Research on DDS-based Portable Signal Generation Testing Device

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Abstract. The signal generator has a wide range of applications in the fields of communication, measurement and control, navigation, radar, and medical treatment. At present, most of the signal generators in the laboratory are purchased precision instruments, which are not only expensive, but also can not fully perform their functions, resulting in a waste of resources [1]. Based on the analysis of the working principle of the existing signal generator, this paper takes the programmable DDS integrated chip as the core, and designs a sine wave and square wave signal generator that is simple in structure, high in accuracy, small in size, and suitable for laboratory requirements. The precision and error analysis are carried out on it. The signal generator is composed of a power supply system, a single-chip computer system, a DDS waveform generation module, an amplitude adjustment module, a square wave generation module, and a relay output module. A multiplier is used to multiply the sine signal and the analog signal of the single-chip microcomputer to achieve the purpose of amplitude modulation of the waveform. Compared with the general signal source, the signal generator has the advantages of small output signal frequency error, high resolution, full digital realization, easy integration, small size, light weight, convenient use, stable work, etc.

1. Introduction
In scientific research, engineering education and production practice, the use of signal generators is very common. [1-7] Square wave and sine wave signal is a kind of signal with very wide application, usually as standard signal, used for performance test or parameter measurement of electronic circuit. In addition, many testers also need to use standard square wave signals and sine wave signals to detect some physical quantities. However, the commonly used signal generators generally have some shortcomings, such as expensive, fixed instrument and functional modes, and do not have the function of defining and programming the instrument by the user. In order to solve these problems, a square wave and sine wave signal generator is designed and implemented. It is small in size and flexible in use. It can generate square wave signals with adjustable frequency, pulse width and duration, and adjustable amplitude and frequency. High-precision sinusoidal signals can meet the requirements of various occasions. The introduction of microprocessors and high-precision DDS devices greatly improves the accuracy of the system.

The task of this subject is to design a simple-to-use and excellent performance experimental device for sine and square wave signal generation based on the characteristics and application of the signal generator, combined with a new generation of high-performance chips. The signal generating experimental device has the functions of frequency adjustment and amplitude adjustment. The whole system is controlled by a single-chip microcomputer, DDS chip as the core, equipped with
corresponding peripherals (including keyboard, liquid crystal, etc.) and interface circuits, and developed in C language to form a multifunctional signal generating experimental device. Perform precision and error analysis on the system.

2. The overall design scheme of the signal generating experimental device
The functional structure block diagram of this signal generating experimental device is shown in Figure 1, which is mainly composed of power supply system, single-chip microcomputer system, DDS waveform generation module, amplitude adjustment module, square wave generation module, relay output module and so on. In the power supply system, to provide several power supply voltages of 2.5V, 3.3V, ±5V, ±15V, it adopts +5V input, and obtains 2.5V and 3.3V power through a three-terminal integrated voltage regulator, and adopts a DC-DC integrated power supply module pair. The input voltage is converted to obtain ±5V and ±15V power supplies. DDS has the advantages of high frequency resolution, frequency conversion time, phase continuity, quadrature output, etc. [9]. This design uses this method and selects an integrated DDS chip for design, which simplifies the hardware, and improves the stability and output analog waveforms. the quality of. The single-chip microcomputer system is used for the operation control of the man-machine interface, realizes the keyboard reading and LCD display, adjusts the output sine wave amplitude, and programs the DDS device to generate the corresponding frequency signal, control the relay action, and perform the sine wave and square wave output Switch.

![Figure 1 Block diagram of the experimental device for signal generation based on DDS](image)

The DDS waveform generation module AD9833 is controlled by a single-chip microcomputer, with fast frequency switching and continuous phase. The output frequency and phase of AD9833 can be programmed by software, easy to adjust, the frequency register is 28 bits, when the main frequency clock is 25MHz, the accuracy is 0.1Hz, when the main frequency clock is 1MHz, the accuracy can reach 0.004Hz.

In the amplitude adjustment module, the multiplier chip MPY634 is used to multiply the sine waveform output by the AD9833 and the single-chip D/A output to achieve the purpose of amplitude modulation on the waveform. Pass a sine waveform of a certain amplitude through a hysteresis comparator to obtain a square wave output of the same frequency. Adjust the comparison voltage to output a rectangular wave with an adjustable duty cycle. The relay selects the corresponding waveform for output according to the button.

3. Circuit design of signal generating experimental device
3.1 The design of the sine wave generating circuit
The signal generation experimental device uses ADI's DDS chip AD9833, 25MHZ active crystal oscillator as the reference clock. With only one AD9833, accurate output of multiple waveforms can be
achieved, saving hardware circuits and costs. When the frequency and waveform need to be switched, it can be realized by programming the AD9833 directly with the microcontroller.

To achieve the function of sine wave amplitude modulation, you can adjust the magnification of the amplifier through the potentiometer, but it is required to display the amplitude of the signal. This solution must be sampled with A/D. This method has some problems: sampling at high frequencies. The signal peak requires high-speed A/D devices, and the method of collecting the effective value of the sinusoidal signal can also be used, but it is not suitable for use in low-frequency situations.

Therefore, the scheme adopted in this design is: according to the amplitude of the required sinusoidal signal input by the keyboard, make the microcontroller D/A output the corresponding DC signal, and input it into the multiplier to multiply the sinusoidal signal with a fixed amplitude to achieve the amplitude adjustment. Features.

