Musical Instrument: Electronically Resonated Metal

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1. Introduction

1.1 Statement of Purpose

We have chosen this project because each of us has some interest in music and we wanted to apply our knowledge of electrical engineering to develop a new musical instrument prototype. This instrument will produce a unique sound, and when we are finished we will have a working instrument for others to learn and play.

1.2 Objectives

1.2.1 Goals and Functions

The main goals of this project are to create a control system that initiates vibrations in the steel rod when a button is pressed, to sustain vibrations in the steel rod until the button is released, and to create a more powerful driver coil and a pickup coil compared to the ones commercially available.

The four main components in this design are connected via a feedback loop. The controller is responsible for starting the vibrations and adjusting the amount of current that goes into the driver coil. The driver coil causes the whole system to vibrate and can change its frequency based on the feedback (will verify this with Skot) in order to match the frequency of the rod. The pickup coil converts the vibrations into an electrical signal, which goes into the amplifier and feedback loop.

1.2.2 Benefits

- The harmonics of a vibrating metal rod are not whole number multiples of the fundamental frequency. This creates an interesting sound with which musicians and composers can experiment and add expression to their music.
- This is a musical instrument, so it will provide people with the opportunity to learn how to play it for fun.

1.2.3 Features

- A roller holds the rod in place and makes it slide easily.
- A button will initiate the system's vibrations.
- A powerful driver coil vibrates the entire system.
- A pickup coil that has a preamp and a gain stage.

- Modularity in the design.
- Markings so that the user knows what note he or she is playing.
- Sensors to sense how hard the player is pressing down on the platform. Greater pressure would cause the volume to increase. This allows the player to play more expressively (will add if time permits).
- Filters that would filter out some of the harmonics if the player desires. This would add variation to the sound (will add if time permits).

2. Design

2.1 Block Diagram

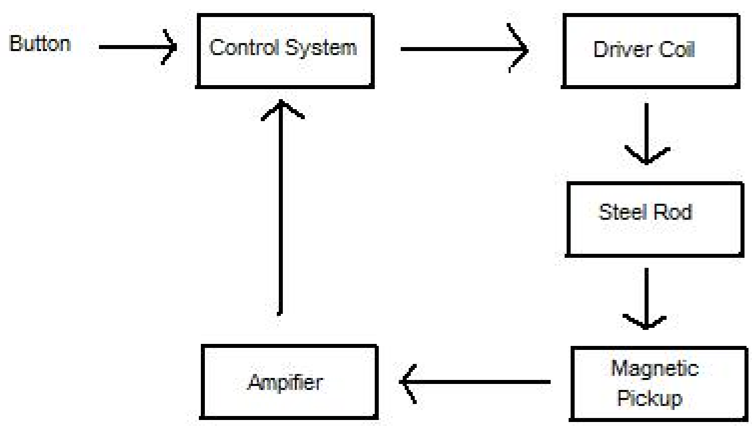

Figure 1: Higher Level Block Diagram of the Electronically Resonated Metal

2.2 Block Descriptions

2.2.1 Button

When the player presses the button, it lets the control system know that it is time to initiate vibrations. The system stops vibrating as soon as the player releases the button.

2.2.2 Control System

The control system includes a switch, a transistor, and a register. If the the switch is open, there will be no current to the base; this leads to the cut-off condition of the transistor and as a result, no current is sent to the driver coil. If the button is pressed, the transistor switch in the the control system will be closed. The sufficient current will flow in the base and the transistor will be in the saturation condition. Consequently, the control system will send a sinusoidal input current to the driver coil.

2.2.3 Driver Coil

The driver coil consists of a coiled wire inside of a magnetic field. It receives a sinusoidal input current and voltage from the control system, which causes the coils to move up and down. It will be placed underneath the steel rod so that it will cause the rod to vibrate. This coil should be able to vibrate at a range of frequencies that encompasses the steel rod's frequency range.

2.2.4 Steel Rod

The steel rod is what changes the pitch of the notes produced on this instrument. The driver coil initiates the rod's vibrations, and based on the feedback it changes its vibrating frequency to the resonant frequency of the rod. When the player slides the rod back and forth on its platform, the effective length of the rod changes. The resonance frequency will increase with decreasing length, and therefore the pitch increases. The mechanical vibrations of the rod will be converted into an electrical signal by the pickup.

