Decade Counter Applications

Building a Music Sequencer

Build Together 8

The Voltage Controlled Oscillator

Back to the 555

- In order to move into our next project with the 4017 decade counter, we first have to go back to the 555 and investigate a new way to vary the output frequency of the timer.
- So far, when using a 555 timer, we have always grounded pin 5 (control voltage) through a 100 nanoFarad (104) capacitor.
- We are now going to see what happens if you don’t do that but rather put a varying voltage at pin 5 (control voltage)!

Build Together 8: The VCO

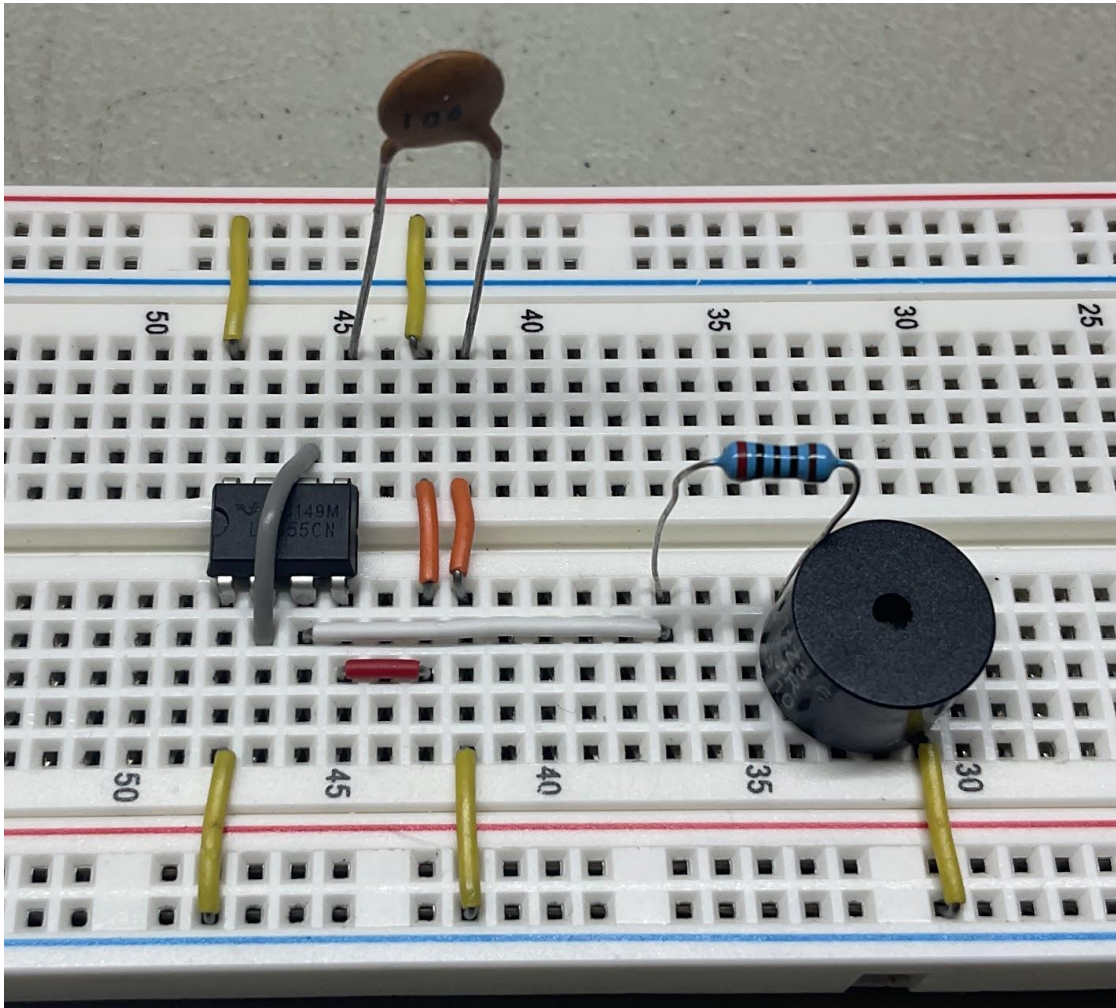
- A voltage controlled oscillator (VCO) can be created by wiring up a 555 timer in astable mode. We have done this many times before.
- Then, in parallel with the 100 nanoFarad (104) capacitor on pin 5 (control voltage) we can hook up a potentiometer as a variable resistor.
- We can use this potentiometer to vary not only the pulse width of the wave but also the output frequency.

- As you are building, try to think about what you are doing and why the circuit is designed the way that it is.

ADVANCE to the next slide, let's build this together!

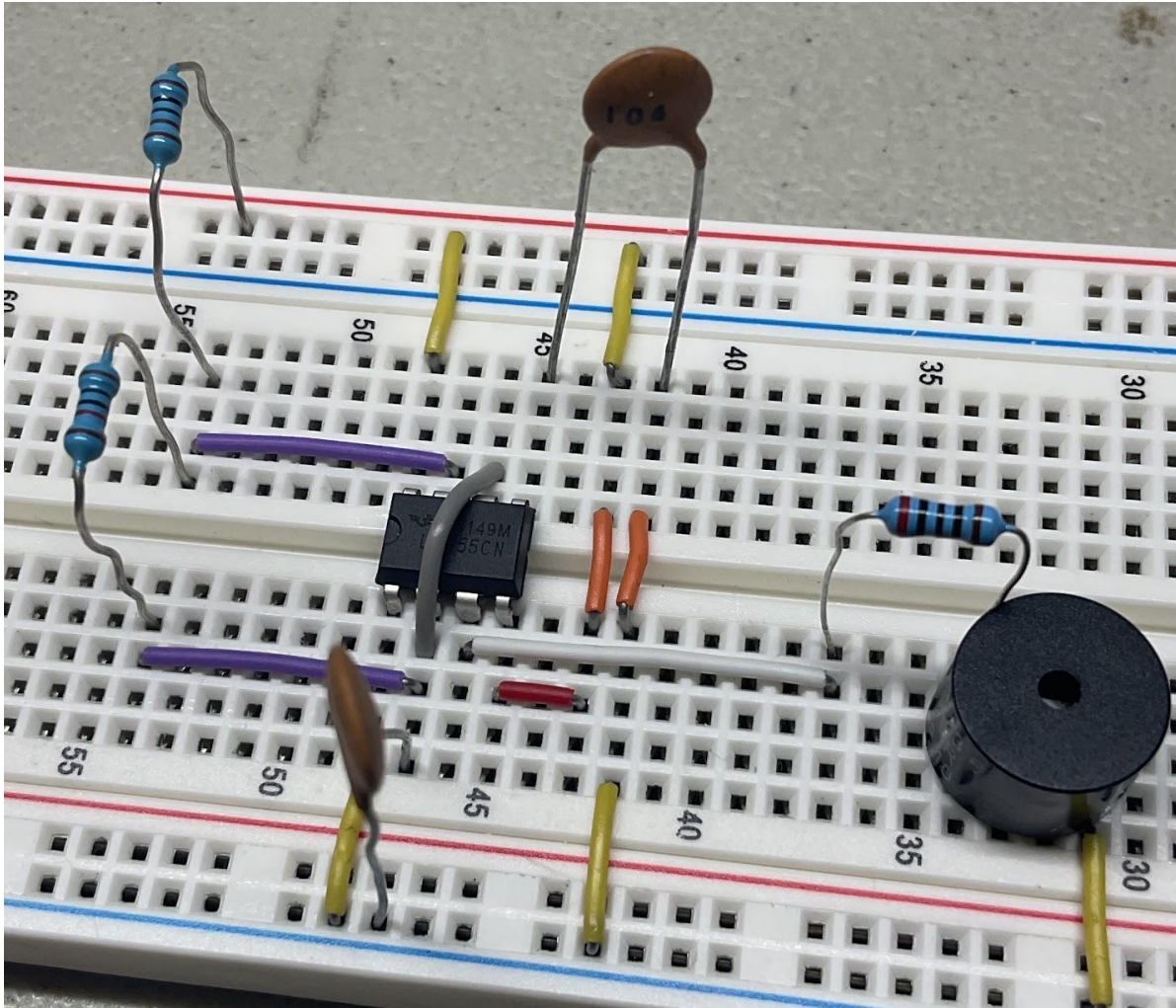
The VCO

- Place a 555 timer into the breadboard.
- Connect pin 8 (Vcc) to Vcc.
- Connect pin 1 (ground) to ground.
- At the output place a 200 ohm (red, black, black, black) resistor to a speaker to ground.
- Make sure you connect pin 2 (trigger) and pin 6 (threshold) together as well as connecting pin 4 (reset) to Vcc.
- For now, let’s ground pin 5 (control voltage) through a 100 nanoFarad (104) capacitor.



The VCO

- Now let’s build our RC network that will determine the output frequency of our signal.
- Create a voltage divider with a 1K (brown, black, black, brown) and 10K (brown, black, black, red) resistor.
- Connect the midpoint of the voltage divider to pin 7 (threshold).
- Connect the bottom of the voltage divider to pin 2 (trigger).
- Ground pin 2 (trigger) through a 100 nanoFarad (104) capacitor.
- You should hear a single tone.



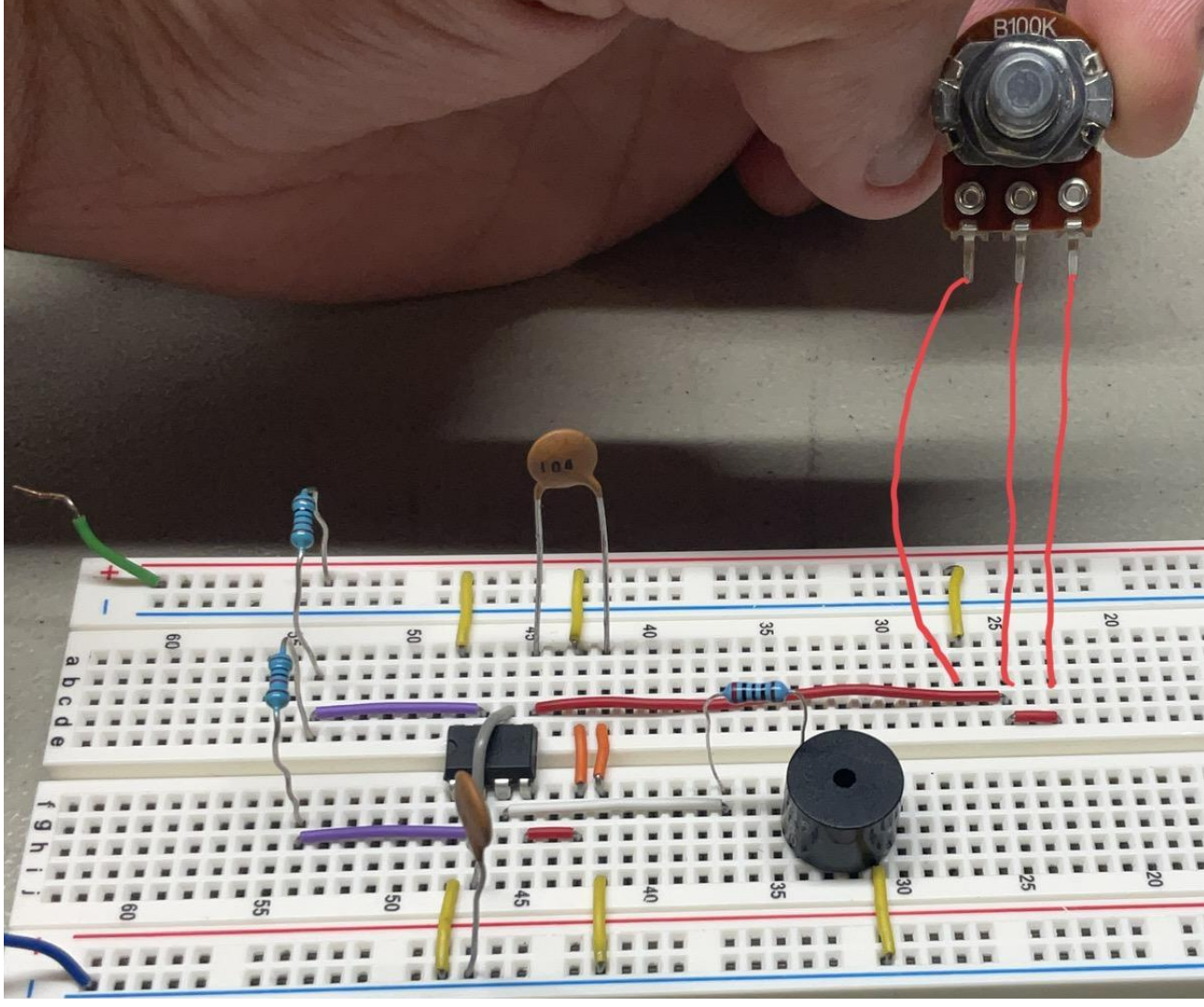
The VCO

- As of now, we have an RC circuit that is connected to pin 2 (trigger) and pin 6 (threshold).
- It's this network that determines the output frequency of our 555 timer.
- When the voltage is less than ⅓ Vcc, pin 2 is triggered and the chip turns on.
- When the voltage is greater than ⅔ Vcc, pin 6 is triggered and the chip turns off.
- So far we have always used a potentiometer for R2 to vary the RC time constant, which would adjust the frequency.

- Pin 5 (control voltage) can be used to override these default values of ⅓ Vcc and ⅔ Vcc by supplying an external voltage to pin 5. This will not change the RC time constant but rather when the chip will turn on/off.
- By varying when the chip turns on and turns off we can alter the pulse duration of the chip as well as the output frequency.
- This is known as a voltage controlled oscillator or VCO.

