

Music Bot

Standards and Risks

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1 Standards, Codes, and Regulations

Table 1: Standards of Practice as Applied to this Project

<u>Standard Number or Code</u>	<u>Title of Standard</u>	<u>How it applies to Project</u>
ISO/CD 13482	Safety requirements for service robots	Specifies safety requirements for service robots and considers the conditions for physical human-robot contact. Entertainment is a service so this standard applies to our project better than the standards for industrial and medical robots which have their own separate standards.
ISO 12100:2010	Safety Of Machinery - General Principles For Design - Risk Assessment And Risk Reduction	Specifies basic terminology, principles and a methodology for achieving safety in the design of machinery.
ANSI Z535.1	American National Standard for Safety Colors	Ensures safety labels are the correct color so that the level of danger can be identified universally.
ANSI Z535.3	American National Standard for Criteria for Safety Symbols	Ensures safety labels use the correct symbols so that the danger can be universally identified.

2 Risk Analysis and Mitigation

2.1 FMEA

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
1 Servo	High Cycle Fatigue	Guitar can no longer pick one of the strings	Internal gear falling due to high stall torque if pick gets stuck on string	56	Include circuit breakers in the power line
2 Solenoid	Temperature Induced Deformation	Guitar can no longer fret one of the notes	Actuated for too long at too high voltage	75	Lower actuation voltage, heat sinks
3 Servo Driver	Impact Wear	None of the strings can be picked	Gets hit while being moved around	24	Put in electronics enclosure
4 Circuit Breaker	Temperature Induced Deformation	One string's picking mechanism stops working	High current draw from servo causes rise in temperature	14	None
5 MOSFET Board	Impact Wear	Four notes can no longer be played	Gets hit while being moved around	28	Put in electronics enclosure
6 Arduino Mega	Impact Wear	Entire system stops working	Gets hit while being moved around	64	Put in electronics enclosure
7 Arduino Power Supply	Impact Wear	Entire system stops working	Gets hit while being moved around	32	Put in electronics enclosure
8 Power Strip	Impact Wear	Entire system stops working	Gets hit while being moved around	24	Put in electronics enclosure
9 5V Power Supply	Impact Wear	Servos can no longer pick strings	Gets hit while being moved around	24	Put in electronics enclosure
10 12V Power Supply	Impact Wear	No fretted notes can be played	Gets hit while being moved around	24	Put in electronics enclosure
11 Guitar	Yielding	More force needed to fret notes, pick holders must be readjusted	High string tension warps neck	40	Adjust truss rod
12 Guitar Strings	Yielding	String snaps, no notes can be played on that string, flying debris and sharp object	String gets tensioned too high	40	Replace string, use electronic tuner to make sure the tension is correct
13 Ground Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	Wire jacket rubs against something	96	Put in electronics enclosure
14 PWM Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	Wire jacket rubs against something	96	Put in electronics enclosure
15 Ground Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	Wire jacket rubs against something	96	Put in electronics enclosure
16 Power Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	Wire jacket rubs against something	96	Put in electronics enclosure
17 Signal Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	Wire jacket rubs against something	96	Put in electronics enclosure
18 Arduino Pins	Low Cycle Fatigue	Broken electrical connection, one solenoid stops fretting notes	Pins bent while inserting	60	Solder PWM pins to a large header block that plugs into the arduino
19 String Ferrules	Deformation Wear	Wire comes out of ferrule, exposed conductors, sparks	Over tightening in screw terminals	56	Tighten just until ferrule won't come out of terminal then stop
20 Bracket Leg	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	Solenoids overheat	120	Heat sinks, lower solenoid actuation voltage, revised material selection
21 Bracket Base	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	Solenoids overheat	120	Heat sinks, lower solenoid actuation voltage, revised material selection
22 Group Mount	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	Solenoids overheat	120	Heat sinks, lower solenoid actuation voltage, revised material selection
23 Solenoid Mount	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	Solenoids overheat	120	Heat sinks, lower solenoid actuation voltage, revised material selection
24 Picking Bracket Top	Temperature Induced Deformation	Servos become loose, lower sound quality	Servos overheat	40	None
25 Picking Bracket Bottom	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	Servos overheat	42	None
26 Picking Bracket Left	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	Servos overheat	56	None
27 Picking Bracket Right	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	Servos overheat	56	None
28 Pick Holder	High Cycle Fatigue	Flying debris, notes can't be played on that string	Reversing stress every picking motion	32	Revised material selection
29 Wood Screws	Yielding	Screws stuck in guitar make assembly difficult	Over tightening	8	None
30 M3 Bolts	Yielding	Assembly difficulties	Over tightening	8	None
33 Tremolo Springs	Yielding	Guitar bridge pulls up, could cause servos to stall, poor sound quality	Over tightening	24	None

The following is a list of the top 10 failures on our FMEA. When iterating on the design of the guitarbot, we will focus on mitigating these failures by prioritizing the most critical potential failure modes.

