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An Infrared-Based Parking System Using Non-Processor OBU Device

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Abstract. In the conventional parking systems for home or community, the drivers of vehicles mostly use the wireless remote controller or RFID card to open the parking barrier gate by identification when they enter into or exit from the parking lot. However, it is inconvenient by a manual operation even these approaches are simple and easy. Therefore, more and more parking systems develop toward to automatic identification and control, and the OBU (On Board Unit) devices need to be installed on the vehicles. Most of the OBU devices use MCUs to control the infrared transmission and reception for the infrared-based parking systems. However, the more battery power of the OBU device will be dissipated. In this paper, a non-processor OBU device is proposed to reduce its standby power consumption. Besides, when the OBU device receives an infrared induced signal to cause transmitting an infrared identification signal, the data collision also can be avoided by the design of the delay control circuit to further increase the stability of identification.

Keywords: data collision, delay control, infrared parking systems, OBU device

1 Introduction

There are various methods of identification applied to the parking systems, for example, the car driver uses a wireless remote controller or RFID card to open the parking barrier gate when the vehicle approaches to the entrance/exit of the parking lot. Although these two approaches are simple, easy and cheap, it is an inconvenient for the car driver due to requiring a manual operation. Using the technology of license plate recognition indeed achieves a benefit to realize automatic identification and control, however, such a parking system must raise its system cost, and the identification rate is not 100% because the image recognition is easily affected by many environment factors, such as lightness and angle for taking a picture [1]. Therefore, based on cost consideration, the parking system using license plate recognition is less adopted by the small or middle parking lots.

As the ETC system of freeway using E-tag identification [2], no OBU device needs to be set in the vehicle, and only requires a passive E-tag pasted on the vehicle for automatically completing the system identification. However, in such a system, there may be a worry about doing harm to human health if the RF station with high power is established near home or community, especially for a long communication distance. Moreover, due to using high RF band, it may interfere with the present mobile communication, and the entire system cost is still high. Therefore, a low-cost parking system based on infrared communication is suggested to adopt. Fig. 1 shows a basic structure of the parking system based on

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infrared communication. Whether OBU device or RSU (Road Side Unit) system, they require a pair of TX/RX modules to transmit or receive the infrared signal each other. When the car enters into the detection range, the RSU system will send an induced signal. Once the OBU device receives this signal, and it then transmits an identification signal indicating its own ID code back to the RSU system. After recognition, the RSU system will open the parking barrier if the ID code is correct [3-5].

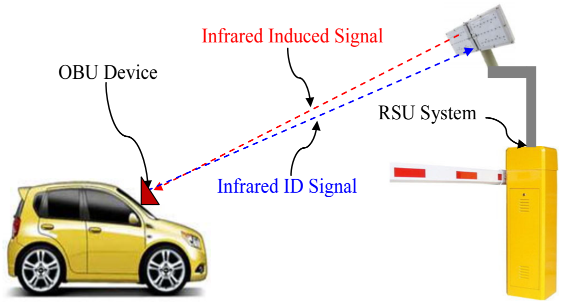

Fig. 1. A parking system using infrared signal processing

Traditionally, most of the OBU devices of vehicles use MCUs to control the infrared transmission and reception; however, it will consume more battery power. Since the OBU device only waits for the induced infrared signal from the RSU system at usual time, and then it sends an infrared identification signal back to the RSU system only if receiving a correct induced signal. In this paper, we try to build an infrared-based parking system including the RSU system implemented by an embedded system and a proposed low-power OBU device using non-processor architecture, the standby power consumption of the OBU device is therefore saved. Besides, the accompanying data collision also can be avoided by the design of the delay control circuit to further increase the stability of identification.

