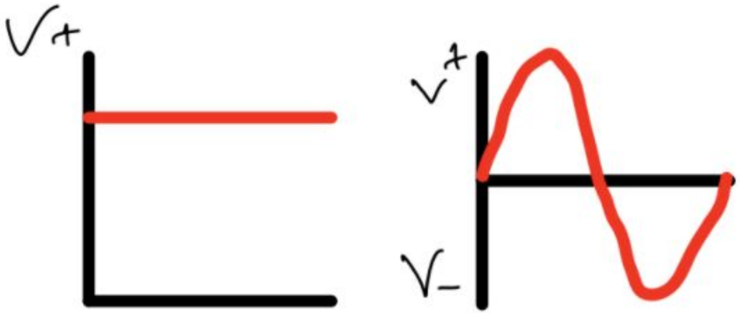
Transistors and Capacitors AC Applications

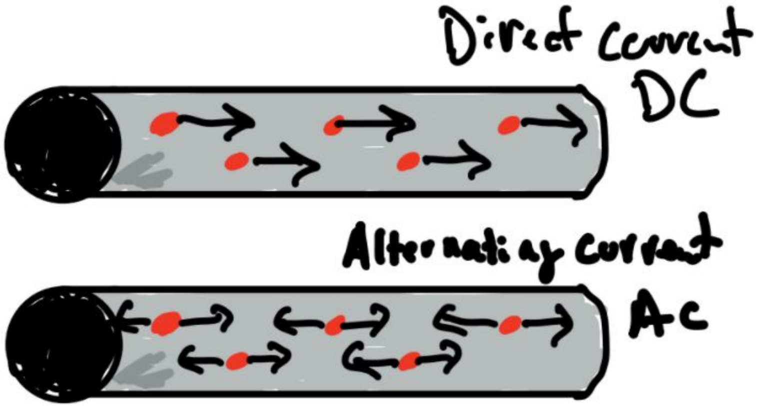
Alternating Current

AC versus DC

- Everything that we've done so far has been powered by a 9 volt battery or power supply.
- Batteries provide DC voltage.
- DC, or **direct current**, is current that flows in one direction; the positive direction.

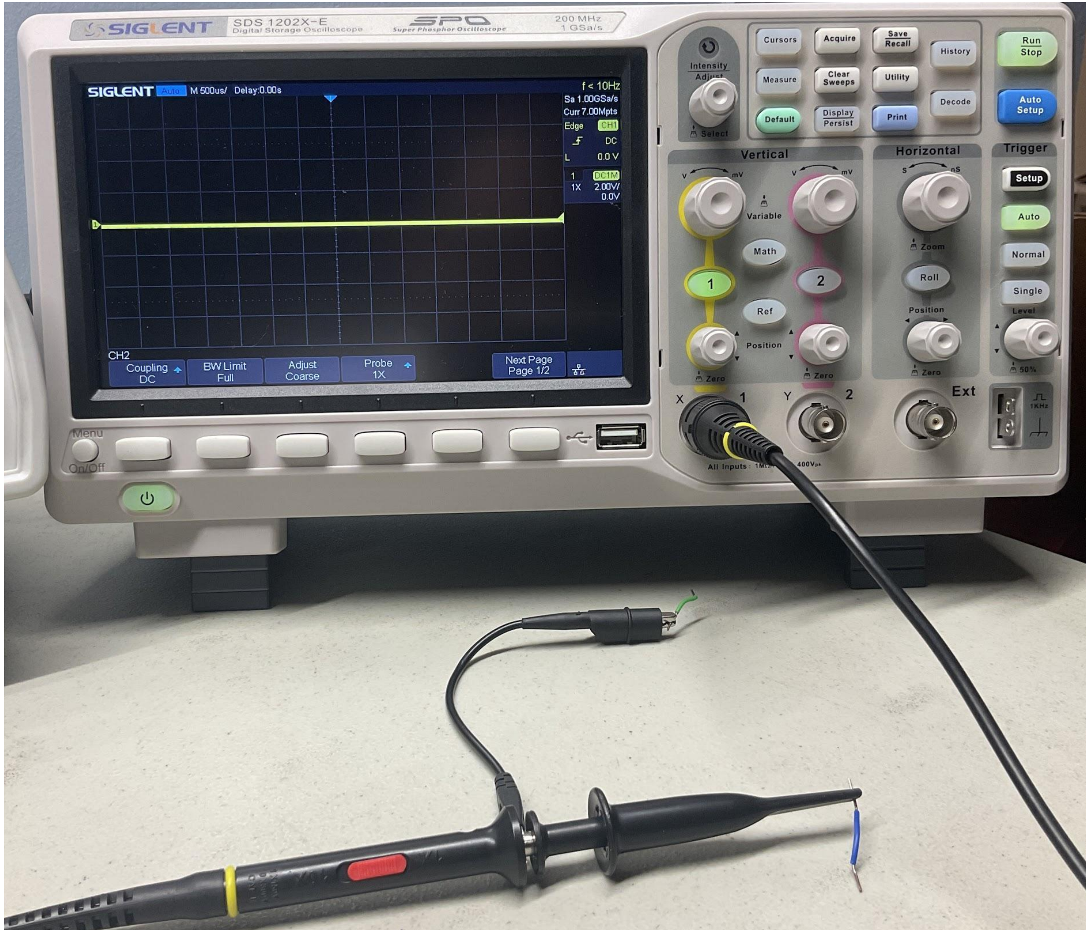


- AC, or **alternating current**, is current that flows in two directions; positive and negative, constantly alternating the direction of in which the charge is moving.
- Electrical outlets, audio signals, or a function generator can supply AC voltage.



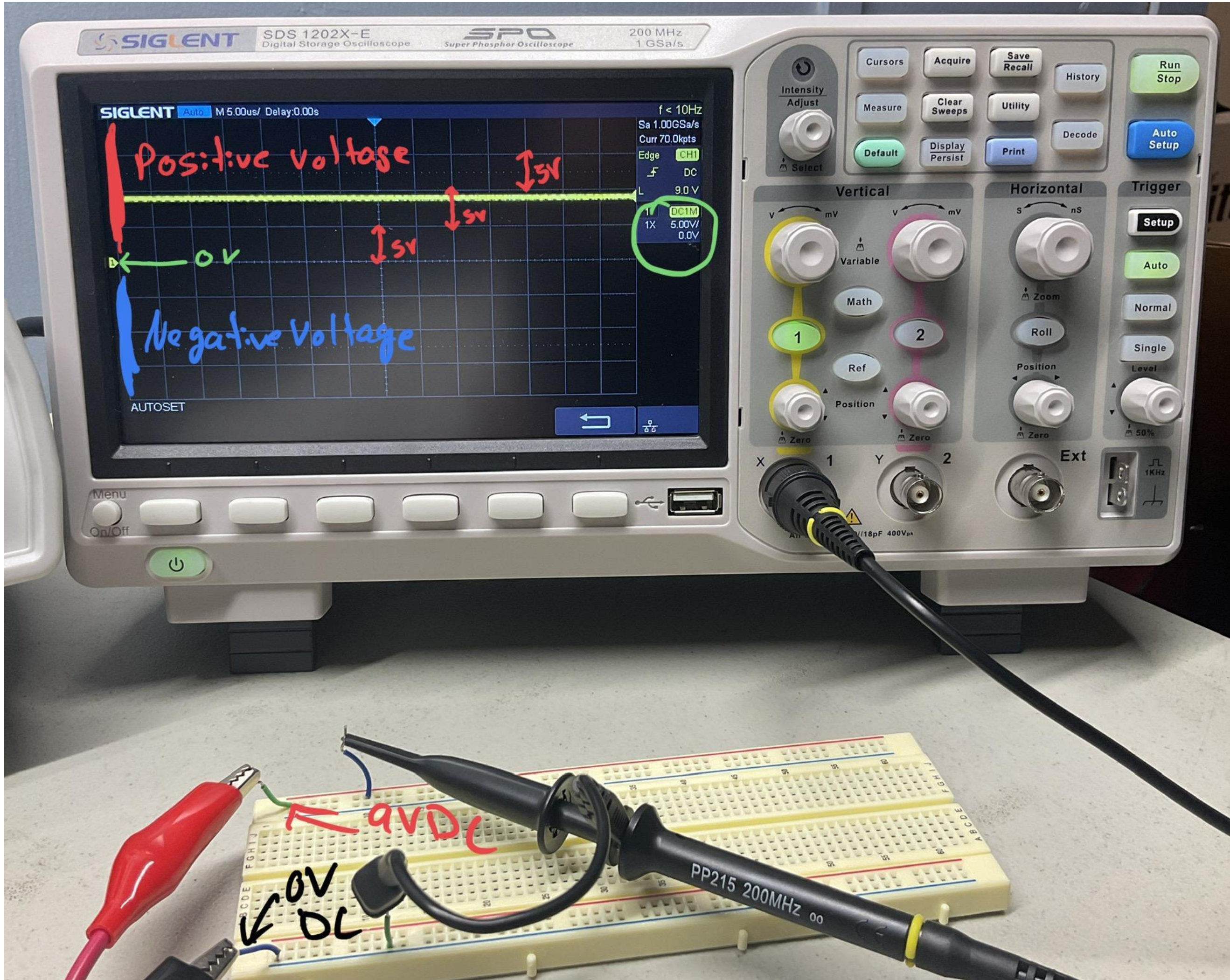
New Tool: The Oscilloscope

- A voltmeter was a good tool to measure DC voltages; this is because the voltage wasn't changing with respect to time.
- With AC signals, the voltage does change with respect to time. This makes reading AC signals with a voltmeter difficult.
- Instead, we can use an **oscilloscope** to measure signals.
- The oscilloscope has a probe that you can put into your circuit to read values. The probe must be grounded!



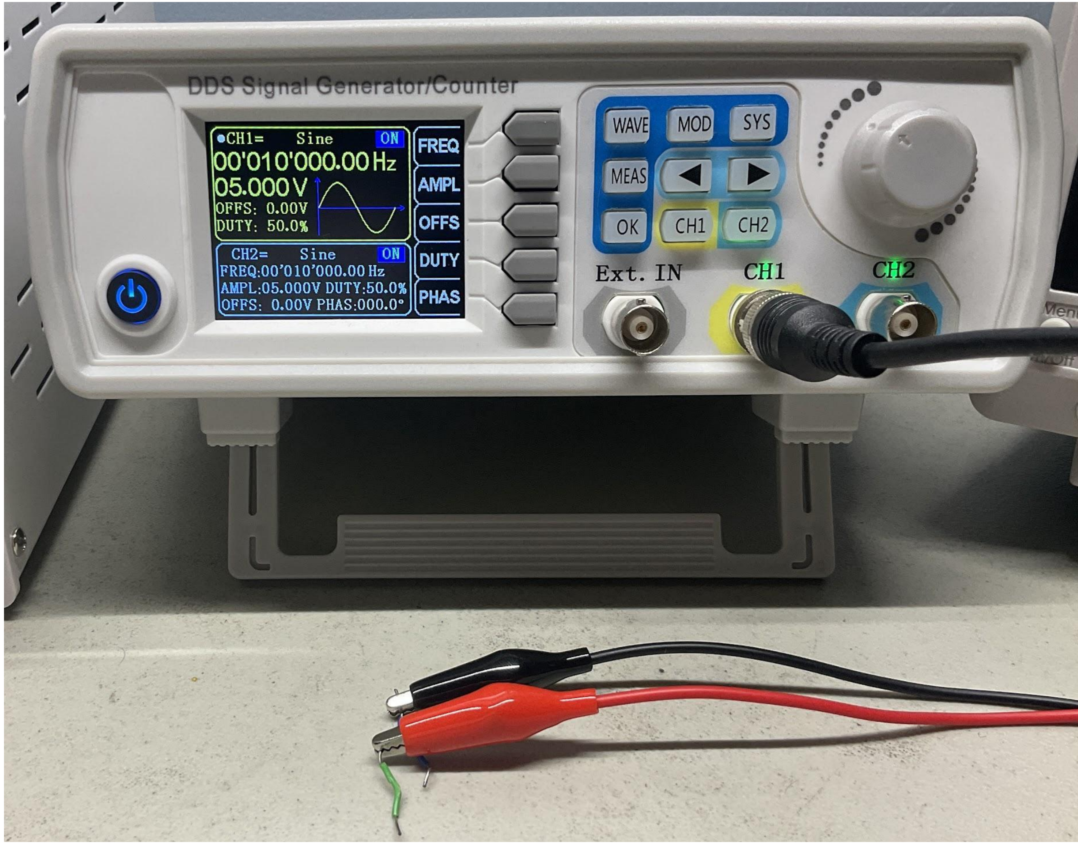
Oscilloscope DC

- Note the reference to ground (0 volts).
- Everything above ground is positive voltage.
- Everything below ground is negative voltage.
- Note how the 9V DC signal is always positive and never changes into negative. It never changes direction.
- You have to be aware of the scale. Here we are at 5 volts per division so each division represents 5 volts.



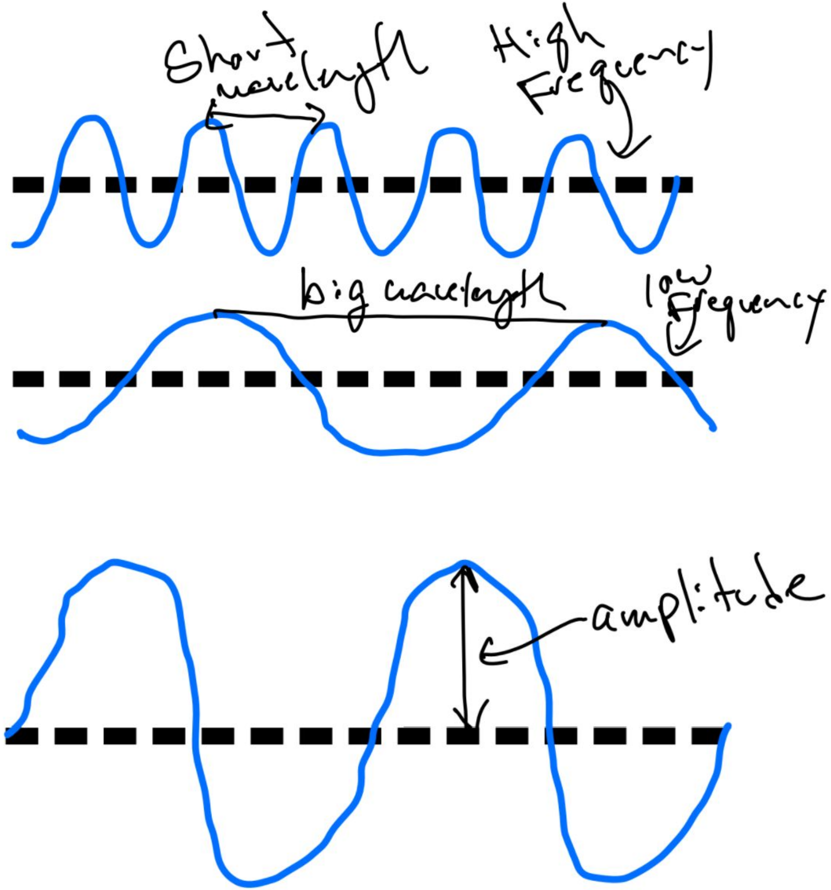
New Tool: The Function Generator

- A function generate is a tool to generate AC signals.
- Typically, you can control the frequency and amplitude of the signal.
- You can also control the waveform and other characteristics as well.
- The function generator has two leads that you can put into your circuit to provide an AC signal.



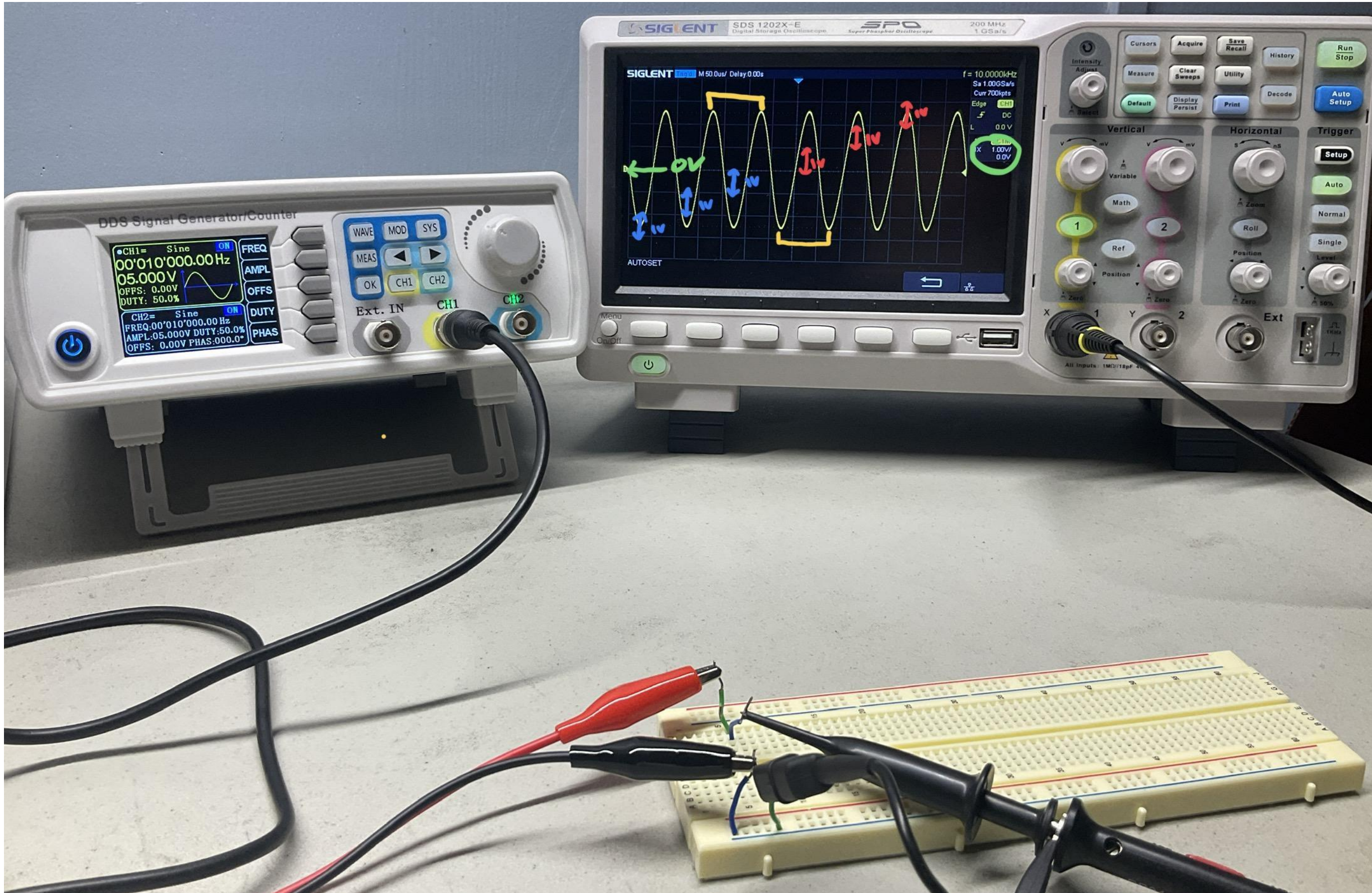
AC Waveforms

- **Frequency** (hertz) is a measure of how quickly the oscillations of a wave are happening. For sound, the higher the frequency, the higher the pitch.
- **Amplitude** (volts) is a measure of the displacement of the wave from its equilibrium position (ground). For sound, the higher the amplitude of, the louder the sound.



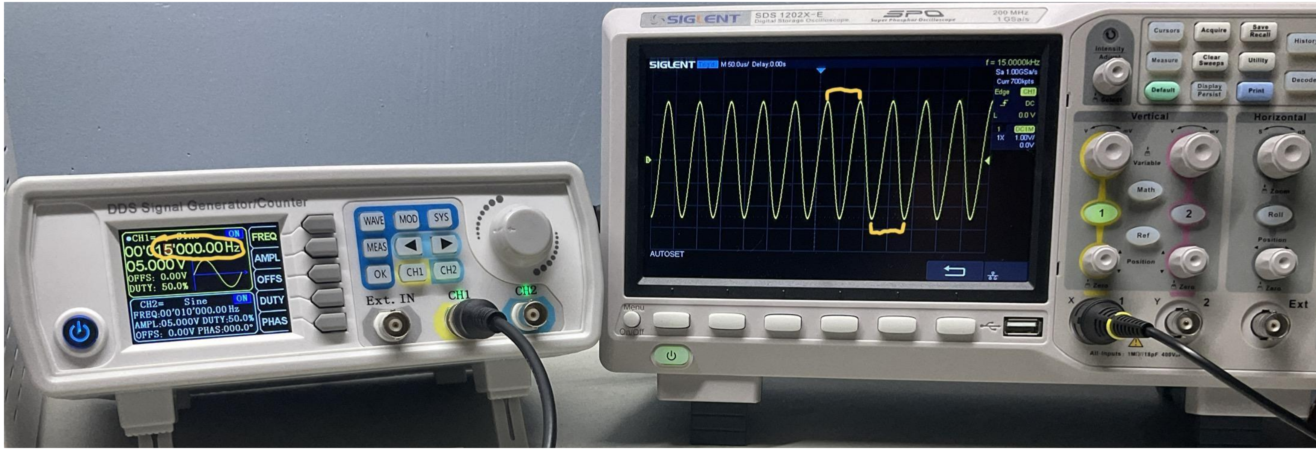
Oscilloscope AC

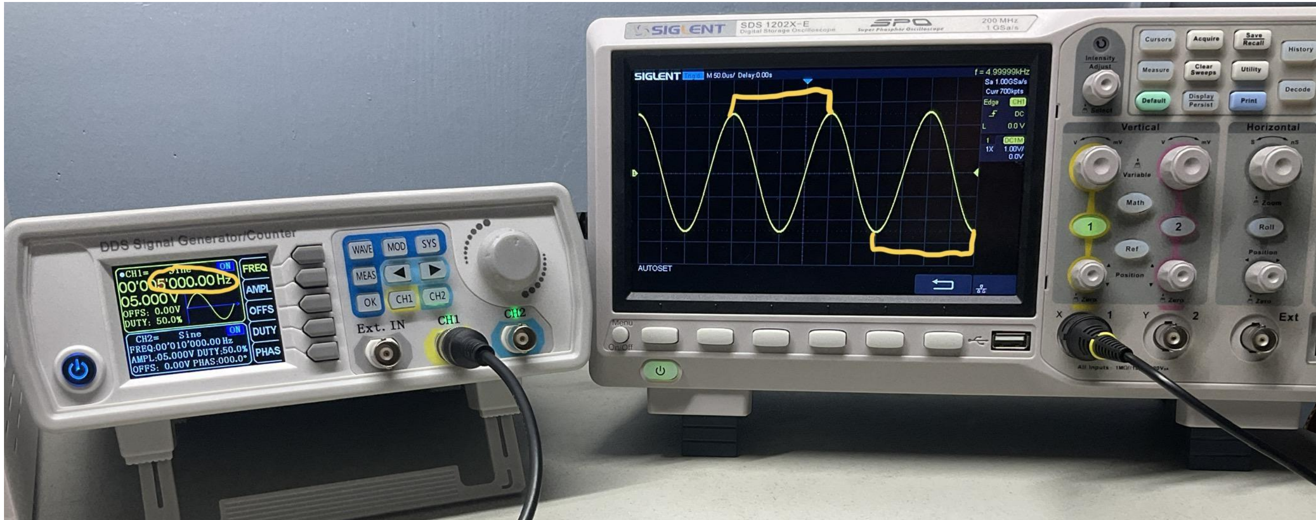
- On the scope, note the scale is 1 volt per division.
- There are roughly 2.5 volts above ground (positive) and 2.5 volts beneath ground (negative) giving a total voltage of 5 volts.
- The frequency is 10,000 Hz.



