

The Circuit Design of Voltage Controlled Phase-Shift for Sinusoidal Voltage Waveform

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Abstract

This paper proposes the two-output voltage controlled phase shift circuit design using MATLAB/SIMULINK. Analog Circuits consist of the input reference voltage and DC voltage controller for adjusted phase shift output voltage. These output voltage can be adjusted phase shift voltage angle as lagging and leading when compare with the reference voltage. Furthermore, the proposed analog circuit method can support under variations of input reference voltage from 1 to 10 peak voltage and 10 to 100 Hertz. The validity of this proposed method is verified by calculation and simulation results.

Keywords: circuit design, voltage control, phase shift voltage

1 Introduction

The simple circuits for phase shift voltage are established from resistor, capacitor and inductor as show in Fig.1. The circuit in Fig.1 describes the basically of phase shift voltage by R-C load as a result phase shift angle has occurred between V_s and V_c as shown in Fig.1 (b).[1]

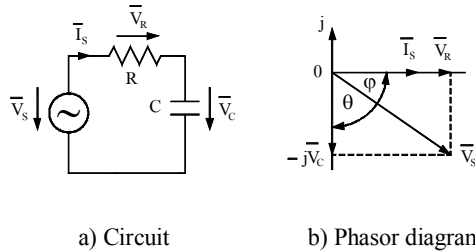


Fig.1 R-C series circuit

When V_c is assumed as the output voltage. The magnitude and the phase shift angle can be expressed as follows.

$$V_c = \frac{V_s(1/\omega C)}{\sqrt{R^2 + (1/\omega C)^2}} \quad (1)$$

$$\theta = \tan^{-1}(-V_R/V_c) \text{ and } \theta = \tan^{-1}(-\omega RC) \quad (2)$$

From equations (1) and (2), the angular velocity (ω) of the capacitor voltage (V_c) has fixed, the capacitor voltage magnitude will be changed by supply voltage (V_s) value, while the phase angle (θ) is constant. On the other hand, if ω is changed, both capacitor voltage magnitude and phase angle will be changed too.

Fig.2 shows the RC network which connected with Op-Amp circuit, output voltage lags input voltage for all pass of waveform [2]. When $R_1 = R_2$ the phase angle of the output voltage can be calculated by

$$\theta = -2\tan^{-1}(\omega C_1 R_3) \quad (3)$$

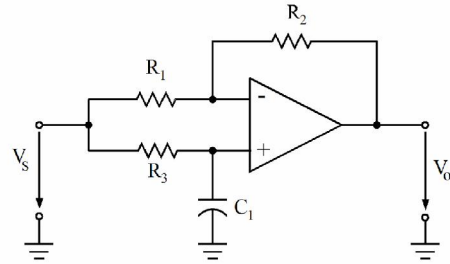


Fig.2 All pass phase lag shifting circuit

From Fig.2 and equation (3), the phase angle of output voltage can be shifted in the range of 0° to 180° depend on the frequency of input voltage, C_1 and R_3 .

The circuits shown in Fig.1 and Fig.2 are not comfortable to employ in the automatic control system because the phase angle can be made by changing the passive device value. This phase angle changing unable controlled by electrical signal.

2 The proposed of voltage control phase shifter circuit

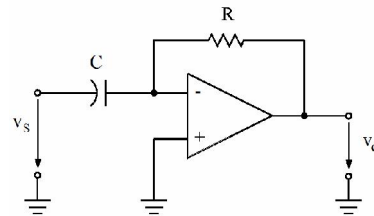


Fig.3 Differentiator circuit

Differentiator circuit for phase shifter consideration shows in Fig.3. The equation of supply voltage is $V_m \sin \omega t$. Therefore output voltage of differentiator circuit can be expressed as

$$v_d(t) = -\omega RC \cdot V_m \cos \omega t \quad (4)$$

The output voltage in equation (4) shows the relationship between input voltage and output voltage magnitude. Namely, phase shift angle of output voltage can be shifted about 90° all

the time, while the output voltage results depend on the peak voltage and the frequency of input voltage and value of R-C passive elements.

Fig.4 shows the block diagram of the voltage control phase shifter for sinusoidal voltage waveform.

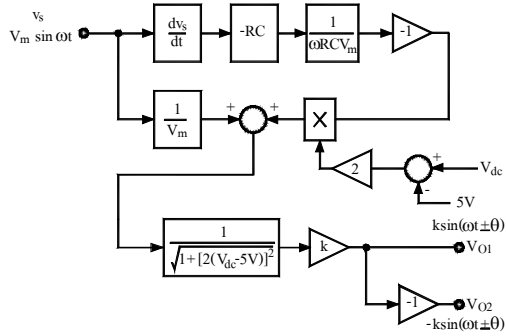


Fig.4 Proposed block diagram of the voltage control phase shifter for sinusoidal voltage waveform.

