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Multiband NCO for BPSK, FSK and FM techniques

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Abstract --There are various modulation schemes that are used in communication system. Some of the modulation technique includes Binary Shift Keying (BPSK), Frequency Shift Keying (FSK), Frequency Modulation (FM) etc. The modulating signal and the carrier play an important role. Generation of the carrier can be done using the Numerically Controlled Oscillator (NCO) techniques. There are different methods like ROM look-up-table (LUT), Cordic , Feedback Circuit can be used to build NCOs. In this paper a look up table based NCO is discussed. The key element of this NCO is a LUT that translates the control input into a desired frequency. This technique is digital, it offers several advantages such as fast switching speed between output frequencies. In the present design the switching speed is 3 clock cycles for 0.1 us clock. It also provides a fine frequency resolution of 4.768 Hz and operation over a broad spectrum of frequencies from 4 Hz to 2.5 MHz.

Index Terms-Binary Shift Keying, Frequency Shift Keying, Frequency Modulation, Frequency Tuning Word, Numerically Controlled Oscillators,ROM Look Up Table, SFDR.

1 Introduction:

In the communication system the modulator is used at the transmitter side and the demodulator at the receiver side. The block diagram of the communication system is as shown in the fig1.

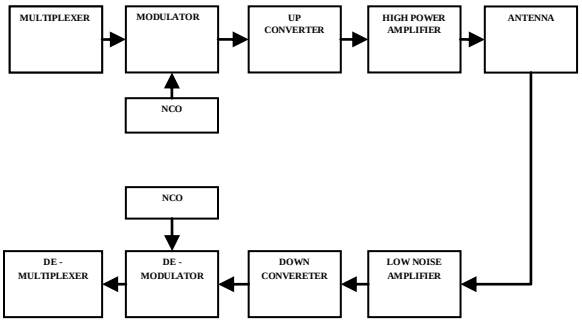

Fig1: System Level Block diagram for Communication Systems

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In the BPSK the data bits are used to control the phase of the carrier. The modulator shifts the carrier in one of the two values either in-phase 0 or off-phase180.

In FSK two carrier frequencies are needed which corresponds to f1 and f2. The frequency f1 is transmitted when data bit is 0 and f2 when data bit is 1[1]. In FM the deviation plays an important role. When the audio signal is modulated onto the frequency carrier, the new frequency signal moves up and down in frequency. The amount by which the signal moves up and down is important and this determines the deviation. The carrier frequency range is from 50 KHz to 100 KHz. [2]

In order to implement all this techniques the aid of numerically controlled oscillator is very important, and is used in many digital signal processing applications including most modern communication systems [3]. There are many advantages of using a NCO. It has Micro-Hertz tuning resolution of the output frequency and sub-degree phase tuning capability. Extremely fasthopping speed with continuous phase. No manual tuning required as in case of analog systems. NCO finds application in satellite communication, radar, medical imaging, cellular telephony

etc. There are a number of ways to generate a digital sinusoidal signal. Three such methods are [4]:

- LUT based NCO
- Cordic based NCO
- Feedback Circuit based NCO

The most common technique for implementing an NCO is based upon ROM table-look-up. In this technique the ROM is used to store the samples of the sinusoid which are then read out at appropriate time intervals to produce the sinusoidal signal. The main advantage of using this technique is that there is no DC drift, no amplitude distortion and no frequency drift for long term oscillations [4]. Improvement in the frequency resolution can be achieved but at the expense of increased table length.

2 Implementation of LUT based NCO:

The design of LUT based NCO and its implementation using VHDL is presented here. NCO is a source of local oscillation in digital modem. This implementation is done using MATLAB and MODELSIM. The samples of a sine wave corresponding to a frequency say f is obtained from MATLAB and stored in the ROM table. The ROM table constructed has data width of 10 bits and 1024 locations. Hence a 10*1024 ROM is implemented. The address is the input to the ROM table, the discrete amplitude sequence of the corresponding sine signal can be produced. The rate at which the ROM table is read determines the frequency of the output waveform. The accuracy of the wave is determined by the number of bits used to define the ROM table. The resolution of the NCO is determined by the samples stored in the ROM look up table. The structural implementation is as shown in the fig 2.

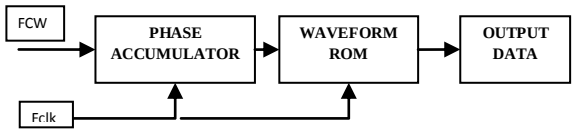


Fig2: Structure of NCO

2.1 Algorithm for the implementation of NCO

Step1: Start

Step2: Plot the sine wave of frequency f in Matlab and obtain the sample values.

Step3: Convert the obtained decimal values into binary values.

Step4: Write the VHDL code to implement the NCO

Step5: ROM look up table is constructed and the sample values obtained is stored in the ROM location.

Step6: The required frequency is obtained by calculating the Frequency Control Word using the formula and added with the address value.

Step7: The corresponding sample value is read and the required signal is obtained.

Step8: Write the testbench in VHDL and verify the results.

Step 9: End

3 Design:

We design the frequency control word (FCW) using the formula:

$$FCW = (Fout * 2\wedge n) / Fclk \qquad (1)$$

Where

Fout=required output frequency

Fclk= clock frequency

n= no of address bits used

FCW= Frequency Control word

In digital processing phase quantization is necessary [6]. The phase that a cycle of the sine signal experience is 2*pi. Therefore we can conclude that by changing the value of frequency control word we can change the frequency.

