

CROSS-REFERENCE TO RELATED APPLICATION

10 BACKGROUND

[0001] The invention relates to an electronic apparatus, and particularly relates to a RFID card learning apparatus and an operating method thereof.

[0002] In modern society, a radio frequency identification (RFID) technique is widely applied in various domains such as elevator cards, entrance cards, ID cards, micro payment, etc. due to its advantages of non-contact identification and high data security. A RFID system is mainly composed of a reader and a RFID tag. The reader and the RFID tag are all configured with coils to facilitate implementing the wireless RF transmission. The RFID tag (for example, a RFID card) includes a coil and a RFID chip, where the RFID chip is electrically connected to the coil. When the RFID tag approaches the reader, the coil of the RFID tag and the coil of the reader induct and communicate with each other.

[0003] However, since the RFID card has been widely applied in daily life, a user has to carry the RFID card when going out, and although a RFID card combined with a portable device (for example, a pendant, a back cover of a mobile phone) or a wearable device (for example, a bracelet) has been developed in the market, if the RFID card is
5 required to be replaced, the portable device or the wearable device has to be replaced together, and the original device cannot be continually used. Therefore, further review is required for the aforementioned problems, so as to seek a feasible solution.

SUMMARY

10 [0004] The invention is directed to a radio frequency identification (RFID) card learning apparatus and an operating method thereof, by which an ID number and data of at least one RFID card are read, and the read ID number and data are stored into the RFID card learning apparatus for replacing the read RFID card.

[0005] The invention provides a RFID card learning apparatus, which is adapted to
15 read an ID number and data of a low frequency RFID card. The RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load or antenna, where the RFID card learning apparatus does not contain a RFID card reading chip.

20 [0006] The invention provides a radio frequency identification (RFID) card learning apparatus, which is adapted to simulate a low frequency RFID card and transmit an ID number and data. The RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal

to form an electromagnetic load or antenna, where the RFID card learning apparatus does not contain a RFID card induction chip.

[0007] The invention provides a RFID card learning apparatus, which is adapted to mutually exchange an ID number and data with a high frequency RFID card. The
5 RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load or antenna, where the RFID card learning apparatus does not contain a high frequency RFID card read-write chip.

[0008] The invention provides a RFID card learning apparatus, which is adapted to
10 simulate a high frequency RFID card and mutually exchange an ID number and data with a high frequency RFID read-write device. The RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load or antenna, where the RFID card learning apparatus does not contain a high frequency RFID card chip.

15 [0009] The invention provides a RFID card learning apparatus, which is adapted to read an ID number and data from a low frequency RFID card, and mutually exchange the ID number and data with a high frequency RFID card. The RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load
20 or antenna.

[0010] In an embodiment of the invention, the RFID card learning apparatus stores a plurality of different ID numbers and data. When the RFID card learning apparatus approaches a low frequency reading device or a high frequency RFID read-write device,

the RFID card learning apparatus automatically performs determination according to a received carrier frequency, and transmits the ID number and data when approaching the low frequency reading device, and mutually exchanges the ID number and data with the high frequency RFID read-write device when approaching the high frequency RFID read-write device.

[0011] The invention provides a RFID card learning apparatus, which is adapted to simulate a low frequency RFID card to transmit an ID number and data, and is adapted to simulated a high frequency RFID card, and mutually exchange the ID number and data with a high frequency RFID read-write device. The RFID card learning apparatus includes a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load or antenna.

[0012] In an embodiment of the invention, when the RFID card learning apparatus approaches a RFID card reading device, the RFID card learning apparatus automatically performs determination according to a received carrier frequency, and switches different ID number and data for transmitting to the low frequency RFID reading device at regular time intervals in case of the low frequency RFID reading device, and mutually exchanges different ID number and data with the high frequency RFID read-write device at regular time intervals in case of the high frequency RFID read-write device.

[0013] The invention provides a RFID card learning apparatus including a microcontroller and a coil. The coil is coupled to the microcontroller, and senses an electromagnetic signal to form an electromagnetic load, where when the RFID card learning apparatus approaches a low frequency reading device or a high frequency read-write device of an external device, the microcontroller is waken up due to a level

variation of a carrier signal received from the low frequency reading device or the high frequency read-write device. The RFID card learning apparatus is capable of reading an ID number and data of the low frequency RFID card and mutually exchanging an ID number and data with the high frequency RFID card. The RFID card learning
5 apparatus is packaged in a single chip, where the single chip includes a microprocessor and an induction element, and the induction element is one of a coil, an antenna or a circuit trace on a circuit board.

[0014] The invention provides a RFID card learning apparatus, which is adapted to simulate a low frequency RFID card and transmit an ID number and data, and is adapted
10 to simulate a high frequency RFID card and mutually exchange an ID number and data with the high frequency RFID card. The RFID card learning apparatus is packaged in a single chip, where the single chip includes a microprocessor and an induction element, and the induction element is one of a coil, an antenna or a circuit trace on a circuit board.

