American Journal of Mechanical Engineering and Automation
2017; 4(1): 1-5
http://www.openscienceonline.com/journal/ajmea
ISSN: 2381-6198 (Print); ISSN: 2381-6201 (Online)

Open Science

The Design on Power Supply of ACFM Test System Based on AD9959 Chip

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To cite this article

Ren Shangkun, Hu Jiang, Zhou Liuci. The Design on Power Supply of ACFM Test System Based on AD9959 Chip. *American Journal of Mechanical Engineering and Automation.* Vol. 4, No. 1, 2017, pp. 1-5.

Received: June 23, 2017; **Accepted**: July 19, 2017; **Published**: August 17, 2017

Abstract

The sine wave signal excitation source of meeting the requirements of ACFM was designed. This circuit are composed of direct digital synthesizer, low-pass filters, programmable amplifier and power amplifier. The design idea overcame the shortage that frequency and voltage were uncontrollable in the ACFM traditional detection systems before. It proved that the circuit can realize the objective as follows: the excitation's frequency and voltage are stable and controllable; The output current is strong enough; The signal to noise ratio is high enough. This design are completely satisfied to the ACFM system' requirement

Keywords

Nondestructive, ACFM, Test Systrm, AD9959, Driving Source

1. Introduction

Alternating current field measurement (ACFM) is a kind of NDT test technology developed by eddy current inspection and magnetic flux leakage detection [1-2]. When an alternate current appears on a metal's surface to be detected, the crack's property can be judged through detect the induced magnetic field around the crack [3-5]. Compared with traditional magnetic test methods, the testing technology has a great many advantages, such as fast speed [6-8], high accuracy, non-contact, low cost, and have no use for calibration, detection qualitatively and quantitatively is coinstantaneous, less demanding on the cleanliness of specimen surface, small effect of lift-off et al 9-10]. This measurement can be widely used on aeronautics and astronautics, electric power, railways, pipelines and pressure vessels [11].

When an excitation coil near the metal, it will have an alternate driving current conveys, an induced current will appear near the metal's surface. Because of the crack's resistance is far more big than the metal's, the induced current will be deflected and form an induced magnetic field. The crack's length and width can be measured though detect the induced magnetic [12]. The basis of the ACFM is that homogeneous alternating electric fields and currents can be induced in the specimens by alternating current [13]. The cracks, fatigue damage in the material will change the distribution of the induced current, thereby changing the distribution of the magnetic field inducted on the surface [14-15]. The assessment of crack can be achieved by detecting magnetic field disturbances on the specimens surface caused by defects [16-17].

The driving source's frequency for different metals are different, ranges from hundreds hertz to thousands hertz [18], and for the same metal, the voltage of driving source are different form different occasion. So far, many ACFM detective system's driving source can output only one frequency or one voltage, the driving source's frequency and voltage cannot be changed.

ACFM detective system has a rigorous demand to the driving source that the waveform should be absolutely sinusoid, and the voltage drop shouldn't bigger than 5%, the source's frequency are adjustable from 200Hz to 15kHz, the voltage are adjustable from 5Vpp to 15Vpp.

2. The Driving Source's Circuital Feature

This circuit's main operational principle is a MCU control a direct digital synthesizer (DDS) to produce the waveform that is needed, the wave go through a low-pass filter to filter the high frequency noise, after that the signal should be amplified and the gain should be programmable under the control of the MCU. Power amplifier's main function is strengthen the sine wave's load capacity to produce the driving source for the coil under the protect of a relay. Figure 1 is the structure flowchart of the driving source circuit.

