ECE491: Antenna & Oscillator Design Report

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Abstract

Several species of oscillators, built for 31 MHz, 78 MHz, 230 MHz, and 1 GHz, were built (on breadboard, perfboard, and SMD protoboard) and tested. Dipole antennas were used for transmission and single-angle power gain was characterized.

Contents

1 31 MHz

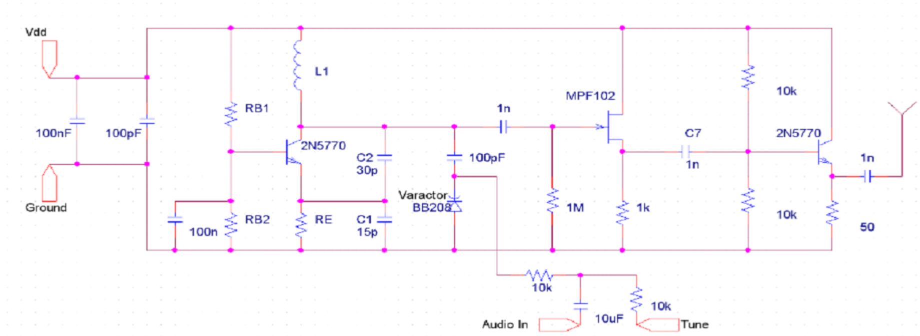

Figure 1: schematic view of the circuit which was used as a starting point for our 31 MHz transmitter.

The first oscillator we designed, as a test bench for longwave antennas, was a 31 MHz modulated oscillator intended for transmission purposes. The oscillator was varactor-tuned to allow for FM transmission; design inspiration came from [1]. The oscillator itself is shown in figure 2, and an experimental receiver we built for use alongside it is shown in figure 3. The schematic of the oscillator is given in figure 1.

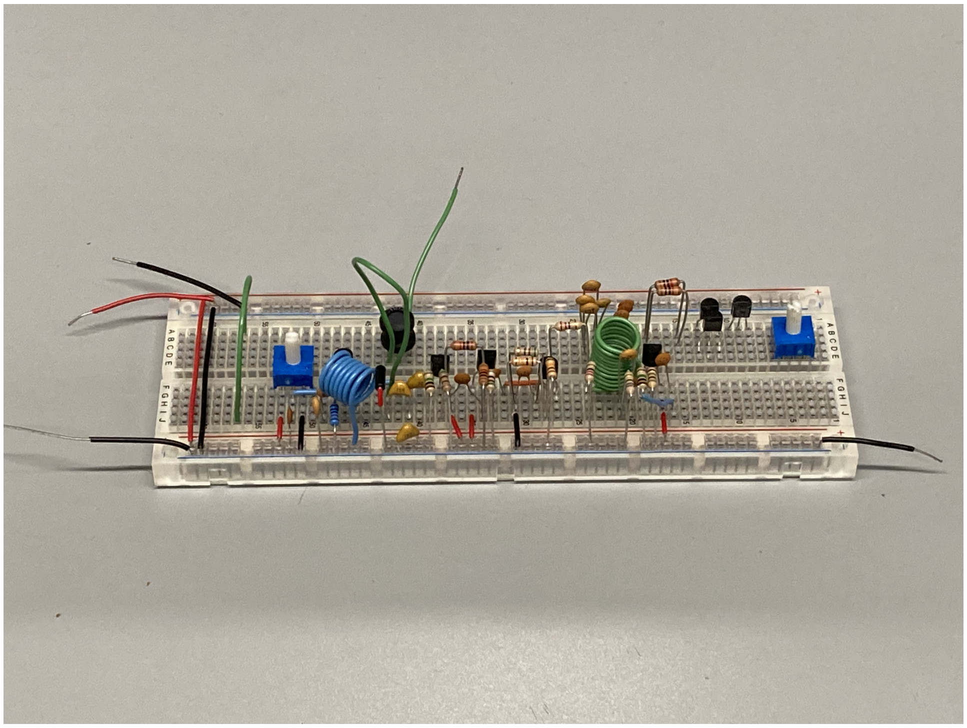

Figure 2: the 31 MHz transmitter, as built on a breadboard.

We also constructed a receiving circuit, shown in Figure 3. However, most of our testing was completed using an RTL-SDR software-defined radio, because of its high adaptability to different frequency ranges and relatively more accurate representation of received signal strength.