Oscilloscope AC

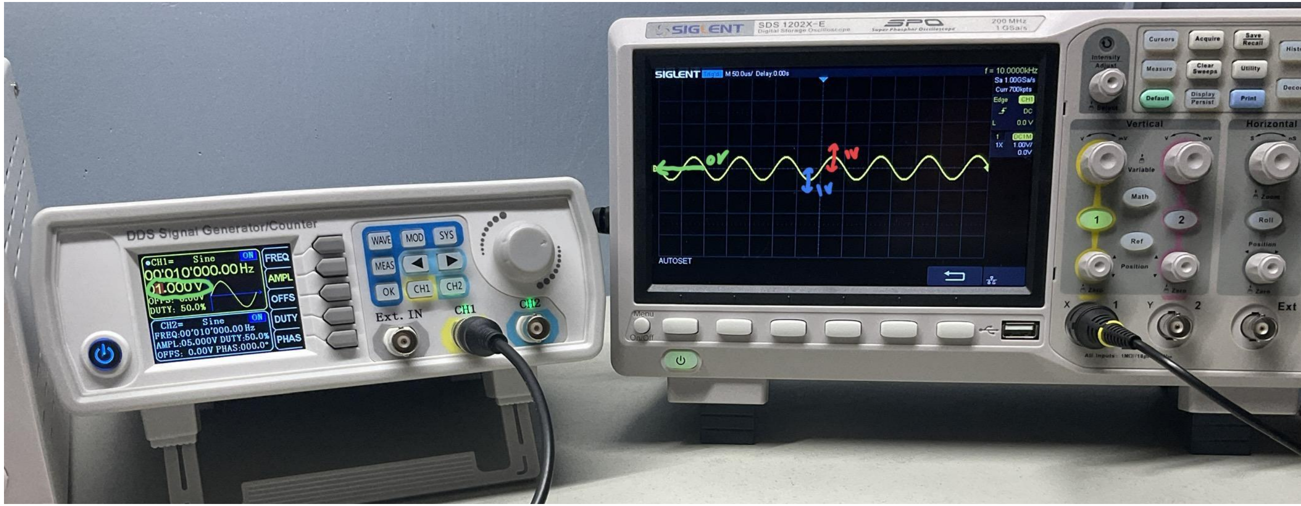
- Increasing the frequency to 15,000 Hz you see the waveforms get closer together.
- Decreasing the frequency to 5,000 Hz you see the waveforms get further apart.





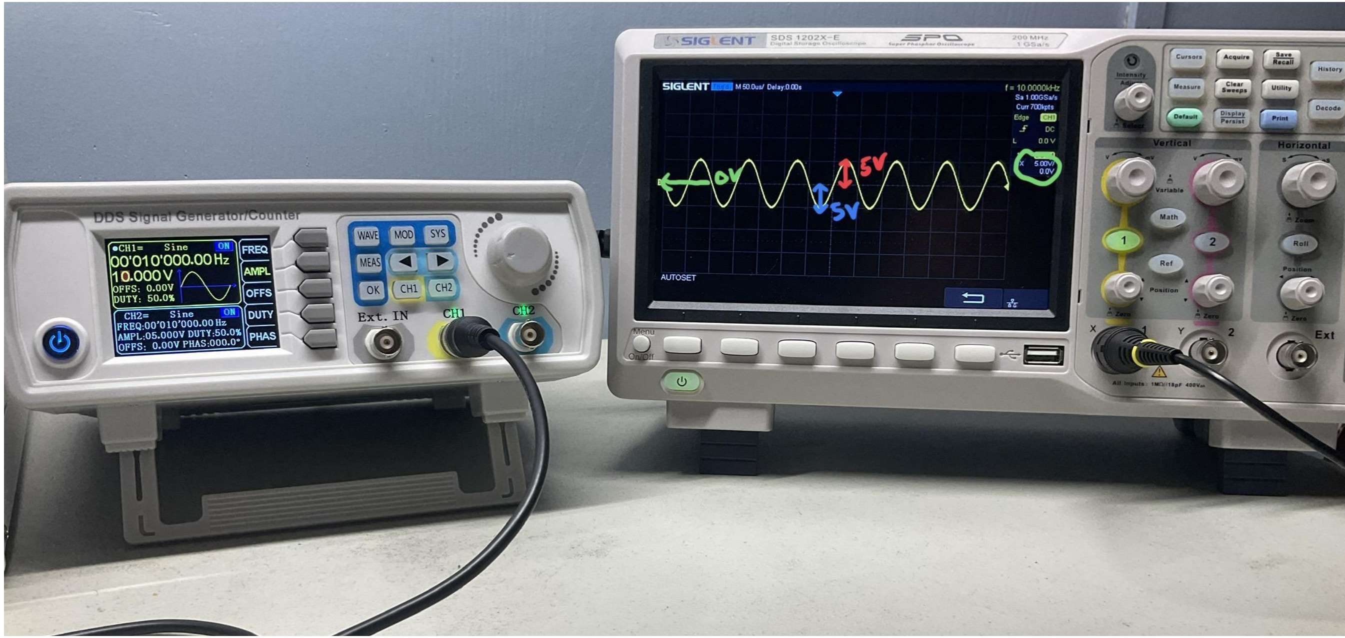
Oscilloscope AC

- Decreasing the amplitude to 1 V makes the waveform shorter.
- Increasing the amplitude to 10 V makes the waveform taller.
- It’s so tall, that it doesn’t fit in our window...we should change the scale from 1 volt per division to something else!



Oscilloscope AC

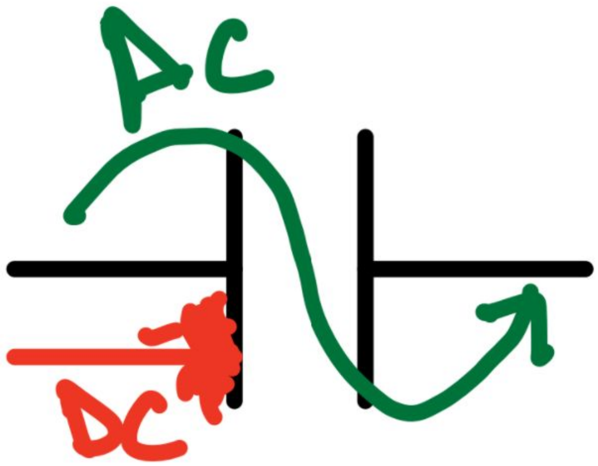
- Here is the same waveform with the scale adjusted to 5 volts per division.



Capacitors and AC

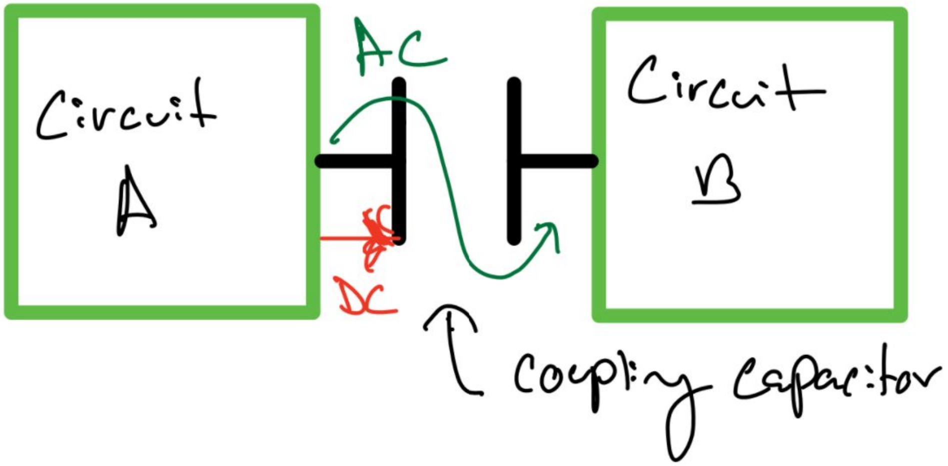
Capacitors and AC Signals

- Capacitors “sort of” behave like resistors.
- They offer HUGE “resistance” to low frequencies (DC has a frequency of 0 Hz)!
- They offer NO “resistance” to high frequencies!



Coupling Capacitors

- Coupling capacitors block DC signals while allowing AC signals to pass through.
- Imaging in the diagram, circuit 1 is a microphone. The microphone will get an audio signal (AC signal) but will need a DC signal to operate.
- Perhaps circuit 2 is an amplifier. We don't want to amplify the DC signal only the AC audio signal so we can block the DC with a coupling capacitor.



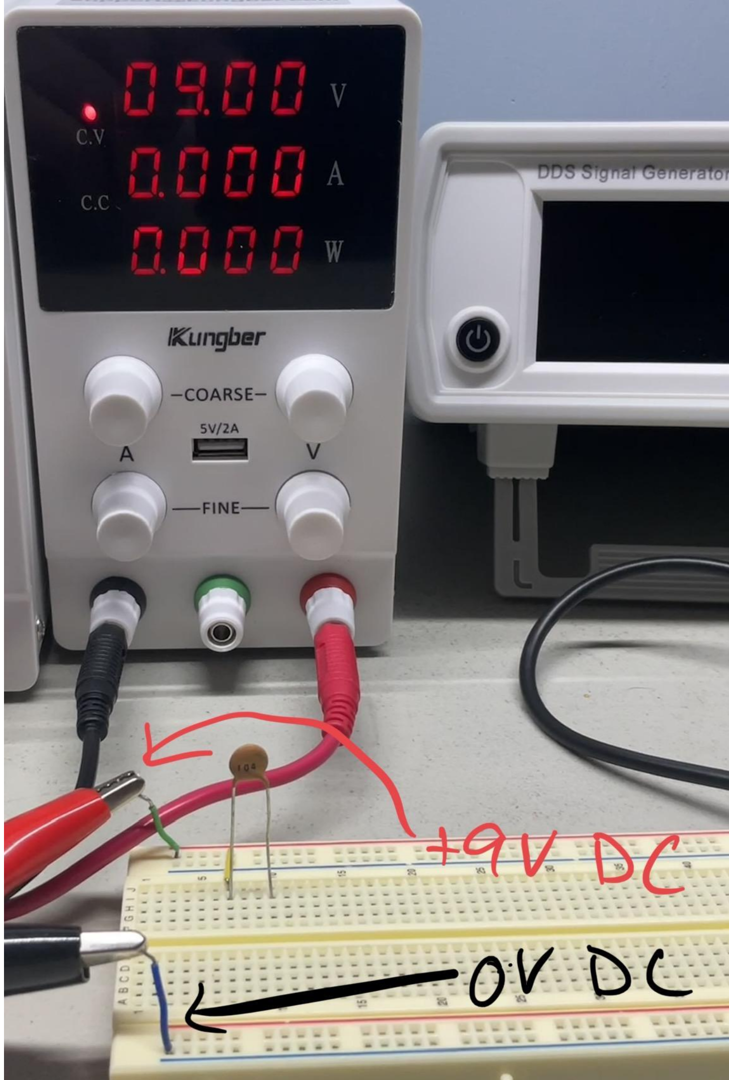
Capacitors offer more "resistance" for lower frequency signals and less "resistance" for higher frequency signals.

Rule of thumb for choosing capacitor values:

- For coupling a 100 Hz signal, a 10 μF capacitor can be used.
- For a 1000 Hz signal, a 1 μF capacitor can be used.
- For a 10 KHz signal, a 100 nF capacitor can be used.
- For a 100 KHz signal, 10 nF capacitor can be used.
- For a 1 MHz signal, a 1 nF capacitor can be used.
- For a 10 MHz signal, a 100 pF capacitor can be used.
- For a 100 MHz signal, a 10 pF capacitor can be used.

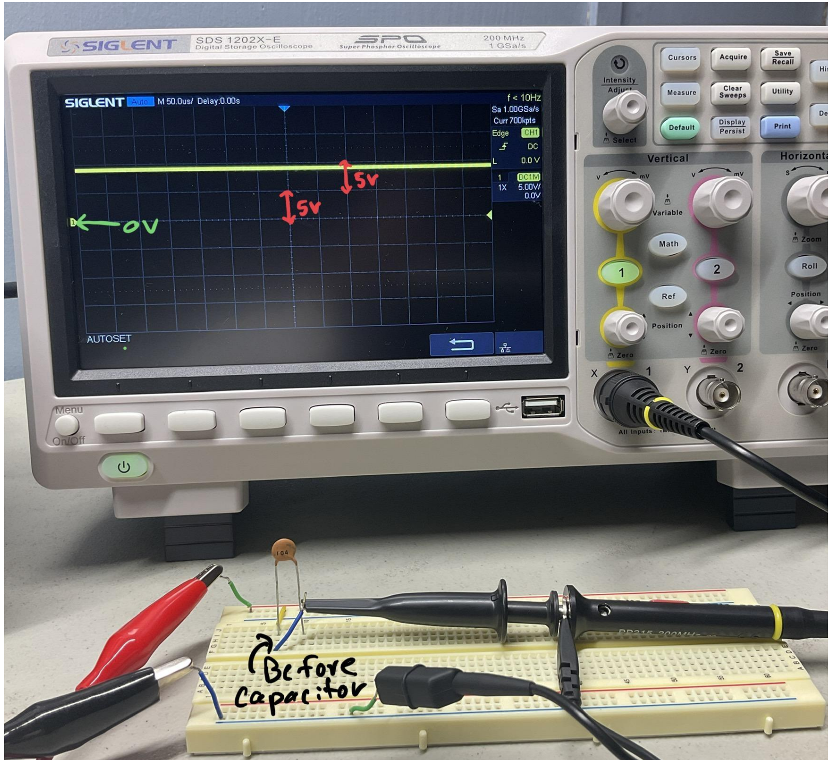
Coupling Capacitors: Blocking DC

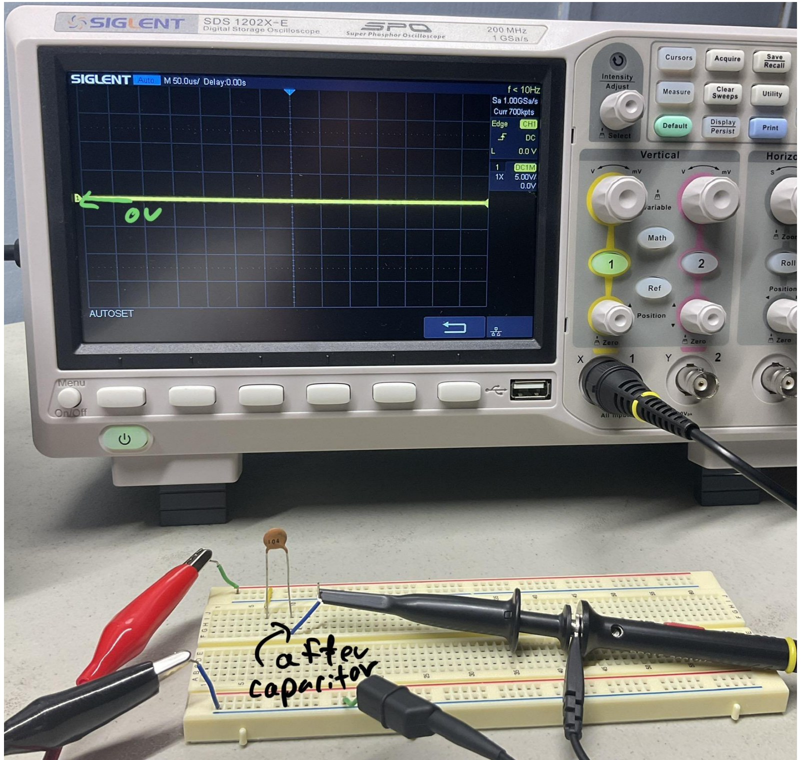
- Here is a 100 nanoFarad (0.1 microFarad) capacitor hooked up to a 9 volt DC signal.
- The capacitor should “block” this DC signal.



Coupling Capacitors: Blocking DC

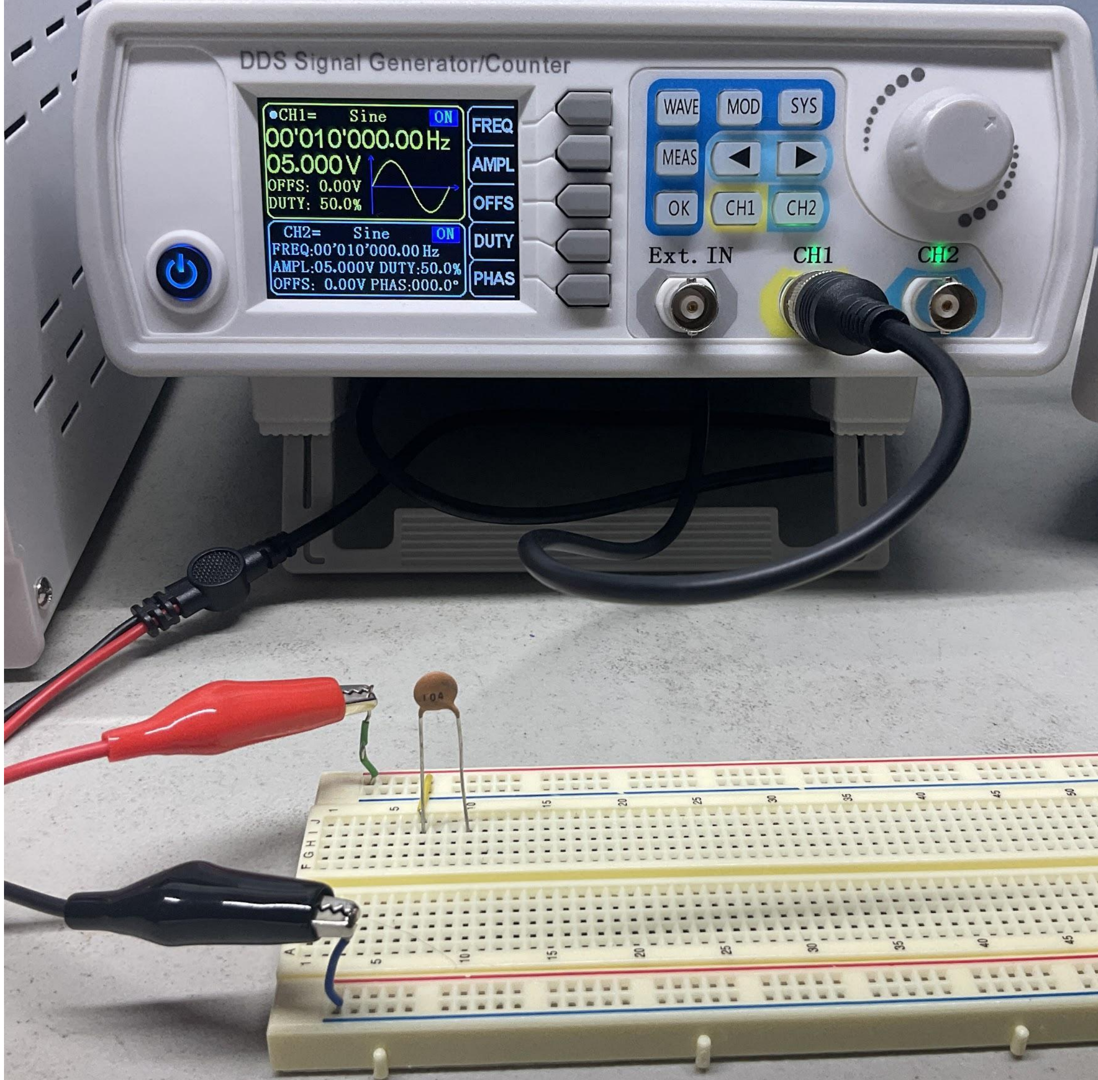
- Putting the scope before the capacitor, you can see the 9 volt DC signal.
- Putting the scope after the capacitor, you can see we are at 0 volts.
- The capacitor blocked the DC signal!





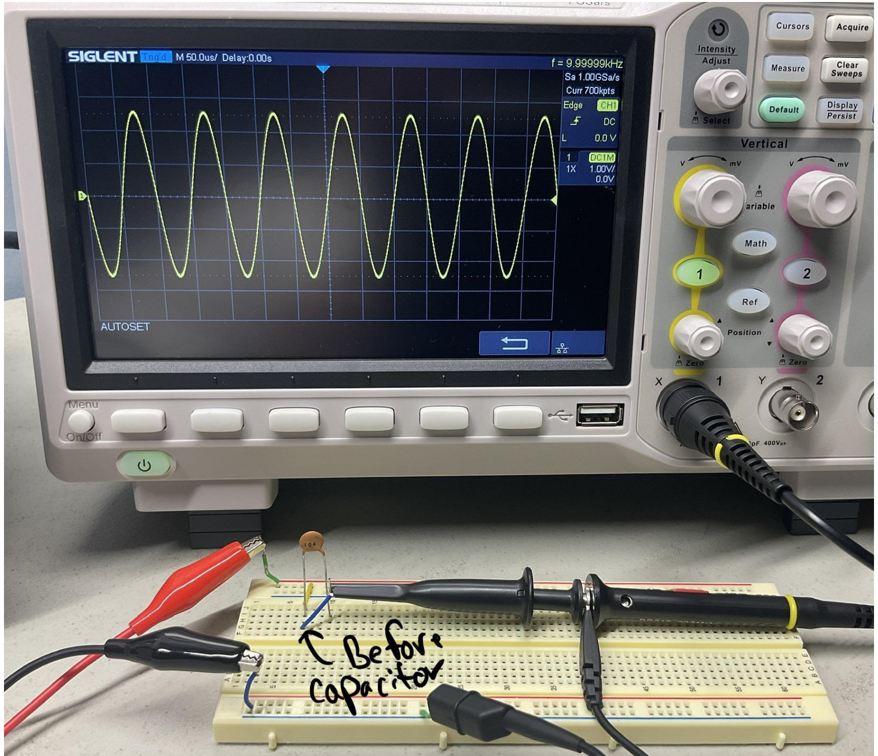
Coupling Capacitors: Passing AC

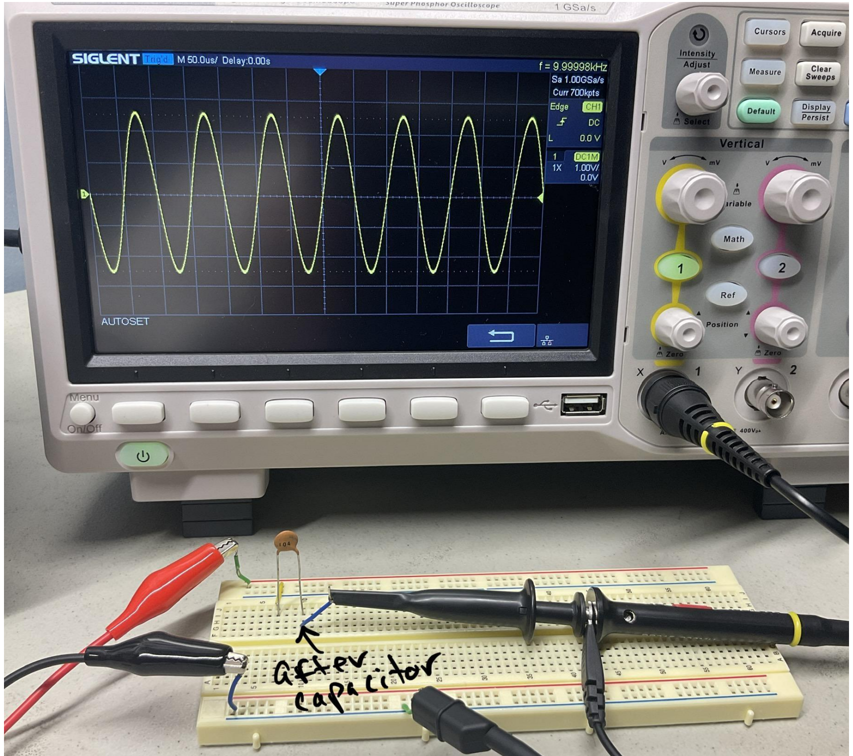
- Here is a 100 nanoFarad (0.1 microFarad) capacitor hooked up to a 5 volt AC signal with a frequency of 10,000 Hz.
- The capacitor should pass this AC signal.



