

# Chapter 2

## Design of Multichannel Waveform Recorder of Aircraft Ground Electric Power Sources

Zhen Wang, Jianfei Si and Yuanfeng Zhang

**Abstract** A multichannel waveform recorder is raised to solve the puzzling problem of failures of aircraft ground power sources. The hardware system is established with embedded single-board computer PC/104 and multichannel parallel data acquisition card, etc. Windows XP Embedded and LabVIEW are used in software architecture. Strategies for automatic segmentation of massive data block are proposed. System testing is done on the medium frequency electric power source. Testing results show that this multichannel waveform recorder is easy to operate, accurate in measurement, and has good stability and portability. It can be used to monitor power supply of aircraft ground electric power source for a longtime, and thus is of high practical value and economic significance.

**Keywords** Aircraft ground power sources · PC/104 · LabVIEW · Automatic segmentation

### 2.1 Introduction

Aircraft ground electric power source is necessary for aircraft maintenance and ground engine starting [1]. In recent years, quality reduction of ground electric power source has led to many accidents such as starting failure, crash, reboot, and

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even over-burning. It is difficult to locate and analyze faults, because these failures seldom reoccur. Power source parameter recorders have been assembled on some new power units. However, it is said that only steady state parameters can be recorded, which play a feeble role in analyzing faults once the power fails. An effective means of locating and analyzing faults accurately is to record the power waveform by a data recorder [2]. But high price and complicated operation limit its promotion. A multichannel waveform recorder of aircraft ground electric power source at a lower cost is designed in this document. It can provide effective detection means of estimating electric power quality and locating and analyzing faults.

## 2.2 Technical Requirements Analysis

Various types and technological disparity of military aircraft bring high requirement for the ground electric power source. There are two kinds of them: vehicle electric power source and static power. They can provide low voltage DC power and medium frequency AC power. Some special ones can supply 28.5 V/57 V (boost) and 0–70 V DC power for different aircraft engines starting. Therefore, multichannel signals including AC voltage, AC current, DC voltage, and DC current should be recorded simultaneously. Detail specifications are as follows:

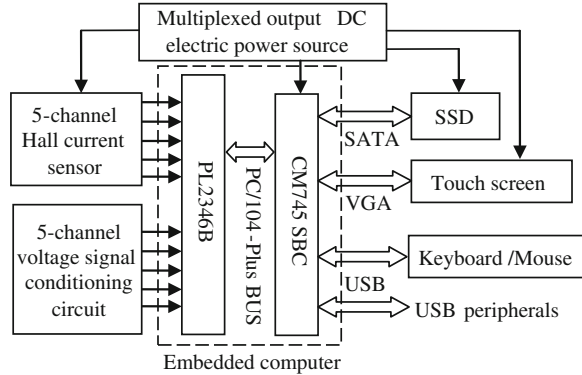
- a. 10-channel electrical parameters record: three-phase AC voltage (0–300 V), three-phase AC current (0–200 A), 2-channel DC voltage (0–100 V), 2-channel DC current (0–600 A, 0–3000 A).
- b. Sampling mode: Single channel 200 kS/s, parallel acquisition.
- c. Record duration: More than 1 h.
- d. Others: Well portability, wide temperature range, and anti-seismic, etc.

## 2.3 System Design

The hardware platform is mainly made up of embedded single board computer (SBC) PC/104 [3] and multichannel parallel data acquisition (DAQ) card PL-2346B [4]. Windows XP-Embedded and LabVIEW are used in software architecture.

PC/104 platform has many advantages such as small size, reliable electrical connection. Above all, it has high data handing capacity though under lower power dissipation. Windows XP Embedded is the successor to Windows NT Embedded 4.0. Based on the same binary files as Windows XP Professional, it enables us to rapidly develop reliable and full-featured devices.

**Fig. 2.1** Block diagram of hardware System



### 2.3.1 Hardware Implementation

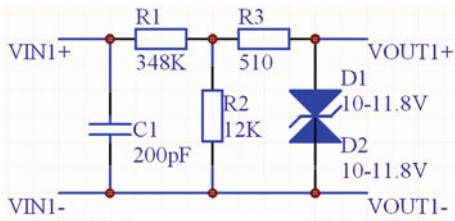
The hardware system is consisting of Hall current sensor, signal conditioning circuit, embedded computer system, DC electric power source, industry touch screen and solid state disk (SSD). Block diagram of hardware system is shown in Fig. 2.1.

