ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

Design of Two-stage Dual-sampling Amplifier Based on ARM

Meng Zhiguo[1], Ding Dushu[2] and Liu Yuguo[3]

[1,2,3]*School of Information Technology, Guangdong Industry Polytechnic, Guangzhou 510300, China*
E-mail: 2004106091@gdip.edu.cn

ABSTRACT: *In order to meet the digital requirements and high fidelity of power amplifier, MCU is been used as the core, and AC/DC of the chip is been used sample conversed circuit from analog to digital. The control equation model is established to design modular and debug, and to choose the appropriate features state step by step. The front part of Two-stage Dual-sampling feedback amplifier is directly coupled amplify the weak signal voltage up to the highest 3.3V without distortion. At the secondary level the front part of signal power amplifier is enlarged by field effect push-pull tube. Through computer process, the output screen show signals about the power of the amplifier, the output power and the machine efficiency index. The test results show that the circuit has a good pass-band. AC/DC access signal can dynamically change PWM modulation according to different loads. The state control equation and mapping algorithm improve the flexibility of two-stage dual-sampling feedback amplification.*

KEYWORDS: *MCU, Sampling Circuit, Power Amplifier, State Governing Equation*

Overview

Class A, class B, class AB and class D are common power amplifiers. Class A, class B and class AB are analog amplifiers. However, class B amplifiers may produce alternating distortion due to poor switching characteristics or improper selection of circuit parameters in the switching process of transistor on and off state. Class D amplifier is actually a digital amplifier, which have advantages such as high efficiency distortion, good frequency response curve, few peripheral components. Class AB amplifier and class D amplifier are the basic circuit forms of audio power amplifier.

This design choice is how to use digital means to optimize the class AB amplifier, adopts the modular design and debug, step-by-step implementation. Two-stage amplifier and digital signal processing system is designed first, write-handlers to validate measurement accuracy and the function, improving design and parameter tuning. On the basis of feasibility adequately validated and the man-machine interface design, it will achieve convenient operation.

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

1 Design of System Circuit

CNC regulator amplifier is an important part of electronic equipment. Its quality directly affects the reliability of electronic equipment. So amplifiers are getting more and more attention. Electronic circuits and electronic devices on amplifiers, the most basic requirements are amplifiers output voltage or output current to be stable. Through consulting a large number of materials, it is shown that the circuit and the control circuit are the core part of the circuit. There are three options for it:

Scheme one adopts analog circuit. An analog adjustable voltage regulator use a multilevel switch to control the output voltage, and the display system simply indicates the voltage value next to each level of the multilevel switch. With the development of electronic industry, its disadvantages of not durable have made it gradually leave the stage of history.

Scheme 2 adopts pure digital circuit. Amplifiers of pure digital circuits avoid wear and wear between the hardware, making the service life greatly improved, and its output voltage does not produce error over time. But its circuit is more complex, it is very difficult to make, because of the complexity of the circuit will produce a lot of problems.

Scheme 3 adopts the method of single chip microcomputer. Using microcontroller digital voltage regulator, digital circuit and microcontroller are well combined together, not only can achieve the effect of digital circuit, but also can greatly simplify the complex pure digital circuit. After the adoption of single chip microcomputer, it can so use software to achieve the protection function, to expand other functions that very easy.

After a comprehensive comparison, the circuit design is more reasonable. On line with the standard of technical indicators, the use of the SCM method on scheme three is simple, flexible, expansibility, more suitable for the graduation design, and can meet the requirements of indicators.

CNC dc regulator design requirements are to use single-chip microcomputer control dc regulator output adjustable control and output display. This amplifiers system design system is mainly composed of main circuit, converter control circuit and MCU control circuit.

The system design part mainly completes the tasks of parts selection, component design, software compilation, etc. Each task adopts different research methods or technical routes. In this design, class AB amplifier is selected as the basic carrier of the design. The on-chip AC/DC converter STM32F10X single-chip microcomputer is adopted for processing chips.