[0015] The invention provides a RFID card learning apparatus including a microcontroller and a coil. The coil is coupled to the microcontroller, and receives a first signal, where the first signal includes a RFID card number. The microcontroller receives the first signal through the coil, and stores the RFID card number. When the microcontroller receives a read request, the microcontroller transmits the RFID card
20 number through the coil.

[0016] The invention provides an operating method of a RFID card learning apparatus, which includes following steps. A microcontroller and a coil are configured, where the microcontroller receives a first signal through the coil, the first signal includes

a RFID card number, and the microcontroller stores the RFID card number. When the microcontroller receives a read request, the microcontroller transmits the RFID card number through the coil.

[0017] According to the above descriptions, the RFID card learning apparatus and
5 the operating method are capable of reading and storing the ID number and data of at least one RFID card, so that the ID numbers and data of a plurality of RFID cards can be integrated in one device. Since a microcontroller is used to implement the RFID card learning apparatus of the invention, portability of the apparatus is achieved.

[0018] In order to make the aforementioned and other features and advantages of the
10 invention comprehensible, several exemplary embodiments accompanied with figures are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The accompanying drawings are included to provide a further understanding
15 of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0020] FIG. 1 is a schematic diagram of a radio frequency identification (RFID) card learning apparatus according to an embodiment of the invention.

20 [0021] FIG. 2 is a circuit schematic diagram of a RFID card learning apparatus according to an embodiment of the invention.

[0022] FIG. 3 is a circuit schematic diagram of a RFID card learning apparatus according to another embodiment of the invention.

[0023] FIG. 4 is a flowchart illustrating an operating method of a RFID card learning apparatus according to an embodiment of the invention.

[0024] FIG. 5 is a circuit schematic diagram of a RFID card learning apparatus according to another embodiment of the invention.

5 [0025] FIG. 6 is a circuit schematic diagram of a RFID card learning apparatus according to another embodiment of the invention.

[0026] FIG. 7 is a schematic diagram of a RFID card learning apparatus implemented by a watch.

[0027] FIG. 8 is a schematic diagram of an application of a RFID card learning
10 apparatus according to an embodiment of the invention.

[0028] FIG. 9 is a schematic diagram of another application of a RFID card learning apparatus according to an embodiment of the invention.

[0029] FIG. 10 is a waveform diagram of a RFID card learning apparatus 10 of FIG. 2 when a pin I/O Port 1 and a pin I/O Port 2 are not connected to a coil 12.

15 [0030] FIG. 11 is a waveform diagram of the RFID card learning apparatus 10 of FIG. 2 when the pin I/O Port 1 and the pin I/O Port 2 are connected to the coil 12.

[0031] FIG. 12 is an enlarged view of a block b1101 of FIG. 11.

[0032] FIG. 13 is a diagram listing values that a pin ADC Input converts input analog signals into digital signals when a RFID card is not read in the embodiment of
20 FIG. 2.

[0033] FIG. 14 is a diagram listing values that the pin ADC Input converts the input analog signals into digital signals when the RFID card is read in the embodiment of FIG. 2.

[0034] FIG. 15 is a signal waveform diagram when a low frequency RFID card is simulated.

[0035] FIG. 16 is a waveform diagram of a pin I/O Port 2 and a pin PWM Output Port when the coil 12 is not connected.

5 [0036] FIG. 17 is a waveform diagram of the pin I/O Port 2 and the pin PWM Output Port when the coil 12 is connected.

[0037] FIG. 18 is a waveform diagram obtained when a microcontroller controls an output PWM signal of a pin PWM Output Port to enable/disable sending of a REQA instruction according to a transmission format.

10 [0038] FIG. 19 is a waveform diagram when a microcontroller sends a REQA instruction.

[0039] FIG. 20 is a waveform diagram when a microcontroller sends a REQA instruction.

[0040] FIG. 21 is a waveform diagram when a microcontroller sends a SELECT
15 instruction.

[0041] FIG. 22 is a waveform diagram when a microcontroller sends a REQA instruction and receives an ATQA response from a high frequency RFID card.

[0042] FIG. 23 is a waveform diagram with an enlarged time axis when a RFID card responds an ATQA response.

20 [0043] FIG. 24 is a waveform diagram when a microcontroller transmits a SELECT instruction and receives a UID number transmitted back from a RFID card.

[0044] FIG. 25 is a waveform diagram when a RFID card transmits back an ATQA response.

[0045] FIG. 26 is a waveform diagram when a RFID card transmits back an ID number.

[0046] FIG. 27 is a schematic diagram of analysing UID waveform data and converting the same into an ID number.

5 [0047] FIG. 28 is a waveform diagram when a microcontroller 11 receives a REQA instruction sent by a RFID card reader.

[0048] FIG. 29 is a waveform diagram when a microcontroller 11 receives a REQA instruction from a RFID card reader and transmits an ATQA response.

[0049] FIG. 30 is an enlarged waveform diagram of an ATQA response of FIG. 29.

10 [0050] FIG. 31 is a waveform diagram when the microcontroller receives a SELECT instruction from the RFID card reader and transmits a UID number stored in the RFID card learning apparatus.