Coupling Capacitors: Passing AC

- Putting the scope before the capacitor, you can see the 5 volt AC signal.
- Putting the scope after the capacitor, you can see we have the same signal.
- The capacitor passed the AC signal!

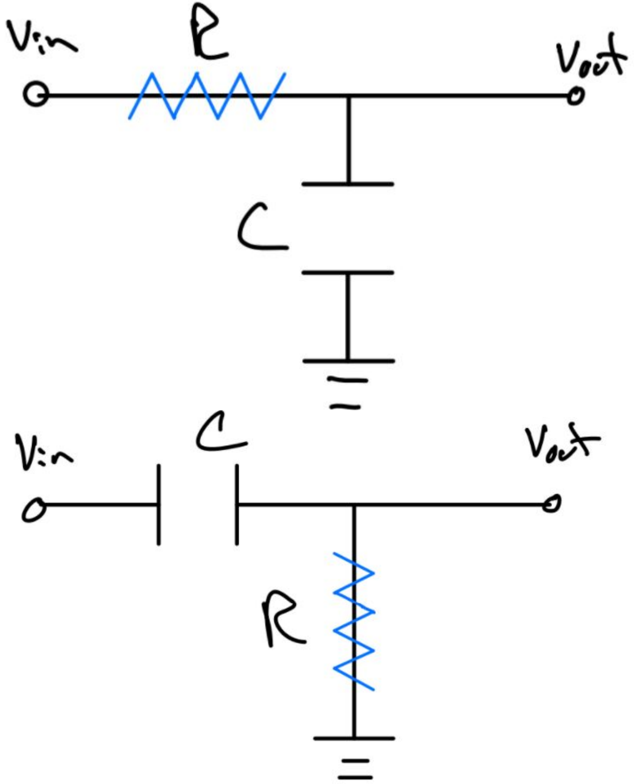




RC Filters

$$f_{cutoff} = \frac{1}{2\pi RC}$$

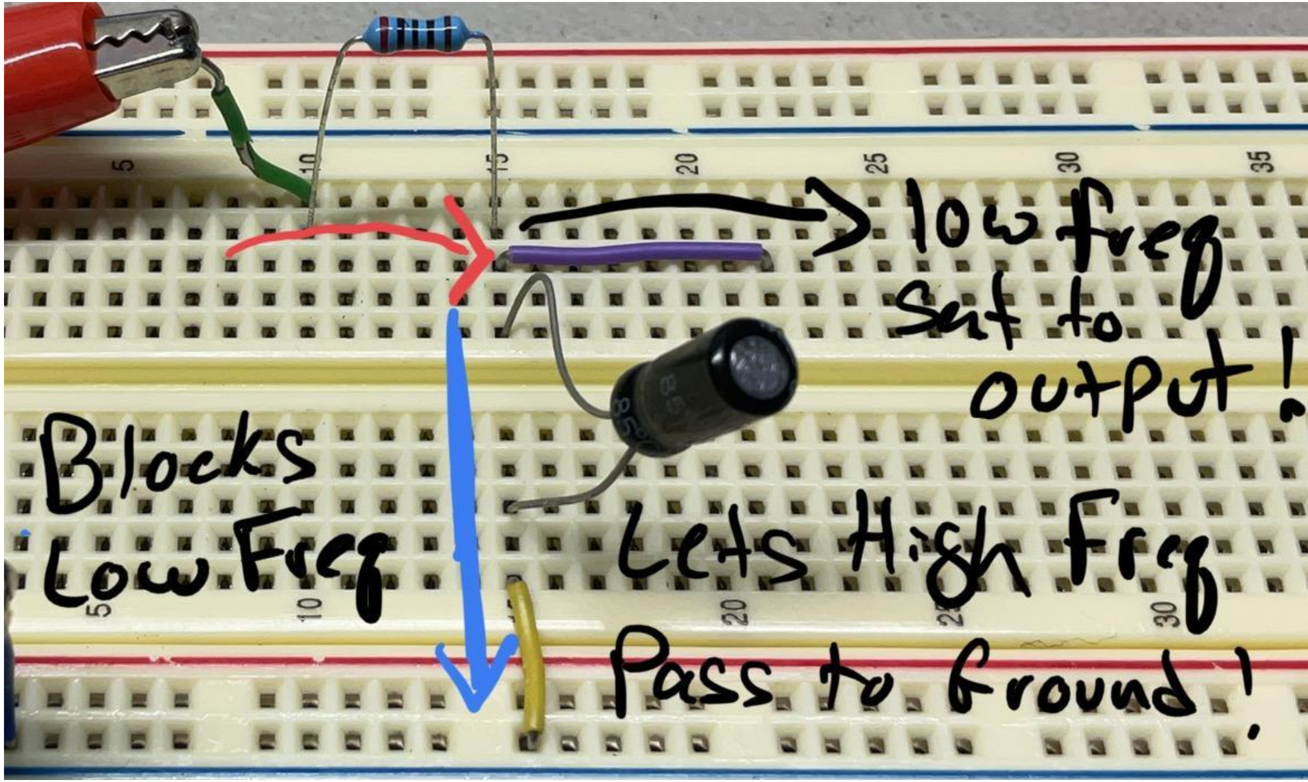
- While a coupling capacitor essentially blocks all “low frequencies” while letting all “high frequencies” pass, one can get better control over the range of frequencies blocked or allowed to pass by creating an RC filter.
- An RC filter is a resistor and capacitor combination that has a “cutoff frequency” of $1/(2\pi RC)$.
- The cutoff frequency is the point at which the output voltage falls to roughly 70% the input voltage.



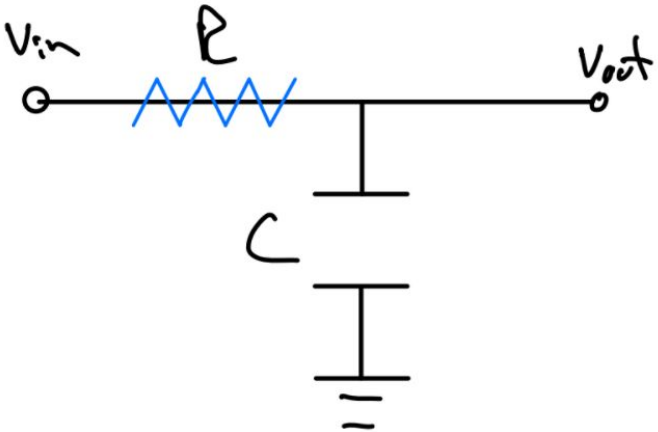
RC Low Pass Filters

RC Filters: The Low Pass Filter

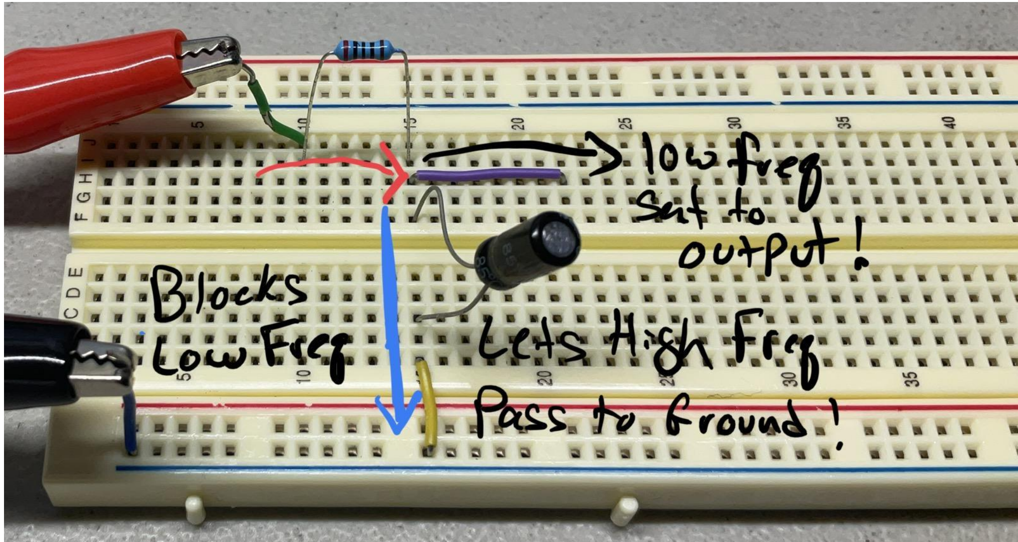
- We can build a low pass filter by first placing a 200 ohm (red, black, black, black) resistor into the breadboard.
- Connect a jumper wire at your resistor to move the output of your filter away for easy access.
- Connect a 1 microFarad capacitor from your resistor to ground.
- Your low pass filter is complete!



RC Filters: The Low Pass Filter



- The AC signal passes through a 200 ohm resistor and then is presented with two paths.
  - First, the signal can travel to the output.
  - Second, the signal can travel to a 1 microFarad capacitor to ground.
- For low frequencies, the capacitor offers LARGE resistance, so the low frequencies pass to the output.
- For high frequencies, the capacitor offers ZERO resistance, so the high frequencies pass right to ground.
- High frequencies do not go to the output.



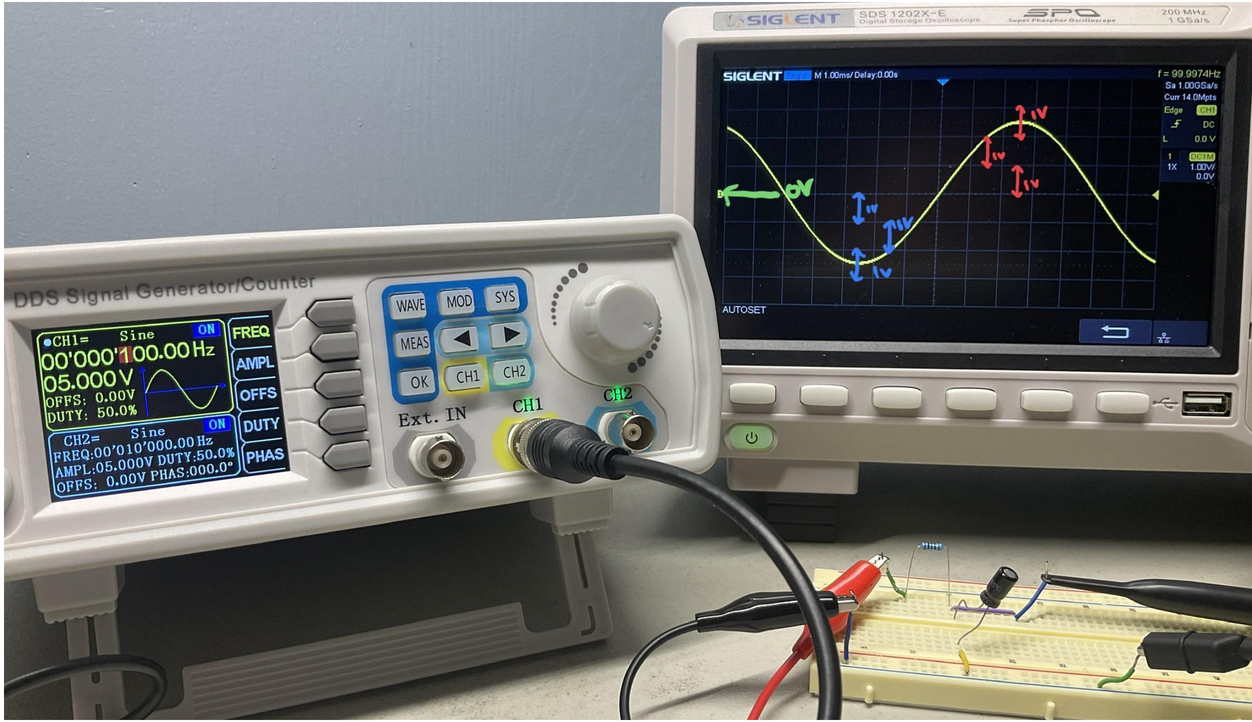
RC Filters: The Low Pass Filter

- At 100 Hz, the AC signal has an amplitude of roughly 5 volts after the low pass filter.
- The cutoff frequency of this filter is

$$1/(2\pi RC)$$

$$1/(2\pi * 200\text{ohms} * 1\text{microFarad})$$

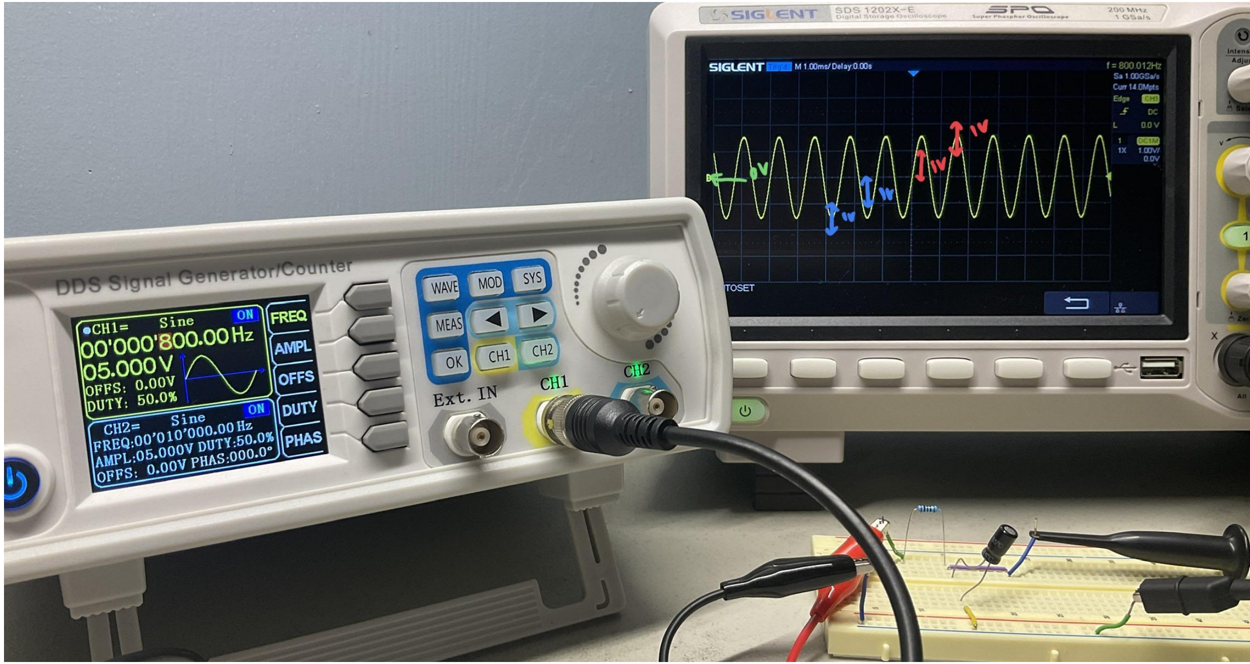
796 Hz



RC Filters: The Low Pass Filter

- At 800 Hz, the AC signal has an amplitude of roughly 3.4 volts after the low pass filter.
- This is approximately the cutoff frequency which is where the signal should be roughly 70% the input voltage.

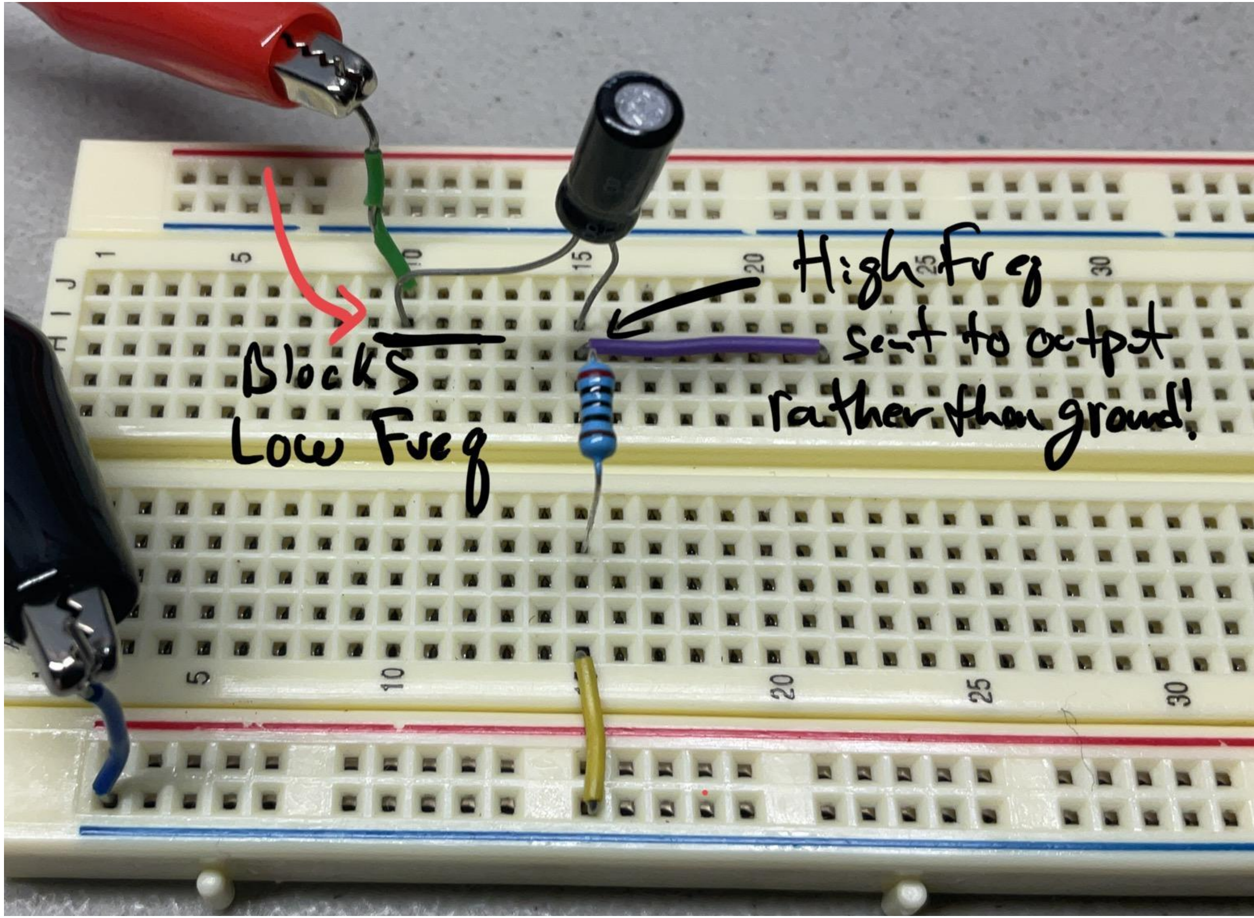
5 volts * 0.70 = 3.5 volts



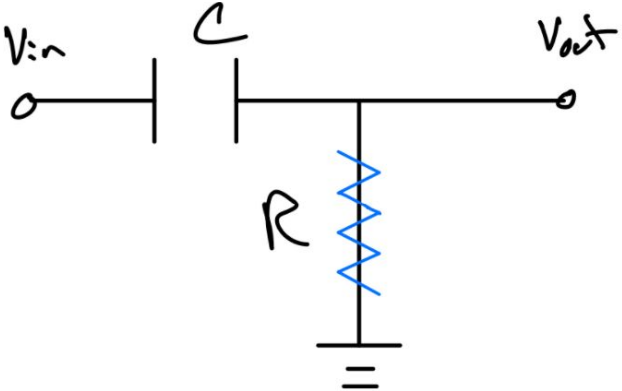
RC High Pass Filters

RC Filters: The High Pass Filter

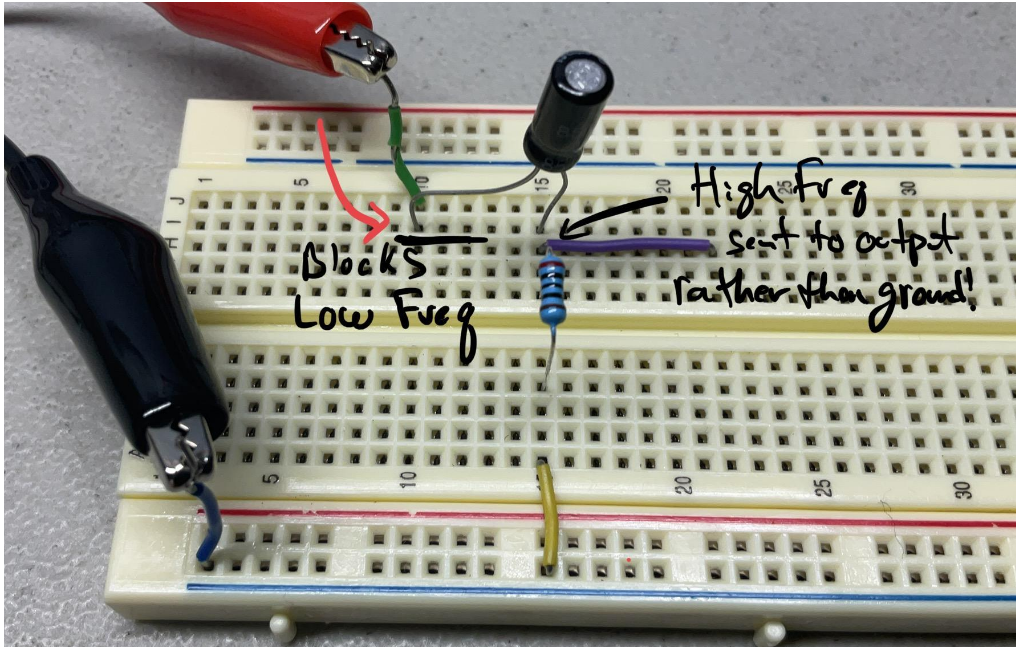
- We can build a high pass filter by first placing a 1 microFarad capacitor into the bread board.
- Connect a jumper wire at your capacitor to move the output of your filter away for easy access.
- Connect a 200 ohm resistor (red, black, black, black) from your capacitor to ground.
- Your high pass filter is complete!



RC Filters: The High Pass Filter



- The AC signal passes through a 1 microFarad capacitor.
- For low frequencies, the capacitor offers LARGE resistance, so the low frequencies are blocked.
- For high frequencies, the capacitor offers ZERO resistance, so the high frequencies pass through.
- The high frequencies are then presented with two paths.
    - First, the signal can travel to the output.
    - Second, the signal can travel to a 200 ohm resistor to ground.
- Since, the path to output offers minimal resistance, high frequencies will go to the output.