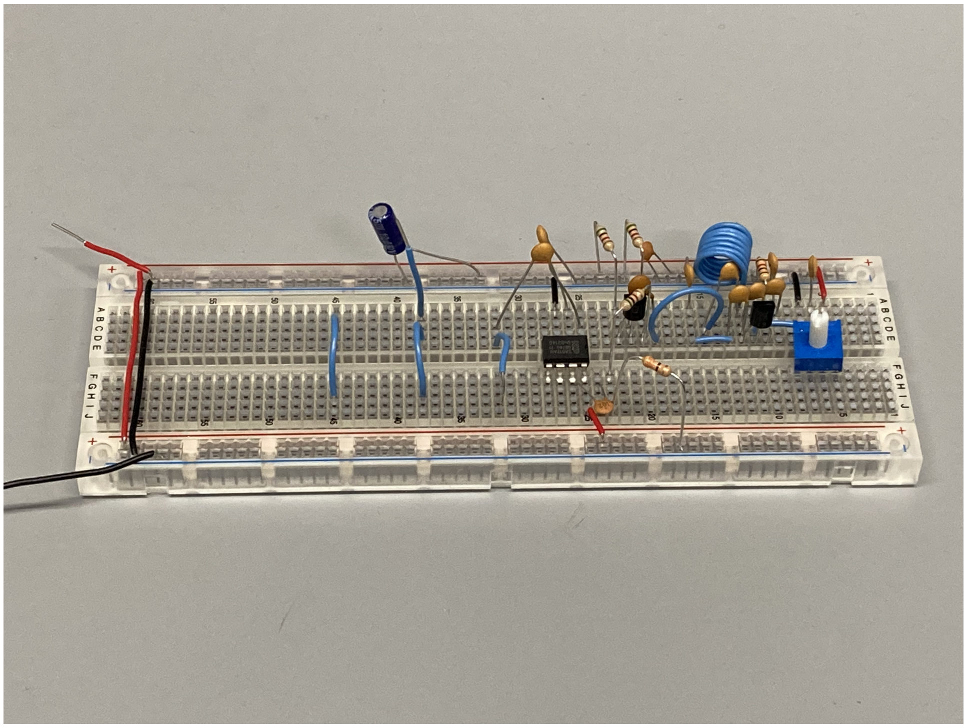

Figure 3: an experimental 31 MHz receiver.

1.1 Use with Dipole Antenna

We constructed a dipole antenna for use with the 31 MHz oscillator, to test transmission efficacy. This antenna was designed using the information on half-wave dipole antennas in [2]. Received power (measured on the other side of the lab) improved by about 30 dB with the antenna attached, as shown in figures 4 and 5.

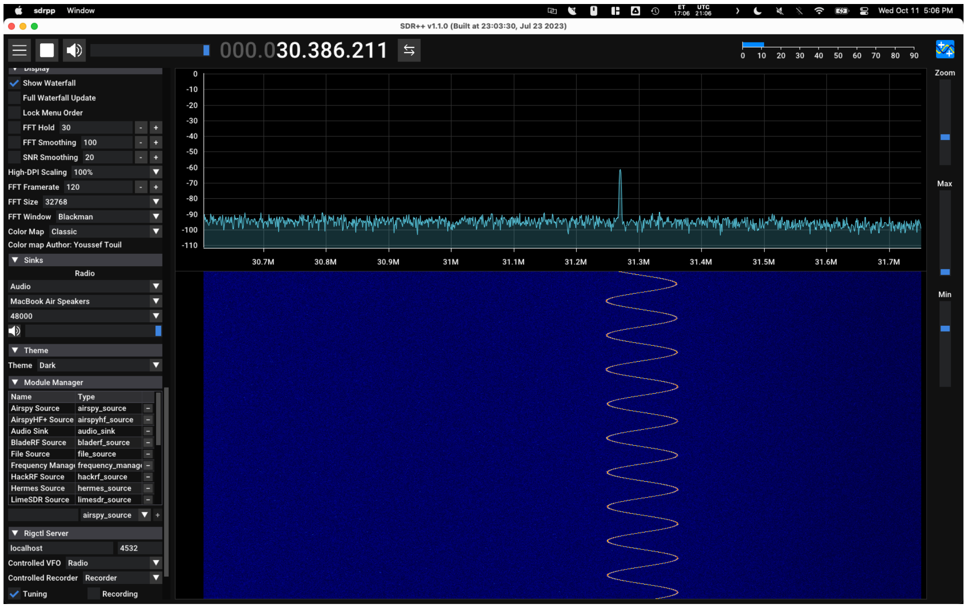

Figure 4: the transmitted signal of the 32 MHz oscillator, as received by our SDR, with no antenna attached. Received power was about 60 dB down from our reference.