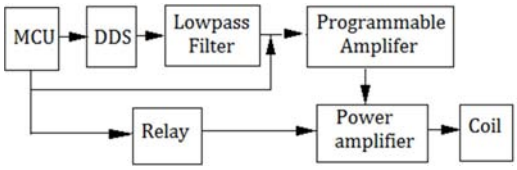


Figure 1. *The structure flowchart of the driving source circuit.*

2.1. The Generation of Sine Wave

The direct digital synthesizer is through check a table in high speed flash and AD convert technology to produce a kind of analog signal [19]. Compared with traditional signal device who use resistance, capacitance and inductance, this synthesizer have many advantages like small size, the frequency can be adjusted easily and so on. As the development of large scale integrate technology, a new kind of DDS chip which can change the output voltage and phase are invented, like AD9959.

AD9959 has four channels, every channel are independent to each other. Every channel have a frequency resolution of 32 bits and a phase resolution of 15 bits. In the highest sampling frequency of 500MSPS each channel's frequency resolution can reach 0.1165Hz and each channel's phase resolution can reach 0.011°[20].

When MCU controls the AD9959, first it should send 8bits control-words to the register in AD9959 to set an address and determine the next operation is read data or write data. After that the MCU will read or write data to the room the address pointed to [21]. To save the I/O pins, the communication mode between MCU and AD9959 will use serial mode, all the data will be inputted through SDIO0 pin. the program flow diagram is showed in figure 2.

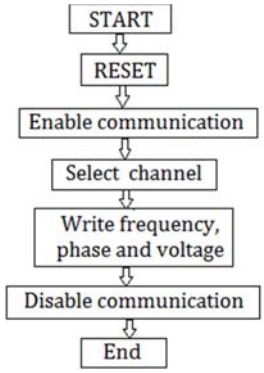


Figure 2. *The program flow diagram of AD9959.*

2.2. The Low-Pass Filter of Sine Wave

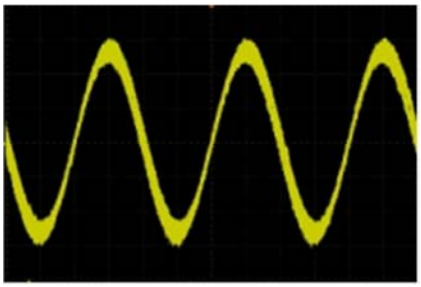


Figure 3. *Unfiltered sine wave.*

AD9959 is a high-frequency digital chip, this chip will make high-frequency electromagnetic interference to other chips and signals when it's working. Figure 3 shows the sine wave form that the AD9959 generated, the wave form contains many more high-frequency harmonic waves. So it is necessary to filter the sine wave.

The low-pass filter use 3 orders elliptic LC net filters to get a steep attenuation curve, filter circuit's schematic diagram is showed in figure 4. To fundamental wave, this circuit's resistance are relatively smaller than third harmonic, quintuple harmonic, which are main harmonics, so the harmonics can be filtered easily.

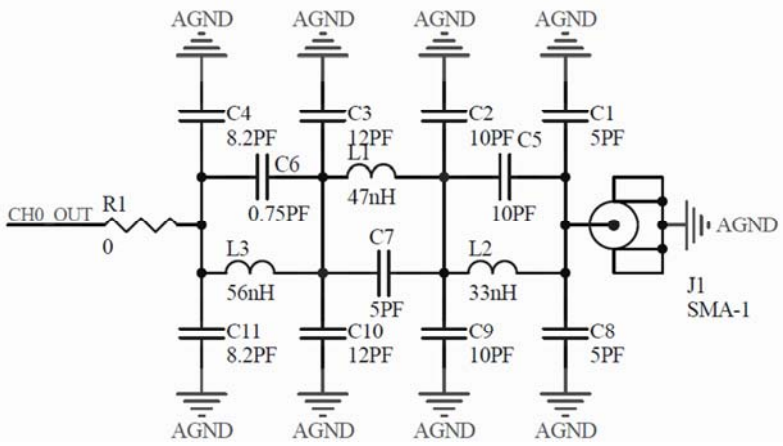


Figure 4. *Low-pass filter's schematic diagram.*

Figure 5 shows the sine wave form after filters, harmonics are restrained effectively.