2.2 Critical Failures

1. Solenoids Overheat

Our greatest concern with the current design is the overheating of solenoids. To mitigate this risk we will run tests to find out what the lowest possible voltage is that gives us a consistent sound on each string. We will then add resistors in series with the circuit, to give us a voltage drop and lower the temperature of the solenoids. We will also consider adding heat sinks or fans if the voltage is not lowered enough.

2. Damage to Wires

With as many wires as we have, it is very possible that they may get tugged, leading to sparks, short circuits, and exposed conductors. To reduce this risk, we will build an enclosure for the electronics, as well as cover exposed wires with a jacket.

3. Bent Arduino Pins

When working with Arduino, one must exercise caution to not bend any of the pins. To make things easier, we will solder the pwm pins to a header block that plugs into the Arduino.

4. Servos Overheat

If our servos get to hot, they could warp the 3d printed mounts that it is attached to. We would need to then add insulation to the mounts.

5. Wire Comes out of Ferrule

We have the ends of our wires in a ferrule to ensure good conductivity. It is possible for them to

get pulled out, so we make sure that the ferrule is properly tightened and has a strong connection to the wire.

6. Overtightened Hardware

It is possible that we could damage parts of the guitar or mounts if we overtighten the hardware. To ensure that this does not happen, we will tighten all hardware as much as possible by hand and then only use the screwdriver / allen wrench to lightly tighten the hardware an additional few turns depending on the hardware.

7. Warped Neck

When using very high tension with thick strings on a cheap guitar, it is possible that we could warp the neck. We will make sure to adequately adjust the truss rod so that the neck is straight.

8. Pick Holder Fatigue

Due to the high cycles and frequency of picking, it is possible for the pick holders to fatigue due to tensile stress. If this happens we will print a new pick holder and replace them as needed. If it happens frequently we will print the holder with a thicker infill, or use a stronger material.

9. Electronics Impact

Electronics may become damaged if they take impact. We will shield the electronics with an enclosure to reduce this risk.

10. String Snaps

If a guitar string fatigues due to repeated tensile load, it may snap. If this happens, we will have replacement strings ready.

2.3 Risks and Trade-offs Analysis

The one trade-off we had to consider when evaluating these critical failures was String Snapping vs Neck Strength. The more rigid the neck is, the more tension that will be applied to the strings. This means they are more likely to break. However, a guitar neck is much more expensive than guitar strings, so we prioritized neck rigidity over string life. This could also mean using thinner strings (less tension on the neck), if neck warping becomes a problem.

