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New Approach to Generate Second Signal

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Abstract

A phase coincidence phenomenon between two arbitrary frequency signals is a periodic phenomenon. One application of this phenomenon is a new method to generate a stable time signal. Using two frequency signals with a certain frequency difference and a phase coincidence detection circuit to detect the phase coincidence signal of them, one can get a periodic coincidence signal. And then moving the phases of the two frequency signals properly, one can get a coincidence signal synchronizing with a standard time signal. The advantage of the new method is the second signal generated by it is easy to transmit and comparison with high resolution.

***Keywords**: phase coincidence points, second signal, two arbitrary frequency signals*

1. Introduction

In practice, a second signal is always obtained from frequency standard signals by a frequency division method. In time transfer process, second signal must be modulated at the time transmitting terminal, and be demodulated at the user terminal [1]. Now, time service is playing a more and more important role, and the requirement for the precision is higher and higher. It will be meaningful if we can design new method to generate second signal to meet the need of high precision time service. It is hard to obtain time information from a single frequency signal directly, but it is possible to get it from two frequency signals. For example, the phase difference between two periodic frequency signals is a function of time and their phase coincidence points can be used as standard time signal. The new time signal generation method was thought to have two advantages: the first, the time signal need not to be modulated during transfering. It eliminates the influence of the modulation and demodulation radically. Secondly, it has the advantage of comparing between two time signals. By the use of phase compare instead of time compare, we can improve the precision and decrease the cost.

2. Phase Characteristics between Two Frequency Signals

To two frequency signals f_1 and f_2, if $f_1 = Af_0, f_2 = Bf_0$, and the two positive integers A and B are prime with each other, then f_0 is the greatest common frequency between f_1 and f_2. Its period T_{minc} is equal to the multiples of the period of f_1 and f_2. Take the waveforms shown in Figure 1 as an example. By comparing the rising edge of f_1 and f_2 in a T_{minc} period we can find the relative phase difference can be shown as follows:

$$T_1^{'} = n_1 T_1 - T_2$$

$$T_2^{'} = n_2 T_1 - 2T_2 \quad (1)$$

$$T_B{}' = AT_1 - BT_2$$

where T_1' 、 T_2' 、 …… T_B' express the phase difference between f_1 and the reference signal f_2 to every special phase point, shown as the width of impulses in the third waveform. They are all positive and $(n_X - 1)T_1 < XT_2$, where n_1、 n_2、 ……A and X are positive integers. In the equation 1, to any equation

$$T_X{}' = n_X T_1 - XT_2 ,$$

As

$$f_1 = A \cdot f_{\max c} , \quad f_2 = B \cdot f_{maxc} \tag{2}$$

that is
$$T_1 = \frac{T_{\min c}}{A} , \quad T_2 = \frac{T_{minc}}{B} \tag{3}$$

so we can get

$$\begin{aligned} T_X' &= n_X T_1 - XT_2 = \frac{n_X B - AX}{A \cdot B} T_{\min c} \\ &= \frac{B \cdot n_X - A \cdot X}{B} T_1 \end{aligned} \tag{4}$$

where n_1、 n_2、 ……A and X are positive integers, and $T_X{}' \geq 0$, so $Bn_X - AX$ must be a positive integer or zero. And the equation 1 can also be expressed as follows:

$$T_1' = \frac{Y_1}{B} \cdot T_1 , T_2' = \frac{Y_2}{B} \cdot T_1 ,\ldots T_B{}' = \frac{Y_B}{B} . T_1 \tag{5}$$

where Y_1、 $Y_2 \ldots Y_B$ can be positive integers or zero。 Because of

$$0 \leq T_X{}' \leq T_1 \tag{6}$$

and T_1' 、 T_2' 、 …… T_B' can not be equal to each other in a T_{minc} period, so Y_1 、 $Y_2 \ldots\ldots Y_B$ must be positive integers which are not equal to each other and less than B, that is Y must be 0、1、2、…… $B-1$, so the change between two adjacent phase difference must be

$$\Delta T = \frac{1}{B} T_1 \tag{7}$$

By further analysis we can know in a T_{minc} period, there are some values between the quantitative phase difference of two signals, which equal to the initial difference add 0, ΔT, $2\Delta T$, …,during these points, we define the point which has the minimum phase difference as the phase coincidence point of two signals. From equation 3 and 7 we can obtain equation 8 shown as follow:

$$\Delta T = \frac{T_1}{B} = \frac{f_{\max c}}{f_1 \cdot f_2} \tag{8}$$

It shows that to two signals, the changes of the phase difference is certain. The two diffrrent frequency signals has a phase coincidence point in a T_{minc} period, the period of this point appears is equal to the period corresponding to the greatest common frequency $f_{\max c}$.Generally , the period corresponding to $f_{\max c}$ is much larger than any one of the two signals. By the use of high precision frequency source, we can obtain the two frequency signals. By choosing the proper frequencies and adjusting their phase coincidence points to the time signal, then by testing the phase coincidence points we can get the time information.

