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DC Supply System Detector of UAV

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1. Introduction

This chapter introduces an embedded smart detector in the DC supply system of an unmanned aerial vehicle (UAV) based on AT89C2051, which can measure load insulation failure in direct current supply system and insure that UAV can operate at steady status. The measuring principles are analyzed first in this chapter and the system design schemes of software and hardware are given out as well. Finally, the measure error has been analyzed and counted. Compare with the Hall instrument, this detector possesses characteristics of low-cost, low-power consumption. And this device has also high measurement precision, and high reliability. Practical experiments show that the sensor system, of which the measurement precision achieves 0.01mA, could meet the demands of detection accuracy, achieve the expected criteria of design, and could be spread.

Unmanned Air Vehicle (UAV) is entering development rapidly since the Middle East wars in last century[1], which is applied to more and more fields, and at the same time a lot of researchers have been engaged in the research. The study of various sensors is always one of key technologies of UAV, this paper mainly engaged in a smart sensor for load insulation failure detection in the DC supply system of UAV.

In the present of DC supply system[2]-[3], Hall instrument is commonly used to detect unbalance status in the load current, which has characteristics of high detection precision, but high expensive price accordingly. So, in one system, simultaneous using two or more hall instruments are very costly and, further, measurement data can not be calculated on-line, and also increase the burden of the detection and computation of the upper PC.

Therefore, a smart sensor based on AT89C2051 is presented in this paper, which can measure load insulation failure in direct current supply system and possess characteristics of low-cost, low-power consumption, and easy to use. This kind of sensor will be pulled-on the positive-negative polar line of each directly current branch circuit. When insulation level of every loop is normal, the current passes through the sensor will have the equal value, and the opposite direction (notice that the current which flow across these coils terminal is defined I_+, the negative current is I_-, and the composed current is ΔI. Then the zero flux condition will be tested in the synthetic magnetic field of direct current

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of the sensor, otherwise the output will be nonzero due to $\Delta I = (I_{+} - I_{-})$. Therefore, by going make a circuit of the output state of the sensor to determine if the loop occur ground fault in direct current supply system. After fault recognition, through detecting data by the sensor, the function that processing fault information and sending alarm signal will be accomplished.

2. Measurement Principle and Hardware Circuit

2.1 Measure Principle

This smart sensor is mainly used to measure unbalance current in each branch circuit, and check circuit if over-current occurs due to overload or else reasons. Coil is the key testing component of this smart sensor, and is also an important unit in the oscillatory circuit. Branch wire that was measured crossed through the center of coil. When synthetic direct current in the loop fluctuate ΔI (magnetic flux produce $\Delta\Phi$ changed, and at the same time coil current produce ΔL_x changed), frequency loop of the oscillatory circuit will change consequent, and then test the variation of frequency Δf to compute current value crossed.

The relational expression can be described as follows in an ideal case:

$$\Phi = \mu \frac{NI}{2R} a^2 \tag{1}$$

Where
μ — core magnetic conductivity;
a — radius of transverse section of endless solenoid core;
R — radius of annular core;
N — turns.

$$L = \frac{N\Phi}{I} \tag{2}$$

$$f = \frac{2R^2C - 3L}{4RLCln(2R^2C/L)} \tag{3}$$

Where R = 5.1 KΩ; C = 1NF.

However, the nonlinear relation exists between coil current and oscillation frequency, which can be detected by conducting experiments, and it is difficult to test current directly. Methods are taken to solve the above problem: firstly, we have a testing experiment and obtain the relation curve between the frequency of the prototype and the corresponding current, and then obtain linear equations of several intervals by piecewise linearization of the curve. Secondly, obtain computing equations best suited for this device by analyzing and comparing the frequency calculated with the data in the table. Finally, actual current value can be calculated using the equation.

2.2 System Design

The whole system architecture of sensor is consisted of several modules: CPU circuit, watchdog circuit, communication circuit, power module and measurement circuit, which is shown in Fig.1.

