Quadrature Down Oscillator

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***Abstract*—To understand, analyse ,design and implement a quadrature down converter, a setup that is widely used in modern day wireless receivers such as Bluetooth, Wi-Fi and WLAN. Quadrature Down Converter (QDC) improves the quality of communication.**

I. Introduction

Through this project we intend to model a Quadrature Down Converter
Our converter consists of three basic modules:

- Quadrature oscillator.
- Switch (Mixer).
- Low Pass Filter.

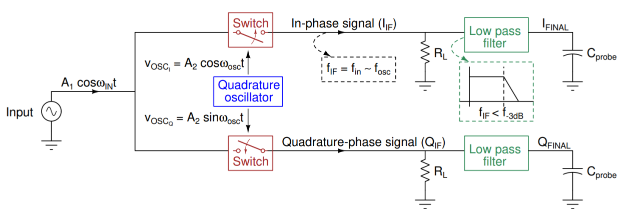

Fig. 1. Prototype for QDC

II. QUADRATURE OSCILLATOR

The purpose of designing the Quadrature Oscillator is to produces two sinusoidal signals at 100 kHz with a phase difference of 90°and oscillation amplitude of 1 V_{p-p}.

The quadrature oscillator is another type of phase-shift oscillator, but the three RC sections are configured so that each section contributes 90° of phase shift.

The loop gain can be calculated as:

$$A\beta = \left[\frac{1}{R_1 C_1 S}\right]\left[\frac{R_3 C_3 S + 1}{R_3 C_3 S(R_2 C_2 S + 1)}\right] \quad (1)$$

When $R_1C_1 = R_2C_2 = R_3C_3$, Equation 1 reduces to Equation 2.

$$A\beta = \frac{1}{(RCs)^2} \quad (2)$$

when $\omega = \frac{1}{RC}$, the Equation 2 reduces to phase of $-180°$, so now the oscillation occurs at $\omega = 2\pi f = \frac{1}{RC}$.

A. LT Spice Simulations

1) Quadrature circuit

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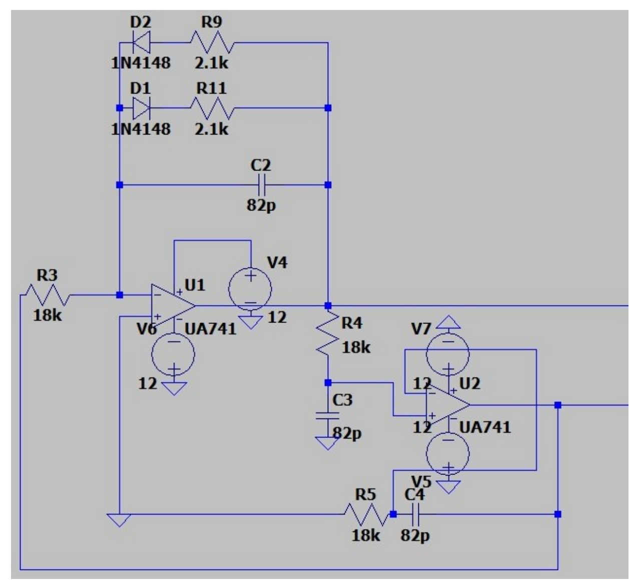


Fig. 2. Circuit

B. Calculations

We want the output frequency from the mixer to be 100 kHz, therefore the value for R and C we get are as follows:

$$RC = \frac{1}{2\pi f}$$

$$RC = 1.6 \times 10^{-6}$$

Therefore the chosen values for the practical circuit are:

