

## High Performance Computing on Fast Lock Delay Locked Loop with Low Power State and Simultaneous Switching Noise Reduction

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**Abstract: Problem statement:** In any multimedia processor, controller may consume most of the on-chip memory resources. The memory requirement is directly depends on algorithm shared by different blocks, so leads to failure in the system models. **Approach:** This study presents the implementation of DLL unit used for memory optimization. Various aspects of the underlying coarse lock detector are explored and modifications are made with software reference implementation. The whole system is implemented in 0.18  $\mu\text{m}$  CMOS technology, where an input reference clock to an outgoing data clock monitors and true locking is initialized with 50% duty cycle correction. **Results:** From the measurement result of DLL operation, the output clock jitter is analyzed. Power consumption of DLL including large size output buffer is about few mW. **Conclusion:** The great challenge in this implementation is communication bandwidth, has brought to process variation and power state reduction techniques. In addition, inefficiency of computing capacity and simultaneous switching noise is reduced in the real time applications.

**Key words:** Delay locked loop, voltage control delay line, coarse lock detector, process variation, simultaneous switching noise

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### INTRODUCTION

In recent years, the performance is the most important in real time image and video applications. As circuit speed increases with shrinking device dimension, the clock frequencies increase and the effects of clock skew and jitter on a system becomes an increasingly larger percentage of data valid window ( $t_{DQV}$ ). If false lock prevails, by detecting and correcting the pulse to withstand the data. There is no system exists to handle this type of issues in the realistic implementations.

A Double-Data-Rate Synchronous Dynamic Random Access Memory (DDR SDRAM) is an example of an application that uses a Delay-Locked Loop (DLL) to maximize the data valid window (Shin *et al.*, 2009b). When the data valid window shrinks, the integrity of the system is detrimentally affected and high performance suffers. If a fixed amount of delay were used instead of a DLL to align the incoming clock and output data, then variations in PVT would significantly increase clock skew ( $t_{DQSK}$ ). This increase effectively shrinks the data valid window ( $t_{DQV}$ ) and makes the system more subject to timing errors. In a Very Large Scale Integrated (VLSI) circuit design, it is advantageous to use a digital DLL design (Garlepp *et al.*, 1999), for its portability across process nodes.

### MATERIALS AND METHODS

This study proposes a new approach to achieve fast, true locking and evaluated the impact of timing jitter. In a PLL implementation the own reference clock that is phase-locked to an external clock pulse, where noise on the reference clock dominates and self-induced jitter within the VCO is negligible. In multimedia (streaming) applications, it processes more data, which stresses communication bandwidth, raises more computational complexity. So the multistage clock buffer implementation with a long inverter chain leads to drive a heavy capacitive load. It is difficult to hold the clock duty cycle at its ideal value 50%, irregularity in signal and variation (P and N MOS) in the long buffer. So the clock duty cycle deviates, the clock pulse may vanish inside the clock buffer, width becomes Shorten or lengthy (Garlepp *et al.*, 1999).

A delay buffer acts as a timing adjusting element, is of identical structure. Here Current Starved Delay Element (CSDE) is used for the realization of the delay buffer (Stojcev and Jovanovic, 2008). The contribution for the design was the following:

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- Independent delay regulation in both rising and falling edges
- The current variation in p-type and n-type MOS transistor, leads to independent delay regulation

In this approach, control voltages directly drive gates of transistors, act as symmetric loads in the Fig. 1 and are used for two purposes: (a) linearizing the voltage to delay transfer function and (b) provides correct initiator for DLL operation even control voltages are out-of-regulation limits. If mismatches between taps are negligible, the tap delay is independent of device parameters even in the presence of temperature and process variations. DLLs have much more relaxed tradeoffs among gain, bandwidth and stability since it can be designed as a first-order system, a simple capacitor for the loop filter.

Here, Current Starved Delay Element (CSDE) offers good delay stability in respect to temperature and voltage variations. But it is relatively limited range of delay regulation. The nominal delay which corresponds to one clock period determines the optimization of delay elements.

