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# Design of 800 MHz to 1.5 GHz Voltage Controlled Oscillator for Data Communication

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***Abstract-*** High frequency variable oscillator is central to the construction of high speed clock for data communication. A very wide variable frequency oscillation is designed that could be used in data communication for reliable and fast data transmission. A voltage controlled oscillator in Colpitt configuration is used in the design. The design is found to be capable of producing frequencies from 800MHz to 1.5GHz for a reverse biased voltage (VR) of 0 to 25V while maintaining a good tuning flatness throughout the range. The design is found to be free from noise and frequency variations over the tuning range.

***Index Terms***- oscillator, transistor, capacitor, inductor and varactor diode.

## I. INTRODUCTION

Transfer of large amount of data at high speed is on high demand currently. These two aspects of telecommunication are accomplished using very fast clock of the processor. Clock and data recovery circuit in data communication need to be designed nowadays using silicon devices for their high power handling capabilities compared to MOSFET at high frequency [2].

High frequency oscillators are needed for the construction of fast clocks. For data recovery the oscillation (clocking) must be at different frequencies. This is achieved normally using voltage controlled oscillator (VCO). The frequency of the VCO determines the speed of the clock. If there is noise in the VCO it makes the output of the clock lower. The efficiency, reliability and speed of data transmission in the communication systems are all related to the speed of the processor of the two communicating hardware. The processor speed is based on its clock. Very high frequency oscillator free from noise is vital to digital communication systems.

Commonly, both ring oscillators and LC oscillators are used in GHz range applications [7]. However, ring oscillators suffer from poor phase noise compared to that of LC oscillators and are less suitable for high-end wireless communication systems [8]. LC oscillators are more attractive due to their better phase noise performance and lower power consumption. However, they occupy larger area compared to that of ring oscillators [9].

This work is intended to present the design and simulation of high frequency voltage controlled oscillator that can be used in the construction of fast clocks for processors.

## II. METHODOLOGY

Since amplifier is an element of oscillator, we started with the design of a wideband amplifier to be used in our oscillator circuit. The oscillator configuration we used is colpitt with the feedback element consisting of a varactor diode for turning. The advantage of this type of tank circuit configuration is that with less self and mutual inductance in the tank circuit, frequency stability is improved along with a more simple design [6].

### 2.1 Amplifier Design

A classA amplifier is designed. The circuit diagram of the amplifier is shown in figure 1.