2 Basics of Infrared

The infrared communication, a kind of wireless communication technology, uses the infrared signal to transfer data between transmitters and receivers. Due to no physical connection, the infrared communication benefits low implementation cost and easy operation, and therefore it is widely applied to remote control for many electrical appliances [7]. Recently, the infrared signal is also usually used as a medium to perform the information switching between computers and mobile devices such as intelligent phones or PDAs. The following sub-sections will describe about some basic characteristics of the infrared signal and the technologies used for infrared data communication such as coding/decoding and modulation/demodulation.

2.1 Infrared Radiation

The infrared radiation belongs to an invisible light with longer wavelengths than that of the visible light, lying from 0.75μm to 1000μm and being emitted from all kinds of objects [7]. According to Planck's law [8], the spectral radiance $B_\lambda(T)$ is given by:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda kT} - 1}, \tag{1}$$

where T is the absolute temperature, λ is its wavelength, k is the Boltzmann constant, h is the Planck constant, and c is the speed of light. We further find that the infrared radiation intensity depends on its wavelength and the temperature of an emitting object. Fig. 2 shows the relationship between the relative radiant intensity of IR LED and its angular displacement [12], and we find that the infrared signal has a characteristic of direction, which means the IR LED can obtain a largest radiant intensity when its emitting angle is 0°, but the radiation intensity will decrease down as the emitting angle shifts. In summary, the infrared suits for slow and short communication in a space with fewer obstacles. However, comparing with the RF radiation, the infrared signal almost does not damage human body in most cases.

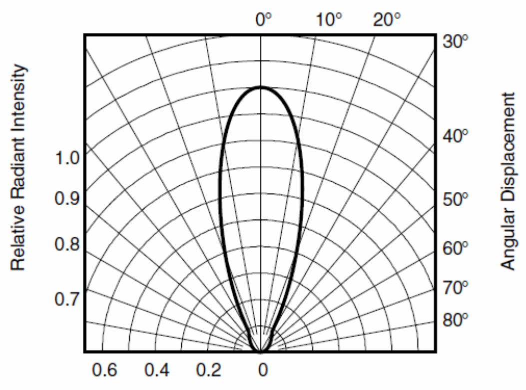

Fig. 2. The relative radiant intensity for IR LED: TSAL6200. (from Vishay Semiconductors)

2.2 Encoder and Decoder for Infrared Communication

The infrared signal is easily affected and interfered by sunlight or fluorescent light, if the transmitter directly sends data by the infrared signal under no further processes, and thus the infrared receiver cannot read correct data. Therefore, the data encoding/decoding and modulation/demodulation are necessary for the infrared communication. A carrier frequency of 30 KHz to 60 KHz, typically 38 KHz, is used for the infrared transmitter to modulate the transmitted data, and then the receiver can receive the demodulated data after removing the carrier. As for encoding and decoding in the infrared data communication, most of encoders define data bit '0' or '1' according to a given pulse width shown in Fig. 3 [9], and then construct a message word including a series of address bits and data bits. The decoder can decode this message word obtained at receiving end. Like the often-used encoder/decoder chips: HT12E and HT12D [9-10], their main common features are shown as follows:

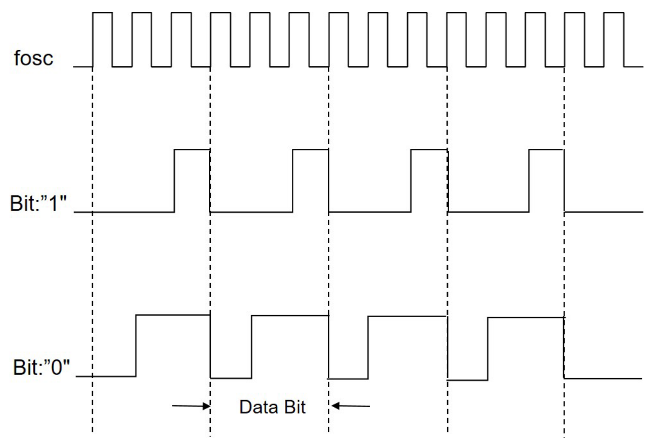

Fig. 3. Representation of data bit using pulse width

(1) Wide operating voltage: 2.4V~12V.
(2) Low power and high noise immunity by using CMOS technology.
(3) Ultralow standby current.
(4) Programmable 256 addresses and 16 data.
(5) Only an external resistor required to provide the operating frequency.