3 REFERENCES

<https://www.bradyid.com/resources/ansi-z535-safety-signs-standard>

<https://blog.ansi.org/ansi-z535-1-2022-safety-colors-standard/>

<https://blog.ansi.org/ansi-z535-3-2022-criteria-safety-symbols/>

<https://www.iso.org/committee/5915511/x/catalogue/>

<https://www.iso.org/standard/83498.html?browse=tc>

4 APPENDIX

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurrence (O)	Current Design Controls Test	Detection (D) RPN	Recommended Action
1 Servo	High Cycle Fatigue	Guitar can no longer pick one of the strings	7	Internal gear failing due to high stall torque if pick gets stuck on string	4	Play through every possible note	2 56	Include circuit breakers in the power line
2 Solenoid	Temperature Induced Deformation	Guitar can no longer fret one of the notes	5	Actuated for too long at too high voltage	5	Cycle test with thermal camera	3 75	Lower actuation voltage, heat sinks
3 Servo Driver	Impact Wear	None of the strings can be picked	8	Gets hit while being moved around	3	Play through every possible note	1 24	Put in electronics enclosure
4 Circuit Breaker	Temperature Induced Deformation	One string's picking mechanism stops working	7	High current draw from servo causes rise in temperature	2	Visual inspection of breaker indicators	1 14	None
5 MOSFET Board	Impact Wear	Four notes can no longer be played	7	Gets hit while being moved around	4	Visual inspection	1 28	Put in electronics enclosure
6 Arduino Mega	Impact Wear	Entire system stops working	8	Gets hit while being moved around	4	Visual inspection	2 64	Put in electronics enclosure
7 Arduino Power Supply	Impact Wear	Entire system stops working	8	Gets hit while being moved around	4	Visual inspection	1 32	Put in electronics enclosure
8 Power Strip	Impact Wear	Entire system stops working	8	Gets hit while being moved around	3	Visual inspection	1 24	Put in electronics enclosure
9 5V Power Supply	Impact Wear	Servos can no longer pick strings	8	Gets hit while being moved around	3	Visual inspection	1 24	Put in electronics enclosure
10 12V Power Supply	Impact Wear	No fretted notes can be played	8	Gets hit while being moved around	3	Visual inspection	1 24	Put in electronics enclosure
11 Guitar	Yielding	More force needed to fret notes, pick holders must be readjusted	5	High string tension warps neck	2	Check neck straightness with notched straightedge	4 40	Adjust truss rod
	Impact Wear	Unpleasant appearance	2	Gets hit while being moved around	5	Visual inspection	2 20	Transport in a case or wrapped in a towel
12 Guitar Strings	Yielding	String snaps, no notes can be played on that string, flying debris and sharp object	8	String gets tensioned too high	5	Visual inspection	1 40	Replace string, use electronic tuner to make sure the tension is correct
	Fretting Wear	String snaps, no notes can be played on that string, flying debris and sharp object	8	Vibrations from strings themselves rubbing against the frets	5	Visual inspection of areas around frets	1 40	Replace string
13 Ground Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	8	Wire jacket rubs against something	3	Visual inspection, multimeter probe checks	4 96	Put in electronics enclosure
14 PWM Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	8	Wire jacket rubs against something	3	Visual inspection, multimeter probe checks	4 96	Put in electronics enclosure
15 Ground Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	8	Wire jacket rubs against something	3	Visual inspection, multimeter probe checks	4 96	Put in electronics enclosure
16 Power Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	8	Wire jacket rubs against something	3	Visual inspection, multimeter probe checks	4 96	Put in electronics enclosure
17 Signal Wire	Abrasive Wear	Exposed conductors, short circuits, sparks	8	Wire jacket rubs against something	3	Visual inspection, multimeter probe checks	4 96	Put in electronics enclosure
18 Arduino Pins	Low Cycle Fatigue	Broken electrical connection, one solenoid stops fretting notes	6	Pins bent while inserting	5	Visual inspection, multimeter probe checks	2 60	Solder PWM pins to a large header block that plugs into the arduino
19 String Females	Deformation Wear	Wire comes out of female, exposed conductors, sparks	7	Over tightening in screw terminals	4	Visual inspection, multimeter probe checks	2 56	Tighten just until female won't come out of terminal then stop
20 Bracket Leg	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	8	Solenoids overheat	5	Cycle test with thermal camera	3 120	Heat sinks, lower solenoid actuation voltage, revised material selection
21 Bracket Base	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	8	Solenoids overheat	5	Cycle test with thermal camera	3 120	Heat sinks, lower solenoid actuation voltage, revised material selection
22 Group Mount	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	8	Solenoids overheat	5	Cycle test with thermal camera	3 120	Heat sinks, lower solenoid actuation voltage, revised material selection
23 Solenoid Mount	Temperature Induced Deformation	Solenoid mount unable to hold up solenoids, strings get muted, notes can't be played	8	Solenoids overheat	5	Cycle test with thermal camera	3 120	Heat sinks, lower solenoid actuation voltage, revised material selection
24 Picking Bracket Top	Temperature Induced Deformation	Servos become loose, lower sound quality	5	Servo overheat	2	Cycle test with thermal camera	4 40	None
25 Picking Bracket Bottom	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	7	Servo overheat	2	Cycle test with thermal camera	3 42	None
26 Picking Bracket Left	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	7	Servo overheat	2	Cycle test with thermal camera	4 56	None
27 Picking Bracket Right	Temperature Induced Deformation	Servos move to close to strings, causing servos to stall and trip circuit breakers	7	Servo overheat	2	Cycle test with thermal camera	4 56	None
28 Pick Holder	High Cycle Fatigue	Flying debris, notes can't be played on that string	8	Reversing stress every picking motion	4	Cycle test	1 32	Revised material selection
29 Wood Screws	Yielding	Screws stuck in guitar make assembly difficult	4	Over tightening	2	Tighten with a torque rated screwdriver	1 8	None
30 M3 Bolts	Yielding	Assembly difficulties	4	Over tightening	2	Tighten with a torque rated screwdriver	1 8	None
31 Inset Foot	Fretting Wear	Low sound quality on that note	5	Vibrations from strings themselves rubbing against the feet	5	Visual inspection, play every note	2 50	Possible revision of material selection
32 Long Inset Foot	Fretting Wear	Low sound quality on that note	5	Vibrations from strings themselves rubbing against the feet	5	Visual inspection, play every note	2 50	Possible revision of material selection
33 Tremolo Springs	Yielding	Guitar bridge pulls up, could cause servos to stall, poor sound quality	6	Over tightening	4	Tighten with a torque rated screwdriver	1 24	None