

Design of small irrigation control system

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Abstract. The most potted plants have different live habits and require different soil moisture. So we designed a small irrigation control system to make the potted plants with different habits have more suitable soil environment to live. This system can detect the soil moisture of potted plants in real time and decide whether the potted plants need to be irrigated according to the set range of soil moisture. That realizes the automatic irrigation to ensure the survival conditions of potted plants.

1. Introduction

The most families planted potted plants to make their living environment beautiful and hope its can clean the air of living room, bedroom, and so on.

All kinds of potted plants have different living habits. Some loves water and can only survive in soil with high humidity. But some loves dry and can not live in soil with high humidity. So the family needs to irrigate plants in time to ensure its soil moisture.

2. Hardware Design

The hardware design of small irrigation control system includes piping design and electrical control design. For easy to extend the pipeline, the standard fittings such as pipe, quick joints and valves were selected. The main control unit of electrical control is designed based on STM32 microcontroller.

2.1. Hydraulic circuit of small irrigation control system

The hydraulic circuit of the small irrigation control system is shown in Figure 1, which is composed of a storage water tank, a water inlet valve, drain valves, an overflow valve, a hydraulic pump and a DC motor.

A pressure sensor is installed at the bottom of the storage water tank to detect the water level in the tank.

The hydraulic pump uses the diaphragm pump whose DC motor is integrated with the pump. The diaphragm pump has overvoltage protection. Furthermore, it's safe and convenient to use the PWM to change the speed of DC motor for adjusting the pressure of the pipeline in time.

A pilot-operated hydraulic relief valve is installed in the system to control the maximum pressure of the hydraulic pipeline. That increases the safety of the hydraulic system. The inlet valve is used to control the water replenishment of the storage water tank. When the water level is lower than the min value, the inlet valve is opened and the water flows from the inlet pipe to the sink. When the water level reaches the max value, the inlet valve is closed to stop replenishing water.



The drainage valve is used to drip irrigation or spray for potted plants, and each drainage valve corresponds to a special potted plants.

The pipeline is connected by quick connector, which is easy to disassemble and assemble and convenient for expansion.

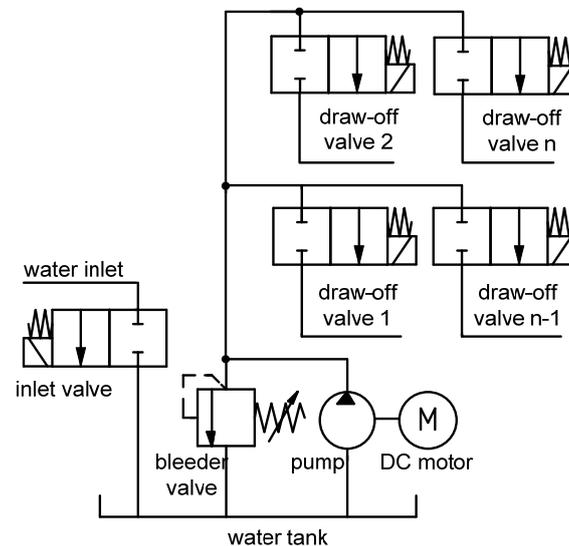


Figure 1. The hydraulic circuit of the small irrigation control system.

2.2. Control unit of small irrigation control system

The electrical control consists of the main control unit and sub control units. As shown in Figure 2, the main control unit and the sub control units communicate by RS485 bus, and the 12V DC power line and the communication line are concentrated in the same one cable. The cable between units is connected by aeronautical joints and the pipe between units is connected by fast joints.

STM32 is selected as the main microprocessor of the control units which include display module, key module, soil-moisture detecting module and drain valve control module. The main control unit also includes WIFI module, water level detecting module, inlet valve control module, diaphragm pump control module and power management module. The sub control unit includes the address setting module.

If the number of potted plants to be irrigated is small and their distribution area is close, the system which only includes a main control unit can work perfectly without the sub control unit. If the number of potted plants is large, it is necessary to extend sub control units. We can set the address of the sub control unit, and connect the cable in which there is power supply and signal line with the aviation connector, and connect the liquid circuit by quick connector. Then a control system is built.

