Eric “Magneto” Clapton
An Electromagnetically Actuated Guitar

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Main idea and Motivation

Our goal was to create a guitar attachment that uses electromagnets to excite guitar strings

- New Possibilities for Sounds (dynamic control, crescendos) that aren't normally possible on guitar (violin bowing)
- Human Controllable (pitch and volume)

Prior Art

EBow

- Guitar Accessory
- Uses electromagnets to activate guitar strings
- Infinite Sustain, pitch gliding, crescendos
- Only activates one note at a time.

Resonator Piano

- Project by Andrew McPherson
- Uses Pulsing electromagnets to activate piano strings
- One electromagnet for every piano string
- Very cool possibilities for sounds that wouldn’t normally be possible on piano.

Design

Requirements

Musical

- Infinite Sustain
- Controllable Dynamics (crescendo)
- Exciting multiple strings at once
- Pitch Gliding

Autonomy

- Player Controls both pitch and dynamics of notes

Visual

- Looks like the player is actually controlling and playing the instrument

Timbre

- The ability to crescendo should make it sound similar to a bowed violin.

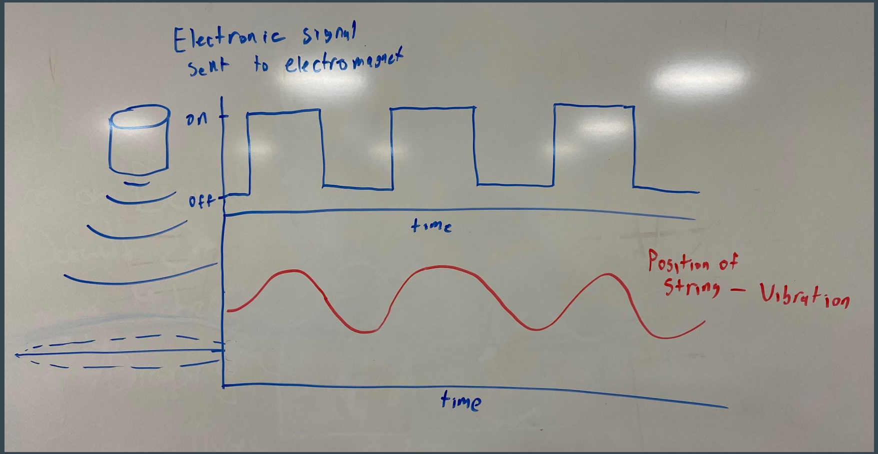
Transportability/Technical

- All electronics are attached to the guitar, can plug into a separate amp, and receive separate wall power.

The plan

<u>Circuitry and Electronics</u>

- Send electric signals to an electromagnet, which will push and pull on a guitar string
- Send a pulsing signal at a certain frequency to create a frequency in the string, creating a sound.



<u>Arduino Pseudocode</u>

```
Loop
    digitalWrite magnetPin to HIGH
    delay(half of frequency)
    digitalWrite magnetPin to LOW
    Delay(half of frequency)
```

