Clapp Oscillators and RF Mixer

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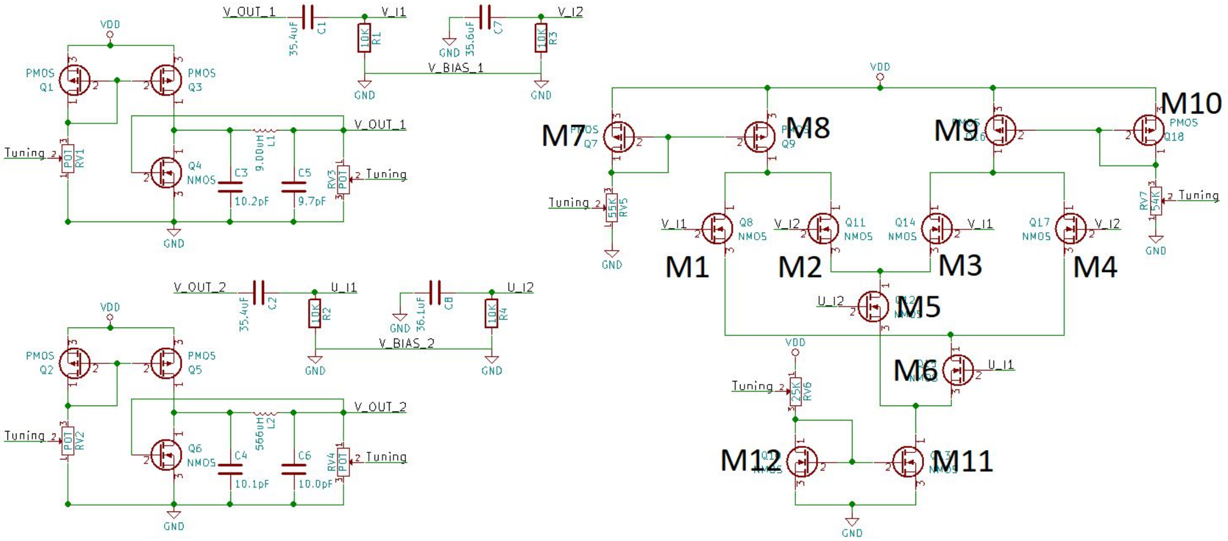
Approved by Robin, Checked off by Robin/Shimin

Schematic



Description

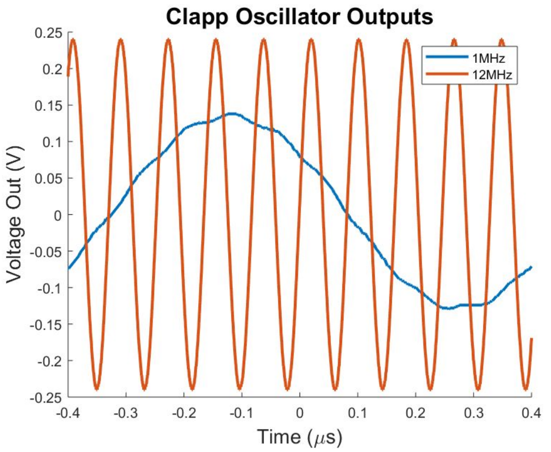
The circuit is a combination of two Clapp oscillators and a double-balanced RF mixer. The two oscillators convert noise into AC signals. The mixer multiplies two differential signals together.