**Hall current sensor:** Hall current sensor detects AC/DC electrical current and generates an analog voltage output in  $\pm 10$  V proportional to it. It runs in tracking mode to record waveform. There are 5-channel current sensors. Three of them are used for three-phase AC current measurement ranging from 0 to 200 A. One of the rests is used for low voltage DC current measurement ranging from 0 to 600 A. Actual current can be up to 2800 A when the electric power unit directly starts. So the last one is used for 0–3000 A, and it is mainly used to support direct starting of electric power unit.

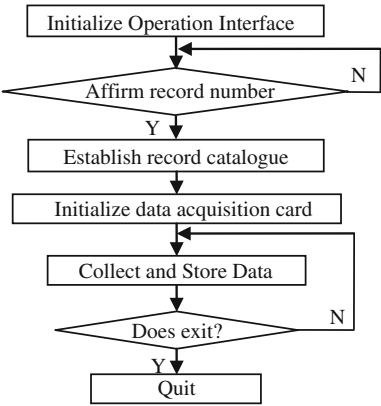
**Voltage signal conditioning circuit [5]:** In the conditioning circuit voltage signal can be reduced to suitable value for DAQ. It also delivers over-voltage protection and filtering function. Schematic diagram of single channel voltage signal conditioning circuit is shown in Fig. 2.2, in which RC filter, precision resistance, and fast recovery voltage-regulator diodes are included.

**Embedded computer system:** It is composed of AD-Link's CM745 SBC and ZTIC's multi-function DAQ PL2346. CM745 is an exceptionally high integration, high performance, compatible with PC/104 standard. Its features are as follows: Intel Atom™ Processor D525, up to 4 GB single channel DDR3 SDRAM, Intel 82574 Gigabit Ethernet, 4 GB SSD onboard, single Channel 18-bit LVDS and analog VGA. PL2346B is a 12-channel, multi-function DAQ module for PC/104-Plus form factor. The A/D on it features a sampling rate of up to 450 kS/s. So CM745 and PL2346B are particularly well suited to either embedded or portable applications and meet the size, power consumption, temperature range, quality, and reliability demands of embedded system applications.

**Fig. 2.2** Schematic diagram of single channel voltage signal conditioning circuit



**Fig. 2.3** Overall software flowchart



Multichannel DC electric power source: It supplies  $\pm 12, 5\text{ V}$  for sensors, computer, disk, and screen. Total power is less than  $100\text{ W}$ , and then the system's size can be controlled in a low range.

**2.3.2 Software Design**

Windows XP Embedded is used as the embedded operating system delivering the power of the Windows operating system in componentized form to rapidly build reliable and advanced embedded devices. Data integrity can be achieved. The software platform and development environment is LabVIEW. Overall software flowchart is shown in Fig. 2.3.

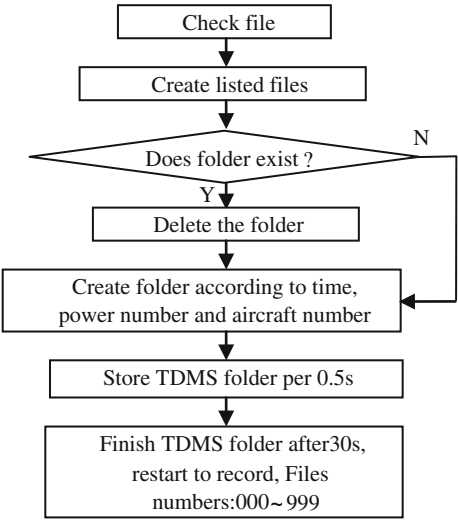
Waveform data format and size: Acquired data is 64-bit double precision floating point type [6], which are 8 bytes (1 byte = 8 bits). At the sampling rate of 200 k, 10-channel data size in a second is:  $200\text{ k} \times 10 \times 8\text{ byte} / 10242 \approx 15.26\text{ MB}$ .

Relationship between sampling rate, sampling time, and data size is shown in Table 2.1.

**Table 2.1** Relationship between sampling rate, sampling time, and data size

Sampling rate	Sampling time	Data size	Notes
200 k	1 s	16 MB	Reduce corresponding times when sampling rate is reduced
	1 min	916 MB	
	30 min	26.8 GB	
	60 min	53.6 GB	
	120 min	107.2 GB	

**Fig. 2.4** Flowchart of storing data segmentation



Workflow of data acquisition: To ensure data integrity, data acquisition must be synchronized with data storage. DAQ works in continuous mode and storage is done once buffer data is detected.

