

Design, Implementation and Comparison of FFT Analysis of efficient Digital PLLs for clock generation using 50nm SPICE models for CMOS

Jayati Shukla, Paresh Rawat

Department of Electronics and Communication Engineering Truba College of Science and Technology
Bhopal, India

Department of Electronics and Communication Engineering Truba College of Science and Technology
Bhopal, India

Abstract:- The most versatile application for digital phase locked loops is for clock generation and clock recovery in any complex computer architecture like a microprocessor or microcontroller, network processors. Digital Phase locked loops are commonly used to generate timing on chip clocks in high performance mixed signal analog and digital systems. Most of the systems employ digital PLL mainly for synchronization, skew and jitter optimization. Because of the need of high speed circuitry there is a need of PLL. Mostly communication, wireless systems, RF Processors operate in Gigahertz range, there is a necessity of PLL that too digital which operate in high order frequencies. Digital PLL is a mixed signal integrated circuit and presented work focuses on design and analysis of efficient digital phase locked loops for clock generation using 50nm SPICE models. The presented design Digital PLL performs the function of mainly generating a clock signal also consists of design of sub circuits and systems like phase detector, loop filters and voltage controlled oscillators. A detailed FFT analysis is also presented with parameters magnitude, phase and group delay calculated for each sub circuits and systems. The results of DPLL designed using proper optimization method is also compared with traditional method.

Index Terms:- Digital PLL, SPICE, VCO, Phase Detector, FFT, Loop filters

I. INTRODUCTION

Digital Phase locked loop is a mixed signal analog integrated circuit. Digital PLL is the heart of many communication as well as electronic systems. Mostly a higher lock PLL range with lesser locking time and should have tolerable phase noise.

The most versatile application of a digital PLL is for clock generation or synchronization, clock recovery, communication systems and frequency synthesizers. In high performance digital systems like processors digital PLL or DPLL are commonly used to generate well timed on chip clock signals. Modern RF circuits or wireless mobile communication systems use PLL for synchronization, timing based synthesis, skew and jitter reduction. Digital PLL is extensively used in advanced communication systems, electronic and medical instrumentation systems. The PLLs are an integrated part of larger circuits on a single chip. A simple PLL consists of namely four to five integrated blocks. They are phase frequency detector, charge pump, Loop filters, voltage controlled oscillator and frequency dividing circuits.

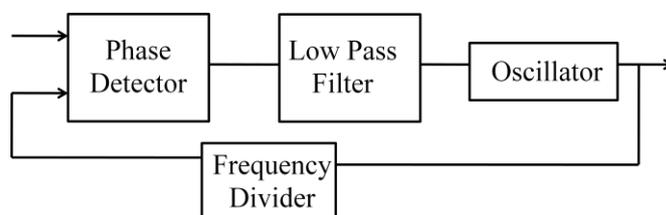


Figure.1 Basic Block diagram of a Digital Phase locked loop

Today in terms of high frequency usage in mixed signal analog integrated circuits deploy PLLs of faster locking abilities. In this paper the faster locking of PLL is particularly concentrated with respected to 50 nm process technology. The design and simulation results are based on cmos models using the same process technology. Digital PLL takes in to account suitable circuit architectures and associated parameters. The

optimization of the Voltage controlled oscillator is also carried out using simple CMOS and current starved CMOS inverters to get a better frequency precision.

II. DESIGNING A DIGITAL PLL

A PLL is a closed-loop feedback system that sets fixed phase relationship between its output clock phase and the phase of a reference clock. A PLL is capable of tracking the phase changes that falls in this bandwidth of the PLL. A PLL also multiplies a low-frequency reference clock CKref to produce a high-frequency clock CKout this is known as clock synthesis. A PLL has a negative feedback control system circuit. The main objective of a PLL is to generate a signal in which the phase is the same as the phase of a reference signal. This is achieved after many iterations of comparison of the reference and feedback signals. In this lock mode the phase of the reference and feedback signal is zero. After this, the PLL continues to compare the two signals but since they are in lock mode, the PLL output is constant. A basic PLL is a negative feedback system that receives an incoming oscillating signal and generates an output waveform that exerts the same phase frequency relationship as the input signal. This is achieved by constantly comparing the phase of output signal to the input signal with a phase frequency detector (PFD).