Phase Accumulator- The Phase Accumulator[7] increments its contents each time it receives a clock pulse and the magnitude

of the increment is determined by the frequency control word and it effectively sets how many points to skip. This word forms the phase step size between reference-clock updates. The larger the jump size, the faster the phase accumulator overflows and completes one full round.

Sine/Cosine ROM- The address to a ROM corresponds to the samples of the frequency in the ROM. After each clock cycle, the appropriate magnitude of the ROM output is assigned to create a complete sine wave. The frequency range of the NCO is given by Fmin=Fclk/2^n and Fmax=Fclk/2. For Fclk = 5 MHz the NCO range is 4 Hz to 2.5 MHz.

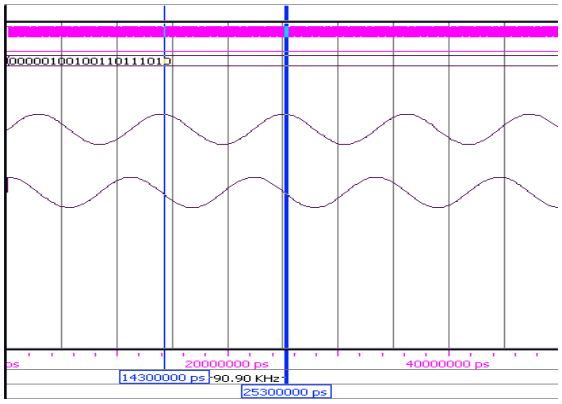
4 Simulation results:

4.1 Case 1: frequency suitable for FM carrier wave

Clock Frequency =5 MHz

Number of bits =20 bits

Generated frequency=90 KHz

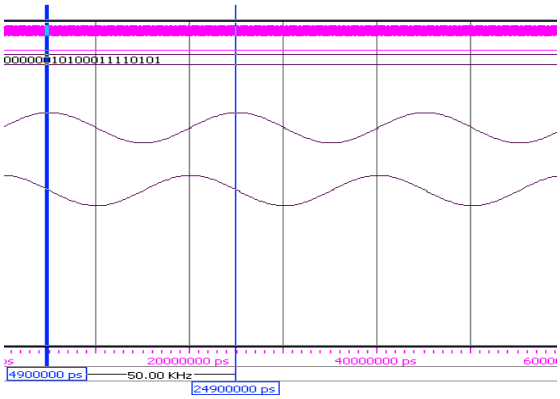


4.2 Case2: mid range frequency

Clock frequency=5 MHz

Number of bits=20

Output frequency= 50 KHz

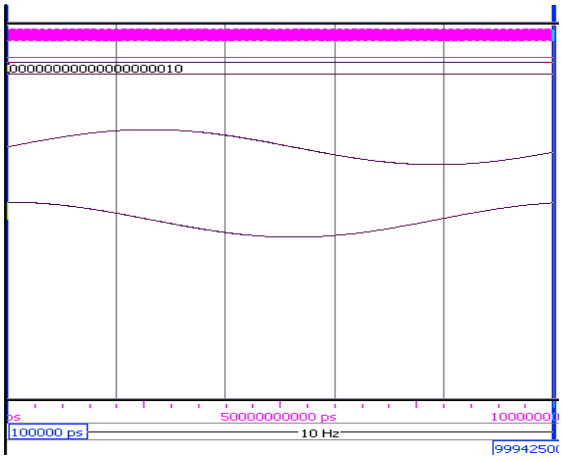


4.3 Case3:Minimum Frequency

Clock frequency =5 MHz

Number of bits=20

Output Frequency=10Hz

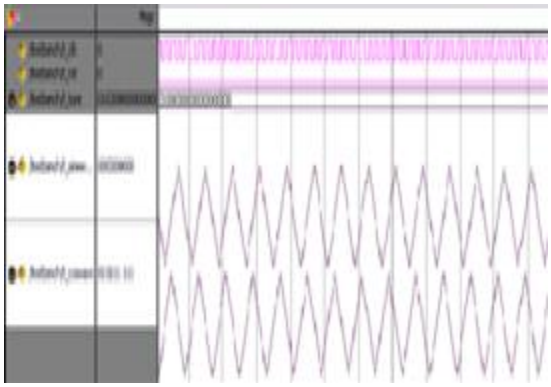


4.4 Case4: Maximum Frequency

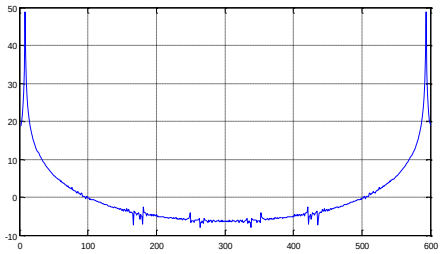
Clock frequency= 5 MHz

Number of bits=20

Output frequency=2.5 MHz



4.5 Case5 :SFDR for 50 KHz wave



5 Conclusion:

In this paper various modulation techniques and the use of NCO for various techniques is discussed. The NCO implemented is digital oscillator which has several advantages. This method is suitable when number of bits is less. In this case a 10 bit data is stored in the LUT as a result 1024 memory locations are needed. The use of ROM based method increases the accuracy. The output switching time between two frequencies is found to be 3 clock cycles and it is better when compared to AD9851 from Analog Devices which requires 13 clock cycles [8]. The resolution offered by the above design is sufficient for my application. The resolution can be further improved by increasing the number of bits. The SFDR calculated for 50 KHz is found to be -56 db.

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