See Fig. 1, the signal amplification part includes: preamplifier circuit, power amplifier circuit. Signal sampling and detection mainly include: RMS conversion circuit, amplifier circuit, AC/DC (digital - analog) conversion circuit. In order to satisfy the high fidelity and design power, the circuit is divided into the front part and the power amplifier part. Through direct coupling, the front part can amplify the voltage of weak signal to 0.4v-3.3v without distortion. The power amplification part

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

further amplifies the signal power of the front part to increase the power to the designed power. In order to further reduce the distortion, the external main power frequency interference signal is attenuated, and a passive wave limiting device is specially designed to filter the power frequency interference signal before entering the amplifier through the wave limiting degree of attenuation greater than 6dB/50Hz.

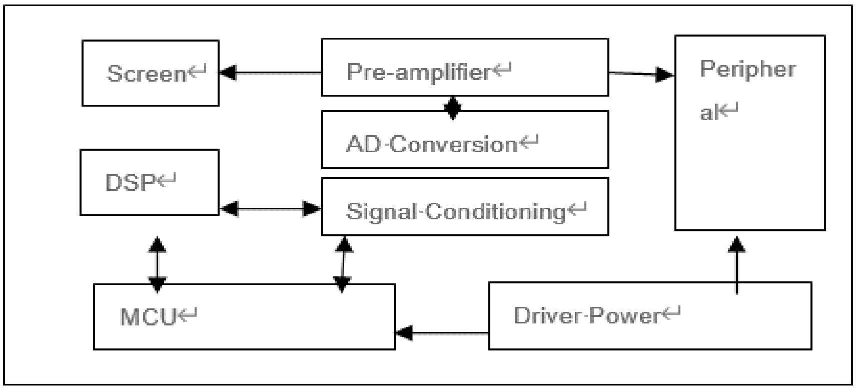

Fig. 1 System design

1.1 Sampling circuit

Power sampling circuit according to the power bus in a series of 0.25 resistance, sampling circuit according to the voltage at both ends of this resistance first through voltage attenuator, then differential amplification, and then through the single-chip internal analog-to-digital converter. The output power sampling circuit design is shown in Fig. 2. Since the output of power amplifier is AC signal, the true RMS value sampling of the output voltage is firstly carried out, and then the signal is amplified, and finally the AC/DC converter inside the single-chip microcomputer.

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

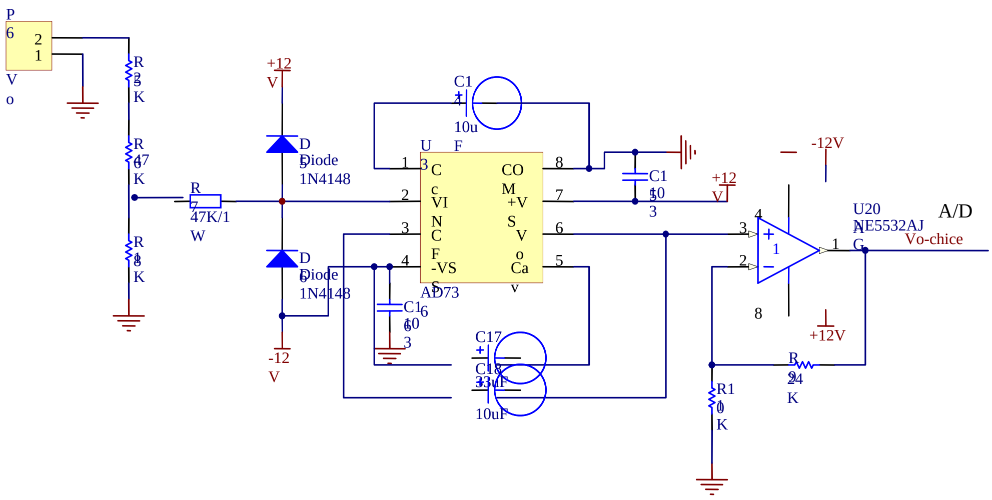

Fig. 2 Output power sampling circuit

1.2 Power amplifier circuit selection

Common low-frequency power amplifier circuit connection form mainly OCL, OTL, BTL, and there are various ways of work (class a, class b, class a&b, class S), there are a lot of options.