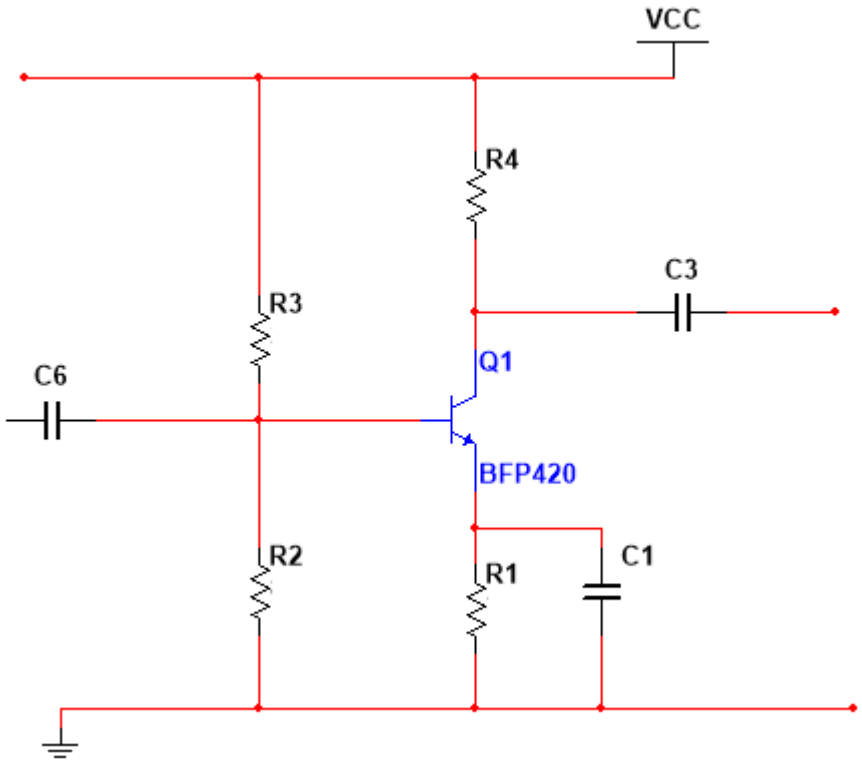


**Figure 1a Schematic diagram of the amplifier**

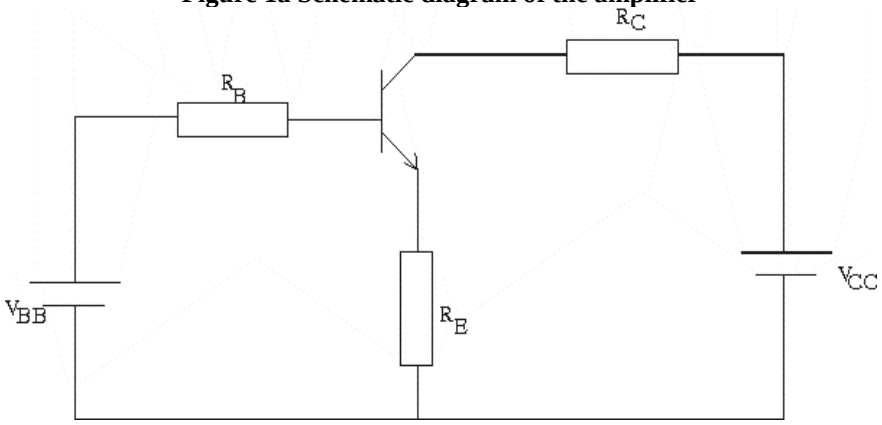


**Figure 1b DC equivalent circuit of the amplifier**

**2.3 Biasing Method**

We developed the transistor characteristics. The operating point (Q point) was found to be $V_{CE}$ = 4.5V and $I_C$ = 2.6mA. Voltage divider bias technique is employed. The circuit of figure 1 is considered and following calculations were made.

**2.4 Design Equations**

Applying Kirchhoff's law to the output and input side of the D.C. equivalent circuit of figure 1 we have

$V_{CC} = I_C R_C + V_{CE} + I_E R_E$ ……. (1)
$V_{BB} = I_B R_B + V_{BE} + I_E R_E$ …….. (2)

For thermal stability of the amplifier [1].

$R_B \leq 0.3\beta R_E$ …… (3)
and
$R_E = 0.2R_C$ …… (4)

Where $R_B = \frac{R_2 R_3}{R_2 + R_3}$ ……. (5)

**2.5 Design Calculation**

From the Q point (Appendix A) we used: $V_{CC}$ = 9v, $V_{CE}$ = 4.5v, $I_B$ = 40µA, $I_C$ = 2.6mA and $V_{BE}$ = 0.71V

$\beta = \frac{I_C}{I_B} = 65$ …… (6)

$I_E = I_C + I_B = 2.64Ma$ …… (7)

Substituting the Q point, $V_{CC}$, $I_B$, $V_{BE}$, and $I_E$, in (1) and (2) we have four equations with four unknown. Solving simultaneously we have

$\frac{V_{BB} - 0.71}{4.5} = \frac{(1.2\,x10^{-5}\beta + 2.6\,x\,10^{-3})R_E}{(0.013 + 2.64\,x\,10^{-3})R_E}$ ; $V_{BB} = 1.694V$ ….. (8)

From (2) we have

$1.694 - 0.71 = 40 \times 10^{-6} R_B + 2.64 \times 10^{-3} R_E$ …… (9)

Substituting (3) in (5)gives

$0.984 = 40 \times 10^{-6} \times 0.3 \times 65 R_E + 2.64 \times 10^{-3} R_E$

$R_E = \frac{0.984}{3.42\,x\,10^{-3}}$

$R_E = 287.7\Omega, R_B = 5610.15\Omega$

But $R_B = \frac{R_2 R_3}{R_2 + R_3} = 5610.15\Omega$ …… (10)

$V_{BB} = \frac{R_2 V_{CC}}{R_2 + R_3} = 1.694$ …….. (11)

Solving (10) and (11) simultaneously we have

$R_2 = 6910.748\Omega$, $R_3 = 29809.5112\Omega$

From (4)

$R_C = R_E \times 5 = 1438.6$

Considering (3), we choose $R_2$ and $R_3$ to be 8.25kΩ and 30kΩ respectively.