The plan

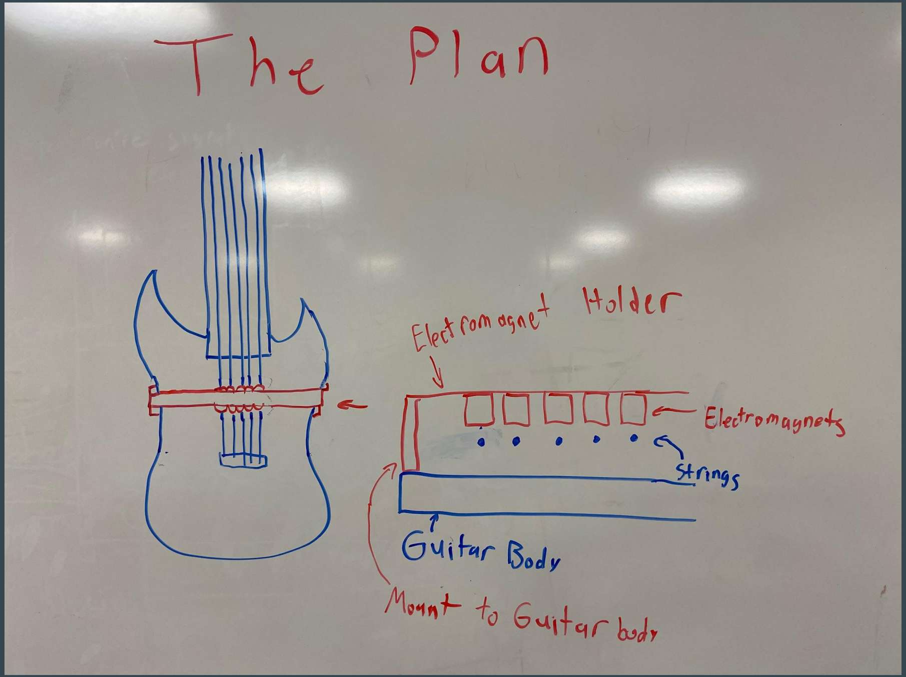
Circuitry and Electronics

- To control dynamics, we would use some kind of potentiometer or analog input device to control the power sent to the electromagnet.
- More power to the electromagnet = stronger pull = guitar string moves more = louder sound.
- This ended up being an audio amplifier

The plan

Mounting/Construction

- We would use a rod/plank to hold electromagnets over the strings.
- We would affix this whole assembly to the body of the guitar.
- All necessary electronics would also be mounted to the body of the guitar, separated from the magnets and wired together.

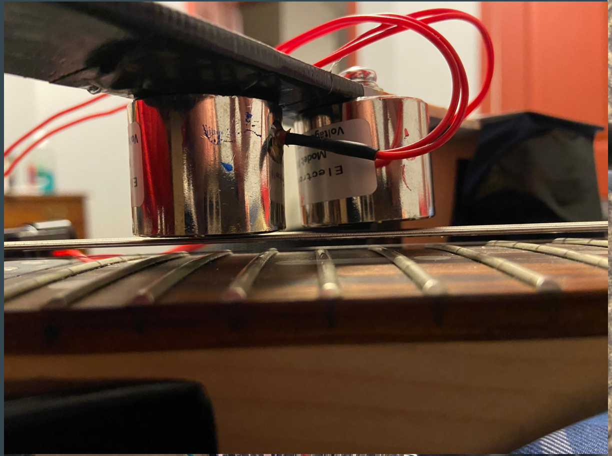


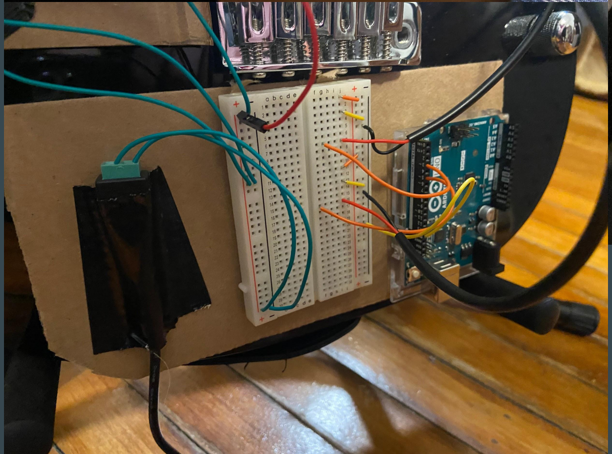
Realization

Problems we ran into

- Magnet Frequency (Changing this, first solution with potentiometers, final solution of playing the series of frequencies)
- Mounting the device onto the guitar

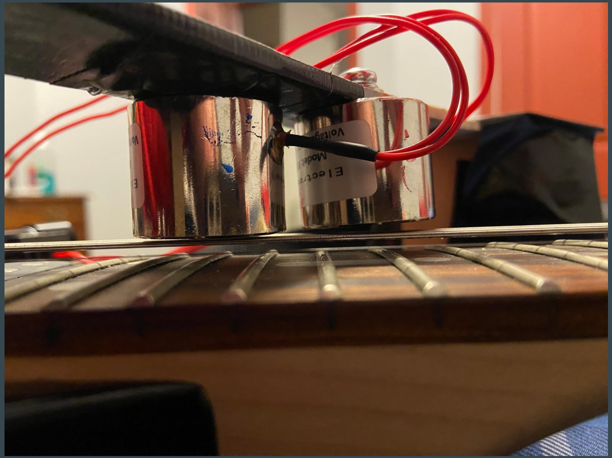
The building process





Build Process

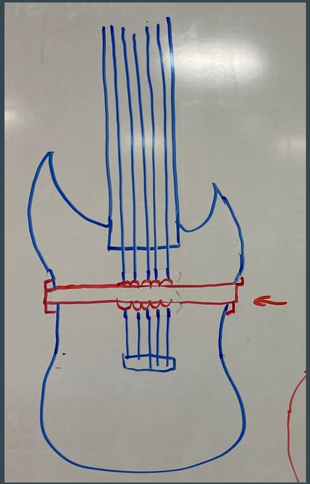
- Makeshift
- Plank of wood to hold magnets (paint dipstick)