$$R = 18k\Omega$$

$$C = 82F$$

C. Plots and Simulations

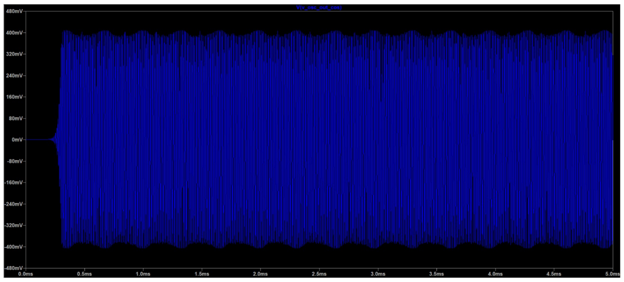


Fig. 3. Cosine output

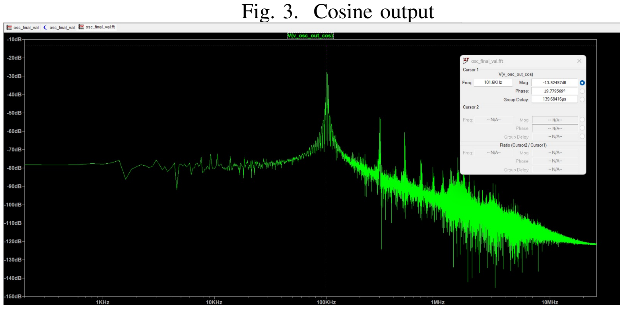


Fig. 4. Fourier Transform

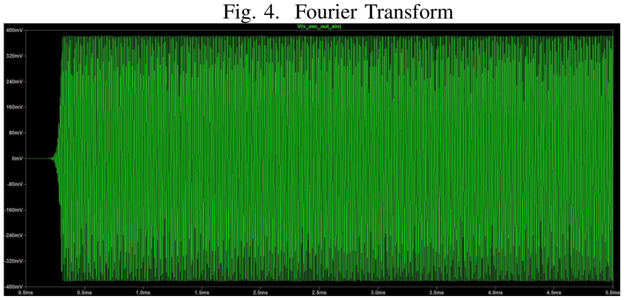


Fig. 5. Sine output

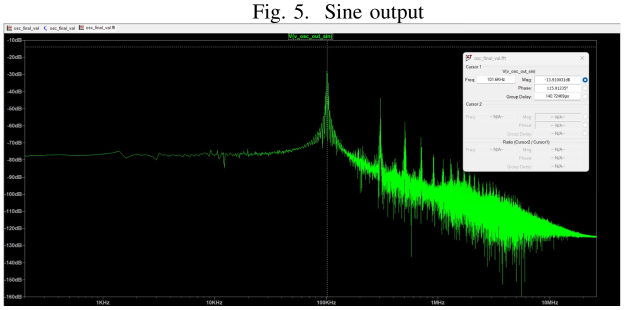


Fig. 6. Fourier Transform

III. SWITCH (MIXER)

In a quadrature down-converter, a mixer plays a crucial role in converting a high-frequency signal (RF) to a lower intermediate frequency (IF) signal while preserving the original information contained in the RF signal.

In a quadrature down-converter, two mixers are used in conjunction to generate two separate IF outputs that are having phase difference of 90°.These two outputs are often denoted as In-phase(I) and Quadrature (Q).

D. Results from Actual Circuit

1) Cosine Signal

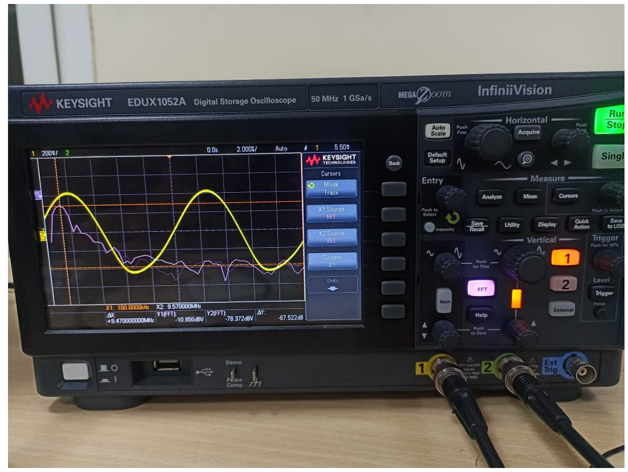
: 

Fig. 7. Transient and FFT plot for Cosine.

2) Sine Signal

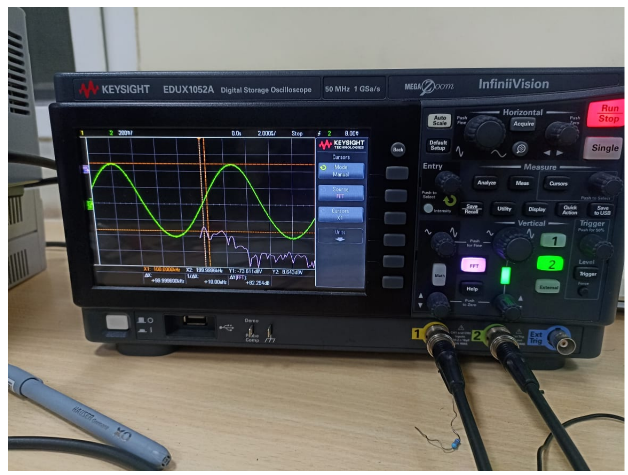
: 

Fig. 8. Transient and FFT plot for Cosine.