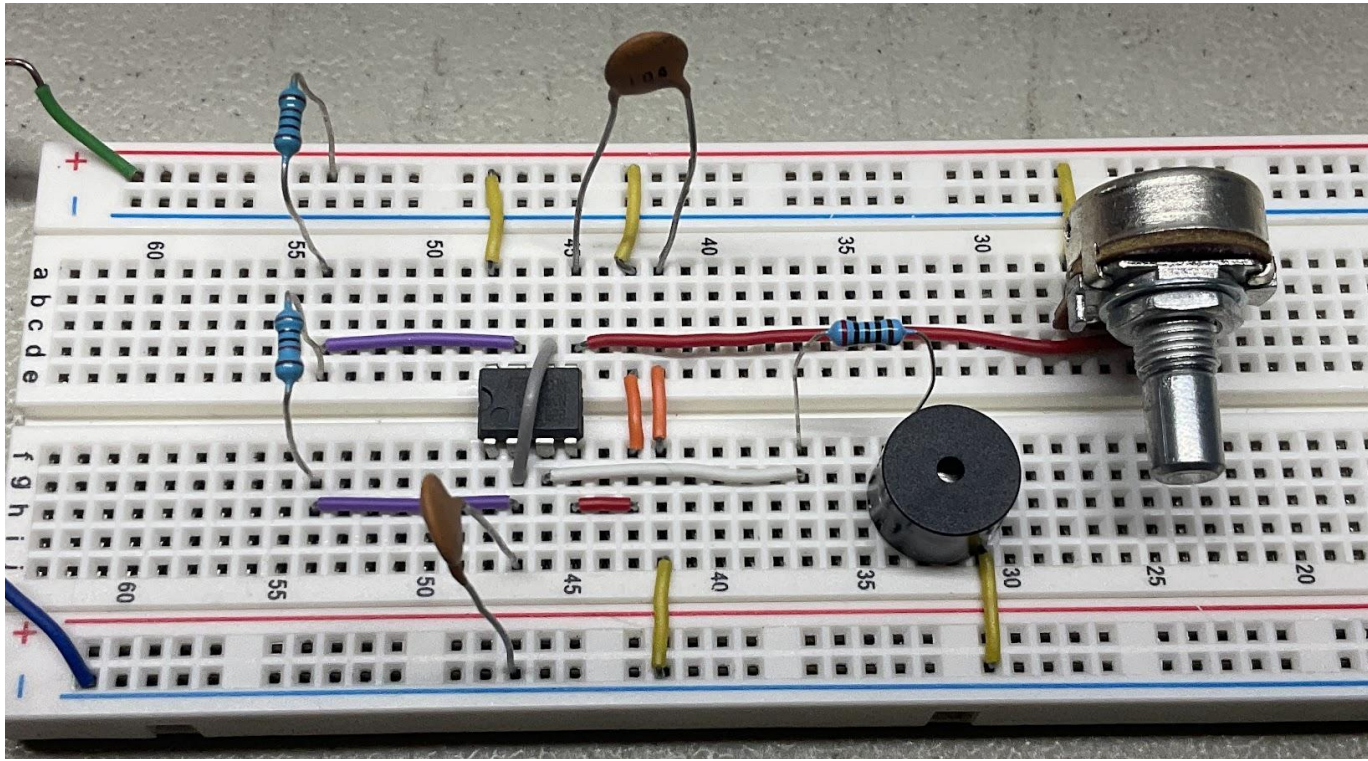
The VCO

- Connect a 100K potentiometer to pin 5 (control voltage). This potentiometer will be in parallel to the 100 nanoFarad capacitor already connect to pin 5.
- We will wire the potentiometer up as a variable resistor.
- We can now supply a varying external voltage to pin 5 (control voltage) which should allow us to vary the output pulse duration and frequency.



Build Together 8: Final Circuit

- As we turn the potentiometer, we alter the default ⅓ Vcc and ⅔ Vcc turn on and turn off thresholds.
- We are now varying the frequency based on the voltage supplied to pin 5 (control voltage).
- Hence, the voltage controlled oscillator!



Build Together 9

The 4 Step Sequencer

4 Step Sequencer

- So far we've used a decade counter to move through a series of outputs to light up LEDs.
- What if instead of LEDs we had resistors of different sizes. We would have very specific voltage drops across each resistor.
- We would then feed these voltages into a VCO to vary the output frequency of a 555 timer!
- This would allow us to generate different notes at a set interval!
- This idea is known as a sequencer and is the heart of electronic music.

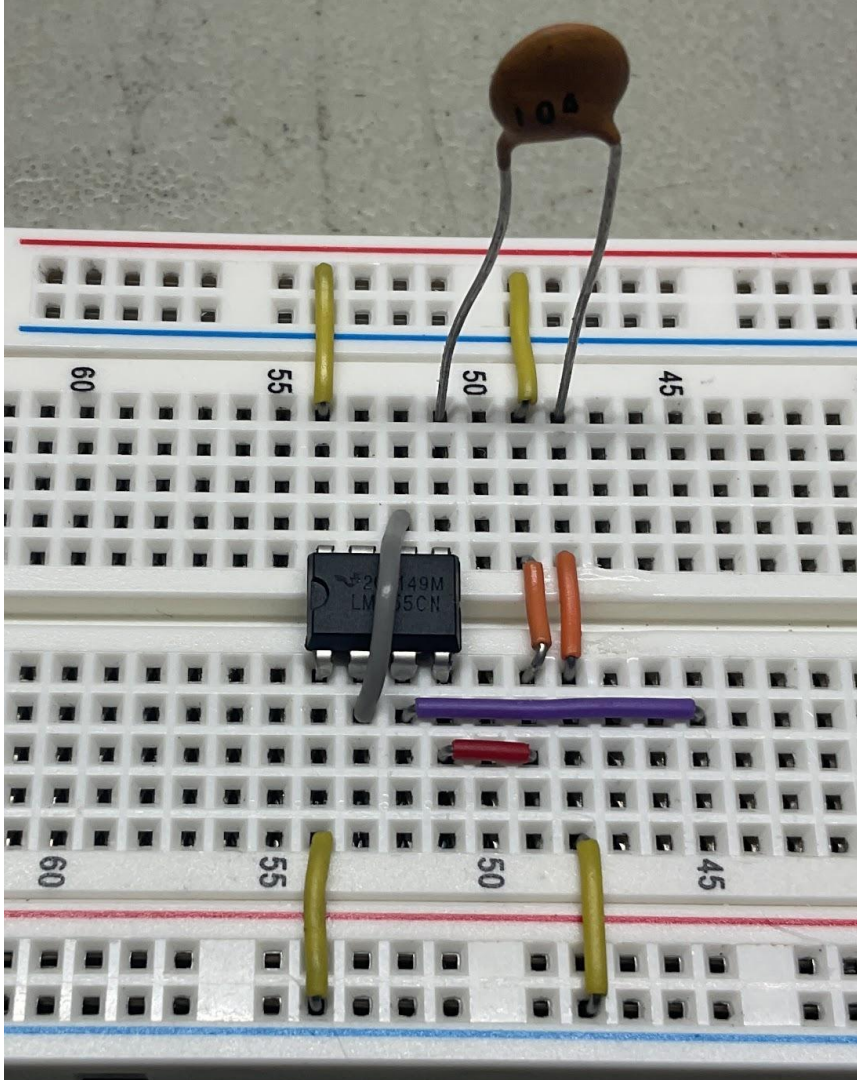
Build Together 9: The 4 Step Sequencer

- Let's build a 4 step sequencer.
- This circuit should have three distinct sections.
  - A clock - a 555 timer wired up in astable mode.
  - A sequence - a decade counter set to move through 4 outputs. Each output should be connected to a common “rail”.
  - A tone - a 555 timer wired up in astable mode with pin 5 set to vary voltage. These voltages should come from the common “rail”.
- As you are building, try to think about what you are doing and why the circuit is designed the way that it is.

ADVANCE to the next slide, let’s build this together!

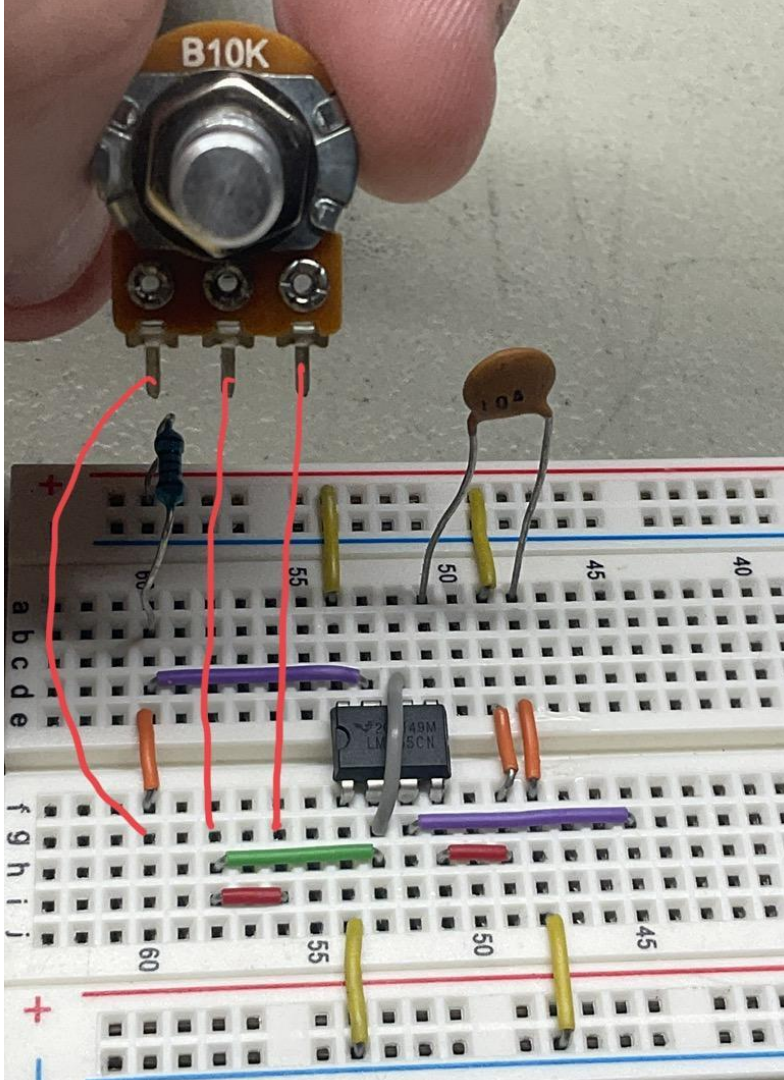
4 Step Sequencer - The Clock

- Begin by setting a 555 timer up for astable mode on the left side of the bread board.
- This 555 will control the speed of our sequence and serve as our clock.
- Connect pin 8 (Vcc) to Vcc.
- Connect pin 1 (ground) to ground.
- Move pin 3 (output) away from the chip for easy access.
- Connect pin 4 (reset) to Vcc to ensure the chip does not reset.
- Connect pin 5 (control voltage) to ground through a 100 nanoFarad (104) capacitor.
- Connect pin 2 (trigger) and pin 6 (threshold) together.



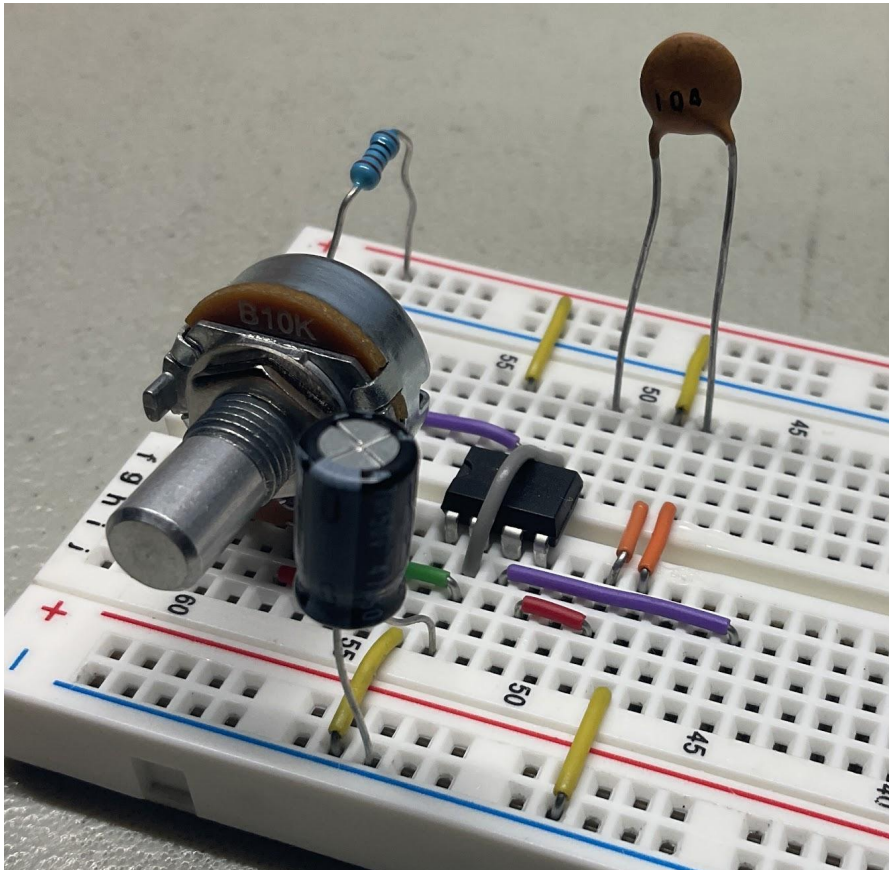
4 Step Sequencer - The Clock

- Set up an RC network to control the output frequency of the 555 timer.
- Create a voltage divider using a 1K (brown, black, black, brown) resistor and a 10K potentiometer.
- We will wire the potentiometer up as a variable resistor.
- Connect the midpoint of the voltage divider to pin 7 (discharge).
- Connect the bottom of the voltage divider to pin 2 (trigger).



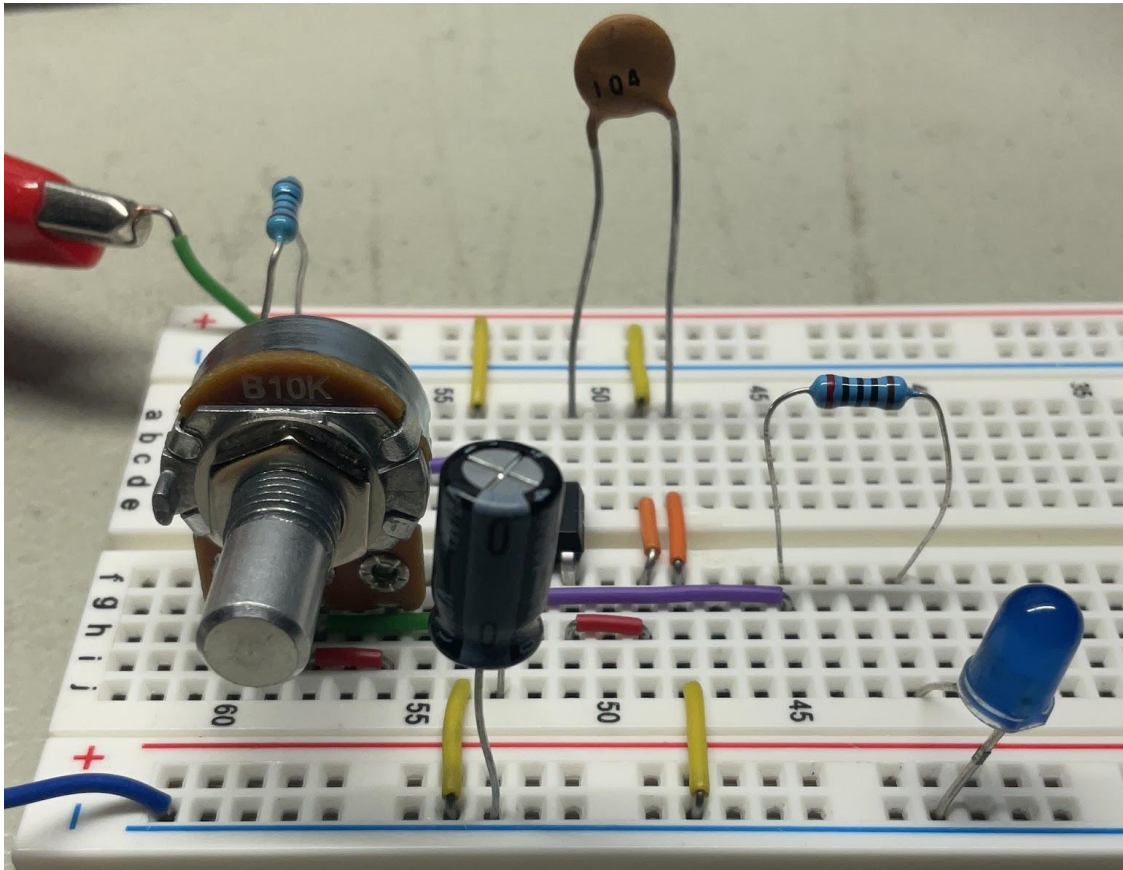
4 Step Sequencer - The Clock

- Connect pin 2 (trigger) to ground through a 47 microFarad capacitor.
- This should give us a frequency that is slow enough so we can easily hear different tones in our sequence.
- If the clock is too fast, we won’t be able to distinguish one tone from another.



