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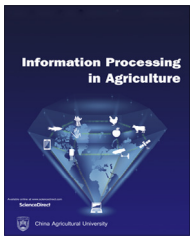


# Development of a portable multi-channel system for plant physiological signal recording

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ABSTRACT

Bioelectrical signals can reflect physiological state of organs or tissues in plants and have a significant potential value in research of plant stress tolerance. In order to study the relationship between environment factors and electrical signals in plant, a portable multi-channel physiological signal acquisition system which relevant in plant physiology research was developed. Environment parameters and electrical signals can be measured in different channels by the acquisition system simultaneously and the measurement data will be displayed in an embedded integrated touch screen which is the system processing core. The system was validated to be stable and reliable after the calibration and repeated experiments of recording electrical signals in *Helianthus annuus* L.



## 1. Introduction

Bioelectrical signals are important parameters for revealing physiological state in plants. Electrical signals in plants will participate in regulating plant physiological processes by environmental changes [1–6]. The study of electrical signals in plants can determine whether the plants are in normal status, and can reflect plant stress tolerance [7–9]. To investigate the relationship between environment factors and plant signals, a portable physiological signal acquisition system that can acquire plant signals and environment factors synchronously is demanded. However, presently, most commercial bioelectrical signal acquisition devices are designed for animals, and have a limitation on channel number and the input impedance (input impedance must be higher than $10^{10}\,\Omega$ for plant) [10,11]. All of them are difficult to meet requirements for plant physiological signal acquisition. In addition, almost all of the traditional plant bioelectrical signal acquisition systems are based on personal computer or laptop [5,12], however, those recording systems are cumbersome and not suitable to work in a greenhouse. In this study, a portable multi-channel physiological signal acquisition system for plant physiology research was designed. Using the embedded integrated touch screen as the system processing core, the device has realized system integration, and can meet actual needs of the portable, low-power, and easy-operation.

## 2. The prototype of system

Multi-channel physiological signal acquisition system consisted of hardware and software with the function of data acquisition and data processing. The system includes eight

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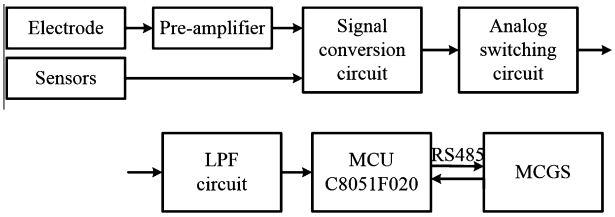


**Fig. 1 – The prototype of multi-channel physiological acquisition system.**

electrical signal channels, two light quantum channels, two temperature channels, and a humidity and temperature channel, which can achieve fourteen-channel signals at the same time according to the requirements.

Block diagram of the system prototype is shown in Fig. 1. The system has five parts as follows: (1) Sensors module, which includes temperature, humidity sensor and light quantum sensor etc. (2) Signal conversion circuits, which is composed of pre-amplification circuit, current-to-voltage conversion circuit and so on. (3) The digital to analog conversion, which is implemented by C8051F020 microcontroller built-in eight-channel twelve-bit ADC converter (Silicon Laboratories Inc. USA). (4) Communication module, which is implemented by RS485 transfer order and data between upper and lower computers. (5) The acquisition program is supported by Monitor and Control Generated System (McgsE7.6 (03.0002)).

### 2.1. *System hardware*

In order to completely record the electrical signals in plants which belong to weak signal source with high impedance, the system should provide high input impedance to avoid the distribution by the noises from amplifier, background or circuits [13–16]. Therefore, AD549 has been chosen, because it is an instrumental amplifier with high input impedance,


**Fig. 3 – The system main interface, including the software name (pointed by line 1); channel selection, historical curve, real-time curve and data storage (from top to bottom pointed by line 2) and a reset button (pointed by line 3).**

high CMRR and low drift to connect in-phase amplifier circuit (Analog Devices Inc. USA). It can obtain undistorted amplification signals magnified by ten times. The per-amplification circuit is packaged in a small box individually.

The control chip C8051F020 minimal system contains a clock circuit, a reset circuit, a JTAG circuit, and a reference voltage 3.3 V using an external reference.

According to the characters of voltage signal, light, temperature and humidity, the system uses a rail-to-rail amplitude output operational amplifier chip TCL2272 to connect signal conversion circuit (Texas Instruments Inc. USA). Signal input of A/D in C8051F020 was unipolar, however, the plant electrical signal was bipolar, thus the signal conversion circuit was applied by a TCL2272. A current-to-voltage conversion circuit was built because of the current signal of light quantum sensor. Temperature sensor was NTC thermistor with precision of 0.1 °C in a as voltage follower way. AMT2001 is temperature and humidity module (GuangZhouLeXiang Co. China), and humidity working range is 0–100%RH, voltage

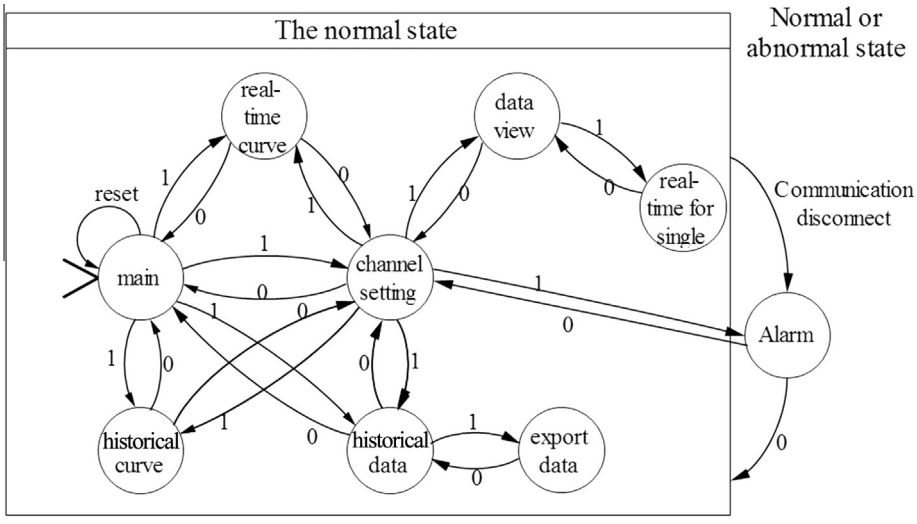


**Fig. 2 – The state machine diagram, in which input is keys or label, and "1" means enter another window, while "0" means back to previous window. When the device connection is interrupted, the software will be transferred to alert window automatically.**