Scheme 1: power amplifier stage adopts a typical OTL circuit. As the output end adopts electrolytic C coupling to the load, while the system load is only 8Ω, and its equivalent R value is small, it is unfavorable to the distortion free output of broadband signal, especially to the attenuation of low-frequency signal.

Scheme 2: this circuit is firstly amplified by a preposition circuit with two stages, and a sufficiently large voltage driving amplifier stage is obtained. The amplifier stage first goes through Q4 and Q5 for differential amplification, and then goes through the amplification tube Q2 and Q6 to further amplify the signal, and then pushes and pulls the amplification through the field effect to avoid tube Q3 and Q7.The cascade voltage negative feedback circuit is adopted to improve the stability of the circuit, eliminate self-excitation and effectively improve the efficiency of power amplifier.

1.3 Two-stage amplifier circuit

This circuit first goes through a two-stage amplifier of a front-circuit. The schematic diagram of the power amplifier circuit is shown in Fig 3, and a large enough voltage is obtained to push the power amplifier level. The power amplifier stage first goes through Q4 and Q5 for differential amplification, and then further amplifies the signal through the amplifier tube Q2 and Q6, and then amplifies through the field effect push-pull tube Q3 and Q7.The cascade voltage negative feedback circuit is adopted to improve the stability of the circuit, eliminate self-excitation and effectively improve the efficiency of poweramplifier.

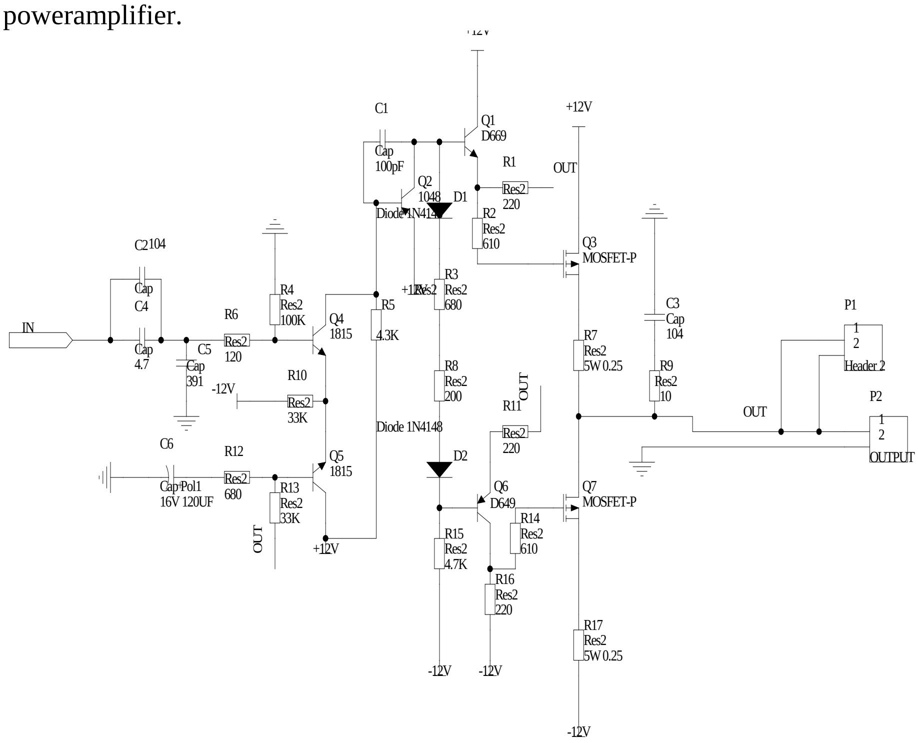

Fig. 3 Two-stage amplifier circuits

1.4 Sampling circuit and AC/DC conversion circuit selection

The system can be divided into signal amplification part and signal sampling detection part. The signal amplification part includes: preamplifier circuit, power amplifier circuit. Signal sampling detection part mainly includes: true RMS conversion circuit, amplifier circuit, AC/DC (digital to analog) conversion circuit. There are also display module circuits

Processing chip selection: chip with AC/DC converter STM32F103 microcontroller. You can simplify the circuit.

