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Research Article

Design and implementation of a frequency synthesizer using PLL

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Abstract

An investigation has been made to find the new frequency from a reference frequency such is done for the beneficial of day-to-day rapid increase in the technology and its uses. The effect of such is derived from the comparison of analog circuits and digital circuits to find the better result. A software analysis is also done to verify the result. Mainly for the regular use of wireless technology this work is done and compared for the analysis of better result. Phase lock loop is used to get the better frequency response from the crystal oscillator used as a reference frequency. It is a very essential component for modern technology.

Keywords*: Phase lock loop, analog circuits, digital circuits, reference frequency.*

1. Introduction

In our day to day life, we got used with various types of communication systems such as a radio communication system, telecommunication system, wireless communication system, optical communication system and so on to communicate with others. All these communication systems we use in our regular life are controlled using different systems such as a phase locked loop or PLL, cooperative control, networked control and so on. A frequency synthesizer is a circuit design that generates a new frequency from a single stable reference frequency. Mostly a crystal oscillator is used for the reference frequency. Most of the frequency synthesizer employs a phase locked loop circuit, as this technique offer many advantages such as minimum complex architecture, low power consumption and a maximum use of largescale integration technology. There are many designs in communication that require frequency synthesizer to generate a range of frequencies: such as cordless telephones, mobile radios and other wireless products. The accuracy of the required frequencies is very important in these designs as the performance is based on this parameter. One approach to this necessity could be to use crystal oscillators. It is not only impractical, but is impossible to use an array of crystal oscillators for multiple frequencies. Therefore, some other technique must be used to circumvent the problem.

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The main benefit of using phase locked loop technique in frequency synthesizer is that it can generate frequencies comparable to the accuracy of a crystal oscillator. For this reason, most of the communication design make use of a PLL frequency synthesizer [1].

In 1673 spontaneous synchronization of weakly coupled pendulum was noted by the Dutch physicist Christiaan Huygens. [2] In 19th century Lord Rayleigh observed synchronization of weakly coupled organ pipes and tuning forks. [3] In 1919 W. H Eccles and J. H. Vincent found that two electronic oscillators that had been tuned to oscillate at slightly different frequencies but that were coupled to a resonant circuit would soon oscillate at same frequencies. [1] In 1923 Edward Victor Appleton noted automatic synchronization of electronic oscillators. [4] In 1980 the receiver was adjusted to different frequencies by either a variable capacitor or a switch which choose the proper tuned circuit for the desired channel. In 1997 frequency synthesizer and its model is described by Yang. Yang developed a model of a phase locked loop-based frequency synthesizer. The voltage-controlled oscillator utilizing a ring of single ended current steering amplifiers provides low noise, wide operating frequencies and operation over a wide range of power supply voltage. [5] In 2002 PLL with 0.35-m CMOS technology at a supply voltage of 1.8 V has been designed. [6] In 2007 the new methodology presented by Azizi which takes into consideration the effect of within-die process variations on a low voltage parallel system. They showed that in the presence of process variation one should use a high supply voltage than would otherwise be predicted to minimize the power consumption of parallel systems [7]. In this paper we have tried to find the new frequency from a reference

frequency such is derived from the comparison of analog circuits and digital circuits to find the better result and a software analysis is also done to verify the result.

2. Experimental details

2.1 Working principle of PLL

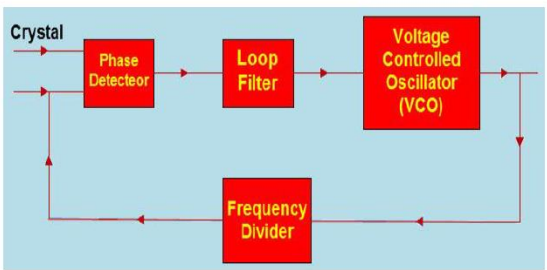
The phase detector compares the phase of the output signal to the phase of the reference signal. If there is a phase difference between the two signals, it generates an output voltage, which is proportion to the phase error of the two signals. This output voltage passes through the loop filter and then as an input to the voltage-controlled oscillator (VCO) controls the output frequency. Due to this self-correcting technique, the output signal will be in phase with the reference signal.

When both signals are synchronized the PLL is said to be in lock condition. The phase error between the two signals is zero or almost zero at this. As long as the initial difference between the input signal and the VCO is not too big, the PLL eventually locks onto the input signal. The period of frequency acquisition, is referred as pull-in time, this can be very long or very short, depending on the bandwidth of the PLL. The bandwidth of a PLL depends on the characteristics of the phase detector (PD), voltage-controlled oscillator and on the loop filter.