[0051] FIG. 32 is an enlarged waveform diagram when a microcontroller transmits the UID number in FIG. 31.

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DETAILED DESCRIPTION OF DISCLOSED EMBODIMENTS

[0052] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings.

Wherever possible, the same reference numbers are used in the drawings and the

20 description to refer to the same or like parts.

[0053] FIG. 1 is a schematic diagram of a radio frequency identification (RFID) card learning apparatus according to an embodiment of the invention. Referring to FIG. 1, the RFID card learning apparatus 10 includes a microcontroller 11 and a coil 12. The

microcontroller 11 can be a hardware device having computation capability. In the present embodiment, the microcontroller 11 can be integrated in an integrated circuit (for example, a chip). The microcontroller 11 may output a voltage to the coil 12 in a regular frequency. Moreover, the microcontroller 11 can be an 8-bits microcontroller or can be a 4-bits microcontroller, which is not limited by the invention. In the present embodiment, the coil 12 serves as a medium for transmitting radio signals between the RFID card learning apparatus and a RFID tag.

[0054] In the present embodiment, the RFID card can be a RFID tag or a RFID key fob or a near field communication (NFC) tag, though the invention is not limited thereto.

The RFID card can be an entrance card, an elevator card, an ID card, etc. In the present embodiment, the coil 12 can be an induction coil adapted to the RFID technique or the NFC technique. In other embodiments, the coil 12 can be implemented by an inductor, though the invention is not limited thereto. In an exemplary embodiment, the RFID card learning apparatus can be packaged in a single chip, i.e. the single chip includes the aforementioned microcontroller and an induction element (for example, the microcontroller 11 and the coil 12 of FIG. 1). In another exemplary embodiment, the induction element can be an antenna of a specific RFID card or a circuit trace on a circuit board, and the induction element can be an inductor or other active or passive device having an induction function.

[0055] In the present embodiment, the RFID learning apparatus may store a plurality of different ID numbers and data. The RFID learning apparatus 10 is capable of reading an ID number and data of a low frequency RFID card and mutually exchanging an ID number and data with a high frequency RFID card. The low frequency RFID

card is, for example, a RFID card with a communication carrier frequency below 150kHz, and the high frequency RFID card is a RFID card with a communication carrier frequency above 150kHz and below 40MHz.

[0056] The RFID card learning apparatus of the invention is capable of reading the ID number and data of the low frequency RFID card and mutually exchanging the ID number and data with the high frequency RFID card. In another embodiment, the RFID card learning apparatus of the invention is adapted to simulate a low frequency RFID card, and transmit the ID number and data, and is adapted to simulate a high frequency RFID card and mutually exchange an ID number and data with a high frequency RFID read-write device.

[0057] FIG. 2 is a circuit schematic diagram of a RFID card learning apparatus according to an embodiment of the invention. Referring to FIG. 2, the RFID card learning apparatus of FIG. 2 is adapted to read and simulate a low frequency RFID card. The low frequency RFID card is, for example, a RFID card with a communication carrier frequency below 150kHz, and a common application thereof includes an entrance card, an elevator card, etc. The RFID card learning apparatus of FIG. 2 is an active apparatus, and a power pin VDD and a ground pin GND of the microcontroller 11 thereof are connected to an external power 13, for example, a battery or a direct current (DC) power, etc. In the embodiment of FIG. 2, one end of the coil 12 is coupled to a pin I/O Port 1, and a pin I/O Port 2 is coupled to a pin ADC Input. Another end of the coil 12 is coupled to the pin I/O Port 2 and the pin ADC Input. The pin ADC Input is used for receiving an analog signal sensed by the antenna, and the microcontroller 11 converts the sensed analog signal into a digital signal for interpreting information such

as the ID number, etc. Moreover, as shown in FIG. 3, the RFID card learning apparatus of the invention can also be a passive apparatus, and the passive apparatus does not require an external power.

[0058] FIG. 4 is a flowchart illustrating an operating method of a RFID card learning apparatus according to an embodiment of the invention. Referring to FIG. 2 and FIG. 4, the microcontroller 11 receives a first signal through the coil 12, where the first signal includes a RFID card number, and the microcontroller 11 stores the RFID card number (step S410). When the microcontroller 11 receives a read request, the microcontroller 11 transmits the RFID card number through the coil 12 (step S420).

[0059] The RFID card learning apparatuses of FIG. 5 to FIG. 6 are adapted to read and simulate the high frequency RFID card and the low frequency RFID card. The high frequency RFID card is a RFID card with a communication carrier frequency above 150kHz and below 40MHz, which includes the RFID cards with specifications of ISO/IEC 14443A, ISO/IEC14443B, JIS X 6319-4, ISO/IEC15693, ISO/IEC18000-3, etc.

