PROCESSING OF THE PULSE SIGNALS PERIODS

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Abstract

This article presents a brief report of a new approach to time processing of the input and output periods and time differences between them. The general view of this new field is based on the recently published articles. For this new field of electronics, it is necessary to use more scientific disciplines. The methodological approach of mathematical and system analysis, as well as the ways of realization of these electronic systems are pointed out. Some of the applications described in the published papers are illustrated in the article. The most recent works in this field are related to a new type of FIR and IIR digital filters intended for filtering the periods of the pulse signal. The other areas of possible applications of this scientific discipline were indicated, as well as the next desirable steps of its further development.

Keywords: Digital circuits, Digital filters, PLL, FLL, Pulse circuits, Linear discrete system.

INTRODUCTION

According to refs. [1 to 13], the processing of input and output periods and time differences between them, allows a number of new and powerful applications in all areas of applied electronics, which have not been described in the literature. At the beginning of the development of the FLL (Frequency Locked Loop) and PLL (Phase Locked Loop) based on the time processing, it was intended to discover one new system with some new properties, in comparison with the existing ones: analogy, digital and hybrid FLL and PLL. Let us call these new systems, in short, Time FLL (TFLL) and the Time PLL (TPLL). The articles [1-13] fulfilled the expectations. At the very beginning of their development, TFLL and TPLL were applied in the field of frequency averaging, phase shifting, time shifting, phase control, tracking, predicting, frequency synthesizers, noise rejection, frequency multipliers and the others. One of the new properties of the period TPLL, is its ability to generate the desired phase difference between the input and output signals, thereby opening up a wide range of new applications in electronics and other fields. It is worth underlining that this area is also the basis of a new theory of digital filters intended for filtering the periods of pulse signals, refs. [1, 2, 3]. The rest of articles and books in the references, are used as the theoretical base for the different fields.

SYSTEM DESCRIPTION

Let us consider Fig. 1, which represents a general case of the input and output signals Sin and Sop of TPLL. Because of simplicity, all discrete times in brackets are changed with the

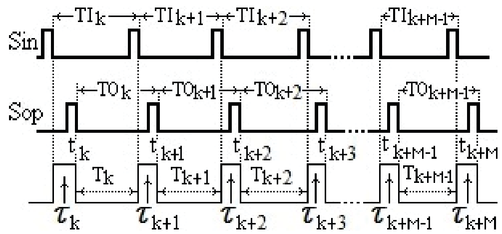

Fig. 1. *The time relations between the input and output variables of TPLL.*

corresponding index in Fig. 1, for instance instead of $TO(k+M)$, TO_{k+M} is used. In comparison to the classical PLL and FLL, the input and output frequencies are changed by the input and output periods in Fig. 1, and the phase differences are changed by the time differences, just like in refs. [1-13]. The periods TI_k and TO_k, as well as τ_k and T_k occur at discrete times t_k, t_{k+1}, t_{k+2},…t_{k+M-1}, t_{k+M}, which are defined by the falling edges of the pulses of Sop in Fig. 1. Note that TI_k, TO_k, τ_k and T_k are distributed in time in Fig 1, so that every input period overlaps with the output period of the same order. Due to this distribution in time and overlapping, in the real time applications, an output period TO_{k+M} can be calculated only using the previous $TI_k...TI_{k+M-1}$, $TO_k...TO_{k+M-1}$, $\tau_k...\tau_{k+M-1}$ and $T_k...T_{k+M-1}$, as presented in eq. (1).

$$TO(k+M) = \sum_{i=1}^{M} b_i \cdot TI(k+M-i) + \sum_{i=1}^{M} a_i \cdot TO(k+M-i) + \sum_{i=1}^{M} c_i \cdot \tau(k+M-i) + \sum_{i=1}^{M} d_i \cdot T(k+M-i) \quad (1)$$

It comes out from eq. (1), that there are "M" system parameters $b_1, b_2... b_M$, "M" system parameters $c_1, c_2... c_M$, "M" system parameters $d_1, d_2... d_M$ and “M+1” system parameters $a_0, a_1, a_2... a_M$, where $a_0=1$. If we wont to complete the calculation of TO_{k+M} with all system parameters, it is necessary "M" input periods. Equation (1), corresponding to Fig. 1, uses the maximum number of system parameters for M input periods, what makes it look very complicated. But in practice, we can choose only some of the parameters or we can completely omit some of variables from the basic algorithm in order to obtain the desired function and/or easier implementation. The best examples for the simplification of the basic algorithm in practice are just shown in refs. [1 to 13], in which very simple systems of the lower order were able to perform the required electronically functions.

In addition to eq. (1), we can notice the natural relations between the variables in Fig. 1, expressed by eqs. (2) and (3). Note that τ_{k+1} is a function of TO_k. T_k is also indirectly a function of TO_k. This means that using any of τ_k, T_k or TO_k in eq. (1), system gets feedback, which plays very important role in the applications of TPLL.

$$\tau_{k+1} = \tau_k + TO_k - TI_k \quad (2)$$

$$T_k = TI_k - \tau_k \quad (3)$$

REALIZATION OF TPLL

Papers [1 to 13] describe electronic modules that perform the necessary measurements, calculations and output period generation. The approaches described are similar, but the modules for calculating the period, differ to some extent because they depend on the chosen algorithm.