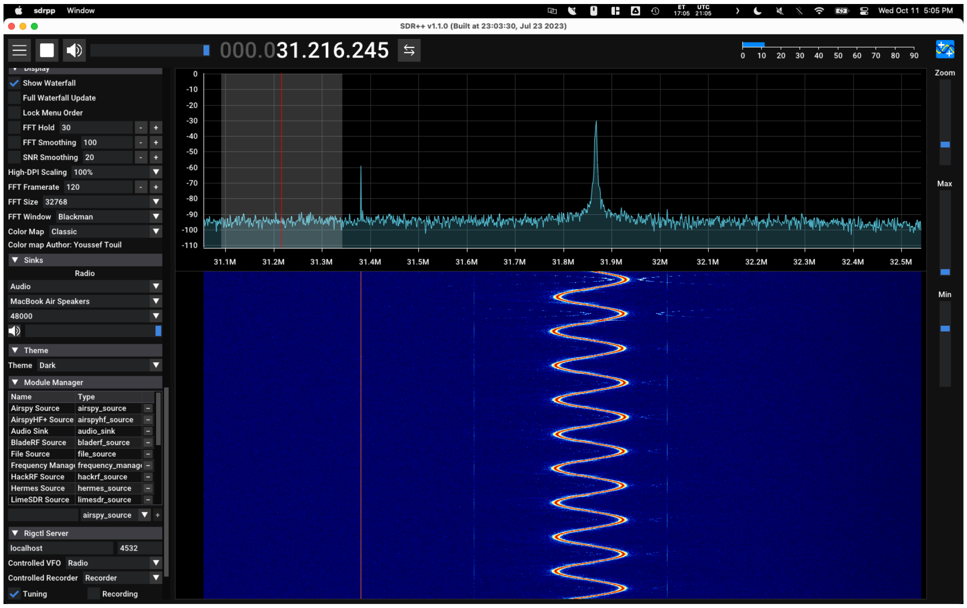

Figure 5: the transmitted signal of the 31 MHz oscillator, as received by our SDR, with a half-wave dipole antenna attached. Received power was about 30 dB down from our reference.

2 78 MHz

The second oscillator we built was a 78 MHz, varactor-tuned oscillator, also intended for transmission. The oscillator as built is shown in figure 6, and its output is shown in figures 8 and 9. This oscillator was also based on the circuit shown in figure 1; component values of the LC resonator were changed to achieve a higher carrier frequency. An amplitude compression circuit was added to the output of the transmitter, to produce output with more uniform amplitude across frequency.

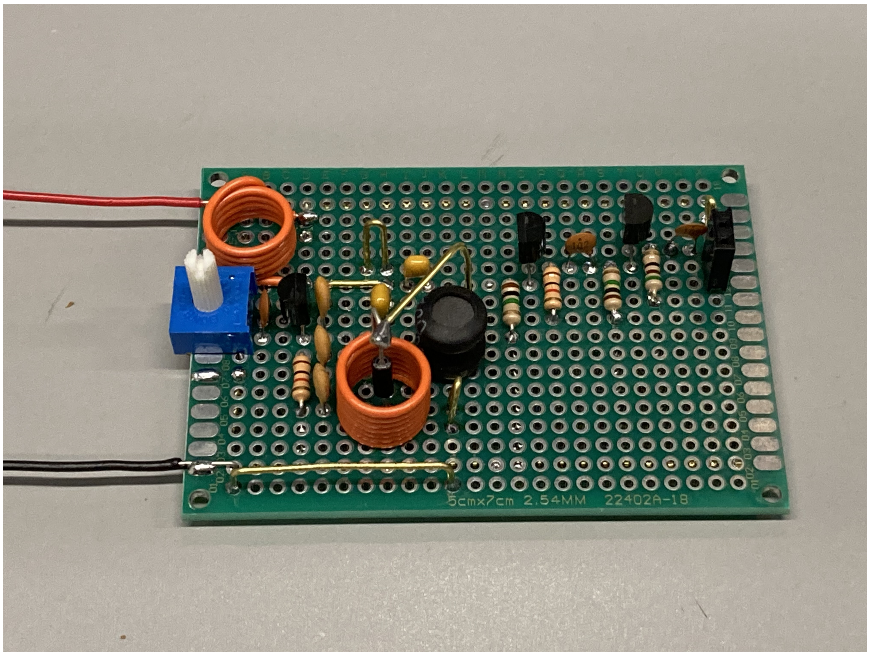

Figure 6: the 78 MHz oscillator, as built on perfboard.