- Highly focused on circuitry and making sound
- Electronics housed on cardboard and taped to guitar

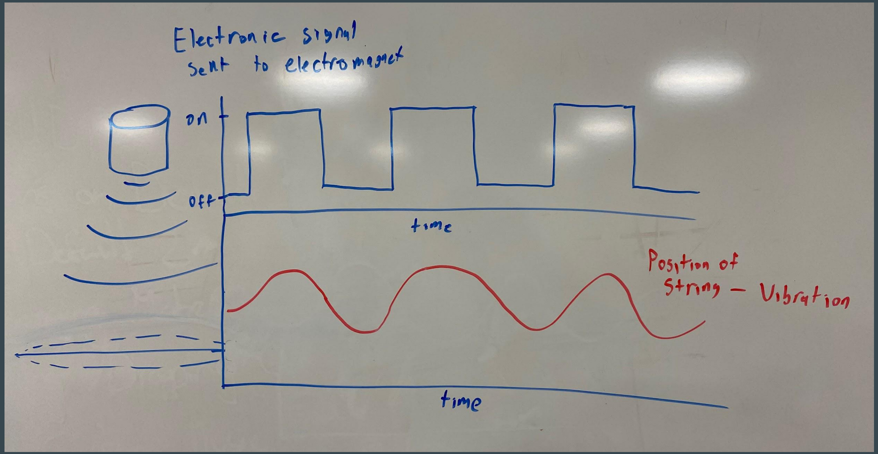
Problem - Electromagnetic Pickups

- Electric guitar pickups: changes in magnetic field -> sound
- Naturally, putting a pulsing electromagnet next to these pickups will cause interference.
- So our original plan for mounting the electromagnets would need to change slightly



Problem - Resonant Frequencies

- Magnet Pulse Frequency needed to match the note played by the string, meaning we need a way to change the "delay" that we wrote in this pseudocode to match that frequency.
- This also meant adding a way for the player to control this frequency while playing



So this red frequency line needed to match the frequency of whatever note we need to play, meaning the Square electric wave sent to the electromagnet needed to change

Arduino Pseudocode

```
Loop
    digitalWrite magnetPin to HIGH
    delay(half of frequency)
    digitalWrite magnetPin to LOW
    Delay(half of frequency)
```

The Potentiometer

- Original Code was intended to let user pick frequency of the electromagnet for each note using a potentiometer.
- There was a specific assigned frequency for each note which we calculated delay by dividing 1000 by the frequency. This worked fine with one string but because the delay affected both electromagnets, it was hard to sync two separate frequencies
- Also impractical to switch to exact notes on the potentiometer while playing

```
//potentiometer input
dialInput1 = (double) analogRead(potentiometerPin1);

if(stringEFreq != changeFrequency(dialInput1)){
  stringEFreq = changeFrequency(dialInput1);
  Serial.print("Magnet 1: ");
  Serial.println(stringEFreq);
}
  if(input >= 0 && input < 85.25){
    return Afreq;
  }
  else if (input >= 85.25 && input < 170.5){
    //Should be Bflat/Asharp
    return Afreq;
  }
  else if (input >= 170.5 && input < 255.75){
    return Bfreq;
  }
  else if (input >= 255.75 && input < 341){
    return Bfreq; //Actual C
  }
  else if (input >= 341 && input < 426.25){
    return Cfreq; //Actual C#
  }
  else if (input >= 426.25 && input < 508.5){
    return Dfreq;
  }
  else if (input >= 508.5 && input < 590.75){
    return Efreq; //Actual D#
  }
  else if (input >= 590.5 && input < 673){
    return Efreq;
  }
  else if (input >= 673 && input < 755.25){
    return Ffreq;
  }
  else if (input >= 755.25 && input < 837.5){
    return Ffreq; //Actual F#
  }
  else if (input >= 837.5 && input < 919.75){
    return Gfreq;
  }
  else{
    return Gfreq; //Actual G#
  }
}
```

Cycling Frequency

- Used a list of numbers which are the frequencies of notes A through G.
- Does not have flats or sharps but can resonate those notes
- No need for potentiometer
- Goes through cycle of one note and the next and loops through the list

