

Author's Response for comments of review

Comments from reviews:

1.1 There are some grammatical errors in this article that need to be corrected.

1.2 The author's response:

I have modified the paper thoroughly by correcting the grammatical errors and rephrasing some paragraphs to present a clear expression.

1.3 Author's changes in manuscript

(1) Page 1, Line 2

Error 1 : the exploitable potential and reserve of proven mines have been proven

Modify 1 : the exploitable potential and reserve of proven mines are insufficient

(2) Page 1, Line 4

Error 2 : Because of the existing instruments have less channels and insufficient sampling rate, the development and experiment of the transient electromagnetic instrument with multi-channel synchronous receiving are therefore proposed.

Modify 2 : There are some disadvantages of the existing instruments, such as few channels and slow sampling rate, etc. Therefore, multi-parameter transient electromagnetic instrument with synchronous receiving has been developed and tested.

(3) Page 1, Line 6

Error 3 : the real-time synchronous transient electromagnetic acquisition system in six channels is achieved with 128k sampling rate

Modify 3 : the real-time synchronous transient electromagnetic acquisition system of six channels is achieved with 128k sampling rate

(4) Page 1, Line 9

Error 4 : the measured data curves of the mining area is highly consistent with the existing geochemical exploration curves and geological profile.

Modify 4 : the measured data curves of the mining area are highly consistent with the existing geochemical exploration curves and geological profile.

(5) Page 1, Line 16-17

Error 5 : it often using as the launch signal, data acquisition is completed during the bipolar wave intermittent

Modify 5 : periodic bipolar waves are used as launch signals, and data acquisition is completed during the bipolar wave intermittence,

(6) Page 1, Line 17-19

Error 6 : The instrument collects and studies characteristics of the intensity, distribution, space and time decay of the second field, and then deduces the underground anomalies.

Modify 6 : The instrument collects and studies the decay characteristics of the intensity of each component, distribution, space and time of the secondary fields to deduce the underground anomalies.

(7) Page 1 , Line 19-20

Error 7 : which are very useful for low-resistivity geologic bodies with high penetration, which can effectively improve the actual exploration depth

Modify 7 : which can easily penetrate low-resistivity geologic bodies, and therefore the actual exploration depth can be effectively improved

(8) Page 2, Line 1

Error 8 : Conventional transient electromagnetic (TEM) use mostly magnetic source or electrode source mode, the magnetic source mode TEM volume effect is relatively small, high detection accuracy,

Modify 8 : Conventional transient electromagnetic (TEM) **uses** mostly magnetic source or electrode source mode. In the magnetic source mode TEM volume effect is relatively small, and it has high detection accuracy,

(9) Page 2, Line 3

Error 9 : and the high Geological response is not sensitive.

Modify 9 : and the response to high resistivity geological bodies is not sensitive.

(10) Page 2, Line 7

Error 10 : the reduce of transceiver distance can both greatly enhance the exploration depth, , but also effectively improve the signal to noise ratio

Modify 10 : the reduction of transceiver distance can both greatly enhance the exploration depth, , but also effectively improve the SNR

(11) Page 2, Line 19

Error 11 : China's overall theoretical level and engineering practice in the field of transient electromagnetic remain at the same level with the international, but the domestic instruments in the technical indicators comparing with foreign countries there is still a certain gap,

Modify 11 : China's overall theoretical level and engineering practice in the field of transient electromagnetic remain at the international level, but compared with foreign instrument, the domestic instruments still have some disadvantages in the technical indicators

(12) Page 2, Line 25

Error 12 : By comparing most of the transient electromagnetic surveys at home and abroad since recent 20 years, the main problems and gaps in the domestic transient electromagnetic instrument lie in that

Modify 12 : By comparing most of the transient electromagnetic surveys at home and abroad **in** recent 20 years, the main problems of the domestic transient electromagnetic instrument lie in that

(13) Page 3, Line 1

Error 13 : Waveform acquisition and multi-channel receive by using high-precision GPS timing unit to synchronize, combined with programmable high-precision counter to further improve the synchronization accuracy.

Modify 13 : Transmitting current waveform acquisition and multi-channel reception can be synchronized by using high-precision GPS timing unit, and programmable high-precision counter

is adopted to further improve the synchronization accuracy.