Figure 7: the current consumed by the 78 MHz oscillator with a 10 V supply; power use was then ∼360 mW.

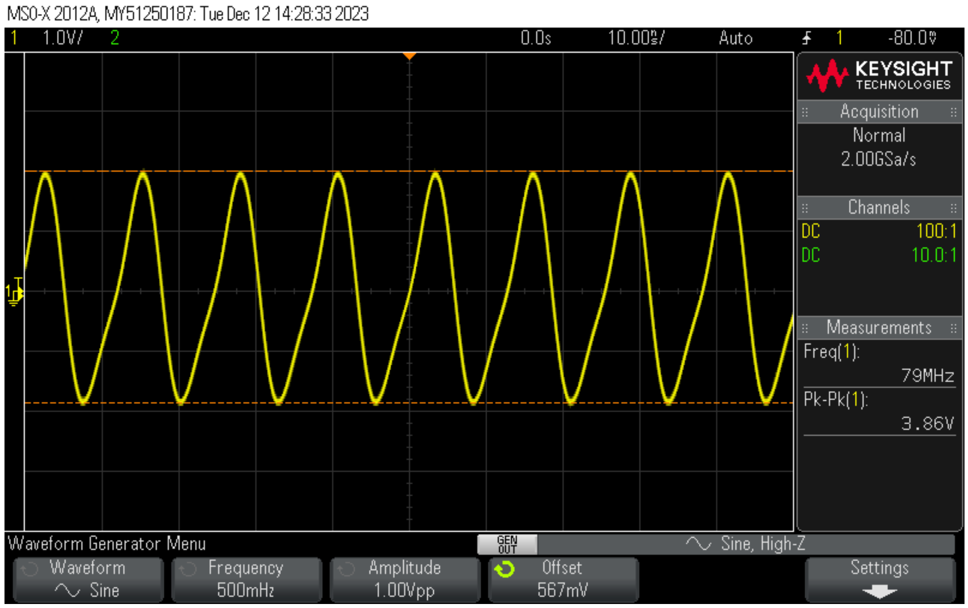

Figure 8: the output waveform of the 78 MHz oscillator.

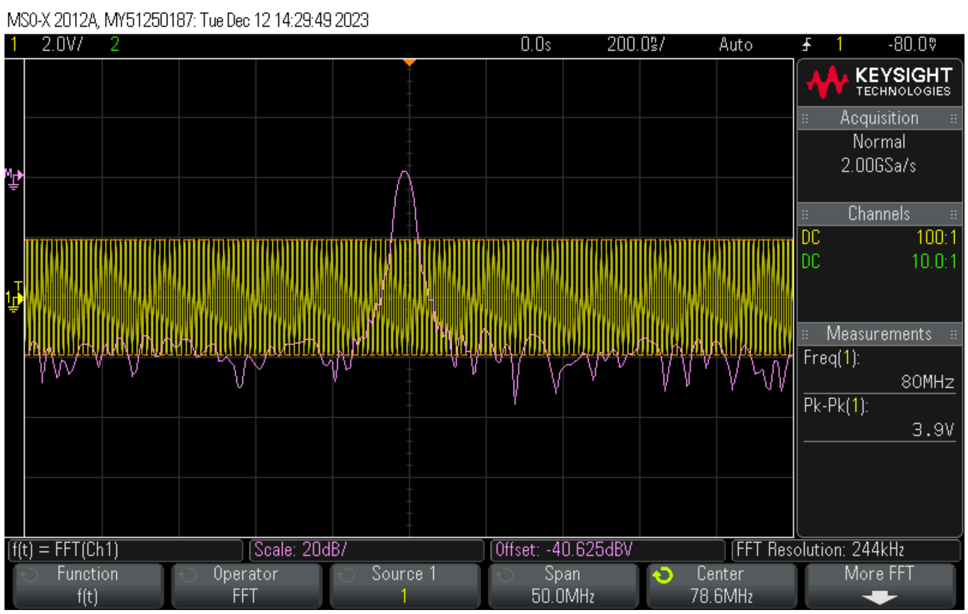

Figure 9: the output spectrum of the 78 MHz oscillator.

2.1 Modulation

For transmission tests (likely to be performed in depth next semester), we constructed a small audio amplifier to allow direct FM music streaming through the 78 MHz oscillator. The amplifier is shown in figure 10. The amplifier is a simple adjustable op-amp based design, so its schematic is omitted.