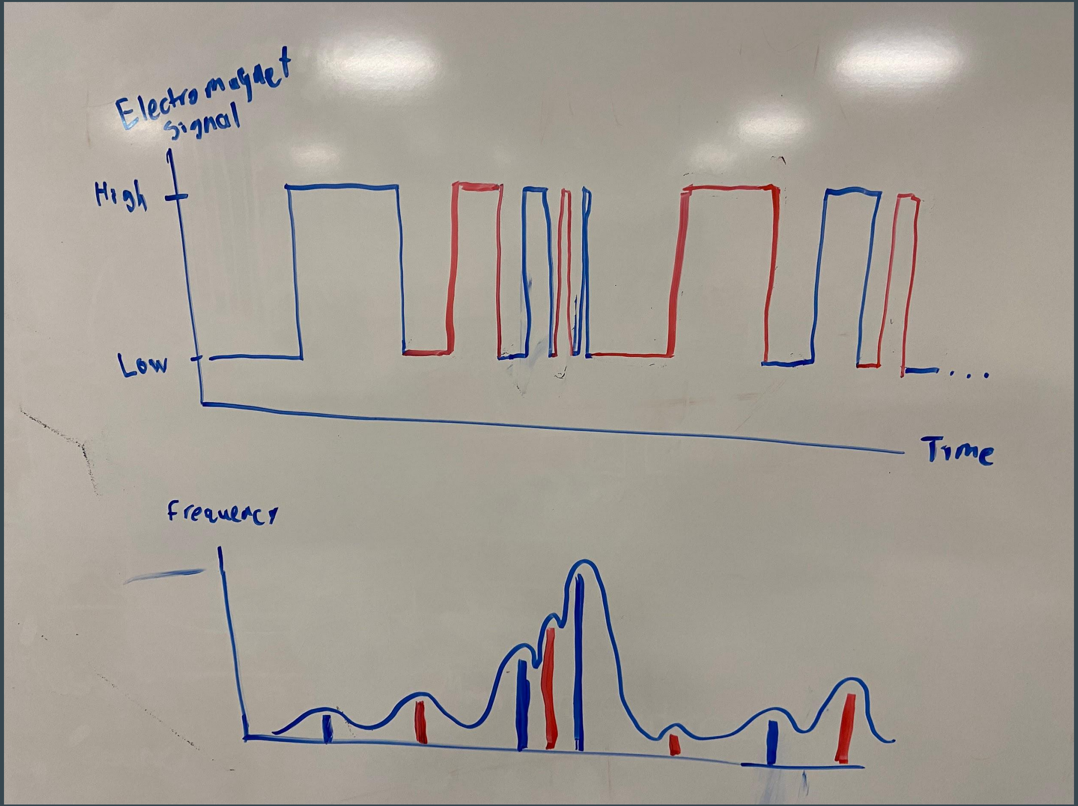
```
//Note Frequencies
double Afreq = 27.5;
double Bfreq = 30.87;
double Cfreq = 32.7;
double Dfreq = 73.42;
double Efreq = 41.2;
double Ffreq = 87.31;
double Gfreq = 49;

double noteArray[] = {Afreq, Bfreq, Cfreq, Dfreq, Efreq, Gfreq};
```

```
for(double note: noteArray){
  digitalWrite(magnetPin1, HIGH);
  digitalWrite(magnetPin2, HIGH);
  delay(noteDelay(note));
  digitalWrite(magnetPin1, LOW);
  digitalWrite(magnetPin2, LOW);
  delay(noteDelay(note));
}
```

*Thanks to the other electromagnet group for this solution

Cycling Frequencies - Visualized



Connects to Fourier Transform: We are using a whole bunch of different waves to create a more complex wave.

Final Product

- Can resonate any note on E and A strings.
- Dynamic control with amplifiers
- Pitch Gliding

Possibilities for future development

Shortcomings for our project

- A bit quiet
- Some EM interference can be heard on the pickups
- Plays two strings out of six
- Not the sturdiest of designs

Possibilities for Future Development

- More Accessible Mounting
- More Magnets for all strings
- Investigate Muting to quiet strings
- More powerful magnet
- Look at more continuous change of frequencies

Resources

Balanzat, D. (2020, October 1). Motional EMF with a Guitar String. YouTube. https://youtu.be/RvsNgxxmoIQ?si=tnRs86QoNe2ZWh5Q

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