22.071 Final Presentation

By Mateo Pisinger

Original Goal: Radio Receiver in a Pen

Success criteria:

- Tunable to two different radio stations
- Fits in your pocket

Motivation

RF transmission technology is ubiquitous in the modern world, and (at least for the average person) is very reliable.

Why RF Technology?

I understood the basic concepts of RF transmission prior to the class, however I wanted to learn exactly how the core technology worked in detail.

Why AM signals?

They are much simpler to demodulate, which would allow me to design and test the electronics in the time given for the project.

Why fit it in a pen?

My cellphone fits in my pocket, and it can do a lot more than a radio receiver. This makes the technology convenient, and convenience is what makes technology get adopted.

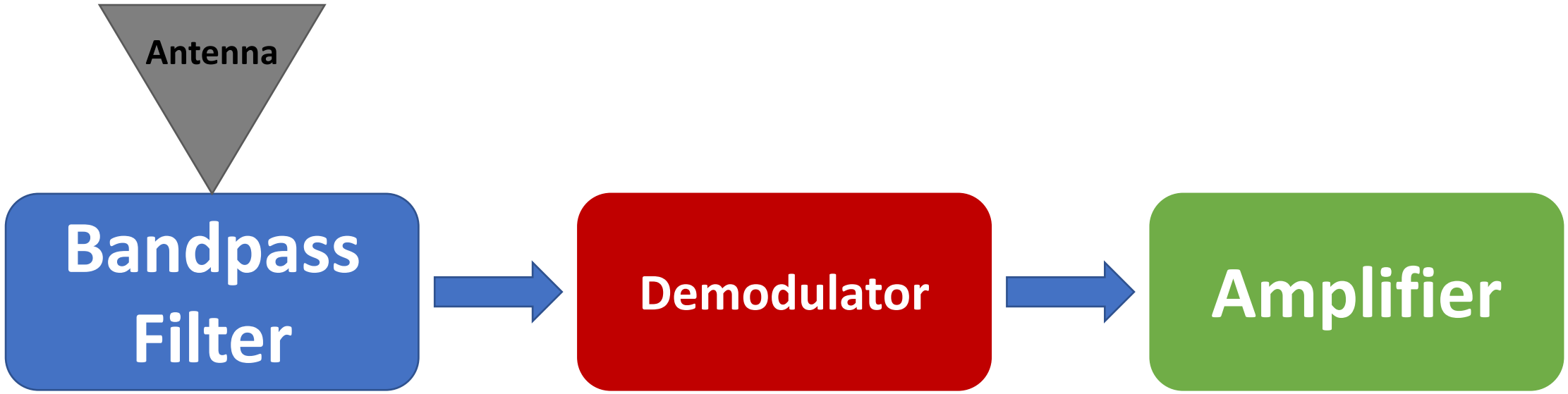
Original Goal: Radio Receiver in a Pen

Success criteria:

- Tunable to two different radio stations
- Fits in your pocket

*Neither of these were met.

Radio Receiver Fundamentals



Selects a specific carrier frequency via resonance. (a.k.a. “Resonator”)

Extracts the signal from the carrier wave.

Adds power to signal to make it audible.

Theory: Antennas

- Antennas extract signal (energy) from the EM waves that are emitted from radio stations.

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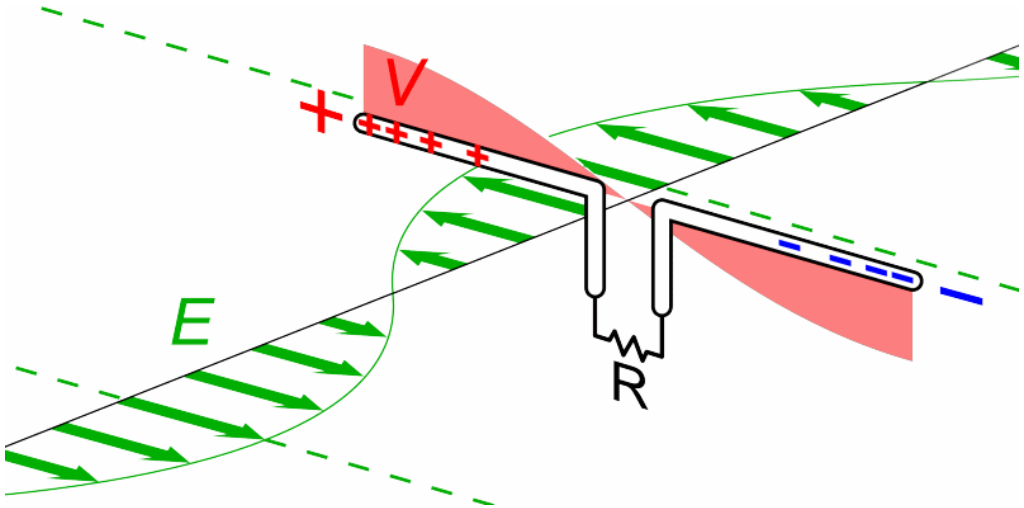
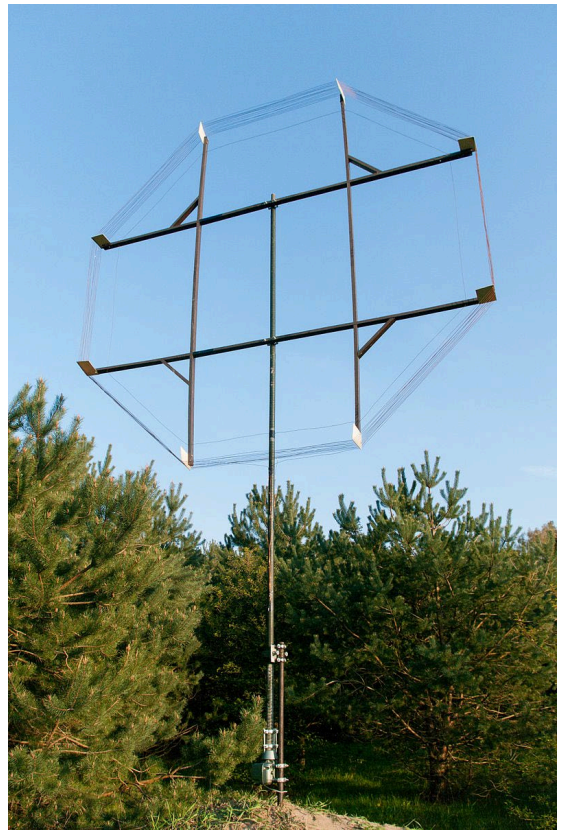
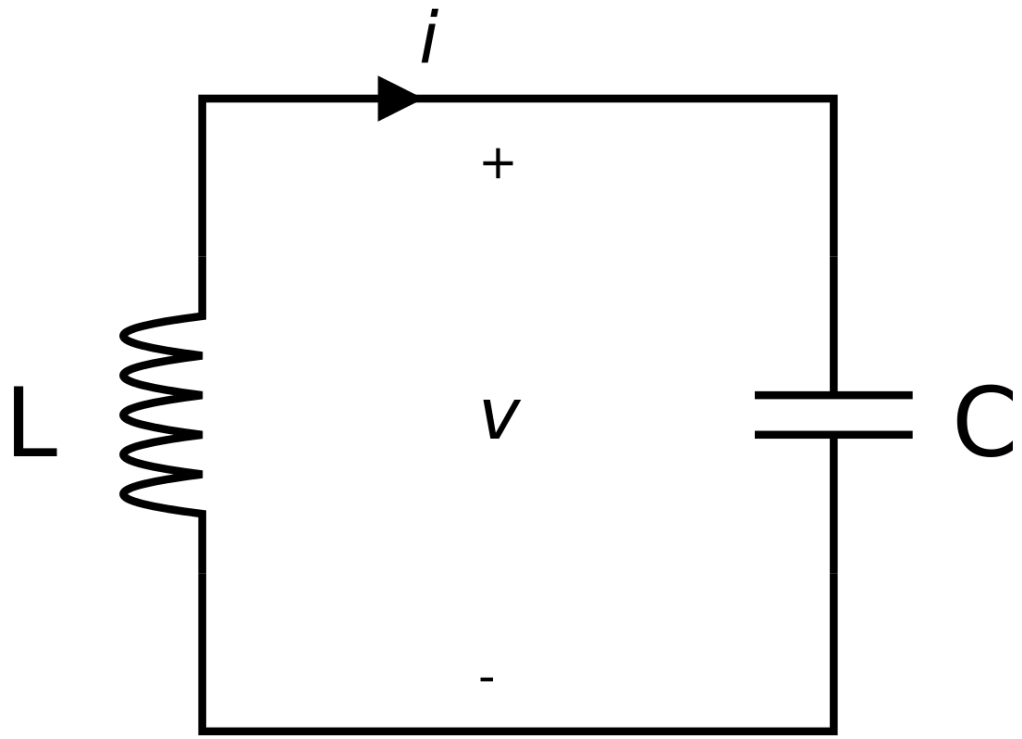
- Antennas extract signal (energy) from the EM waves that are emitted from radio stations.
- Come in two forms: Dipole or Loop Antennas.
  - Length = λ/4 (for optimal energy extraction