The Phase frequency Detector (PFD) is one of the main parts in PLL circuits. It compares the phase and frequency difference between the reference clock and the feedback clock. Depending upon the phase and frequency deviation, it generates two output signals UP and DOWN. The Charge Pump (CP) circuit is used in the PLL to combine both the outputs of the PFD and give a single output. The output of the CP circuit is fed to a Low Pass Filter (LPF) to generate a DC control voltage. The phase and frequency of the Voltage Controlled Oscillator (VCO) output depends on the generated DC control voltage. If the PFD generates an up signal, the error voltage at the output of LPF increases which in turn increase the VCO output signal frequency. On the contrary, if a Down signal is generated, the VCO output signal frequency decreases. The output of the VCO is then fed back to the PFD in order to recalculate the phase difference, and then we can create closed loop frequency control system.

III. PLL ARCHITECTURE

In general a PLL consists of five main blocks:

1. Phase Detector or Phase Frequency Detector (PD or PFD)
2. Charge Pump (CP)
3. Low Pass Filter (LPF)
4. Voltage Controlled Oscillator (VCO)
5. Divide by N Counter

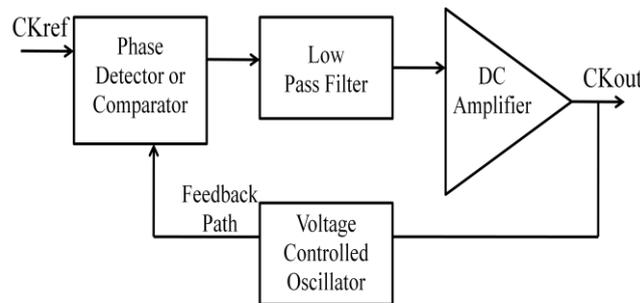


Figure.2 A generic architecture of Digital PLL

3.1 Phase frequency Detector

The phase frequency detector is one of the main integral parts of PLL circuits. It compares the phase and frequency difference between the reference clock and feedback clock. Depending upon the phase and frequency deviation it generates two output signals Up and Down. If there is a phase difference between the two signals, it will generate UP or DOWN synchronized signals. When the reference clock rising edge leads the feedback input clock rising edge UP signal goes high while keeping "DOWN" signal low. On the other hand if the feedback input clock rising edge leads the reference clock rising edge "DOWN" signal goes high and "UP" signal goes low. Fast phase and frequency acquisition PFDs are generally preferred over traditional PFD.