(14) Page 3, Line 6-8

Error 14: Analog board channel numbers are 1/2, 3/4, 5/6 channels respectively, each analog board have two channels. The board contain the signal conditioning, amplification and acquisition of all channels are completely independent and real-time acquisition is achieved in multi-channel.

Modify 14: Analog board channel numbers are 1/2, 3/4, 5/6 channels respectively, **and** each analog board have two channels. The board **contains** the signal conditioning circuit, amplification and acquisition of all channels **which** are completely independent, and multi-channel real-time synchronized acquisition is achieved.

(15) Page 3, Line 16

Error 15: making use of a general IO port to complete the three amplification ratio adjustment.

Modify 15: and a general IO port to complete the three level amplification ratio adjustment.

(16) Page 4, Line 1

Error 16: reducing noise from the front end and reducing the need for front-end anti-alias filter, which using a daisy chain technology to realize the multi-chip series for an efficient parallel device(Liu et al.,2017).

Modify 16: to reduce noise from the front end and the need for front-end anti-alias filter, and daisy chain technology to realize the multi-chip cascade connection for an efficient parallel synchronous acquisition (Liu et al.,2017).

(17) Page 4, Line 3-5

Error 17: The design of the two channels as a result of a, it is two AD7767 series, the FPGA controller to control the three analog boards by three connectors, and then through the FPGA internal logic program, the six channels are the overall data package and storage in real-time.

Modify 17: By adopting modular design, two AD7767 chips are cascaded, FPGA controller is used to control three analog circuit boards separately, and the overall data package and storage in real-time is achieved.

(18) Page 5, Line 7

Error 18: Multi-channel synchronous receiver with embedded controller and programmable logic controller (FPGA) in dual-controller approach(Oballe-Peinado et al.2017) , this control method is flexible and more popular used. FPGA as the core part of the system to collect the front end of the logic control components for the main use of its internal parallel processing functions, a number of internal logic modules driven by the system clock, you can easily achieve the synchronization between the various functional units.

Modify 18: Multi-channel synchronous receiver uses embedded controller and programmable logic controller (FPGA) as dual-controller (Oballe-Peinado et al.2017) , which is flexible and widely used. FPGA is the core logic control part of the collection system, and the synchronization between the various functional units can be easily achieved by its parallel processing function, by which a number of logic modules are driven by the system clock.

(19) Page 4, Line 12-15

Error 19: FPGA unit module is mainly composed of SD card unit circuit, SRAM buffer circuit and the SPI interface which is used to communicate with STM32 controller. It is responsible for the synchronous acquisition and control interface of six channel signals, filter frequency output interface, and GPS's second-pulse signal interface, and power interface.

Modify 19: FPGA unit is mainly composed of SD card unit circuit, SRAM buffer circuit and the SPI interface which is used to communicate with STM32 controller, the synchronous acquisition and control interface of six channel signals, filter frequency output interface, and GPS's second-pulse signal interface, and power interface.

(20) Page 4, Line 19

Error 20: simultaneously display it on LCD . The system also designs a 6*8 metrix keyboard which can

Modify 20: simultaneously displayed on LCD . A 6*8 metrix keyboard is designed to

(21) Page 5, Line 2

Error 21: The software mainly includes two parts: FPGA acquisition control board program, which involves the use of 4-bit data transfer on the SD card storage, and STM32 real-time communication, data buffer area, data processing and other parts. STM32 control board program, this part includes the gain adjustment of the first stage preamplifier, the second stage of programmable amplifier, and natural potential compensation(Khomutov et al.,2017).

Modify 21: The software mainly includes two parts: 1)FPGA acquisition control board program, which involves the use of 4-bit data transfer on the SD card storage, real-time communication with STM32, and data processing in data buffer area ,etc. 2)and STM32 control board program, which includes the gain adjustment of the first stage preamplifier, the ratio setting of second stage of programmable amplifier, and natural potential compensation control(Khomutov et al.,2017).

(22) Page 5, Line 9

Error 22: FPGA's program combine the collected data, the current time information and the channel number together for the later storage.

Modify 22: Time information and the channel numbers are stored in a package through FPGA program.

(23) Page 5, Line 10-12

Error 23: The second pulse signal(PPS) provided by GPS timing unit updates FPGA synchronize the transceiver in every two seconds. It can reduce the cumulative error in long time collection.