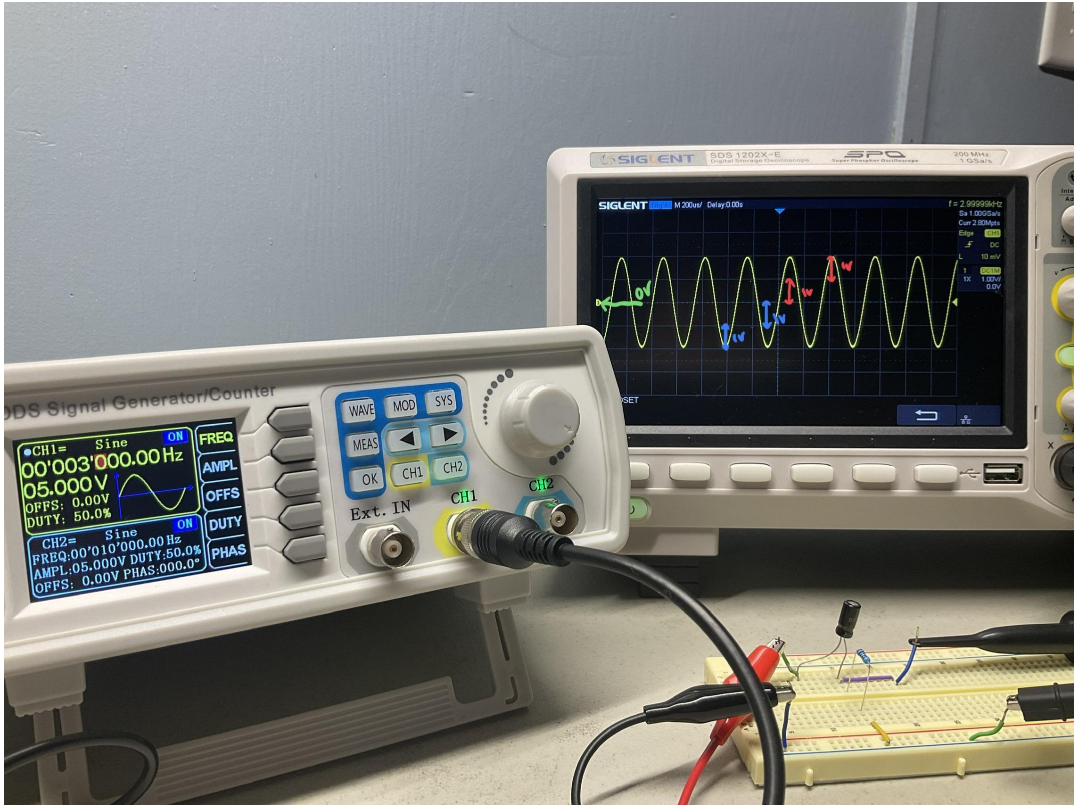
RC Filters: The High Pass Filter

- At 3,000 Hz, the AC signal has an amplitude of roughly 4 volts after the high pass filter.
- The cutoff frequency of this filter is

$$1/(2\pi RC)$$

$$1/(2\pi*200ohms*1microFarad)$$

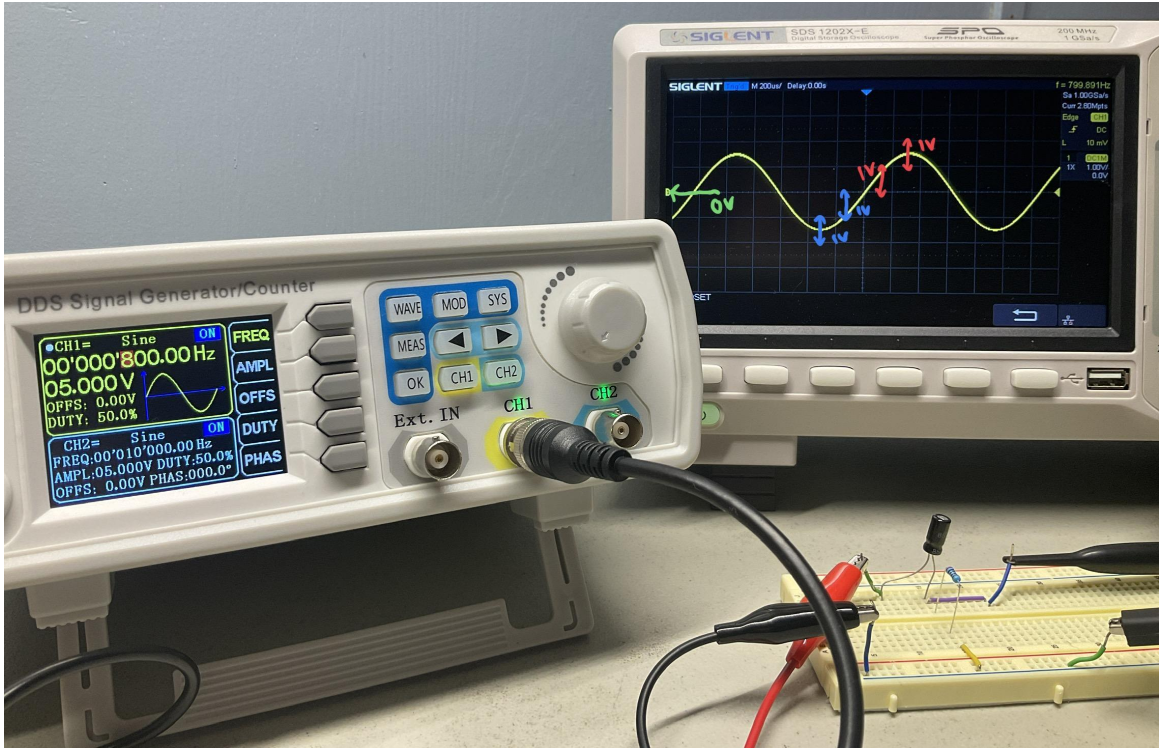
796 Hz



RC Filters: The High Pass Filter

- At 800 Hz, the AC signal has an amplitude of roughly 2.6 volts after the high pass filter.
- This is approximately the cutoff frequency which is where the signal should be roughly 70% the input voltage.

4 volts * 0.70 = 2.8 volts



Circuit Challenge 8

You Shall Not Pass!

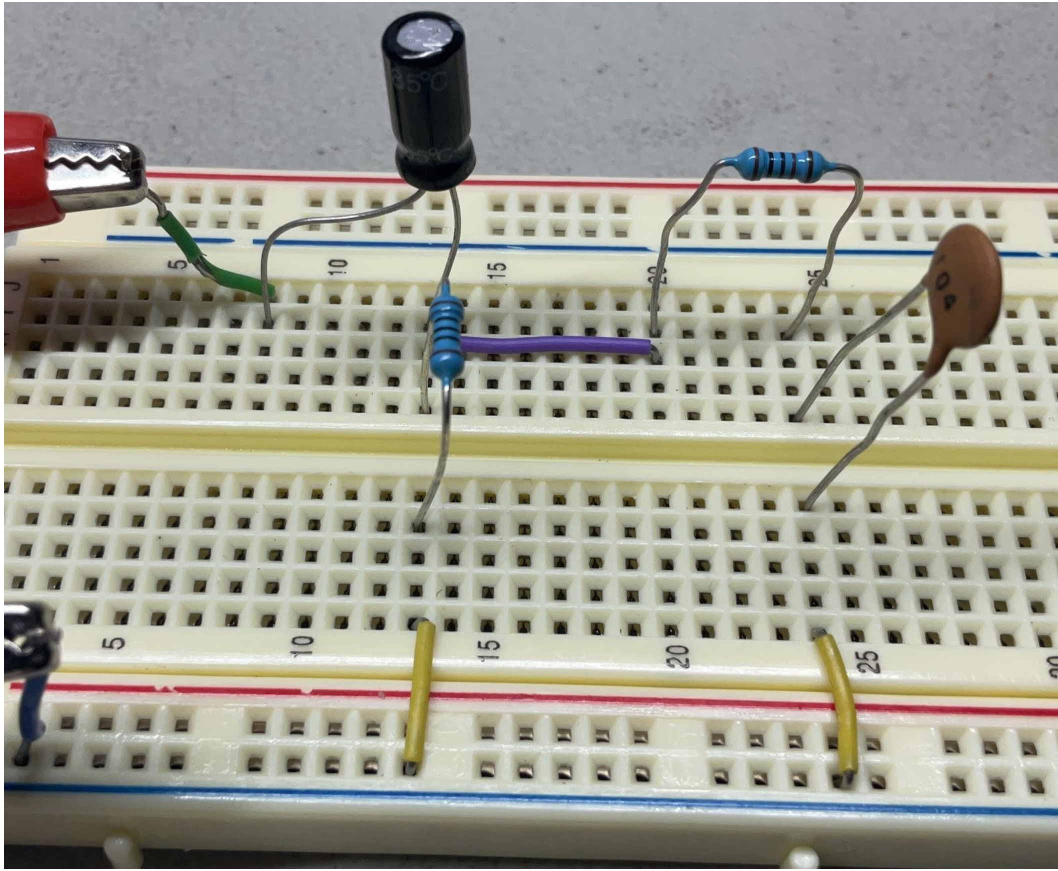
Circuit Challenge 8: You Shall Not Pass!

- Can you make a filter that passes all frequencies below roughly 1600 Hz but begins to block anything below roughly 800 Hz?
- You should use only the following: 100 nanoFarad capacitor, 1 microFarad capacitor, 200 ohm (red, black, black, black) resistor, and 1000 (brown, black, black brown) ohm resistor.
- **Hint**: You’ve made a low pass filter that passes frequencies below a cutoff frequency. You’ve also made a high pass filter that blocks any frequencies below a cutoff frequency...perhaps you need both here???

DO NOT ADVANCE to the next slide without trying to figure this out first!

Circuit Challenge 8: Solution

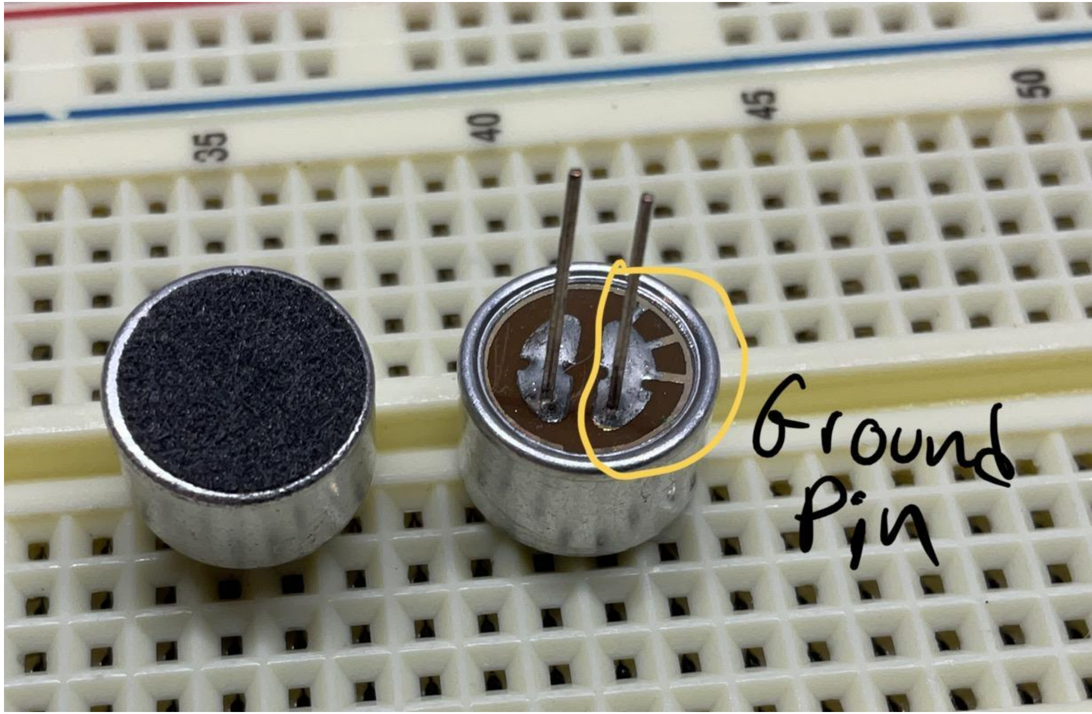
- The first filter (high pass) consists of a 1 microFarad capacitor and 200 ohm resistor for a cutoff frequency of 796 Hz.
- This will begin to block frequencies below roughly 800 hz.
- The second filter (low pass) consists of a 100 nanoFarad capacitor and 1000 ohm resistor for a cutoff frequency of 1591 Hz.
- This will begin to block all frequencies above 1600 Hz.
- This type of filter is known as a **band pass filter** because it passes a band of frequencies. In our case, any signal with frequency between 800 Hz and 1600 Hz will not be attenuated (signal decreased).



Using a Microphone

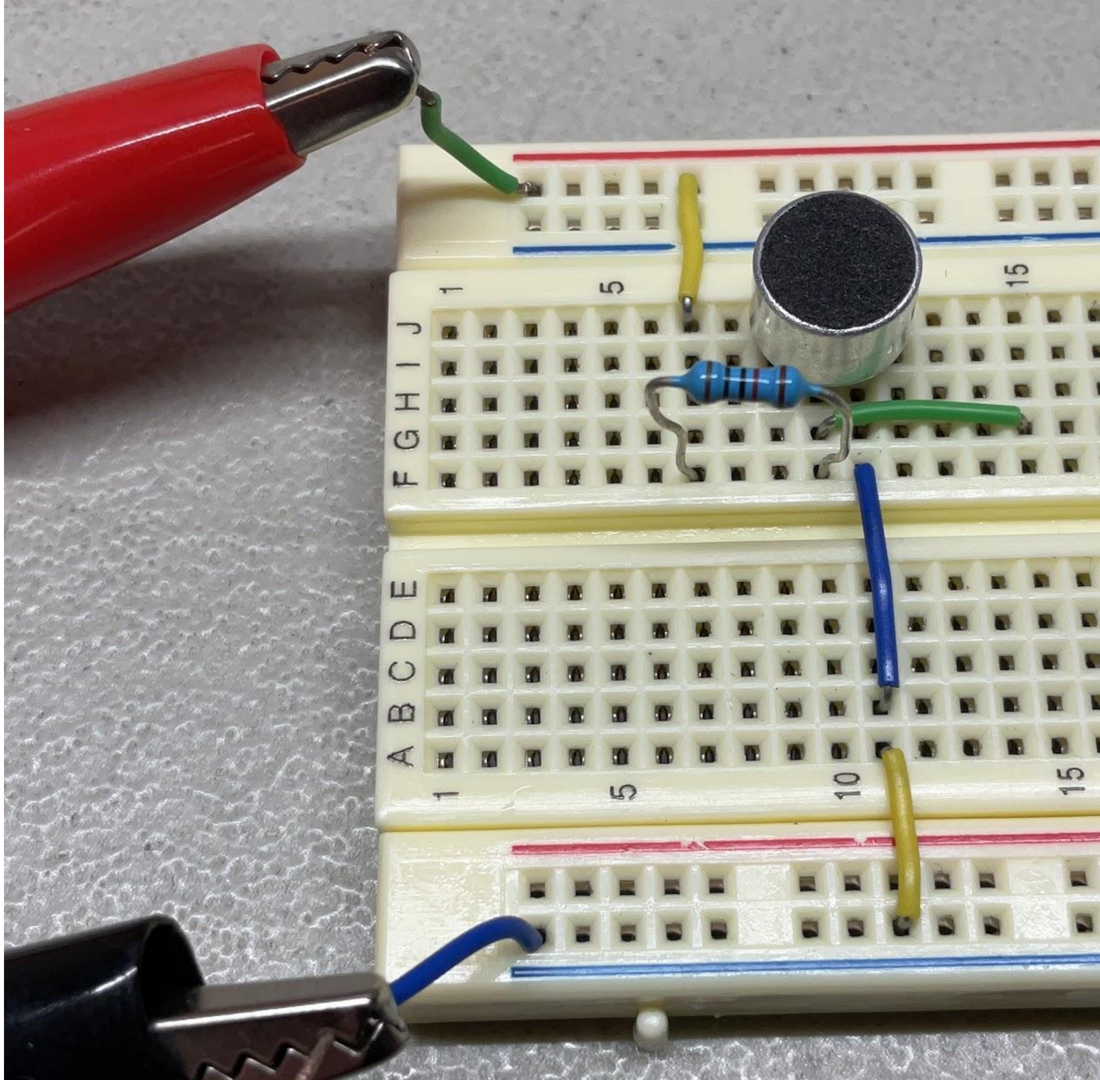
A New AC Source

- An AC signal can be generated using a microphone.
- A microphone will pick up surrounding sound and turn it into an electric audio signal that is AC.
- This signal will have a corresponding amplitude (voltage) and frequency.
- Be aware, that microphones have a pin that must be grounded; indicated by a connection to the outer metal casing.



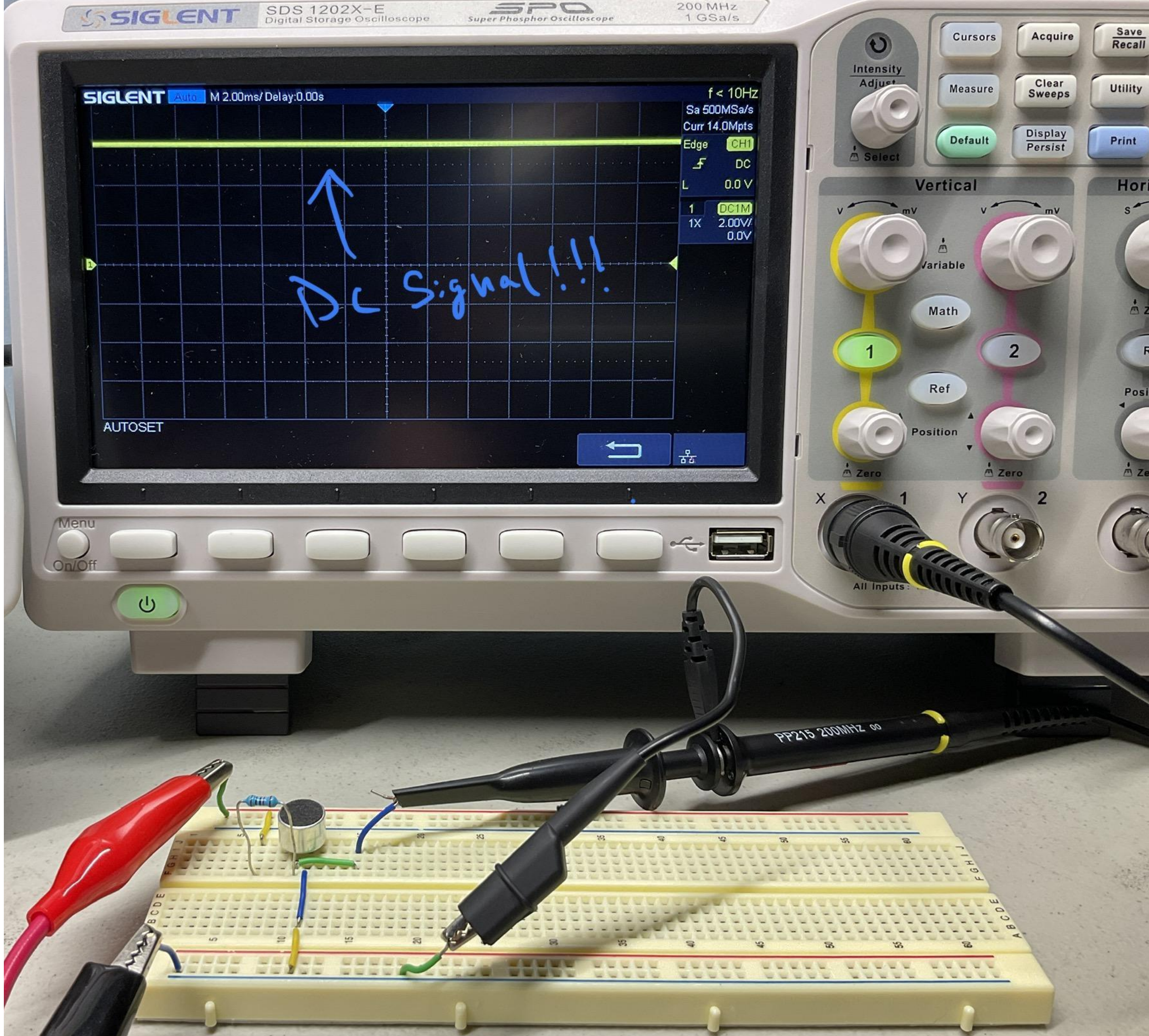
Wiring Up a Microphone

- The microphone will be powered by a 9 volt DC supply.
- However, 9 volts is too much voltage for the microphone, so from Vcc, we will go into a 10K (brown, black, black, red) resistor. This resistor is then connected to the non-ground pin of the microphone.
- The output of the microphone is also connected to this non-ground pin.
- Use a jumper wire to bring the output away from the microphone for easy access.
- The ground pin must be connected to ground in order for the microphone to work properly.



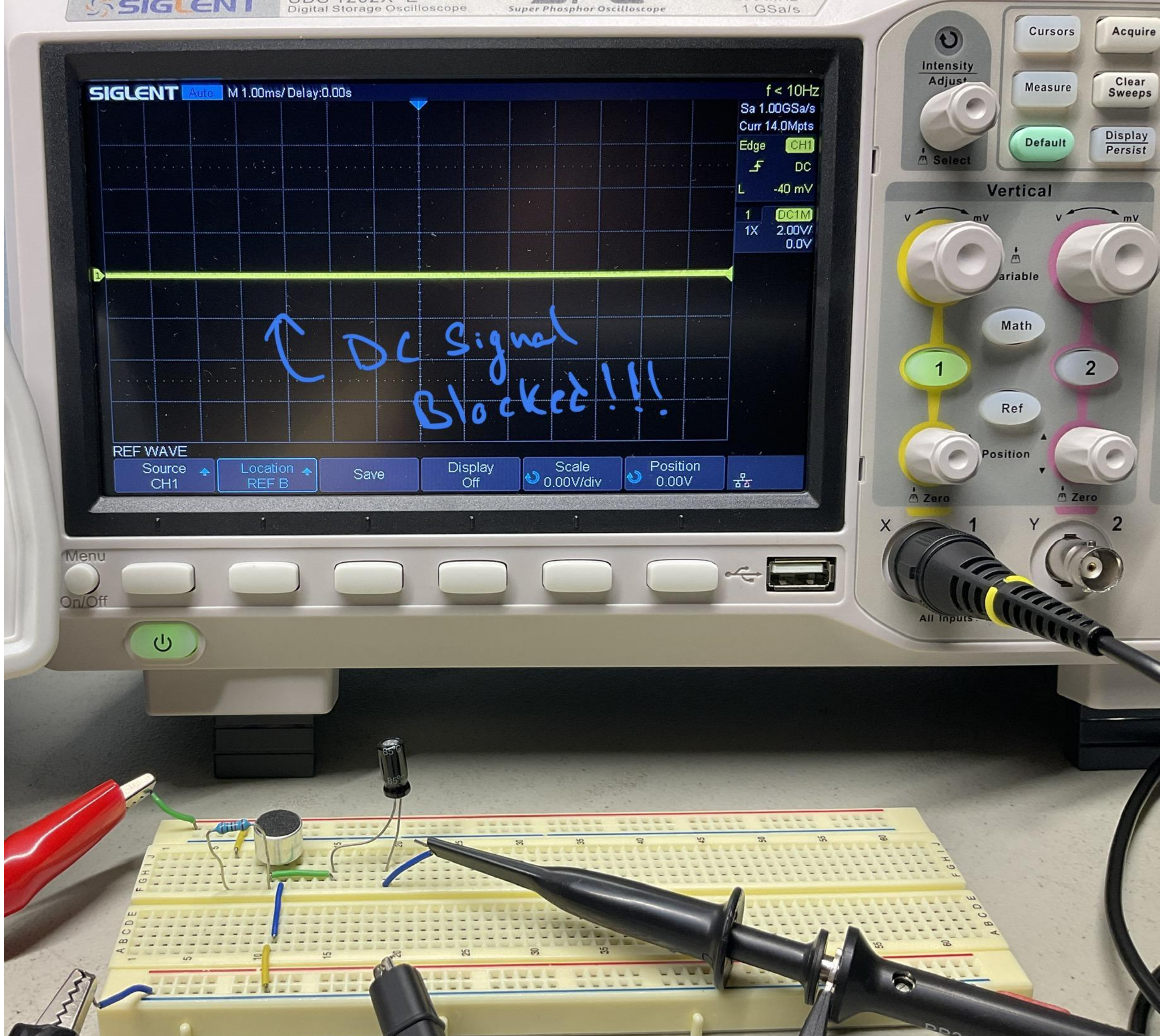
DC Is Getting Through!

