An Online Software Upgrade Method for Intelligent power Distribution Terminal

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ABSTRACT

In order to realize intelligent power distribution terminal to modify and improve software in operation continuously, stably and reliably, this paper designs an online upgrade method for intelligent power distribution terminal to renew the software based on the Flash memory of LPC2138. And the online upgrade solutions, the design of communication protocol, division of program storage space, online updating algorithm and security algorithm are discussed in detail. The experimental results show that the design achieves the performance required. It can complete the intelligent power distribution terminal online upgrade safely and reliably for practical projects.

Categories and Subject Descriptors

D.1.2 [**Programming Techniques**]: Automatic Programming.

General Terms

Algorithms, Design.

Keywords

Intelligent power distribution terminal; software upgrade; In-application programming (IAP)

1. INTRODUCTION

Intelligent power distribution terminal is a very important device in electric power system, which can realize power network working safely, reliably and effectively. According to the collected data, it is able to control the network equipment intelligently. It need to be modified and perfected constantly for application loopholes are inevitable. Once there were some bugs in the software, we could only exchange the devices or update the software with the programming interface. But software update of power system control equipment must be finished in the operation process. So that a method for software upgrade online applied in the intelligent power distribution terminal has an active effect with low cost and convenient operating.

Nowadays, there are two commonly used software update method for the intelligent power distribution terminal: In-System programming (ISP) and In-Application programming (IAP), which many MCUs' Flash memories support. For the ISP, it needs the condition of external trigger [1]. When upgrading, the equipment must be back to factory or taken down for technician to operate, which is neither convenient but also to the disadvantage of the power grid operation, nor causing the costs [2]. IAP is more agile to upgrade software, through the special design of boot program memory. It can program the Flash by calling the IAP function to upgrade the software, which means it can program while the device is operating.

This paper puts forward an online software upgrade method for intelligent power distribution terminal based on wireless communication, which can be convenient, reliable to update software. Abnormalities won't cause the system crash when software updating.

2. THE DESIGN OF THE INTELLIGENT POWER DISTRIBUTION TERMINAL TO UPGRADE SYSTEM

2.1 IAP Technology

The system of this paper makes use of LPC2138 as its MCU [3] [4].The LPC2138 is based on a 32 bit ARM7TDMIS-S CPU. It has 32kb RAM and 512kb Flash memory, which supports ISP or IAP via on-chip bootloader software. In-Application programming (IAP) is the performing of erasing or writing operations on the on-chip Flash memory as directed by the end-user application code. Single Flash sector or fll chip erase is 400ms and programming of 256 bytes is 1 ms. Besides, it has multiple serial interfaces including two UARTs, two Fast I2C-bus (400 kbits), SPI and SSP with buffering andvariable data length capabilities. IAP code of LPC2138 is in BootBlock, written by manufacture before leave the factory [5]. The Flash boot loader provides the interface for programming the Flash memory. User shall not modify the IAP code, but can call it. IAP program is the Thumb code, locating at address 0x7ffffff0. It is not only to realize the jump but also to realize transition status, when calling IAP function. Because IAP needs to use the top 32 bytes of RAM, users have to change the stack space position [6] [7]. The IAP function could be called in the following way using C. This section is taken from the User Manual.

Define the IAP location entry point.

#define IAP_LCOATION 0x7fffffff1

Define data structure or pointers to pass IAP command table and result table to the IAP function.

unsigned int command[5];

unsigned int result[2];

Define pointer to function type, which takes two parameters and returns void. Note the IAP returns the result with the base address of the table residing in R1.

typedef void (*IAP) (unsigned int [],unsigned int []);

IAP iap_entry;

Setting function pointer

iap_entry= (IAP) Iap_location.

Call IAP routine.

iap_entry (command, result);

As seen above, iap_entry does not have to be defined anywhere in the application, as the linker now knows it is been defined in the image residing in Flash through the symdefs file.