Mixer uses input signal (at source) and the signal developed by quadrature oscillator, thus mixing them to give various other frequencies.

As an example let us say that the two signals are having frequency ω_1 and ω_2, then in the output we will have the signal having frequencies like $\omega_1 + \omega_2$, $\omega_1 - \omega_2$, ω_1, ω_2 and their many more multiples.

A. Values chosen and Intuition

1) Given values::

- $R_L = 1k\Omega$.
- Amplitude for $V_{in} = 100\ mV_{p-p}$.

2) Values Taken::

- $R_{BIAS} = 1M\Omega$. The value of R_{BIAS} is kept so, as when small signal analysis is done then gate do not get

shorted directly to the ground along with the fact that we do not want any current to flow from gate to the right connections, in which high value resistance would help.
- Amplitude for $V_{in} = 100\ mV_{p-p}$.
- $C_c = 10nF$.

B. LT SPice Simulations (FFT and Transient Plot)

1) $F_{in} = 95k\Omega$

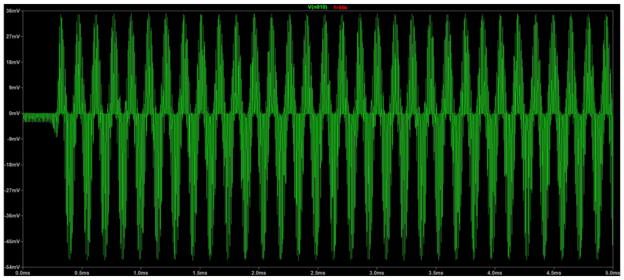
: 

Fig. 9. Transient

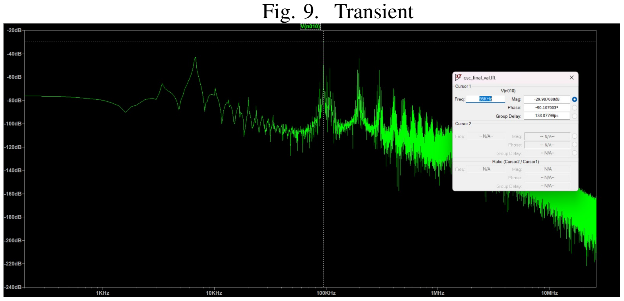


Fig. 10. FFT

2) $F_{in} = 98k\Omega$

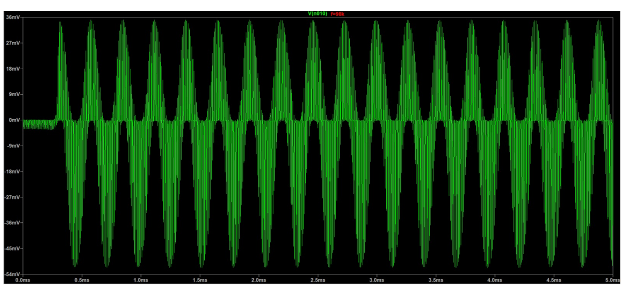
: 

Fig. 11. Transient

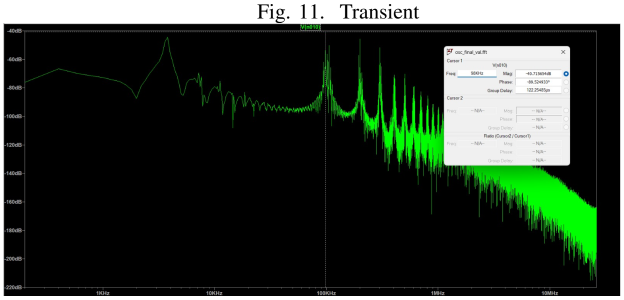


Fig. 12. FFT

3) $F_{in} = 99k\Omega$

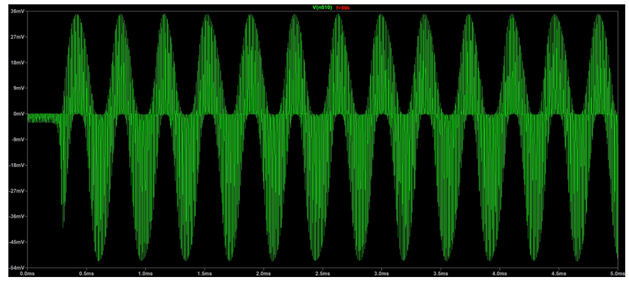
: 