- Hooking the microphone up to the oscilloscope we can see there is a DC signal coming through (about 6 volts DC here).
- We do not want this DC signal if we are trying to capture audio (an AC signal).
- So we need to filter out this low frequency DC signal.



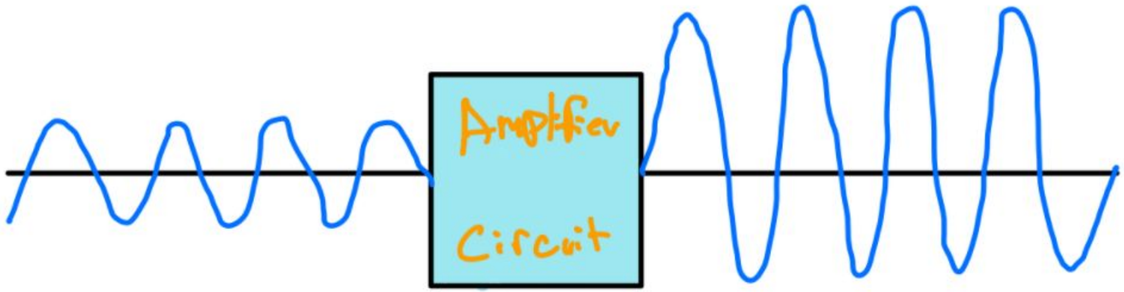
Blocking DC!

- For now, put a 1 microFarad capacitor on the output of the microphone.
- We can see that the DC signal is now being blocked.
- Hopefully, the only thing that will get through the capacitor is our higher frequency audio signals.



Microphone Limitations

- A clear limitation of our microphone is that the output voltage of the microphone is very small.
- When the oscilloscope was set to 2 volts per division, the AC signal was hardly visible.
- However, when set to 100 milliVolts per division, then the AC signal was visible.
- We may need a larger AC signal if we want to actually do something with the signal!

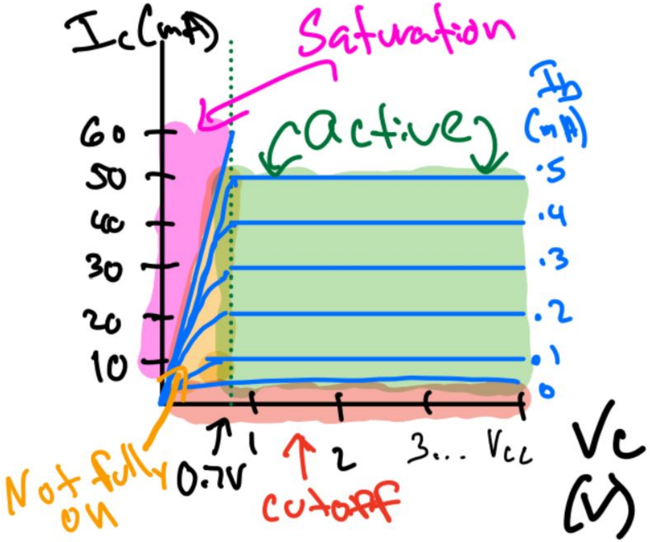


Transistor Amplifiers

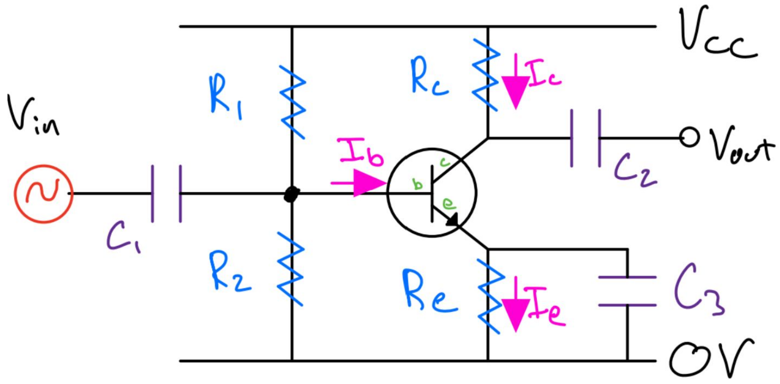
The Common Emitter Amplifier

Transistor Amplifiers

- We've already seen how a small amount of current can turn into a large amount of current using transistor switches.
- A transistor as a switch is either fully on (saturation region) or fully off (cutoff region).
- However, if we somehow keep the transistor in between these two regions (the active or linear region), then the transistor will work as an amplifier.
- We will do this by "biasing" the transistor.



Transistor Amplifiers



Assumptions:

- Ib is very small and Ic = Ie is much larger.
- The diode in the transistor will use roughly 0.7 volts to turn on at the base-emitter junction.
- We will want about 1/10 Vcc at the emitter.

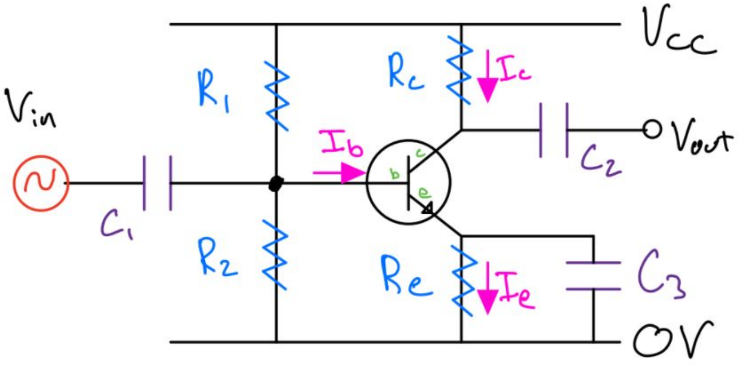
Setup:

- Choose Re to get the desired current Ie = Ic.
- Choose R1 and R2 (which form a voltage divider) to “bias” the transistor such that the voltage at the base is 1.7 volts. Remember, we will use about 0.7 volts to turn the transistor on at the base-emitter junction leaving about 1 volt at the emitter.
- Choose Rc such that you are at roughly half Vcc at the output. This will give the maximum amount of room for the AC signal to be amplified.

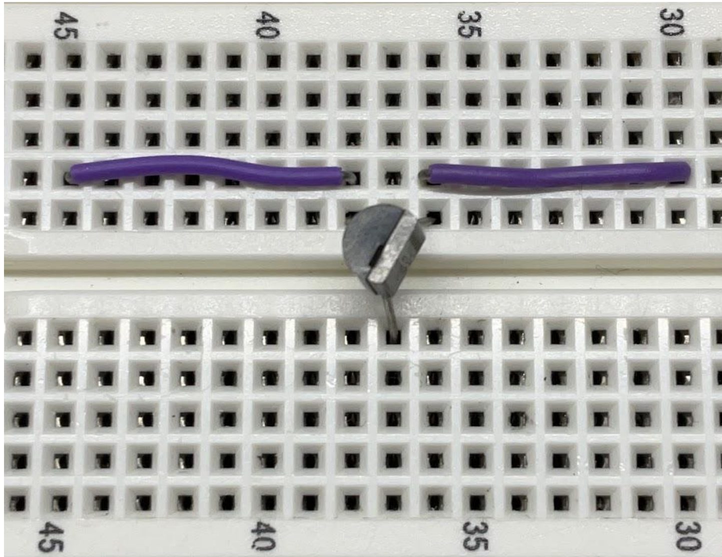
Let’s build a transistor amplifier together as an exercise. We’ll use a supply voltage of 12 volts to learn how to set it up and then you will build one with a supply voltage of 9 volts.

Transistor Amplifiers

- When designing your transistor amplifier, you have to start with a few assumptions.
- What will the supply voltage be?
  - We will use 12 volts.
- How much current do you want at the collector?
  - We will want 1 mA.
- What is the Beta or current gain of the transistor (look at the data sheet)?
  - We will assume a Beta of 100.
- Start by putting a transistor in the bread board and moving the base and collector away for easy access.

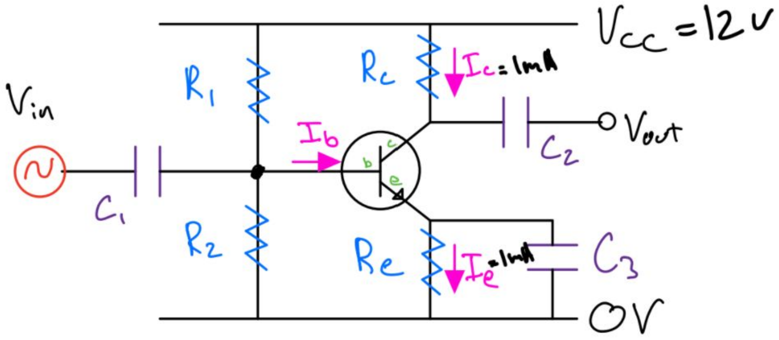


$\beta = 100$, $I_c = 1mA$, $V_{cc} = 12V$



Transistor Amplifiers

- For stability purposes, it is good practice to try to keep the voltage drop across the emitter resistor Ve at roughly 1/10 Vcc.
- One of our assumptions is that Ic = Ie because Ib is so very small.
- Now that we know Ve and Ie we can use Ohm's law to calculate Re.
- Put a 1K (brown, black, black, brown) and 200 ohm (red, black, black, black) resistor on the emitter to ground.



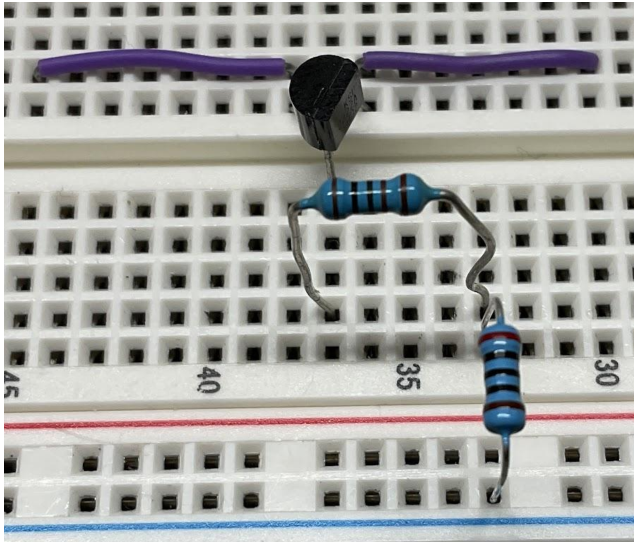
$V_e \approx \frac{1}{10} V_{cc}$

$V_e = 1.2v$

$V_e = I_c R_e$

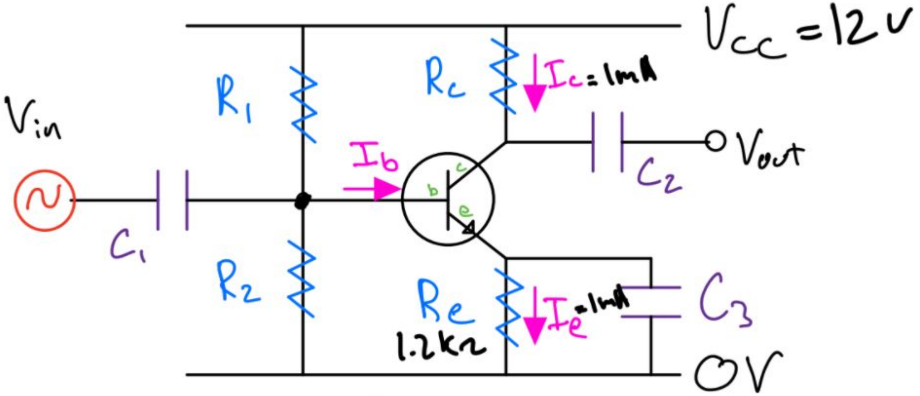
$1.2v = 1mA(R_e)$

$\boxed{R_e = 1.2K\Omega}$



Transistor Amplifiers

- Beta is the current gain of the transistor. It's what we multiply the small base current by to get the much larger collector current.
- Using our collector current and Beta, we can solve for our base current.
- We also know that we have a 0.7 volt drop across the diode in the transistor so we can now solve for V2, the voltage drop across R2.



$$I_b = \frac{I_c}{\beta} = \frac{1mA}{100}$$

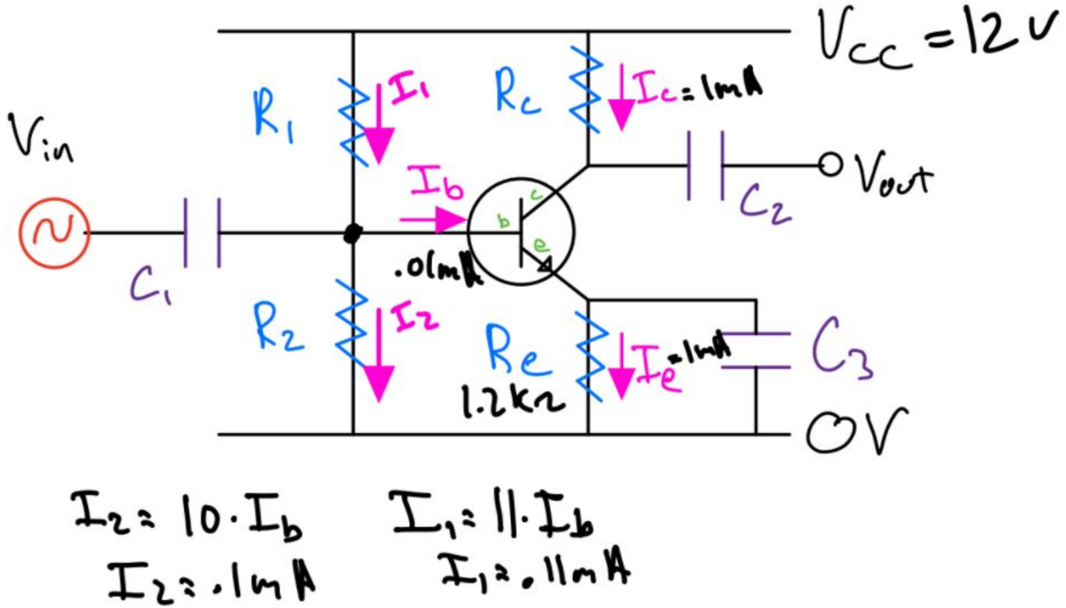
$$I_b = .01mA$$

$$V_2 = V_e + 0.7V$$

$$V_2 = 1.9V$$

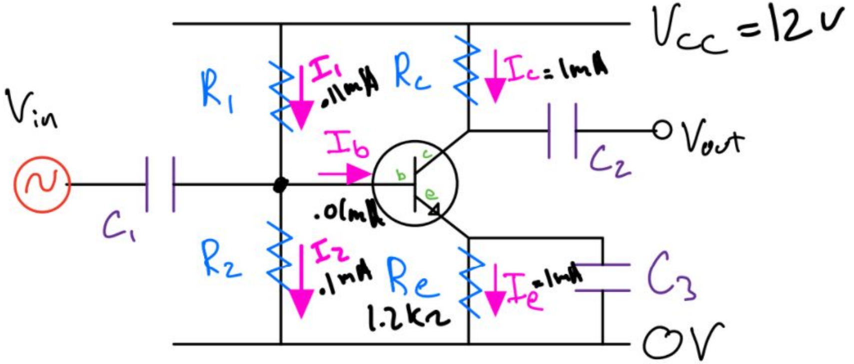
Transistor Amplifiers

- There are a couple of different ways we can do the next step…essentially, we want to create a "stiff" voltage divider; one that won't be affected when we load the voltage divider.
- When we load the voltage divider, R2 is now the parallel combination of R2 and whatever we loaded it with. This could potentially throw off our values.
- To combat this, we will assume that the current flowing through R1 and R2 are 11 and 10 times larger than the base current.



Transistor Amplifiers

- Now that we know the V2 and I2 we can use Ohm's law to calculate R2.
- For simplicity, put two 10K (brown, black, black, red) resistors from the base to ground.
- While our R2 value is 20K, which is not 19K…it's close enough!



$V_2 = I_2 R_2$

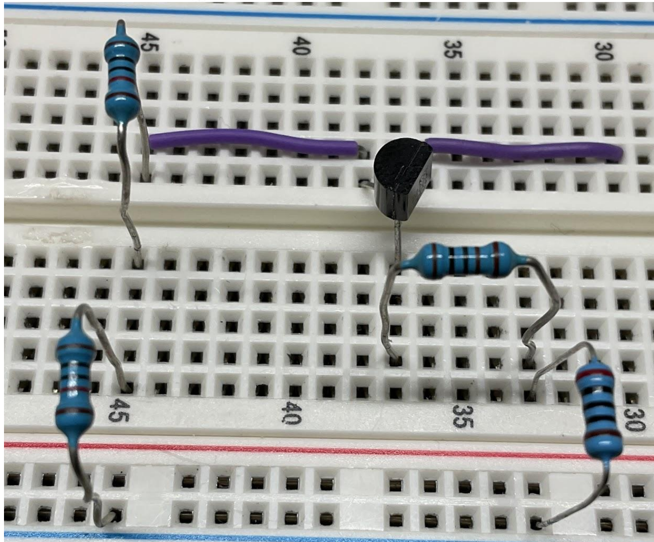
$1.9V = .1mA\,(R_2)$

$\boxed{R_2 = 19k\Omega}$

$V_1 = I_1 R_1$

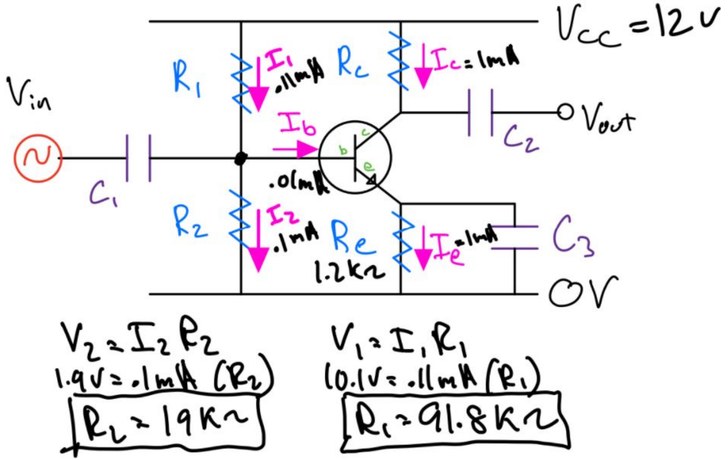
$10.1V = .11mA\,(R_1)$

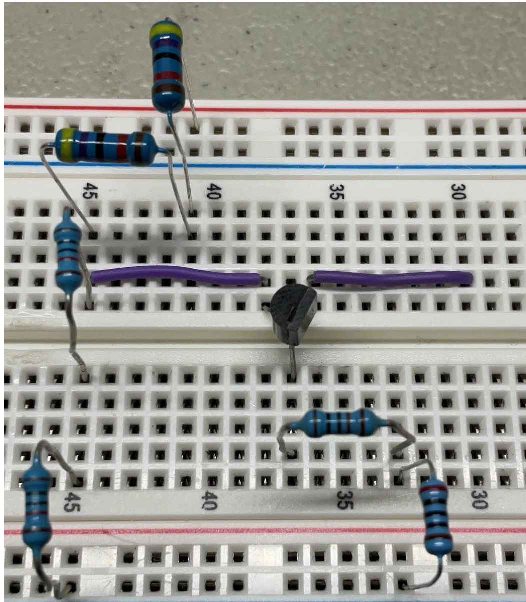
$\boxed{R_1 = 91.8k\Omega}$



Transistor Amplifiers

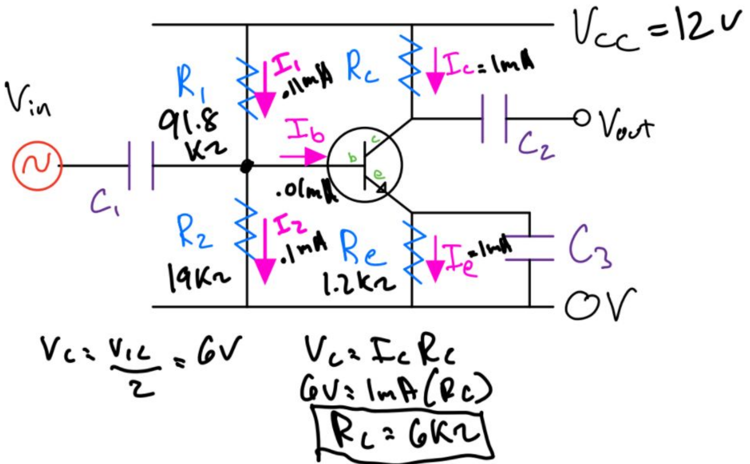
- V1, the voltage drop across R1 must leave us with 1.9 volts to drop across R2. Therefore, V1 is 10.1 volts (Vcc - V2).
- Now that we know V1 and I1 we can use Ohm's law to calculate R1.
- For simplicity, put two 47K (yellow, purple, black, red) resistors from Vcc into the base of the transistor.
- While our R1 value is 94K, which is not 91.8K…it's close enough!