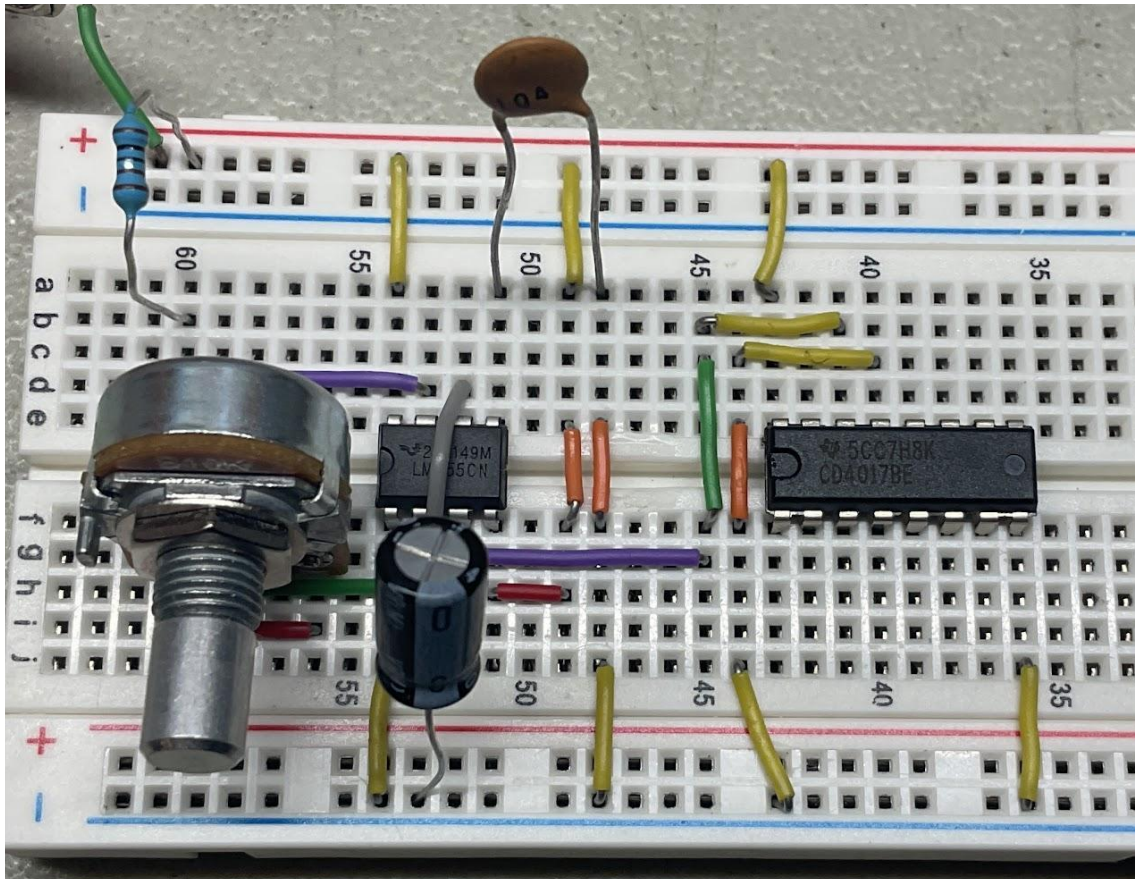
4 Step Sequencer - The Clock

- For now, connect a 200 ohm (red, black, black, black) resistor to pin 3 (output) to an LED to ground.
- Test the circuit to verify that you are getting a good signal that will be used for a 4017 clock!



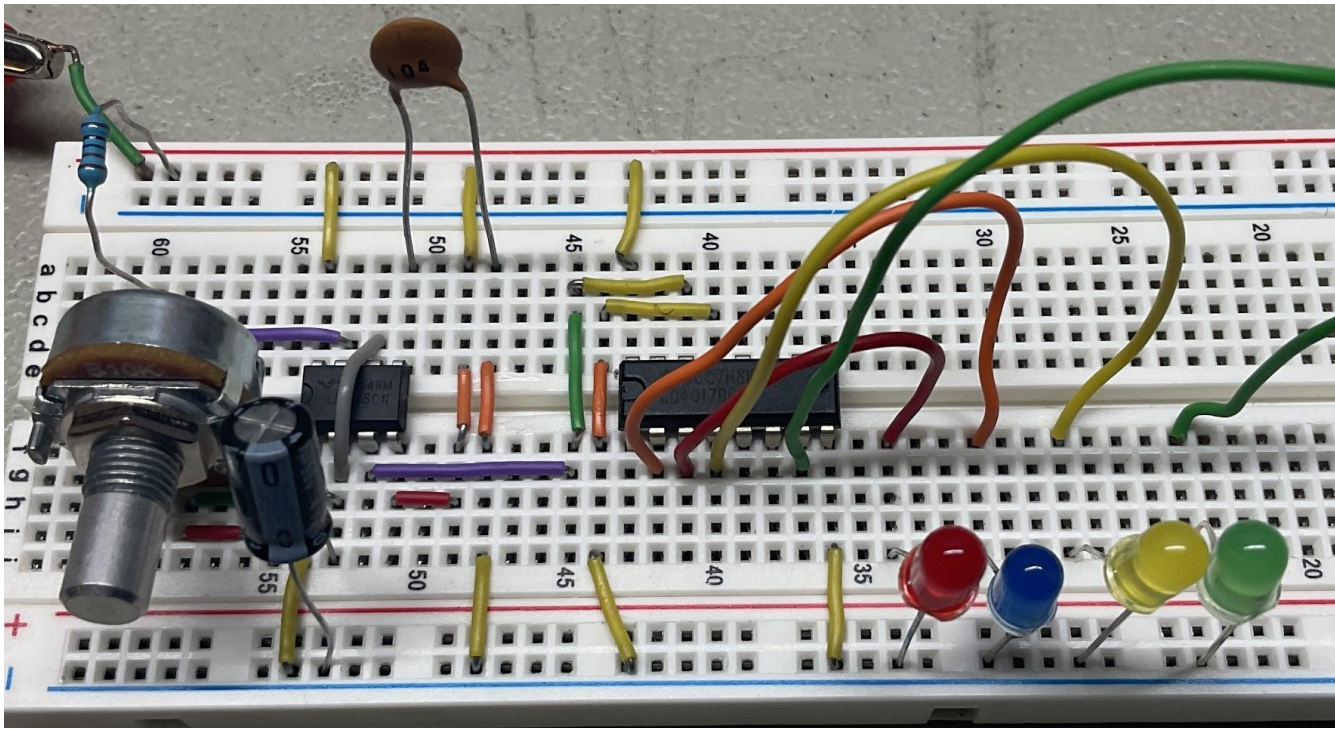
4 Step Sequencer - The Sequence

- Now that we have a clock, we will use that clock to step through a sequence of tones.
- We will use a 4017 decade counter to step through the sequence.
- Place a 4017 in the board.
- Connect pin 16 (Vdd) to Vcc.
- Connect pin 8 (ground) to ground.
- Connect pin 14 (clock) to pin 3 (output) of the 555 timer.
- Connect pin 13 (clock enable) to ground.



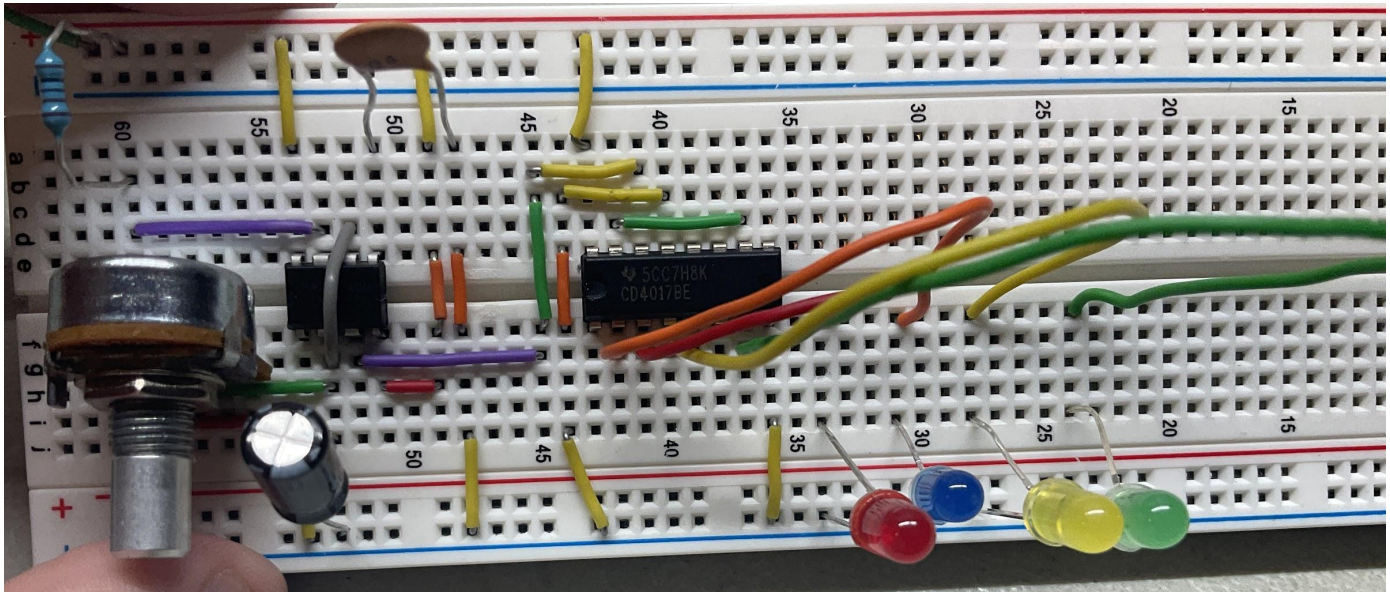
4 Step Sequencer - The Sequence

- To ensure that the 4017 is working properly, wire up 4 LEDs to the output pins.
- Pin 3 (output 0) - red wire
- Pin 2 (output 1) - orange wire
- Pin 4 (output 2) - yellow wire
- Pin 7 (output 3) - green wire
- These are the first 4 outputs of the decade counter.



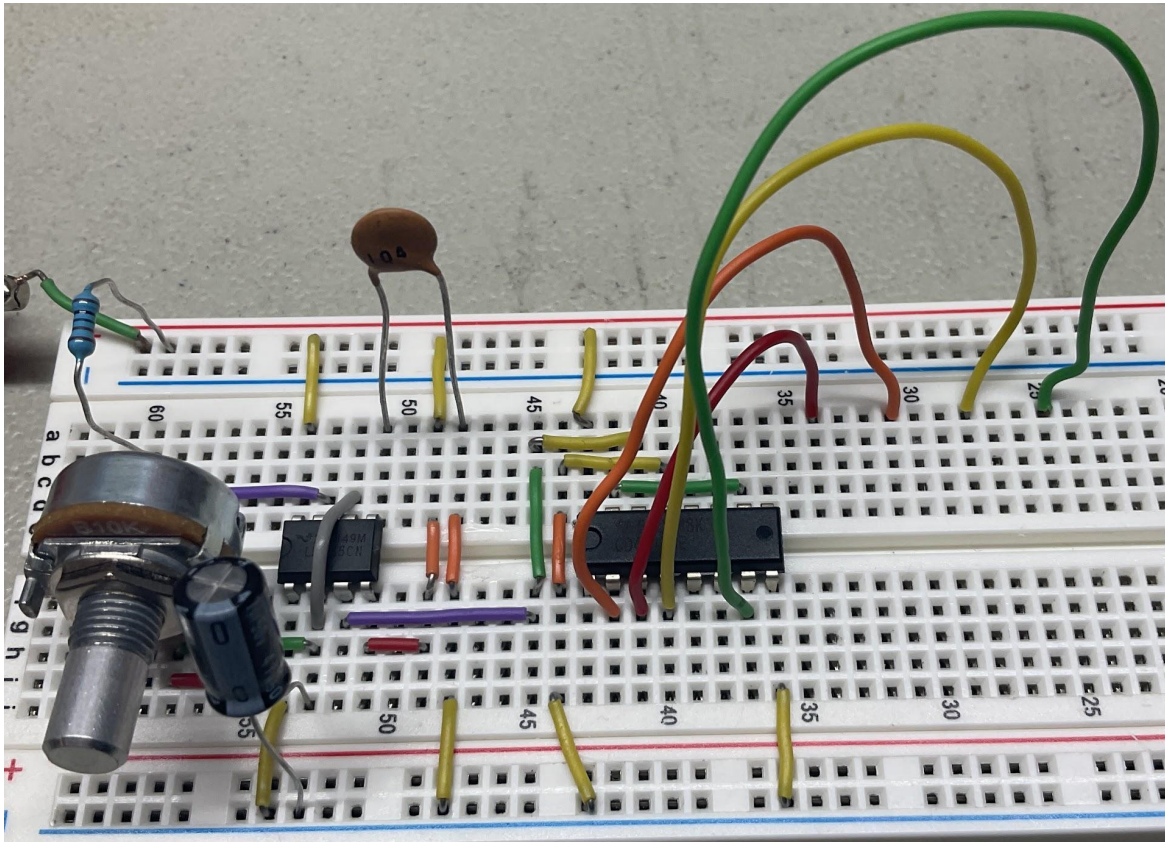
4 Step Sequencer - The Sequence

- Since we are only going to use 4 steps in our sequence, we need the chip to reset once the sequence is over.
- Connect pin 10 (output 4) to pin 15 (reset). This is my green wire.
- This will ensure the chip resets once our desired sequence is over



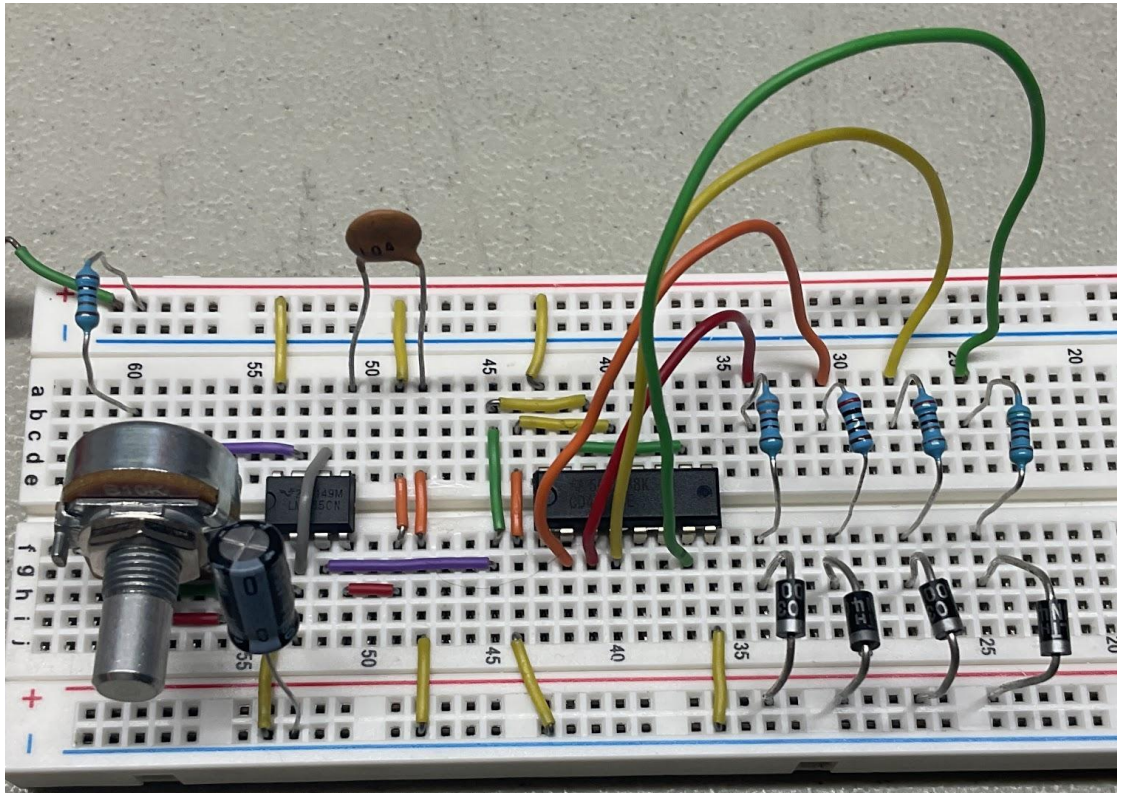
4 Step Sequencer - The Sequence

- Now that we've verified that our clock is driving our decade counter correctly, we will remove the LEDs and move our jumper wires for better placement.
- We want to instead have each output be a set resistance value that voltage will drop over.
- This unique voltage will then be fed into the control voltage pin of a second 555 timer controlling our tone.
- The varying voltage from each output should change the frequency and pulse width of the second 555 timer.