Coupling Capacitors $C_2$ and $C_3$

The low-frequency cut-off for each coupling capacitor is given by`

$f_{min} = \frac{1}{2\pi CZ}$ ……. (12)

Where Zis the resistance seen by C [4].

Taking 1MHz as our low-frequency cut-off[3].

$Z = Z_{in\,(base)} // R_2 // R_3 = \frac{R_2 R_3 Z_{in(base)}}{R_2 R_3 + R_2 Z_{in(base)} + R_3 Z_{in(base)}}$ ….. (13)

$Z_{in(base)} = \beta re'$ ……. (14)

$re' = \frac{25mV}{I_E} = 625\Omega$ …..(15)

$Z = 569.9482\Omega$

$C_2 = \frac{1}{2\pi Z\, f_{min}}$ ……. (16)

$C_2$ = 279.12pf

For $C_3$ we have

$C_3 = \frac{1}{2\pi R_4 f_{min}}$ = 111.25pf ….. (17)

Where $R_4$ = 1430 (i.e. the load resistor).

Bypassed Capacitor $C_1$

A good rule of the thumb is that $X_{C1}$ of the bypassed capacitor should be at least 10 times smaller than the $R_E$ at the minimum frequency of oscillation [5].

$10X_{C1} \leq R_E$…… (18)

$C_1 = \frac{10}{2\pi f_{min}}$ ……. (19)

$C_1$ = 1.5908µf

This completes the design of our common emitter amplifier circuit.

**2.6Resonator Design**

For the oscillator, we need a resonator. The schematic diagram of the designed VCO is as shown in figure 2. The resonating circuit is made up of two center tapped capacitors and one inductor connected in series for colpitt oscillation. The series combination of the varactor diode and $C_4$ form one of the center tapped capacitor. The resonant frequency is given by [3].