Fig. 4 shows the operation timing of HT12E and HT12D [9-10]. When a trigger input (/TE) of the encoder (HT12E) is enabled, the output (DOUT) of HT12E generates a 4-word transmission cycle, and this cycle will repeat itself as long as /TE remains low. Once /TE returns to a high level, DOUT completes its final cycle and then stops [9]. Simultaneously, when a signal appears on the input (DIN) of the decoder (HT12D), it will activate HT12D to receive the incoming message words that are transmitted by an encoder, where each message word contains the address bits and data bits. After receiving the transmitted addresses three times continuously, if the received address codes all match the local address assigned to HT12D, the VT output goes high to indicate a valid transmission, otherwise it always keeps a low level. Besides, the data bits are also decoded to the data output pins, and this VT will remain high unless the address code is incorrect or no signal is received [10].

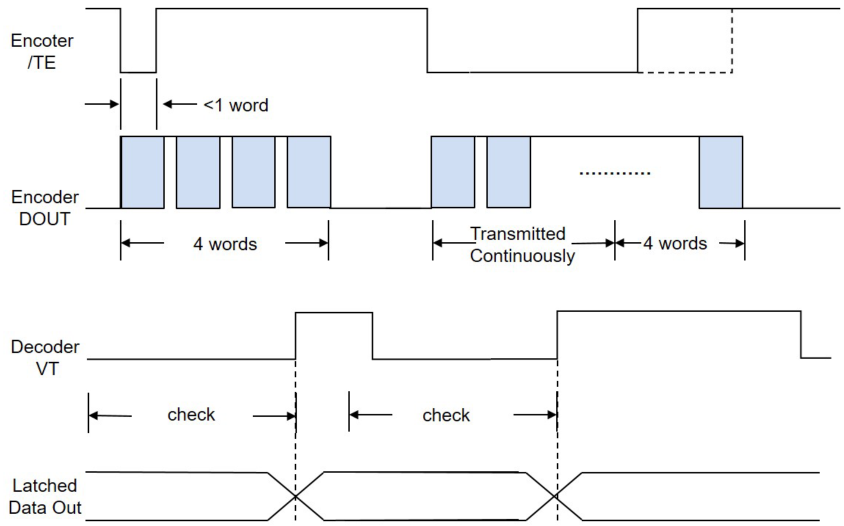

Fig. 4. The operation timing of HT12E and HT12D

3 Design of Infrared-Based Parking System

Based on the principle of infrared transceiver, a parking management system is designed for community household vehicles in this paper, and this system can complete the functions as follows:

Editing management via network. The administrator can connect to the system host computer and log in the database (MySQL), and then directly edit and set the information of the vehicles that enter/exit the parking lot through the web page, where these editing features of the vehicle information include: addition, modification, query, and deletion.

Automatic identification and control. When the vehicle is close to the sensing area and is about 5~10 meters from the entrance/exit of the parking lot, the parking barrier gate will be automatically opened. Therefore, the vehicle does not need to halt at the entrance/exit of the parking lot to wait for opening the gate.

Report of exception. When the vehicle stays at the entrance/exit end for a long time, the system will send an abnormal message through the network to the system host computer, which reminds the administrator to deal with this exceptional situation.

Camera-assisted monitoring. For avoiding the failure of system identification, the system can take pictures by the camera to assist the administrator to further check the situations of all vehicles that enter into or exit from the parking lot.

There are two parts including the OBU device and the RSU system in this parking system, where different encoding addresses are assigned to their individual transmitters and receivers, respectively. The following sub-sections will describe the design of the OBU device and RSU system in detail.

