Investigating the Effect of Voltage Controlled Oscillator Delay on the Stability of Phase Lock Loops

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ABSTRACT:
In this paper, the effects of the delay caused by the frequency change in self-priming locking oscillators are investigated in the phase lock loops. Self-injected locking phenomena in oscillators are used to reduce phase noise and more sustainability. Instead of using an external signal in an intruder lock, part of the output signal itself is returned to the oscillator again. In this case, the time required to restore the circuit after the injection of the external frequency is important, especially when this oscillator is used in the shape of a phase lock loop. This delay has the ability to unstable the phase lock loop. In this paper, the stability requirements for phase locking loops with delayed oscillators are fully investigated and the results are validated by simulation.

KEYWORDS: Phase Lock Loop, Delayed Systems, Oscillator, Stability.

1. INTRODUCTION

The injection of a periodic signal into an oscillator causes interesting phenomena such as locking or pulling injections, which is examined by Adler [1] and the rest of the researchers [2], [4]. Nowadays, these effects have become more important and have become intrusive in many areas of electronics. This phenomenon is true for all oscillators, including oscillators. In fact, electronic systems are usually covered by these phenomena. The 17th century was the period for which this phenomenon was first recognized and, as with all the peculiarities of the world, this recognition was surprisingly and scientifically incredibly visible to scientists through an accident. Christensen Hagens, a priest and danish scholar who was sleeping sick in bed, suddenly found an idea of one of the most fundamental theories of fluctuation, observing the old wall clocks hanging on the wall against him. The wall clock pendulums were oscillating in a single way, while their only connection was the wall that hung on the wall. Hughes found that the mechanical coupling from the joint wall makes the swing of one of the watches in the other injected and make them fluctuate. Hugens also gained other interesting results in his studies in a completely different field with hours and about the injection of oscillations. Those who are in isolation chambers will increase their sleep-awakening period to 25 hours, which, after returning to normal for a sufficient amount of time, returns to their normal sleep-wake-up period, in fact, this Individuals are injected in the normal state of rotation of the Earth lock [2]

Injection of the lock in many applications, including frequency multiplication [5], frequency division and the production of four-phase sinusoidal waves [6,7], frequency increase [8], phase noise reduction [9,10], and synchronization [11] is used. On the other hand, injectable stretch marks appear to be unfavorable in most electronic applications. For example, in broadband transmitters-receivers shown in reference [2]. In Fig. 1, the first voltage controlled oscillator in the transmitter, VCO1, is locked to a local crystalline oscillator, while the second-voltage regulated oscillator in the receiver, VCO2, is locked to the input data, which in fact is the frequency of that value The frequency of sending is slightly different. As a result, these two oscillators may interfere with each other due to the effect of coupling the bed in an injectable pull phenomenon. Or the input data, having enough energy near the sent or received frequency, may still lead to an injection traction in both VCOs used in the system.

As another example, the power amplifier referred to in reference [2] and shown in Fig. 2 illustrates one of the following cases of improper injection molding, in which this phenomenon results in the formation of a frequency spectrum the intruder has been investigated near the frequency of the local oscillator in the RF transmitter and receiver.

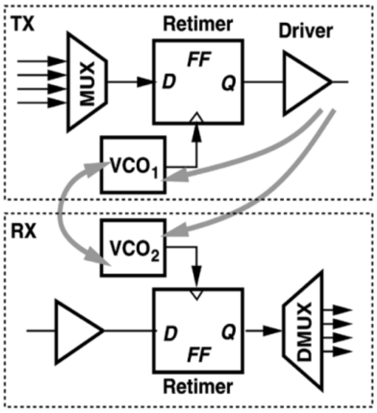

Fig. 1. The undesirable effect of injectable traction on broadband transmitters / receivers [2].

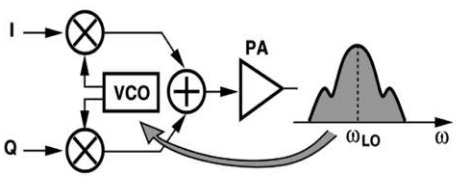

Fig. 2. The undesirable effect of injectable traction on RF transmitters – receivers [2].