From block diagram in Fig.4, output voltage in the instantaneous value can be expressed as follows.

$$v_{O1}(t) = k \sin(\omega t + \tan^{-1}[2(V_{dc} - 5V)]) | k \neq 0 \quad (5)$$

As shown in equation (5) the phase angle of output voltage will be shifted by setting V_{dc} . If the V_{dc} is varied range from 5V as 0 Volt and 10Volts respectively, the phase angle will be shifted in the range of $0^\circ \pm 84^\circ$ for output V_{O1} and $180^\circ \pm 84^\circ$ for output V_{O2}

3. Simulation results

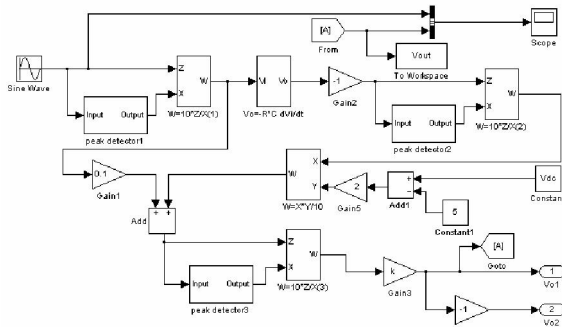


Fig.5 the SIMULINK model base on MATLAB

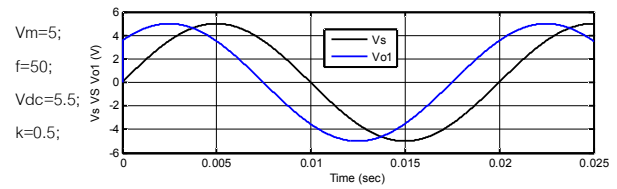
For the simulation results, MATLAB/SIMULINK has been used for validity of this proposed method by SIMULINK block set diagrams in fig. 5 referred from the proposed block diagram of the voltage control phase shifter for sinusoidal voltage waveform in fig. 4[3]. Output voltage equation can be defined as

$$v_{O1}(t) = k \times 10 \sin(\omega t + \tan^{-1}[2(V_{dc} - 5V)]) | k \neq 0 \quad (6)$$

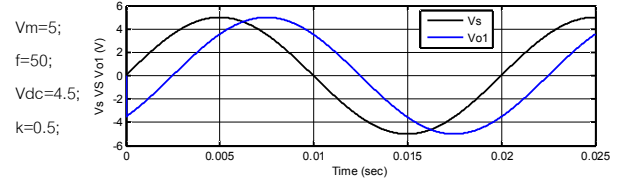
$$\text{When } \theta = \tan^{-1}[2(V_{dc} - 5V)]$$

The simulation results are separated as 2 conditions as follows.

4.1 Case 1: V_m, f, k are fixed and V_{dc} is varied



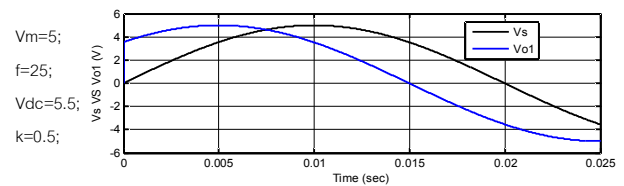
(a) V_{O1} leads V_s by 45° at 5.5 Vdc



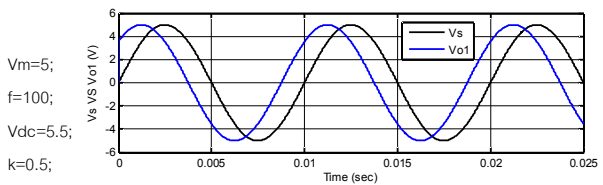
(b) V_{O1} lags V_s by 45° at 4.5 Vdc

Fig.6 Behaviors of V_{O1} and V_s for case 1

4.2 Case 2: V_m, k, V_{dc} are fixed and f is varied



(a) V_{O1} lead V_s 45° when $f = 25\text{Hz}$



(b) V_{O1} leading V_s 45° when $f = 100\text{Hz}$

Fig.7 phase shift response when frequency is varied

4. Conclusion

In the paper, the simulation results are divided into two conditions. For the case 1, the phase shift of output voltage can be controlled as lagging or leading depending on the DC voltage value adjusted from 0 – 10V. When the DC voltage is defined as 5V to 10V, phase shift output voltage of V_{O1} is increased from 0 to 84 degrees leading. Otherwise, if the DC voltage is defined as 5V to 0V phase shift output voltage of V_{O1} is decreased from 0 to -84 degrees lagging. For the case 2, if the frequency of input voltage is changed, phase shift output voltage will be fixed. The proposed circuit design has many benefits for application with automation control, grid connected converter and so on

References

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- [3] The Math Works Inc., "Simulink Dynamic System Simulation for MATLAB", 1999