Automatic segmentation of data block: As mentioned, data size of 1 min is nearly 1 GB at 200 kS/s. When time goes by, data size increasingly increases, which results in huge occupancy of system resources. So strategies for automatic segmentation are adopted in the system. Flowchart of storing data segmentation is shown as in Fig. 2.4. Program schematic diagram is shown as in Fig. 2.5.

### 2.4 System Testing

The system testing is finished on AC power source DS053AT which can supply three-phase AC voltage (0–346 V) from 300 to 500 Hz.

Here, only medium frequency three-phase AC voltage is recorded as an example. Measurement of other types of single is similar to them. So, output of the

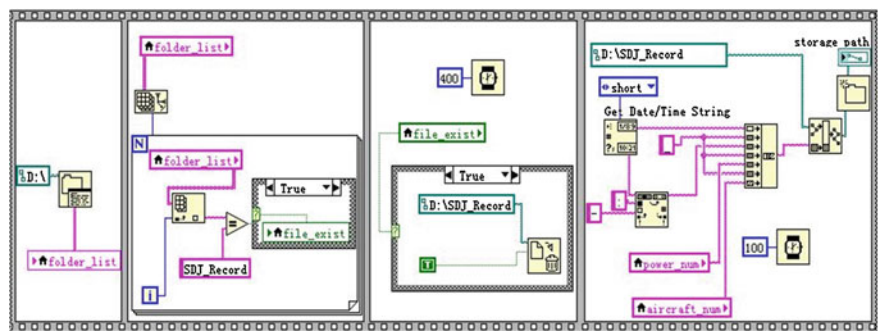


Fig. 2.5 Program schematic diagram

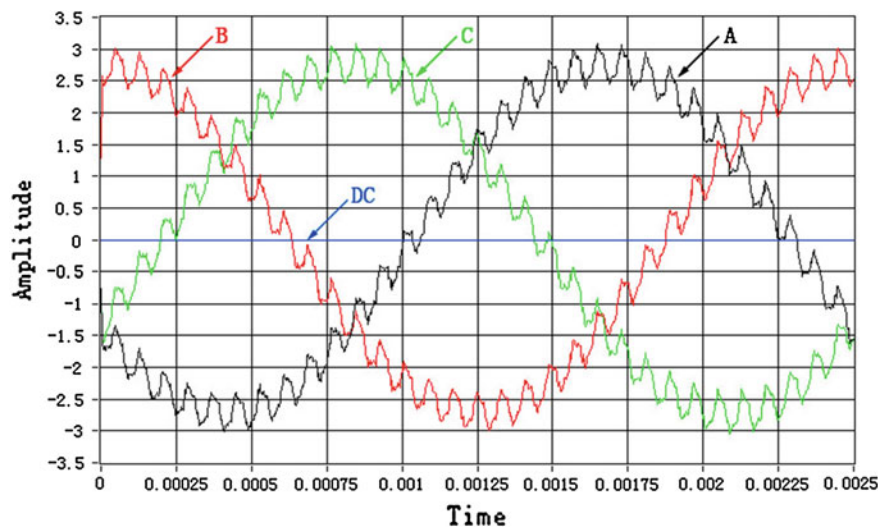


Fig. 2.6 Testing waveform

AC power source is set to 400 Hz, 115 V which is the input of the multichannel waveform recorder.

When recording, every execution time is less than 500 ms, which meets the requirement of that every data acquisition time is no more than 0.5 s. Waveform files are numbered correctly and every size is less than 500 MB. They can be easily transcribed. TDMS waveform data is opened by LabVIEW. Testing waveform is shown as in Fig. 2.6, in which A, B, C indicates every phase. We can get integrated waveform without DC element and serious distortion. Meanwhile, software testing verifies the system’s working stability during long hours.

## 2.5 Conclusion

A multichannel waveform recorder of aircraft ground electric power sources is proposed based on embedded computer PC/104 and DAQ PL2346B. The system can be used to monitor power supply of aircraft ground electric power source for longtime. The hardware selection and architecture, parts of software workflows are presented. To avoid huge occupancy of system resources by high speed recording, strategies for automatic data segmentation are adopted in the system, so that a single data size is limited and system efficiency and reliability increases correspondingly. After practical testing, the system can work reliably and steadily. Design requirements are completed. Nevertheless, response speed of software system could be improved and files' storage format should be optimized further.

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