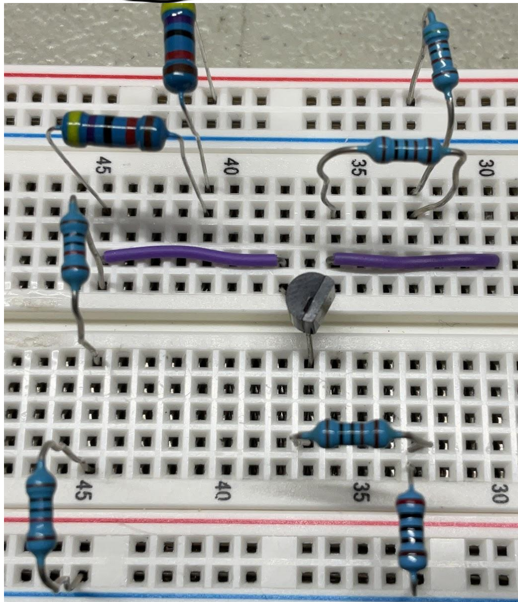




Transistor Amplifiers

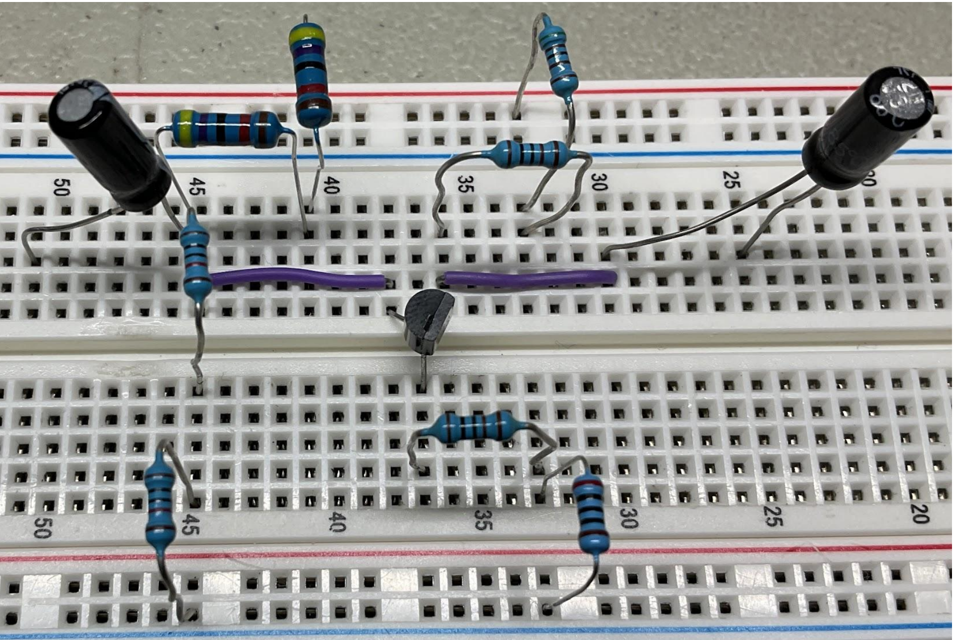
- It is ideal to try to keep the DC voltage at the collector, Vc at Vcc/2. This way there is equal room to amplify above and below this point. This will help us avoid clipping.
- Recall that we chose Ic to be 1 mA.
- Now that we know Vc and Ic we can use Ohm's law to calculate Rc.
- Put a 5.1K (green, brown, black, brown) and 1K (brown, black, black, brown) resistor from Vcc into the collector.

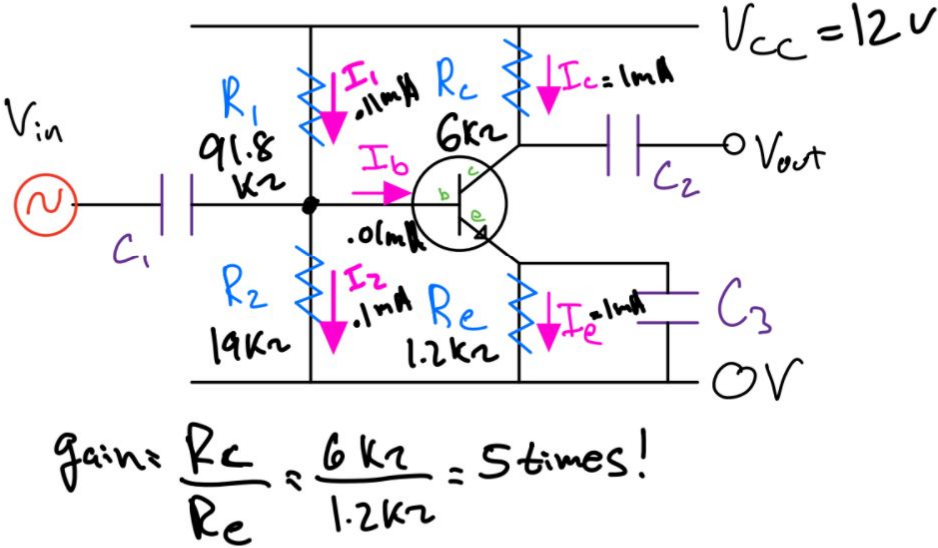




Transistor Amplifier

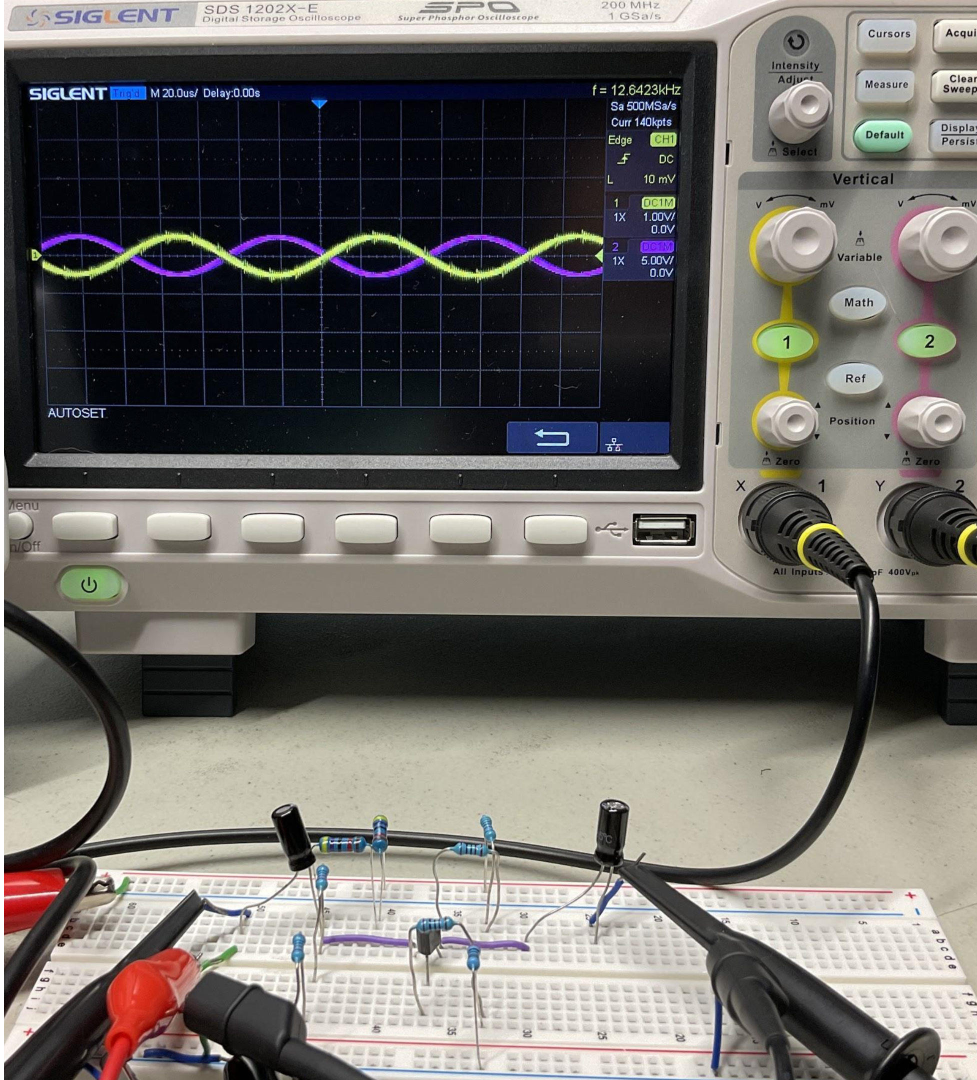
- Lastly, put 1 microFarad capacitors at the base and collector.
- We'll discuss C3 later…
- The gain of the amplifier is the ratio of Rc/Re…in our case, 5 times!





Transistor Amplifier

- Here we are running the amplifier off a 12 volt source with a 1 volt, 10KHz sine wave.
- The input is in yellow at a scale of 1 volt per division.
- The output is in purple at a scale of 5 volts per division.
- It looks like the amplifier is working the way we expect it to!



Circuit Challenge 9

I Can’t Hear You!

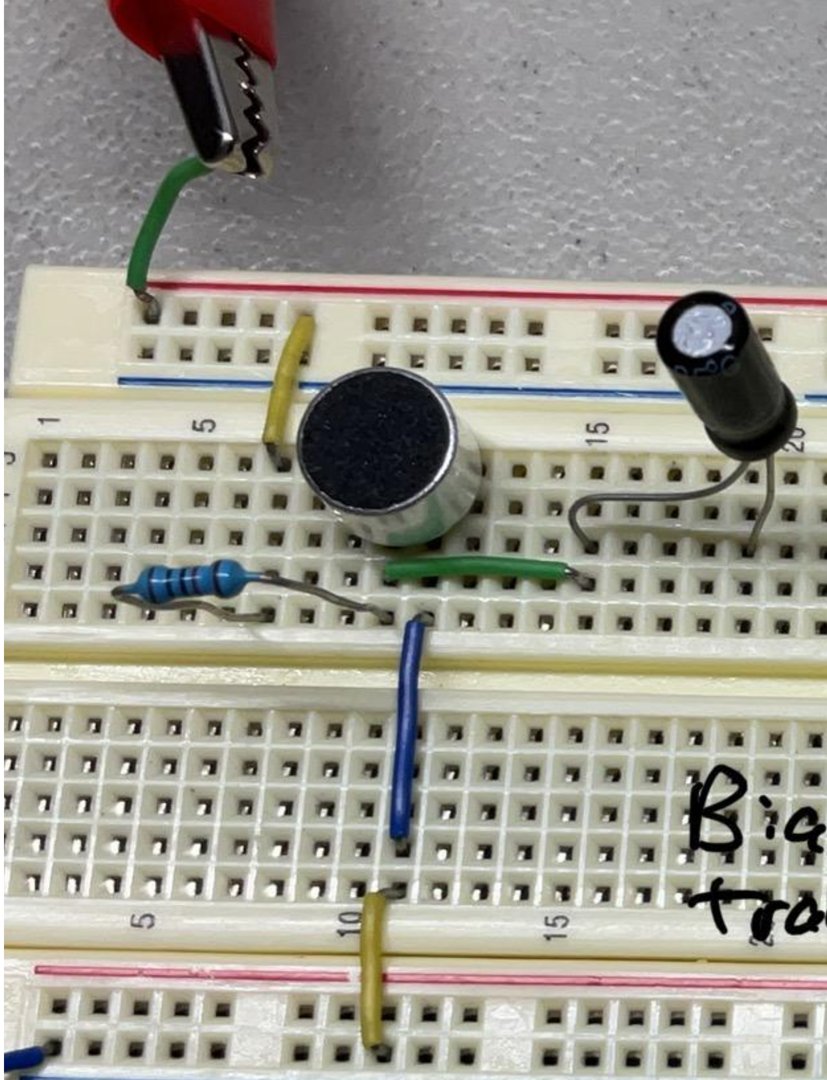
Circuit Challenge 9: I Can't Hear You!

- For this challenge you are going to create a transistor amplifier that runs off a 9 volt supply that will amplify our microphone signal.
- Let's assume the following:
  - Vcc is 9 volts.
  - Ic is 1 mA.
  - Beta is 100.
  - Ve is about 1/10 Vcc. This gives 0.9 volts. We'll assume 1 volt.
- This amplifier will make your AC signal coming out of your microphone larger so we can use it!

DO NOT ADVANCE to the next slide without trying to figure this out first!

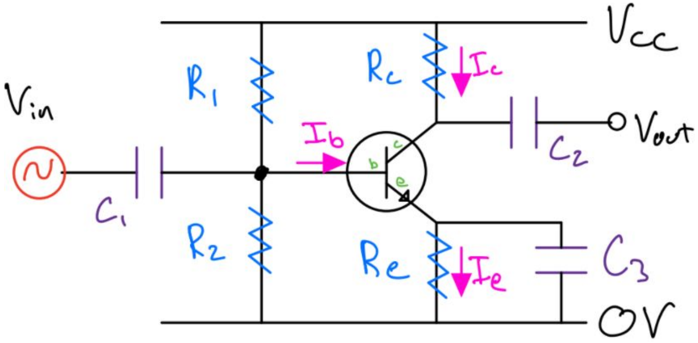
Setting up the Microphone

- From Vcc, we will go into a 10K (brown, black, black, red) resistor. This resistor is then connected to the non-ground pin of the microphone.
- The output of the microphone is also connected to this non-ground pin.
- Use a jumper wire to bring the output away from the microphone for easy access.
- Connect a 1 microFarad capacitor to block any DC signal.
- Ground the ground pin of the microphone.

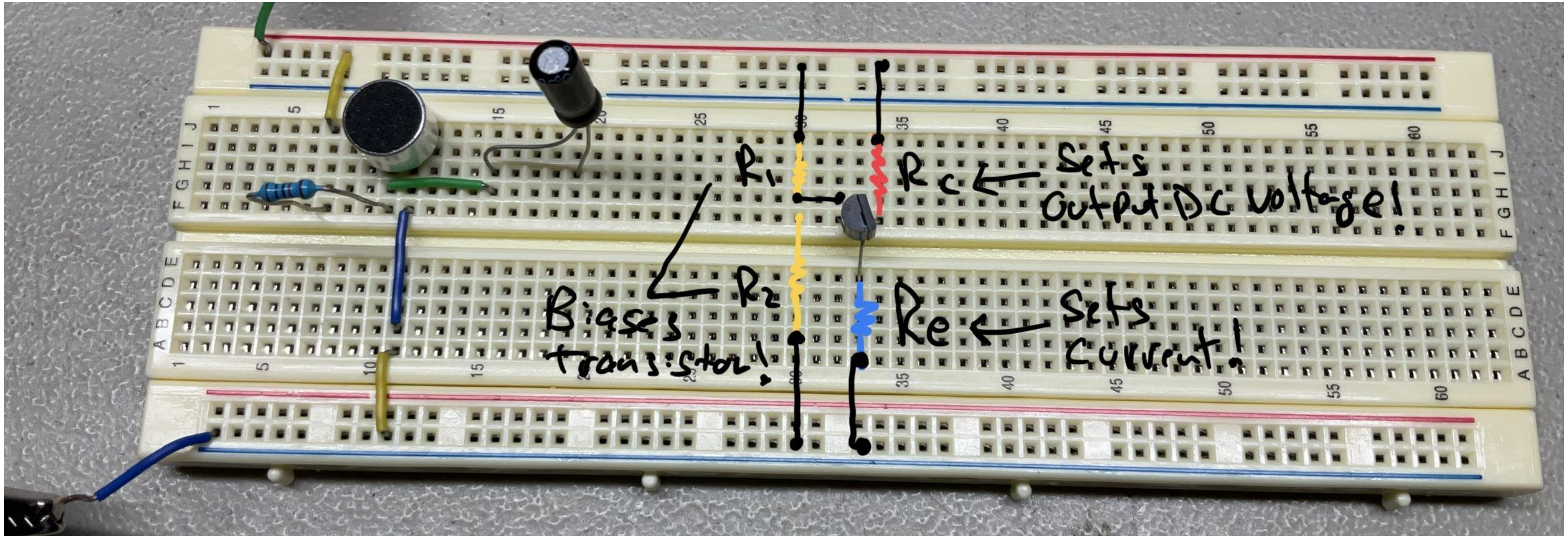


Adding a Transistor Amplifier

- Place a transistor in the breadboard leaving room to the right (we will add to this circuit later on!)
- Note the resistors we will eventually add.

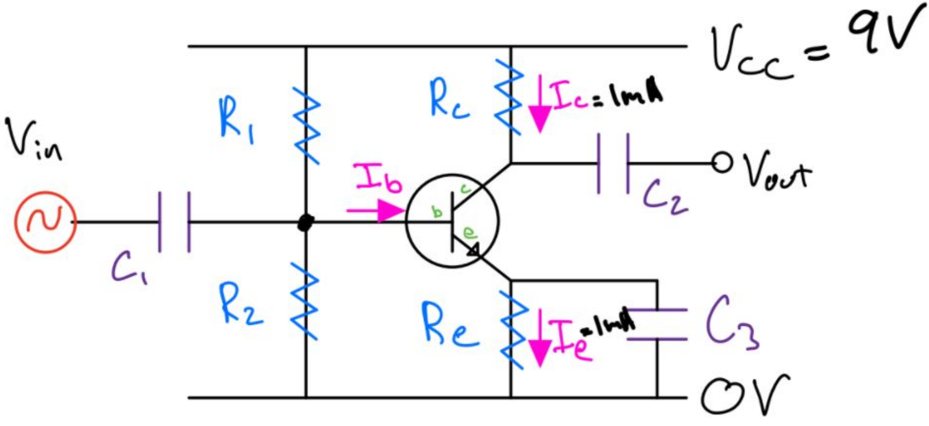


$\beta = 100$, $I_C = 1mA$, $V_{CC} = 9V$



Emitter Resistor - Re

- For stability purposes, Ve, the voltage across the emitter resistor should be roughly 1/10 Vcc. This gives us 0.9 volts. Let's assume 1 volt.
- Recall we want a collector current of 1 mA. Ic and Ie are equal because Ib is so small.
- Now that we know Ve and Ie we can use Ohm's law to calculate Re.
- Place a 1K (brown, black, black, brown) resistor from the emitter of the transistor to ground.



$$V_e \approx \frac{1}{10} V_{cc}$$

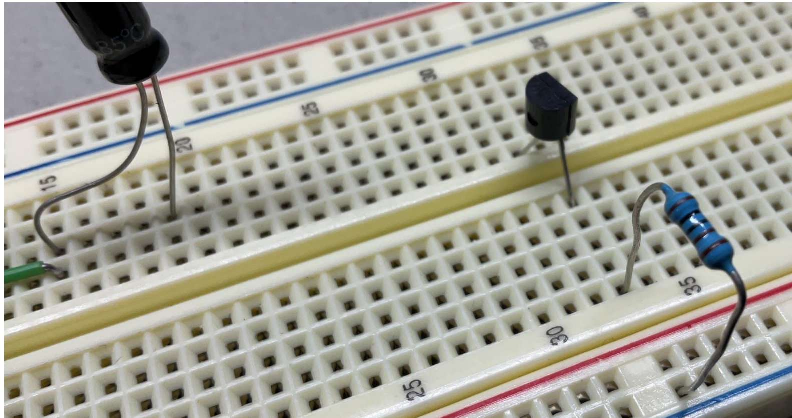
$$V_e = .9V$$

$$V_e = 1V$$

$$V_e = I_e R_e$$

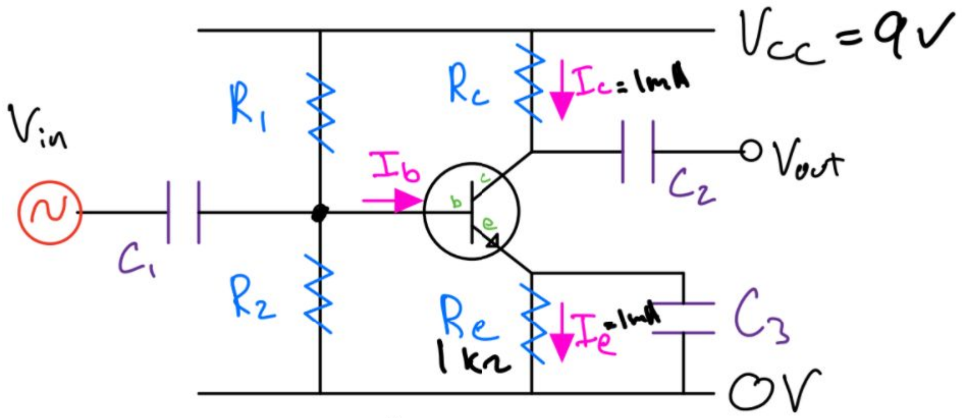
$$1V = 1mA (R_e)$$

$$\boxed{R_e = 1K\Omega}$$



Transistor Amplifiers

- Beta is the current gain of the transistor. It's what we multiply the small base current by to get the much larger collector current.
- Using our collector current and Beta, we can solve for our base current.
- We also know that we have a 0.7 volt drop across the diode in the transistor so we can now solve for V2, the voltage drop across R2.



$$I_b = \frac{I_c}{\beta} = \frac{1mA}{100}$$

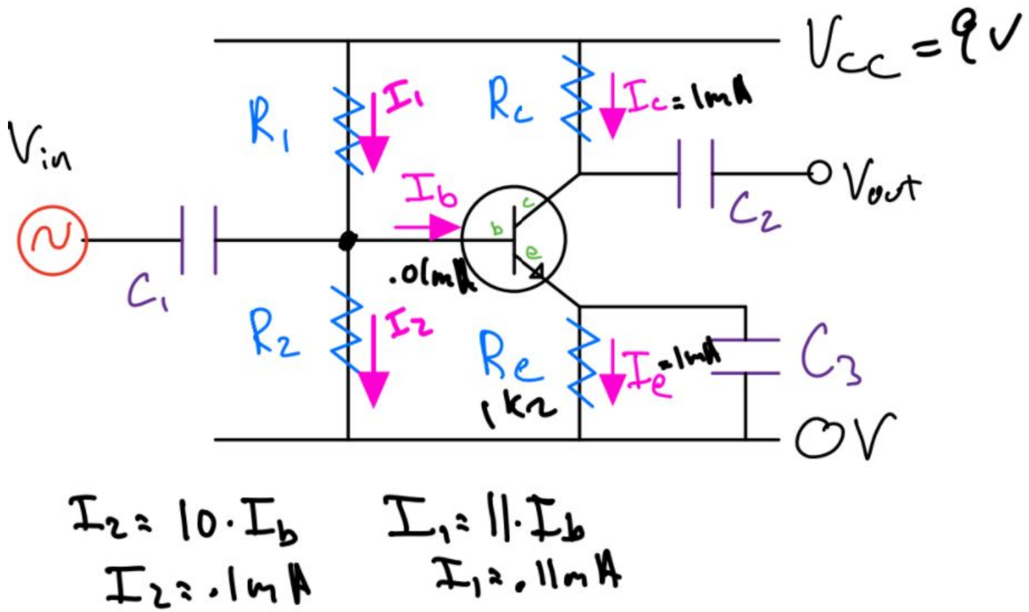
$$I_b = .01\,mA$$

$$V_2 = V_e + 0.7V$$

$$V_2 = 1.7V$$

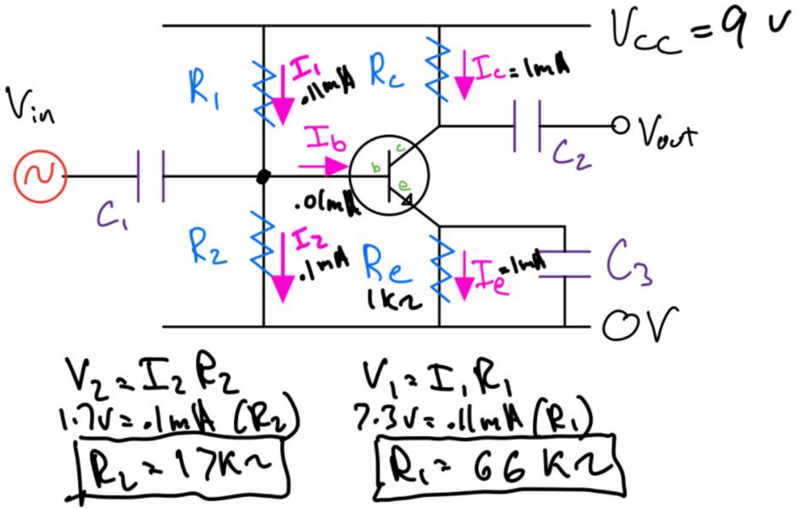
Transistor Amplifiers

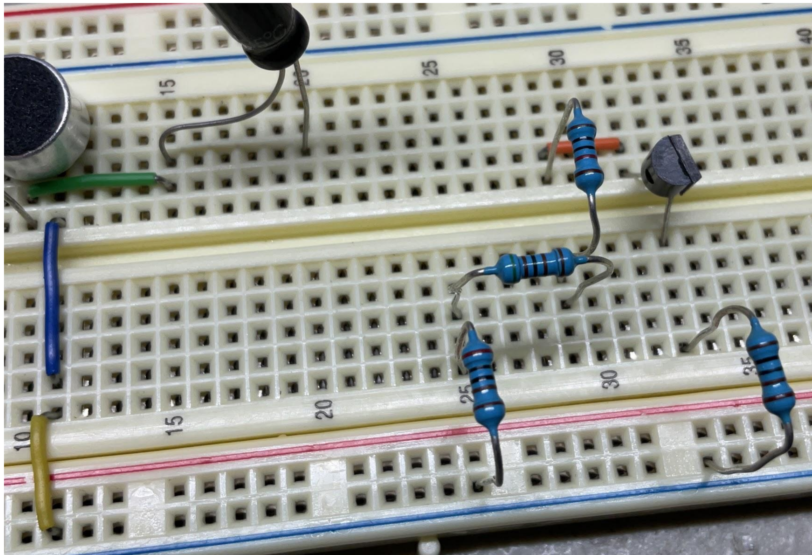
- There are a couple of different ways we can do the next step…essentially, we want to create a “stiff” voltage divider; one that won’t be affected when we load the voltage divider.
- When we load the voltage divider, R2 is now the parallel combination of R2 and whatever we loaded it with. This could potentially throw off our values.
- To combat this, we will assume that the current flowing through R1 and R2 are 11 and 10 times larger than the base current.



