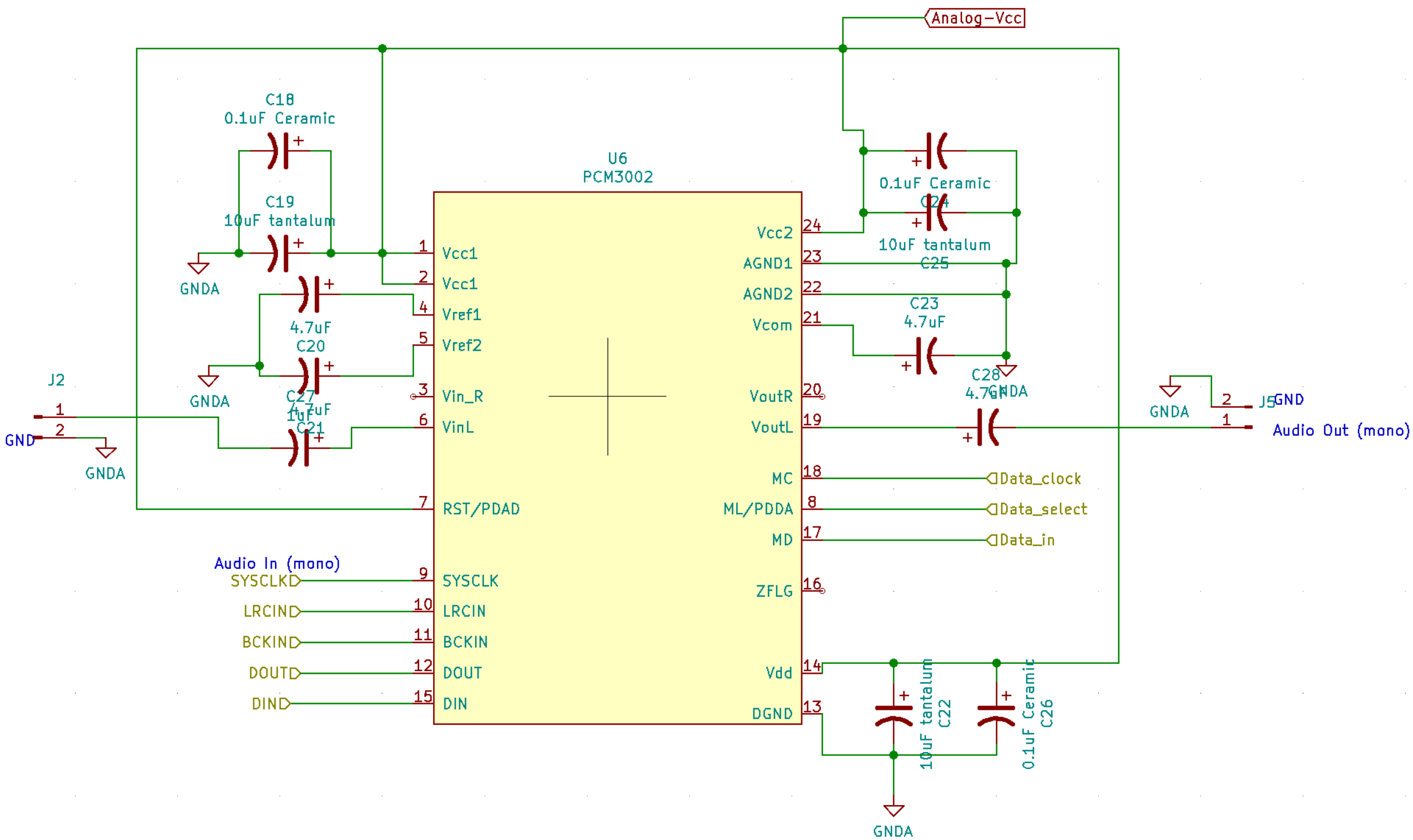

Figure 4: Audio Codec circuit

3. Bluetooth System

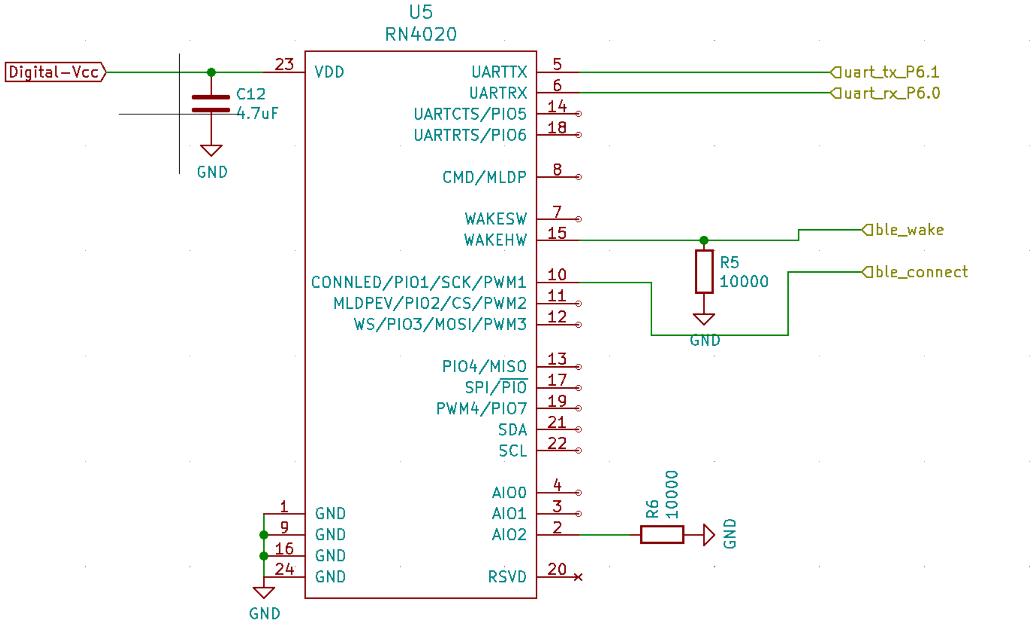

Figure 5: RN4020 BLE transceiver circuit

4. Microcontroller

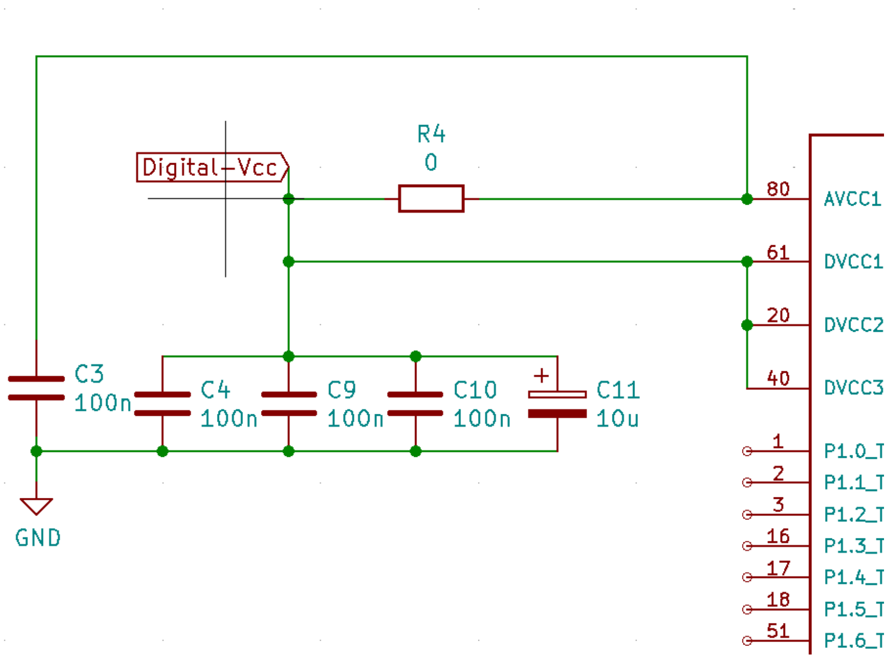

Figure 6: Microcontroller bypass capacitors

Appendix B: FMECA Worksheet

1. Power System

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
A1	Unreliable battery performance	PMOS switch failure	Battery life degradation due to simultaneous charge & discharge	Voltage drop across PMOS using probe	High	May cause battery fire
A2	No LDO output	Shorted bypass capacitor, LDO failure, Completely depleted Li-ion cell	Board does not power up	Observation	Medium	May damage other components on system
A3	Voltage greater than 3.3V on LDO	V > 5V on USB input	Schottky diode & LDO failure	Observation	Low	Will only damage schottky diodes before damaging the rest of the board

It is not necessary to calculate the probability of each failure mode. These numbers would usually be taken from the reliability analysis, but since you are not performing a complete analysis, they do not need to be included in your FMECA worksheet.

No.				Detection		
B1	No audio output	Bypass capacitor short	Audio codec/amplifier failure	Observation	Low	N/A

B2	No Audio Output	Output speaker drawing too much current, or wrong audio input	Audio Codec Failure	Observation	Low	N/A

3. Bluetooth System

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
B1	Unable to pair/detect device	Bypass capacitor short, BT antenna damage	BT IC failure	Observation	Low	N/A

4. Microcontroller

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
B1	Unresponsive board	Bypass capacitor short, power supply issues, physical board damage	Unusable device	Observation	Low	N/A