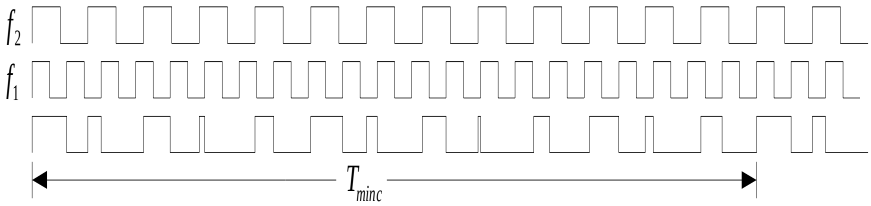

Figure 1. The Phase Relationship between Two Frequency Signals

3. Experiment

Two experiments have been completed to test this method: the first one was to make the phase coincidence points move in a T_{minc} period by shifting the phase of one of the two frequency signals. The result is that 0 to 360 degreed phase shift of one of them causes the phase coincidence move in a T_{minc} period, but it is a discrete movement. When the phase of the two signals were shifted synchronously, the phase coincidence points would be moved in T_{minc} continuously and the moving range was T_{minc} .The result was consistent with the analysis.

Another experiment was to test the stability and accuracy of the phase coincidence points. The content is showed below. A 10MHz signal and a 10.0001MHz were chosen in the experiment. Then the f_{maxc} is 100Hz and the phase coincidence period is 0.01s. From formula 7 we can get the quantization phase shift resolution which is 1ps. It's good enough to be used as stable time signal. The experiment diagram is shown in Figure 2. A Cesium clock 5585B, a frequency synthesizer HP8662 and a time interval measuring instrument SR620 were used in the experiment. First we compare the phase coincidence points with the second signal which was obtained by frequency division method. From this we can get the information of the phase coincidence points which were referred to the 1pps output from the 5585b. The measurement results are shown in Table 1. In order to get the stability and accuracy information of the phase coincidence points, this type of data process method was adopted: First, subtract the second number from the first ,the third from the second, and so on, subtract the first from the last; second, subtract times of 100ns from every data available until there is a data between 0ns and 100ns. The results are shown as Table 2.

The reason why we use the above data process method is as follow: In theory there is only one phase coincidence point in a T_{minc} period. But the device used in the experiment is not perfect so that there are more than one phase coincidence points in a T_{minc} period, which also means there are outputs when the two signals are not coincident absolutely. If the stop signal triggering the time interval measurement instrument is not the most perfect one, the time signal available will have an error as much as times of 100ns, 100ns is the period of 10MHz. Because both 10MHz and 10.0001MHz signals are come from an atomic frequency standard, the least common multiple period is very accuracy. We can believe if the difference between the two results is more than 100ns, it is result from the stop signal which is not the perfect phase coincidence. The error can be erased by soft process or using of an advanced circuit.

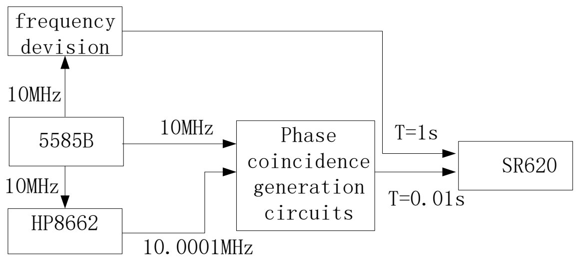

Figure 2. Experiment Diagram to Test the Stability and Accuracy of the Phase Coincidence

Table 1. Information of the Phase Coincidence Points before Processing

NO.	results（s）	NO.	results（s）
1	0.006649228814	9	0.006649428771
2	0.006649328837	10	0.006649428790
3	0.006649328818	11	0.006649228833
4	0.006649428775	12	0.006649328814
5	0.006649328824	13	0.006649328725
6	0.006649528878	14	0.006649328827
7	0.006649528717	15	0.006649528723
8	0.006649428821	16	0.006649528826

The maximum data after the process above is 161 ps, this means in the experiment the maximum instability of the standard time signal generated by the phase coincidence points of two frequency signals. But the 161ps contains all the errors, such as the frequency instability of the two frequency signals, the random noise of the circuit, the error of the measurement instrument, and so on. For example, when SR620 is used to measure an time interval, the value of the trigger voltage will have an effect as much as100ps[6]. At present, time service can get the accuracy about several nanosecond degree and 161ps is about one fifths of it so it can be ignored. In other words, this time signal obtained by this way can meet the need of high precision time service. Second, the 1pps output of 5585B was measured using the SR620. The 1pps output of the 5585B is obtained by frequency division method, and study shows the highest instability of it is 25ps. In the results shown in table 2, we can find some are better than it and some worse. The 1pps output of 5585B is very good and it can provide a more stable trigger voltage for SR620.

Through analysis and comparison, we find that the time signal obtained from the previous experiment can meet the request of the high accuracy time service, and that an advanced circuit can obtain a more stable time signal. The result of the experiment is filled with the previous theory analysis The accuracy and stability of phase coincidence points resulted by the two frequency signals are rather good and they can form a standard time signal.

Table 2. Information of the Phase Coincidence Points After Processing

first processing (s)	second processing (ps)	first processing (s)	second processing (ps)
0.000000100023	23	0.000000000019	19
0.000000000019	19	0.000000200043	43
0.000000100057	57	0.000000100019	19
0.000000100051	51	0.000000000089	89
0.000000200054	54	0.000000000102	102
0.000000000161	161	0.000000200104	104
0.000000100104	104	0.000000000103	103
0.000000000050	50	0.000000300012	12

4. Conclusions

The paper explains the feasibility of using the phase coincidence points of two frequency signals as a standard time signal. The precision, stability of the signal and the advantages of the new method are analyzed. The result is that the time signal obtained by this way can meet the need of high precision time service. At present more and more industry need higher precision time service. It is necessary to research the method and the next work is to improve the phase coincidence points testing circuit and develop a phase comparator.

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