Modify 23: The second pulse signal(PPS) provided by GPS timing unit updates the internal base time of FPGA in every two seconds. It can reduce the time cumulative error.

(24) Page 6, Line 5-7

Error 24: For the same point in time, the extraction of the value of each channel compared to obtain the average of each channel error, the average absolute error and error percentage, as shown in Table 2.

Modify24: The extracted numerical values of each channel at the same time are compared to obtain the average error, the average absolute error and error percentage, as shown in Table 2.

(25) Page 6 , Line 8-11

Error 25: In the AC testing, the six channels of positive and negative parallel are access to the sine wave from the standard signal source. The waveform output by the system after the acquisition is shown in Figure 3, the input signal peak-10mV, frequency of 20Hz. As can be seen from the figure, each channel has high consistency and no phase offset occurs. After the system is enlarged, each channel waveform shows peak-to-peak 1000mV through amplifier.

Modify 25: In the AC testing, the six channels of positive and negative terminals are connected in parallel, and the sine waves are input from the standard signal source. The output waveforms after the system acquisition are shown in Figure 3. The peak to peak value of input signal is 10mV, and the frequency is 20Hz. As can be seen from the figure, the consistency between each channel is quite high and no phase offset occurs. After the input signals are amplified by the system, peak to peak value displayed by waveforms of each channel reaches to 1000mV.

(26) Page 7, Line 2-3

Error 26: Figure 4 is the first channel in Figure 3, by fast fourier transform, it can be seen from the frequency spectrum of the sine wave in the left time domain, and few harmonic components in the right frequency domain.

Modify 26: In Figure 13, the left figure is about the waveform of 3 cycles of data acquisition by the first channel in Figure 12. The right figure is about the frequency spectrum formed by waveforms in the left one, which underwent fast fourier transform. As is shown in the right one, the frequency of the input sines waves is 20Hz, with few harmonic components, which indicates the excellent performance of analog circuit board and high stability of power circuit.

(27) Page 7, Line 5

Error 27: In the field testing, sensor is a hollow coil with 400 turns and it's diameter is 50cm, the effective area of the coil is 40 m^2 . The transmitter uses Phoenix's T-4 transmitter, which transmits a bipolar pulsed numbered TD50 with a 50\% duty cycle(Wang et al.,2015).

Modify 27: In the field testing, a hollow coil with 400turns and a diameter of 50cm is used as the test sensor, and its effective area is 40 m^2 . The transmitter is Phoenix's T-4 transmitter, which transmits a bipolar pulsed waveform numbered TD50 with a 50\% duty cycle(Wang et al.,2015).

(28) Page 8, Line 1-9

Error 28: Two sites were selected, the first one is a relatively open site and the second one is the actual mining area. The test uses a near-field measurement method. The transmitting source of the field adopt grounded electrode source. Four aluminum plates are respectively buried in the ground with 40cm of aluminum plate and covered with salt water and soil, so that the grounding resistance is less than 10 ohms. The spacing of the transmitting electrodes is 400 meters, the power supply using four batteries, voltage control between 40-50V, the emission current of 3A, and the launch frequency of 25Hz.

During the test, the power supply electrode is stationary, while the preset measurement and emission level is at an offset of 40 meters. During the test, two machines were used, one of them is used to record the emission current waveform and the other is used to receive the voltage of the magnetic

flux density (dB/dt) at the preset point. Figure 5 below shows the original one-cycle data.

Modify 28: Two sites were selected, one of which is a relatively open site while the other is the actual mining area. Near-field measurement method is used in the test. Grounded electrode source is adopted as the field source. Four aluminum plates as electrodes are respectively buried 40cm deep in the ground and covered with salt water and soil, so that the grounding resistance is less than 10 ohms. The distance between the transmitting electrodes A and B is 400 meters, and the four batteries are used as the power supply. The voltage ranges between 40-50V, while the emission current is 3A, and the emitting frequency is 25Hz.

During the test, the power supply electrodes are stationary, while the preset measurement line is parallel with the emission points A and B. The offset is 40 meters. The changing rate of the magnetic flux density (dB/dt) is received by the coil. Figure 5 below shows the one original one cycle.

(29) Page 8, Line 10-12

Error 29: The open area to be tested is formed by the mixing and filling of soil and slag. Each survey line was observed at 8 points.

