A new charge-pump PLL for tracking bursty signals

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A charge pump phase locked loop comprising of a ring oscillator has been proposed to extract continuous carrier signal from burst like input signal. Experimental studies confirm that the simple structural modification provides a fairly steady reconstructed carrier signal.

The use of charge-pump phase locked loops (CP-PLLs), based on tristate phase frequency detectors (PFDs) in the carrier reconstructing systems of a communication receiver is well documented. However, when the input signal bearing information data does not have a carrier signal component in continuous time domain, the conventional CP-PLLs face problems in extracting the carrier signal information. In some communication systems, the carrier signal is transmitted in an intermittent fashion, like a burst of short duration, as in the case of color subcarrier transmission in TV broadcasting. The reconstructed carrier signal using conventional CP-PLLs will drift in phase and frequency during the off intervals of the burst signal. The reason is that the tristate PFDs detect transition missings at one input. This will result in the draining out of the pump current from the loop filter and the VCO control will change. This problem can be overcome if the forthcoming transition missing instant is detected beforehand and the pump circuit is disabled accordingly. The present circuit uses a ring oscillator as the loop VCO which provides a number of outputs, each of same frequency but different in phase relative to one another. The present investigations deal with a conventional CP-PLL comprising a ring oscillator capable of tracking a bursty input signal with a negligible phase drifting in the locked state. The circuit modification is simple enough and will be useful from the total power consumption point of view. The ring oscillator is capable of providing multiphase signals and this property has been used to implement the present modified circuit. The algorithm of structure modification and the experimental results obtained from the present studies are reported. A few comments regarding the limitations of the circuit are also given.

Algorithm of the Modified Circuit
The functional block diagram of a CP-PLL based carrier reconstructing circuit is shown in Fig. 1. When one of the input signals applied to the PFD is bursty in nature, (i.e. the signal is present for certain interval of time (“ON”) and absent for another interval (“OFF”)), and the other one is a continuous wave (obtained from the loop VCO), obviously the PFD will detect transition missings at one input. This will result in the draining out of the pump current from the loop filter and the VCO control will change. This problem can be overcome if the forthcoming transition missing instant is detected beforehand and the pump circuit is disabled accordingly. The present circuit uses a ring oscillator as the loop VCO which provides a number of outputs, each of same frequency but different in phase relative to one another. Amount of phase difference depends on the structure of the ring oscillator. Actually, number of inverter stages used to design the ring oscillator determines the phase difference of one output with the other. In the proposed circuit the following outputs of the ring oscillator are used:

- Burst input
- PFD
- D1/D2
- CP Filter
- VCO
- Buffer
- +1

Fig. 1 — Functional block diagram of a CP-PLL
oscillator are taken. One output \(VCO(2)\) is used as the reference signal to the PFD; other two outputs \(VCO(1)\) and \(VCO(3)\) are used to detect the transition missing instant of the input signal and disable the pump current circuit. \(VCO(1)\) leads \(VCO(2)\) while \(VCO(3)\) lags \(VCO(2)\). \(VCO(1)\) and \(VCO(3)\) are used to clock two separate D-flip flops each having input bursty signal as the data input. The outputs of these two D flip flops are logically OR-ed and applied to control the pump out circuit accordingly as shown in the Fig. 2. \(D2\) signal in the modified circuit plays the role of \(D1\) signal used in the conventional circuit. Since the additional part of the circuit is capable to detect the "OFF" interval of the burst signal, the interval of unnecessary draining of charge from the loop filter can be reduced and this leads to the improvement of the system performance.

**Experimental**

The performance of the proposed modified CP-PLL in the face of a bursty input signal has been tested through a hardware experiment. The proposed circuit is found to work as predicted. The experimental set up (realised using common TTL ICs) is shown in Figs 2 and 3. The modified CP-PLL is designed using common IC functional blocks, viz., one D flip-flop-based PFD, additional logic circuit comprising of a D flip-flop, an OR gate and a NAND gate, a transistor-based charge pump circuit, a unity gain buffer and a VCO. Here, the VCO is a ring oscillator designed as cascaded combination of 15 NOT gates (as shown in Fig. 4). In this oscillator the minimum phase difference between two properly chosen oscillator outputs is \(2\pi/15\). The loop performance has been tested for different ON/OFF periods of the bursty input signal. Some experimental results have been incorporated in this paper when the burst ON period is 12.5% and OFF period is 87.5% of the burst repetition period. Fig. 5 shows the spectrum of the bursty input carrier signal of frequency 1.3438 MHz where the burst on period is 12.5%. Fig. 6 gives the variation of the VCO control signal (d.c.) as a function of time in such a situation. It can be seen from Fig. 6a that the VCO controlled voltage drifts away from its lock-state value during the OFF interval of the input signal in the conventional structure. But it remains constant at the lock-state value in the modified structure as shown in Fig. 6b. Figs 7a and 7b show the spectra of the regenerated carrier signal using conventional and modified PFD, respectively. The purity of the spectrum in case of modified PFD confirms the validity of the proposed algorithm.
Results and Discussion

The proposed circuit successfully performs the function of continuous carrier signal extraction in the face of burst-like input signal. However, the use of a ring oscillator providing multi-phase output signal and the "OFF" detection circuit comprising of digital edge sensitive flip flops restrict the application potential of the modified circuit in some respects. The phase difference between consecutive stages of the ring oscillator depends on number of inverter stages (n), and if `n` is made high, the operating frequency of the ring oscillator reduces. Further, the input signal should be made unipolar before applying to the loop, so that the edge sensitive digital ICs may be used. The whole circuit can be integrated as a single application specific IC (ASIC) and can prove to be useful communication receiver building block.

Conclusions

The reconstruction of the carrier signal in the face of a burst-like input signal is difficult to get using a conventional PLL-based receiver. The problem can be successfully solved using the modified PLL reported in this paper. The suggested PLL uses a ring oscillator capable of providing multiphase outputs. One of the outputs is used to disable the effect of unwanted error correcting signal generated by the loop PFD and thus making the improved performance of the loop possible. Using the state of art integrated circuit technology employing inverters having propagation delay of 1-10 nano seconds, the proposed system can be efficiently applied in reconstructing the color sub carrier signal of conventional TV receivers, or in the receivers of standard time and frequency signals (STFS) used in precise time transfer systems.
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References