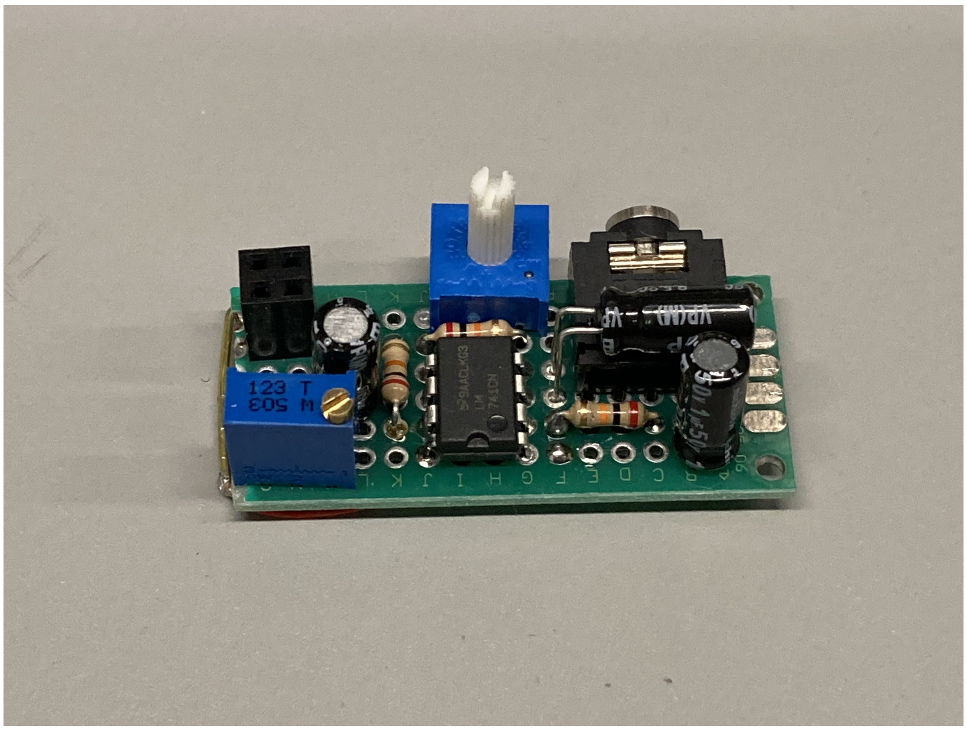

Figure 10: an audio amplifier to allow modulation of the 78 MHz oscillator with a computer's aux output.

3 230 MHz

As an experiment, we decided to find the highest frequency we could generate using ordinary parts from our lab. The highest frequency we achieved was just above of 230 MHz, using the oscillator shown in figure 11. This oscillator notably uses a 2N3904, which has a transit frequency of 300 MHz — barely higher than our oscillation frequency! The oscillator also does not use a discrete inductor: it uses its own parasitic trace inductance instead. For this reason, we believe that

230 MHz is about the upper frequency limit for through-hole perfboard oscillators made using “traditional” (non-RF aware) techniques. The output waveform of this oscillator is given in figure 13.