Figure 5. *The sine wave after filters.*

2.3. Sine Signal's Programmable Operational Amplify

AD9959's output voltage are very small, only 540mVpp, and the voltage that ACFM Detective System need is 10-15Vpp. The sine signal's drive capability after filter are very weak that it cannot drive power amplifier. So an operational amplifier is needed. OPA134 is a kind of operational amplifier made by Texas Instruments Company. This chip has a very low distortion of 0.00008%. it's operate voltage is±2.5V-±18V, bandwidth is 8MHz, this chip can easily meet this system's design requirement.

Conventionally, operational amplifier's gain is controlled by potentiometers, which is very inconvenient to regulate. Digital potentiometer can avoid this problem. Digital potentiometer is a kind of potentiometer that can change it's resistance under the control of a MCU. X9313U is a typical 32 degrees Digital potentiometer made by American Xicor Company, it's resistance ranges from 40Ω to 50kΩ, increased by 1613Ωper degree. The connect circuit of X9313U and OPA134 is showed in figure 6. If R1=1.6kΩ, than the voltage of SIGNAL OUT is between 1.565Vpp and 17.415Vpp, increased by 0.544V per degree.

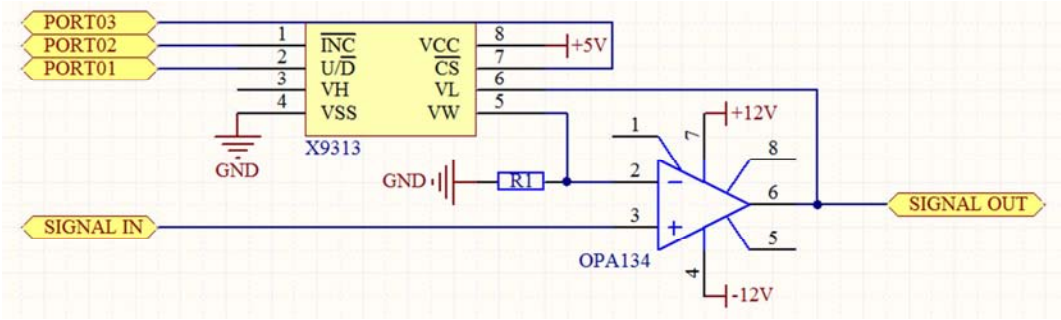


Figure 6. *The connect circuit of X9313U and OPA134.*

2.4. Sine Signal's Power Amplify

Conventionally, the large current provided to excitation coil can be produced by PWM technology. But this current contains too much harmonics. So in this system power operational amplifier is used. OPA564 is a kind of power operational amplifier made by Texas Instruments Company, power supply in dual is ±3.5V to ±12V, the biggest output current is 1.5A at 20Vpp. It's bandwidth is 17MHz, those parameters make this chip can meet this system's design requirement.

OPA564's operate temperature cannot higher than 140°C, this chip's output will shutdown when it's temperature is too high, At the same time pin T_{FLAG} will be forced to high. OPA564 has a temperature sensor inside, Measuring the OPA564 junction temperature can be accomplished by connecting the T_{sense} pin to a remote-junction temperature sensor, such as the TM411 [17].