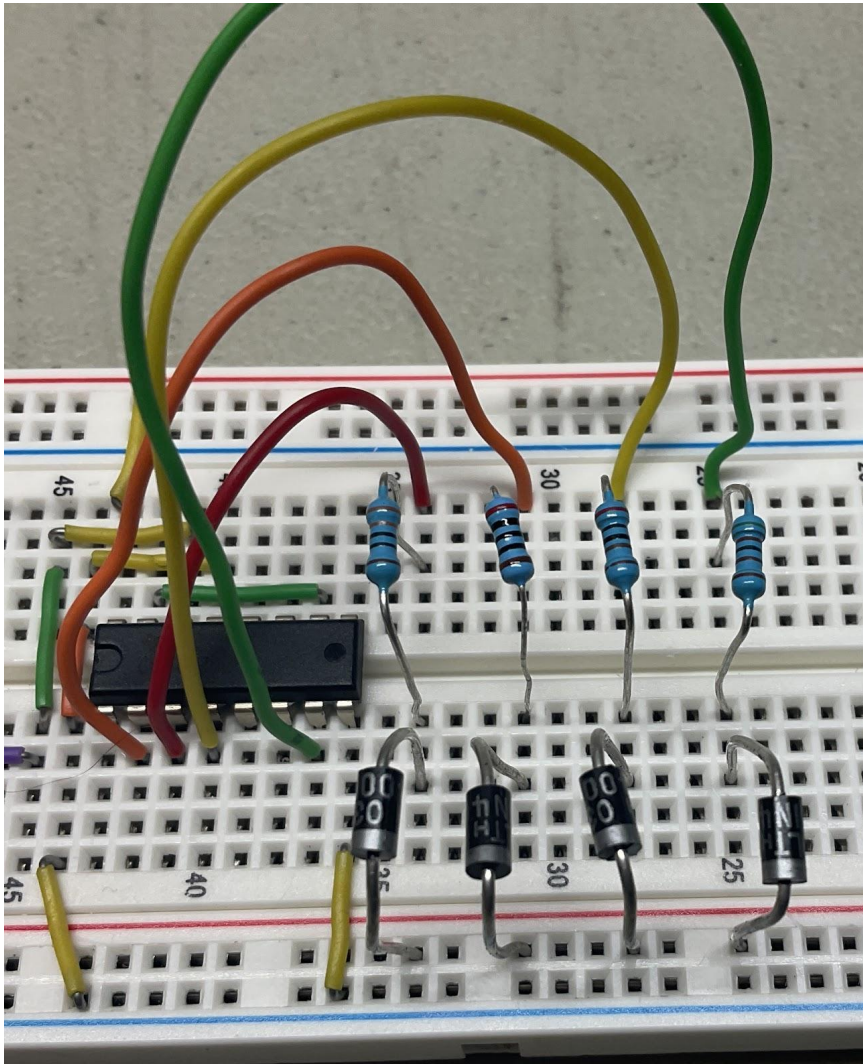
4 Step Sequencer - The Sequence

- For each output we will have a resistor into a diode into the non-ground rail at the bottom of the bread board.
- By changing the resistor values, the tone generated during that step of the frequency will change. However, you have to pick values that will work with whatever speaker/buzzer you hook up at the end. For my little buzzer, best results were with values under 10K. For a large speaker, 10K + worked fine.
- All outputs will be fed into the non-ground rail at the bottom of the board. Since we will have a common connection, we can just send that common connection into the control voltage pin of a 555 timer later.
- We need the diodes to prevent any interactions between outputs since they are all connected to a common point. The diode will let current flow one way (into the non-ground rail) but not back the other way.



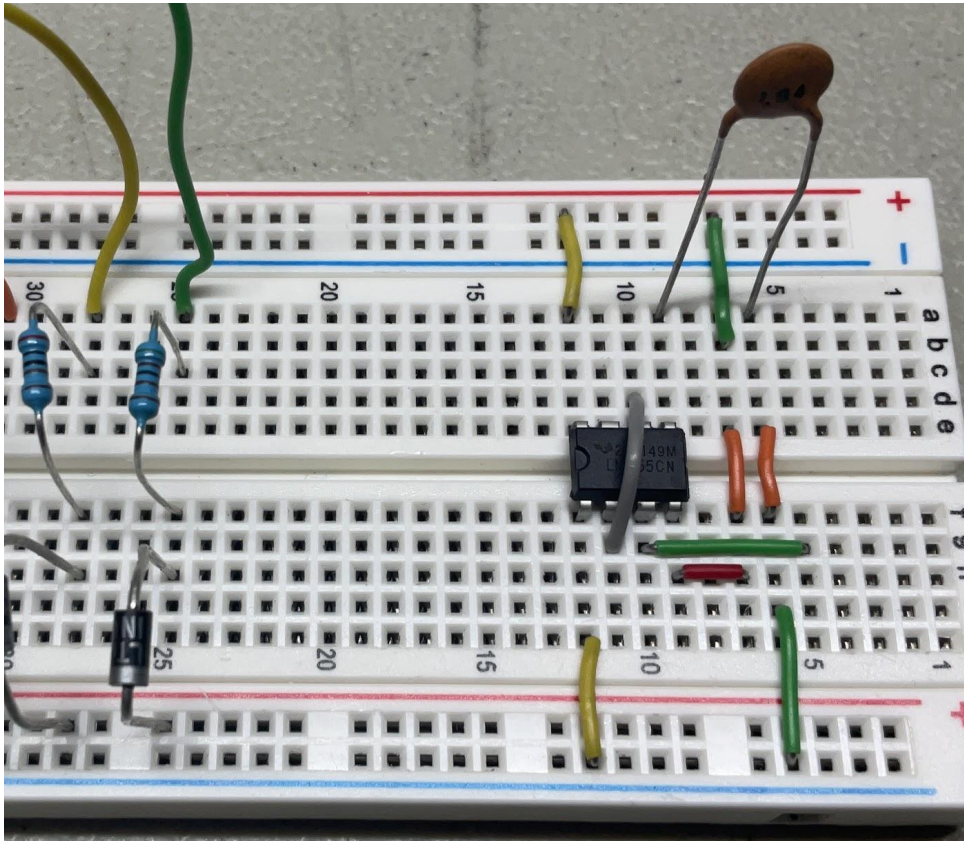
4 Step Sequencer - The Sequence

- On output 0 (pin 3) I chose a 330 ohm (orange, orange, black, black) resistor to diode to ground.
- On output 1 (pin 2) I chose a 200 ohm (red, black, black, black) resistor to diode to ground.
- On output 2 (pin 4) I chose a 2K ohm (red, black, black, brown) resistor to diode to ground.
- On output 3 (pin 7) I chose a 5.1K ohm (green, brown, black, brown) resistor to diode to ground.
- Our sequence is now complete!



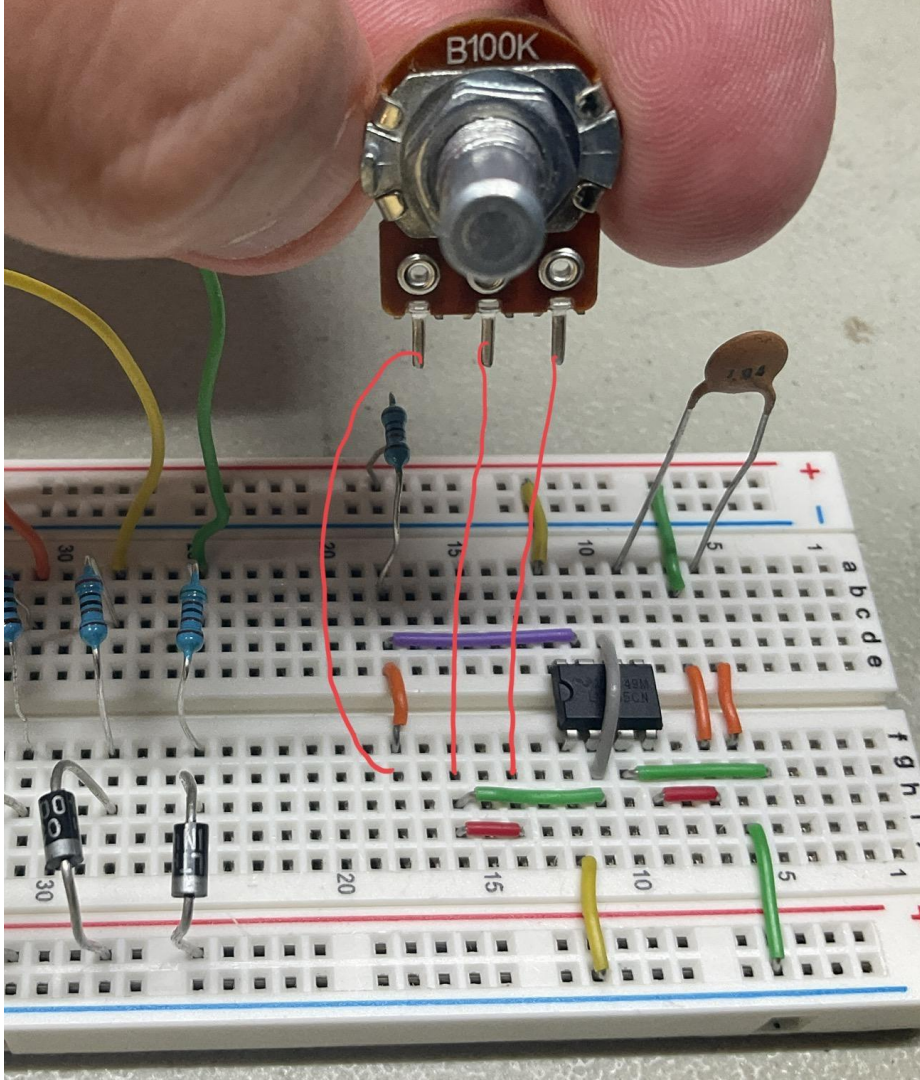
4 Step Sequencer - The Tone

- Now that we have a clock (555 timer) stepping through a sequence of tones (4017 decade counter), we need something to play the tones: Another 555 timer in astable mode!
- Put a 555 timer to the right of your 4017 decade counter and begin wiring it up in astable mode.
- Connect pin 8 (Vcc) to Vcc.
- Connect pin 1 (ground) to ground.
- Move pin 3 (output) away from the chip for easy access.
- Connect pin 4 (reset) to Vcc to ensure the chip does not reset.
- Connect pin 5 (control voltage) to ground through a 100 nanoFarad (104) capacitor.
- Connect pin 2 (trigger) and pin 6 (threshold) together.



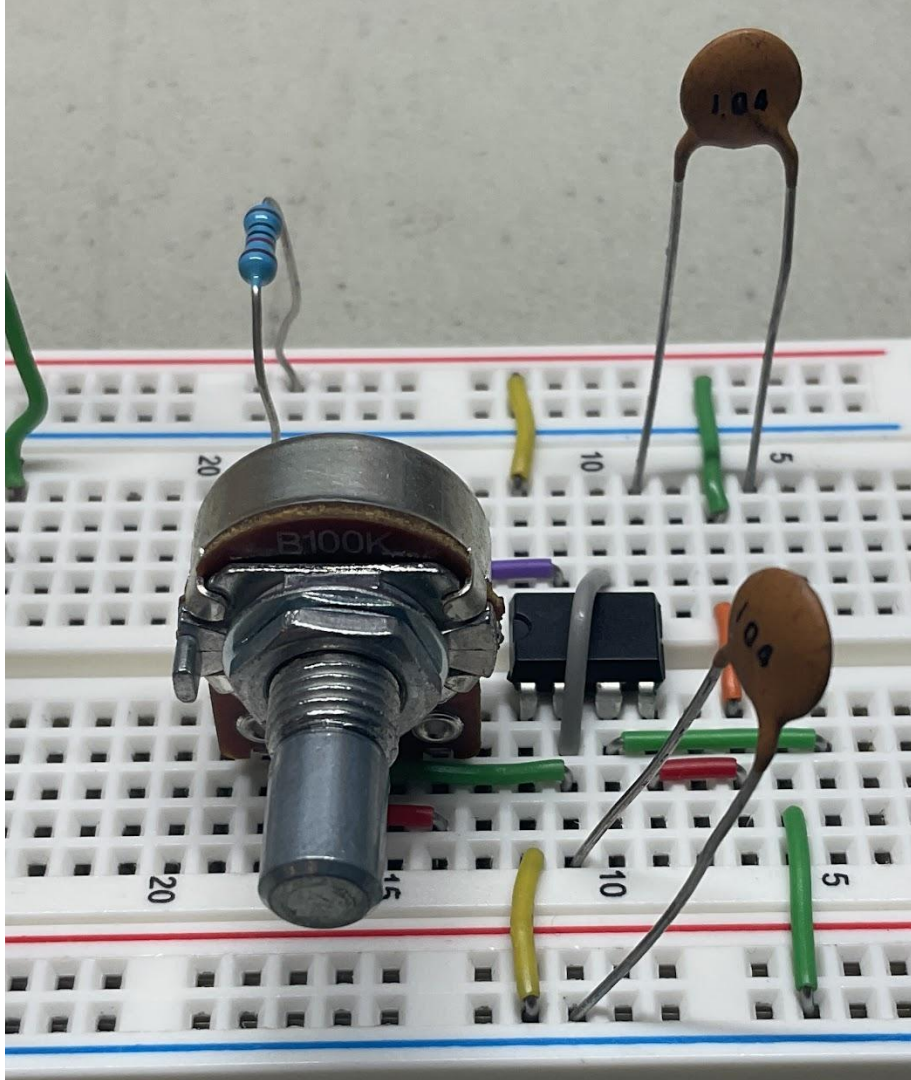
4 Step Sequencer - The Tone

- Set up an RC network to control the output frequency of the 555 timer.
- This will essentially set the “octave” our sequence of tones will move through.
- Create a voltage divider using a 10K (brown, black, black, red) resistor and a 100K potentiometer.
- We will wire the potentiometer up as a variable resistor.
- Connect the midpoint of the voltage divider to pin 7 (discharge).
- Connect the bottom of the voltage divider to pin 2 (trigger).