Referring to FIG. 5 and FIG. 6, a difference between FIG. 5 and FIG. 6 is that the RFID card learning apparatus of FIG. 5 is an active apparatus, and the power pin VDD and the ground pin GND of the microcontroller 11 thereof are coupled to the external power 13, for example, a battery, a DC power, etc., while the RFID card learning apparatus is a passive apparatus, which is unnecessary to connect an external power. Compared to FIG. 2, the microcontroller 11 of FIG. 5 further includes a pin PWM Output Port for outputting an output pulse-width-modulation (PWM) signal), a pin OP+ Input, a pin OP-Input, a pin OP Output and a pin I/O Port 3. The pin PWM Output Port is coupled to the pin I/O Port 1. One end of the antenna 12 is coupled to the pin PWM Output

Port and the pin I/O Port 1, and another end of the antenna 12 is coupled to the pin I/O Port 2 and the pin ADC Input.

[0060] An input terminal of an input stage circuit 14 is coupled to the other end of the antenna 12, and an output terminal of the input stage circuit 14 is coupled to the pin OP+Input and the pin OP-Input. A diode D1 is used for rectification. The input stage circuit 14 includes capacitors C1, C2 and C3, resistors R1, R2 and R3, and the diode D1. An anode of the diode D1 and one end of the capacitor C1 are coupled to the input terminal of the input stage circuit 14. Another end of the capacitor C1 is coupled to the ground, and a cathode of the diode D1 is coupled to one end of each of the resistors R1, R2 and R3. Another end of the resistor R1 is coupled to the ground, another end of the resistor R2 is coupled to one end of the capacitor C2 and the pin OP+ Input, and another end of the resistor R3 is coupled to one end of the capacitor C3 and the pin OP-Input. The other ends of the capacitors C2 and C3 are coupled to the ground. The resistors R2 and R3 are used for low-pass filtering. The capacitor C1 is a coupling capacitor, which is used for adjusting a frequency. After an electromagnetic signal sensed by the antenna 12 is processed by the input stage circuit 14, the electromagnetic signal is transmitted to an operational amplifier OP1 in the microcontroller 11 through the pin OP+ Input and the pin OP- Input, and the electromagnetic signal is amplified and is output through the pin OP Output. In the present embodiment, the number of windings of the antenna 12 of the active RFID card learning apparatus 10 of FIG. 5 is about 8 to 9 rounds. The number of windings of the antenna 12 of the passive RFID card learning apparatus 10 of FIG. 6 is at least about 60 or more in order to generate an adequate current for driving the microcontroller 11 when the RFID card approaches the

antenna 12. Moreover, the RFID card learning apparatuses 10 of FIG. 5 and FIG. 6 may send a low frequency signal and a high frequency signal in alternation to read a low frequency RFID card read and a high frequency RFID card reader.

[0061] FIG. 7 is a schematic diagram of a RFID card learning apparatus
5 implemented by a watch. Referring to FIG. 7, the RFID card learning apparatus 70 includes a watch body 75 and a watchband 76. A microcontroller is built in the watch body 75, a coil 72 is disposed on the watch body 75, and a time display region 751 and an indicating lamp 752 are disposed in the watch body 75. The time display region 751 can be a liquid crystal display. The indicating lamp 752 can be an LED lamp. The
10 watch body 75 has buttons 753 and 754 on a side surface thereof, which are used for switching modes of the RFID card learning apparatus 70.

[0062] FIG. 8 is a schematic diagram of an application of a RFID card learning apparatus according to an embodiment of the invention. Referring to FIG. 8, the RFID card learning apparatus 70 may store ID numbers of a plurality of RFID cards, and an ID
15 card 81, an entrance card 82 or an elevator card 83 can be taken for approaching the RFID card learning apparatus 70, and the button on the RFID card learning apparatus 70 is pressed to start a RFID card duplication mode (a learning mode), and the duplication is complete when the indicating lamp 752 is lighted. One set or a plurality sets of duplicated RFID card numbers and data can be stored in a rewritable flash memory
20 (FlashRom), an electrically erasable programmable read only memory (EEPROM) or a static random access memory (SRAM) in the microcontroller 11, or stored in an external device or memory electrically connected to the microcontroller 11. The ID number of the low frequency RFID card occupies a capacity about 5 bytes. Besides storing the ID

number, the high frequency RFID card further stores information, and the ID number and information of the high frequency RFID card occupy a capacity about 1k bytes, and the buttons can be used to switch storing the ID number of the high frequency RFID card alone or storing the ID number plus the information of the high frequency RFID card.

[0063] FIG. 9 is a schematic diagram of another application of a RFID card learning apparatus according to an embodiment of the invention. Referring to FIG. 9, the RFID card learning apparatus 70 that stores information (such as the ID number, etc.) of the entrance card 82 can be used as the entrance card 82, and when the RFID card learning apparatus 70 approaches a RFID card read-write device 91, the RFID card learning apparatus 70 simulates a signal of the entrance card 82. The RFID card read-write device 91 refers to a card reader (for example, a card reader device used for elevator or entrance control), a mobile phone, a tablet PC, etc., that is capable of mutually exchange data with the RFID card. The RFID card learning apparatus 70 may sequentially switch different RFID card numbers in a time interval (for example, 50ms-200ms), or the button 754 can be pressed to switch different RFID card numbers.