The proposed DLL architecture is shown in the Fig. 2. The clock aligner is composed of a voltage controlled delay line, VCDL, two phase detectors, PD1 and PD2, two charge-pumps, CP1 and CP2, two first order low-pass filters, LP1 and LP2 and a multistage clock buffer, CB. The negative feedback in the loop adjusts the delay through the VCDL by integrating the phase shift errors that result between the periodic reference input,  $CLK_{ref}$  and the multistage output,  $CLK_{out}$ . The underlying idea for this approach is to provide delay regulation for both a rising and trailing edge of the output clock pulse  $CLK_{out}$ . For implementation of variable delay regulation the building block VCDL is used. The control voltage  $V_{bn}$  ( $V_{bp}$ ) defines delay regulation of a rising (trailing) clock pulse edge. The phase detector PD1 (PD2) compares a phase shift of rising (trailing) edges between the input,  $CLK_{in}$  and output,  $CLK_{out}$ , clock pulses.

The LP1's (LP2's) output,  $V_{ctrl1}$  ( $V_{ctrl2}$ ), is connected to the VCDL control input at node  $V_{bn}$  ( $V_{bp}$ ). When the system enters in stable state both edges of  $CLK_{out}$  are synchronized and phase shifted in respect to the referent clock  $CLK_{ref}$ .

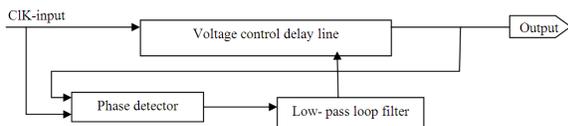


Fig. 1: Block diagram of DLL

A false lock should be avoided when the maximum delay of VCDL equals to the twice of input clock period. If the VCDL electrical length is  $2TCLK$ , the quadrature output is  $TCLK/2$  from  $CLK-IN$  instead of  $TCLK/4$ . Another way to implement DLL uses all-digital techniques and it can be designed as a 0th-order system, where no integration is taken place in such a system. The delay is changed using method one, i.e., changing the number of delay taps (Tu, 2006). The big benefit of all digital DLLs is easy to scale for other processes and applications

The coarse lock detector receives an input clock and odd-numbered phases, from the VCDL. The HCLD generates a clock whose frequency is half the input's and counts edges in its every evaluation phase (Chi *et al.*, 2011), thus it can avoid harmonic lock and stuck problems without requiring any external reset. The conventional CLD has shortcomings in speed and area. To overcome these problems, before entering a flip-flop, a clock is delayed for the same delay amount of the counting logic and we can acquire some timing margin.

At first, the HCLD locks in a narrow mode. After the coarse lock lasts 3 cycles, it changes the coarse lock range to a wide mode. The specifications also limit the allowable clock jitter to Gaussian (or normal) distribution. If the clock jitter is not Gaussian in nature, then the clock violates the timing specifications. In a DLL design, the effect of SSN ripples must be considered along with harmonic lock and stuck problems. As system bandwidth increases, power and ground distribution for high-speed systems becomes critical (Oklobdzija, 2003). In these high performance systems, Delay Locked Loops (DLLs) and Phase Locked Loops (PLLs) are usually used to generate the clock signal which is required to implement clock deskewing circuit in RF transceiver, inter-chip communication interfaces and clock distribution. Variations in this timing reference (i.e., clock jitter) require designs to incorporate additional margins that degrade performance and can cause bit errors in communications systems. When DLL circuit is operating in real on-chip circumstance, it is suffered from several noise sources. The major noise source of the DLL circuit include Simultaneous Switching Noise (SSN) from external circuit, phase detection noise, Voltage Controlled Delay Line (VCDL) internal noise from substrate, external reference clock input noise and VCDL control voltage noise. The data rate of current DDR3/4 systems is expected to move from 2Gbps to 4Gbps. At such high data rates, SSO noise introduced by output drivers becomes the major bottleneck in designing memory channels. GDDR3/4 is based on the Pseudo Open Drain Logic (PODL) (single ended) signaling. It generates substantial AC current peaks

when output drivers are simultaneously switching. These current peaks generate a large amount of (Simultaneous Switching Output) SSO noise in the system if the impedance of the power distribution system is not sufficiently low.

While SSO noise by itself can be simulated without much difficulty, its impact on channel voltage and timing margin is much harder to characterize. Co-simulation of PDN and channel model requires long simulation time and often results in convergence issues (Chun *et al.*, 2001). Furthermore, supply noise in the system strongly depends on the switching data pattern. The worst case data pattern for supply noise is a function of the PDN resonance; whereas, the worst case pattern for signal noise, such as crosstalk and Inter-Symbolic Interference (ISI), depends on the channel transfer function. Therefore, finding the excitations that models the worst case system voltage and timing margin considering both signal and power integrity effects is a challenging task.