The amplitude range of the sinusoidal signal is 0.038~0.650V, and the DC component is 0.344V. It is obtained by the method of resistor divider. The AS1117-2.5 three-terminal regulator provides a voltage of 2.5V, and the offset of 0.344V is obtained after the resistor divider. Voltage.

![Figure 2 Multiplier bias voltage generating circuit](image)

Take:
\[ R_1 = 60K\Omega, R_2 = 10K\Omega, R_3 = 10K\Omega \]

Then the reference voltage output range is:

\[ V_{\text{ref min}} = 2.5 \times \frac{R_1}{R_1 + R_2 + R_3} = 2.5 \times \frac{10}{60 + 10 + 10} = 0.3125V \]

\[ V_{\text{ref max}} = 2.5 \times \frac{R_2 + R_3}{R_1 + R_2 + R_3} = 2.5 \times \frac{10 + 10}{60 + 10 + 10} = 0.6250V \]

It can be seen that the output reference voltage range is 0.3125V~0.6250V. By adjusting the potentiometer, an offset voltage of 0.344V can be obtained to eliminate the DC component in the sinusoidal signal output by the DDS. The measured result of the sine wave is shown in Figure 3.
3.2 The design of the square wave generating circuit

The comparator is used to reshape the sine signal to generate a square wave signal. When the level of the positive input terminal is higher than the negative input terminal, the output is high, otherwise, the output is low. The most common comparison circuits are single-limit gate comparators and hysteresis comparators. This design uses hysteresis comparators. A resistor divider branch is drawn from the output of the comparator to the non-inverting input, and positive feedback is introduced into the circuit to form a hysteresis comparator.

The square wave generating circuit is shown in Figure 4. VREF is the voltage regulator block that outputs 2.5 volts. The comparison voltage can be adjusted by adjusting the potentiometer.
3.3 The design of the relay output control circuit

The relay model is UA2, which is equivalent to a double-pole double-throw switch. The control terminals are pin 1 and pin 8, respectively connected to +5V power supply and sine wave/square wave switch. Pins 2, 3, and 4 are the final waveforms. The switch for output switching, pins 6, 7 and 8 are switches for switching the sine wave to the hysteresis comparator to generate a square wave. Diode D1 plays the role of freewheeling to prevent the impact of excessive current on the circuit.

When the sine wave/square wave switch is released, SIN/REC is at high level. At this time, there is no current through the relay coil or the current is very small, and no magnetism is generated. At this time, pin 7 is connected to pin 6, and the sine wave is input to the comparator. Compare in the device, generate a square wave signal, and then input it to the 2 pin of the relay. At this time, the 2 pin is connected with the 3 pin, that is, it is output to the external interface.

If the sine wave/square wave switch is pressed, SIN/REC is at low level. At this time, the relay coil is magnetic, and pin 5 is connected to pin 6. Disconnect the sine wave from the comparator to prevent interference, pin 4. Connect to pin 3, that is, output the sinusoidal signal output by the amplifier to the external interface.

![Figure 5 Relay control circuit](image)

4. Software design of signal generating experimental device

In this design, the main work of the microcontroller is keyboard input, liquid crystal display, adjusting the amplitude of the sine wave and controlling the working state of the DDS chip. The single-chip microcomputer first displays some boot information on the LCD screen, and then reads out the frequency, amplitude and waveform input by the keyboard. If there is a key input, the frequency control word is calculated according to the input frequency, and program the DDS chip to make the DDS chip generate a sine wave of the corresponding frequency; adjust the output voltage of the single-chip microcomputer D/A according to the input amplitude, thereby controlling the amplitude of the sine wave, and save the frequency and amplitude in the internal FLASH space of the single-chip microcomputer to prevent data lost. If there is no keyboard input, the system defaults to output 1V, 1HZ sine wave or 1HZ square wave. If a watchdog reset or a clock loss detector reset occurs during the working process, the frequency and amplitude values saved during the last operation are read out, and the working state before the reset is restored. Make the user feel that the system has been reset.

The software in this design adopts a structured and modular approach, which can improve the reliability of the system and greatly reduce the hardware expenditure of the system. At the same time, the thinking is clearer and easier to debug. The initialization program is mainly to write several special function registers, the purpose is to set the working mode and initial value of each module, and initialize the variables used. Then output the default waveform. If the reset source is the watchdog or clock loss detector, the last working state will be restored. Carry on the scanning of the keyboard, realize with the timer T0, according to different waveforms and waveform generation modes, switch to different sub-functions.
5. Conclusion
The waveform signal generation experimental device developed in this design adopts direct digital frequency synthesis (DDS) technology, which is a specific application of DDS technology in the field of signal sources. This subject uses integrated programmable DDS devices to achieve direct frequency synthesis. Under the control and coordination of the single-chip microcomputer, the signal waveform with adjustable frequency and phase is output, and the variable voltage is generated by the on-chip 12-bit D/A of the single-chip microcomputer. The amplitude sine signal is multiplied to adjust the amplitude of the sine signal. A sine signal with a certain amplitude is passed through a hysteresis comparator to obtain a square wave signal, and the comparison voltage can be adjusted to a rectangular wave with a variable duty cycle.

The signal generating experimental device has the advantages of small frequency error, high resolution, small size, light weight, convenient use, stable work and so on. Very suitable for laboratory use.

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