Design of signal conditioning circuit at the output end of signal source based on AD9954

Lei Yang
International Studies College, National University of Defense Technology, Nanjing, Jiangsu, 210039, China
*Corresponding author’s e-mail: 2997026629@qq.com

Abstract. The signal source based on DDS technology has the characteristics of high precision and high resolution, and is widely used in precision testing, instrumentation and other fields. However, interference signals such as high frequency harmonics and noise will inevitably appear in the output signal of the DDS chip, and even the sinusoidal signal generated by the DDS will be completely covered. This article takes ADI’s 14-bit high-precision DDS chip AD9954 as an example. I/V conversion and elliptic filter circuits are added to the output of the chip to obtain a pure sinusoidal signal. The rationality of the design is verified by multisim simulation software. This circuit provides strong support for the design and implementation of high-precision signal sources based on DDS.

1. Introduction
With the rapid development of science and technology, various fields (especially precision detection, precision instrumentation, remote sensing measurement and control, etc.) have higher and higher performance requirements for signal sources[1]. The emergence of direct digital frequency synthesis (DDS) technology has greatly improved the performance of signal sources[2]. Compared with traditional frequency synthesis technology, DDS technology has higher resolution, wider signal frequency band and faster frequency switching speed. ADI’s DDS chip has stable performance and high integration, occupying the largest market share. This text takes ADI's 14-bit DDS chip AD9954 as an example to design a signal conditioning circuit at the output of the DDS chip.

2. Signal conditioning circuit design
AD9954 chip adopts advanced technology to integrate 14-bit DAC, has 400M/s internal clock speed and excellent dynamic performance. In addition, AD9954 is small in size and consumes only 200mW. Compared with other chips, it has significant advantages and is widely used in radar and scanning. High-precision fields such as systems, test and measurement, and precision instruments. The pin connection of AD9954 is shown as in Figure 1.
Figure 1. AD9954 chip pin connection diagram.

According to the AD9954 chip manual, its input signal is a differential current signal, and it is very weak, with a maximum of only 10mA, which is difficult to transmit directly. In this design, the output current signal is converted into a voltage signal (I/V conversion) and amplified to facilitate signal transmission. In order to filter out high-frequency harmonic interference, a 7-order elliptic function filter is added for filtering. The signal conditioning circuit is shown in Figure 2.

Figure 2. AD9954 signal conditioning circuit.

In this design, the output current signals I1 and I2 of the AD9954 are pulled up to the reference voltage (AVDD) through resistors to achieve I/V conversion. Assuming that the pull-up resistor value is R and the reference voltage is V, then:

$$U_1 = V - I_1 \cdot R \quad (1)$$

$$U_2 = V - I_2 \cdot R \quad (2)$$
After I/V conversion, I1 current signal becomes a voltage signal with an amplitude of I1·R. In order to filter out the interference of high-frequency harmonics (usually more than tens of megabytes) in the signal, a 7-order elliptic function filter with a cut-off frequency of 1MHz is designed in this paper. The basic model of the seventh-order elliptic function filter is shown in Figure 3[3]. R1 is the characteristic impedance. In order to ensure that the circuit has sufficient load carrying capacity, R1 should be as large as possible, but the value of the characteristic impedance also directly affects the value of the capacitance and inductance[4]. When choosing the size of the characteristic impedance, it is necessary to consider common capacitors on the market. The range of size and inductance. The characteristic impedance selected in this design is 390Ω.

![Figure 3. Basic model of seventh-order elliptic function filter.](image)

According to the characteristic impedance and cut-off frequency, the parameter values of each element of the seventh-order elliptic function filter are obtained by the normalization method, as shown in Table 1.

| X1/pF  | X2/pF  | X3/μH  | X4/pF  | X5/pF  | X6/μH  | X7/pF  | X8/μH  | X9/μH  | X10/pF |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 276.44 | 299.05 | 48.54  | 683.33 | 42.88  | 92.00  | 727.56 | 173.76 | 61.43  | 346.38 |

In practical applications, it is difficult to obtain such precise values for capacitance and inductance, and only capacitors and inductance components that are close to the values in Table 1 can be selected, as shown in Figure 2. In Figure 2, the OPA2134 amplifier chip is added to the end of the elliptical filter, and the reverse input end of the amplifier is directly connected to the output end to form a voltage follower, which has the characteristics of high input impedance and low output impedance, avoiding the back-end circuit Impact on AD9954 chip and filter circuit.

3. Simulation Analysis of Signal Conditioning Circuit

In order to verify the rationality and effectiveness of the designed signal conditioning circuit, this paper simulates and analyzes the I/V conversion circuit and the elliptic function filter circuit based on the multisim software.

3.1. I/V conversion circuit simulation analysis

We set the AD9954 output full-scale current to 10mA. Since the pull-up resistor is 120Ω, according to formula (1), the output differential voltage amplitude should be 1.2V. The simulation result of I/V conversion circuit is shown as in Figure 4.
Figure 4. I/V conversion circuit simulation results.

According to Figure 4, the output voltage signal amplitude is:

\[ U_0 = \frac{(T_2 - T_1)}{2} = 1.1905\text{V} \tag{3} \]

It is approximately equal to the set 1.2V output voltage, which verifies the rationality of the designed circuit.

3.2. Simulation Analysis of Elliptic Function Filter Circuit

The simulated Bode plot of the elliptic function filter circuit is shown in Figure 5. It can be seen from the Bode plot that when the signal frequency is lower than 996.337KHz, the signal attenuation is less than 2.594dB, and the attenuation starts to accelerate when it is greater than 996.337KHz, which basically meets the design requirements.

Figure 5. Elliptic function filter circuit simulation Bode plot.

4. Conclusions

According to the characteristics of the output signal of the 14-bit high-precision DDS chip, this paper sets up the corresponding I/V conversion circuit, elliptic function filter circuit, and voltage follower circuit. The simulation results show that this circuit can convert the DDS output current signal into a
voltage signal, and effectively filter out high-frequency noise, and effectively improve the accuracy and resolution of the signal source output signal. This circuit design method also has certain reference significance for the circuit design of ordinary DDS chip.

References
[1] Zhang Bugao, Ma Xizhi. Design of signal source real-time display system based on AD9910[J]. Dianzi Jishu Yingyong, 2018, 44(8):
[2] Amir M. Sodagar, G. Roientan Lahiji, Ali Azarpeyvand. Reduced-Memory Direct Digital Frequency Synthesizer Using Parabolic Initial Guess[J]. Analog Integrated Circuits and Signal Processing, 2003, 34(2):
[3] Ki-Cheol Yoon, Seungyoung Ahn, Jong-Chul Lee. Elliptic function compact-size of the band-pass filter using complimentary MNZ metamaterial resonator[J]. Microwave and Optical Technology Letters, 2018, 60(12):
[4] Yang Yang, Ke Cao, Chong-Hu Cheng. Design of trisection bandpass filter based on elliptic-function filter[J]. Microwave and Optical Technology Letters, 2016, 58(8):