Conventional charge-pump type Delay Locked Loop (DLL) usually has been applied for multiphase clock generator in transceiver system (Shin *et al.*, 2009a). The core loop consists of eight pseudo differential delay elements including dummy elements, a self-bias circuit for regulated bias voltage, a differential charge pump and a linear phase detector. There are two kinds of filter capacitors in DLL. Loop filter capacitor decides the loop bandwidth of DLL. Bias filter capacitor is inserted for reduction output jitter. Each filter capacitance can be changed by external control switch.

Hence the effect of SSN such as:

- Fluctuation of on-chip  $V_{DD}$  and  $V_{SS}$
- Reduce noise margins of digital circuits
- Change the Operating Point of Analog Circuits
- Increase the Timing Jitter of Oscillators/Clocks can be reduced with the help of power distribution network

Inter-die and Intra-die variations present significant power-speed-yield trade-offs. The problem of process variations become all the more predominant with the scaling of devices for each new generation. The problem of process variations is all the more complicated in analog circuits (Kinget, 2005). They have a considerable effect on the bias conditions, gain, frequency response and bandwidth of the circuit.

Another technique is the design methodology to develop circuits that compensate for process variations without the need for post-fabrication efforts. The main advantage of this methodology stems from the fact that we can use it to optimize the circuit to reduce variation on a parameter which we consider important such as gain, bandwidth.

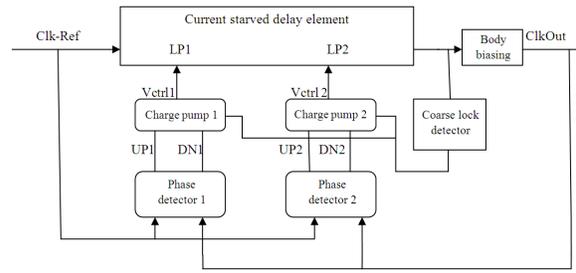


Fig. 2: Proposed DLL architecture

The timing error in a DLL accumulates over only one cycle of the input frequency. Hence the random timing error in one cycle is independent or uncorrelated to the random timing error of the next cycle. Thus there is a flat region in the phase noise plot and rolls off as the two timing indices approach each other within the period of the reference crystal frequency.

DLL suffers due to simultaneous switching noise. Hence DLL used in memory controllers must be designed in such a way that it does not affect due to SSN and harmonic stuck problem. Hence DLL for a memory controller is designed using a Hysteresis Coarse Lock Detector (HCLD). With the proposed HCLD, a DLL becomes immune to SSN, free from harmonic lock and stuck problems without a reset signal and faster than that using a conventional Coarse Lock Detector (CLD).

Under an SSN environment in a memory controller, control voltage is unstable even in a lock state. In a conventional CLD, this environment breaks the lock state and the CLD recovers the coarse lock quickly again, which will happen continuously at all times. This can be a jitter source because a frequency tracking loop and a phase tracking loop may interfere with each other during the interval when the CLD transfers control signal to the PD and vice versa.

## RESULTS

Hence the threshold variations can be reduced with the help of sizing and calibrating the delays which makes the DLL to be process invariant. The Fig. 3, gives the analysis of percentage of duty cycle error. In a Hysteresis CLD (HCLD), once a lock state is entered (Lin and Huang, 2004), the coarse lock range becomes wide as shown in the Fig. 4. So the PD keeps controlling, hence jitter is reduced. Moreover, by using hysteresis, it controls the coarse lock range, thus reduces jitter. The DLL neither suffers from harmonic lock and stuck problems nor needs an external reset or start-up signal.

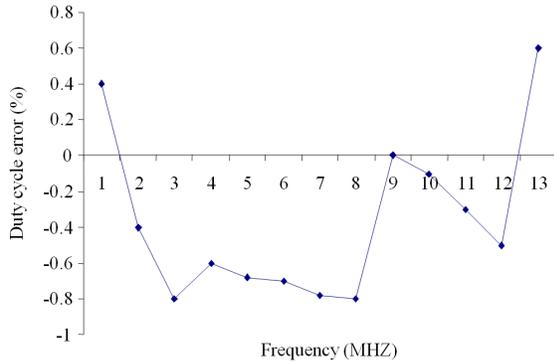
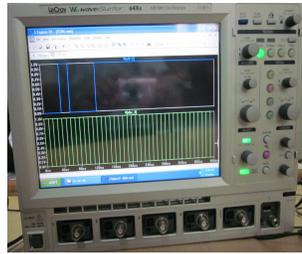
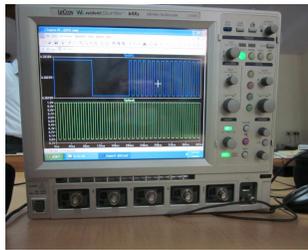


