Design of High-Precision Frequency Measure System Based on CPLD Time Delay Unit

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Abstract. Introduced a method for high-precision frequency measurement, which do not need the complicated measuring control circumstance. CPLD is used for improving the precision of measurement by the method of quantization time-delay. High precision frequency adjustable module based on the method has been used on the photoelectricity data acquisition system. Frequency accuracy is $-8.306 \times 10^{-10}$, which meet the requirement of instrument.

1. Introduction

The measurement of frequency is actually the measurement of the time intervals. Direct count method [1], which using the quantity of known frequency, is the common way. The desynchronization of the rising edge of measuring frequency and the under test frequency may lead to $\pm 1$ pulse error. We can increase the frequency to avoid the problem. However, in most situations, clock frequency cannot change. How to get the high precision in the situation of stable clock frequency is a desiderate problem.

The appear of quantization time-delay [2-5] make it possible. We use it to design a high-precision frequency measure System Based on GPS second pulse, which is low cost and power consumption, without traditional complex frequency measure system. It meets the demand of high-precision frequency.

![FIG.1 the phase of reference frequency and related frequency](image)

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In frequency measuring, such as GPS second pulse signal, phase equality and high precision of the under test frequency and basic frequency are most important. The core element is enhancing the resolution of the time interval. In direct counting method, 10Mhz Frequency can only lead to the measurement resolution of 10ns. Increasing or doubling the base frequency of the crystal oscillator, increases the resolution by a very limited level, it also increases the cost. Therefore, if we use the method of quantization time-delay, which is related with gate signal time and frequency of the basic signal, and is unconcerned with the resolution and frequency of the under test signal [6-8]. Such as FIG1, We can measure time interval $\Delta t_1$ and $\Delta t_2$ in order to improve the resolution without change the basic frequency.

Make use stability of signal delay, we can measure $\Delta t_1$ and $\Delta t_2$ qualitative the signal delay. The principle can explain below: let the signal pass by some delay unit, record the situation of the delay unit and calculate the relative difference of the frequency based on the basic frequency, then adjust the VCO sensitivity. Such as FIG1, $T_G=NT_m+\Delta t_1-\Delta t_2$, $T_G$ is ideal gate signal. If we can measure the time interval $\Delta t_1$ and $\Delta t_2$, we can get $T_G$ Accurate. Device of delay unit can use passive conductors, gate device or other way [9]. The delay time of conductor is too short and may cause complex circuit. The delay time of gate device is too long to control. In general, we choose LCELL logic unit in Complex Programmable Logic Device (CPLD) as delay unit [10], which can reduce conductor disturb, make system stable and simple.

2. Material and methods
In real design, using VCXO to generate 16.384M frequency standard, using GPS module Navman JUPITER 21 to generate standard second pulse, using MCU PIC18F452 control GPS module and adjust D/A device feedback voltage, which achieve using GPS second pulse lock high stable VXCO, and get adjusted second pulse output with long term stability.

![FIG.2 Functional block diagram of the high precision of measurement by the method of quantization time-delay based on CPLD](image)
bus will be locked at the raise edge of the clock frequency. $\Delta t_1$ can be measured by the quantity of LCELL which changed from 0 to 1, we also can measure $\Delta t_2$ by the quantity of LCELL which changed from 1 to 0. The key lock module is programmed by verilog HDL as below:

```
module lock(s1,clk,sin,sout);
input s1,clk;
input[31:0] sin;//delay pulse input
output[31:0] sout;//lock signal output
reg flag=0;/*first pulse flag, flag=0 and S1=1 show the first pulse coming in*/
reg[31:0] sout;
always @(posedge clk):
    if(s1)
        begin
            if(flag= =0)
                begin
                    sout<=sin;//now input the value of time delay
                    flag<=1;
                end
            else  //s1=1, not first pulse
                flag<=1;
        end
    else //s1=0,stop count, reset flag
        flag<=0;
```

The acquisition quantity LCELLs of $\Delta t_1$ and $\Delta t_2$ counted by CPLD transmit in MCU serial port. According to the change of $\Delta t_1$ and $\Delta t_2$. We use The Kalman Filter Algorithm[12-13], which principle is minimum mean square error and using the previous estimate value and last observed value to correct standard value[14], deducing with state equation and recurrence method and reducing error by filtering the time difference. Standard frequency and GPS second pulse will output after adjusting D/A output.

3. Results & Discussion
The frequency correction system can adjust frequency accuracy to a higher resolution in 40 seconds when it correctly receive GPS second signal. Actual measurement may be disturbed by external
factors such as field or weather, so the stability is decreased. Table 1 shows measured value of the crystal oscillator after correction. (Standard frequency is 16.384Mhz)

| Time  | Frequency  | Time  | Frequency  |
|-------|------------|-------|------------|
| (h:m:s) | (Hz)        | (h:m:s) | (Hz)        |
| 11:00:10 | 16383999.8772 | 11:00:15 | 16384000.1072 |
| 11:00:11 | 16383999.8792 | 11:00:16 | 16384000.1037 |
| 11:00:12 | 16383999.8766 | 11:00:17 | 16384000.0881 |
| 11:00:13 | 16383999.8875 | 11:00:18 | 16384000.0787 |
| 11:00:14 | 16383999.8873 | 11:00:19 | 16384000.0684 |

Table 1 Measured value of the corrected crystal oscillator

We can calculate the accuracy of the frequency is \(-0.8306\times10^{-9}\)[15]. It’s better than the initial frequency accuracy, which value is \(-4.963\times10^{-8}\). After being multiple tested, the system can reach \(10^{-10}\) degree of accuracy in 5 minutes.

4. Conclusion

The method can enhance measurement accuracy without having to increase manufacturing cost and power consumption. Now it has worked well in the circuit of sampling photoelectricity system.

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