The STM32 microprocessor, which is produced based on the ARM Cortex-M core, has many advantage such as high performance, low cost and low power consumption. It can be programmed in-line by MBED and there are many peripherals formed in the chip. The main control unit selects STM32F401, and the control unit selects STM32F103 [1, 2].

ESP8266 is selected as the WI-FI module. This module can complete a self-contained Wi-Fi network or dismount all Wi-Fi network functions by other processors.

NodeMCU, an open source Internet platform, has developed firmware for ESP8266. That firmware enables ESP8266 to support the Lua language. We can program with Lua program to make ESP8266 work in direct transmission mode. In direct transmission mode, the information sent by the mobile client can be sent directly to the main control unit through ESP8266, and the information sent by the main control unit is sent to ESP8266 through the serial port, then a package packed the information is sent to mobile clients after ESP8266 encapsulation. That means the main control unit can

communicate directly with the mobile clients through the serial port and realize the remote monitoring for users.

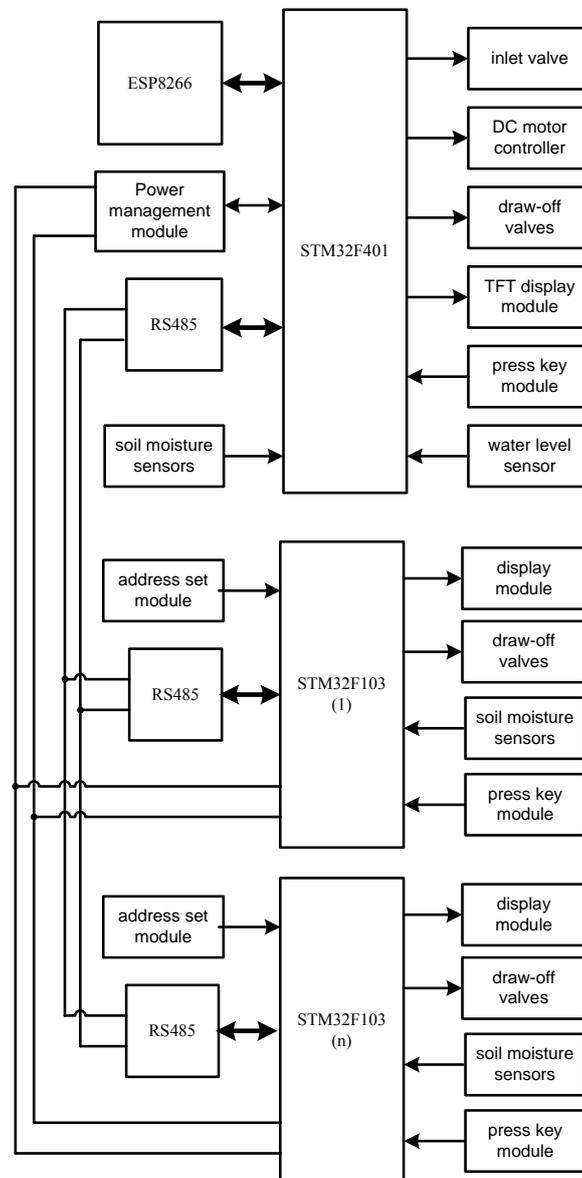


Figure 2. The system block diagram of the small irrigation control system.

A TFT screen is selected as display module which can display large amount of information with friendly man-machine interface in static display mode [3]. The soil moisture can be detected by the soil moisture sensor. The analog output signal of soil moisture sensor is sent to the analog data acquisition channel of the control unit to convert into digital processing after being filtered. The best soil moisture range of different plants is determined by empirical method.

In order to reduce the volume of the control unit, the press key module selects independent press key extension mode. The pin which would be used as press key extension pin is set as DigitalIn and PullUP mode, so the pull resistance can be omitted. And the function of press key is reused by software.

2.3. Driving unit of small irrigation control system

The inlet valve and drain valve are driven by 12V DC voltage, and their working current is only 0.2A. Therefore, ULN2003, a seven-Darlington integrated circuit, can meet the control requirements. The address of sub control units is set by a dial switch. Considering the control scale and the response speed, the dial switch is a four-bit dial switch which can set the address between 0 and 15.