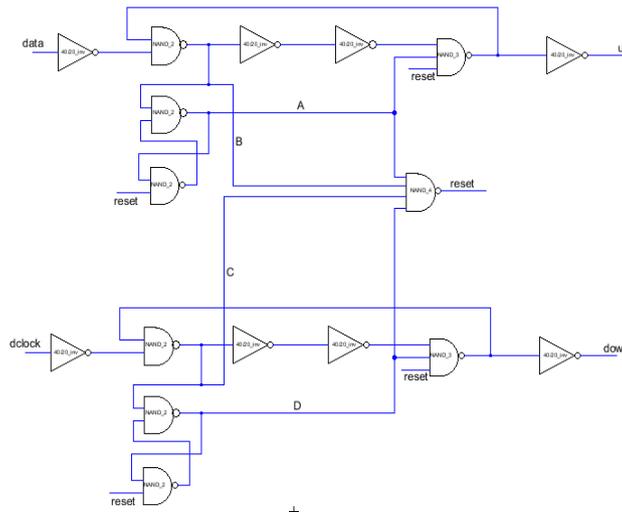


Figure.3 Schematic Diagram for Phase frequency Detector

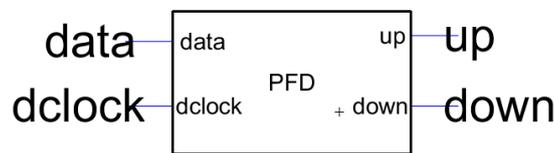


Figure.4 Icon view for schematic in Figure 3 PFD

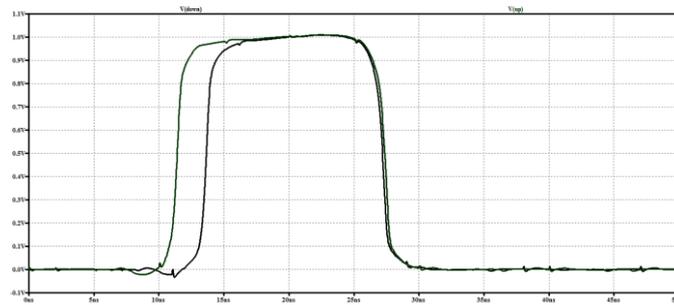


Figure.5 Simulation plot for Up and Down signals in PFD

Figure.5 shows the waveform formed by the PFD. It has two waveform, one for UP signal and other for down signal.

3.2 Charge Pump and Loop Filter

Charge pump circuit is an important block of the whole PLL system.

It converts the phase or frequency difference information into a voltage, used to tune the VCO. Charge pump circuit is used to combine both the outputs of the PFD and give a single output which is fed to the input of the filter.

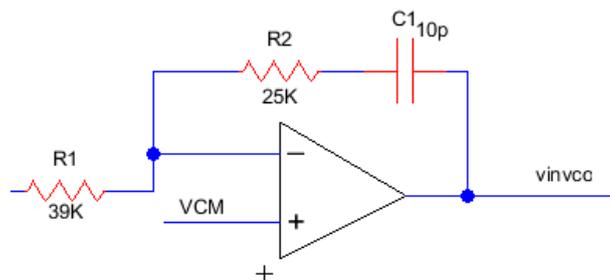


Figure.6 Basic Charge Pump Loop Filter using Op-amp

3.3 Voltage Controlled Oscillator

An oscillator is an autonomous system which generates a periodic output without any input. The most popular type of the VCO circuit is the current starved voltage controlled oscillator (CSVCO). Here the number of inverter stages is varied, generically used with 21 stage with simple inverter or current starved configurations.

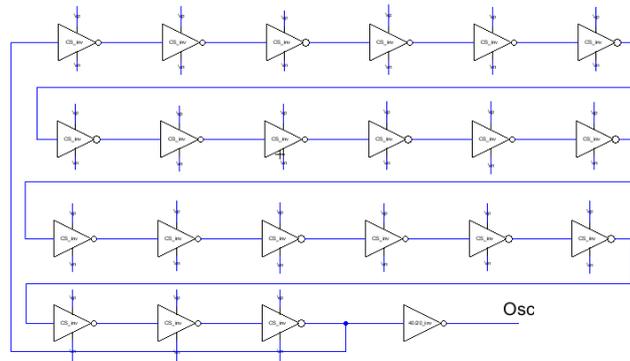


Figure.7 Schematic for 21 stage Voltage Controlled Oscillator

3.4 Frequency Divider

The output of the VCO is fed back to the input of PFD through the frequency divider circuit. The frequency divider in the PLL circuit forms a closed loop. It scales down the frequency of the VCO output signal. A simple flip flop (FF) acts as a frequency divider circuit. The schematic of a simple divider based divide by 2 frequency circuit is shown in the Figure 8