Modify 29: The open area where the test was carried out, is formed by the mixture of soil and slag. Each measurement line observed at 8 measuring points.

(30) Page 8, Line 13-15

Error 30: Figure 6 shows the cross-section of this line. The cross-section shows that the overall response tends to be flat. The difference between the two launch points is due to the close proximity of the emitter point received by the signal is relatively strong, closer to the middle, the profile line slowly flat.

Modify 30: Figure 6 shows the profile, which shows that the overall response tends to be flat. The signals received at the measurement points close to the transmitting nodes are relatively strong, while the central part of the profile becomes flat slowly.

(31) Page 8, Line 17-18

Error 31: The use of electrode source emission, emitter distance of 400 meters, testing line offset 80 meters, measuring point spacing of 40 meters.

Modify 31: The electrode source emission is adopted, and the distance between the transmitting electrodes stance is 400 meters. The testing line offset is 80 meters, and the distance between the measuring points is 40 meters.

(32) Page 9, Line 1-6

Error 32: The second-field extraction, filtering and interpolation are performed on the data collected in the mining area. After 200 superimposed waveforms, the waveform of the time domain is smoother, which can well reflect the response of underground media to transient electromagnetic. The data of each measuring point are processed in the same way to obtain the pure secondary fields curves, and the time sampling is performed to form a sectional view of the measuring line. In Fig. 8, $t_1 \sim t_{12}$ respectively represent the extraction time, and connect the extracted values of different collection points together to form 12 curves at different times.

Modify 32: After the collected data in the mining area are second-field extracted, filtered and

interpolated, the waveform is formed. The waveform curve of the time domain is smoother after, 200 superimposed waveforms, which can well reflect the response of underground geological bodies to transient electromagnetic. The data of each measuring point are processed in the same way to obtain the pure secondary field curves, and the time domain order waveforms are extracted to form the profile of the measuring line. In Fig. 8, $t_1 \sim t_{12}$ respectively represent the extraction time, and the extracted values of different collection points are collected together to form 12 curves at different times.

(33) Page 10, Line 2-11

Error 33: The purpose of this paper is to develop a set of receiver device that can adapt to application of transient electromagnetic prospecting. First, the hardware circuit and software program are designed to realize all functions which are presented above. By means of dual controller, the instrument can receive six channels signal synchronously. Then, the data stored in SD card is processed by computer program and generate graphic. The overall performance was tested, All the channels reached an error of less than 0.35%, and, each channel can connect different sensors, such as coil, magnetic probe, electrode. This kind of receiver can be used to collect transient electromagnetic information acquisition. It has high precision, high sampling rate can capture the fast falling edge of TEM, ultralow noise and soon. Hence, the multi-channel synchronous acquisition of magnetic field information in three directions and electric field information in two directions and the rate of change of magnetic induction intensity can be used for time domain reception. Meanwhile, pseudo Random reception and distributed 3D reception provide strong support for further exploration of different ways.

Modify 33: The purpose of this paper is to develop a set of receiver device that can be applied in transient electromagnetic prospecting. First, the hardware circuits and software programs are designed to realize all functions which are presented above. By means of dual controller, the instrument can receive signal synchronously through six channels. Then, the data stored in SD card are processed by computer programs to generate graphs. The overall performance of the receiver was tested and verified. All the collected data error of each channel is less than 0.35%, and, each channel can connect different sensors, such as coil, magnetic probe, electrode. This kind of receiver can be used to collect transient electromagnetic information. Due to its high precision and high sampling rate, it can capture the fast falling edge of TEM, ultralow noise and so on. Hence, the multi-channel synchronous acquisition of magnetic field information in three directions and electric field information in two directions and the changing rate of magnetic induction intensity can be used for time domain reception. Meanwhile, the receiver can be used for pseudo random signal reception and distributed 3-dimension data reception, which can improve geophysical exploration efficiency.

2.1 In the Multi-channels receiver hardware part, the article is more about the basic knowledge of hardware circuit design, not give the specific design steps of the experimental scheme.

2.2 The author's response

I have added the relevant circuit diagram to the part of hardware design. And a detailed description is given in the uploaded manuscript.

2.3 Author's changes in manuscript

The newly added figures which are Figure 2,3,4,5,6,7,8 and 9 in the uploaded manuscript, are shown below. And these figures are inserted into relevant sections.