Theory: Bandpass Filter (Resonator)

- Resonators are circuits that allow AC signals of a specific frequency to pass while attenuating those of other frequencies.

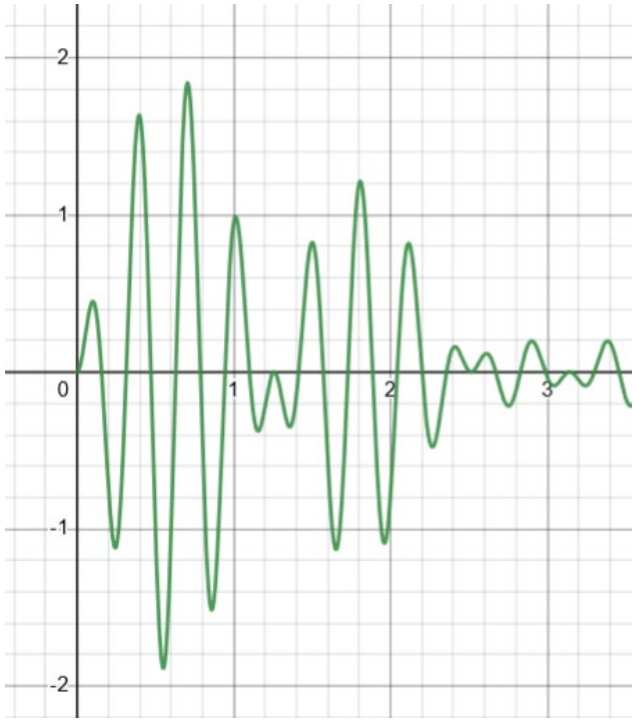


Resonant Frequency:

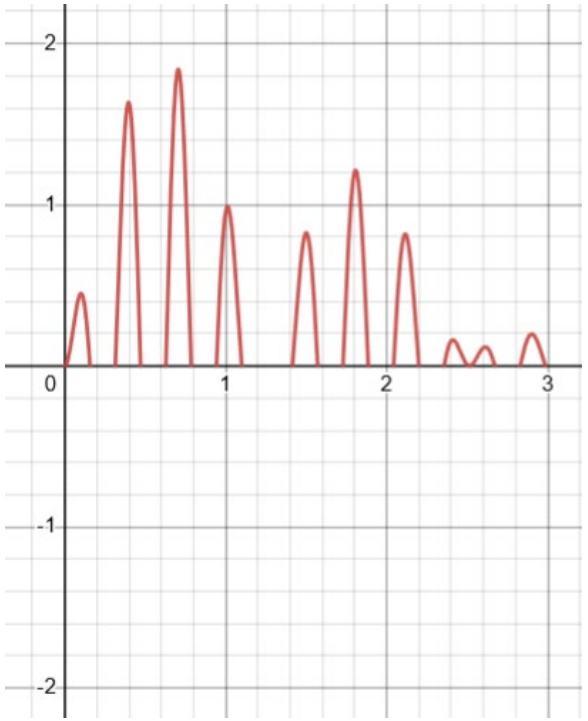
$$f = \frac{1}{2\pi\sqrt{LC}}$$

Theory: Demodulator

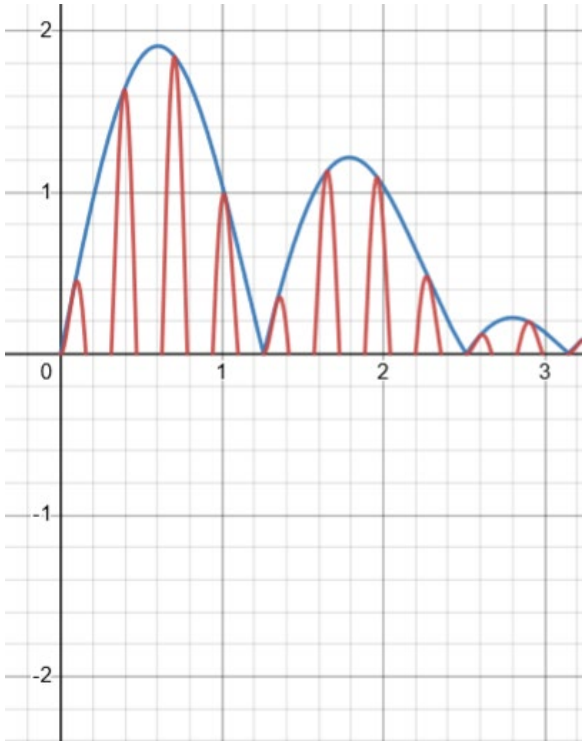
- Demodulators extract the modulated signal from the “carrier” signal.
- For an AM wave, this can be as simple as a diode, a resistor, and a capacitor.