1) CPU circuit

The CPU chip of smart sensor used is ATMEL AT89C2051 single chip[4], which provides the following features: high performance, ease to use, and high function-price ratio. This chip has 2K flash ROM built-in and be compatible with MCS-51™ Products. The CPU performs the function that records the frequency produced by the oscillatory circuit, and computes the current value according to the relation curve of unbalance current (ΔI) and the oscillatory frequency (Δf). In addition, the CPU is also in charge of the task as communication interface to the Upper PC.

2) Watchdog circuit

MAXIMUM X25045 programmable chip[5] is used in the watchdog circuit, which initialization program is stored in the AT89C2051 chip.

3) Communication circuit

The communication circuit function is mainly performed by MAX485, which is low-power transceiver for RS-485 communication.

Compared with RS-232 communication, the RS-485 communication features high transmission speed and far transmission distance, which is commonly the first-chosen to the lower system. The communication task is controlled by the single chip.

4) Power module

Operating voltages of this system are +5V and +6.5V, which are converted by the voltage regulator chip TL750L05C [6], +6.5V voltage regulator tube and voltage regulator diode from ±8V supply power.

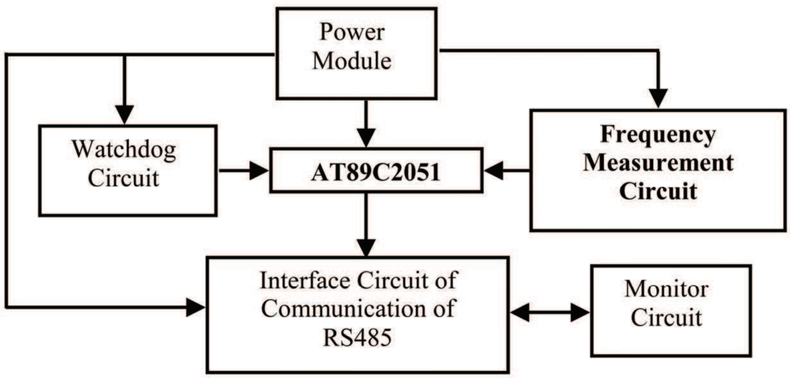

Figure 1. Block diagram of this sensor system

5) Oscillatory circuit

The oscillatory circuit is the key component of frequency measurement circuit, which is consisted of operational amplifier TLE2141CP[7], coils, resistor - condenser oscillatory circuits and high speed diodes, and which operate principle is that the oscillatory frequency of the whole oscillatory circuit will change as the unbalance current flowing across coils center work a change, then the unbalance current value can be calculated by MCU by measuring the varying quantity of the input voltage frequency. Structure diagram is shown in Fig.2 (the direct current resistance value is 6.22Ω in this sensor, and the inductance value is about 100mH as no current flowing through this sensor).

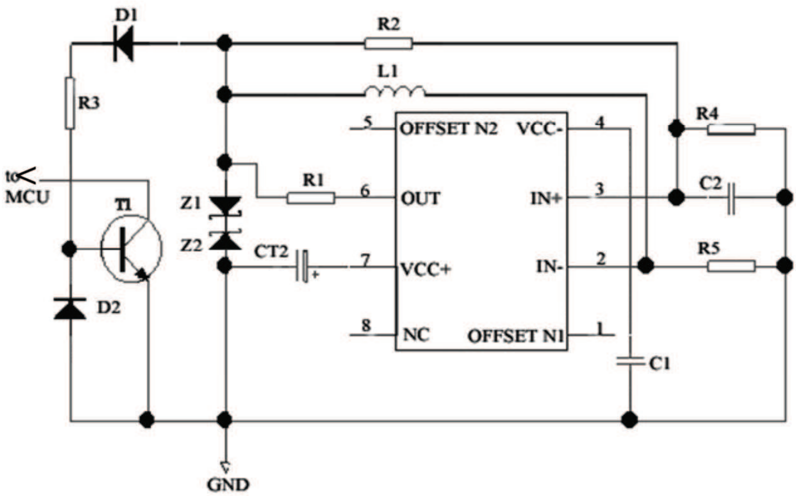

Figure 2. Structure diagram of the oscillatory circuit

3. Software Flowchart and Measurement Methods

3.1 Measure Principle

Software flowchart is shown in Fig.3.