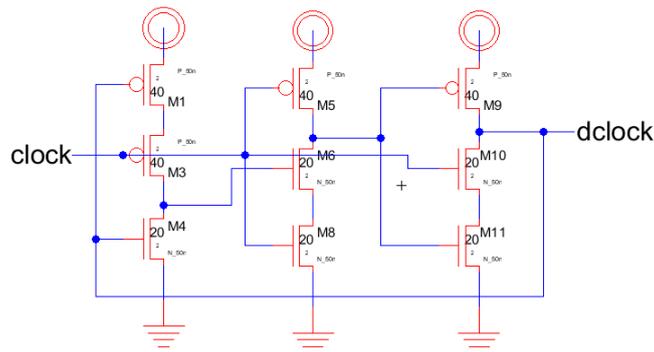


Figure.8 Schematic view for frequency divider network

IV. DESIGN AND SYNTHESIS OF DPLL

The schematic level design entry of the circuits is carried out in the Electric CAD VLSI Design Environment. The structure of the DPLL is designed in Electric CAD using 50 nm SPICE models for CMOS. In order to analyze the performances, these circuits are simulated in the LTSPICE simulator of Level 3 or 4 BSIM SPICE CAD. Different performance indices such as phase, group delay and corresponding magnitude are measured in this environment. Transient parametric sweep and phase analyses are carried out in this work to find out the performances of the circuit. The optimization of the current starved VCO circuit, the scale factor for transistor sizing is found out using the LTSpice environment.

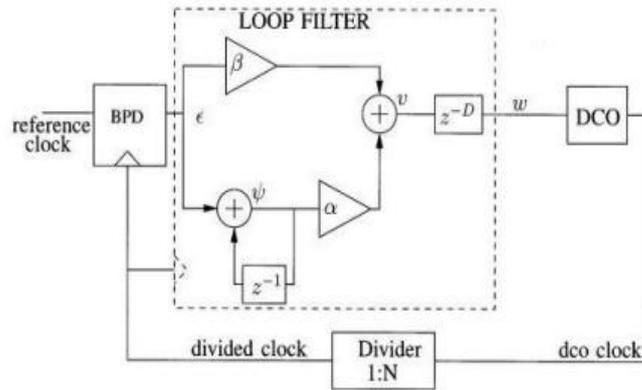


Figure.9 Design of ADPLL from Base Paper [1]

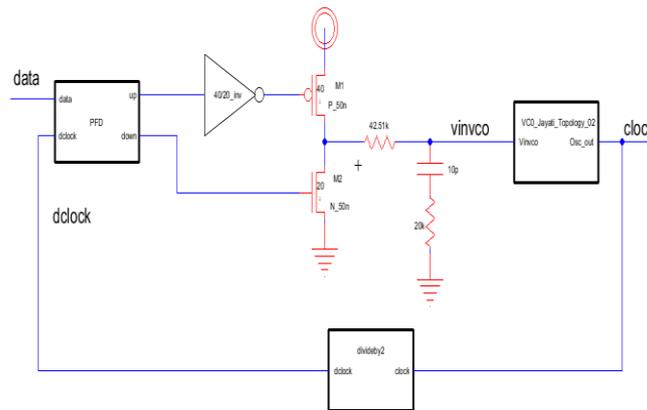


Figure.10 DPLL using Op-amp, PFD and RC loop filter and Charge pump

Figure.9 is the design of ADPLL which were used in our Base Paper. But there are certain limitations in the design of ADPLL which is given in base paper, like, jitter problem, phase and timing, locking time, core area, performance, power consumption. So in this work, we are going to design our own ADPLL or DPLL with different components and try to remove all the problems of previous design.

Figure.10 is our own designed DPLL with different components. In this, as compare to Figure.9 we have used Phase/Frequency Detector (PFD) in place of BPD, Voltage Controlled Oscillator (VCO) in place of Digital Controlled Oscillator(DCO), divide by 2 divider in place of divide by N.

V. SIMULATION RESULTS

This section describes the circuit, transient plot and waveform of different components obtained during the designing of DPLL.

Figure.11 shows the 21 stage VCO using simple CMOS inverter.