Power sampling circuit: power supply power sampling is based on a 0.25 Ω resistor string on the power bus. According to the voltage at both ends of the resistor, the sampling circuit first passes through the voltage attenuator, then carries

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

out differential amplification, and then goes through the MCU internal analog-to-digital converter.

Output power sampling circuit: because the power amplifier output is an AC signal, so the true RMS of the output voltage is sampled first, and then the signal is amplified, finally to the MCU internal AC/DC converter.

Display circuit: liquid crystal is adopted due to the high precision of the displayed data, the large number of digits and the display status at the same time.

2 Calculate of Main Circuit Parameters

2.1 Output power and gain distribution

Considering that the output power is greater than 5W when the input signal is 5mV, the output power of the preliminary design circuit is 12W and the load is 10 equivalent resistances. Then the output sinusoidal group amplitude is required as:

$$\text{Aom} = \sqrt{2\times P_0 \times R} = \sqrt{2\times 10\times 8} \approx 13V$$

This is closely related to power supply voltage selection and efficiency, which will be further discussed in the power supply section later. Since the input sine wave amplitude is 5mV, the voltage gain of the entire amplifier channel is Avo = 20 lg [13/(5* 10-3)]=70db.

Power amplifier application is Av2 = 20 lg (150 /10) =24 db. Therefore, the voltage gain of the preamplifier stage is: Av1 = Aom-Av2 = 70db-24db =48db. It can confirm the front stage adopts two stages.

2.2 Calculation of preamplifier stage

The preamplifier stage mainly completes the voltage amplification task of small signals, and its distortion degree, noise and pass-band have the greatest influence on the system, which should be given priority. High quality operational amplifier is adopted, with high signal-to-noise ratio, wide pass-band, good linear small signal amplification. The gain of the first stage is Av1= (30K/600) =34 db. The second level pre-gain is Av2 = (100 K/3.3K) = 30 db.

Considering the wide range of input signals, Rw1 is used as a voltage divider to change the gain of the whole system. In order to stabilize the working point of the power amplifier, the capacitor coupling between the front stage and the power amplifier stage is adopted.

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

2.3 Calculation of power amplifier

The current gain of the two pairs of tubes Q4 and Q5 at the final power stage β is about 100, and the output tubes Q3 and Q7 are about 40. The two key parameters of these two types of tubes are characteristic frequency f_T and maximum allowable dissipated power PCM of collector.

The relationship between the characteristic frequency f_H and the upper limit (drop 3dB) frequency of such a large circuit is as follows: $f_T = \beta * f_H$

The rise time t_r of the system step response has the following relationship with the upper limit frequency f_H of the amplifier circuit: $t_r * f_H$ = 0.35.The characteristic frequency of the drive tube is: $f_r \geq (0.35/t_r)\beta_h = (0.35/12\times10^{-5})\times100 = 3MHz$.

The characteristic frequency of the output tube is $f_r \geq (0.35\times12\times10^{-5})\times40 \approx 1MHz$. According to the above calculation and considering the improvement of the index and engineering practice. The push tube is selected as the pair tube 1815/1855. The output tube is selected as the field effect tube. The parameter that can meet the design requirements is: $f_T = 60MHz, P_{CM} = 150W, V_{CBO} = 180V$.

2.4 Calculation of power supply circuit

As mentioned above, the amplitude of sine wave output of this circuit is 13V. Considering the improvement of efficiency, the closer the power supply voltage of power amplifier level is to 13V, the better. However, considering the pipe consumption and other factors, a power supply of 12V, namely 24V, is selected.

If the large current of the amplifier level flows through the common ground, a voltage drop will be generated. This will interfere with the front stage. The whole system contains both large signals and small signals, so enough attention should be paid to anti-interference. Therefore, anti-interference measures of single point grounding should be adopted, that is, a ground is used for the pre-stage and a ground is used for the power amplifier. Finally, two single points are connected to the common ground of the transformer.

2.5 Measure of sampling circuit

Power sampling feedback circuit, because the power supply voltage is relatively high, direct sampling is easy to burn out the circuit through a voltage error meter, differential amplification, then AC/DC conversion.

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

The output power sampling circuit, because the output signal is AC, first put the signal into the RMS conversion circuit, then carry out amplification, and finally carry out AC/DC conversion.