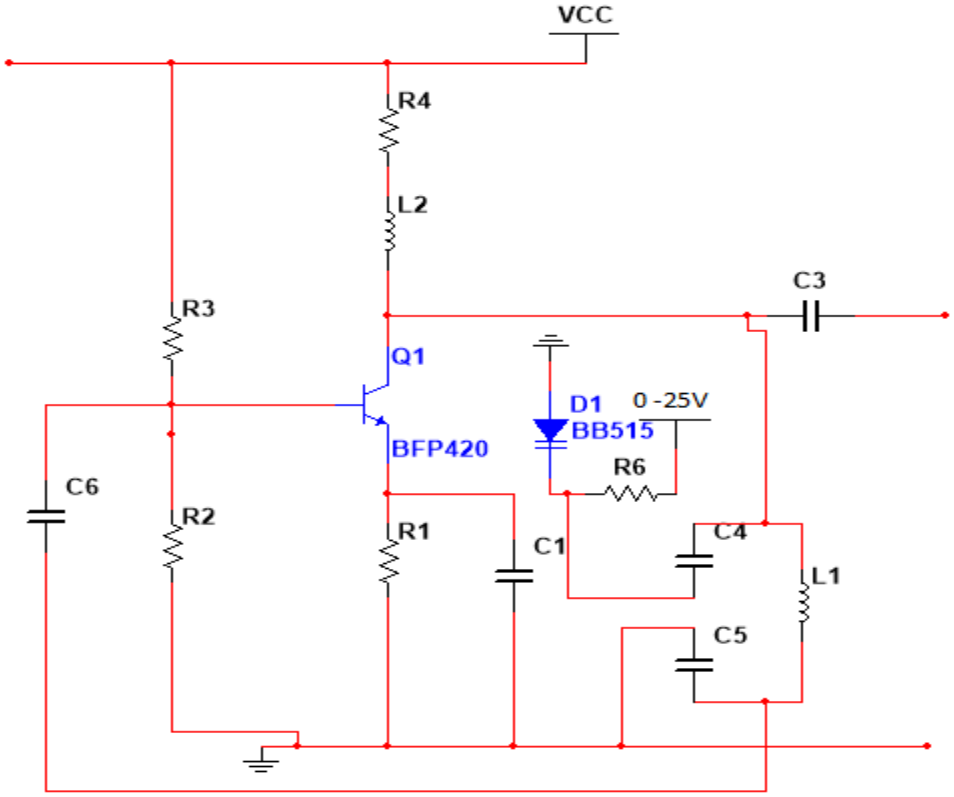


**Fig 2 schematic of the designed VCO**

$f_r = \frac{1}{2\pi LC}$ …….. (20)

where C is the series combination of $C_4$ and $C_5$ given by

$C = \frac{C_4 C_5}{C_4 + C_5}$ …….. (21)

For oscillation to occur,

$$A_{v(min)} = \frac{C_5}{C_4} \geq 1 \quad \ldots\ldots (22)$$

Where $A_{v(min)}$ is the minimum gain of the amplifier with feedback [4].

$$A_{v(min)} = \frac{R_C}{R_E}, \quad A_{v(min)} = \frac{1438.6}{287.72} = 5$$

Therefore, $C_5 = C_4$ x 5 ……. (23)

Substitute (23) into (21) gives

$C = 0.8333C_4$ …… (24)

Let $f_r$= 900MHz and $L_1$ = 5nH

Substituting fr, $L_1$into (16), we have

C = 6.2488pf

Substituting for C in (24) and the result into (23), we have

$C_4$ = 7.4988pf, $C_5$ = 39.494pf

**2.6.1 Varactor diode design**

The varactor diode is connected in series with $C_4$. From BB515 datasheet, the capacitance of the varactor diode for a reverse bias voltage of 1V is 18.7pf. Using this, the value of new $C_4$ was calculated. The new C4 is in series with $C_{var}$ and their equivalent capacitance is 7.5pf.

## III. RESULTS

This circuit was simulated using Multism 12.0.1. Figure 3 is the result of the AC analysis using the designed amplifier shown in figure 4. This shows that the designed amplifier is a wide band amplifier.