Biasing Resistors - R2

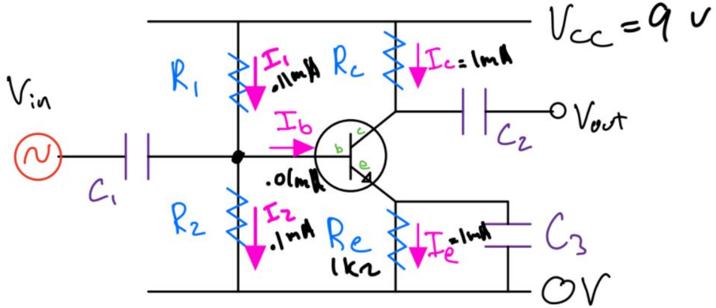
- Now that we know V2 and I2, we can use Ohm's law to calculate R2.
- We need about 17K for R2 going from the base of the transistor to ground.
- We do not have a single 17K resistor.
- However, we can use the following resistors in series!
    - 10K (brown, black, black, red)
    - 5.1K (green, brown, black, brown)
    - 2K (red, black, black, brown)
- Note that I'm using a jumper wire to connect these resistors to the base of the transistor!





Biasing Resistors - R1

- V1, the voltage drop across R1 must leave us with 1.7 volts to drop across R2. Therefore, V1 is 7.3 volts (Vcc - V2).
- Now that we know V1 and I1 we can use Ohm's law to calculate R1.
- We need about 66K for R1 going from Vcc to the base of the transistor.
- We do not have a single 66K resistor.
- However, we can use the following resistors in series!
    - 47K (yellow, purple, black, red)
    - 10K (brown, black, black, red)
    - 10K (brown, black, black, red)
- Note that I'm using the same jumper wire to connect these resistors to the base of the transistor!



$V_2 = I_2 R_2$

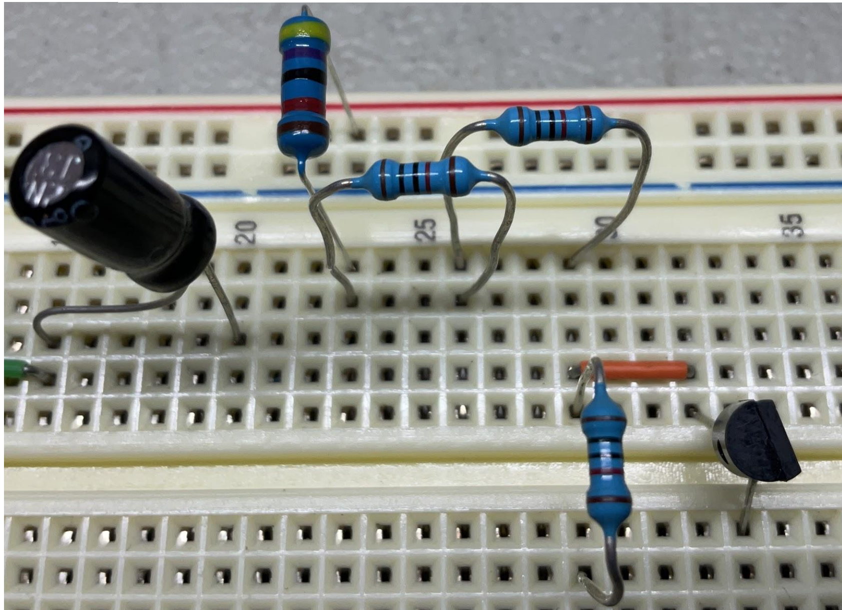
$1.7V = .1mA\,(R_2)$

$\boxed{R_2 = 17K\Omega}$

$V_1 = I_1 R_1$

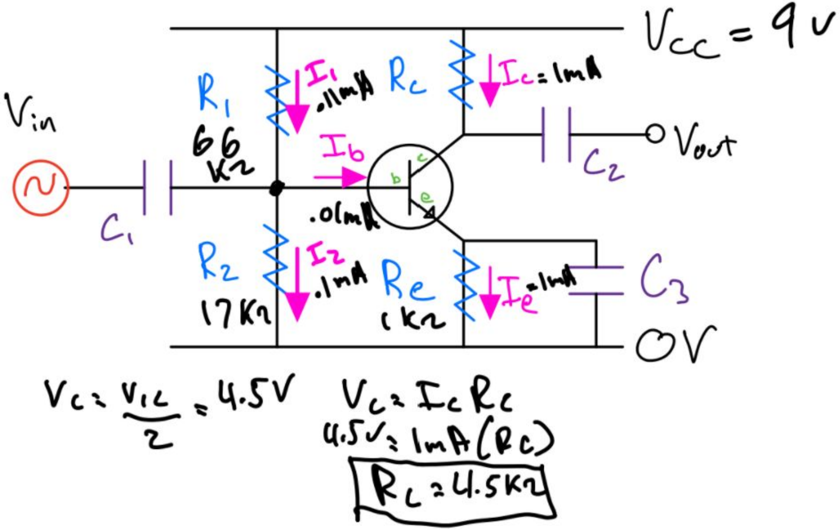
$7.3V = .11mA\,(R_1)$

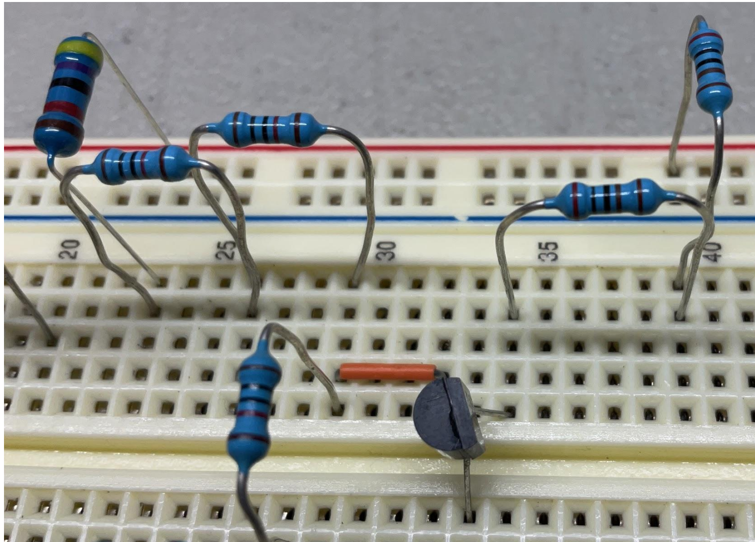
$\boxed{R_1 = 66K\Omega}$



Collector Resistor - Rc

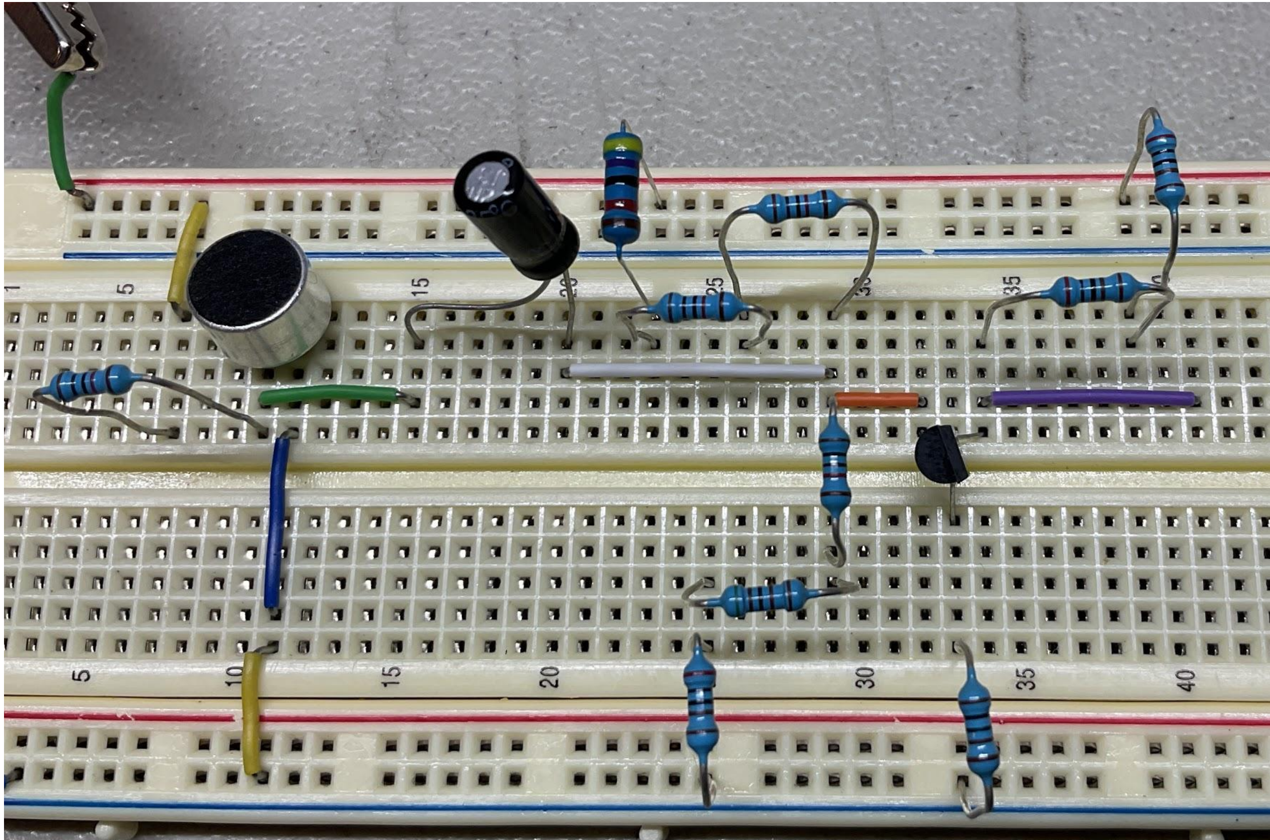
- It is ideal to try to keep the DC voltage at the collector, Vc at Vcc/2. This way there is equal room to amplify above and below this point. This will help us avoid clipping.
- Recall that we chose Ic to be 1 mA.
- Now that we know Vc and Ic we can use Ohm’s law to calculate Rc.
- We will use two 2K (red, black, black, brown) resistors in series to get a total collector resistance of 4K going from Vcc to the collector.





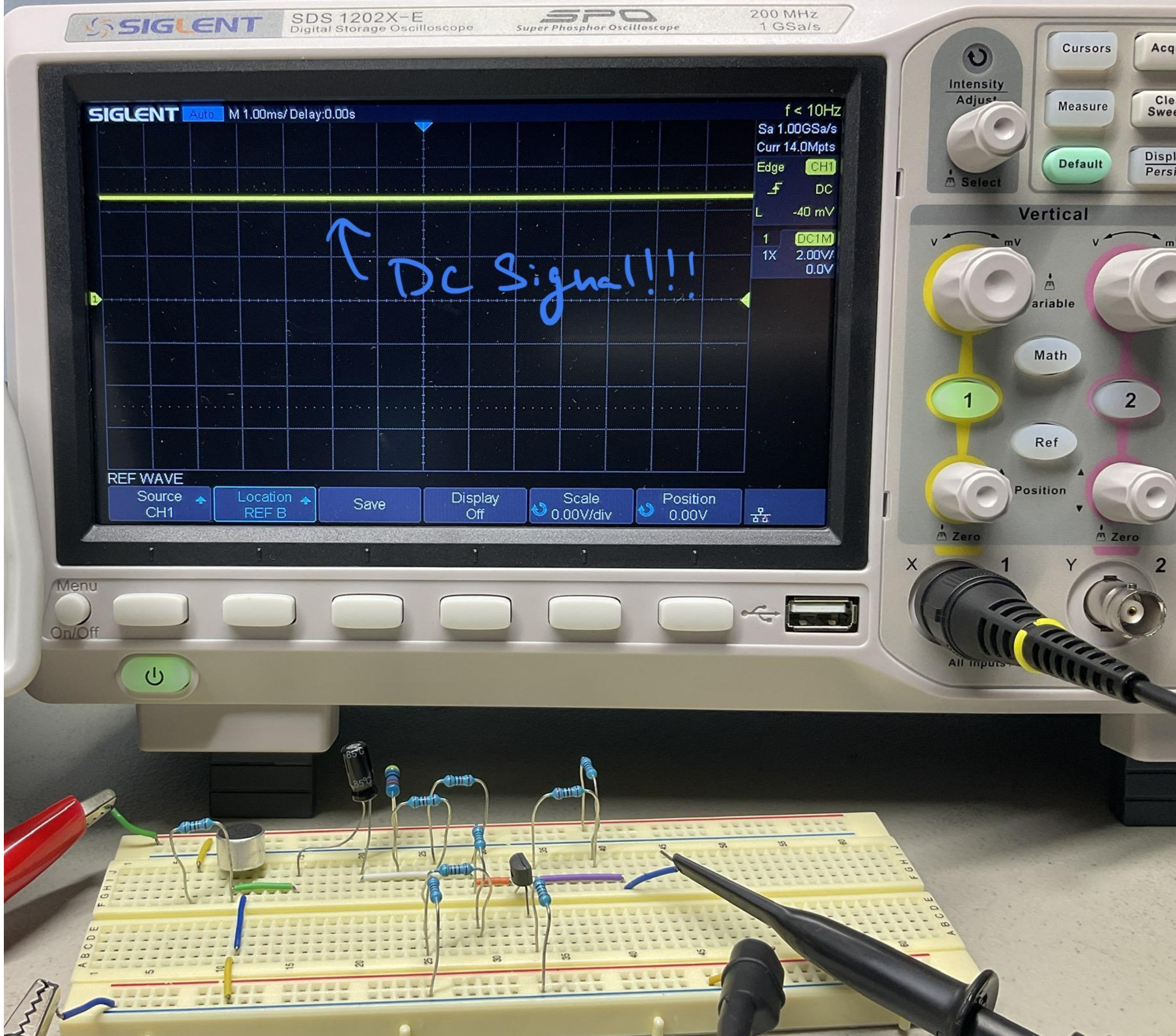
Finished Amplifier (Almost)

- Connect the output of the microphone circuit to the base of the transistor (white jumper).
- Take the output of the amplifier off the collector and move it away from the transistor for easy access (purple jumper).



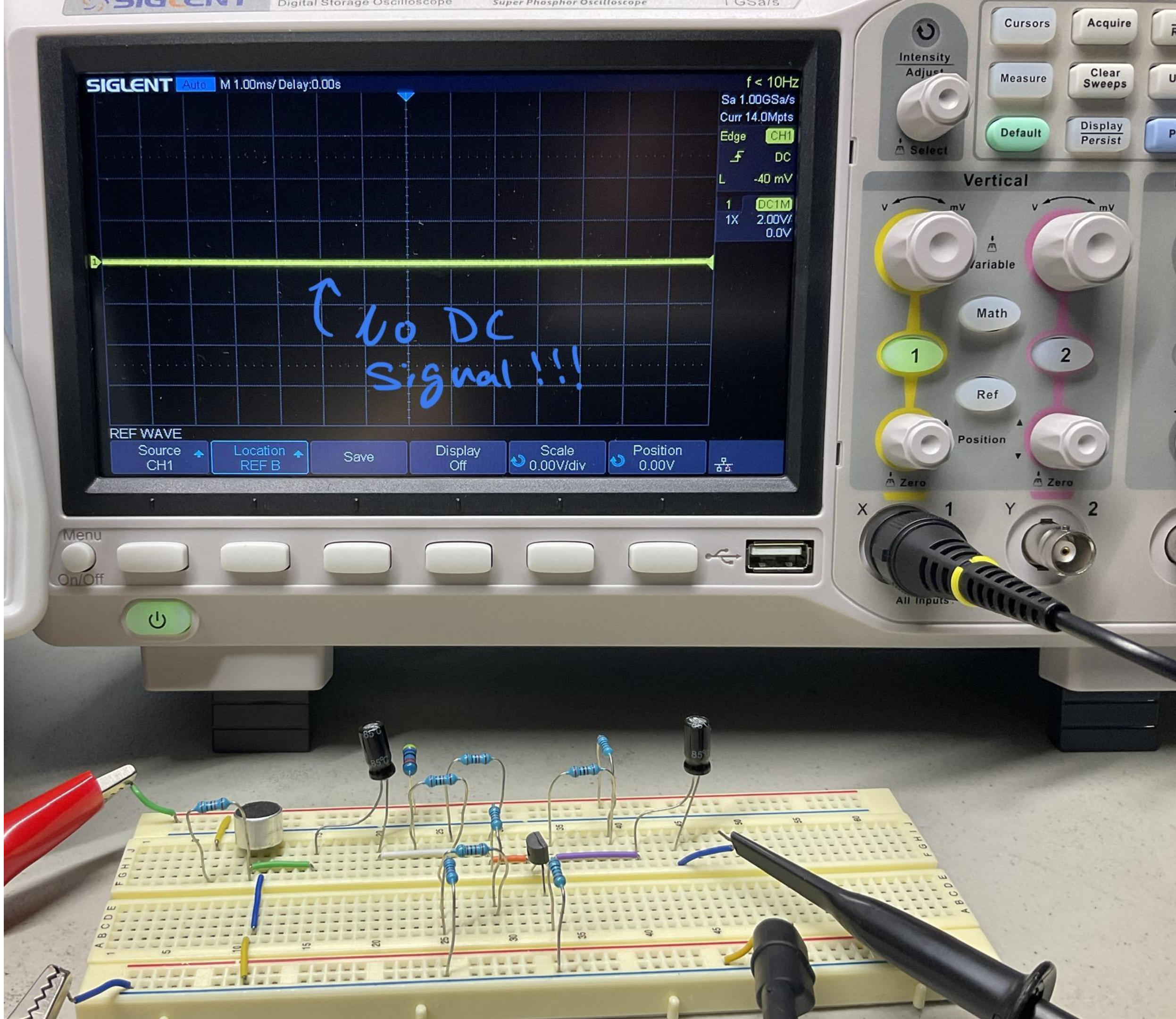
DC Getting Through!

- Hooking the amplifier up to the oscilloscope we can see there is a DC signal coming through (about 4.5 volts DC here).
- We do not want this DC signal if we are trying to amplify audio (an AC signal).
- So we need to filter out this low frequency DC signal.



Blocking DC!

- For now, put a 1 microFarad capacitor on the output of the amplifier.
- We can see that the DC signal is now being blocked.
- Hopefully, the only thing that will get through the capacitor is our higher frequency audio signals.

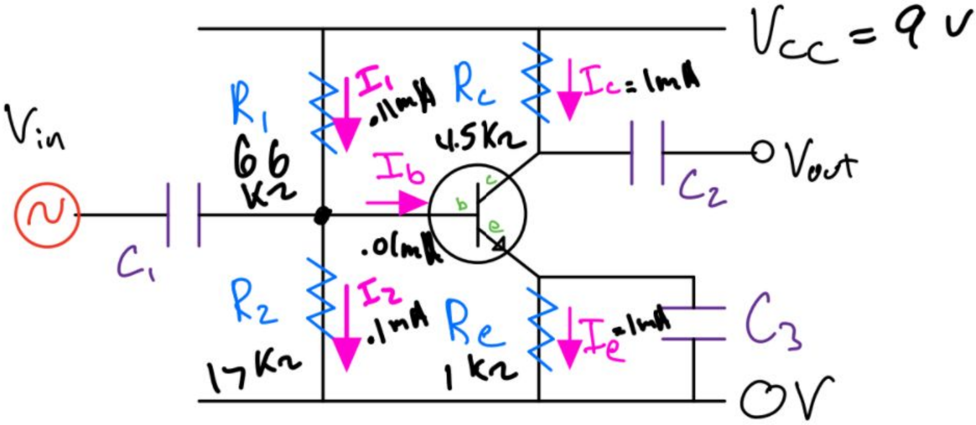


How Much Gain???