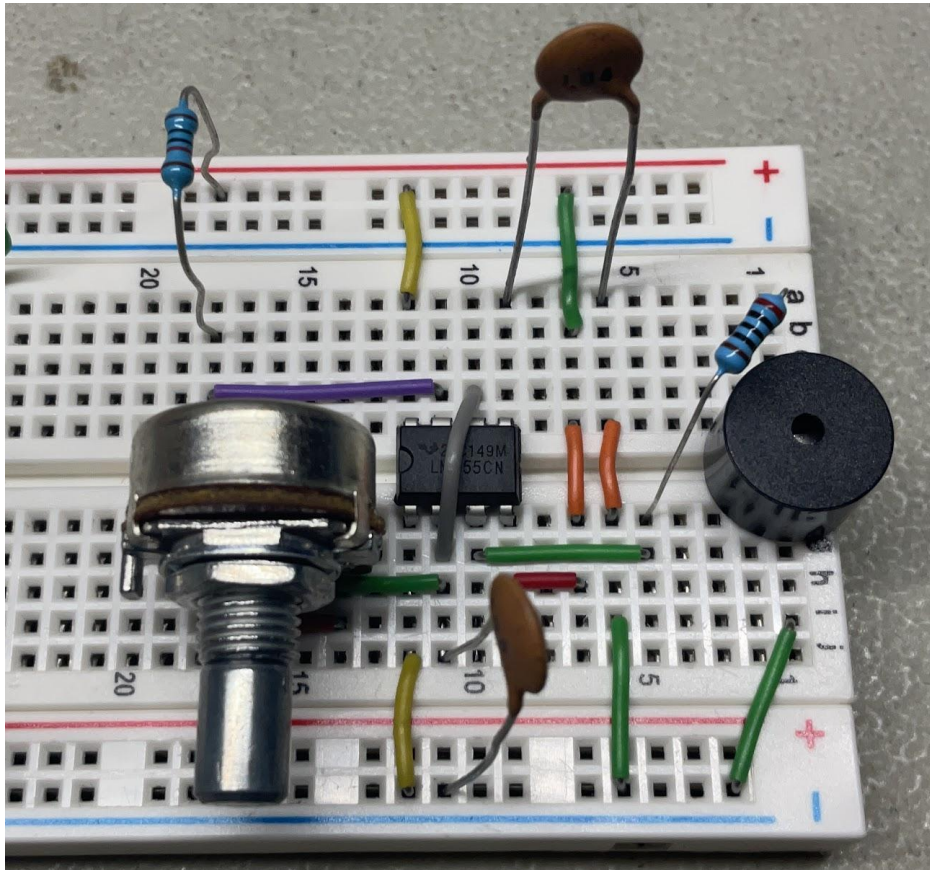
4 Step Sequencer - The Tone

- Connect pin 2 to ground through a 100 nanoFarad capacitor.
- The RC circuit is complete. Right now we should be able to hear a single tone and vary the frequency with our potentiometer.



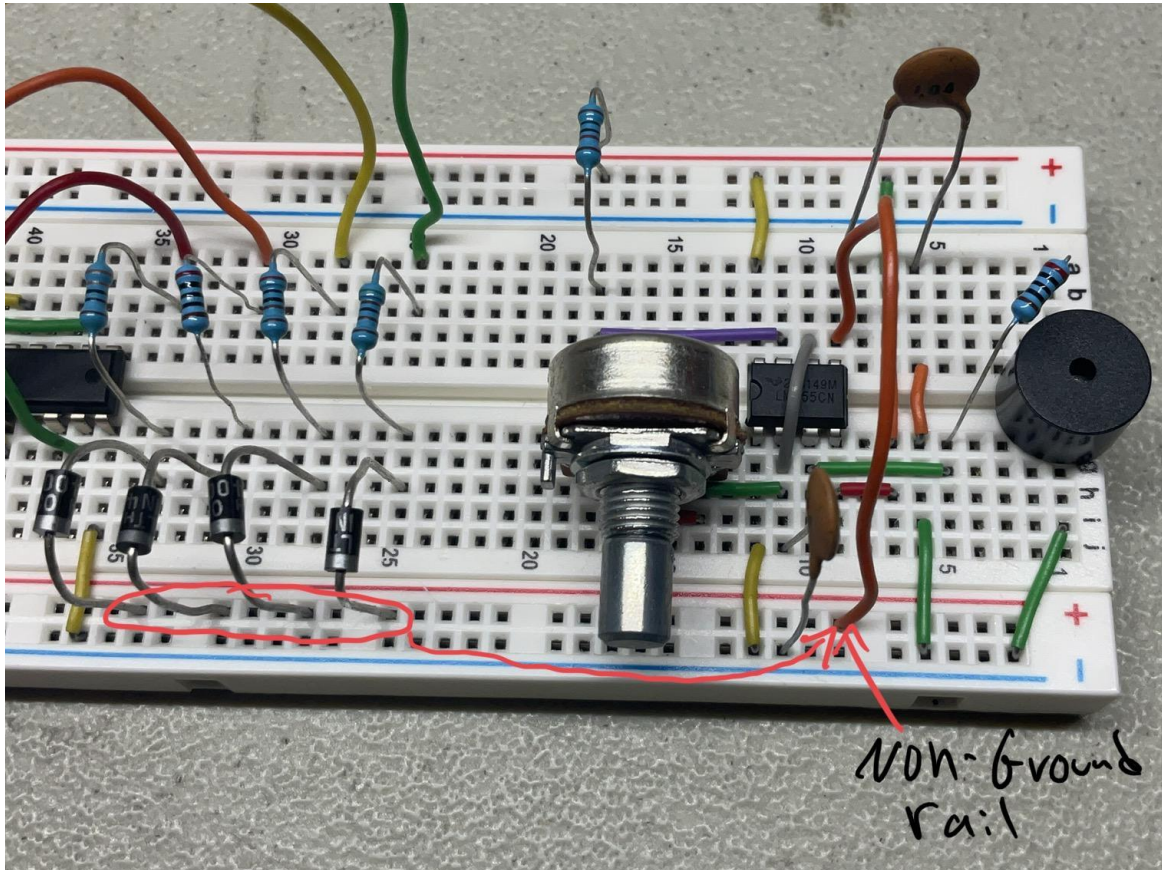
4 Step Sequencer - The Tone

- Connect a 200 ohm (red, black, black, black) resistor to a buzzer to ground off pin 3 (output).
- Note here, I ran out of room on the breadboard so I had to be creative!
- You should hear a single note and vary the note with this potentiometer…but our other potentiometer does nothing right now!



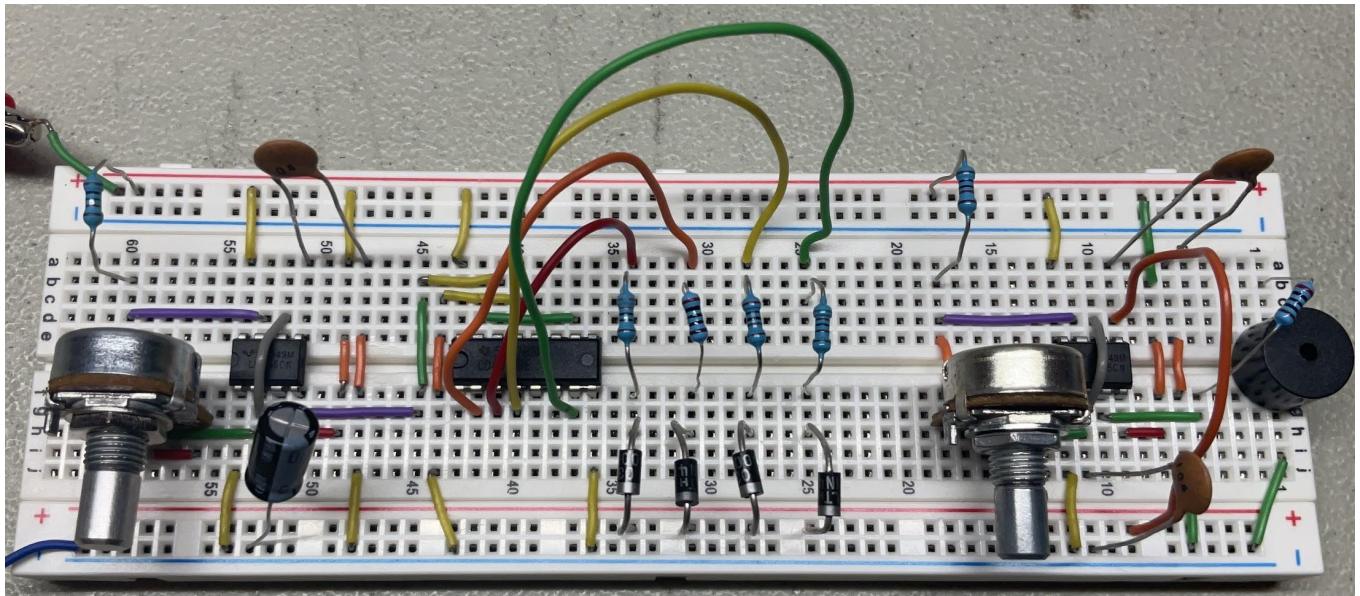
4 Step Sequencer - Connecting it All Together

- In order to connect our tone circuit to the rest of the circuit, we need to feed our control voltage the varying voltage coming off the decade counter.
- Connect the non-ground rail that all of the 4017 resistors/diodes are connected to into pin 5 (control voltage) of the 555 timer.
- This is my orange wire.



Build Together 9: Final Circuit

- As the clock circuit pulses, it will advanced the output on the sequence circuit. This will in turn create a specific voltage (determined by the resistors) that is going to a common rail. That common rail is fed into the control voltage of our tone circuit. This new voltage will alter the rate at which the 555 timer turns on/off varying the output frequency.
- If we hook this up now, we should hear a sequence of 4 notes!
- The left 10K potentiometer controls the speed of the sequence while the right 100K potentiometer controls the overall frequency of the sequence.
- Try new resistor values to see if you can make some cool music!

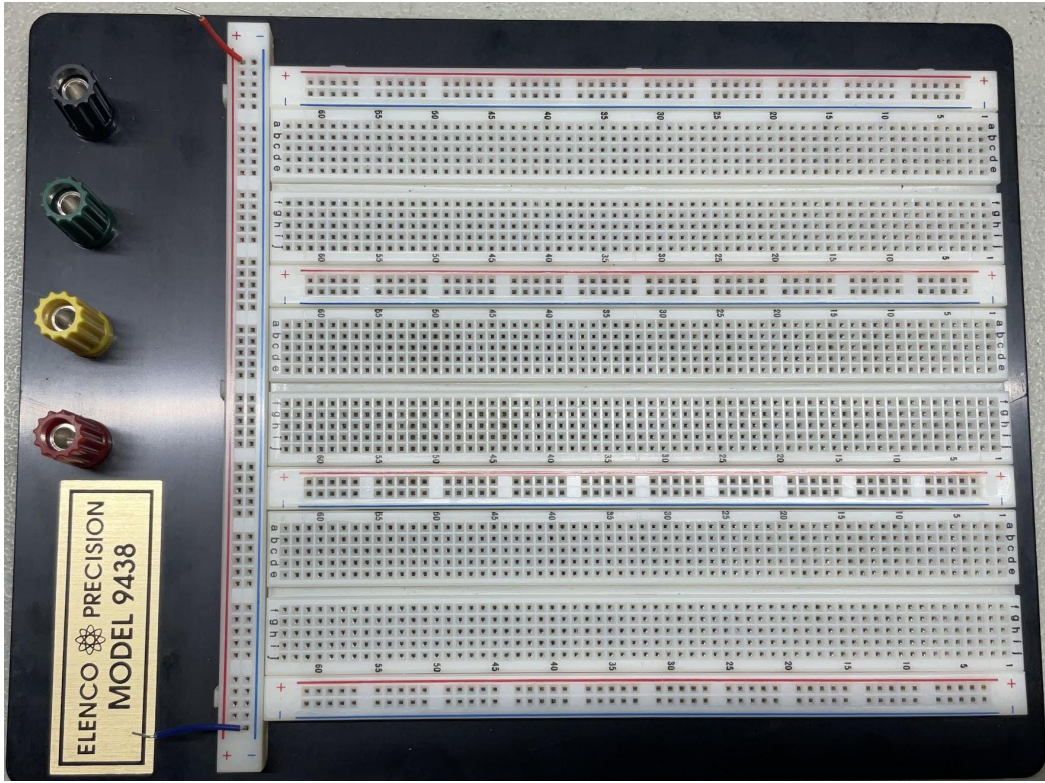


Build Together 10

The Improved 8 Step Sequencer

Expanding the 4 Step Sequencer

- Expanding on the 4 step sequence is rather easy since our 4017 decade counter has 10 outputs.
- In music, a general time signature is 4 beats per measure. Having a sequence as an integer multiple of 4 is common.
- We will use an 8 step sequence this time and we will put potentiometers on all of our 4017 outputs so we can vary the tone at each step!
- This will require more room than a single breadboard can provide and a few more components than we have used the past.