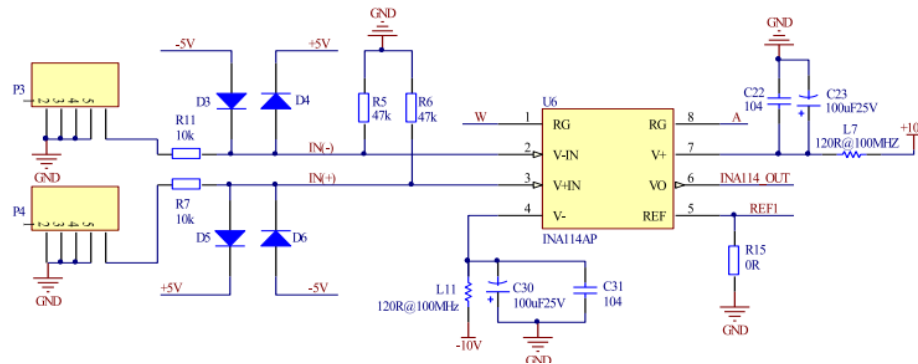


Figure 2

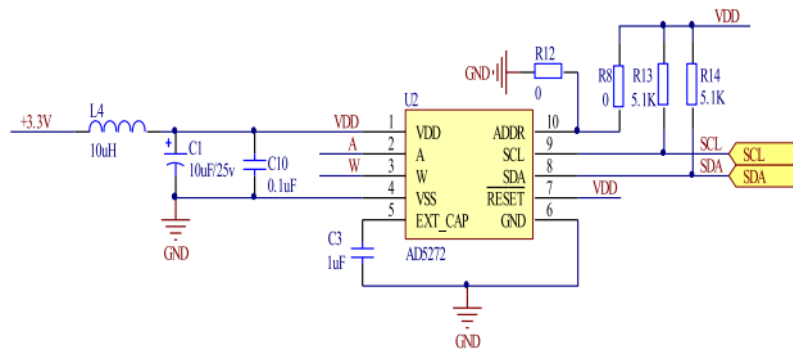


Figure 3

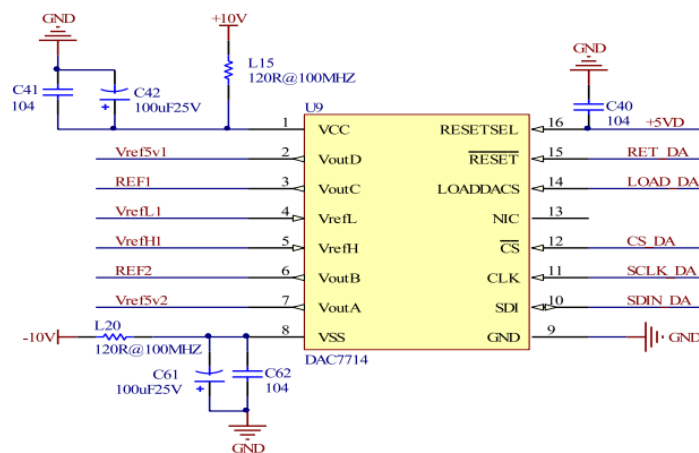


Figure 4

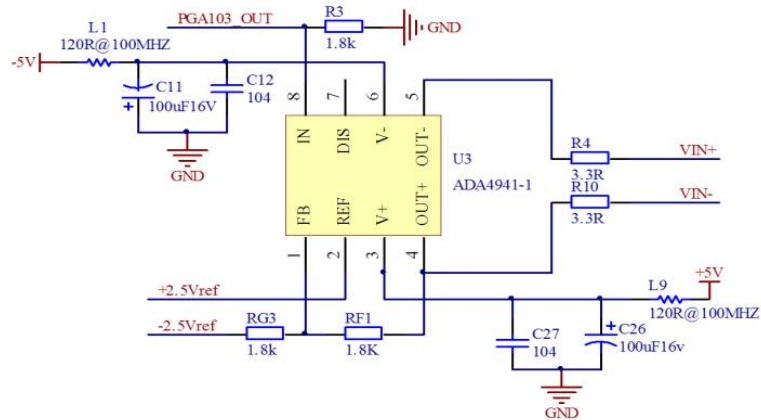


Figure 5

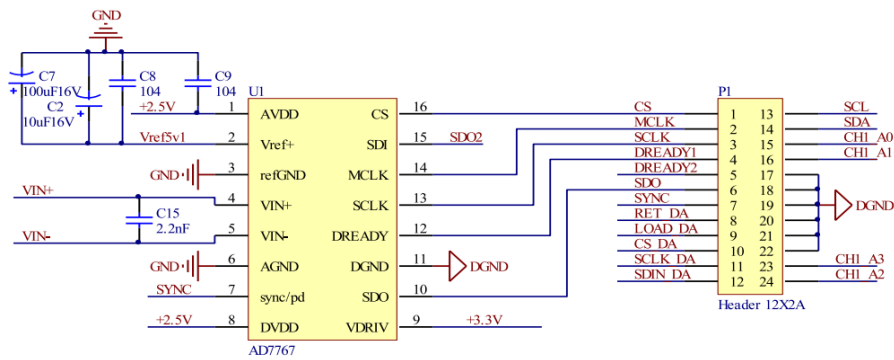


Figure 6

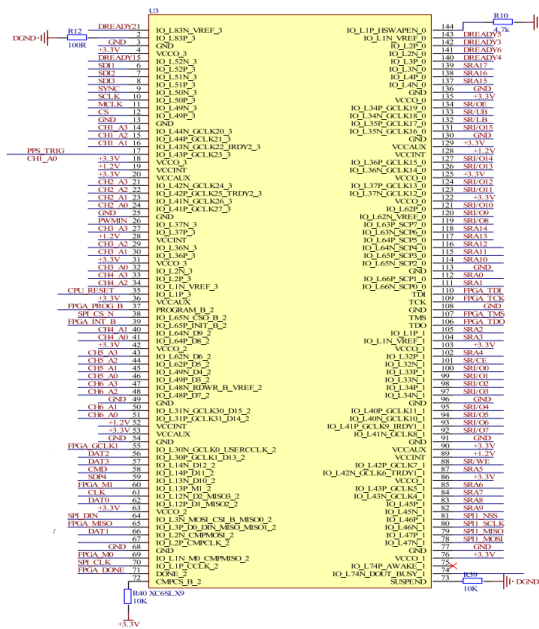


Figure 7

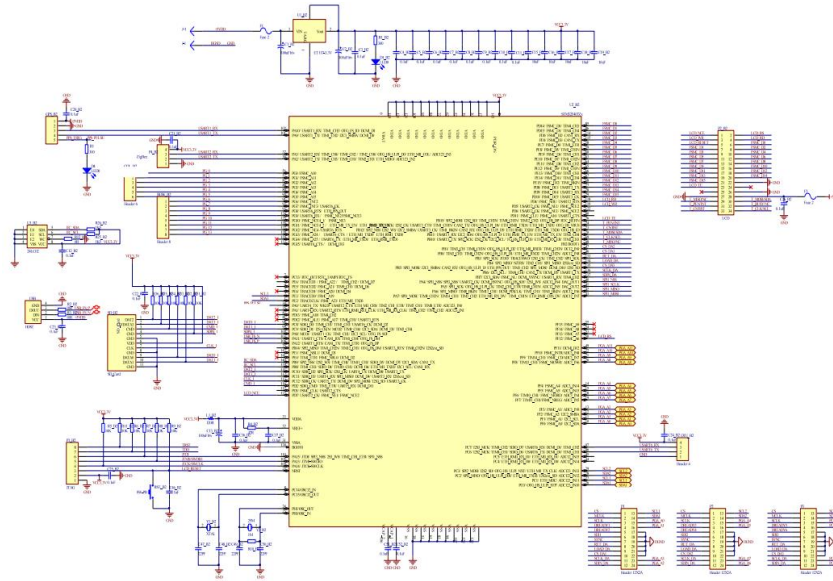


Figure 8

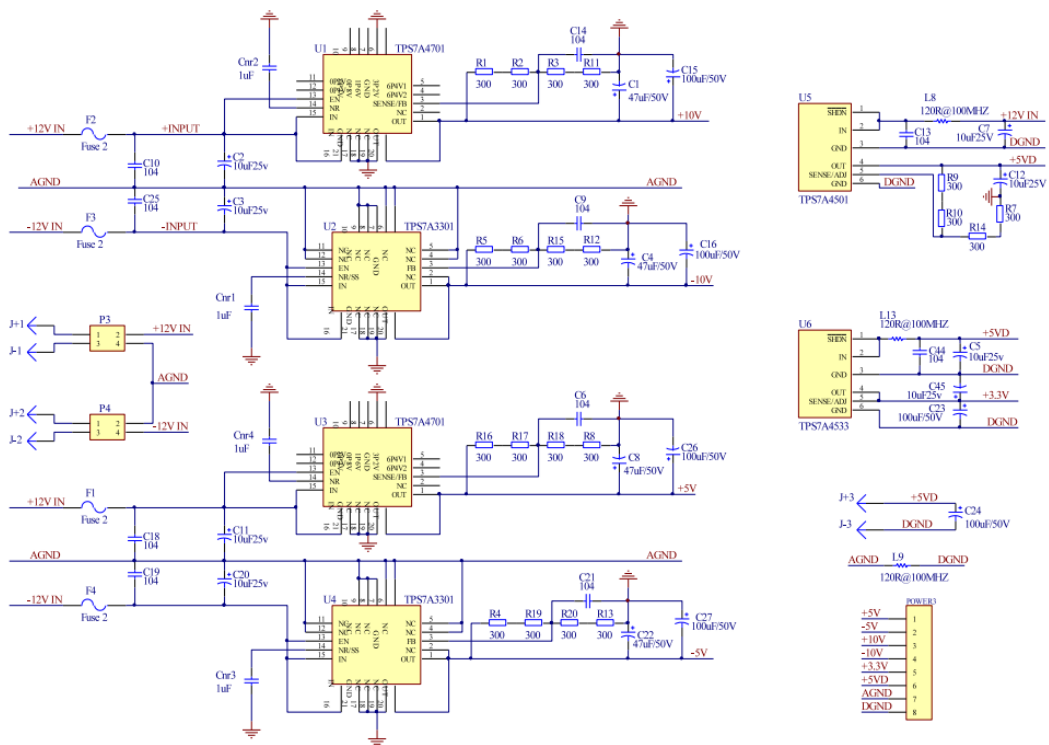


Figure 9

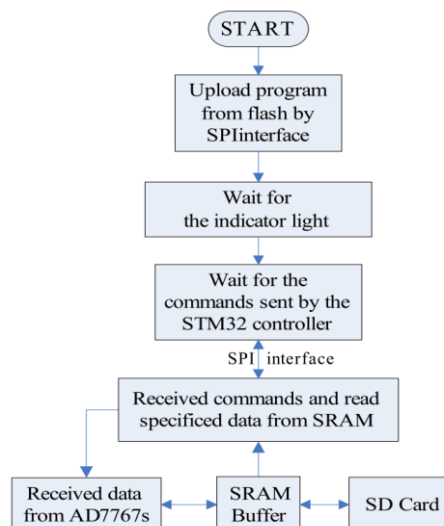
3.1 In the Software design, such as STM32 software implementation part, A/D sampling, Flash storage, D/A output and Flash load, it is best to give the system flowchart, The design part of the hardware and software is not complete and clear.

3.2 The author's response

I have added the flowchart, which is about the program. And the hardware diagrams of the system have been added in the part of hardware design.

3.3 Author's changes in manuscript

There is a new flowchart added as Figure 10 in page 9, which is shown below.



4.1 In the figure 4, not only do not detailed description of the waveform in the graph, but also do not explain the cause of the waveform, suggest elaborating on it in detail.

4.2 The author's response

I have described the characteristics of the waveform in the Figure 4, and explained the cause of the waveform in the discussion version of the manuscript. In the uploaded manuscript, I have added more new figures, therefore the figure sequence numbers have been changed. Now, Figure 4 becomes Figure 13, and Figure 3 becomes Figure 12.

4.3 Author's changes in manuscript

In Figure 13, the left figure is about the waveform of 3 cycles of data acquisition by the first channel shown in Figure 12. The right figure is about the frequency spectrum formed by waveforms in the left one, which underwent fast fourier transform. As is shown in the right one, the frequency of the input sines waves is 20Hz, with few harmonic components, which indicates the excellent performance of analog circuit board and high stability of power circuit.