[0064] In the invention, a microcontroller and a coil are used to implement a RFID card learning function. As long as a suitable microcontroller is selected, a single IC can be used to produce a product having the RFID card learning function. For example, in order to produce the watch having the RFID card learning function as that shown in FIG. 7, the microcontroller having a LCD display control function is selected to develop the product, and in order to produce a key ring or a ring having the RFID card learning function, the microcontroller with a small volume is selected to develop the product.

[0065] An existing RFID card reader includes an antenna, an oscillator, an antenna driver, a demodulator, a filter, an amplifier and a data decoder. The antenna driver receives a signal sent by the oscillator and transmits the signal to the antenna. When the RFID card approaches the antenna to cause a voltage variation of the antenna, the signal is transmitted to the demodulator for analog-to-digital conversion, and is further processed by the filter and the amplifier, and then the signal is processed by the data decoder to obtain the RFID card number and data. The microcontroller of the RFID card learning apparatus of the invention outputs a voltage to an output port connected to the coil in a regular frequency, such that the RFID card closed to the coil is charged, which implements a function of the antenna driver of the RFID card reader. An analog-to-digital converter, a counter or an operational amplifier of the microcontroller detects a current variation or a voltage variation of the coil to determine a load variation of a sensing device, which implements functions of the demodulator, the filter and the amplifier of the RFID card reader. The microcontroller executes a program to analyse the load variation, so as to implement the function of the data decoder to obtain the RFID card number and data. The microcontroller controls the input output port as a varied load, and exchanges the ID number of the RFID card or the data to be read or written with the RFID card read-write device in a wireless induction manner, and when the RFID card read-write device requires to write data, the data is written into the FlashRom, the EEPROM or SRAM of the microcontroller. Moreover, one or a plurality of RFID cards that have been read can be selected in advance, and when the RFID card approaches the RFID card read-write device, the RFID card exchanges the ID number and read-write data with the RFID card read-write device.

[0066] According to the above descriptions, since the RFID card learning apparatus and the operating method thereof can read and store the ID number and data of at least one RFID card, the ID numbers and data of a plurality of RFID cards can be integrated into one device. Since the RFID card learning apparatus of the invention is
5 implemented by a microcontroller, portability of the RFID card learning apparatus is achieved.

[0067] In following descriptions, reading of the low frequency RFID card, simulation of the low frequency RFID card, reading of the ID number and data of the high frequency RFID card, and simulation of the high frequency RFID card are
10 described in detail.

[0068] First, a method that the RFID card learning apparatus reads the low frequency RFID card (the learning mode) is introduced. Referring to FIG. 10, FIG. 10 is a waveform diagram of the RFID card learning apparatus 10 of FIG. 2 when the pin I/O Port 1 and the pin I/O Port 2 are not connected to the coil 12. A waveform P1001
15 represents a voltage variation of the pin I/O Port 1, and a waveform P1002 represents a voltage variation of the pin I/O Port 2. The microcontroller 11 first outputs a square wave through the pin I/O Port 1 and the pin I/O Port 2 in a frequency of a carrier, and a frequency of the square wave is about 125 kHz, and a period thereof is about 8 μ s.

[0069] Referring to FIG. 11, FIG. 11 is a waveform diagram of the RFID card
20 learning apparatus 10 of FIG. 2 when the pin I/O Port 1 and the pin I/O Port 2 are connected to the coil 12. In the present embodiment, the capability that the microcontroller 11 pulls down the voltage to a low level is greater than the capability that the microcontroller 11 pulls up the voltage to a high level. Therefore, when one of

the pin I/O Port 1 and the pin I/O Port 2 outputs the low level and another one outputs the high level, the voltage of the pin I/O Port 1 or the pin I/O Port 2 that outputs the high level is pulled down to the low level within a short time. Referring to a block 1101 encircled by dot lines in FIG. 11, when the voltage P1001 of the pin I/O Port 1 is pulled
5 down to the low level, the voltage P1002 of the pin I/O Port 2 is influenced by the voltage P1001 of the pin I/O Port 1 and is pulled down to the low level from the high level.

[0070] FIG. 12 is an enlarged view of the block b1101 of FIG. 11. Referring to FIG. 12, a declining speed of the voltage P1002 of the pin I/O Port 2 relates to a
10 magnitude of a load impedance. The load impedance relates to the coil 12 and an internal circuit of the read RFID card. In the invention, when the voltage P1001 of the pin I/O Port 1 is pulled down to the low level, an analog-to-digital conversion function is activated. Moreover, the magnitude of the load impedance can be determined according to a slope of the voltage P1002 of the pin I/O Port 2 declining from the high
15 level to the low level, i.e. a value of a voltage drop a_2 divided by a time a_1 . The greater the value of the voltage drop a_2 divided by the time a_1 is, i.e. the greater the slope is, the greater the load impedance is. FIG. 13 is a diagram listing values that the pin ADC Input converts the input analog signals into digital signals when the RFID card is not read in the embodiment of FIG. 2. When the RFID card is not read, the obtained
20 value of the digital signal is "52" or "51", which has a small variation range. FIG. 14 is a diagram listing values that the pin ADC Input converts the input analog signals into digital signals when the RFID card is read in the embodiment of FIG. 2. A block b1401 is a header, and a length thereof is 9 bits in the present embodiment, the

displayed values are 9 consecutive "1", and when the header is obtained, data decoding is performed according to a transmission format of the low frequency RFID card, so as to obtain an ID number shown by the block b1402.