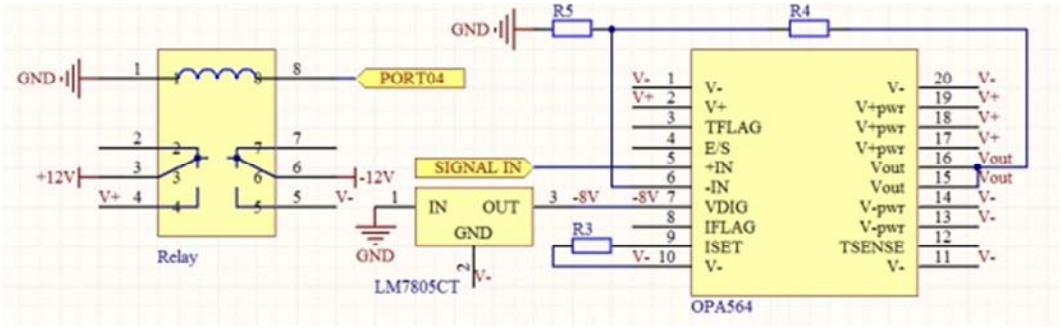


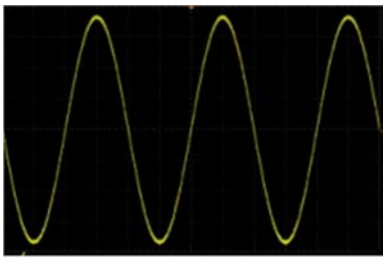
Figure 7. *The connect circuit of OPA564 and relay.*

When OPA564 operates, it need two kinds of voltage: analog voltage and digital voltage. Analog voltage provide power input for it's power output, and digital voltage provide power input for the temperature sensor and some other devices. Digital voltage must be higher 3.3V than analog voltage's GND but no more 5V. Digital voltage must be given before analog voltage and evacuated after analog voltage. To solve this problem analog voltage is provided through a relay, the relay is controlled by

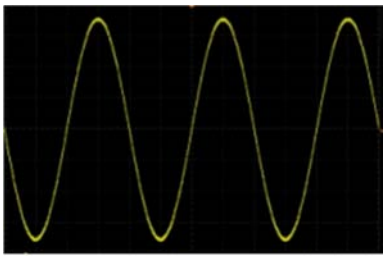
MCU. OPA564 and relay's connect circuit is given in figure 7. In this figure, analog voltage's GND is -12V relative to digital voltage's GND. LM7805's output voltage is higher 5V than analog voltage's GND, with this voltage difference OPA564's temperature sensor can work normally.

3. Test Result

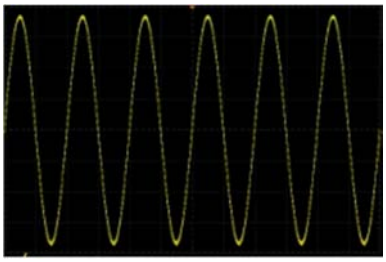
Connect all the modules aforesaid, use a MCU control DDS to produce sine wave, for the convenience of testing the frequency select and use 200 Hz and 15 kHz, regulate the digital potentiometer make it's output resistance is 41.978 kΩ, OPA134's magnification time will be 27.23. It shows excitation coil's inductance is 8 mH, current-limiting resistance is 8 Ω. The wave form of OPA564's output with load and idling are showed in figure 8.



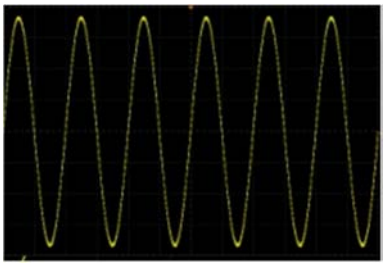
(a) f=200Hz, idling



(b) f=200Hz with load,



(c) f=15kHz, idling



(d) f=15kHz with load,

Figure 8. *OPA564's test wave form.*

The oscilloscope has showed when OPA564's output frequency is 200Hz and 15kHz, all the voltage with no load are 14.7Vpp, when OPA564's output frequency is 200Hz, the voltage with load is 14.3Vpp, and when OPA564's output frequency is 15kHz, the voltage is 14.5V. It was showed in any case the wave form have no distortion, the voltage drop rate is less than 3%. OPA564 is working normally.

4. Conclusion

In ACFM detective system, the magnitude of induced magnetic field and wave form is closely related to driving source, so the design of driving source is very important to ACFM detective system. This design used a kind of sine wave power generator based on DDS technology, whose output frequency can range from 200Hz to 15kHz. This driving source can provide a highest voltage of 17Vpp for ACFM detective system when working, every performance index can meet this design's requirement.

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