3.1 Proposed Non-Processor OBU Device

The conventional OBU device usually uses an MCU as its main controller to achieve a better performance and a low hardware complexity [2], and it handles various operations such as infrared transmission/reception and control of address encoding/decoding. Although the MCU can make itself remain in a power down state during the period to wait for the reception of infrared induced signal, this OBU device still keeps dissipating a few current.

3.1.1 Architecture of OBU Device

For reducing more standby power consumption, a non-processor OBU device is proposed in this paper, and it is fully composed of hardware components shown in Fig. 5 [6], where the decoding address for receiver and the encoding address for transmitter are different. This OBU device only consumes power to transmit an infrared ID code with 38 KHz carrier after receiving an infrared induced signal from the RSU system, and almost no current is lost except for a small current caused by the infrared receiver when remaining in a standby state.

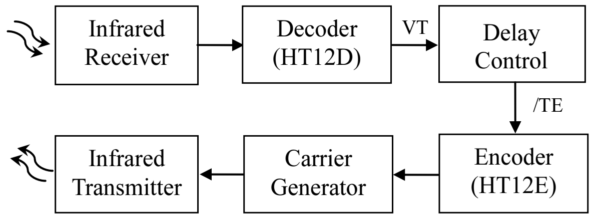

Fig. 5. Architecture of proposed OBU device

3.1.2 Carrier Generator

A well-known and versatile timer chip, NE555, works in a mode of astable oscillator to be a carrier generator of 38 KHz in the proposed OBU device [11], and it can be controlled by the RST input that connects to DOUT of the encoder (HT12E). Therefore, an ASK modulated waveform will output to activate the driver of IR LED, and then transmit the infrared signal. However, NE555 still consumes the battery power even no output, therefore, an extra PMOS is required to switch power to NE555 shown in Fig. 6, and it occurs only when HT12E is enabled by a trigger input /TE.

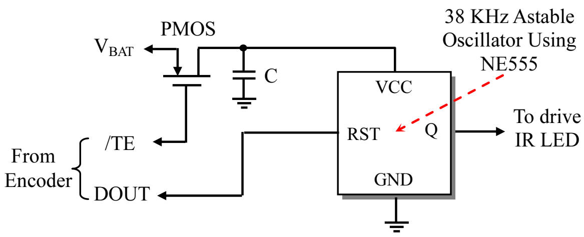

Fig. 6. Circuit of carrier generator

3.1.3 Circuits of Transmitter and Receiver

Usually, an infrared transmitter is composed of several IR LEDs and a driving transistor, and the infrared intensity depends on the number of IR LEDs and the current that flow through LEDs. For example, the infrared driving circuit shown in the left of Fig. 7 has three parallels of IR LED strings, and each string consists of two IR LEDs in series. For a given current I_F of IR LED that obtains the optimal infrared intensity, R_D can be decided by:

$$R_D = \frac{V_{BAT} - 2 \times V_D - V_{DS}}{3 \times I_F}, \quad \textbf{(2)}$$

where V_{BAT} is the battery voltage and V_D is the voltage across IR LED (about 1.5V). When the modulated output from the carrier generator turns NMOS on to drive IR LEDs, the voltage V_{DS} across drain and source of NMOS almost approaches zero, and thus the infrared signal is emitted from IR LEDs.