Coupling oscillators also provide suitable ethods for combining millimeter power in scanning various waveforms. [11] For lower-quality oscillators, the locking interval is larger, and instead of the larger phase noise, due to the coupling of the oscillators together, reference [11] shows that phase noise is less than that of an oscillator. Of course, in many applications, phase noise reduction due to the coupling of the oscillators is not enough, and instead of the injector lock of an oscillator to an external source with low phase noise, the answer is.

In the process of locking a frequency into an oscillating oscillator, the time goes by for changing the frequency that is called locking. Whatever the size of this time, it has a smaller amount, as much as the system has more power to change the frequency. An important issue that is important, regardless of the speed of the frequency change in this phenomenon, is that the oscillator is locked into a phase lock loop. In this condition, the latency inside the loop from the locked oscillator may cause the phase lock loop to become unstable. The purpose of this article is to examine the conditions for sustainability in these systems.

2. INJECTION LOCK

Injectable lock is an interesting phenomenon that relates to free-wheel oscillators. In this view, the injection lock occurs when a free oscillator is affected by another oscillator, so that the frequency of the injected oscillator is not the same as the free-oscillator frequency, but close to it. If the requirements for locking in the initial oscillator (free circular) and the external oscillator are satisfied, the initial oscillator frequency begins to change in the order that it is applied to the injectable frequency. This phenomenon can also be locked onto intermittent frequency dividers, in which case it proposes very good solutions for frequency synchronization without the need for frequency synthesizers [5].

Providing simple methods for electronic issues is not just about synchronization, but also extending to the domain of frequency dividers. Frequency dividers are one of the basic blocks of phase lock loops. In conventional applications, digital dividers are used, but in most applications with power consumption and maximum usable frequencies, the ILFD-based ILFD frequency dividers are appropriate solutions to their digital equivalents [10], [11] ILFDs include free-wheel oscillators that are synchronized with external signals and have lower power consumption. Both LC and Circular oscillators are usable for divider. Because of Q's high-frequency LC oscillators, the frequency range that is usable in these dividers is low, so we have to think about lowering Q in order to solve this problem, which will be high for occupancy and power consumption. Another solution is to use an oscillator ring in the ILFD body because these oscillators have lower Q. An orbital method for frequency division using an intruder lock is shown in Fig. 3 in the reference [11] in which Vinj is the injection voltage to the ring oscillator RO and Vdiv is the output voltage divided by the frequency Be[11.]

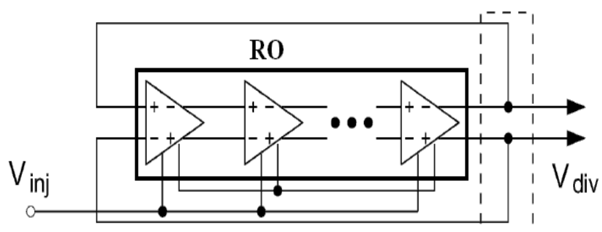

Fig. 3. ILFD using circular oscillators [11].

In another view, lock injection is introduced as a method that presents an innovative method by providing an efficient mechanism for generating a free-to-air ratio and a reference frequency without using full-frequency synthesizers. This phenomenon is due to its high importance in modern electronics, although the phenomenon that has been discussed for a long time in many ways, with numerous mathematical and orbital tools, as well as numerous electronic tests, such as time domain or frequency analysis [1-4], ISF method [5] and delayed method [6]. In the next section, the most important methods and applications of this phenomenon will be examined in detail.

3. INJECTION OF EXTERNAL FREQUENCY INTO AN OSCILLATOR

Injecting an external frequency under specific conditions to an oscillator that is in operation is called an injector lock, so that the initial frequency oscillator is affected by the inoculum frequency or the so-called "injector frequency" on the initial oscillator.