Build Together 10: The Improved 8 Step Sequencer

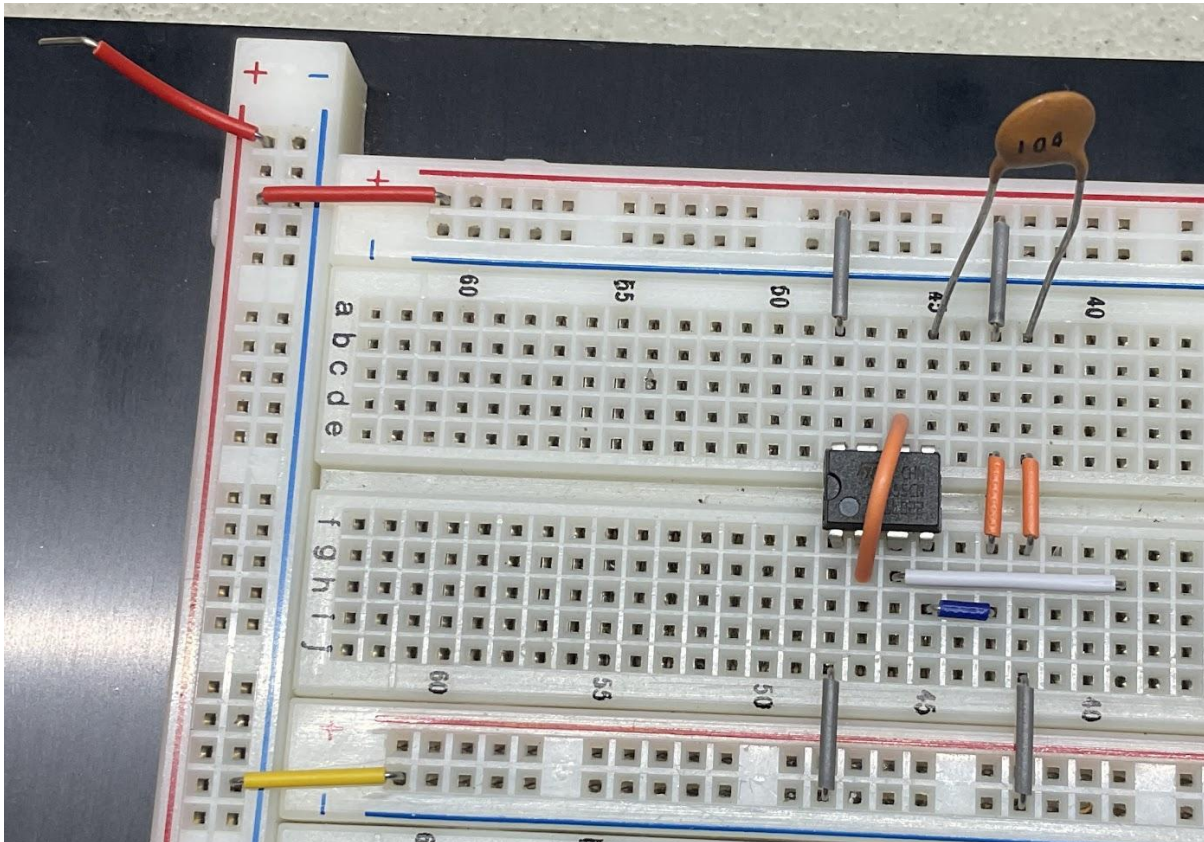
- We are going to create an 8 step sequencer with potentiometers on each of our 4017 outputs so we can vary the frequency of each individual note within the sequence.
- This circuit will require more room so I will be using a larger bread board.

- As you are building, try to think about what you are doing and why the circuit is designed the way that it is.

ADVANCE to the next slide, let’s build this together!

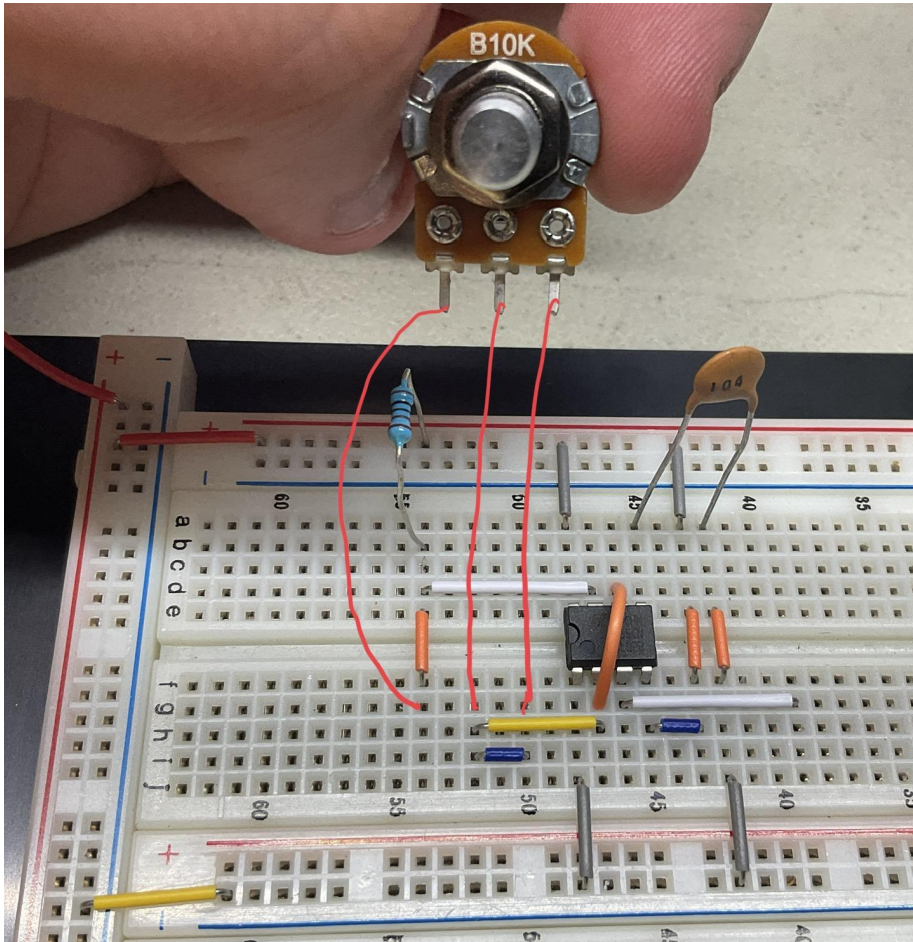
8 Step Sequencer - The Clock

- Wire up a 555 timer in astable mode. Note, here the jumper wires I’m using are a different color than in the past.
- Connect pin 8 (Vcc) to Vcc.
- Connect pin 1 (ground) to ground.
- Move pin 3 (output) away from the chip for easy access.
- Connect pin 4 (reset) to Vcc.
- Connect pin 5 (control voltage) to ground through a 100 (104) nanoFarad capacitor.
- Connect pin 2 (trigger) and pin 6 (threshold) together.



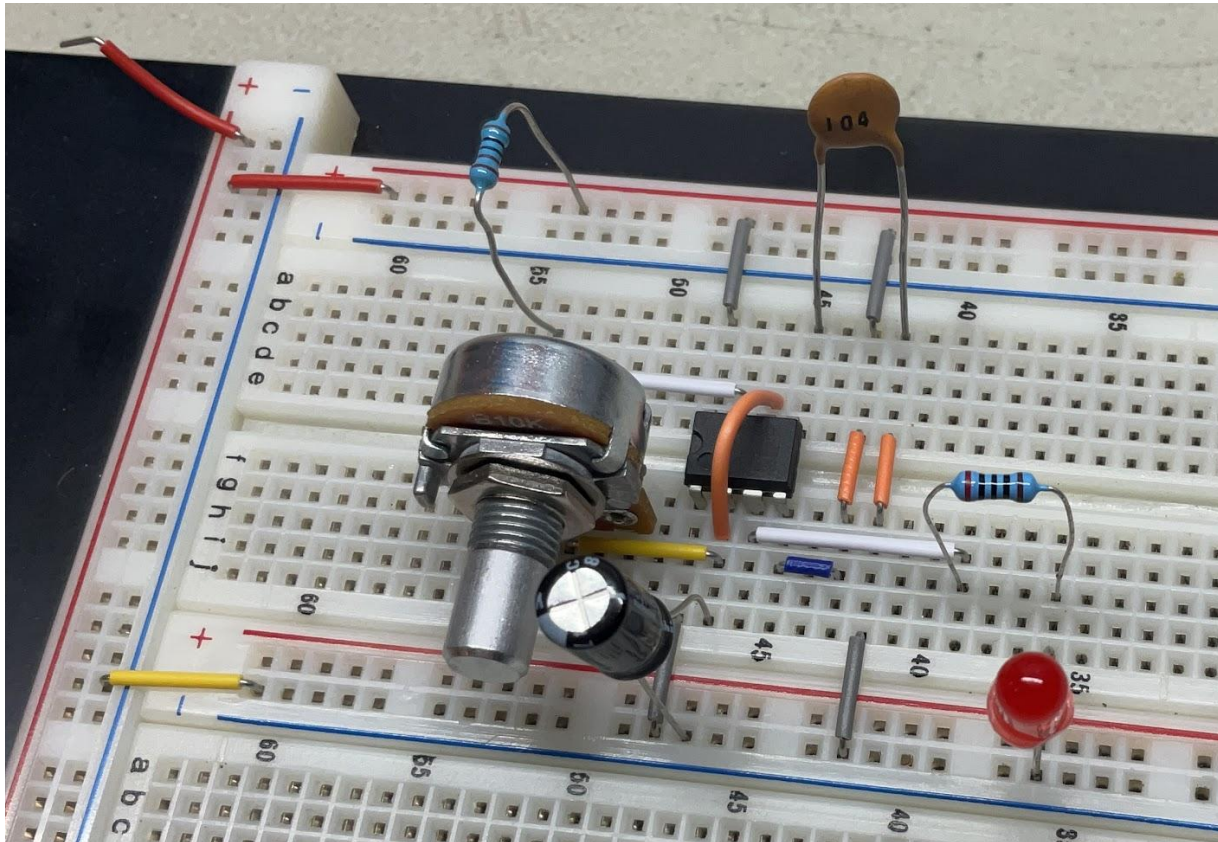
8 Step Sequencer - The Clock

- Begin building the RC network to control the clock frequency.
- Create a voltage divider with a 1K (brown, black, black, brown) resistor and a 10K potentiometer.
- The potentiometer will be wired up as a variable resistor.
- Connect the midpoint of the voltage divider to pin 7 (discharge).
- Connect the bottom of the voltage divider to pin 2 (trigger).



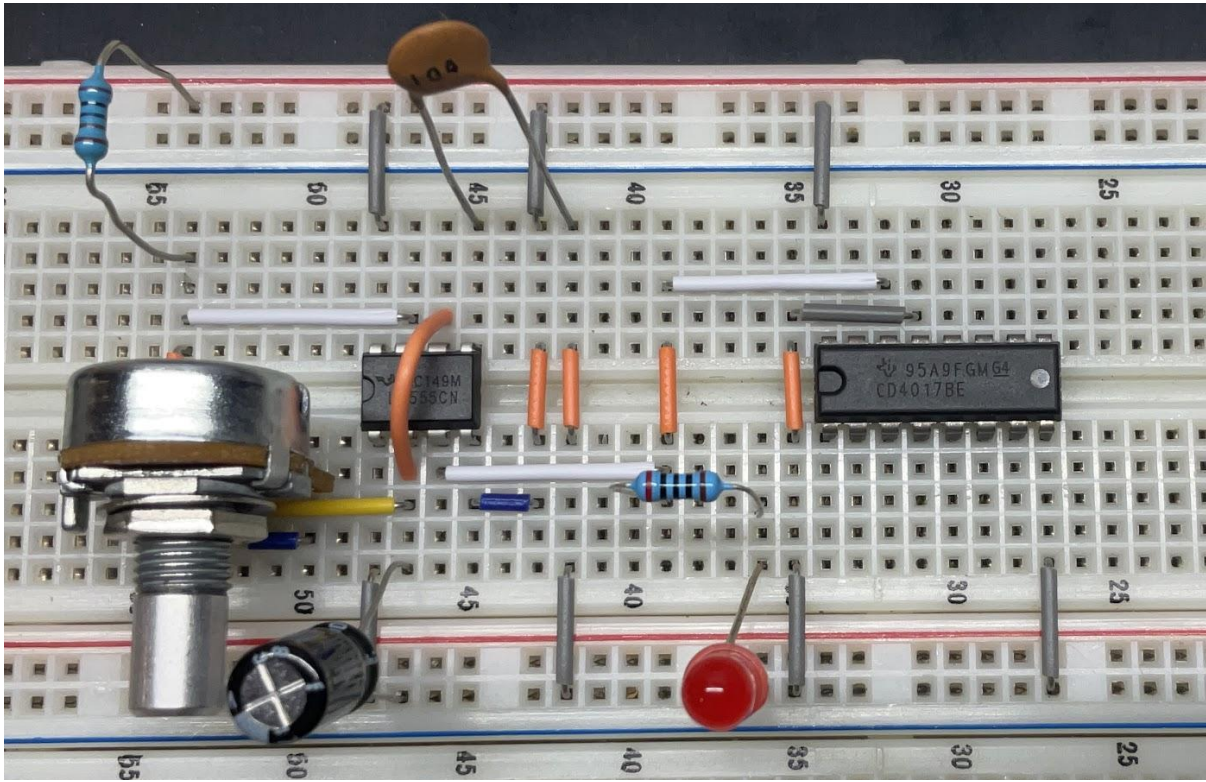
8 Step Sequencer - The Clock

- Connect pin 2 (trigger) to ground through a 47 microFarad capacitor.
- The RC timing circuit is now complete.
- Connect a 200 ohm (red, black, black, black) resistor to an LED to ground on pin 3 (output).
- This will not only allow us to test the clock, but I’m going to leave it in the circuit as a visual representation of the tempo of the sequence.



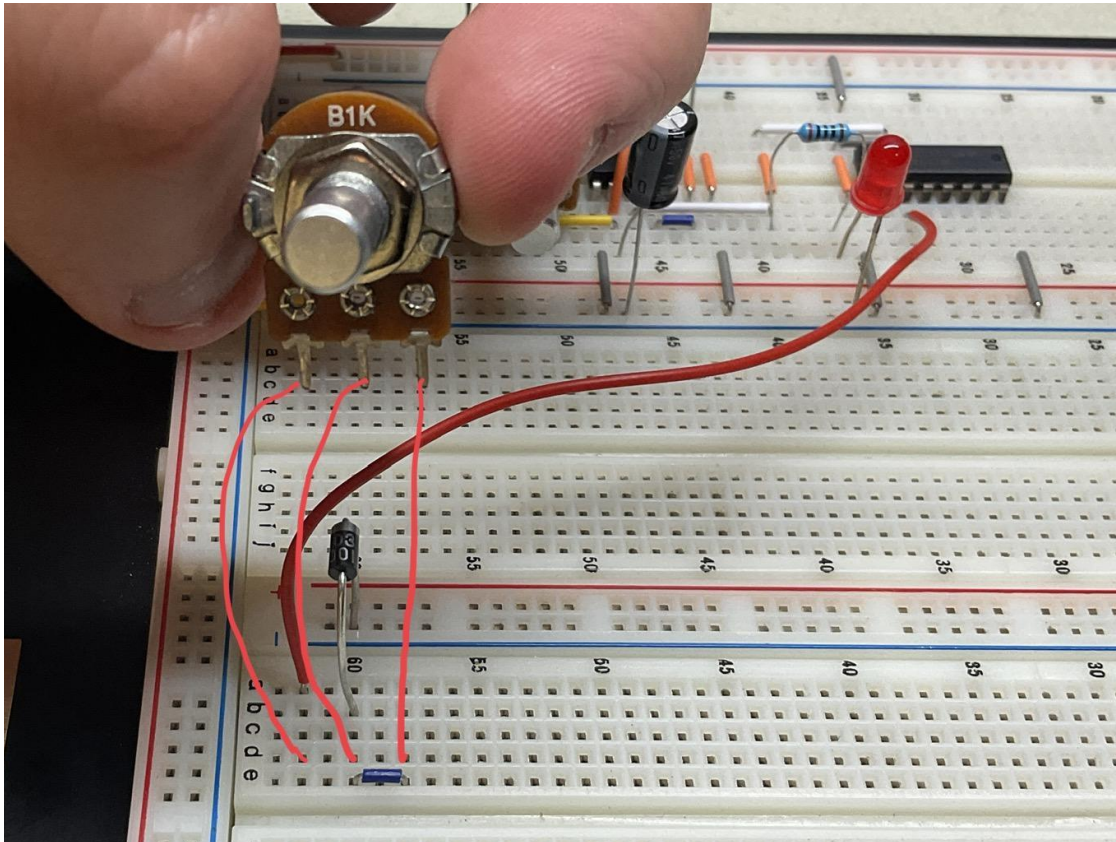
8 Step Sequencer - The Sequence

- Place a 4017 decade counter in the breadboard.
- Connect pin 16 (Vdd) to Vcc.
- Connect pin 8 (ground) to ground.
- Connect pin 14 (clock) to the output of the 555 timer.
- Connect pin 13 (clock enable) to ground to ensure that the chip runs.