Fig. 1 shows the general operation steps of how to use IAP to program Flash [8]. There are four aspects in the IAP calling process as follows:
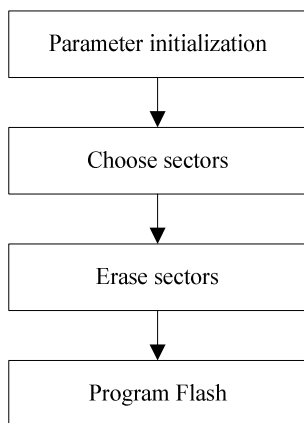

Figure 1.The flow chart of program Flash by IAP

- Parameter initialization: It needs to define some parameters before IAP, such as the system clock, IAP entry address, input parameters and the output parameters.

- Choose sectors: It must first select operation sector before operate flash. It can select multiple sectors at one time. The command code of choosing sector is 50.

- Erase sectors: It must erase operation sector before write flash. It can erase multiple sectors at one time. The command code of erasing sector is 52.

- Program Flash: In this stage, the IAP function will write date from RAM to Flash. The command code of programing Flash is 51.

2.2 Online Software Upgrade Solutions

The online software upgrade uses two serial interfaces, including UART and SPI. UART is connected with wireless module, which uses mobile network. The SPI is connected with EEPROM, which saves data which is mainly the new ad used programs. Fig. 2 shows the design solution of online upgrade for intelligent power distribution terminal. The entire system is composed of four parts, including one hand terminal equipment, two wireless equipment and one intelligent power distribution terminal. The hand terminal equipment is made up of the ARM11, which is running the WinCE. The intelligent power distribution terminal system makes use of LPC2138 as its MCU. First of all, hand terminal equipment, as the source host of new program files, sends update command through the wireless module. Then hand terminal equipment sends the new code to intelligent power distribution terminal after receiving the responding answer. Intelligent power distribution terminal will response the update command through the interrupt mode by verifying its own version number and judge whether to start files downloading or not, then it will receive and check the upgrade data to realize online upgrade. If the upgrade process fail or wait for overtime, intelligent power distribution terminal will give up the upgrade task automatically, and go back to run the original code.
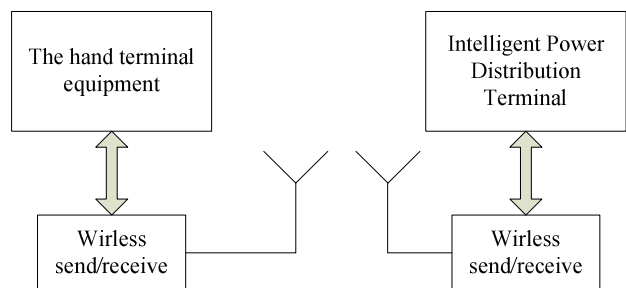

Figure 2.The design scheme of online software upgrade

According to the software structure, online upgrade system includes three kinds of working mode and three program module, as shown in Fig. 3.Guiding code, running on management mode, is in charge of the working mode of the intelligent power distribution terminal and guide the system into the application mode or upgrade mode. It can complete the task of complicated program loading and guiding. Upgrade code running on upgrade mode, is responsible for updating new code. In upgrade mode, all of the interrupt is closed. The user code runs on application mode, which is the application program of intelligent power distribution terminal. It is responsible for the daily work.
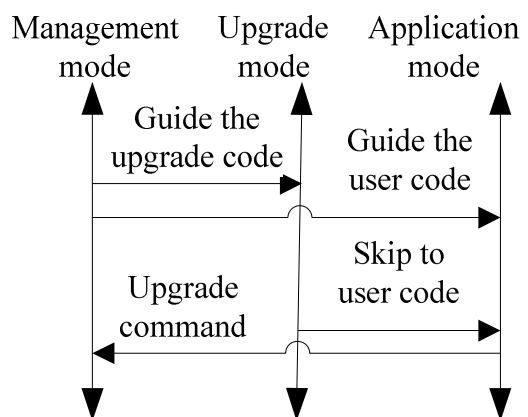

Figure 3.The software structure.

