Design and Implementation of Self-tracking 90 Degrees Phase Shift Circuit

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ABSTRACT

Based on the linear phase shift of Bessel filter and the frequency doubling function of phase-locked loop, the new structure of 90 degrees phase shift circuit is proposed. The input signal is amplified and shaped into digital signal, and the clock of switched capacitor filter MAX296 is generated by the phase-locked loop. It can control the ratio between clock and input signal frequency of the filter. So when sinusoidal signal is as input of the filter, in a wide frequency range of from 20Hz to 1kHz, the 90 degrees phase shift can be achieved at the output of the filter. The working principle of the system is described, and the design circuit and experimental results are given.

INTRODUCTION

In many applications, such as signal analysis and signal detection, an quadrature signal is needed, and the input signal generates quadrature signals by 90 degrees phase shifting [1-3]. If the input signal frequency is fixed, the phase shift 90 degrees can be achieved by adjusting the parameters of the RC circuit [4-5]. The disadvantage is that the parameter value of the component should be adjusted manually, and the error of the component parameters leads the obvious phase shift error. When the signal frequency changes in a certain frequency range, 90 degrees of phase shift will be produced, through the all-pass filter and the auxiliary circuit to achieve [6]. But it has slower tracking speed and larger error. Using Hilbert...
transform to produce 90 degree phase-shift \[7\], its disadvantage is that the circuit is more complex, and the accuracy is not too high.

In this paper, a new method is proposed, which uses digital phase-locked loop (PLL) and switched capacitor filter (SCF) to realize phase shift of 90 degrees in a wide frequency range. The circuit is simple and the phase shift precision is higher.

**SYSTEM COMPOSITION AND WORKING PRINCIPLE**

The Figure 1 is block diagram of the system, the input signal is converted into a digital signal by the input section circuit, and through the PLL frequency circuit it produces a clock of SCF. It controls the ratio of the clock and input signal frequency to obtain 90 degrees phase difference.

The phase shift of the output signal of the filter is linearly related to the input signal of the Bessel type filter. The SCF in Figure 1 uses MAX296, which is an 8th-order Bessel low-pass filter. Its phase response and amplitude response characteristics are shown in Figure 2. For example, the cutoff frequency of the filter should be certain, such as \( f_c = 1 \text{kHz} \). When the \( V_{\text{in}} \) frequency is also 1kHz, the output signal \( V_{\text{out}} \) phase shifted to 180 degrees. When the \( V_{\text{in}} \) frequency is 500Hz, the output signal phase is shifted to 90 degrees. But the output signal amplitude slightly decrease about 1dB, it can be compensated by the post-amplifier. Therefore, if the cut-off frequency of the filter is two times of the input signal frequency, then the phase shift of 90 degrees can be achieved. If the frequency of the input signal changes, the clock of the SCF can flow the change, the SCF can obtain a 90 degrees phase shift between the output signal and the input signal.

How it can realize the signal tracking, and keep 90 degrees of phase shift, because MAX296 is a clock-controlled SCF, and the cut-off frequency \( f_c \) of the filter is related to the clock \( f_{\text{clk}} \) [8]

\[
f_c = \frac{f_{\text{clk}}}{50}
\]

(1)

![Figure 1. Block diagram of the system.](image)
If the 90 degree phase shift will be achieved, it has \( f_c = 2 f_i \), therefore

\[
f_i = f_c / 2 = f_{\text{clk}} / 100 \tag{2}
\]

From formula (2), it can be obtained

\[
f_{\text{clk}} = 100 f_i \tag{3}
\]

Therefore, as long as the SCF clock and the input signal satisfy formula (3), the 90 degree phase shift can be realized in a larger frequency range.

CIRCUIT DESIGN

The input sinusoidal signal is first processed by the Schmidt circuit shown in Figure 3, and the digital signal \( f_i \) is the output. The signal \( f_i \) is added to the PLL frequency doubling circuit shown in Figure 4. The CD4046 is a monolithic PLL integrated circuit, and the CD4518 implements 100 counting functions. In the Figure 4 the output signal and the input signal relationship satisfy the formula (3).
Figure 5 is the circuit of MAX296 filter to achieve 90 degrees of phase shift circuit. $V_{\text{in}}$ is the input signal, and $V_{\text{out}}$ is the output signal. The clock is from the output of PLL in the Figure 4.

**EXPERIMENTAL SIMULATION**

The experimental results show the effectiveness of the proposed circuit. Operational amplifiers use OP07. When the input frequency changes from 20Hz to 1kHz, the phase shift between the input signal $V_{\text{in}}$ and the output signal $V_{\text{out}}$ is maintained at 90 degrees. Fig. 6 is the waveform of $V_{\text{in}}$ and $V_{\text{out}}$ with frequency of 50Hz and 1kHz respectively. The amplitude of output signals decrease about 1dB. It can be compensated by adding a post-amplifier.

![Waveform of $V_{\text{in}}$ and $V_{\text{out}}$ with frequency of 50Hz and 1kHz.](image)

**CONCLUSIONS**

The 90 degree phase shift circuit designed in this paper has simple circuit structure, and realizes the frequency automatic tracking function by the digital phase-locked loop. That is when the frequency of the signal changes, the ratio of the SCF clock to the input signal frequency can be kept unchanged. Therefore, the
stationary phase shift can be achieved. The circuit is suitable for low frequency signal processing and detection occasions.

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