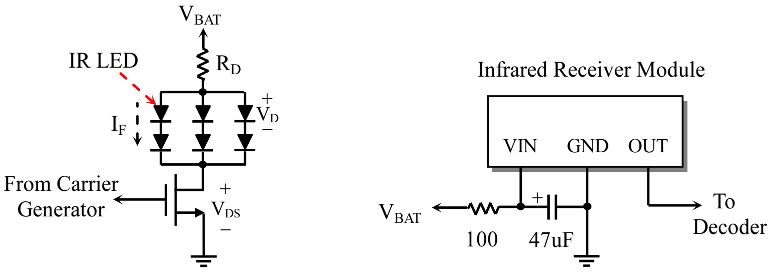

Fig. 7. IR LED driver and infrared receiver module

As for the implementation of infrared receiver, a standard IR receiver module, shown in the right of Fig. 7, is popularly used to receive the infrared signal and remove its carrier of 38 KHz, and then outputs the demodulated signal. This module integrates PIN diode, preamplifier, automatic gain control (AGC), band pass filter, and output stage into a package, and it only provides three pins for a convenient usage [13].

3.1.4 Data Collision

If the valid output (VT) of the decoder, which indicates that the infrared receiver receives an induced signal with correct decoding address, is used to directly activate the transmission of ID code corresponding to the OBU device, the data collision will occur at the RSU system. The reason to generate such data collision shown in Fig. 8 describes as follows [6]:

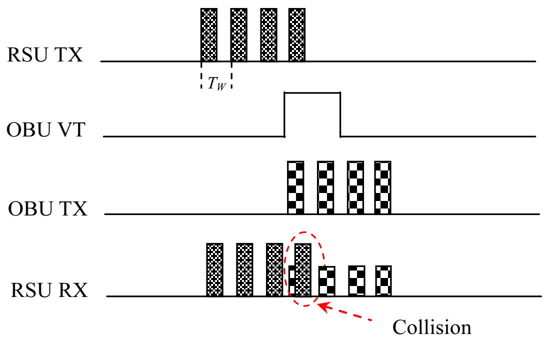

Fig. 8. Data collision of non-processor OBU device without delay time

(1) When the RSU transmitter sends an induced signal with four repeated words via the RSU encoder (HT12E), and this signal also concurrently sends back to the RSU receiver.

(2) Once the OBU receiver receives about three successive and correct words via the OBU decoder (HT12D), the OBU decoder will output a VT signal.

(3) This VT signal immediately enable the OBU encoder to generate an ID code, and the OBU transmitter sends an infrared ID signal back to the RSU system.

(4) The RSU receiver receives the ID signal from the OBU device, which will confuse with the part of the self-feedback induced signal. Therefore, the data collision occurs at this moment.

The data collision easily makes the RSU decoder fail to recognize the ID code because the strength of the received ID signal is often less than that of the self-feedback induced signal. Especially for the communication of a long distance, the identification error rate is more significant.

3.1.5 Delay Control

To avoid the occurrence of data collision, a delay control circuit shown in Fig. 9 is required in a non-processor OBU device [6]. When the output VT of the OBU decoder turns to “Hi”, the voltage V_{C1} is charged through R_1 and C_1, and it is given by:

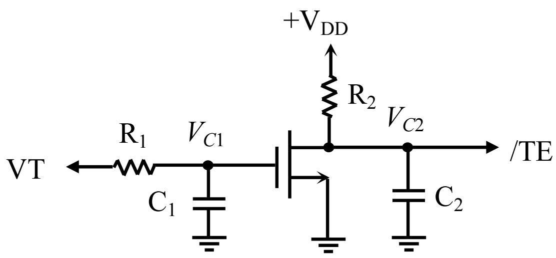

Fig. 9. Delay control circuit

$$V_{C1} = V_H (1 - e^{\frac{-t}{R_1C_1}}), \tag{3}$$

where V_H is the logical high-level voltage of VT. Let R_1C_1 time constant equal to T_{d1} (> one-word time T_W), and thus V_{C1} reaches the threshold voltage (V_{th}) of NMOS after a delay time T_{d1} to turn /TE to "Lo" in order to trigger the OBU encoder. Therefore, the R_1C_1 value is found as:

$$R_1C_1 = \frac{T_{d1}}{\ln(V_{th} / V_H - 1)}. \tag{4}$$

Similarly, when /TE turns to "Hi" from "Lo", the voltage V_{C2} is charged toward to V_{DD} through R_2 and C_2. Finally, V_{C2} reaches a logical high-level voltage V_H after a delay time T_{d2} to disable the encoder, and thus it is expressed as:

$$V_{C2} = V_{DD} (1 - e^{\frac{-T_{d2}}{R_2C_2}}) = V_H. \tag{5}$$

For a given T_{d2} to achieve a longer low period of /TE, by selecting appropriate R_2C_2 value shown as:

$$R_2C_2 = \frac{T_{d2}}{\ln(V_H / V_{DD} - 1)}, \tag{6}$$

the OBU transmitter therefore can repeatedly send more words related to ID code to further increase the stability of identification for the RSU system. Fig. 10 illustrates how to eliminate the data collision by adding a delay control circuit.

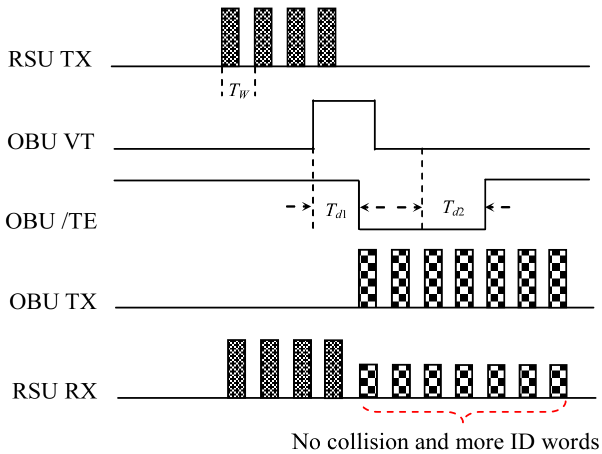

Fig. 10. Elimination of data collision using delay control

3.2 Design of RSU System

Fig. 11 shows the architecture of the RSU system, where an embedded system module (M502) is used as a main controller to control its peripheral circuits or devices. In this RSU system, the M502 starts the CCD to take picture by USB control, and uses its GPIO to control the parking barrier gate and communicate with the remote system host computer by LAN connection. Besides, the circuits of infrared transmitter and receiver controlled by M502 are almost the same as that of the OBU device.

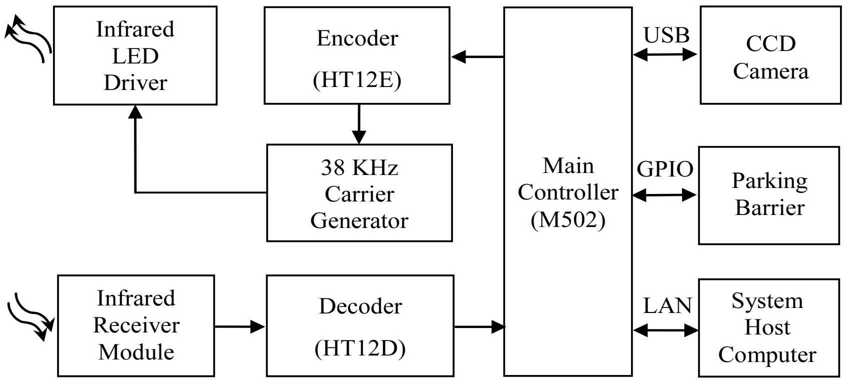

Fig. 11. Architecture of RSU system

3.2.1 Embedded System Module

Although the personal computer (PC) has powerful features such as multimedia signal processing and network connectivity, it is not appropriate to apply to thin, small, and portable electronic products. Thanks to rapid development of VLSI technologies, the embedded system with high performance and low power consumption is becoming a trend of control platform for electronic products. In recent years, ARM CPU series almost have been the mainstream 32-bit embedded processors because they feature low power, high efficiency, rich resources and the support by operating system [14].