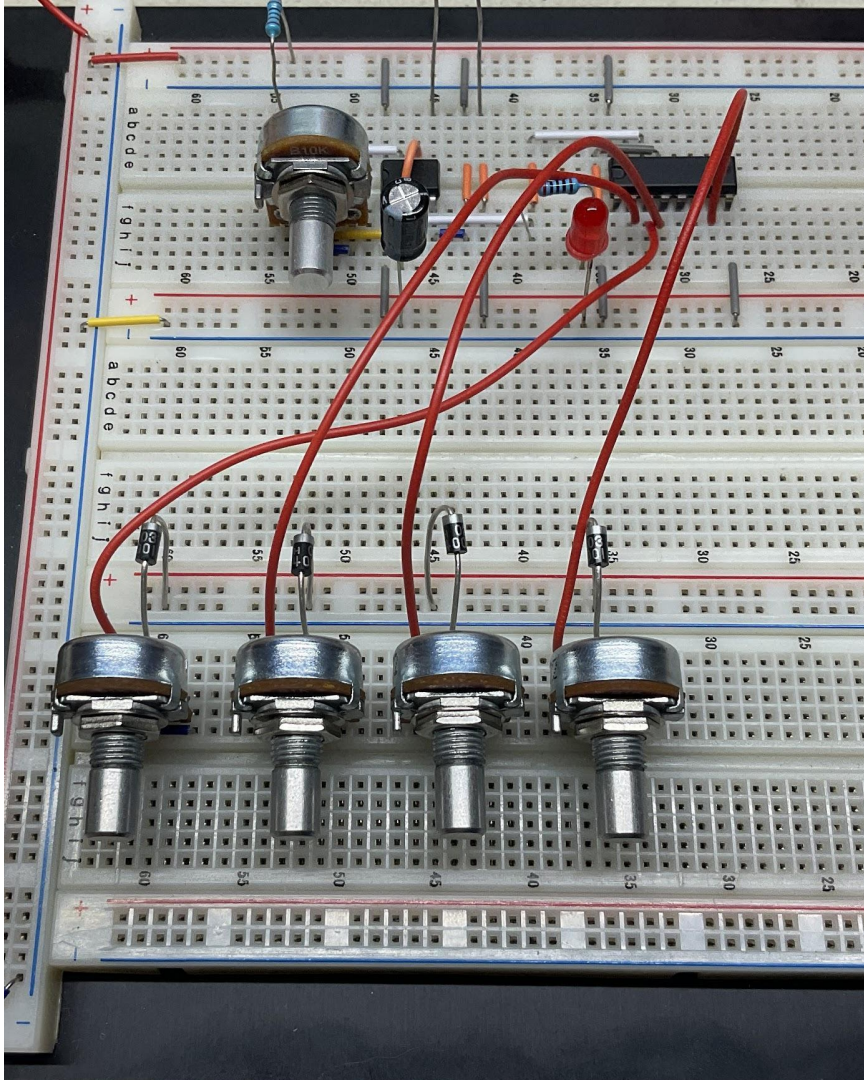
8 Step Sequencer - The Sequence

- At each output of the 4017, instead of having a fixed resistor value we will have a potentiometer wired up as a variable resistor.
- This will allow us to vary the voltage we send to the control voltage pin on our VCO.
- Pin 3 (output 0) is shown here for wiring instructions.
- All diodes, which will prevent any current from flowing back into other potentiometers, will be connect to a common rail (one that is not currently in use).
- I will use four 1K pots and four 10K pots….mainly because that's what I have available!



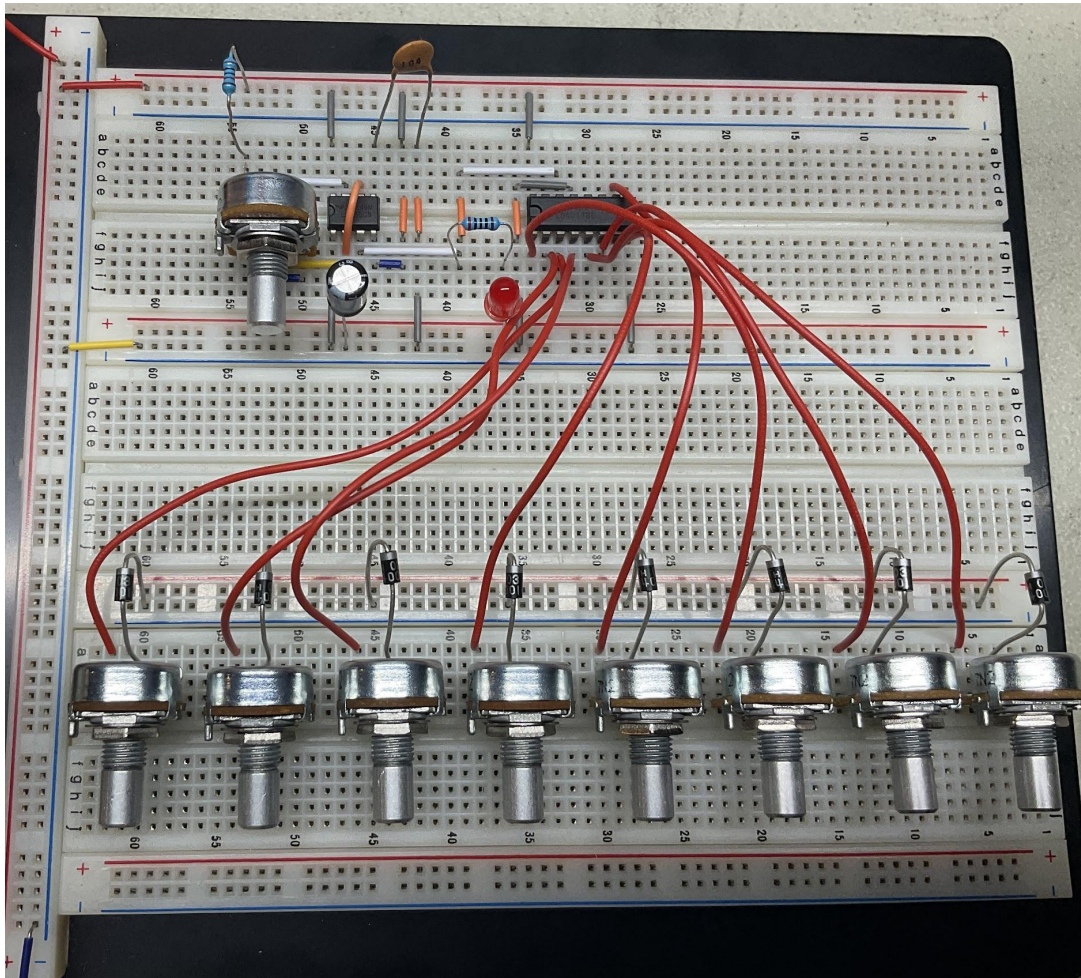
8 Step Sequencer - The Sequence

- Here are four 1K potentiometers wired up to the first four outputs of the 4017.
  - Pin 3 - output 0
  - Pin 2 - output 1
  - Pin 4 - output 2
  - Pin 7 - output 3
- Each potentiometer should be wired the same as shown in the previous slide.



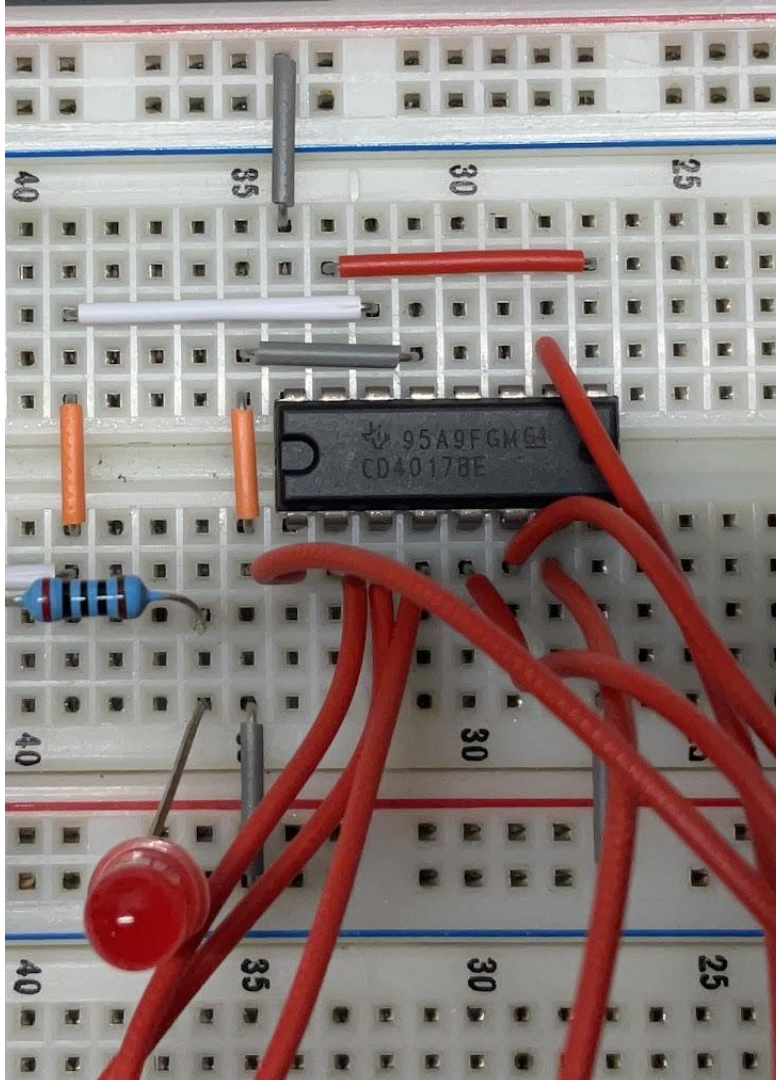
8 Step Sequencer - The Sequence

- Here are four 10K potentiometers wired up to the next four outputs of the 4017.
  - Pin 10 - output 4
  - Pin 1 - output 5
  - Pin 5 - output 6
  - Pin 6 - output 7
- Each potentiometer should be wired the same as shown in the previous slide.



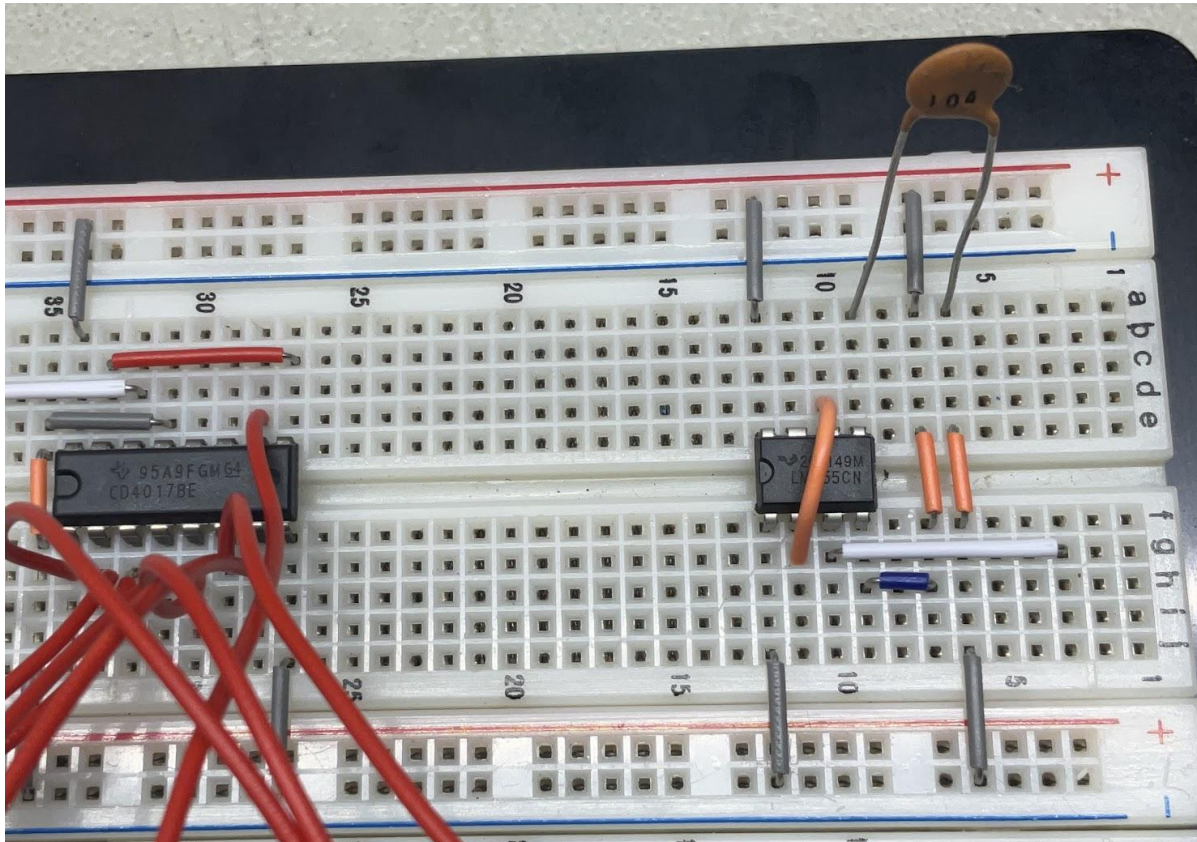
8 Step Sequencer - The Sequence

- Since we only want 8 steps in our sequence, we have to reset the pin after the 8th output has triggered.
- Do this this we can connect pin 9 (output 8) to pin 15 (reset). This is my red jumper wire.
- Our sequence is now complete!