Fig. 13. Transient

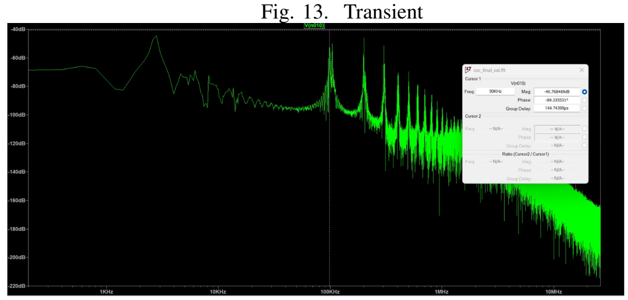


Fig. 14. FFT

4) $F_{in} = 101k\Omega$

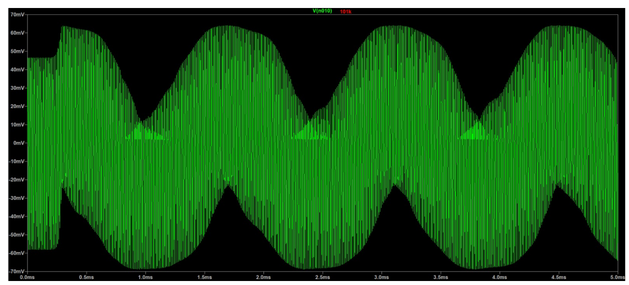
: 

Fig. 15. Transient

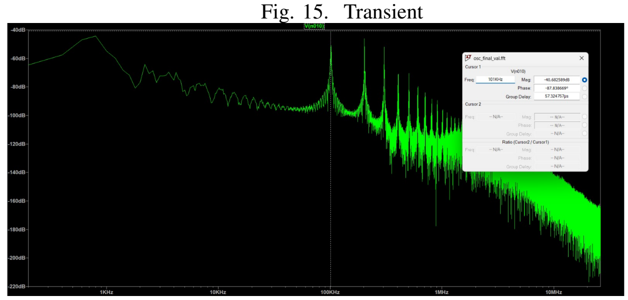


Fig. 16. FFT

IV. LOW PASS FILTER

A low-pass filter (LPF) is a circuit designed to allow signals with frequencies below a certain cutoff frequency to pass through while attenuating (reducing) signals with frequencies above that cutoff frequency.

Here we are using the low pass filter to filter out the high frequency signals which we generated by the switch (mixer). Moreover the configuration being used in the real

5) $F_{in} = 105k\Omega(Mixer)$

:

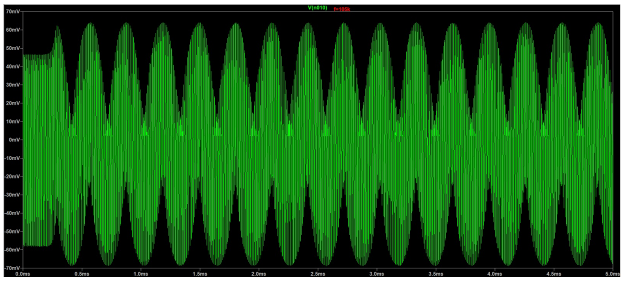


Fig. 17. Transient

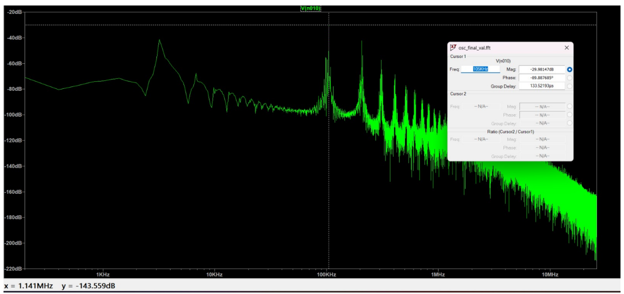


Fig. 18. FFT

life circuit would be a cascaded one.