3.2 Introduce of Measurement Methods

Equations (1-3) show that it is complicated to compute the frequency directly, however, in view of frequency range (about 75HZ ~1000HZ), the relation between the value of the machine oscillation cycles tested and current calculated is linear in the smallest possible interval. So, a curve can be obtained by taking the method of measuring oscillation cycle in programs[8], which is shown in Fig.5, and then process piecewise linearization. The lateral coordinate represents machine cycles value tested (the machine cycles value tested obtain by converting from frequency in the table 1, and the vertical ordinate represents current calculated (unit: mA). To improve the measurement precision and extend the measuring range[9], the equation coefficient is verified by taking different approaches, such as multi-byte addition, subtraction, double byte multiplication, multi-byte cycle shift division. As practical situation stand, the precision of the current calculated, which achieves 0.01mA, can satisfy the request of measurement precision.

The oscillation cycle value begins to be tested by the MCU at the T1 time (the waveform shown in Fig.4, which close to the square wave is commutated by the diode, is produced by the Wien bridge oscillatory circuit.). However, the formal measurement sets to work at the T2 time when the wave between the T1~T2 time slot was removed. The T2~T3 time slot is a

complete cycle and the data tested will be stored in the MCU after the measurement is completed.
By the same above method, the MCU test 30 groups of cycle data in total and make digital filtering respectively at the same time, then calculate the average value of cycles and look for the interval of current tested by the given data table. Finally, according to the corresponding interpolation computation in the locked intervals, the change value of the current of a cycle will be obtained.

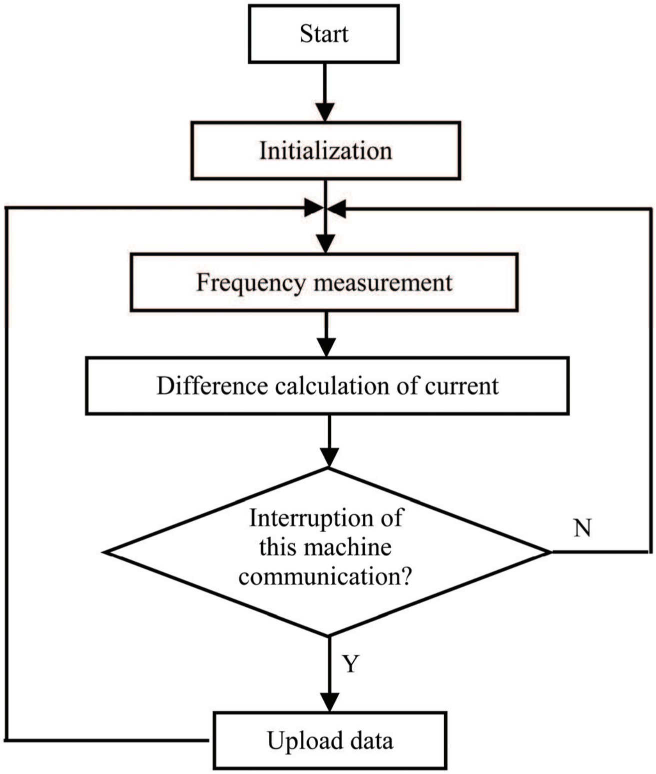

Figure 3. Software flowchart

4. Result Analysis and Methods of Improving Precision

4.1 Result Analysis

During the process of software debugging, part of current values, which are shown in Table 1, are obtained by the actual measurement, and then the subsection curve, shown in Fig.5, will be obtained due to the value. As is shown in Table 1, the current error rate is small, which usually in about 0%-0.8%, therefore the current precision is 0.01mA, which can meet the requirement of the actual project.