Diode

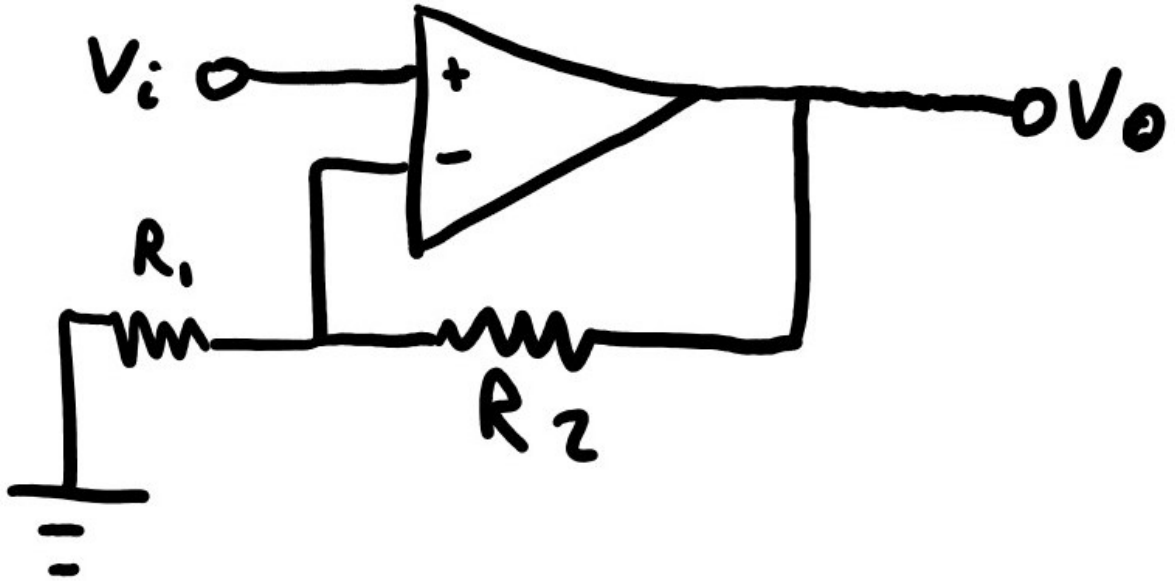


RC
Circuit



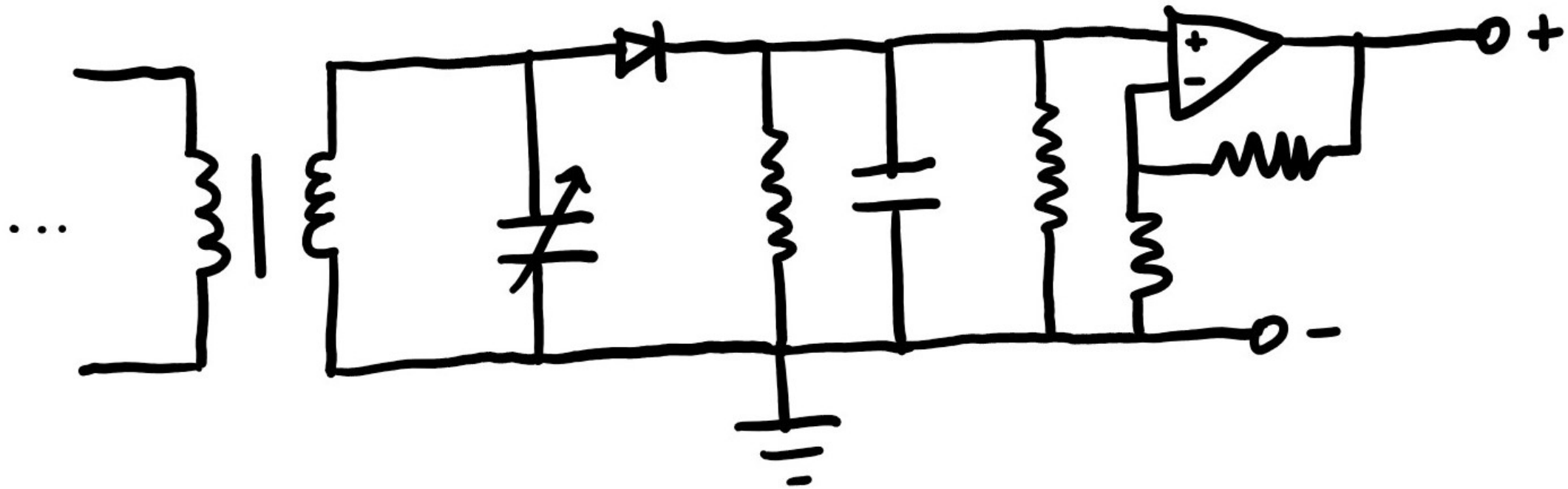
Theory: Amplifier

- Gives the signal more energy to make it audible/usable.

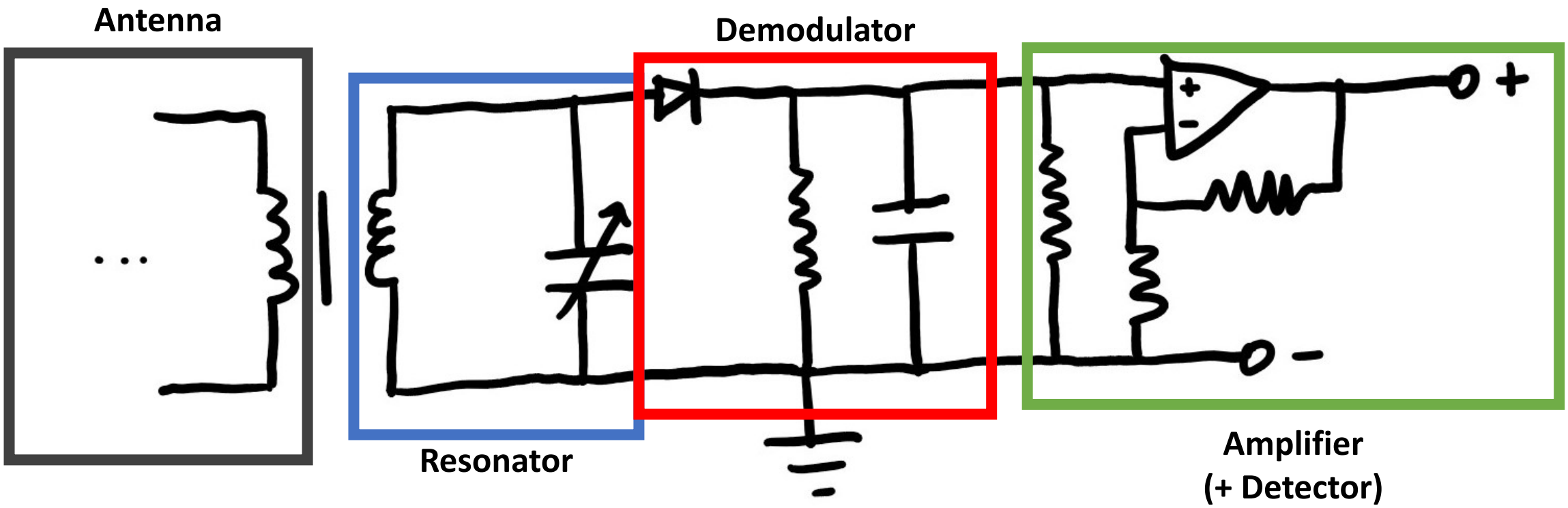


$$\text{Gain G} = \frac{V_0}{V_i} = \frac{R_1 + R_2}{R_1}$$

Final Design:



Final Design:

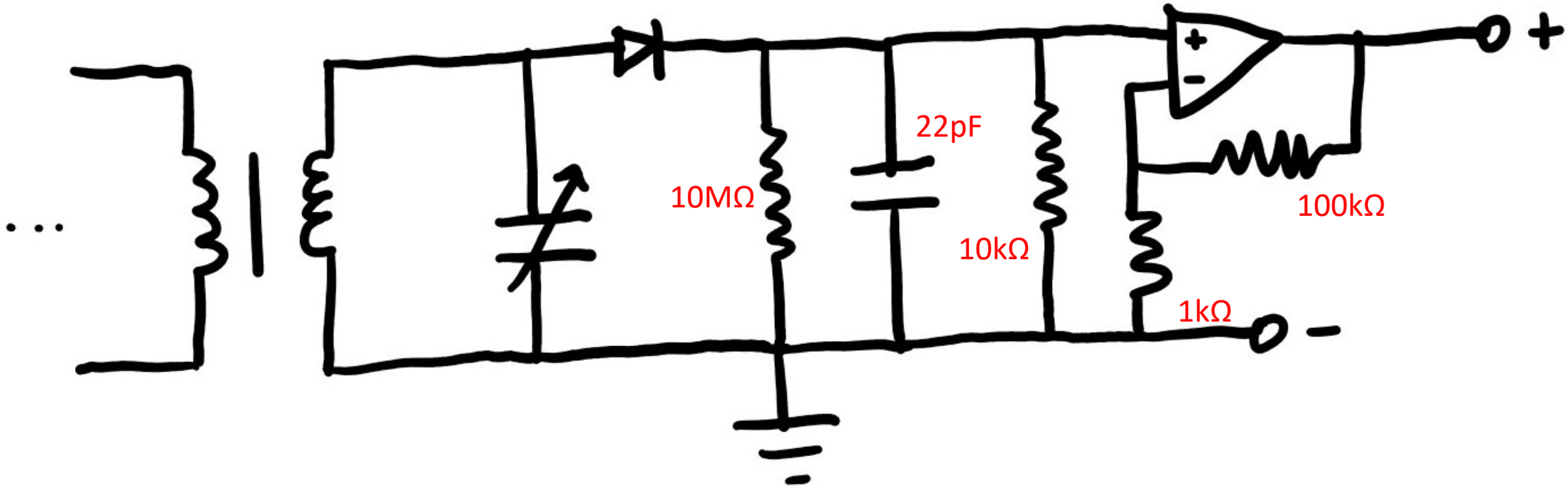


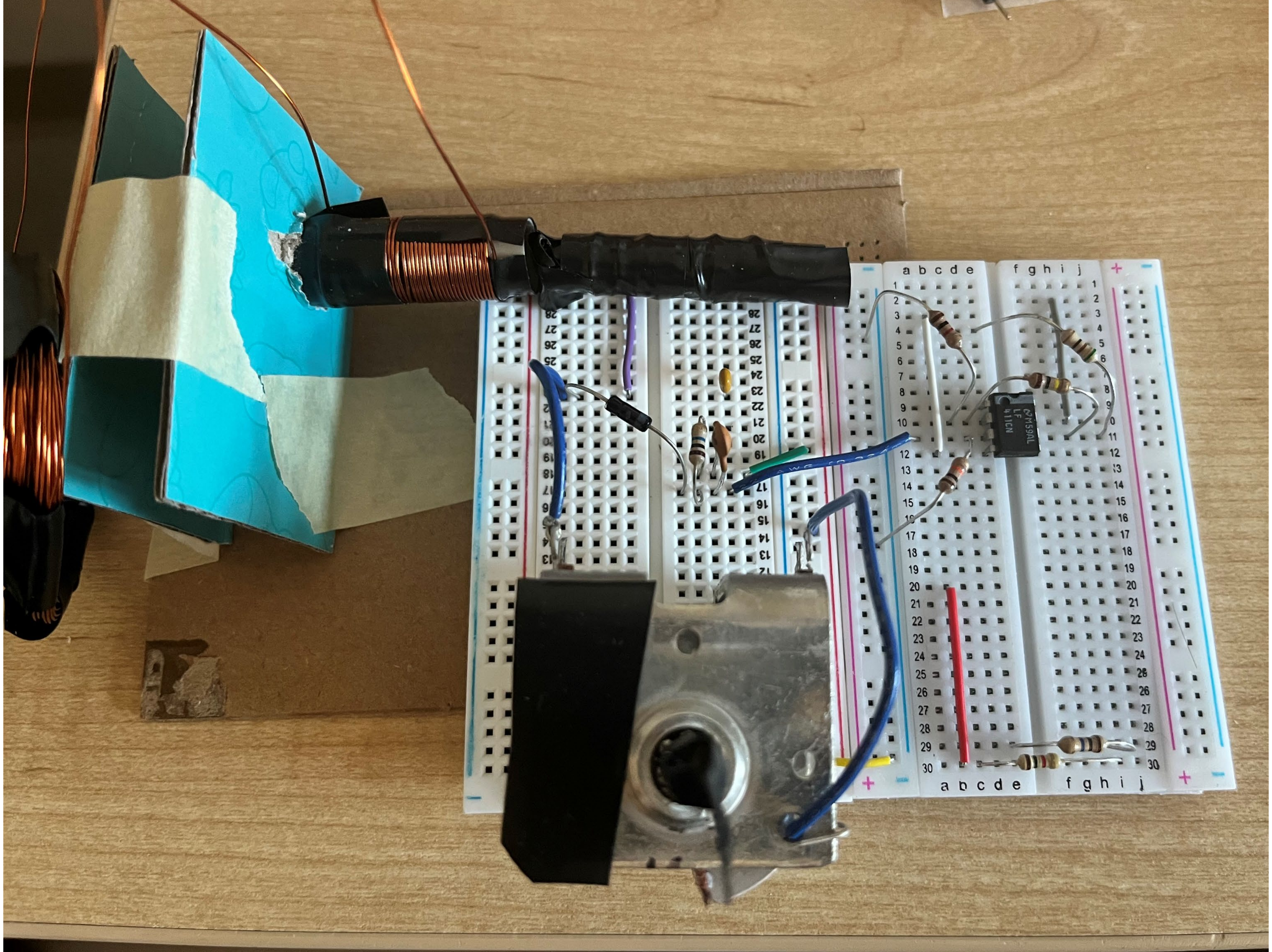
Design Specs:

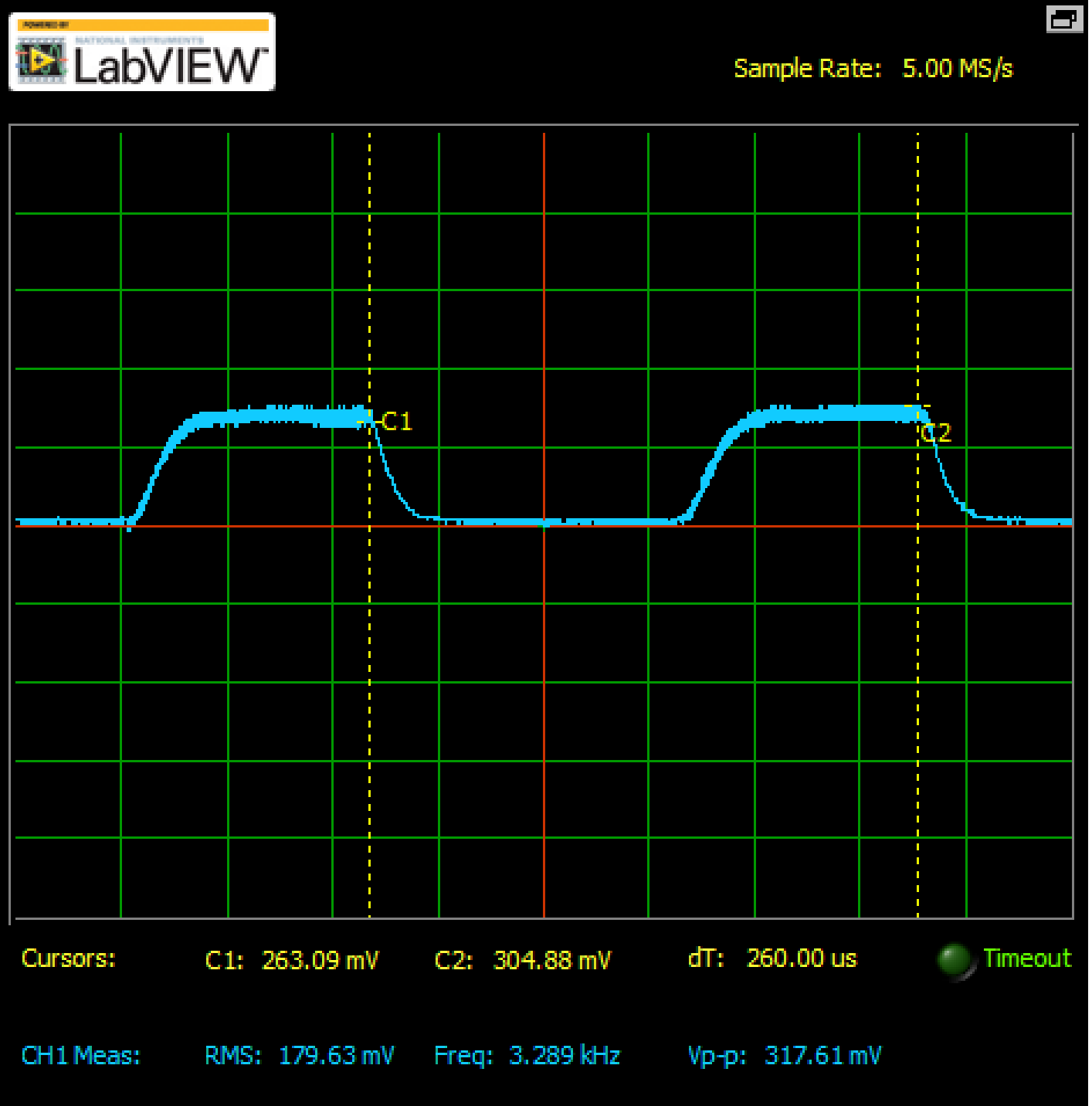
Inductor: 140 uH

Variable Capacitor: 16-415 pF

Op-Amp: LF 411CN







Test Signal:

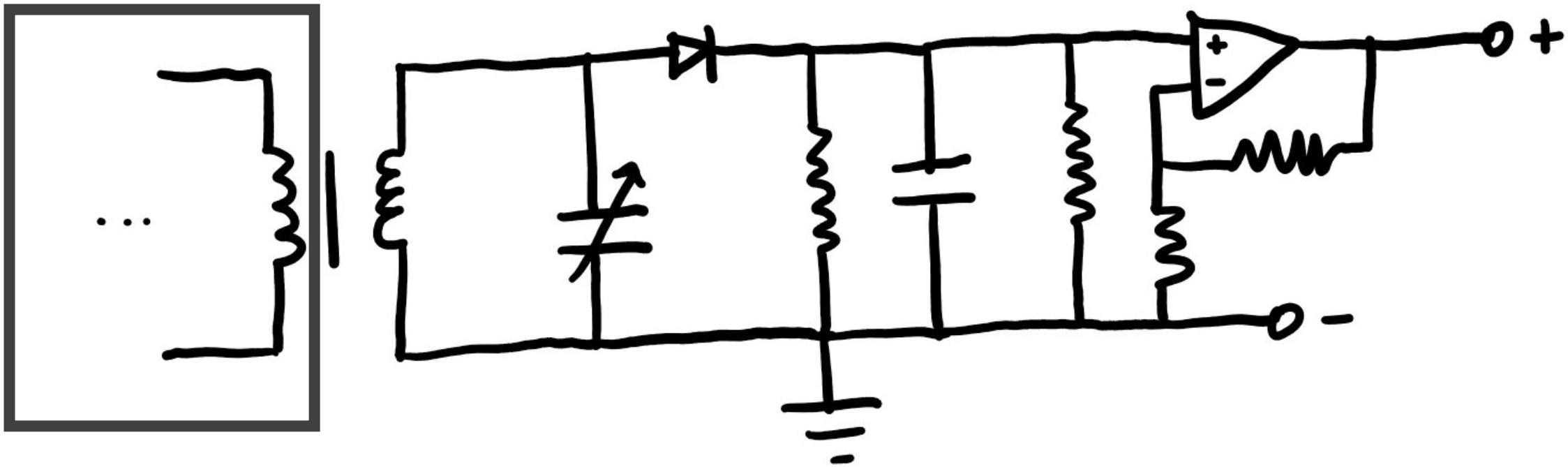
~3.6 kHz square wave Modulating a ~1 MHz carrier

Diagnostics

(or, how do we know it works?)