The diaphragm pump is also driven by DC 12V, but its maximum working current can reach 2A. That is over the rated working current range of ULN2003, so a power MOSFET is used to control the diaphragm pump. STD95N is selected to control the diaphragm pump. The parameters of the STD95N are shown as follows: The typical voltage of the gate threshold is between 2V and 4V. Static drain-source on resistance is less than 6.5m. Drain-source voltage is 40V. Drain current is 80A. The maximum power is 110W [4]. All parameters of STD95N meet control requirements.

The pressure sensor uses Taiwan MEMS (Micro-Electro-Mechanical System) pressure sensor MIS-2503. The range of detection is suitable for detecting water level and the typical power supply voltage is 3.3V. Response time is about 1ms. When the temperature is between 0 and 85 degrees Celsius, full scale output is 2.85V and full scale span is 2.7V. It can be directly join with the AD pin of STM32 microprocessor. Different from the others series of pressure sensors, MIS-2503 have six pins but only four function pins. For example, the NO.3 pins and the NO.4 pin are Vsupply pin named VCC. As the only output pin, the NO.5 pin is signal output pin named Vout through which MIS-2503 connects with microprocessor analog acquisition channel. The NO.6 pin is GND pin. Please pay attention to the GND pin and VCC pin, there is a 0.1uF decoupling capacitor between them.

The measured pressure value can be calculated by the following formula [5]:

$$P = (V_{out} - V_{offset}) \cdot V_{range} / 2.7 \quad (1)$$

In the formula: P is the pressure value. Voff is the offset voltage, the output voltage of sensor without pressure applying. Vout is the output voltage of sensor when pressure applied. Prange is the pressure range of sensor.

The detected water level can be calculated by the following formula:

$$h = P / (\rho \cdot g) \quad (2)$$

In the formula: h is the water level. ρ is the density of water. g is gravity acceleration.

Merger formula (1) and formula (2), we can get:

$$h = (V_{range} \cdot P \cdot (V_{out} - V_{offset})) / 2.7(\rho \cdot g) \quad (3)$$

3. Software Design

The system software of control unit based on MBED is developed by C++ language. The program debugs in Keil uVision5. The program of Mobile client is developed by easy for Android.

The main control unit's software is composed of WIFI communication processing module, sub control unit communication module and main function module. The software of the sub control unit does not include the WIFI communication processing module, but instructions parsing function is added to main function module of the sub control unit to analyze the instruction from the main control unit and deal with the request for the main control unit. The functions of TFT display, digital input, digital output, analog input and so on can be realized by class functions. The system can run in automatic mode or manual mode. When getting the control instructions from mobile client, the system switches to manual mode automatically. The main flow chart of system control program is shown as figure 3. The flow chart of the main function in automatic mode is shown as figure 4.

The run mode of system can be changed by key or remote mobile clients. The code from mobile clients will be received by serial interrupt service program. The driver program of key is based on external interrupt service program. In auto mode, the user and remote mobile clients can not control the pump and the valves directly by press key. IF remote mobile clients want to control the system, the mode of system will changed form auto mode to manual mode automatically by special code. IF the local user wants to control the system by key, he must change the run mode to manual mode by press key.