2.2.5 Pickup Coil

The pickup coil will consist of at least two independent circuits that are connected in series to drive the amplifier. The series connection will give double the inductance. We will be using a piezo element with low impedance for the pickup coil because it is cheap and can be used as a contact pickup. Contact pickups can be attached to the instrument with a glue tack to increase the input to the pickup coil. The input for the pickup coil comes from the mechanical vibrations of the steel rod while the output of the pickup coil is an electric signal which will drive the amplifier. The independent circuitry for this module is the preamp and the gain stage.

2.2.6 Amplifier

The amplifier receives the electric signal from the magnetic pickup as the input and amplifies the signal. It then gives feedback to the driver coil. This lets the driver coil continue to induce a magnetic field so that vibrations of the steel rod can be sustained.

3. Block Level Requirements and Verification Table

3.1 Requirements

3.1.1 Button

If the button is pressed, the control system should produce the current for the driver coil in less than 0.5 seconds

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3.1.2 Control System

Direct current (DC) will be a input current for the driver coil which is interconnected with the control system will. Thus, a rectifier circuit will be needed to be included in the control system in order to convert alternating current (AC) to direct current (DC).

3.1.3 Driver Coil

The driver coil should be able to vibrate within the same range of frequencies as the rod (40-200 Hz). It needs to produce enough force to excite the system for the entire range. Once the amount of force needed is known, then the amount of current flowing through the coil can be found, since current is proportional to force.

3.1.4 Steel Rod

The steel rod should be able to produce notes with fundamental frequencies of 40 and 200 Hz. The 40 Hz tone corresponds to the E in the third octave below middle C, and the 200 Hz tone corresponds to the G in the octave below middle C. This range is roughly two octaves. It should be noted that if the first three overtones of each note are included, the range of frequencies would actually be 40 Hz to roughly 6 kHz.

3.1.5 Pickup

The pickup should be powerful and sensitive enough to convert the mechanical vibrations into a strong electric signal.

3.1.6 Amplifier

The amplifier should produce the powerful voltage across the driver coil to induce the magnetic field needed to initiate vibrations of the steel rod.

3.2 Verification

3.2.1 Button

We can verify if the output current is produced in between 0.2 and 0.5 seconds by plotting the current vs time graph.

3.2.2 Control System

The A/C input and the DC output will be verified by observing the resulting graph on the oscilloscope.

3.2.3 Driver Coil

The amount of push needed for the driver coil to vibrate the steel rod will be tested in the experiment. Through this test, we will be able to verify the amount of current flowing through the coil.

3.2.4 Steel Rod

The range of frequencies will depend on the type of metal, length, and thickness of the rod. To test its range of frequencies, it will be clamped to a table. A pickup will be hooked up to the oscilloscope and placed underneath the rod. The rod will be excited, and the fundamental frequency and overtones can be determined by using the FFT function on the oscilloscope. The lowest frequency occurs when the rod is at its longest length, and the highest frequency will occur when the rod is the shortest it can be while still being able to freely vibrate. By measuring the frequencies we can verify that the rod will vibrate within the desired range of 40 to 200 Hz.

3.2.5 Pickup

We would need to calculate impedances using a resistor which is in series with both the AC voltage source and the pickup. Then we would need to measure the current through the resistor and then measure DC voltages on both ends of the resistor. Then would use ohms law to calculate the input impedance of the pickup coil. We would follow similar procedure to calculate the output impedance of the pickup coil but in this case we would need to have the load resistor in parallel to the pickup coil and also need to use the ohm's law for the AC voltage source.

3.2.6 Amplifier

We would need to test the amplifier with different input voltages, and the calculate the ratio of the output voltage to the input voltage to determine how powerful the amplifier is.

3.3 Tolerance Analysis

In our project, it is essential that our musical instrument produces clean sound. In order to achieve this goal, we will need to determine a fundamental frequency of the vibrating steel rod. The steel rod will be forced into resonance vibrations by the magnetic field induced by the driver coil. When the steel rod vibrates, different standing wave patterns will be produced based on its specific frequencies. Hence, in the experiment we will need to find harmonic frequencies so that the instrument can produce pleasant sound.