3 The Comparison between Design Index and Actual Index

3.1 Input impedance test of power amplifier circuit

The test equipment is dt-9200 digital multi-meter. Test method: the input impedance Ri is the equivalent impedance of the amplifier input. In the measurement, a 1M resistor is firstly connected to the signal source in series to turn it into a signal source with high internal resistance. The no-load voltage U1 is measured by an audio voltmeter, and then the signal source is connected to the input end of the amplifier by a closed switch. At this time, the milli-voltmeter data drops to U2, and then the following formula can be used for calculation. $R_i = [U_1/(U_1 - U_2)] \times 1M\Omega$

3.2 Output power and non-linear distortion factor test

The test equipment includes MOS-620CH oscilloscope (20M), EM1642V function generator and BS3A distortion measuring instrument. Test results see table.1

Table1 Vin =5mV（peak-peak）

f / Hz	1	10	100	1K	10K	20K	50K	100K
γ_{in}	3.0%	1.0%	0.33%	0.32%	0.35 %	0.51 %	0.62 %	0.58 %
γ_{out}	0.45 %	0.40%	0.32%	0.32%	0.50 %	0.63 %	0.71 %	2.0%
γ	0.21 %	0.083 %	0.061 %	0.121 %	0.37 %	0.42 %	0.66 %	1.03 %
V_{out}/V	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.0
P_{out}/W	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.0

3.3 Measurement of noise power

The test equipment is MOS-620CH oscilloscope (20M). Test results: the RMS of ac noise is 3.8 mV. P noise = $(3.8 \times 10^{-3})^2 / R_L = 1.805\mu W$

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

3.4 The efficiency test

The test equipments have MOS-620 oscilloscope, DT-9200 digital multimeter, EM1642 function generator.

Test results is that under the premise of rated power, no power supply supply equivalent current IE= 0.312A, output power equivalent voltage U0= 9.3v.Known: double power UE = $\pm 12V$, load equivalent resistance RL=8 Ω .

P power supply =2UE $\times I_E = 2\times 12\times 0.312W = 15.0W$

P output equivalent power = $U_0{}^2 / R_L = 9.3^2 / 8W = 10.89W$

The efficiency test is $\eta =$ 72.6%

3.5 Power sampling circuit measurement accuracy test

According to the test method 3.4, the measured supply power is: P power supply = 15.0w, the output equivalent power is: P output equivalent power = 10.89w, and the efficiency is: $\eta =$ 72.6%.

After sampling circuit, true RMS value and analog-to-digital conversion are calculated by MCU, the power supply power is: P power supply power 1= 15.88W, the output equivalent power is: P output equivalent power 1= 10.97W, and the efficiency is: 69.0.The sampling circuit measurement error is: $\pm(100\% - \eta_1 / \eta) = \pm$ 3.6%.

3.6 The technical index of power supply

The technical index of stabilized voltage power supply is divided into two types. One is characteristic index, including allowable input voltage, output voltage, output current and output voltage regulation range. The other is quality index, which is used to measure the stability of the dc voltage out of the box, including the voltage stabilizing factor (or voltage adjusting factor), the output resistance (or current adjusting factor), the ripple voltage (ripple factor) and the temperature factor.

The peak value of ac voltage component was superimposed on the output voltage, which measured by oscilloscope on the order of milli-volt. The effective value can also be measured by ac milli-voltmeter, but the ripple is not sine wave, so there is some error. When the load current Io and ambient temperature To remain unchanged, the relative change of the input voltage causes the relative change of the pick voltage. That is the voltage stabilizing coefficient (Io= constant, To= constant).