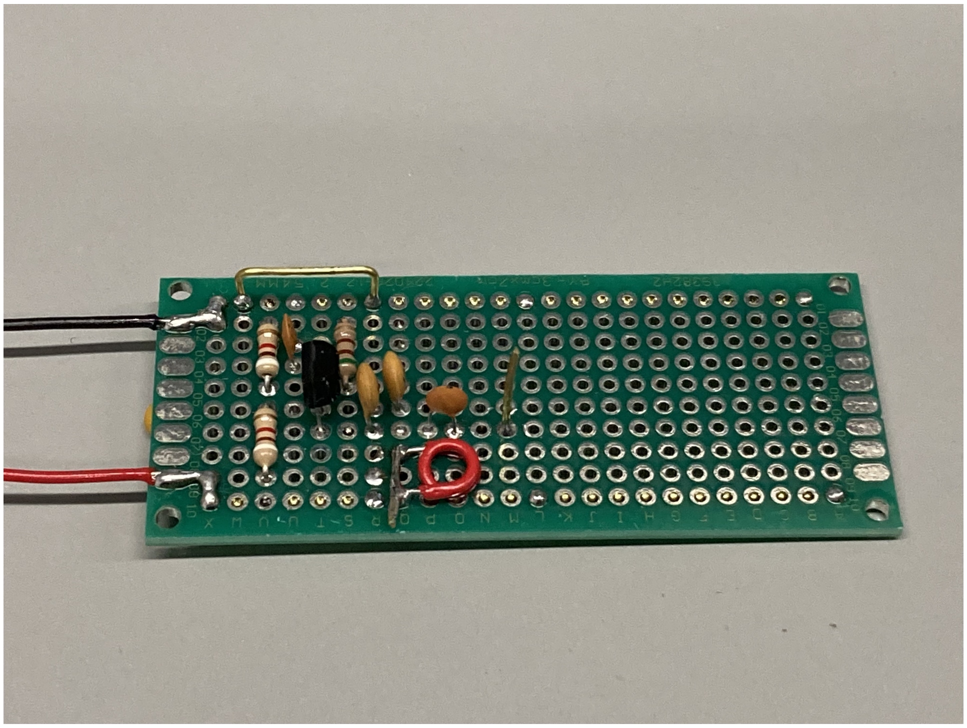

Figure 11: the 230 MHz oscillator, as built on perfboard.

Figure 12: the current consumed by the 230 MHz oscillator with a 10 V supply; power use was then ∼84 mW.

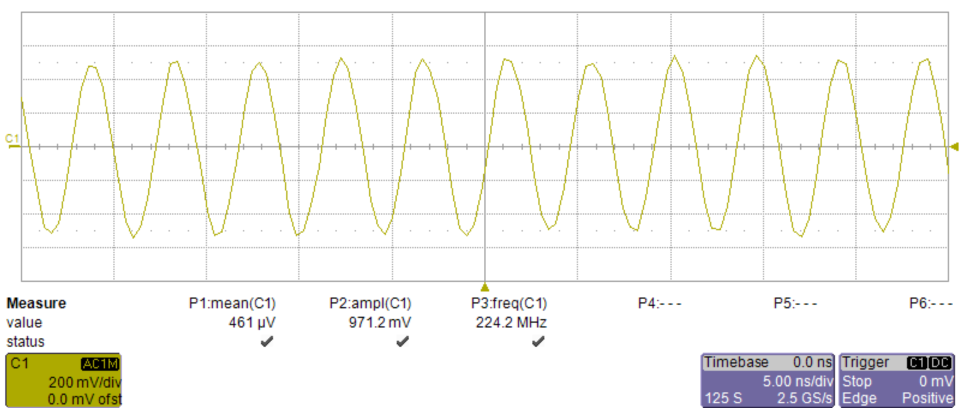

Figure 13: the output waveform of the 230 MHz oscillator.

4 1 GHz

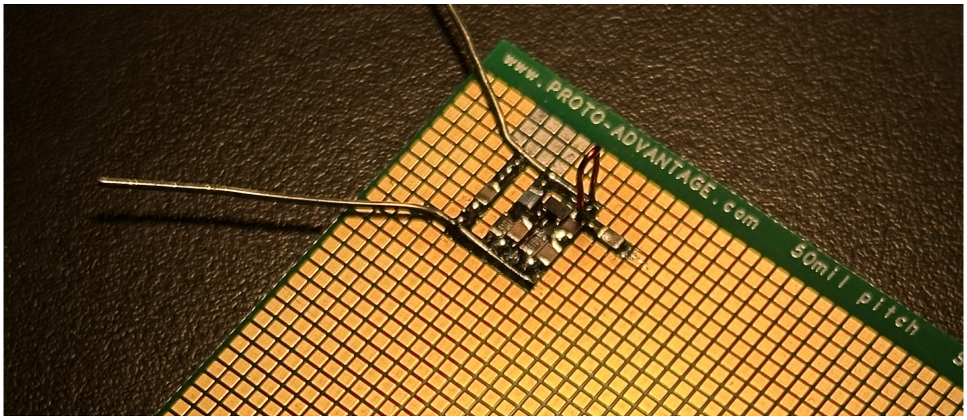

Figure 14: the 1 GHz oscillator, as built on SMD protoboard.

For our last oscillator, we decided to push the upper limit of protoboard oscillators by reducing our footprint and ordering purpose-built SMD transistors and protoboard. The result was the 1 GHz oscillator shown in figure 14. The schematic is given in figure 15, and the output waveform is given in 16.