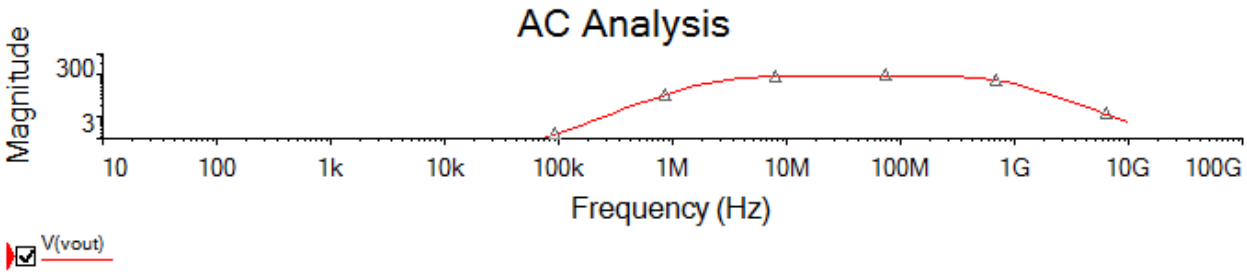


**Figure 3 AC analysis of the designed amplifier**

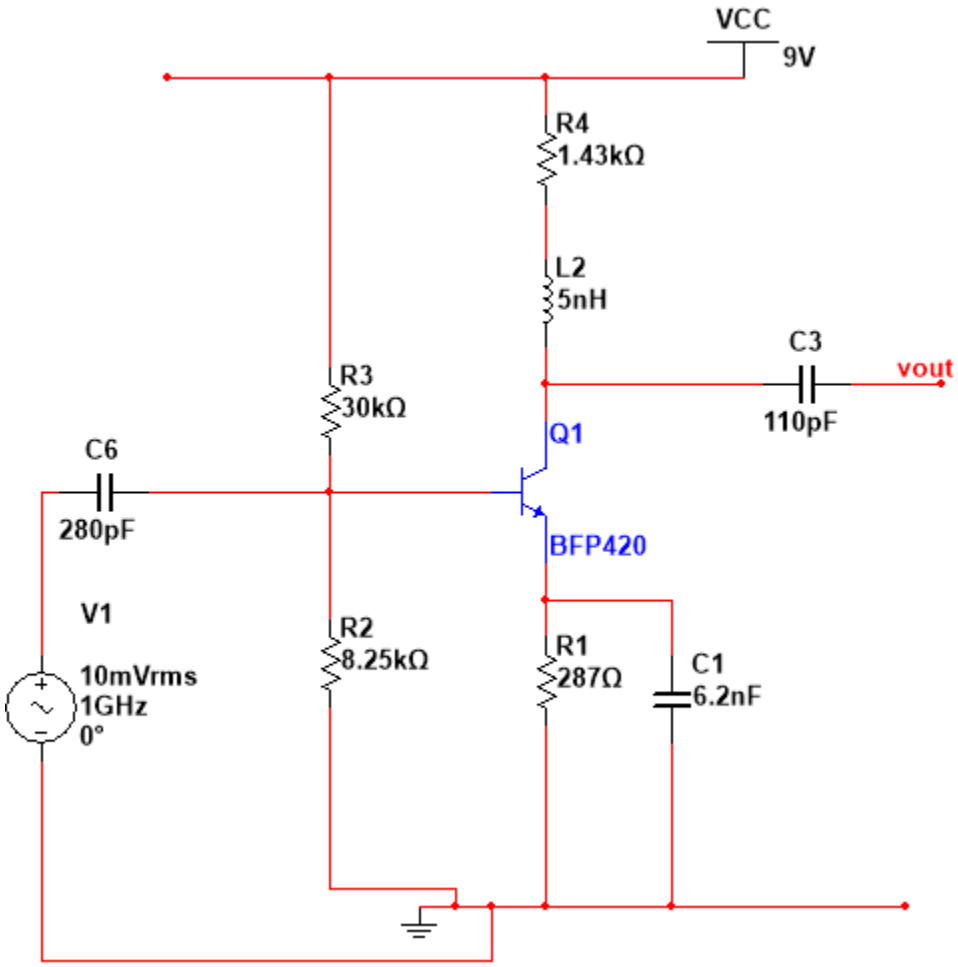


**Figure 4 The circuit of the designed amplifier**

The complete circuit for the voltage controlled oscillator with the designed values above is shown in figure 5. The designed and simulated VCO (voltage controlled oscillator) was found to produce sinusoidal signal at uniform voltage level in the frequency range of 800MHz to 1.5GHz.

