Lab 3 – Generating and Measuring Waveforms

Benjamin Sage
Lab Partners: Marc Huerta, Devorah Simon

***Abstract*—A MOSFET mixer was built and analyzed using a spectrum analyzer. Several important uses and properties of this mixer emerged during the study.**

I. Introduction

A mixer is a three-port electronic device that modulates a waveform's frequency without changing the amplitude or phase.

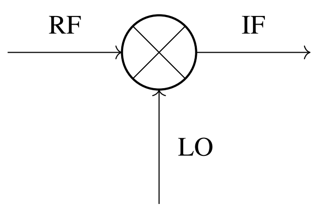


Fig. 1. An Ideal Mixer

The mixer has two input ports. LO, or local oscillator, gets added to or subtracted from RF to generate new frequencies, which are sent to the output IF, or intermediate frequency.

The mixer built in this lab is called a double-balanced FET ring mixer. It utilizes a ring of four MOSFET transistors to mix the LO with the RF. A schematic can be seen in Fig. 2.

II. Experimental Setup

The setup for this experiment consisted of 2 parts:

1) **Wave Generator** Used to produce both the local oscillator (LO) and radio frequency (RF) signals.
2) **Spectrum Analyzer** Used to measure the intermediate frequency (IF) output.

III. Measurements and Results

To begin, we mixed a 2 MHz radio frequency signal with a 10 MHz local oscillator frequency. As shown in **Table 1** and Fig. 3, we achieved the expected result of sums and differences of the frequencies in the intermedite frequency.

Interstingly, we also get harmonic frequencies around 28 and 32 MHz.

A. Changing the Amplitude of RF

We can modulate the amplitude of the radio frequency signal to see if it has an effect on output. See the results in Fig. 4. A larger amplitude results both in greater gain as well as greater noise.

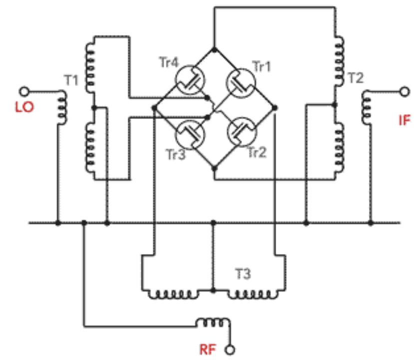


Fig. 2. Double-balanced FET Mixer

TABLE I
Mixer Port Frequencies

Port	**Frequency**
RF	2 MHz
LO	10 MHz
IF	10 ± 2 MHz

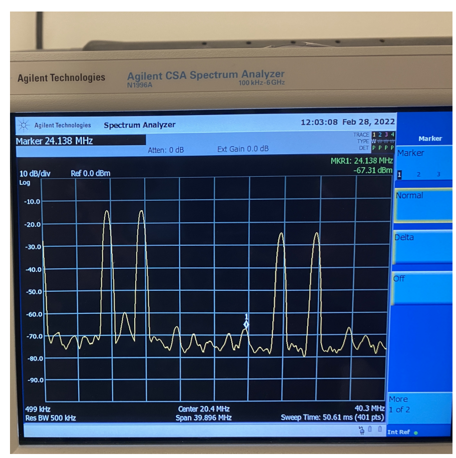
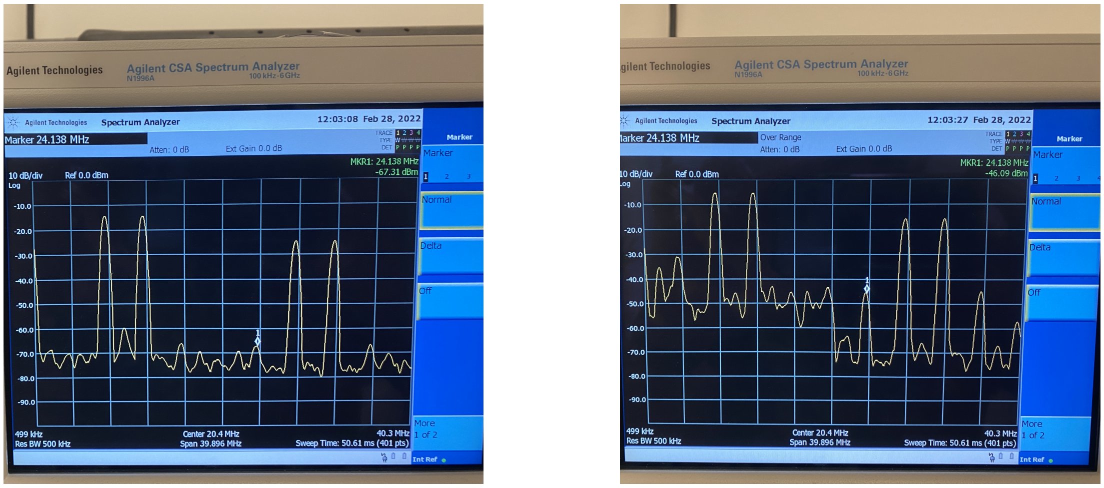