[0071] A method that the RFID card learning apparatus simulates the low frequency

5 RFID card (a normal mode) is described below. Taking the RFID card learning apparatus of FIG. 2 as an example, the pin I/O Port 1 and the pin I/O Port 2 are set as input ports, and a function of waking up the microcontroller 11 through the I/O Port is activated. When the RFID card learning apparatus approaches a RFID card reader, the I/O Port receives a level variation of the carrier signal of the RFID card reader and
10 wakes up the microcontroller 11. The microcontroller 11 determines a frequency of the carrier signal, and in case of the low frequency, the microcontroller 11 sets the pin I/O Port 1 and the pin I/O Port 2 as input port or output port according to the transmission format and timing, so as to form a varied load with the connected coil 12 to transmit the ID number to the RFID card reader.

15 [0072] Referring to FIG. 15, according to the voltage waveform P1001 of the pin I/O Port 1 and the voltage waveform P1002 of the pin I/O Port 2, the digital signal value of the simulated low frequency RFID card is obtained. A block 1501 is the header. When the voltage P1001 of the pin I/O Port 1 is pulled down from a high amplitude to a low amplitude, it represents a binary bit of "1", and when the voltage P1001 of the pin
20 I/O Port 1 is pulled up from the low amplitude to the high amplitude, it represents a binary bit of "0", Blocks b1502 to b1505 respectively represent the transmitted RFID card number of hexadecimal "0", "1", "0" "6". The RFID card reader can interpret the sensed load variation as the ID number and data. When the ID number and data are

consecutively transmitted by several times (about 3-4 times), the RFID card reader accepts the ID number and data transmitted by the microcontroller 11 to complete simulation of the low frequency RFID card.

[0073] A method that the RFID card learning apparatus reads the ID number and

5 data of the high frequency RFID card (the learning mode) is described below. For example, when the RFID card learning apparatus of FIG. 5 reads a NFC type-A RFID card, the microcontroller 11 first outputs a pulse width modulation (PWM) signal in a frequency of a high frequency carrier (13.56 MHz, with a period of a bout 73.7 ns), the pin I/O Port 1 is set to be floating, and the pin I/O Port 2 is set to high potential. FIG.

10 16 is a waveform diagram of the pin I/O Port 2 and the pin PWM Output Port when the coil 12 is not connected, and FIG. 17 is a waveform diagram of the pin I/O Port 2 and the pin PWM Output Port when the coil 12 is connected. A waveform P1601 represents a voltage of the pin I/O Port 2, and a waveform P1602 represents a voltage of the pin PWM Output Port. In FIG. 17, at a time point t1, when the voltage P1602 of the pin PWM Output Port starts to change, the voltage P1601 of the pin I/O Port 2 is accordingly changed. FIG. 18 illustrates a voltage waveform P1601 of the pin I/O Port 2 and a voltage waveform P1602 of the pin PWM Output Port obtained when the microcontroller 11 controls the output PWM signal of the pin PWM Output Port enable/disable to send of a REQA (request) instruction according to a transmission
15 format, where the REQA instruction is a complied with an ISO 14443A specification, and a function of the REQA instruction is to request the RFID card to send signal.

20 [0074] Referring to FIG. 19 to FIG. 26, a waveform P1901 represents a voltage of the pin I/O Port 2 of FIG. 5, a waveform P1902 represents a voltage of the pin OP+

Input (a positive terminal of the operational amplifier OP1) of FIG. 5, a waveform P1903 represents a voltage of the pin OP- Input (a negative terminal of the operational amplifier OP1) of FIG. 5, and a waveform P1904 represents a voltage of the pin OP Output (an output terminal of the operational amplifier OP1) of FIG. 5. FIG. 19 and

5 FIG. 20 are waveform diagrams obtained when the microcontroller 11 sends the REQA instruction. FIG. 21 is a waveform diagram when the microcontroller 11 sends a SELECT instruction. A function of the SELECT instruction is to request the RFID card to send the ID number. As shown in FIG. 22, when the microcontroller 11 sends the REQA instruction (at a time interval from a time point t1 to a time point t2), if a

10 NFC Type-A RFID card approaches the coil 12, the RFID card responds an ATQA response (ATQA response) as that shown from a time point t3 to a time point t4, and the microcontroller 11 determines that the NFC Type-A high frequency RFID card exists. It should be noticed that the ATQA response is complied with the ISO 14443 specification. FIG. 23 is a waveform diagram with an enlarged time axis when the