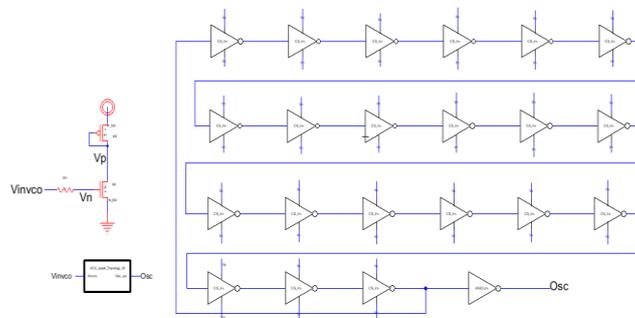


Figure.11 Schematic for VCO using simple CMOS inverter

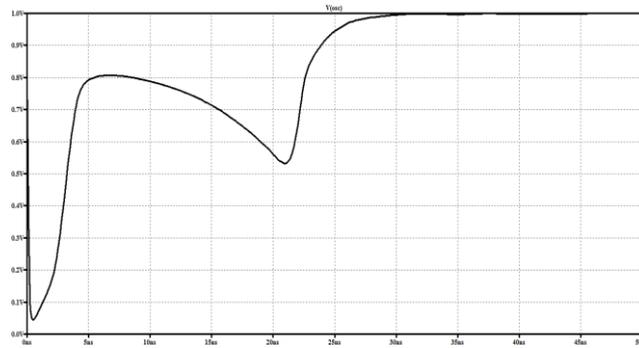


Figure.12 Transient plot for VCO using simple inverter

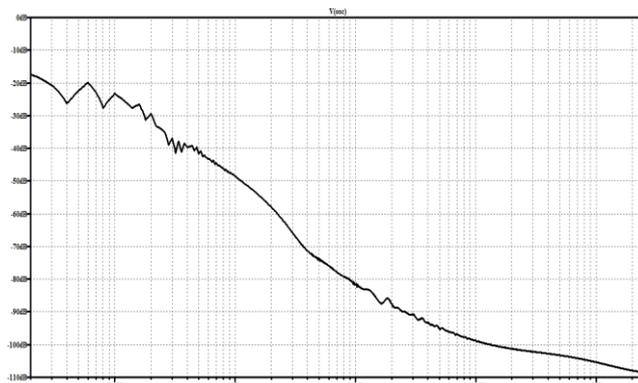


Figure.13 FFT plot for VCO using simple inverter

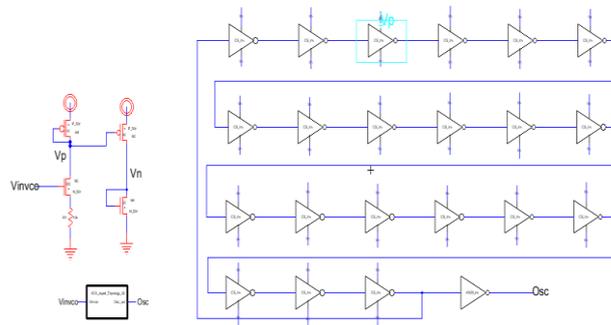


Figure.14 Schematic for VCO using current starved CMOS Inverter

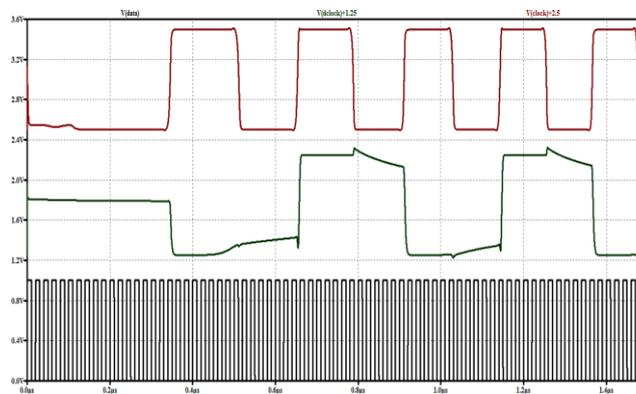


Figure.15 Transient plot for Vdata and Vclock in DPLL

The first waveform of transient plot of Figure.15 represents the voltage of clock which is represented by Vclock and second waveform represents the Vdata.