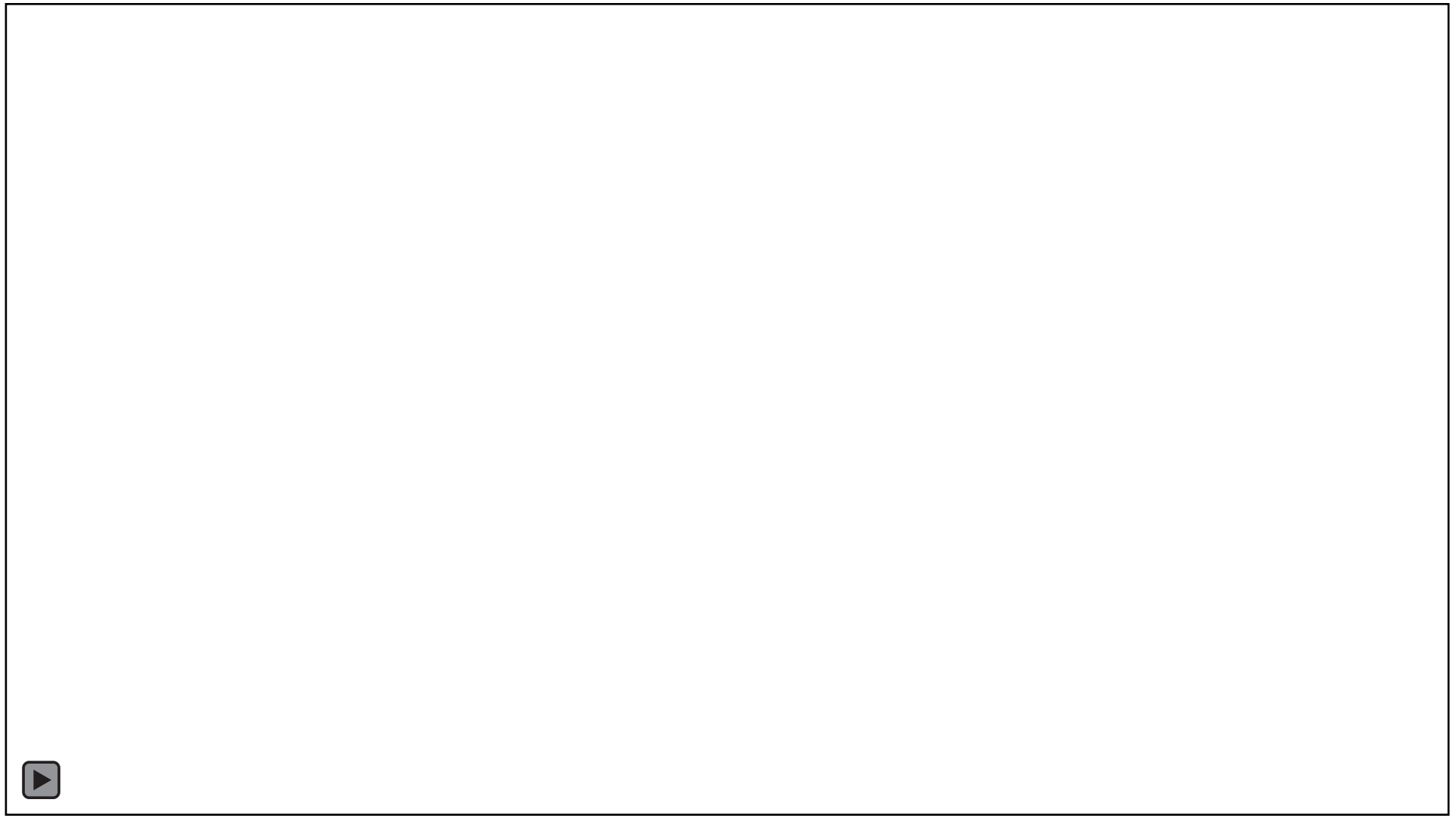
Diagnostic 1:

Function Generator

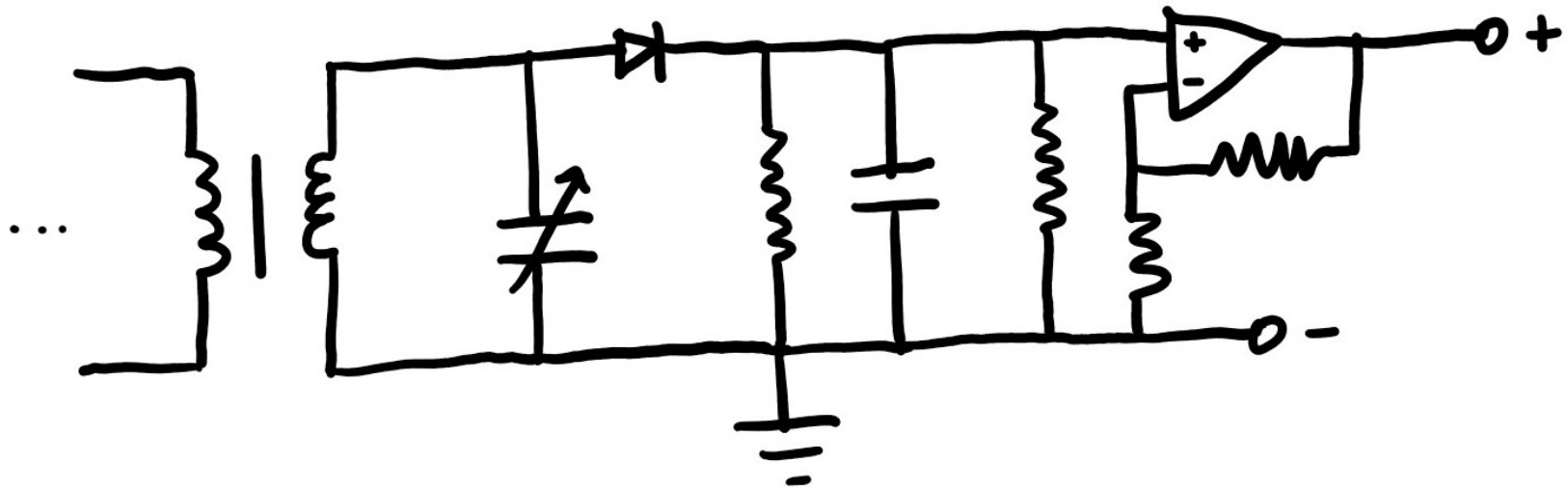


Input sinusoidal signal → Measure DC voltage

(0.2 Vpp at ~1 MHz)



Diagnostic 1 Results:

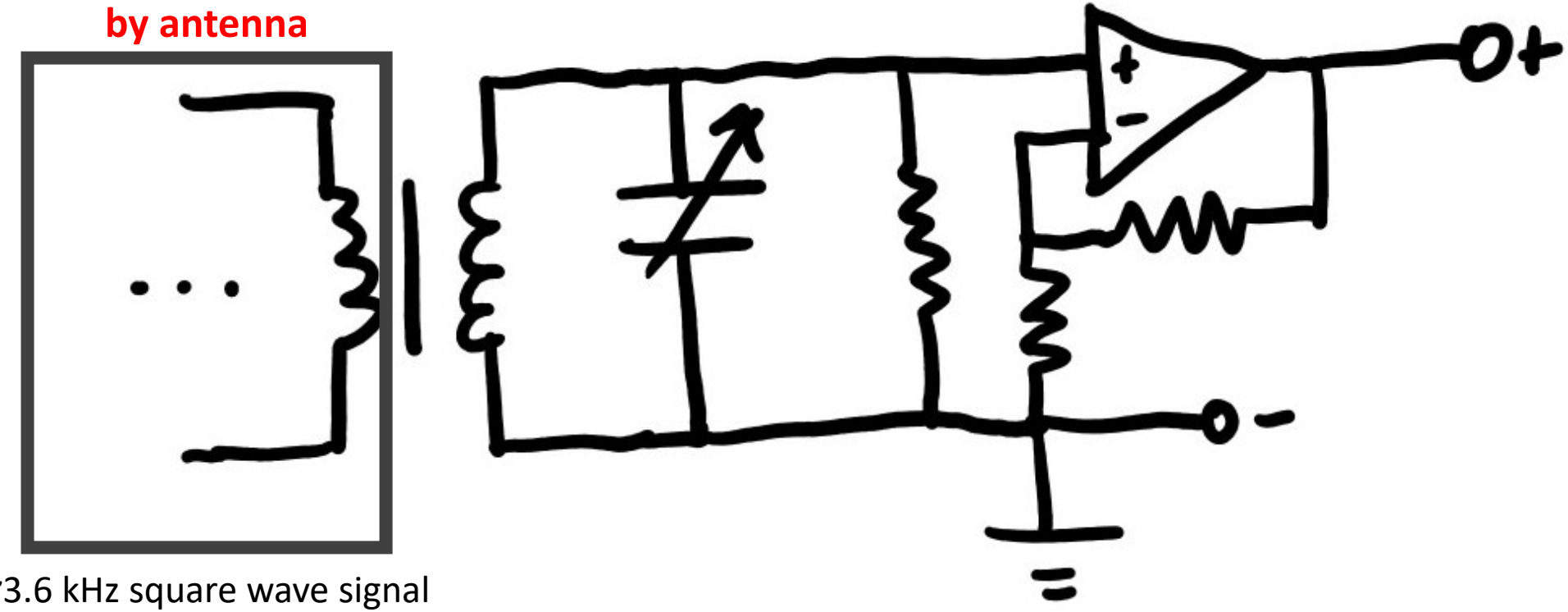


<u>Without amplifier</u>:
Linear gain between 3 and 4.