15 RFID card responds the ATQA response. During a time interval from the time point t1 to the time point t2 of FIG. 24, the microcontroller 11 sends the SELECT instruction, and during a time interval from the time point t3 to the time point t4, the RFID card transmits back a UID number of the RFID card. In FIG. 24, a length of the UID number transmitted back by the RFID card is 4 bytes. FIG. 25 is a waveform diagram

20 of when the RFID card transmits back the ATQA response. FIG. 26 is a waveform diagram when the RFID card transmits back the UID number. FIG. 27 is a record of the output of the pin I/O Port 3 coupled to the output pin OP Output of the amplifier of the circuit of FIG. 5 when the RFID card transmits back the UID number, in which a

block b2701 stores data related to interval lengths of high level and low level transformation of the pin I/O Port 3, and the microcontroller 11 decodes the data to obtain the ID number shown by a block 2702. Then, other data of the RFID card is read according to instruction of the NFC Type-A specification, and is stored in the
5 microcontroller 11 for simulating the data storage memory of the RFID card. In this way, the reading operation is completed.

[0075] A method that the RFID card learning apparatus simulates the high frequency RFID card (the normal mode) is described below. Taking the RFID card learning apparatus of the embodiment of FIG. 5 as an example, the pin PWM Output
10 Port is disabled to stop outputting the output PWM signal. The pin I/O Port 1 and the pin I/O Port 2 are set as input ports, and a function of using the pin I/O port 1 or the pin I/O Port 2 to wake up the microcontroller 11 is enabled (when the RFID card learning apparatus approaches a RFID card reader, the coil 12 has a voltage variation due to electromagnetic induction, so as to wake up the microcontroller 12). When the RFID
15 card learning apparatus approaches the RFID card reader, the pin I/O Port 1 and the pin I/O Port 2 receive a level variation of the carrier signal of the RFID card reader to wake up the microcontroller 11, and the microcontroller 11 determines whether the RFID card reader is a high frequency RFID card reader or a low frequency RFID card reader according to the carrier frequency. If the RFID card reader is the high frequency RFID
20 card reader, the microcontroller 11 waits for responding after the RFID card reader sends an instruction. Referring to FIG. 28 to FIG. 32, FIG. 28 is a waveform diagram when the microcontroller receives the REQA instruction sent by the RFID card reader. A waveform P2801 represents a voltage of the pin I/O Port 2 of FIG. 5, a waveform

P2802 represents a voltage of the pin OP+ Input (the positive terminal of the operational amplifier OP1) of FIG. 5, a waveform P2803 represents a voltage of the pin OP- Input (the negative terminal of the operational amplifier OP1) of FIG. 5, and a waveform P2804 represents a voltage of the pin OP Output (the output terminal of the operational amplifier OP1) of FIG. 5. During a time interval of the time point t1 to the time point t2 of FIG. 29, the microcontroller 11 receives an instruction from the RFID card reader, and after the microcontroller 11 interprets the instruction as the REQA instruction, the microcontroller 11 switches the pin I/O Port 1 and the pin I/O Port 2 as the input port or the output port according to the transmission format and timing, and forms a varied load with the connected coil 12 to transmit a waveform of the ATQA response as that shown from the time point t3 to the time point t4 of FIG. 29. FIG. 30 is an enlarged waveform diagram of the ATQA response from the time point t3 to the time point t4 of FIG. 29. The time interval from the time point t1 to the time point t2 of FIG. 31 represents a waveform when the microcontroller 11 receives the SELECT instruction from the RFID card reader, and the time interval from the time point t3 to the time point t4 of FIG. 31 represents a waveform when the microcontroller 11 transmits the UID number stored in the RFID card learning apparatus. FIG. 32 is an enlarged waveform diagram when the microcontroller 11 transmits the UID number during the time interval from the time point t3 to the time point t4 of FIG. 31. Then, according to the NFC Type-A specification, when the instruction is received from the RFID card reader, the data storage memory in the microcontroller 11 used for simulating the RFID card is accessed to implement simulating the high frequency RFID card.

[0076] In summary, the RFID card learning apparatus and the operating method

thereof are capable of reading and storing the ID number and data of at least one RFID card, so that the ID numbers and data of a plurality of RFID cards can be integrated in one device. Since a microcontroller is used to implement the RFID card learning apparatus of the invention, portability of the apparatus is achieved. Moreover, the
5 microcontroller 11 can be waken up when the pin I/O Port 1 and/or the pin I/O Port 2 receive a voltage level variation of the carrier signal from the RFID card reader, so as to achieve a power saving effect.