- The gain or amplification of the amplifier can be approximated as:

Rc / Re = 4,000 / 1,000 = 4 times

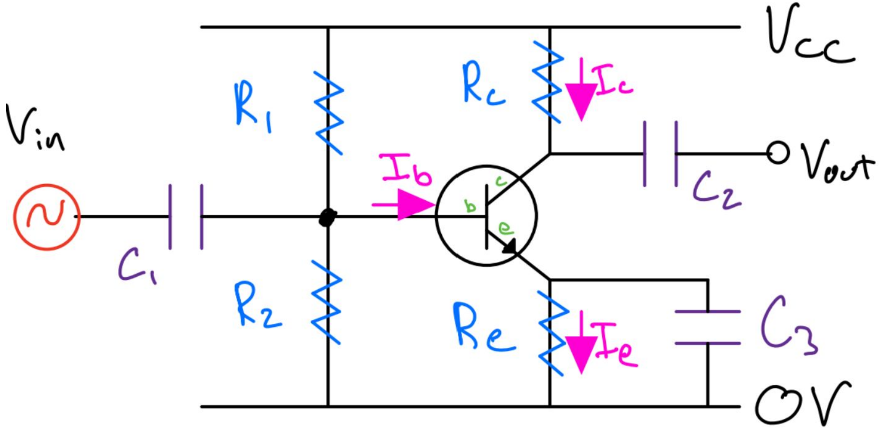
- Not bad, but not great because our microphone input signal is extremely small!
- So a 100 milliVolt signal will turn into a 400 milliVolt signal...still not large enough for some applications!



$$\text{gain} = \frac{R_c}{R_e} \approx \frac{4k\Omega}{1k\Omega} = 4 \text{ times!}$$

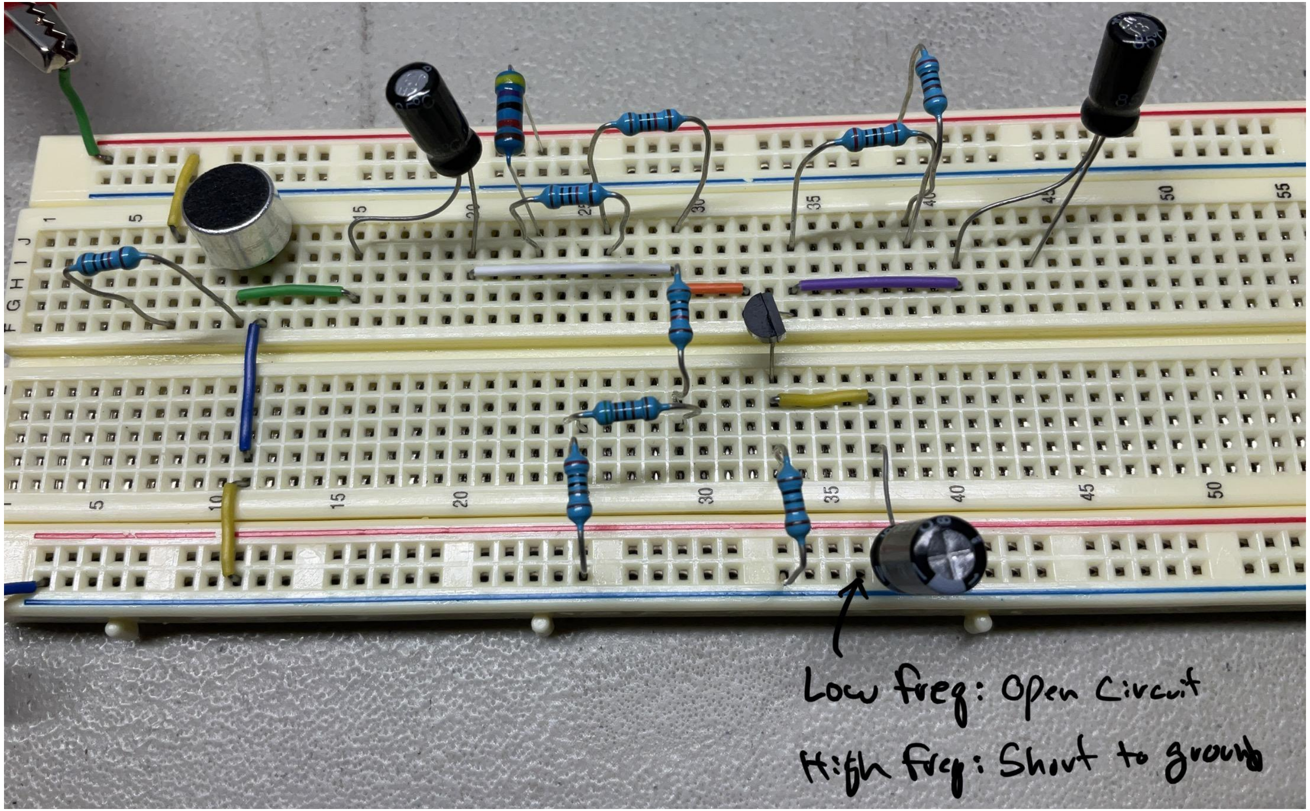
From Good to Great - The Bypass Capacitor

- We can add a bypass capacitor (C3) on our emitter resistor. This will greatly increase the gain of the amplifier.
- For low frequencies such as DC, the bypass capacitor offers HIGH resistance making the denominator of our gain equation very large.
- For high frequencies such as AC, the bypass capacitor offers ALMOST NO resistance making the denominator of our gain equation very small.
- Dividing by a small number means we should have a much larger gain with a bypass capacitor in place for AC signals!



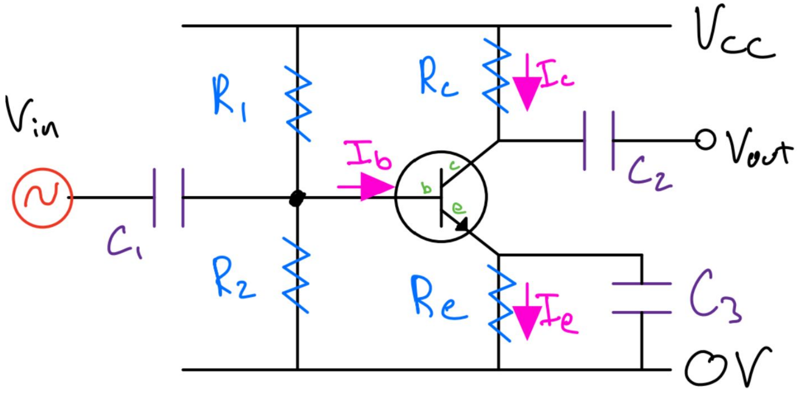
Circuit Challenge 9: Solution

- Add a 100 microFarad bypass capacitor on the emitter of your transistor.
- This capacitor should be in parallel to the emitter resistor going to ground.
- The amplifier is now complete!!!



The Effect of the Capacitors

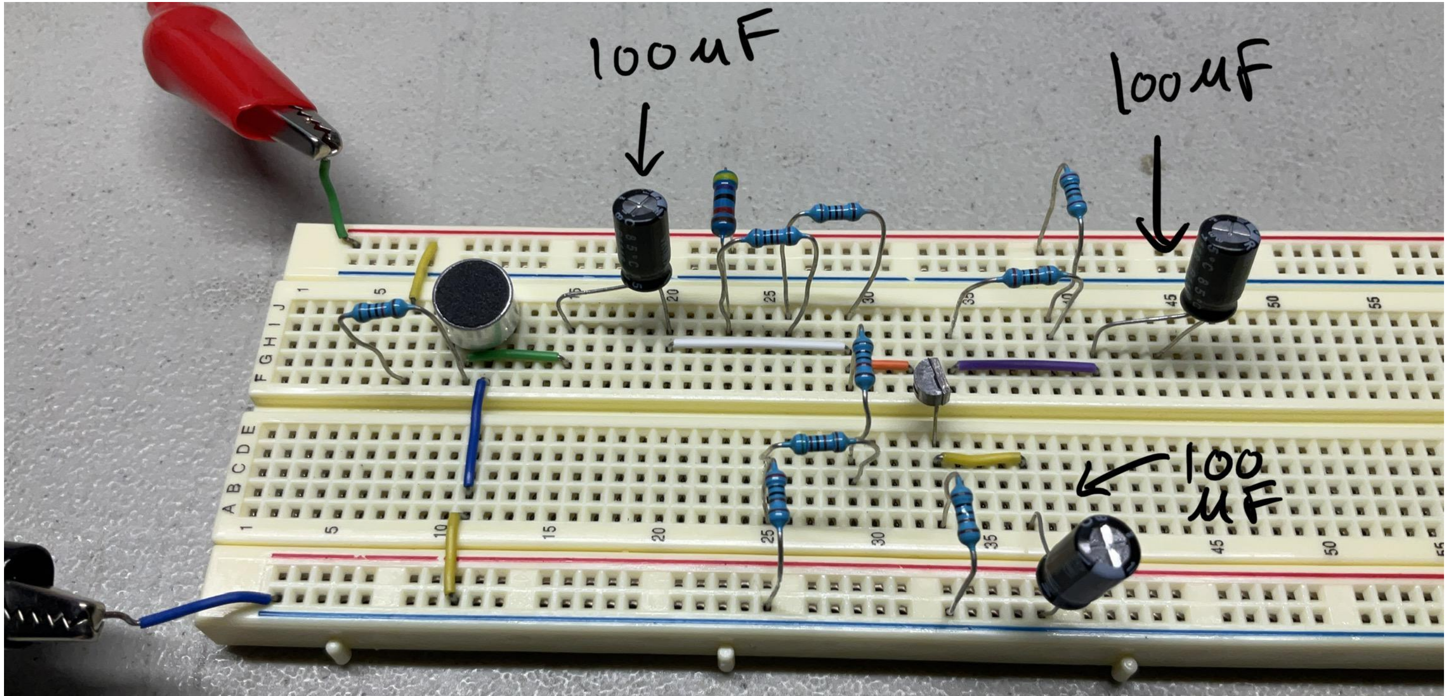
- The capacitors C1 and C2 that we used in our circuit are currently 1 microFarad.
- These capacitors are essentially creating high pass filters where the seen resistance is a complicated combination of all other circuit elements in the circuit.
- A high pass filter will let anything above the cutoff frequency pass. We do not want to set this cutoff frequency to high otherwise, audio signals might be diminished.
- We can lower our cutoff frequency by increasing the values of our capacitors!



$$f_{cutoff} = \frac{1}{2\pi RC}$$

Changing Capacitor Values

- Change the values of C1 and C2 from 1 microFarad to 100 microFarad capacitors.
- This will allow for lower AC frequencies to be amplified more.



Circuit Challenge 10

Rock and Roll Light Show

Circuit Challenge 10: Rock and Roll Light Show

- Using the circuit that you've just created (microphone -> amplifier) can you add a third part to the circuit that safely turns on multiple LEDs as an audio signal is picked up from the microphone.
- You shouldn't have to change anything about your microphone or amplifier circuit.
- The new circuit will have 3 parts:

(microphone -> amplifier -> light show)

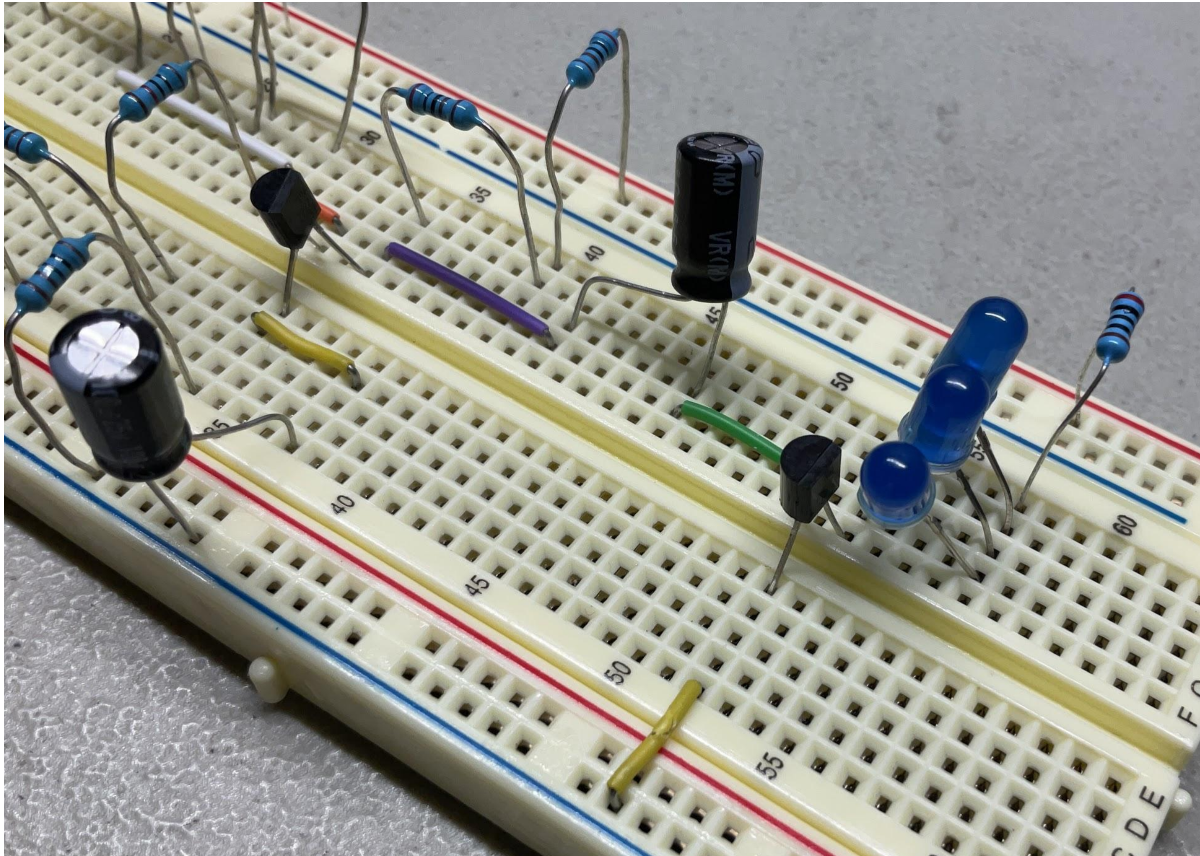
HINTS:

- LEDs run off DC not AC...so don't try to just hook up an LED to the output of your amplifier. Besides, there probably isn't enough current there to light up your LED anyway….
- If only there was a way to have the tiny current coming out of our amplifier control a much larger current that could turn the LEDs on?!?!?
- We definitely have a voltage out of our amplifier that is at least 0.7 volts...maybe enough to turn something on :-)

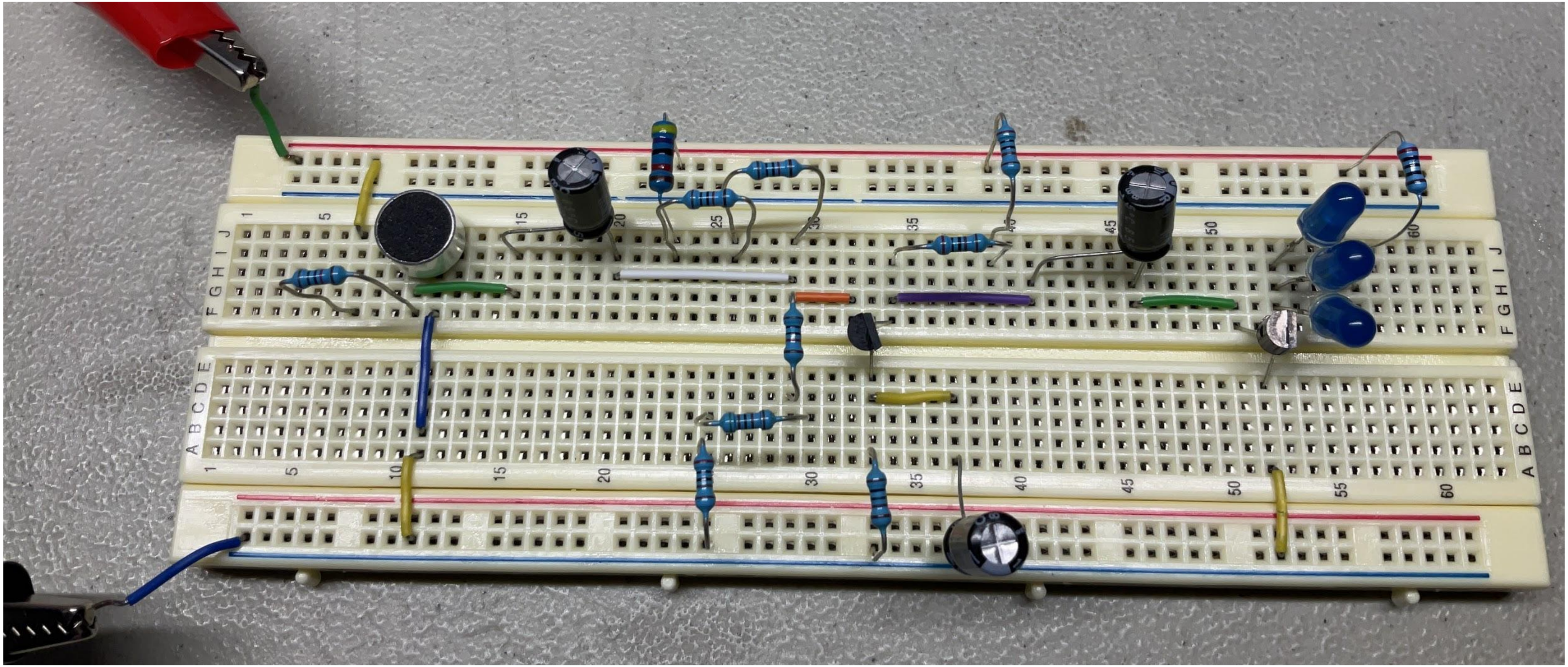
DO NOT ADVANCE to the next slide without trying to figure this out first!

Circuit Challenge 10: Solution

- Use the output of the amplifier to go into the base of a 2nd transistor that will be wired up as a switch.
- Ground the emitter of the 2nd transistor.
- On the collector, put a 200 ohm (red, black, black, black) resistor and three LEDs in parallel.
- A small current flowing into the base will turn on a large current through the collector; turning on the LEDs!

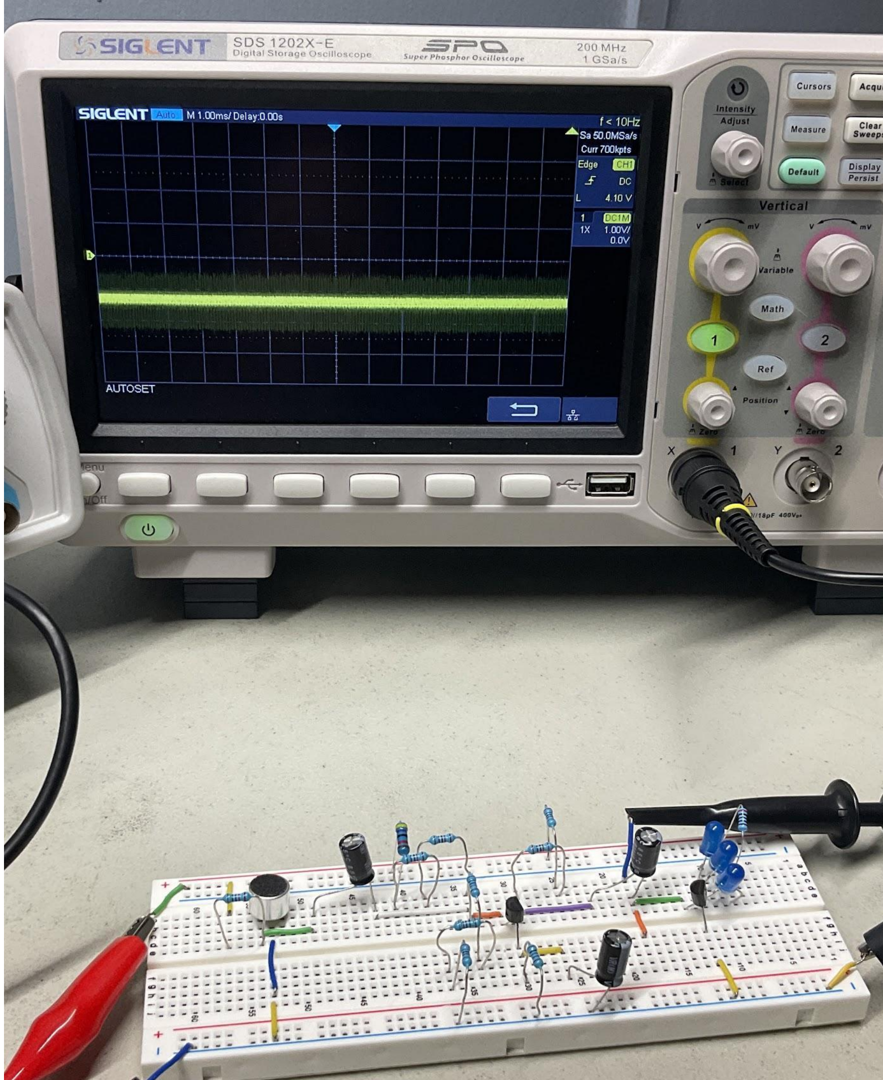


Circuit Challenge 10: Solution



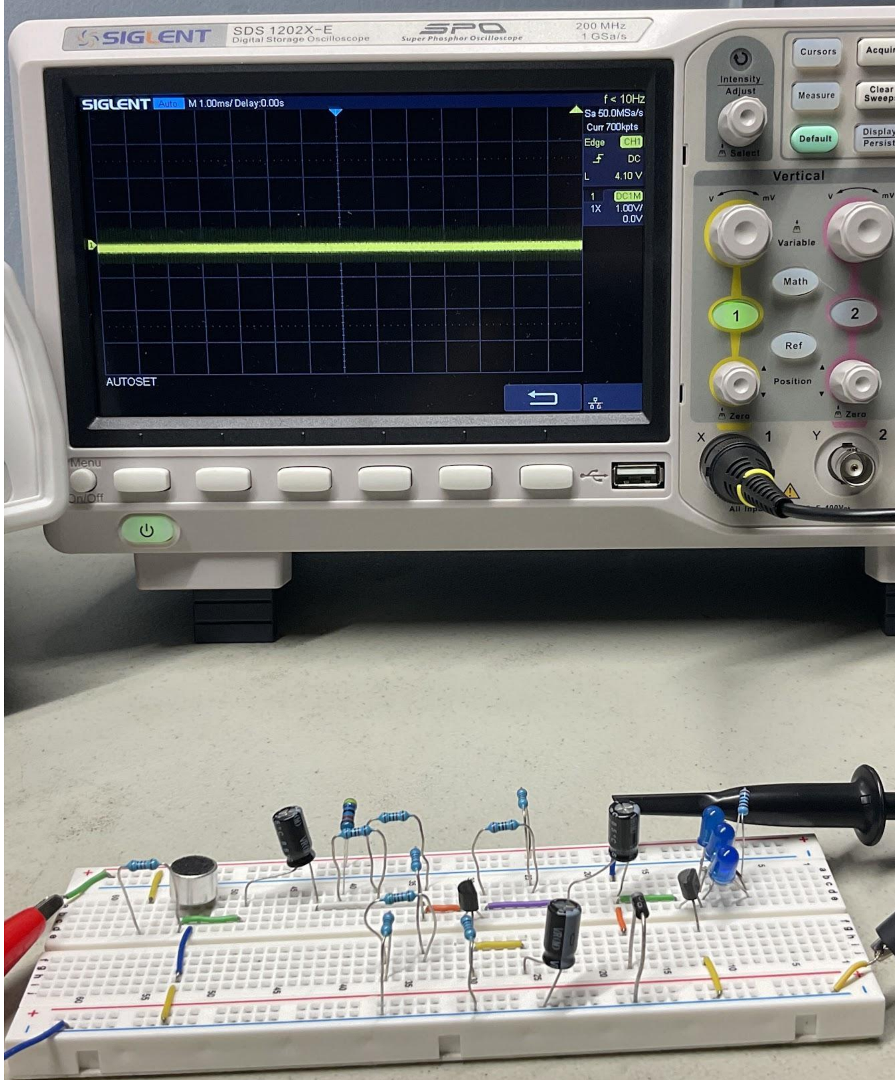
Increased Sensitivity

- As music plays, negative charge builds up on the capacitor and has nowhere to discharge to.
- This can limit the sensitivity of our light show as it would require a larger positive voltage to reach the 0.7 volts needed to turn the transistor on.



Increased Sensitivity

- One way to address this issue is to add a diode (reverse biased) to ground so the negative voltage can be discharged.
- This will increase the sensitivity of the circuit now.
- You may or may not like it though as most sounds will trigger the LEDs to light up.
- Test it and see what you prefer!



Increased Sensitivity