In order to describe this phenomenon, Adler obtained an equation of differential equation known as the Adler equation [1], and then it was examined by other people for the applications that could have been used. In all previous studies, how to extract this equation is focused on briefly, and for brief situations in this phenomenon.

In this paper, the precise time study of this phenomenon called the injectable locus is considered and all the parameters necessary to describe it in the time domain have been extracted.

The main purpose of the injection lock is to adapt the two existing oscillations. Suppose we have a shaft that fluctuates with angular frequency and quality factor. At this time, another oscillator with an angular frequency and under the required conditions [2] is connected to the first silicate. What happens to the output oscillator of the primary silicone? As we know, the oscillator requires a 180 degree phase-dependent shift in the feedback loop to function correctly. During the application of an external signal to the primary silicone, the phase shift in the ring changes, and the oscillator attempts to change its instantaneous momentum to compensate for the imposed phase shift, and this change continues to a point where the instantaneous frequency It is shown to be close to the injection frequency, and the rest of this phase shift is compensated by another phase shift that is shown with [2]. In Figure 4, there is an actuator and input and output signals.

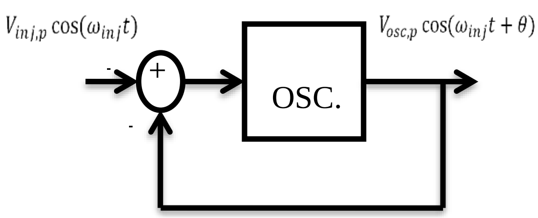

Fig. 4. Injection inlet and outlet silicate.

So due to external signaling $V_{inj,p}\cos(\omega_{inj}t)$ Exit signal to actuator $V_{osc,p}\cos(\omega_{inj}t+\theta)$ Thus, the instantaneous frequency relation can be calculated as follows:

$$\omega(t)=\frac{d}{dt}(\omega_{inj}t+\theta)=\omega_{inj}+\frac{d\theta}{dt} \quad (1)$$

ω_{inj} It has a fixed amount. Therefore, only a sentence that can change the instantaneous frequency ω, angular frequency $(\frac{d\theta}{dt})$ Which, according to studies, transmits the instantaneous frequency from ω_0 to ω_{inj}. The Adler equation, introduced in relation (2), describes the parameter $(\frac{d\theta}{dt})$ (instead of the α symbol of the θ symbol, this differential equation is, in fact, the key to examining transient conditions in an injectable silicate. The new symbol θ is re-written in the following relationship [2].

$$\frac{d\theta}{dt}=\omega_0-\omega_{inj}-\frac{\omega_0}{2Q}\frac{V_{inj,p}}{V_{osc,p}}\sin\theta$$

$$=\omega_0-\omega_{inj}-\omega_L\sin\theta \quad (2)$$

As described in the previous section, ω_L is known as the locking interval [2], [6], [7], and the range that if the frequency of the injected signal lies in it, it will have the ability to act on the oscillator Locked

The locking occurs when $(\frac{d\theta}{dt})$ reaches zero [2], and under these conditions, as shown in equation (1), the instantaneous frequency will be equal to the injection frequency. After locking, the phase shift of the compensator, which is now a constant number $(\frac{d\theta}{dt}=0)$, is computable, which is seen in (2), and is written again under the new symbol θ:

$$\theta=\sin^{-1}(\frac{\omega_0-\omega_{inj}}{\omega_L}) \quad (3)$$

4. THE IMPORTANCE OF LOCKING TIME

In Fig.5, the block diagram shows a typical phase lock loop using a low phase noise oscillator.

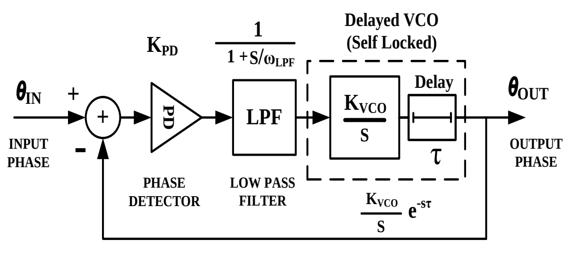

Fig. 5. Is a block diagram of a phase lock loop with a delayed oscillator.