A. Calculation

Therefore, $-3 = 20log\left(\frac{V_{OUT}}{V_{IN}}\right)$

We get transfer equation:

$$\frac{V_{OUT}}{V_{IN}} = \frac{X_C}{X_C + R}$$

By taking the magnitude of the transfer function and then finding the value of RC we get:

$$RC = \frac{1}{2\pi f}$$

Therefore,

$$f = \frac{1}{2\pi RC}$$

Where, we have f = 2 kHz and gain = -3dB.
Therefore, we get the value of RC as 7.9577471×10^{-5}. Chosen values of: $R = 32K\Omega$ and $39k\Omega$ in the cascaded system whereas, the capacitor value, $C = 82pF$ and $68pF$ in the cascaded way.

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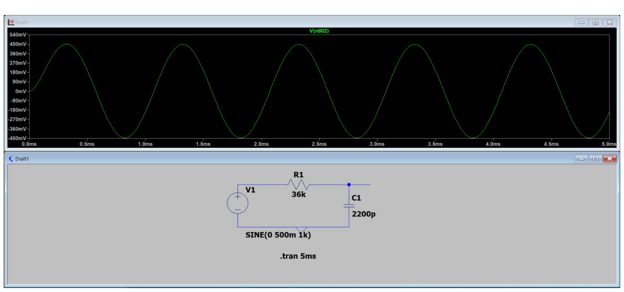