4. Cost and Schedule

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total Hours Invested	Total = Hourly Rate x 2.5 x Total Hours Invested
Venkata Geetha Bijjam	$35.00	150	$13,125
Jin Kim	$35.00	150	$13,125
Rachel Pashea	$35.00	150	$13,125

4.1.2 Parts

Part	Part Number	Unit cost	Quantity	Total
Pickup Coil	SEN-10293	$1.50	10	$15.00
JFET	2SJ103-GR	$1	2	$2.00
Resistors	-	$0.04	50	$2.10
Transistors	2N3904 / 2N3906	$0.07	30	$4.20
Capacitors	-	$5	3	$15.00
Magnet for driver coil	-	$20	1	$20.00
Wire for driver coil	-	-	-	$5.00
Total Cost				$63.30

Grand Total(Labor + Parts)	$39438.30

4.2 Schedule

Deadline	Week (Date)	Tasks	Member
	1 (9/14)	Research (Driver Coil/Tactile Transducer and Resonance)	Rachel
		Research (Amplifier/Control System)	Jin

		Research and test the Pickup Coil borrowed from Skot	Venkata
Proposal	2 (9/17)	Write the Proposal and Order Parts	ALL
		Determine resonant frequencies of rod	Rachel
		Determine power supply voltage & a design of an amplifier	Jin
		Measuring the impedances of the pickup coil in the series and the parallel combinations	Venkata
Design Review Sign-Up	3 (9/24)	Sign-Up for design review Calculate theoretical resonant frequencies of rod and continue to test the rod to verify calculations Design driver coil	Rachel
		Pick a design for a pickup coil and come up with models for impedances and power	Venkata
		Determine a design of the control system	Jin
		Gather specifications and requirements for the Design Review	ALL
Design Review	4 (10/1)	Finalize and present the Design Review	ALL
		Build driver coil	Rachel
		Build the pickup coil circuit	Venkata
		Get feedback and improve the designs for the amplifier and control system	Jin
	5 (10/8)	Finalize the mechanical parts	ALL
		Continue building driver coil	Rachel
		Check if the output fits the models and equations for the pickup coil	Venkata
		Complement the designs	Jin
	6 (10/15)	Test and debug the driver coil	Rachel

		Debug Pickup coil circuit	Venkata
		Build an amplifier and control system & work on debugging	Jin
Individual Progress Reports	7 (10/22)	Continue testing and debugging the driver coil	Rachel
		Add additional functionality for pickup coil to create a more powerful one	Venkata
		Debug the pickup coil and the amplifier as a connected circuit	Jin
	8 (10/29)	Integrate the driver coil with the pickup and the amplifier and test the circuit	Rachel
		Integrate the control system with the other main components and test the final circuit	Jin
		Verify all the components work as they as should by testing the whole instrument	Venkata
Mock-Up Demos and Mock Presentation Sign-Up	9 (11/5)	Sign up for mock-up demo/mock presentation and gather and put together all the materials needed for the control system and the amplifier to use in the mockup demo	Jin
		Gather and put together all the materials needed for the pickup to use in the mockup demo	Venkata
		Gather and put together all the materials needed for the driver coil	Rachel
Mock Presentation	10 (11/12)	Prepare documentation and notes for the driver coil	Rachel
		Prepare notes for the pickup	Venkata
		Prepare for the mock presentation by collecting the documentation for the amplifier and the control system	Jin
Thanksgiving Break!	11 (11/19)	Start working on the final paper and add finishing touches to the musical instrument	ALL
Demo and	12	Sign up for demo and presentation and work on	Venkata

Presentation Sign-Up	(11/26)	the circuit diagrams for the final paper	
		Work on Abstract and the Appendix for the final paper	Jin
		Work on the requirements and the verification table for each block	Rachel
Demos and Presentations	13 (12/3)	Add final entries to each of our lab notebooks and finish the final paper	ALL
Presentations, Lab Notebook Due, and Final Paper Due	14 (12/10)	Presentation & Checkout	ALL

5. References

[1] Gilliland, Chris. "How a Pickup Coil in a Distributor Works." *EHow*. Demand Media, 17 Sept. 2009. Web. 12 Sept. 2012. <http://www.ehow.com/how-does_5426802_pickup-coil-distributor-works.html>.

[2] Hall, Donald E. *Musical Acoustics*. 3rd ed. Print.