3. THE DESIGN OF ONLINE UPGRADE ALGORITHM

3.1 Communication Protocol

According to the reliability requirements of the design, the paper designs the corresponding communication protocol, as shown in Fig.4. This protocol divides upgrade code into frame as the unit for transmission. Each frame includes the head character, control domain, mark domain, the data length domain, data domain, check domain and end domain. And each domain contains some certain bytes. In the frame format, the starting character means the beginning of a frame of information. Control domain means the position of the frame in the total data and shows whether it is the end frame. Mark domain records the frame data retransmission times. End domain indicates the end of a frame of information.
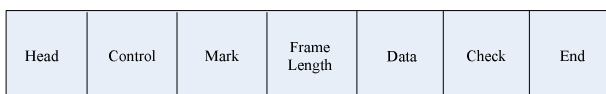
Head	Control	Mark	Frame Length	Data	Check	End

Figure 4.The communication protocol.

3.2 Program storage Space

In order to realize the online software upgrade and fault protection, the system divides the Flash of the MCU into four parts consisting of one Boot storage area, one current user storage area, and two user code storage areas to make the memory's structure logical and avoid the codes covering with each other. Fig. 5 shows the division. As the figure shows, the Boot area, loading the Bootloader of system, is in charge of the software upgrade. The user code is divided into two areas consisting of A and B: one is used to save the operating code; another is used to save the new software code. For safety consideration, the upgrade code is written in the spare area, but not covering the original one, and stores the new code when checksum is right. Then renew the therapy program entry pointer in the information storage area. Even if the upgrade is unsuccessful or breaks off, the last edition code is still stored in another area, to which the programming entry can return to point; the device can still work with the original code. When the current operational code is located at A, the system will upgrade to B. On the other hand, it can upgrade to A when the current operational code is located at A. The area of current user sign stores the currently operational code area and some constants needing backup, which store the beginning address of the operating code.
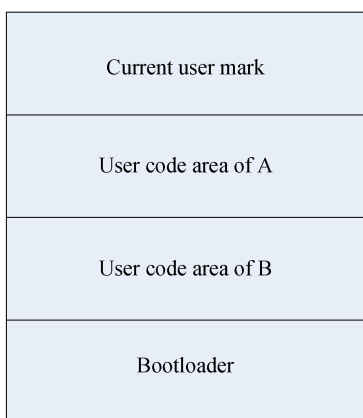
Current user mark
User code area of A
User code area of B
Bootloader

Figure 5.The flow chart of upgrade code.

3.3 Upgrade Algorithm

Because the software update process is automatic, this paper designs the upgrade code specially, written in C language. The starting address of the update is 0x00000000. The device should test some special associated conditions and then starts the upgrade mode. Firstly, the users should start the MCU's reset mode by an update command. The user code will jump to management mode after receiving update command, and then enter the upgrade mode. This kind of design can guarantee priority of software upgrade. And the system keeps reading the serial communication port's buffer to receive the upgrade data and check whether the data is correct. If all data is correct, the system will send response of receiving success and start software upgrade. The MCU erases the specified segments in the Flash, and then writes upgrade data to the Flash. Then the system skips to the new application program and updates the current user mark. The following is the code to ski to the application program:

```
int main(void)
{          ...
    UserProgram = (void (*)()) user;
        if (*FlagPoint == A){UProgram = (void (*)()) (A);}
        else
        {
                if (*FlagPoint == B)
                {UProgram = (void (*)()) (B);}
                else{...}
        }
        (*UProgram)();
}
```

The entire system's operating principle of the IAP wireless high-speed configuration and downloading technology for the upgrade systerm is showm in Fig. 6.
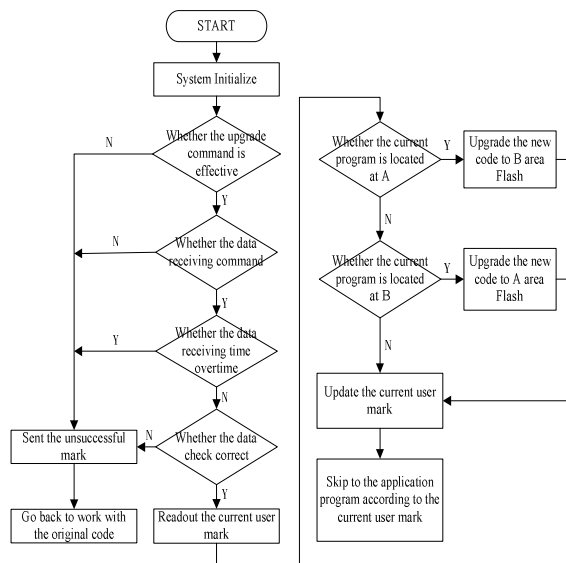

Figure 6.The flow chart of upgrade code.