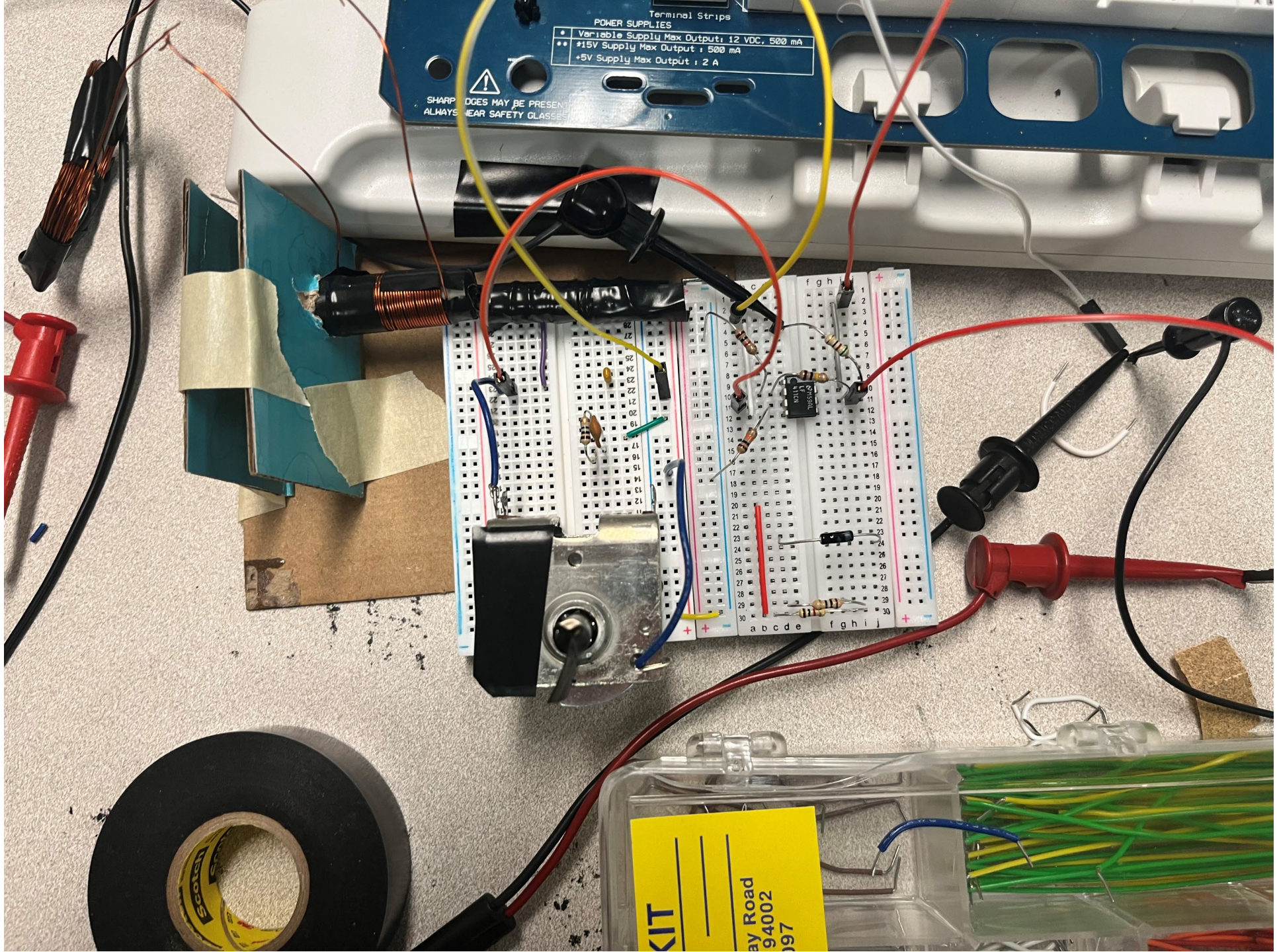
<u>With amplifier</u>:
Linear gain ~35.

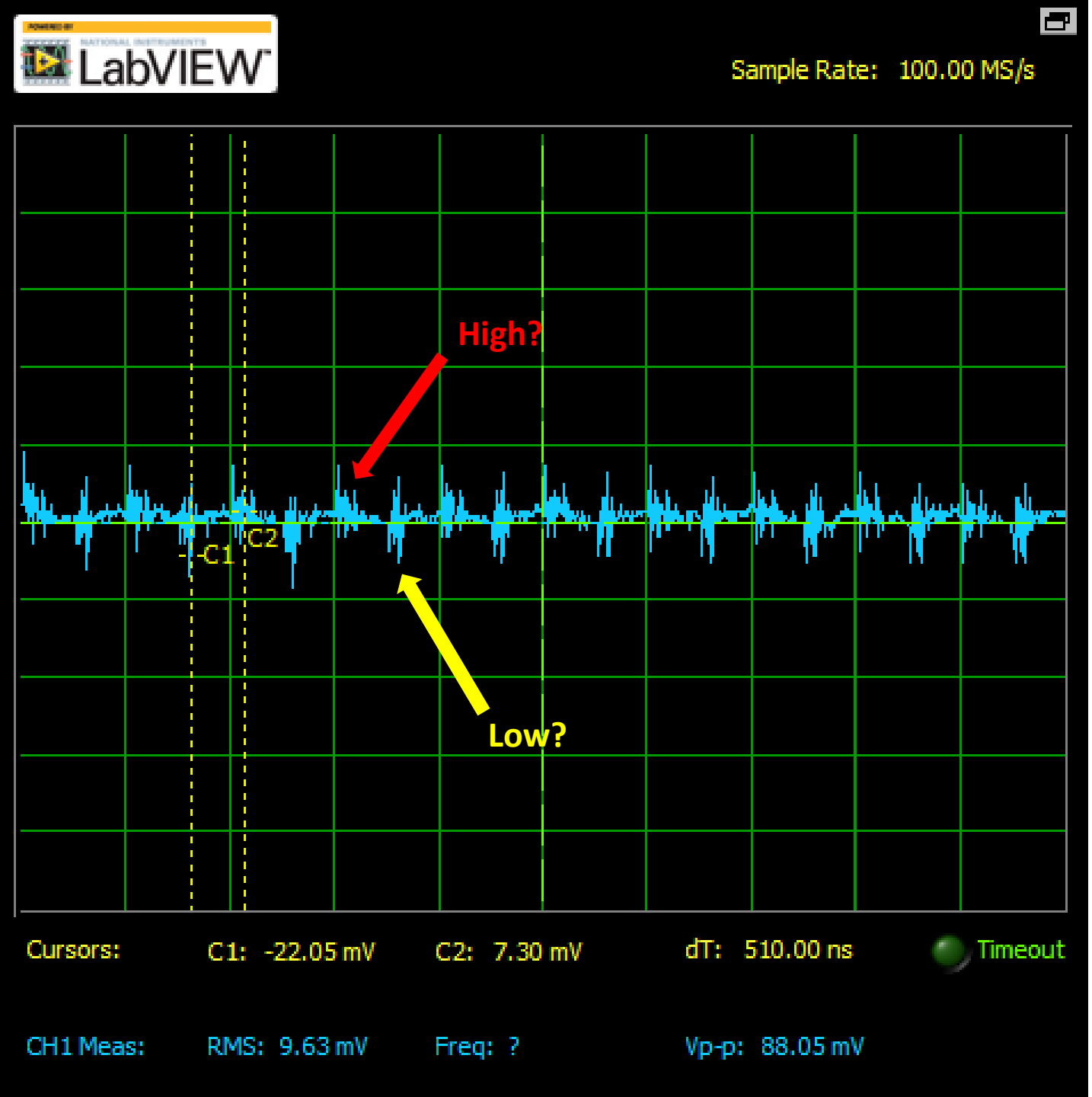
Diagnostic 2:

Transmitted signal picked up by antenna

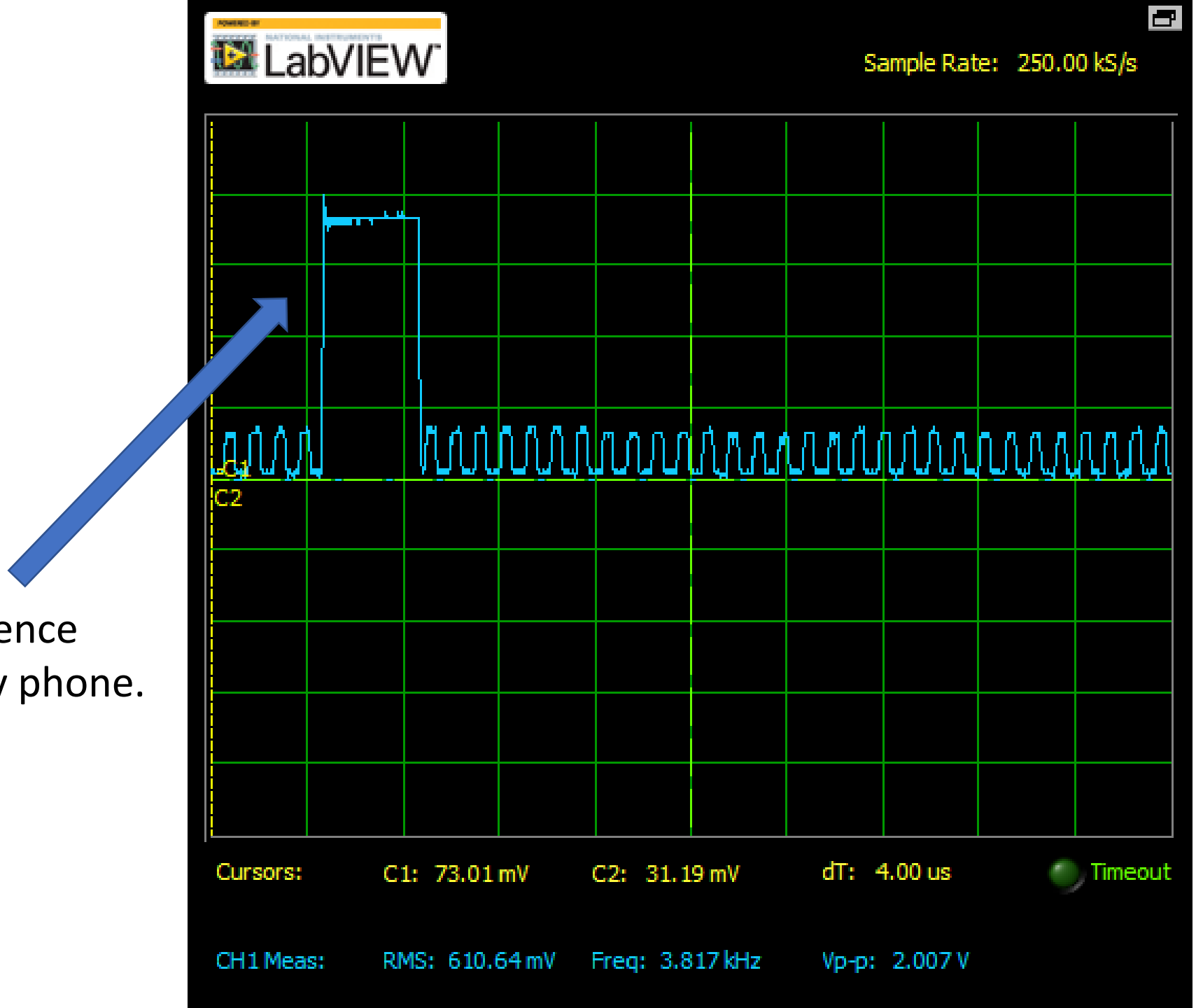


~3.6 kHz square wave signal
~1 MHz carrier


Terminal Strips
POWER SUPPLIES
Variable Supply Max Output: 12 VDC, 500 mA
±15V Supply Max Output : 500 mA
+5V Supply Max Output : 2 A
SHARP EDGES MAY BE PRESENT
ALWAYS WEAR SAFETY GLASSES
KIT
ay Road
94002
097



- Same signal as previously.
- Using demodulated output to look for carrier wave
- Expected to see a ~1MHz sinusoid



Interference from my phone.

Results

Radio station signals were not detected. A couple of times it seemed the oscilloscope picked them up, but they were never audible. Often just noise observed in the entire frequency range of the receiver.

Possible issues:

- Pass-band too narrow or broad (would need to make Bode plot to quantitatively verify).
- Amplifier gain is too low.
- Antenna not picking up enough signal.
- (Some combination of the above.)

Future Steps

1) Bode Plot: Gives me a quantitative description of the behavior of the receiver circuit. Should have been the diagnostic tool to verify bandwidth of radio.
2) More Amplification: Rule out faintness of signal. Need to be careful to not damage the electronics if gain is too large.
3) Get the Receiver Working: At all. Currently it doesn't detect any station's signal. This is the first milestone before the device can be optimized.
4) Fit it in a Pen: The main challenge is making a variable capacitor that can cover the correct frequency ranges. Inductors with correct inductance are easy to make reasonably small.

Conclusions and Lessons

RF receivers are hard to build.

Variable capacitors are easier to make.

RF signals are incredibly faint, and can fade into background noise/be blocked easily.

Interfering with radio circuits directly is easy. They need to be fairly isolated.