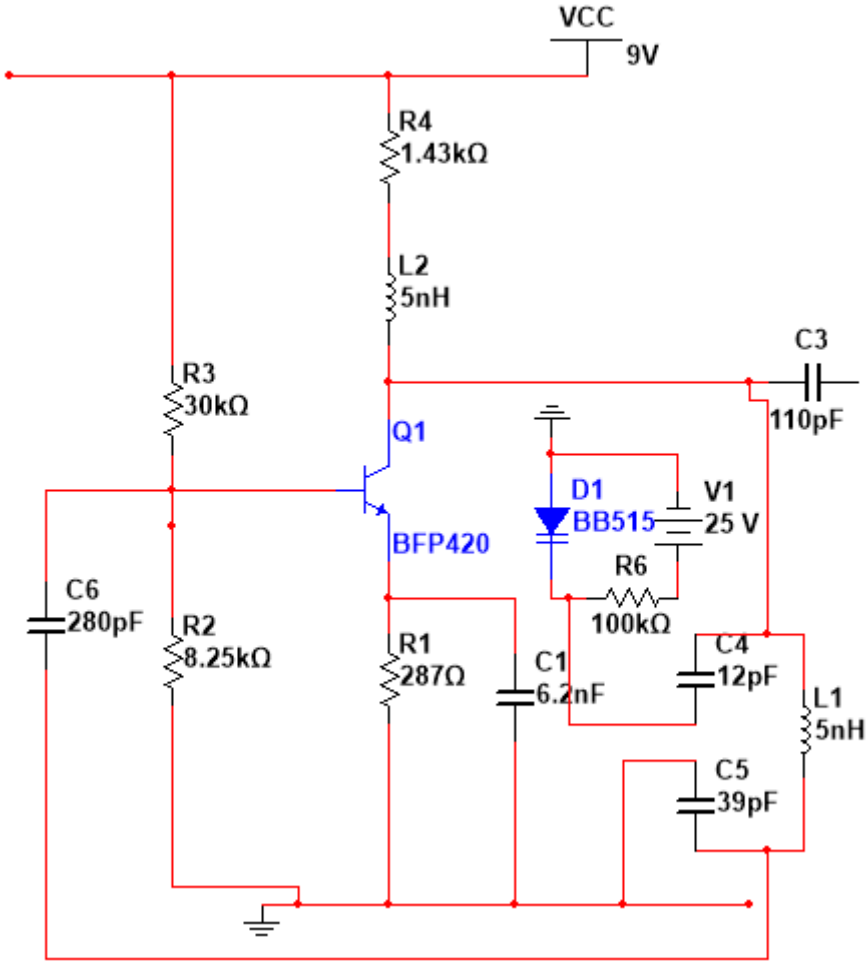


**Figure 5The circuit diagram of the designed VCO**

The simulated tuning range which is the graph of the frequency against reverse biased voltage ($V_R$)of the VCO is shown in figure 6.