Fig. 22. Transient Response for 1 kHz

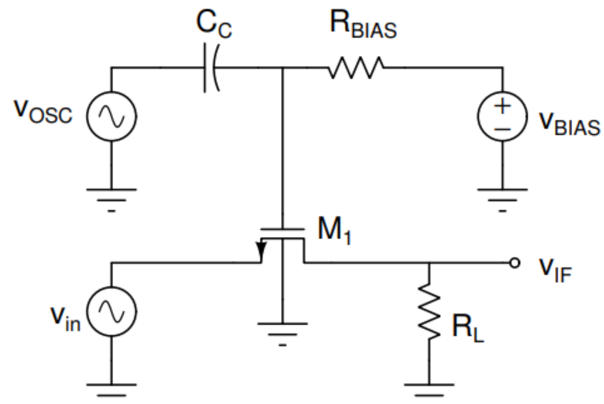


Fig. 19. Schematic for Mixture

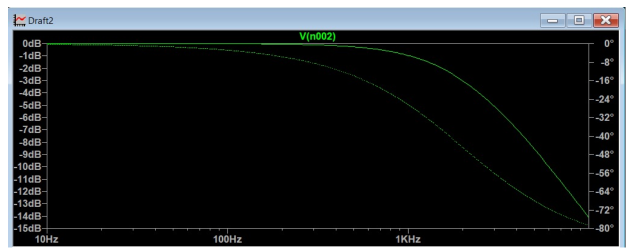


Fig. 20. LT Spice simulation for Low pass

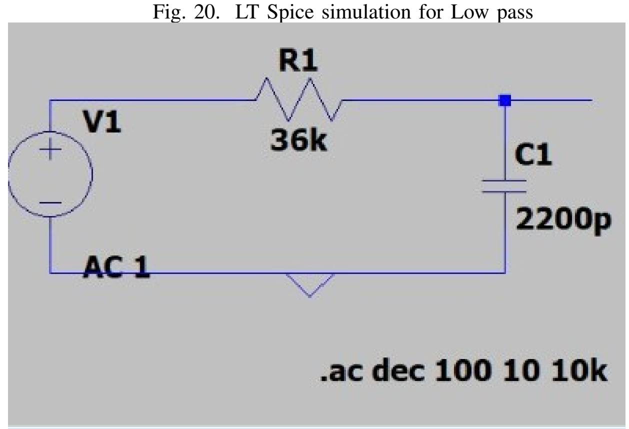


Fig. 21. Schematic for Low Pass Filter

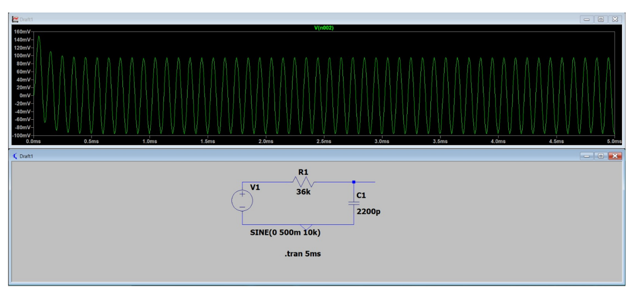
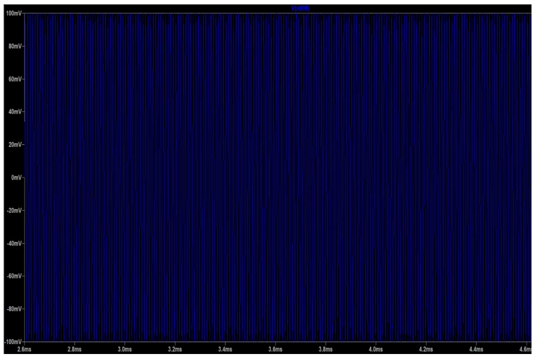


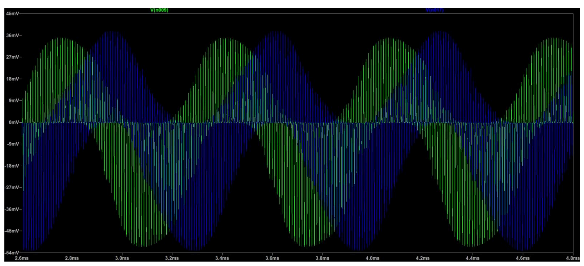
Fig. 23. Transient Response for 10 kHz

V. Integrating all the blocks of the Circuit together.

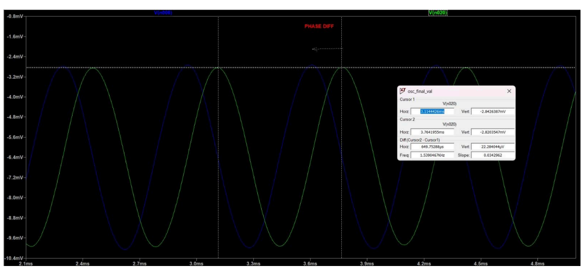
1. Plot for Input Signal



2. Plot for Mixer

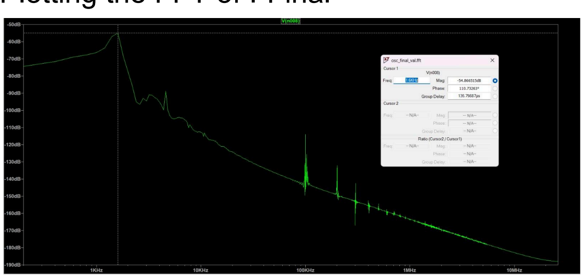


3. Plot for IF-final

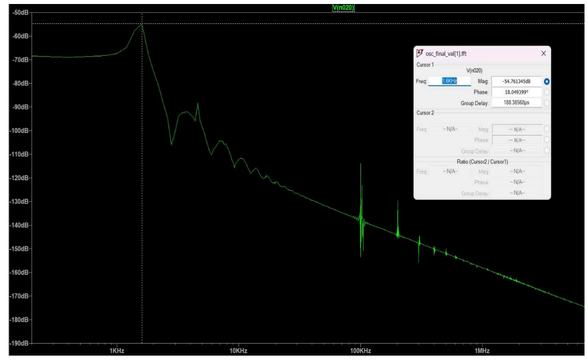


Using the cursor in the simulation we can calculate and get the phase difference of about 88°.