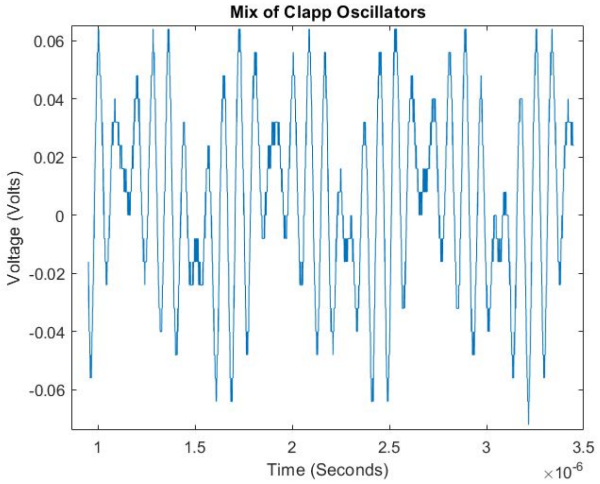
The oscillators work by setting up an amplifier and bandwidth limiting element in a positive feedback loop. Any noise at the frequency selected by the LC tank circuit gets amplified until its magnitude is large enough that the common source amplifier experiences gain saturation. This ensures that the complex loop gain is exactly one. The bandwidth limiting element is an impedance that consists of two capacitors, an inductor, and a resistor. The smallest available discrete capacitors were chosen to decrease the current which was required from the FET. We wanted to have fairly distinct frequencies produced by the two Clapp Oscillators to produce a clear mixed output signal. Since $\omega = \sqrt{\frac{C_1+C_2}{C_1 C_2}\frac{1}{L}}$ at resonance, we chose inductors with the most extreme values which still produced recognizable oscillations.

The RF mixer makes use of differential amplifiers such that the differential output is proportional to the product of two differential input signals. The output will give a signal that has both the sum and the difference of the two input frequencies. We chose the double balanced mixer for its increased linearity and because suppresses both input frequencies. As we were building, we decided to use NFET and PFET current mirrors as current sources and sinks in order to make biasing less prone to error. We designed for 300μA to pass through the very bottom NFET current mirror, so that the DC voltage of the output was approximately 5V, allowing large swings.

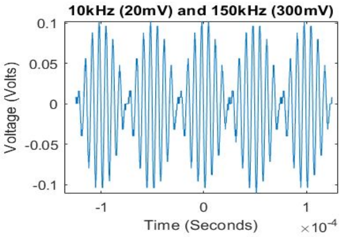
Specifications

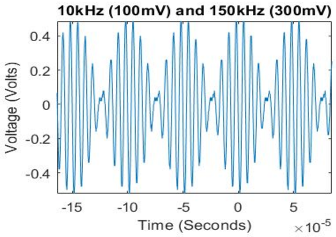
Our oscillators produced oscillations at a slower frequency than expected (12.2MHz vs 23.7MHz and 1.25MHz vs 3.0MHz). This can be accounted for if we assume that the breadboard adds parasitic capacitances on the order of 35-50pF to each of the discrete capacitors. While the 12 MHz oscillator came out pretty well, the 1MHz did not come out exactly as a perfect sinusoid. With tuning the bias resistor, we were able to increase max voltage swing to 4.4V (1.2MHz) and 5.1V (12MHz). We were also able to achieve -48dBc and 31dBc total harmonic distortion (12 and 1.2MHz respectively) and -32dBc second harmonic suppression for both oscillators at 0.6Vpp swingby tuning the filter resistor.

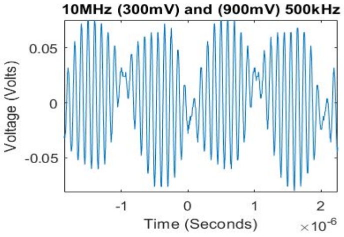


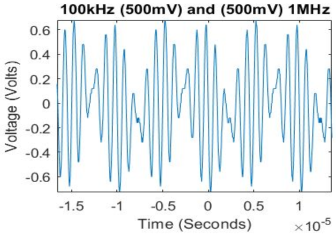


Mixing the oscillators gave a 12MHz signal enveloped in 1MHz beats, as we desired, but with hints of the underlying 1MHz signal. However, most power is at upconverted frequencies.









We then replaced the oscillator outputs with signals from a function generator to better characterize the function of our mixer. The mixer is able to mix frequencies from 10kHz to 10MHz. Our oscillator has a max gain of approximately 50 at f_{lo}=10kHz which sharply drops to 1 at f_{lo}=10MHz as either the amplitude of the input signal increases (gain saturation) or the frequency increases (gain limited by gate capacitances and velocity saturation). DC voltage measurements confirm approximately 75μA passes through each top NFET arm.

DC Voltages

	M11	M6	M3	M8
Gate	1.54V	3.06V	4.19V	8.27V
Drain	1.81V	3.17V	4.86V	4.93V
Source	0V	1.81V	3.17V	10.0V