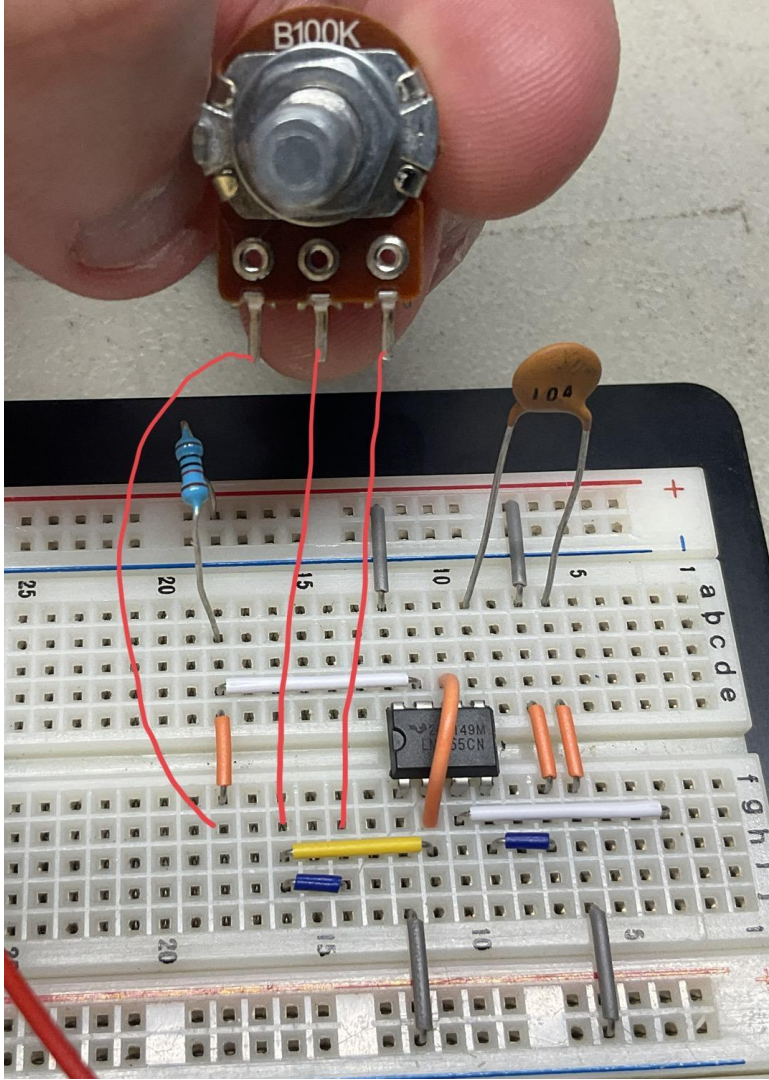
8 Step Sequencer - The Tone

- Wire up a 555 timer in astable mode.
- Connect pin 8 (Vcc) to Vcc.
- Connect pin 1 (ground) to ground.
- Move pin 3 (output) away from the chip for easy access.
- Connect pin 4 (reset) to Vcc.
- Connect pin 5 (control voltage) to ground through a 100 (104) nanoFarad capacitor.
- Connect pin 2 (trigger) and pin 6 (threshold) together.



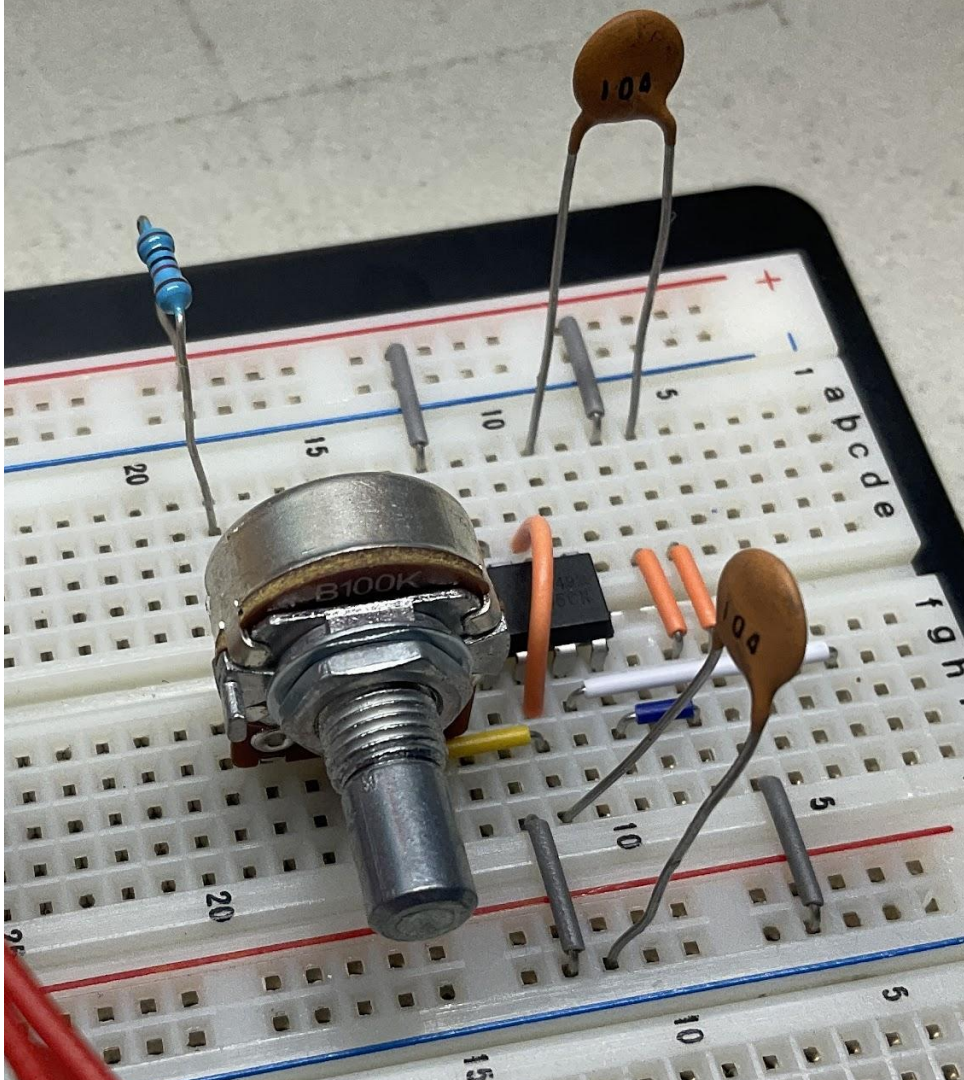
8 Step Sequencer - The Tone

- Begin building the RC network to control the output tone frequency.
- Create a voltage divider with a 10K (brown, black, black, red) resistor and a 100K potentiometer.
- The potentiometer will be wired up as a variable resistor.
- Connect the midpoint of the voltage divider to pin 7 (discharge).
- Connect the bottom of the voltage divider to pin 2 (trigger).



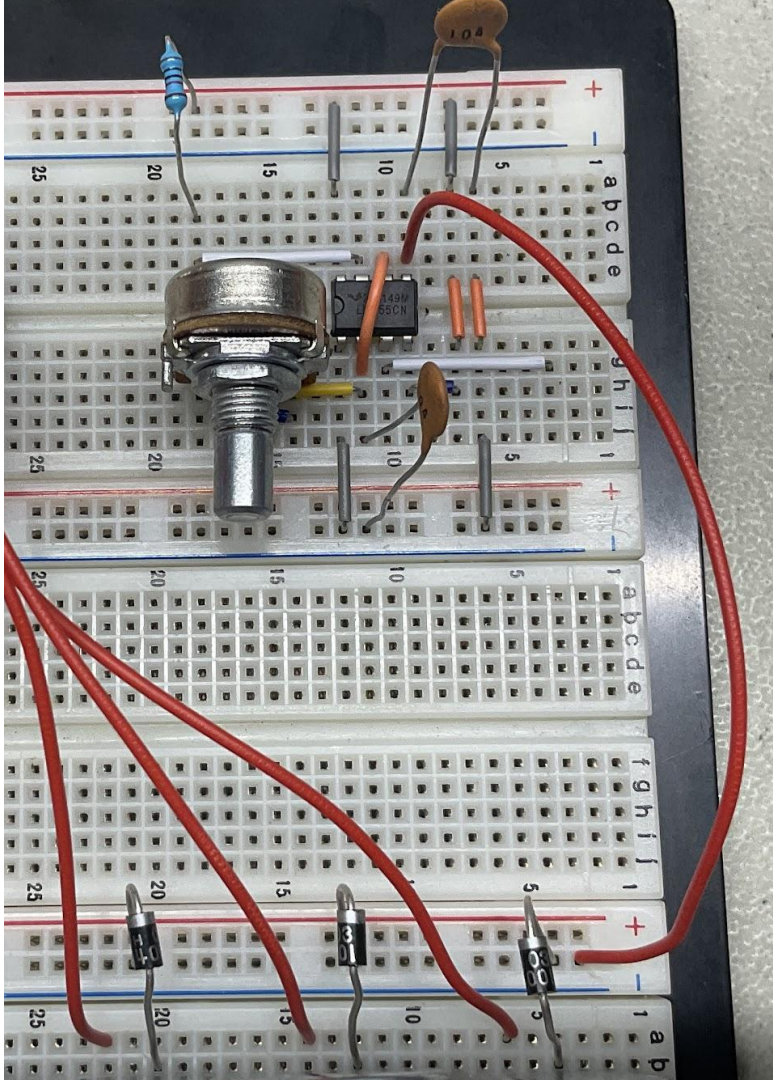
8 Step Sequencer - The Tone

- Connect pin 2 (trigger) to ground through a 100 nanoFarad (104) capacitor.
- The RC timing circuit is now complete.



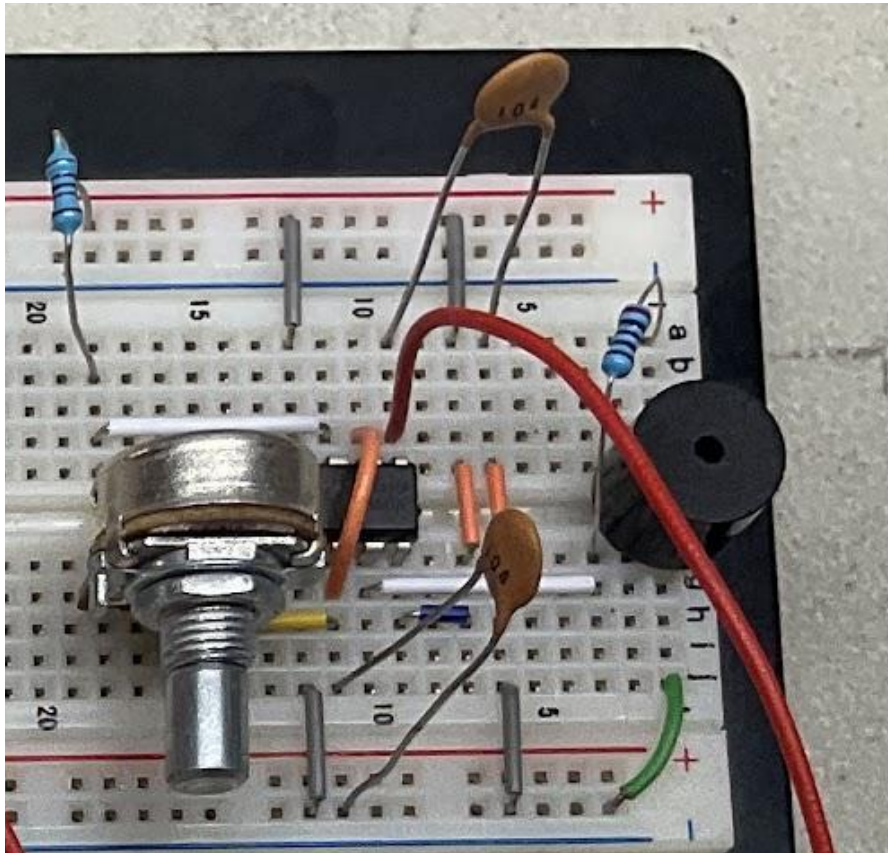
8 Step Sequencer - The Tone

- If we want to connect our tone circuit to the rest of our circuit we have to feed the voltages coming from our variable resistors into the control voltage of the 555 timer.
- The red jumper wire is doing just that; connecting the common rail that all diodes are connected to into pin 5 (control) voltage on the 555 timer.
- We can now vary the frequency of the 555 timer by simply adjusting the voltage present at this pin.



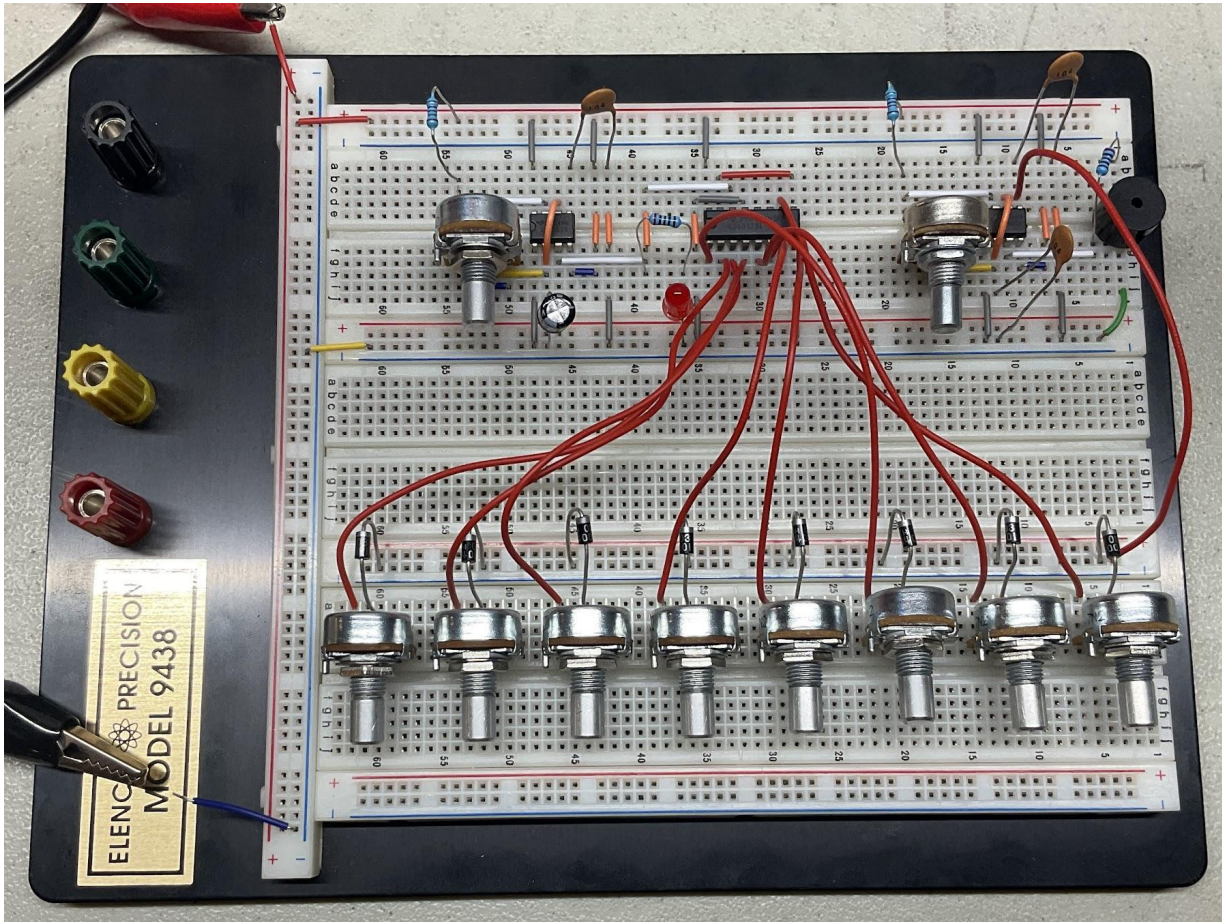
8 Step Sequencer - The Tone

- Lastly, connect a 200 ohm (red, black, black, black) resistor to pin 3 (output) and then connect either a buzzer or speaker to ground.
- We should be all set to make some cool electronic music!



Build Together 10: Final Circuit

- The top left potentiometer will vary the speed of your sequence.
- The top right potentiometer will vary the overall frequency range of the sequence.
- The bottom 8 potentiometers will vary the frequency of each individual note of the sequence.



Final Thoughts

- In what ways could you improve this 8 step sequencer?
- What would be some interesting features to add?
- How do you think you would implement them?