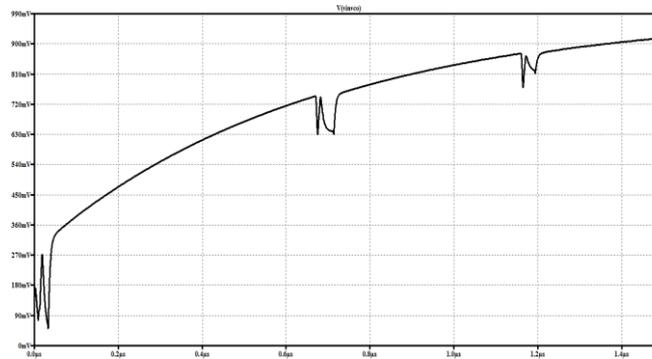


Figure.16 Transient plot for Oscillator output in DPLL

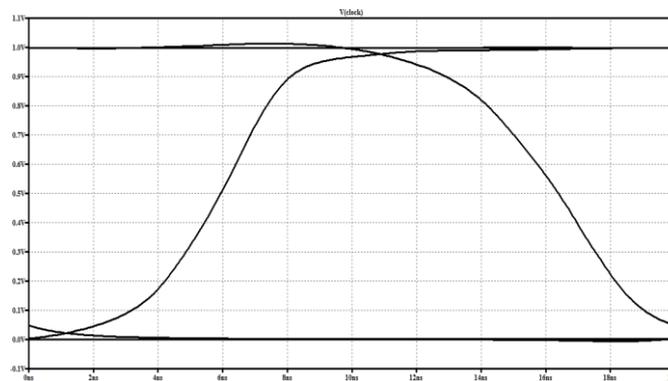


Figure.17 Transient Plot or Eye Diagram for Vclock in DPLL

VI. FFT RESULTS

The following table summarizes the FFT analysis of designed DPLL with parameters like, frequency, magnitude, phase and group delay under different ranges.

Table 1 FFT analysis for designed DPLL

Frequency	Magnitude	Phase	Group Delay
1MHz	-19.82 dB	109.74°	17.85 ns
10 MHz	-37.42 dB	104.85°	48.016 ns
100 MHz	-56.21 dB	92.41°	-37.87 ns
1 GHz	-78.79 dB	91.68°	-3.414 ns
10 GHz	-98.53 dB	105.14°	-78.45ns
100 GHz	-111.30 dB	179.99 °	-3.620 ns

VII. CONCLUSION

In this paper presented DPLL works with better locking times, the digital PLL consumes low power as designed with 50 nm CMOS technology, the transient analysis mainly depends on the type of the PFD architecture used and parasitic parameters utilized for charge pumps and loop filters. So by properly choosing VCO architecture, PFD design and adjusting the charge pump configurations. The efficiency of the overall design also depends on the reduction of transistor sizes which is 50nm.

REFERENCES

- [1]. Dian Huang, Ying Qiao, "A fast locked all digital phase locked loop for dynamic frequency scaling", Moon Seok Kim, Yong Bin Kim, Kyung Ki Kim, "All digital phase locked loop with local passive interpolation time to digital converter based on tristate inverter" IEEE transactions 2012.
- [2]. Jaewook Shin and Hyunchol Shin, "A 1.9-3.8 GHz $\Delta\Sigma$ Fractional-N PLL Frequency Synthesizer with Fast Auto-Calibration of Loop Bandwidth and VCO Frequency," IEEE Journal of Solid-State Circuits, Vol. 47, no.3, pp.665-675, Mar 2012.
- [3]. Luca Vercesi, Luca Fanori, Fernando De Bernardinis, Antonio Liscidini and Rinaldo Castello, "A Dither-Less All Digital PLL for Cellular Transmitters," IEEE Journal of Solid-State Circuits, vol 47, no.8, pp.1908-1920, Aug 2012.