Fig. 2 shows the input and output signals Sin and Sop from ref. [4]. The second order TPLL tries to equalize the output period with the input period, but due to the low clock frequency, it is unable to do so. The clock frequency f_c was chosen intentionally to be low, so that the functioning of TPLL becomes visible. Positive and negative time differences, for the stable system, denoted by $\tau_{\infty+}$ and $\tau_{\infty-}$. alternate with each other at each step in Fig. 2.

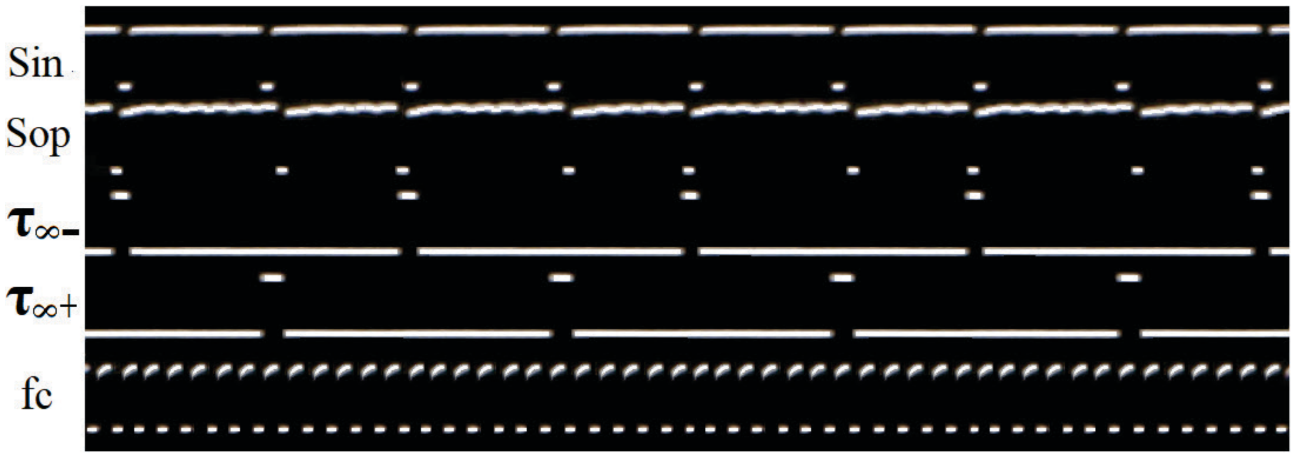

Fig. 2. *Voltage waveforms taken on the realized TPLL.*

PRESENTATION OF SOME ADDITIONAL TPLL APPLICATIONS

Using the presented general mathematical description of the system, for each of the TPLL applications in references [1 to 13] it was necessary to select the basic algorithm for calculating TO_k, to define the input period TI_k and to perform Z transformations of the selected equations. After that it was necessary to determine Z transformation of all output variables depending on the input period as well as the transfer functions of the output variables used. With the help of computer simulation in time domain and theory of linear discrete systems, analyzes of the transient and stable states of the chosen system were performed for the different system parameters. The result of all practical realizations agreed with the simulations and mathematical analyses. The illustrations of some additional applications are following.

Fig. 3 shows the input and output signals Sin and Sop for the circuit in ref. [5]. Signal Sin_d is generated by multivibrators using Sin. The circuit averages the periods of Sin_d, multiplying the frequency of Sin by two, at the same time.

Fig. 3. *Voltage waveforms taken on the realized circuit.*

Fig. 4 shows the input and output signals Sin and Sop and clock CL_c for the circuit described in ref. [5]. The circuit is realized by the professional software package for electronic circuits "Multisim". The circuit generates uniform periods of Sop, whose frequency is equal to the average frequency of Sin.

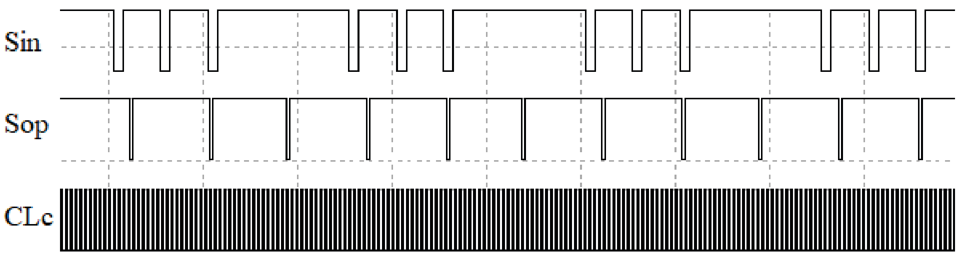

Fig. 4. *The average frequency of Sin is 1 kHz. The frequency of CL_c is 16 kHz.*

A simple version of the second order TFLL is described in ref. [6]. The tracking ability of TFLL is presented in Fig. 5. The input period changes linearly with time. For the different values of system parameters, three output periods TO_1, TO_2 and TO_3 track the input with different transition times. All details are given in ref. [6].