2.2 Frequency synthesizer

Block diagram of frequency synthesizer

One of the most common use of a PLL is in frequency synthesizer which is shown in fig below [8]. A frequency synthesizer generates a range of output frequencies from a single stable reference frequency of a crystal oscillator. Many applications in communication required a range of frequencies or a multiplication of a periodic signal. Besides a PLL it also includes a very stable crystal oscillator with a divide by N programmable divider in the feedback loop. The programmable divider divides the output of the VCO by N and locks to the reference frequency generated by a crystal oscillator. The output frequency of VCO is a function of the control voltage generated by the PD. The output of the phase



comparator, which is proportional to the phase difference between the signals applied at its two inputs, control the frequency of the VCO. So the phase comparator input from the VCO through the programmable divider remains in phase with the reference input of crystal oscillator. The VCO frequency is thus maintained at Nfr. This relation can be expressed as Fr = fo/N This implies that the output frequency is equal to Fo = NFr

Operation of frequency synthesizer

This section defines about the different blocks used in the circuit and the operations. The circuitry is the main part of any electronic circuit and thus understanding each part and its block is also necessary so a brief view of all the important blocks are given below.

2.3 Phase detector

The role of a phase detector/comparator in a phase locked loop circuit is to provide an error signal which is some function of the phase error between the input signal and the VCO output signal. Let theta d represents the phase difference between the input phase and the VCO phase. In response to this phase difference the PD produces a proportional voltage V (d). (The relation between voltage V(d), and the phase difference theta d is linear and periodic, it repeats every 2π radians [9]. This periodicity is necessary as a phase of zero is indistinguishable from a phase of 2π.

The three most important multiplying digital phase detectors are the following.

i. The EXOR gate
ii. JK flip flop
iii. Phase frequency detector (PFD)

2.4 Loop filter

The filtering operation of the error voltage (coming out from the phase detector) is performed by the loop filter. The output of PD consists of a dc component superimposed with an AC component. The ac part is undesired as an input to the VCO, hence a low pass filter is used to filter out the ac component. Loop filter is one of the most important functional block in determining the performance of the loop. A loop filter introduces poles to the PLL transfer function, which in turn is a parameter in determining the bandwidth of the PLL. Since higher order loop filters offer better noise cancellation, a loop filter of order 2 or more are used in most of the critical application PLL circuits. Normally active filters are used now a day for suppressing noise and to isolate a communication of signal from various channels to improve the unique message signal from a modulated signal.

4.2.3 Voltage controlled oscillator (VCO)

A VCO is a voltage-controlled oscillator, whose output frequency w (o) is linearly proportional to the control

voltage v(c) generated by the phase detector. The linear relation between the control voltage and the output frequency simplifies the PLL design.

2.5 Divider

One of the biggest constraints in a high speed frequency synthesizer design is the speed limit of the programmable divider N. a single divide by N unit can handle up to 30 MHZ of frequency. Therefore some special design techniques are necessary to implement a programmable divider in high speed designs. However there are many ways for overcoming this limitation of frequency. Such as VCO output may be fixed with the output of a crystal oscillator and the resulting remaining or the difference frequency can be fed to the programmable divider. The VCO output may be multiplied from a low value in the operating range of the programmable divider to the required high output frequency. Or a fixed ratio divider capable of operating at a high frequency may be inter-posed between the VCO and the programmable divider. All the methods discussed above have their limitations, although all have been used in many applications. The first method is more useful than the other two as it allows narrow channel spacing or high reference frequencies, but it has a drawback. Since the crystal oscillator and mixer are within the loop; any crystal oscillator noise or mixer noise appear in the synthesizer output. The remaining two techniques are not as useful either. However an improved divider technique, known as two modulus pre scaling dividers exits. A master slave divider circuit is used [10]. It follows this equation,
N = A (P+1) + (M-A) P = MP+A

2.6. Crystal oscillator

It is the most important part of the phase locked loop system. The shortcomings of a common FM transmitter can be overwhelmed with stability. This stability can be provided by using a crystal oscillator.

2.7. Computer program validation and verification

MATLAB is a high performance language for technical computing. It integrates computation, visualization and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: [11]

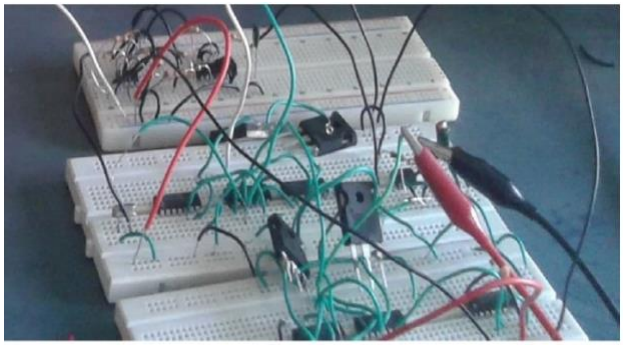
- Math and computation
- Algorithm development
- Modeling, simulation and prototyping
- Data analysis, exploration and visualization
- Scientific and engineering graphics
- Application development including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allow us to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRANS.