When we want to use ADS1.2 software to write Bootloader and application program separately, it uses the scatter, which is used to specify the ARM connector how to distribute the storage address of RO, RW and ZI data to loading the code into the division of Flash just as follows:

```
ROM_LOAD 0x0

{

; IAP Bootloader area

   SYSTEM 0x00000000

   {

      Startup.o (vectors, +First)

      main.o(+RO)

      target.o(+RO)

      *(+RO)

   }

}

; Usercode area

ROM_LOAD2 0x8000

{

   USER 0x8000 FIXED

   {

      User.o (+RO, +First)

      SSP.o(+RO)

   }

   IRAM 0x40000000

   {

      Startup.o (MyStacks)

      * (+RW,+ZI)

   }

   HEAP +0 UNINIT

   {

      Startup.o (Heap)

   }

   STACKS 0x40002000 UNINIT

   {

      Startup.o (Stacks)

   }

}
```

The starting address of IROM is 0x00000000, and the first 0x8000 are used to store the upgrade code. And the user code is locating at the starting address of 0x00008000. It costs 0x00040000. The starting address of IRAM is 0x40000000. It is used to store the variables.

3.4 Security Algorithm

In order to avoid the system breaking off during the software upgrade process which will cause the upgrade task failure and the system crash, this paper formulates the corresponding security algorithm, according to the types of accident. It can ensure the intelligent power distribution terminal continuly update the software online during the stably and reliably operating.

- Before upgrading, firstly, the software will check whether there is legal upgrade command. Then the user sends password and entering orders to get the operating right. If the command is to go back, the system will readout the used program from the used application program area of Flash directly, and wite the used program to the application program area and execute.

- For data, it uses the data validation method, not only for each frame, but also for the entire packet, after the end of the entire packet data transmission, to ensure that all data is corrected received. And during the process, the host will wait for the answer from the device after sending each frame to insure the reliability.

- This design starts the timing function of timer. If the upgrade waits for the overtime, the system will return to the original user code.

- If exceptions occur during the upgrade process, the system will often reset and the reset mark will increase by opening watchdog function. Then the system will enter the management mode to give up this upgrade task. The last edition code is still stored in another area, to which the programming entry can return to point, and the system can still go back to work with the original code.

4. EVALUATION

The design applying the method for upgrading the software of intelligent power distribution terminal is tested in detail after the design and the program are completely finished. The test result shows that the design has good feasibility in the application. The code is built with ADS1.2, analyzed and sent by the hand terminal equipment. More than 30 times of test are carried out in the actual and complex environment, and all upgrades are completed successfully in 3 minutes. As a result, the design is feasible and has a high successful rate at the effective distance. But as a matter of fact, the IAP mode programming to the memory (Flash) needs another absolute complex code stored in the Flash to analysis the upgrade file commonly that will get the code more and more complex. There are some factors affecting the communicating capability. For example, the code size decides the time. The small file will reduce the time obviously. The data in each frame also enhances the efficiency of system. You should better balance the efficiency and reliability to design the protocol of the each frame. Increasing the amount of data in each frame will enhance the efficiency but the more data in a frame, the less reliable it would be. The protocol should balance the efficiency and reliability.

5. CONCLUSION

According to the requirements of the intelligent power distribution terminal, such as continuous, stable and reliable operation, this paper proposes an online software upgrade method, which offers several novel and original features. This method uses a different software frame structure with the common way. It can realize the online upgrade function and keeping the high

reliability and simplifying the system of intelligent power distribution terminal. Even if the upgrade is unsuccessful, the system can still return original status.

6. ACKNOWLEDGMENTS

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