- [4]. Xin Chen, Jun Yang and Long-Xing Shi, "A Fast Locking All-Digital Phase-Locked Loop via Feed-Forward Compensation Technique," IEEE Transactions on Very Large Scale Integration(VLSI) Systems, vol.19, no.5, pp.857-868, May 2011.
- [5]. Chao-Ching Hung and Shen-Iuan Liu, "A 40-GHz Fast-Locked All-Digital Phase-Locked Loop Using a Modified Bang-Bang Algorithm," IEEE Transactions on Circuits and Systems-II, vol.58, no.6, pp.321-325, June 2011.
- [6]. Ping-Hsuan Hsieh, Jay Maxey and Chih-Kong Ken Yang, "A Phase-Selecting Digital Phase-Locked Loop With Bandwidth Tracking in 65 nm CMOS Technology," IEEE Journal of Solid-State Circuits, vol. 45, no.4, pp.781-792, April 2010.
- [7]. Ping-Hsuan Hsieh, Jay Maxey and Chih-Kong Ken Yang, "A Phase-Selecting Digital Phase-Locked Loop With Bandwidth Tracking in 65 nm CMOS Technology," IEEE Journal of Solid-State Circuits, vol. 45, no.4, pp.781-792, April 2010.
- [8]. Liange Xu, Saska Lindfors, Kari Stadius and Jussi Ryynanen, "A 2.4-GHz Low-Power All-Digital Phase-Locked Loop," IEEE Journal of Solid-State Circuits, vol.45, no.8, pp.1513-1521, Aug 2010.
- [9]. Deok-Soo Kim, Heesoo Song, Taeho Kim, Suhwan Kim and Deog-Kyoon Jeong, "A 0.3-1.4 GHz All-Digital Fractional-N PLL with Adaptive Loop Gain Controller," IEEE Journal of Solid-State Circuits, Vol.45, no.11, pp.2300-2311, Nov 2010.
- [10]. Quan Sun, Yonguang Zhang, Christine Hu-Guo, Kimmo Jaaskelainen and Yann Hu, "A fully integrated CMOS voltage regulator for supply-noise-insensitive charge pump PLL design," Microelectronics Journal, Vol. 41, Issue 4, April 2010, Pages 240-246
- [11]. S.J.Li, and H.H.Hsieh, "A 10 GHz Phase-Locked Loop with a Compact Low-Pass Filter in 0.18 μ m CMOS Technology", IEEE Microwave and Wireless Components Letters, VOL. 19, NO. 10, OCTOBER 2009
- [12]. H.Janardhan, and M.F.Wagdy "Design of a 1GHz Digital PLL Using 0.18 μ m CMOS Technology," IEEE Proc. of the Third International Conference on Information Technology,2006.
- [13]. R.E. Best, "Phase Locked Loops Design, Simulation and Applications," McGraw-Hill Publication, 5th Edition, 2003.
- [14]. S.M.Kang, and Y.Leblebici, "CMOS Digital Integrated Circuits: Analysis and Design," McGraw-Hill Publication, 3 rd Edition, 2003.
- [15]. R.J.Baker, H.W.Li, and D.E.Boyce, "CMOS Circuit Design, Layout, and Simulation," IEEE Press Series on Microelectronic Systems, 2002.
- [16]. B. Razavi, "Design of Analog CMOS Integrated Circuits," Tata McGraw Hill Edition,2002.
- [17]. M.Mansuri, D.Liu, and C.K.Yang, "Fast Frequency Acquisition Phase Frequency Detector for GSamples/s Phase Locked Loops," IEEE Journal of Solid State Circuit, Vol. 37, No. 10,Oct., 2002.
- [18]. Youngshin Woo, Young Min Jang and Man Young Sung, "Phase-locked loop with dual phase frequency detectors for high-frequency operation and fast acquisition," Microelectronics Journal, Vol. 33, Issue 3, March 2002, Pages 245-252.
- [19]. S. M. Shahruz, "Novel phase-locked loops with enhanced locking capabilities," Journal of Sound and Vibration, Vol. 241, Issue 3, 29 March 2001, Pages 513-523.
- [20]. Dan H. Wolaver, "Phase Locked Loop Circuit Design," Prentice Hall Publication, 1991.