In this phase locking loop, a phase detector, a low-pass filter, LPF, and a VCO-controlled oscillator are used, with a VCO delayed τ. This PLL aims to minimize the difference between the inθ input phase and the outθ output. In this section, we will attempt to examine the impact of the oscillator generated in the whole loop. For this purpose, in both non-delayed and delayed modes, the conversion function, which is the ratio of the output phase to the input phase, will be calculated. If ζ is the damping coefficient and nω is the natural frequency PLL, then the conversion function is written as follows:

$$H_s = \frac{\theta_{out}}{\theta_{in}}(s) = \frac{\omega_n^{\ 2}}{s^2 + 2\xi\omega_n s + \omega_n^{\ 2}} \tag{4}$$

And in which LPFω is the low bandpass bandwidth and K is the gain of the PLL loop and are defined as follows:

$$\omega_n = \sqrt{K\omega_{LPF}}\ , \xi = \frac{1}{2}\sqrt{\frac{\omega_{LPF}}{K}} \tag{5}$$

And in that LPFω is the low bandpass bandwidth, and K is the gain of the PLL loop and is defined as follows:

$$K = K_{PD}K_{VCO} \tag{6}$$

The relaxation time for the PLL loop is as follows:

$$t_s = \frac{4}{\xi\omega_n} = \frac{8}{\omega_{LPF}} \tag{7}$$

The delay in the VCO can be represented by its e-τs in its conversion function. In order to formulate the relaxation time of the delayed system, we use the approximation of e-τs ≈ 1-sτ which results in the new transformation function Hτ (s) and is expressed as:

$$H_\tau(s) = \frac{\omega_n^{\ 2}(1 - s\tau)}{s^2 + \omega_{LPF}(1 - K\tau)s + \omega_n^{\ 2}} \tag{8}$$

Since the zero effect in the conversion function is negligible for short time delay, it can be shown that the relaxation time tsτ for the delayed system is written as follows:

$$t_{s\tau} = \frac{8}{\omega_{LPF}(1 - K\tau)} = \frac{t_s(\tau = 0)}{(1 - K\tau)} \tag{9}$$

That ts (τ = 0) is the relaxation time of the PLL without delay. Relationship (9) shows that no matter how much VCO delay, the total delay caused by the PLL loop is also prolonged. In Fig. 6, the response of this PLL is shown in the case of zero delay as well as non-zero delays, and as the curves come up, the delay in the closed loop system PLL system takes longer to spend. To achieve a steady state.

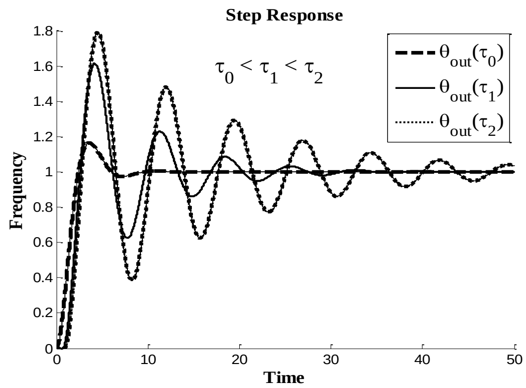

Fig. 6. PLL response steps with different delays for VCO.

5. CONCLUSION

In this paper, the stability analysis of the frequency conversion function is investigated by studying the stability of the fuzzy lock loops, which uses delayed voltage regulated oscillators in their structure. These type of oscillators use self-injection locking to reduce their phase noise. This reduces the phase noise, but increases the time it takes to change the frequency into the phase lock loop. In this paper, the unstable phase lock loop due to this delay as well as the stability conditions is investigated. Using the MATLAB software, the answer to the simulation system is staged and the results are compared with the theory relations.

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