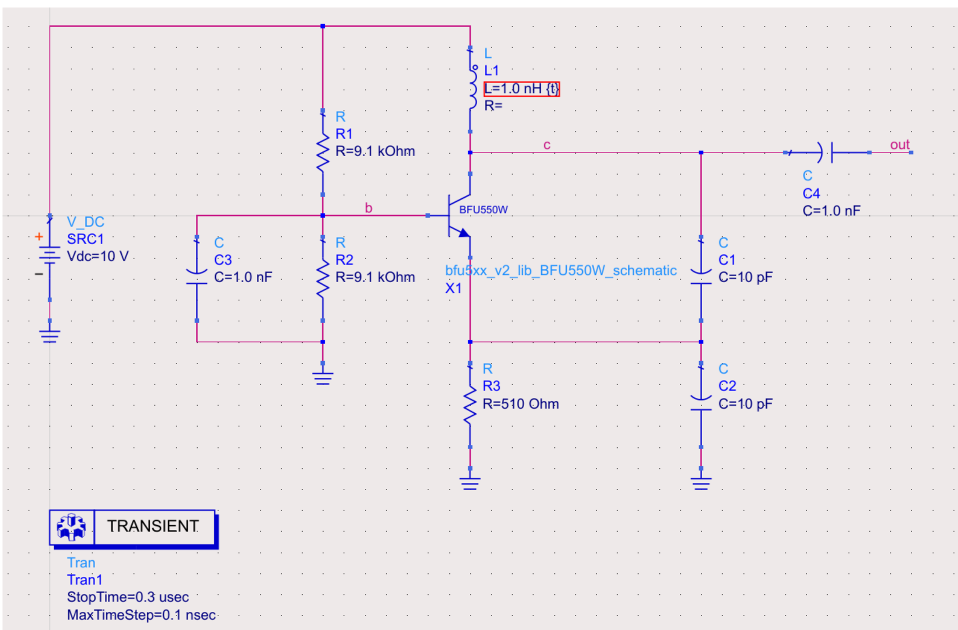

Figure 15: schematic view of the 1 GHz oscillator circuit.

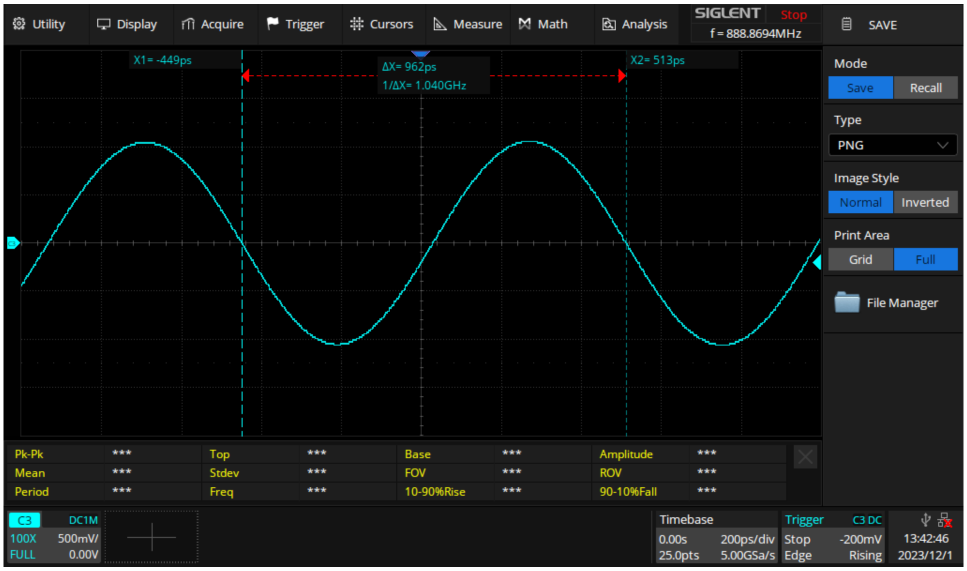

Figure 16: the output waveform of the 1 GHz oscillator.

4.1 Construction

Construction of a 1 GHz RF circuit requires special attention to parasitic inductance and capacitance, as well as wavelength. To this end, we decided to make the circuit as physically small as possible and place a power supply decoupling capacitor as close to the oscillator as we could. The construction of the oscillator is detailed in figures 17 (showing example part placement), 18, and 19.