3.Results and discussion

The hardware projects are made and the best results are found at 11.7 V. The result is verified with the software analysis using MATLAB codes. The comparison of analog circuit and digital circuits but the best result is observed at the analog circuits. The brief description of the comparison, circuitry and the computation part are described in this paper.

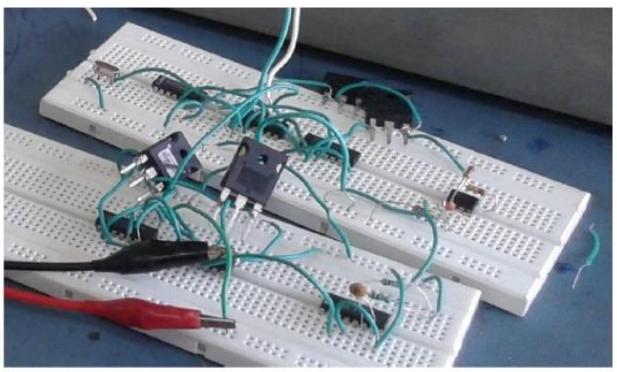
3.1. Design of analog circuit



The phase detector is designed with the analog components of using clipper, integrator diodes, resistors, capacitors.

The phase detector circuit is different for the analog circuitry and the digital circuitry.

3.2. Design of digital circuit



The phase detector of the digital circuitry is made with d flip flops. The clock pulse of the d flip flops of Fr must be less than the clock pulse of the d flip flop from the VCO. Fvco/N. This frequency generation is very tough and the analog circuitry gives better result than the digital circuitry. The regular clock pulse may not match with this data even the matching of this pulse is also very complicated which makes this circuit to gives lesser accurate result and introduction of noise [12].

3.3. Pros and Cons of the synthesizer

3.3.1 Pros of the frequency synthesizer

- Useful in narrow spacing between operating frequencies
- Easily configured for complex synthesis using multi loop.
- Possible to down convert input frequency.
- Possible to generate a jitter free sine wave at the output.
- Phase noise degradation of a signal passing through a filter is possible only if the noise level of the input is very low and if mixers are not optimized.
- In cognitive radios the power consumption is less than 22 mw from a 1.2 v supply.

Cons of the frequency synthesizer

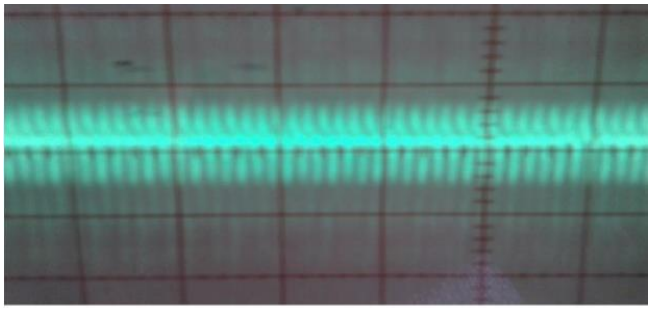
- High phase noise
- Spurious.
- Vast amount of filtering required.
- Lock up time is related to the smallest frequency component.

3.4. Applications of the frequency synthesizer

- Frequency modulation (FM0, stereo decoders, FM demodulation networks for FM operation
- Frequency synthesis that provides multiple of a reference signal frequency
- Used in motor speed controls, tracking filters.
- Used in frequency shift keying (FSK) decodes for demodulation carrier frequencies.
- In cognitive radios.
- Wi max [13].

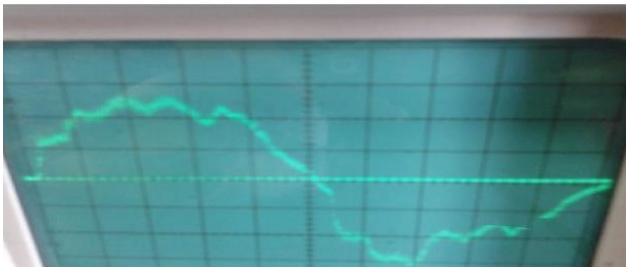
This work is done in two ways by using the analog circuit and the digital circuit and the result is observed and compared.

3.4.1. Output of the analog circuit



The output frequency generated in the analog circuit is very high but the noise level is under control.