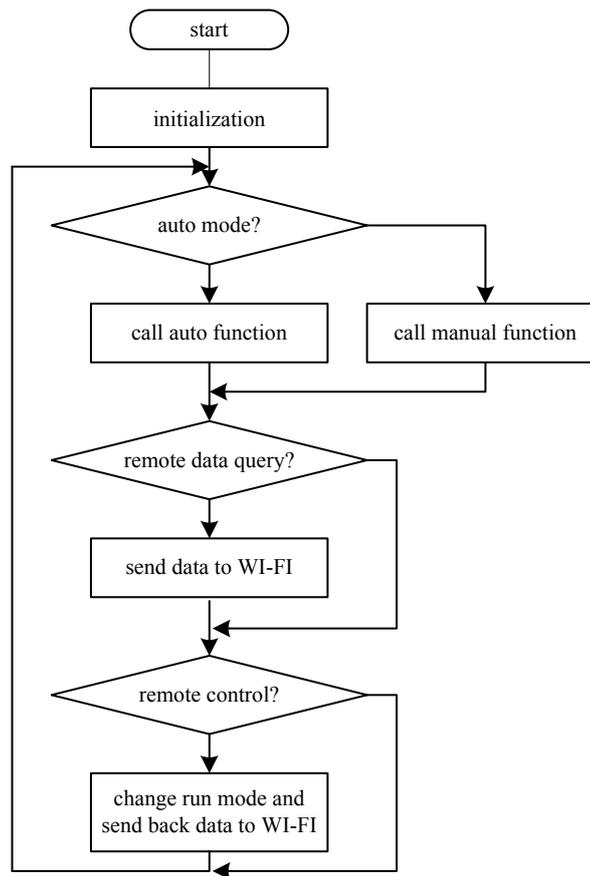


Figure 3. The main flow chart of system control program.

In the communication processing module, the code 0x0A and 0x0D is defined as the end sign of data packet [6]. The Microprocessor can receive data and send data bases on serial interrupts program. When a valid data package exists, the back value of receive function is 1 and the data will be copied into reception memory. If there is not data packet, the back value of function is 0.

It is necessary for realizing transparent transmission function to write the driver program of ESP8266 in Lua language or rewrite the firmware. The following lua code can realize the transparent transmission function of ESP8266 [7, 8].

```

uart.setup(0,9600,8,0,1,0)
wifi.setmode(wifi.STATION)
wifi.sta.config('ABCD', '88888888')
wifi.sta.autoconnect (1)
function receiver(sck, data)  uart.write(0,data) end
uart.on("data", '\r', function(data) if global c~=nil then global c:send(data) end end, 0).

```

4. Conclusion

After the small irrigation control system was put into use, the automatic watering problem of potted plants has been effectively solved. The system can detect the soil moisture of the potted plants and display the data in real time. The system controls potted irrigation according to the set of soil humidity range, and effectively ensures the better growth of potted plants. Although soil moisture sensors may have a certain effect on plant growth, so far, no abnormal growth has been found.

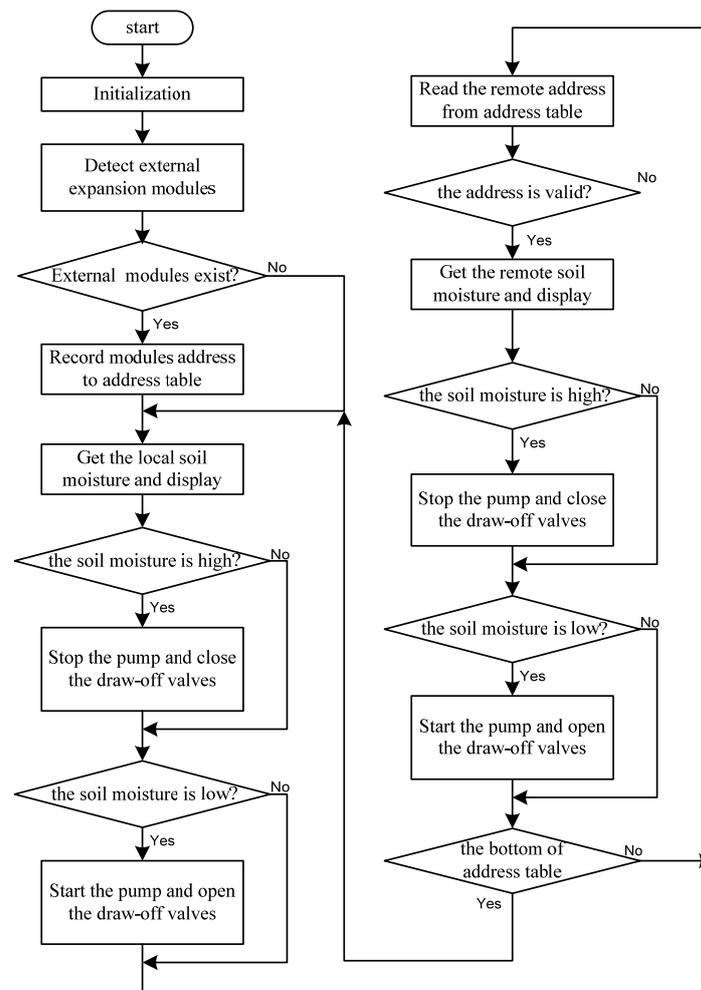


Figure 4. The flow chart of program in auto mode.

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