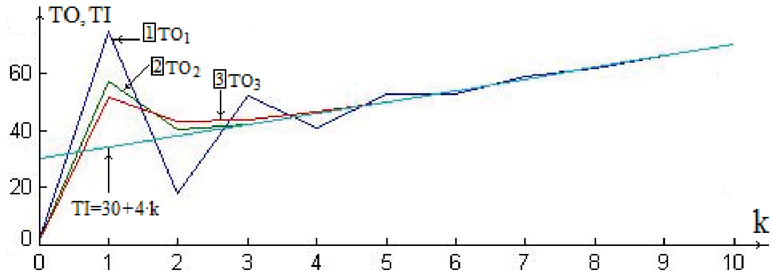

Fig. 5. *The output periods TO_1, TO_2 and TO_3 track the input period.*

The first order TFLL is described in ref. [7]. The circuit suppression ability for uniformed distributed noise is presented in Fig. 6. For the given noisy input TI, TFLL generates the output periods TO_1, TO_2 and TO_3 with the different intensity of noise suppressions, depending on the system parameters. All details are given in ref. [7].

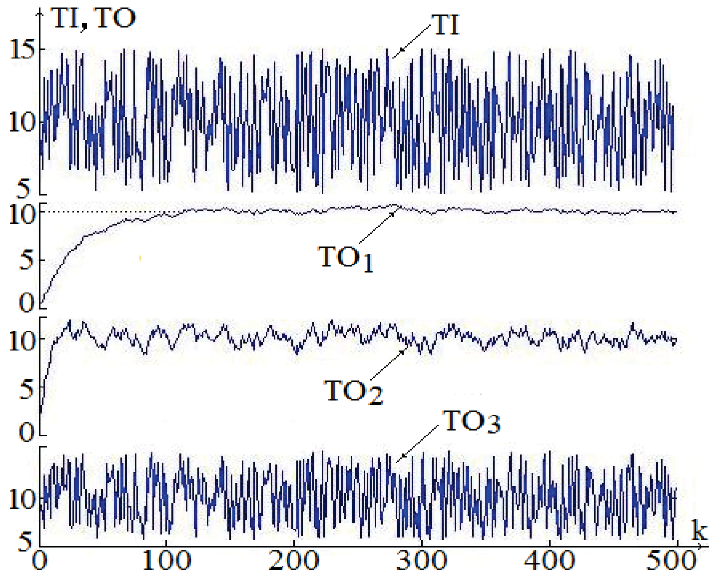

Fig. 6. *The noise suppression at the outputs depends on the system parameters.*

A digital IIR filter of periods, based on TPLL of the third order, is described in ref. [3]. The cutoff frequency of this Butterworth low pass filter is f_g=2000 Hz. The input period of Sin is modulated with two sinusoidal signals of frequencies 1000 Hz and 4000 Hz. Covering the whole sample rate, Fig. 7 shows the spectrums of the input and output signals Sin and Sop. In the spectrum of Sop, the component of 4000 Hz is suppressed, since 4000 Hz belongs to the stop band of the filter. All details are given in ref. [3].

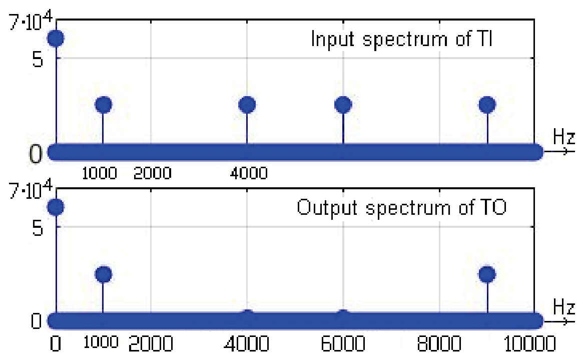

Fig. 7. *The input and output spectrums of TI and TO.*

CONCLUSION

Processing of periods and time intervals of impulse signals represents a new approach which, according to the illustrations shown, has a wide range of influences in the fields of electronics, telecommunications, measurement and control, but also in other fields in which electronics are used. Measuring time as the basic source of information in systems of this type, provides great accuracy and simple solutions. These systems do not require A/D and D/A converters either for connection to the outside world or for filtering purposes. These systems, with the appropriate choice of parameters, have the filter characteristics, either of FIR or IIR digital filters.

The realization of these systems by digital integrated circuits may be acceptable only for the systems of the first order and for the simple systems of the second order. Much more convenient is to use a microprocessor because of numerous calculations.

There are several next logical steps for further development of this area, such as the development of higher order systems, the development of digital filters of this type, finding additional approaches to analyze these systems in the frequency domain and the others.

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