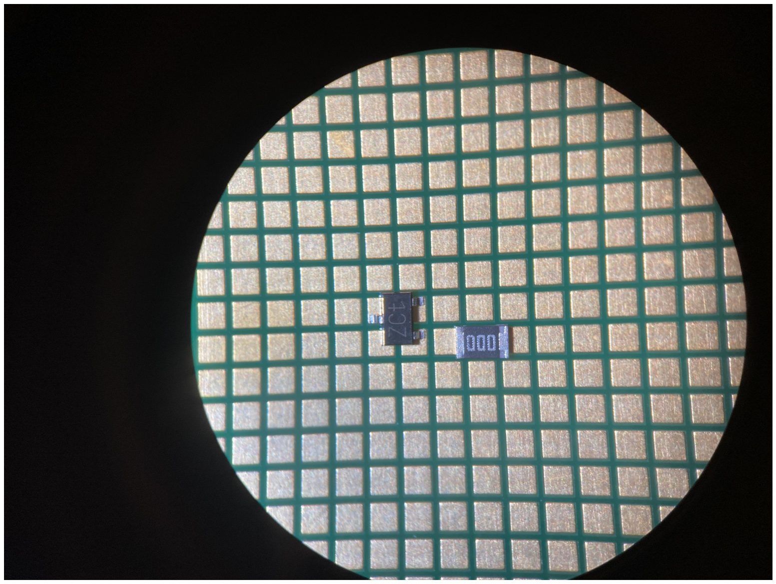

Figure 17: example part layout on SMD protoboard.

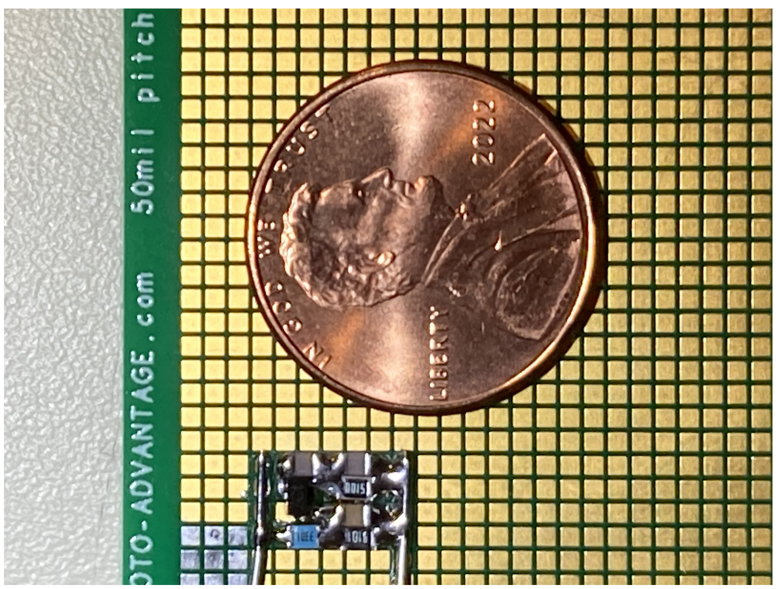

Figure 18: the 1 GHz oscillator before tuning, with a penny for size reference.

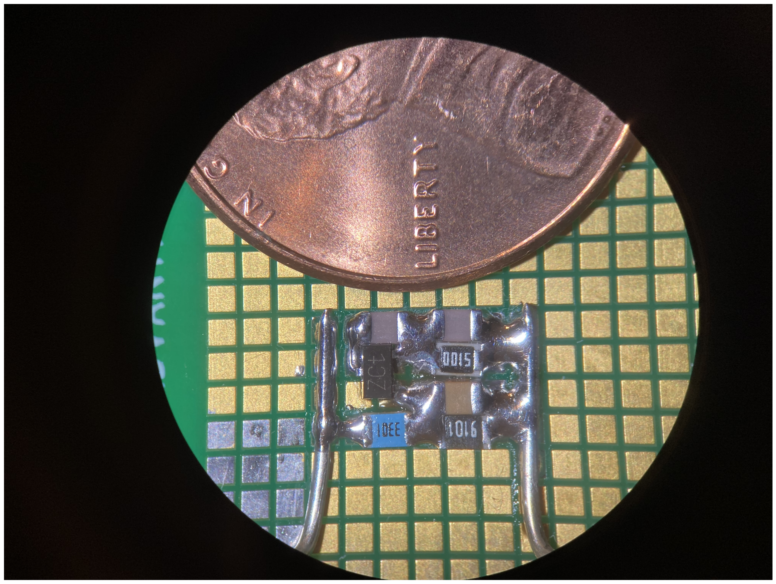

Figure 19: the 1 GHz oscillator, before tuning, under a microscope.

References

[1] J. Koo, *Expected lab report (draft)*, 2023.

[2] C. A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed. John Wiley & Sons, Inc., 2016.