Fig. 3. Intermediate frequency spectrum, with peaks around 8 and 12 MHz.

B. Changing the Amplitude of LO

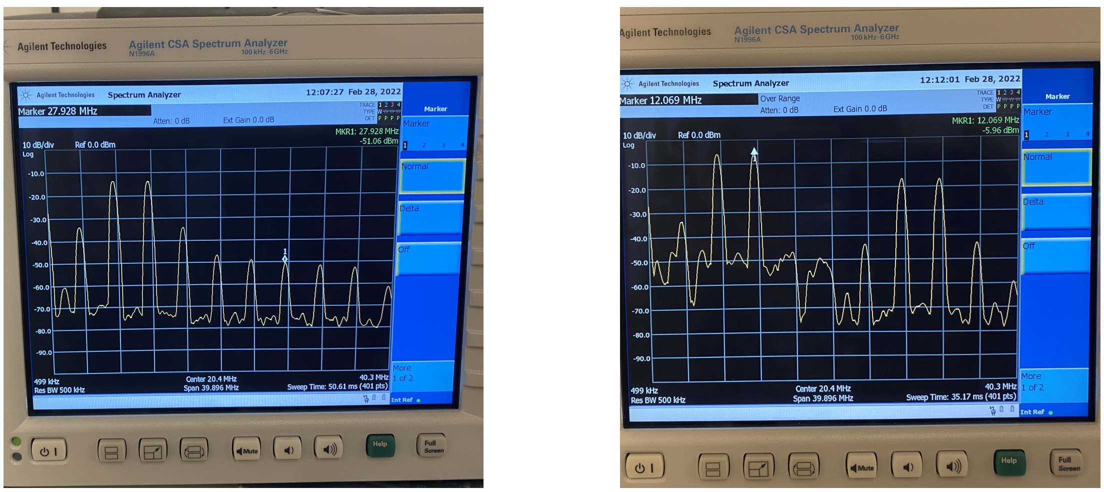
We can also modulate the amplitude of the local oscillator signal to see if it has an effect on output. See the results in Fig. 5. A larger amplitude again results both in greater gain as well as greater noise.

It is assumed that this relation will cease to hold at a certain point. But this exercise is left to the reader.



(a) (b)

Fig. 4. Increasing the amplitude of RF increases the gain as well as the noise. In (a), the amplitude is $0.5\,\mathrm{V}_{pp}$, while in (b), it is $1.5\,\mathrm{V}_{pp}$



(a) (b)

Fig. 5. Increasing the amplitude of LO increases the gain as well as the noise. In (a), the amplitude is $0.5\,\mathrm{V}_{pp}$, while in (b), it is $3\,\mathrm{V}_{pp}$

TABLE II
EFFECT OF CHANGING AMPLITUDE OF LO OR RF

Amplitude	Gain	Noise
↑	↑	↑
↓	↓	↓

IV. CONCLUSION

In this lab, we built a complex passive electronic component called a mixer. Our particular mixer utilized a transistor ring, and thus is dubbed a “MOSFET mixer.”

Using our mixer, we were able to explore the way that signals can be added and subtracted together to get an output waveform with a new frequency.

Lastly, we discovered the amplitude-gain-noise relation. An increase in the amplitude of either input signal results in both more gain and more noise in the output signal.

ACKNOWLEDGMENTS

Special thanks to my lab partners Devorah and Marc for all their help and support. They have lent several of their figures to match the data which I collected in my lab notebook. Thanks also to Yifan for inspiring me to dust off my LaTeXskills, as well as helping with several of the Tikz schematics. Finally, thanks to Joanna and Steve for their endless patience in my quest to learn electronics.