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

$$S_v = \frac{\Delta V_0 / V_0}{\Delta V_i / V_i} \tag{1}$$

In general, the power frequency voltage 200V $\pm$10% is taken as the change range. And the percentage of the relative change of the output voltage, when the relative change of the input voltage is 10% ,is taken as the indicator to be measured as the voltage adjustment rate, namely:

$$S = \frac{1}{U_o} \frac{\Delta U_0}{U_i} \times 100\%, \quad \Delta U_i = 0 \tag{2}$$

The voltage regulation system and voltage regulation both show the influence of the input voltage change on the output voltage, so only test one of them will been. The output resistance is the same as the output resistance of the amplifier. Its value is the absolute value of the ratio between the change of output voltage and the change of output current. When the input voltage remains unchanged, that Output resistance is:

$$r_0 = \left| \frac{\Delta U_0}{\Delta I_0} \right|, \qquad U_i = \text{constant} \tag{3}$$

In engineering, the relative change of output voltage generated, when the output current Io change from 0 to the maximum quota value is commonly used to characterize this performance, which is called current regulation, namely:

$$S_1 = \frac{\Delta U_0}{U_0} \times 100\%, \quad \Delta U_1 = 0 \tag{4}$$

Both output resistance and current regulation indicate the effect of load current changes on output voltage, so only one of them should be tested.

3.7 Required comparison between test and actual indicators.

The test equipment is MOS-620 oscilloscope, EM1642V function generator. Test results: the attenuation degree measured at 50Hz is 7.2db as table 2.

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

Table2.Data of tests

Item	Band-width	input impedance	noise RMS	measure accuracy	distortion	output power attenuation	machine efficiency	POR
Demand indicators	20~20KHz	600Ω	<=5 mV	≥5%	<1%	≥6dB	≥60%	≥5W
measured indicators	1~50KHz	597Ω	4.7 mV	3.6%	0.35%	7.2dB	72.6%	9W

As table2, the output power is measured when the input is 5mV, and the distortion is measured by the low-frequency power amplifier in the frequency band. It can be seen from the test results that the circuit has a good pass-band. High output power, low distortion and high efficiency. This is mainly due to the simple and practical design of the whole circuit. The power amplifier stage adopts ac and dc, and the preamplifier stage and power amplifier stage are both directly coupled.

Firstly, the low-layer superposition of the analog quantity is averaged, and preliminary prediction processing is conducted according to the average quantity to distinguish various data, and then appropriate features are selected to establish the state equation control model, embedded in such formulas as A(k)=Ba(k)+Bv(k), where A(k) represents the actual measurement of step k, Ba(k) is the initial quantity, and Bv(k) represents the change of step k.

According to the prediction model of the first step, the change of the NTH step is predicted, and the optimization scheme of power amplifier in the dynamic environment is designed by combining the simulation and digital mapping method aiming at energy saving in the super-dense environment and the heterogeneous multi-objective mapping method. The actual load of the application varies dynamically, and there are certain environmental factors, so it is necessary to continuously adjust and optimize the model according to the value of Bv(k).

It can be seen from the test results that this circuit has a good pass-band. The output power is also relatively large, distortion degree, high efficiency. This is mainly due to the simple and practical design of the whole circuit, the preamplifier stage and the amplifier stage are both directly coupled, and the power amplifier stage adopts ac-dc large loop negative feedback.

3.8 Important source program

```
// file name: main.c
//Name: low-frequency power amplifier
// 1. Real-time data collection.
```

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

```
// 2. Realize LCD display of relevant information.
// 3. To realize the judgment of keyboard keys and determine the corresponding operation.
// 4. Realize the detection of voltage and current.
// 5. Realize overload protection function. When the current is too large, cut off the PWM output
// 6. Realize the PID algorithm to track the voltage and realize the stable voltage output
    #include "public.h"
    #include "pwm_dac.h"
    #include "systick.h"
    #include "gui.h"
    #include "led.h"
    #include "adc.h"
    #include "printf.h"
/*******************************************************************************
    * Function Name: main
    * Description: Main program.
    *******************************************************************************/
    int main()
    {
      u16 value,value1,value2;
      float ad;
      u8 i=0,j,dat[7],dat1[7];
      pwm_dac_init();
      adc_init();TFT_Init();    LED_Init();printf_init();//
      TFT_ClearScreen(BLACK);//
      GUI_Show12ASCII(10,10,"This is a PWM-DAC Check!",YELLOW,BLACK);
      GUI_Show12ASCII(10,27,"Connect the PB6 PB0!",YELLOW,BLACK);
      GUI_Show12ASCII(10,100,"The DA Value is:",YELLOW,BLACK);
      GUI_Show12ASCII(10,117,"The AD Volage is:",YELLOW,BLACK);
      while(1)
      {     value=0;
            for(i=0;i<=10;i++)
            {     value=25*i;
                  TIM_SetCompare1(TIM4, value);//
                  delay_ms(1);
                  value1=TIM_GetCapture1(TIM4);
                  dat[0]=value1/100+0x30;
                  dat[1]=value1%100/10+0x30;
                  dat[2]=value1%100%10+0x30;
                  dat[3]='\0';
                  ADC_SoftwareStartConvCmd(ADC1,          ENABLE);          //
```