Actual current value flowed through coils (mA)	Current value tested by the sensor(mA)	Absolute error rate ×100%
0	0	0%
83.14	83.3	0.2%
96.85	96.98	0.14%
144.69	143.78	0.62%
160.77	161.44	0.45%
192.93	193.63	0.36%
225.08	226.25	0.52%
241.16	246.51	0.59%
305.47	304.05	0.46%
353.7	351.12	0.73%

Table 1. Part of the fault current data Measured by the smart sensor

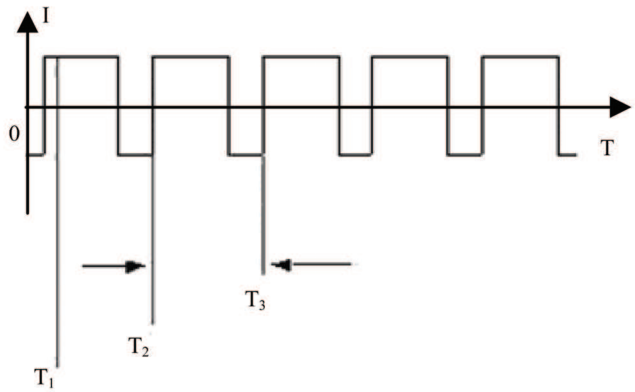

Figure 4. Computing model of a complete cycle

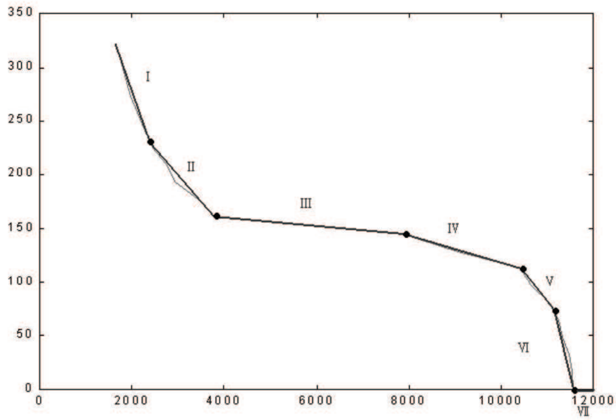

Figure 5. Relation curve between coil current (y-axis) and oscillation cycle (x-axis)

4.2 Methods of Improving Precision

The measurement errors originated from the following sources in this sensor:

1. Relate to the coil sensitivity $\Delta L_X / \Delta I$: The coil inductance changed ΔL_X in direct proportion to the coil current changed ΔI within a certain range, namely $\Delta L_X \propto K \cdot \Delta I$, where K is the proportional coefficient. Coils aging (mainly the heat loss of the coils) would lead to not only decline sensitivity, but also reduce the proportional coefficient K. The resolve method is to replace coils at fixed periods.
2. Relate to the oscillation cycle of coils measured: It would produced errors by measuring the oscillation cycle by calculating the machine cycle, and the maximum frequency value tested is 1KHZ due to the actual measurement, so the biggest error produced (the crystal oscillator of AT89C2051 is 11.0592MHZ) is $(12/11.0592\mu s)/1000\mu s \times 100\% = 0.185\%$ that can satisfy the request of the actual project.
3. Relate to the subsection lineal fitting by the measurement of curve. It can be seen that the effect of the lineal fitting is better within a certain range, however, the lineal fitting errors would be produced due to the little bias existed. The resolve method used is to take the direct interpolation method or increase points measured.

5. Conclusion

This sensor, which has small size, high ratio of performance and price, and high reliability, achieves good results in real operation and measures accuracy. The results show that this design scheme is feasible, could achieve the expected criteria of design and could be spread.

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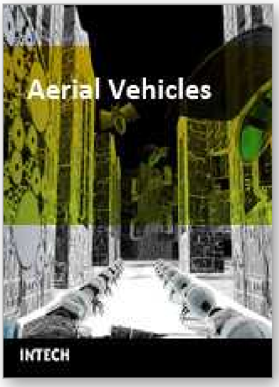

Aerial Vehicles

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This book contains 35 chapters written by experts in developing techniques for making aerial vehicles more intelligent, more reliable, more flexible in use, and safer in operation.It will also serve as an inspiration for further improvement of the design and application of aeral vehicles. The advanced techniques and research described here may also be applicable to other high-tech areas such as robotics, avionics, vetronics, and space.

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