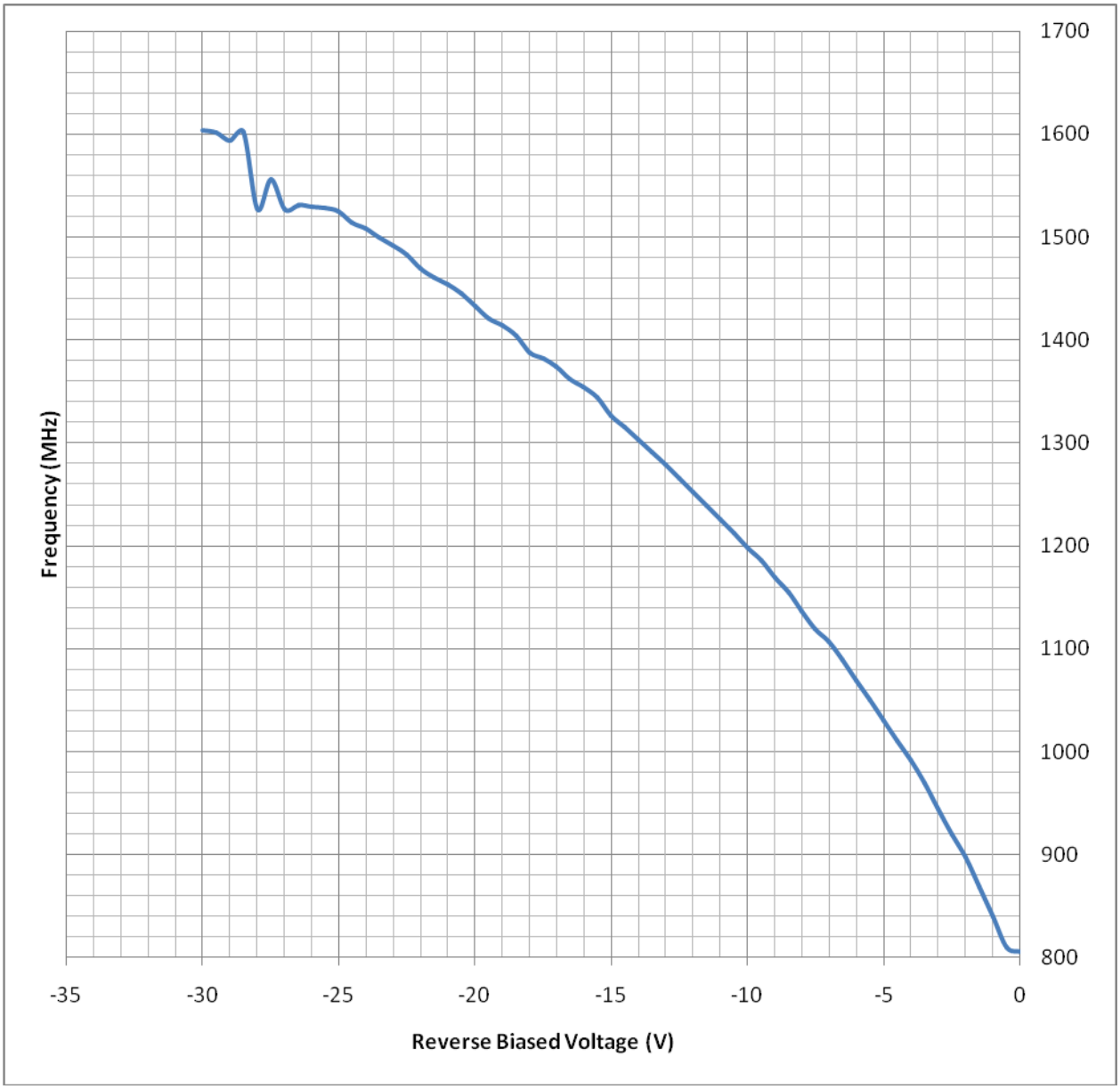


**Figure 6 Simulated tuning range**

The output signal has good tuning flatness for the frequency range of 800MHz to 1.5GHz when the reverse biased voltage changes from 0V to 25V as seen in figures 7 through 9.