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

```
while(!ADC_GetFlagStatus(ADC1,ADC_FLAG_EOC)); //
                value2=ADC_GetConversionValue(ADC1);
                ad=value2*3.3/4096;
                value2=ad*100;
                dat1[0]=value2/100+0x30;
                dat1[1]='.';
                dat1[2]=value2%100/10+0x30;
                dat1[3]=value2%100%10+0x30;
                dat1[4]='V';
                dat1[5]='\0';
                GUI_Show12ASCII(160,100,dat,YELLOW,BLACK);
                GUI_Show12ASCII(160,117,dat1,YELLOW,BLACK);
                delay_ms(500);
                if(j>1)
                {     j=0;
                      GPIO_SetBits(GPIOC,GPIO_Pin_0);      }
                else
                {     j++;
                      GPIO_ResetBits(GPIOC,GPIO_Pin_0);
                }          }
     }          }
```

4 Conclusions

Under the condition of high fidelity the design power are fully satisfied, analog ammeter or power meter are mostly used for real-time power measurement at present. The average voltage is measured, sent to MCU for power calculation to get the actual power, and the instantaneous voltage is converted into the average voltage to get the accurate result of sample. With supply power measurement and single-chip processing, the power amplifier and the efficiency of the whole machine display real-time through LCD and conduce to digital processing and intelligent.

Acknowledgement

This paper is supported by 2019 college students innovation and entrepreneurship training program. (NO.1083319007)

References

[1] Xia Qinglai, Zhang Jinhong, LED (Light-emitting Diode) dual-dimming control system based on WIFI (Wireless Fidelity) network, J. Chinese Science Bulletin.56:2312-2319 (2011)

[2] Huang Fan, Yang Xianzhao, Chen Yang, Energy saving control of intelligent adjustable light LED luminaires based on Android, J.High Technology Letters. 7:703-711 (2016)

ISSN 2706-655X Vol.2, Issue 2: 16-29, DOI: 10.25236/IJFET.2020.020202

[3] Razzak Muhammad.Energy efficient distributed face recognition in wireless sensor network(J). WirelessPersonal Communications, 3:571-582(2011)
[4] Xiaoqin Li, The design and implementation of LED dimming and toning luminaire with wireless remote control, J.Microcomputer & Its Applications.14:86-88(2016)
[5] Zhou.S, Niu.Z, A Framework for Scalable Collaboration in Heterogeneous Networks with Cognitive Synergy[J], IEEE Wireless Communications, 8, 133-139(2013)
[6] Cheng J H, Sun D W. Rapid and non-invasive detection of fish microbial spoilage by visible and near infrared hyper spectral imaging and multi variate analysis[J]. LWT - Food Science and Technology, 62 (2): 1060-1068(2015).
[7] Rani R Ranjani, Ramyachitra D, Brindhadevi A. Detection of dynamic protein complexes through Markov Clustering based on Elephant Herd Optimization Approach. [J]. Scientific reports,9(1).106-110(2019)
[8] Ding Dushu, Zhao Hui, Low-frequency power amplifier[D], Graduation Project Set ,2010
[9] Liang Fan. Design on video monitoring system of smart plant growth cabinet based on Internet of things and Android platform[J]. Chinese Agricul Tural Mechanization.459-62(2016)
[10] Steffen Waldherr,Diego A. Oyarzún,Alexander Bockmayr. Dynamic optimization of metabolic networks coupled with gene expression[J]. Journal of Theoretical Biology365(2015)