Fig. 3: Duty cycle-error free estimation



(a)



(b)

Fig. 4: (a) Output of HCLD in Lecroy oscilloscope (b) Phase shifted locking timing diagram

### DISCUSSION

The memory interface used to operate in the active state, where the signals are all active mode of operation. The high-speed reference clocks distributed across both the controller and DRAM interfaces. Based on the command traffic from the memory host controller, the appropriate low power states are employed (Leibowitz *et al.*, 2010; Balamurugan *et al.*, 2008; Lee *et al.*, 2009; Poulton *et al.*, 2007).

When the CA controller queue gets empty, the last command rise to clock pause state. The controller synchronously pause the PLL output by halting all the switching activity. The Table 1 shows the performance report on proposed DLL. Finally the work concludes the duty-cycle of  $CLK_{out}$  is maintained at value of 50%.

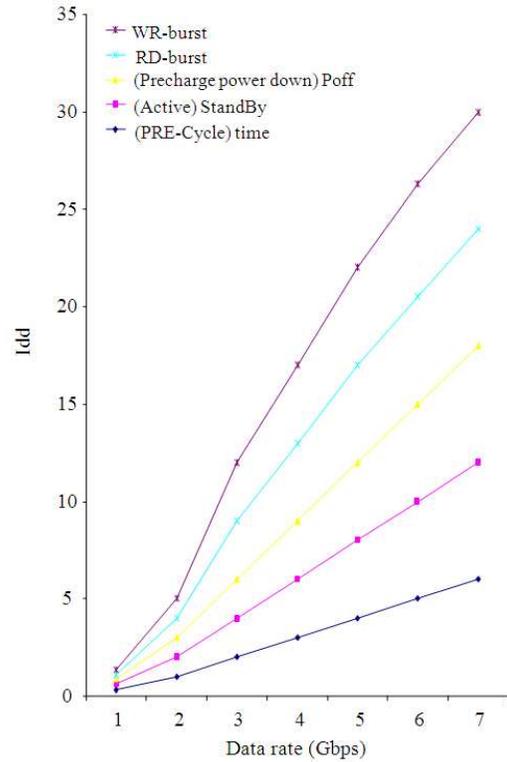


Fig. 5: Memory Transactions on Supply current Vs Data rate

Table 1: Summary report

Frequency range	500-1200MHz
Locking time	200ns
Duty cycle error	0.8%
Edge correction	Double Edge
Duty cycle correction	20-80%
Reference clock	External
Coarse lock	Hysteresis type
Process variation	Invariant to threshold voltages
Measured Jitter (RMS and PP)	3.2 ps at 500 MHz and 20.5 ps at 1100 MHz -pp

This operation disables their front-end DQ transceiver circuits, since does not receive any signal transition. The clock pause operation (Balamurugan *et al.*, 2008), responds to programmable number of successive No-Operation (NOP) commands. When the host controller requests a memory transaction, then the interface exits (Lee *et al.*, 2009), synchronously un-pausing the interface clocks. The front-end DQ transceiver circuits (Balamurugan *et al.*, 2008) are initialized to the appropriate read or write configuration after the first CA command is communicated as shown in the Fig. 5. It is similar to the front-end power configuration change in a normal read/write bus turn around during active operation.

## CONCLUSION

A prototype circuit is designed in 0.18  $\mu\text{m}$  technology, duty cycle error reduces to 0.8% which makes good stability, fast-responsive. The DLL is optimized for reduction in the variation of threshold voltage. Moreover, by using hysteresis, it controls the coarse lock range, thus reduces jitter. While the actual power consumption of a burst-mode interface will be heavily dependent on real-world read and write activity patterns. So the improvement enhances the theoretical power and bandwidth scaling capabilities provided by these power states. Therefore, judicious use of low power states can maintain good overall power efficiency. Also the inefficiency of computing capacity is reduced. Finally, overall power efficiency shows more than two orders of magnitude in effective interface bandwidth. The proposed work can also be applied to clock distribution network within the SOCs, high-speed DRAM and MEMS devices.

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