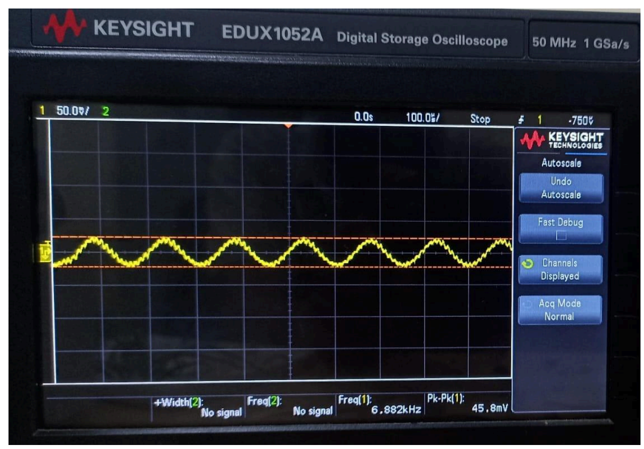
4. Plotting the FFT of I-Final



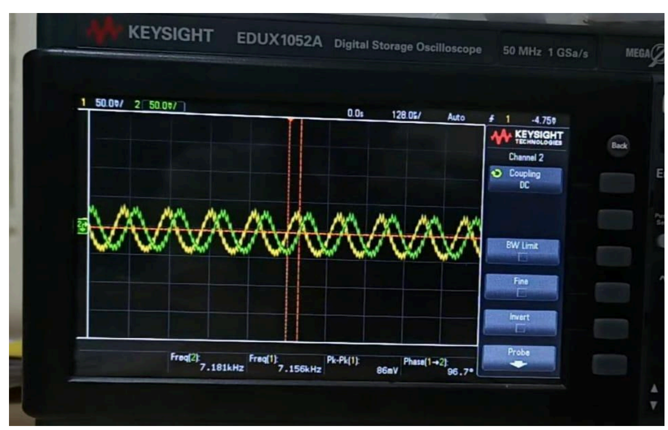
5. Plotting the FFT of I-Final

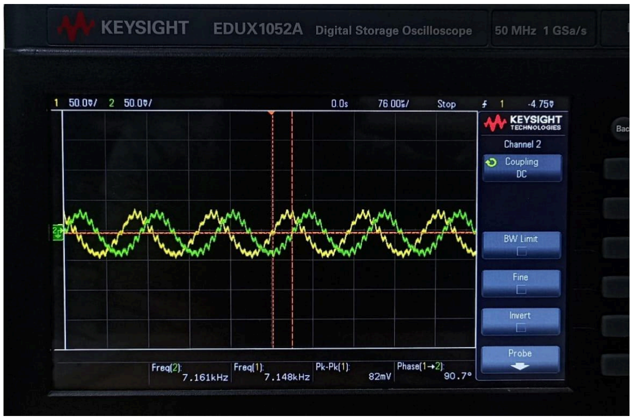


VI. Realization of circuit in Labs and the Final Output



Transient Plot of Cosine wave





Transient Plot for both the output signals(I-Final and Q-Final)

VII. Comparison Table for the measurement of LT Spice and Hardware created.

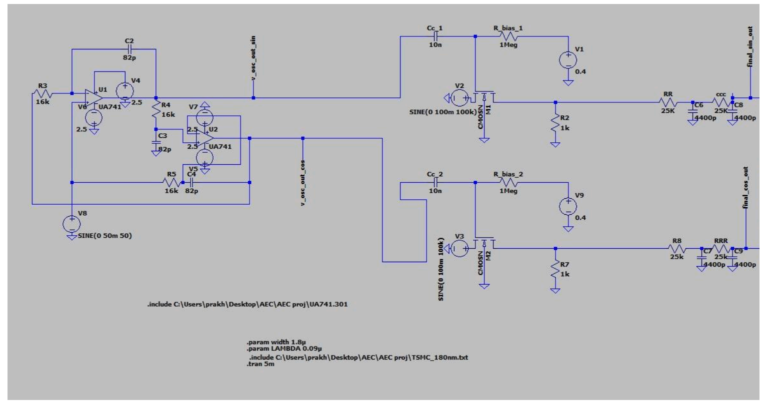
Parameters	Simulated	Measured
Oscillator Frequency	101 kHz	93.5 kHz
Oscillator amplitude (I-phase)	500 mV	490 mV
Oscillator amplitude (Q-phase)	500 mV	490 mV
Input Frequency	100 kHz	100 kHz
IF	101 kHz	93 kHz
Supply	6	13.5
Vbias	0.44	0,99
Cc	10n	10n

VIII. Conclusion

Using the fundamental active and passive component, we were able to realize a Quadrature Down Converter which is able to convert in the range 1-5 kHz.

Finally we got a sine wave and a cosine wave at the phase difference of almost 90° . In the actual circuit we could observe a bit of distortion which is due to some non-ideality in all the electrical components.

Final LT Spice Simulation:



LT specification:

Width = 1.8 u

Lamda = 0.09 u

AD = {5 * width * LAMBDA}

AS = {5 * width * LAMBDA}

PD = {10 * LAMBDA + 2* width}

PS = {10 * LAMBDA + 2* width}