[0077] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the invention without departing from the
10 scope or spirit of the invention. In view of the foregoing, it is intended that the invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

WHAT IS CLAIMED IS:

1. A RFID card learning apparatus, adaptive to simulating a card reader for reading at a serial number and data of at least one of a plurality of RFID cards, and simulating the at least one of the plurality of RFID cards to transmit the corresponding serial number and data of the simulated one of the plurality of RFID cards, the RFID card learning apparatus comprising:

a microcontroller, comprising at least one I/O port and one ADC input port;

and

a coil, having one end connected to the I/O port of the microcontroller and another end connected to the ADC input port, the coil sensing an electromagnetic signal,

when the RFID card learning apparatus operates in a learning mode for simulating the card reader to read one of the plurality of RFID cards,

the microcontroller outputs a voltage signal with a frequency through the I/O port to the coil for charging the one of the plurality of RFID cards,

the microcontroller receiving a sensing electromagnetic signal in response to the voltage signal from the coil through the ADC input port, detecting a current variation or a voltage variation of the sensed electromagnetic signal to determine a load variation, using the load variation to obtain a digital signal as the ID number and data corresponding to the one of the plurality of RFID cards, and storing the ID number and data corresponding to the one of the plurality of RFID cards as one of the plurality of different ID numbers and data,

when the RFID card learning apparatus operates in a normal mode for simulating the at least one of the plurality of RFID cards,

the microcontroller being triggered by a level variation of a carrier signal of the RFID card reader, and the microcontroller determines whether the RFID card reader is a high frequency RFID card reader or a low frequency RFID card reader according to a carrier frequency of the carrier signal, such that the microcontroller simulates the one of the plurality of RFID cards by sequentially transmitting the plurality of ID numbers and data corresponding to the plurality of RFID cards according to a corresponding transmission format and a corresponding timing.

2. The RFID card learning apparatus as claimed in claim 1, wherein each of the plurality of RFID cards is a RFID key fob, a RFID tag or a NFC tag.

3. The RFID card learning apparatus as claimed in claim 1, wherein each of the plurality of RFID cards is a low frequency RFID card with a communication carrier frequency below 150kHz.

4. The RFID card learning apparatus as claimed in claim 1, wherein each of the plurality of RFID cards is a high frequency RFID card with a communication carrier frequency above 150kHz and below 40MHz.

5. The RFID card learning apparatus as claimed in claim 1, wherein the microcontroller further comprising another I/O port, a PWM Output Port, the microcontroller outputting a pulse-width-modulation (PWM) signal through the PWM Output Port, the PWM Output Port being connected to the one end of the coil which is connected to the I/O port of the microcontroller, wherein

when the RFID card learning apparatus operates in the learning mode, the I/O port of the microcontroller is set to be floating, the another I/O port of the microcontroller is set to be a high potential, and the PWM signal is transmitted to the coil for reading the one of the plurality of RFID cards.

6. The RFID card learning apparatus as claimed in claim 1, further comprising an input stage circuit, wherein

the microcontroller further comprises a positive OP input port, a negative OP input port, an OP output port and an operation amplifier, inputs of the positive OP input port and the negative OP input port are used as two inputs of the operation amplifier, and output of the operation amplifier is coupled to the OP output port, wherein

an input terminal of the input stage circuit being connected to the another end of the coil, the ADC input port,

a first output terminal of the input stage circuit being connected to the positive OP input port of the microcontroller, and

a second output terminal of the input stage circuit being connected to the negative OP input port of the microcontroller, wherein

the input stage circuit being capable of adjusting a frequency of the electromagnetic signals sensed by the coil by using a capacitor coupling to the coil, and the input stage circuit being capable of low-pass filtering before the electromagnetic signals sensed by the coil being transmitted to the positive OP input port of the microcontroller or to the negative OP input port of the microcontroller.

7. A wearable product, integrated with a microcontroller and a coil, wherein the microcontroller comprising a first I/O port, a second I/O port and a ADC input port; and

a coil having one end connected to the first I/O port of the microcontroller and another end connected to the second I/O port and the ADC input port, the coil forming as an electromagnetic load or antenna,

wherein the microcontroller outputs a voltage signal with a frequency through the first I/O port to the coil for charging one of a plurality of RFID cards,

the microcontroller receives a first signal through the coil without demodulation, wherein the first signal comprises a RFID card number and data,

the microcontroller stores the RFID card number and data by detecting a current variation or a voltage variation of the first signal to determine a load variation, using the load variation to obtain the RFID card number,

when the microcontroller receives a read request and is being triggered by a level variation of a carrier signal of the RFID card reader, the microcontroller determines whether the RFID card reader is a high frequency RFID card reader or a low frequency RFID card reader according to a carrier frequency of the carrier signal, such that the microcontroller transmits the RFID card number through the coil according to a corresponding transmission format and a corresponding timing.

8. An operating method of a wearable product, wherein the wearable product comprises a microcontroller and a coil, and the operating method comprising:

outputting a voltage signal with a frequency to the coil for charging one of a plurality of RFID cards by the microcontroller;

receiving a first signal in response to the voltage signal through the coil, the first signal comprises a RFID card number;

detecting a current variation or a voltage variation of the first signal to determine a load variation, using the load variation to obtain the RFID card number, and

stores the RFID card number by the microcontroller; and

transmitting the RFID card number through the coil by the microcontroller when the microcontroller receives a read request and is being triggered by a level variation of a carrier signal of the RFID card reader, wherein the microcontroller determines whether the RFID card reader is a high frequency RFID card reader or a low frequency RFID card reader according to a carrier frequency of the carrier signal, such that the microcontroller transmits the RFID card number according to a corresponding transmission format and a corresponding timing.