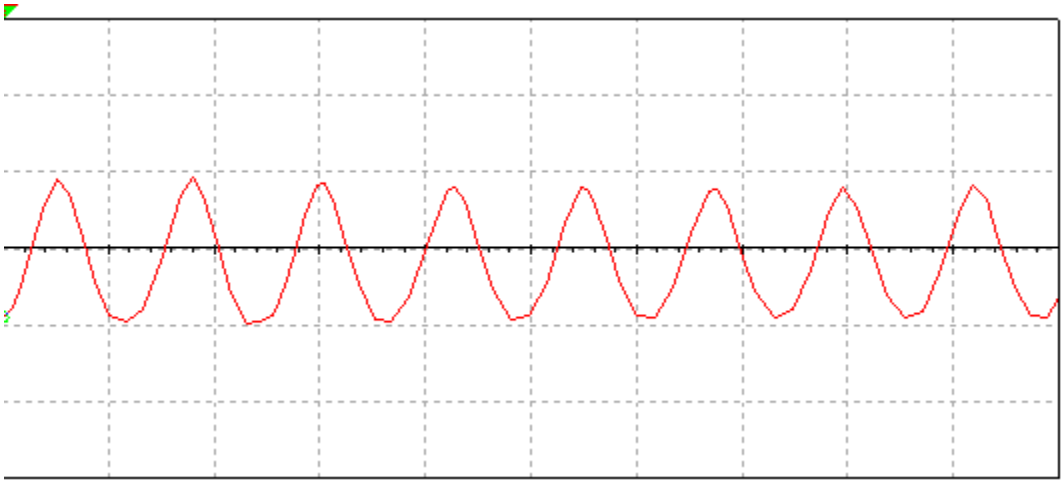

**Figure 7 output waveform for $V_R$ = 1V, frequency = 818MHz**

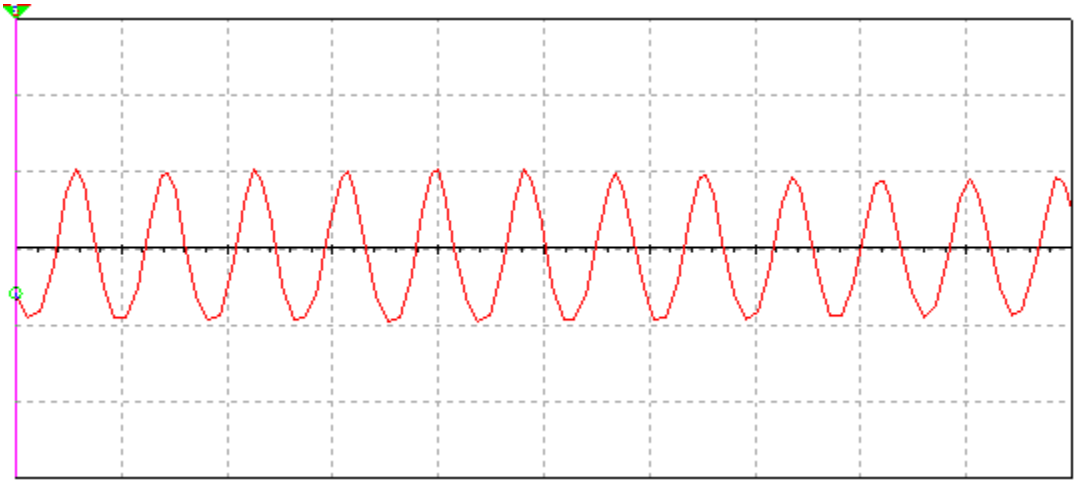

**Figure 8 output waveform for $V_R$ = 10V, frequency = 1.2GHz**

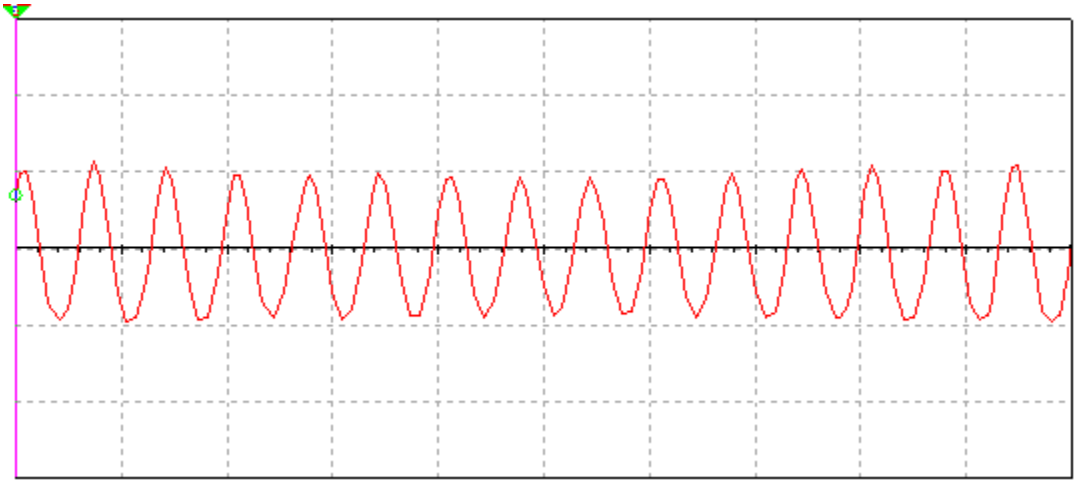

**Figure 9 output waveform for $V_R$ = 24V, frequency = 1.5GHz**

The VCO has an average positive tuning slope of 31.07MHz/V throughout the frequency range.The minimum and maximum values of the tuning sensitivity are 1V and 25V respectively.

## IV. DISCUSSION

We found the designed and simulated VCO to produce sinusoidal signal with a frequency range of 800MHz to 1.5GHz over a voltage range of 0V to 25Vwith nice tuning flatness, tuning slope of 31.MHz/V at a voltage of 2.5V.Furthermore, the designed VCO has monotonic tuning characteristics and low pushing over the tuning range of 0 to 25V.

In view of the above features of the designed and simulated high frequency voltage controlled oscillator, the VCO can be used in the construction of high speed processors used in data communication for reliable and fast data transmission because of its frequency range of about 690MHz.This wide range also makes it very fit for microwave application such as surveillance and very versatile for many purposes especially when it is used in conjunction with either frequency divider or multiplier circuits as the case may be. The smoothness of the VCO waveforms throughout its tuning range indicated the absence of jitter noise and thus makes it a very good item for accurate timing of electronic communication activities.

## V. CONCLUSION

In this work we designed VCO using colpitt oscillator configuration which operates in 800MHz to 1.5GHz range. In view of the result it shows that the circuit has a bandwidth of 690MHz with a tuning flatness of about 86%. Its wide frequency range, smooth waveform and positive turning slope throughout its turning range are excellent features of this design.

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