3.4.2 Output of the digital circuit



The noise level is very high in this circuit due to the mismatch of the clock pulses and the frequency generated is also very low.

3.5 Computer Program

3.5.1 Introduction

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects [14][15], which together represent the state of the art in software for matrix computation [16]. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard tool for introductory and advanced courses in mathematics, engineering and science. In industry, MATLAB is the tool of choice for high productivity research, development and analysis. MATLAB features a family of application specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow us to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Area in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation and many others.

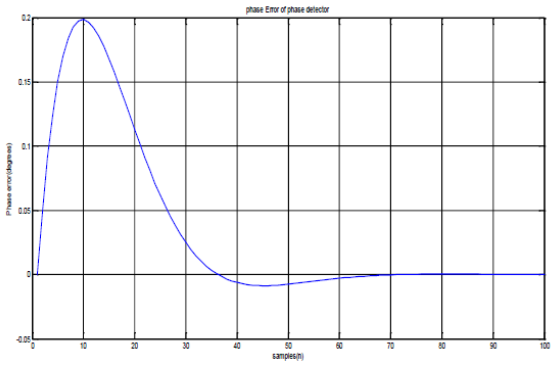
3.5.2 The code

```
close all;
clear all;
reg1=0;
reg2=0;
reg3=0;
eta =sqrt(2)/2;
theta=2*pi*1/100;
Kp=[(4*eta*theta)/(1+2*eta*theta+theta^2)];
Ki=[(4*theta^2)/(1+2*eta*theta+theta^2)];
d_phi_1=1/20:
n_data=100;
for nn =1:n_data
phi1=reg1+d_phi_1;
phi1_reg(nn)=phi1;
s1=exp(j*2*pi*reg1);
s2=exp(j*2*pi*reg2);
s1_reg(nn)=s1;
```

```
s2_reg(nn)=s2;
t=s1*conj(s2);
phi_error=atan(imag(t)/real(t))/(2*pi);
13
phi_error_reg(nn)=phi_error;
sum1=Kp*phi_error+phi_error*Ki+reg3;
reg1_reg(nn)=reg1;
reg2(reg(nn)=reg2;
reg1+phi1;
reg2=reg2+sum1;
reg3=reg3+phi_error*Ki;
phi2_reg(nn)=reg2;
end
figure(1)
plot(phi1_reg);
hold on
plot(phi2_reg,'r');
hold off
grid on
title('phase plot');
xlabel('samples');
ylabel('phase');
figure(2)
plot(phi_error_reg);
title('phase error of phase detector');
grid on
xlabel('samples(n));
ylabel('phase error(degrees)');
t=0:E+6:1;
x=cos(2*pi*500t);
plot(t,x);
[b,a]=butter[5,2*pi*25,'low','s');
H=freqs(b,a,2*pi(0:500));
plot(0:500,abs(H));
hold on
title('lowpass filter');
xlabel('frequency');
ylabel('gain(db)');
figure(3)
plot(real(s1_reg));
hold on
plot(real(s2_reg),'r');
hold off
grid on
title('input signal and output signal of vco');
xlabel('samples');
ylabel('amplitude');
axis([0 n_data -1.1 1.1]);
```

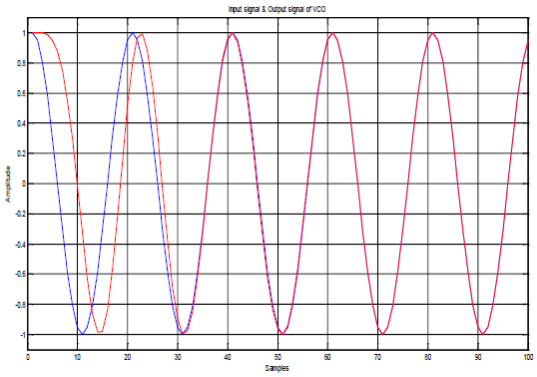
The main program used in this project for the analysis of the output result

3.5.3 Output of the filtering circuit



The output the filtering circuit from the software analysis.

3.5.4 Output of the VCO



The output of the VCO also the actual output of the system from the software analysis is as such.

Conclusion

An investigations has been made on the digital circuitry and the analog circuitry to find which one is giving a better result and why and thus it is concluded the analog circuitry is working better thus giving us more accurate result than the digital circuit as it is very tough to make the clock pulse accurate in the flip flops used which is mentions above. Moreover, the result is also compared with the software analysis.

Acknowledgment

We also would like to thank all the faculties and researchers of the Signal Processing Lab of Electronics and Communication Department. We also like to thank our parents for giving us constant support and strength.

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