An industrial Linux-based ARM9 system on module [14], M502 shown in Fig. 12, is selected as a main controller in this RSU system. The M502 is powered by 400MHz ARM926EJ-S ARM thumb processor with memory management unit, and equipped with 64MB SDRAM, 128MB NAND Flash, and 2MB Data Flash. It also provides flexibilities in peripheral expansion, such as Ethernet, USB 2.0, UART, GPIO, SD card interface, serial SPI port, I2C bus, I2S bus, and 8-bit local bus [14]. Moreover, a RTC unit is built in M502 to keep the system time when power is off, and the M502 also can support the installation of web sever and database (MySQL).

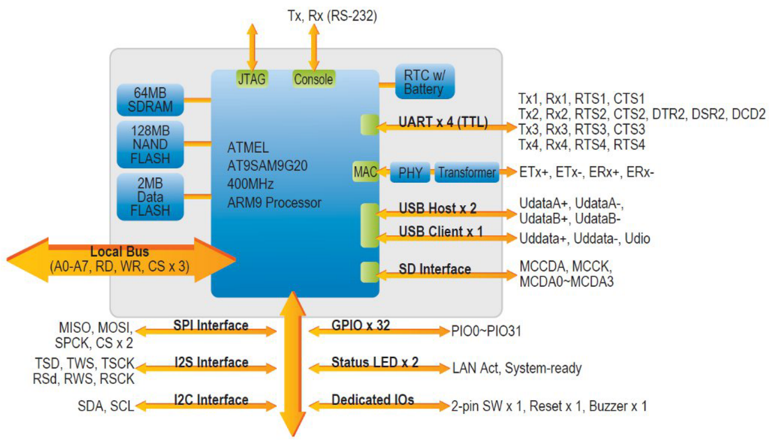

Fig. 12. Function block diagram of M502 (from Artila Electronics)

3.2.2 Identification Code

For obtaining the identification (ID) code of the vehicle, the M502, in turn, sets the encoding address and sends the corresponding induced signal by driving the infrared LED. If the coded address matches with that of the OBU device, and then the OBU device will send an infrared ID signal back to the RSU system. When the RSU system receives the ID signal that matches with its own address, the M502 can extract the data (D0 ~ D3) from HT12D as the lower 4 bits of the identification code and use the currently transmitted coded address (A0 ~ A1) as the upper 2 bits of the identification code. Therefore, the format of ID code of the vehicle is shown in Fig. 13.

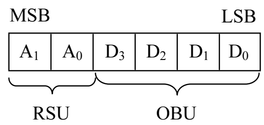

Fig. 13. Format of ID code

3.2.3 Operations

Fig. 14 illustrates the operation flow of this RSU system when it communicates with the OBU of the vehicle, and these operations are separately described as follows:

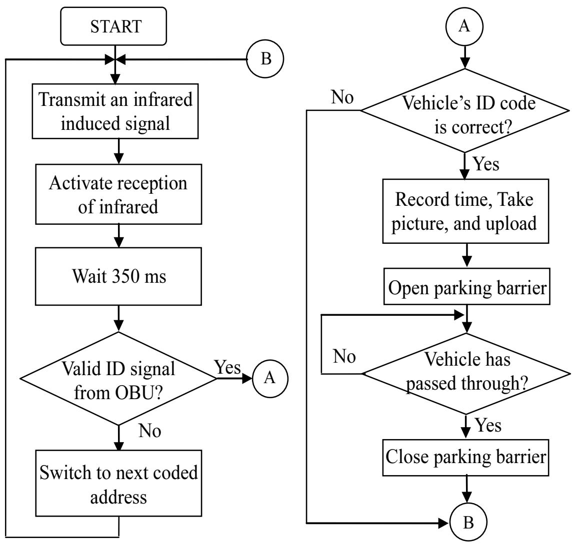

Fig. 14. Operation flowchart of RSU system

(1) Firstly, the M502 sets the coded address and drives the IR LED to transmit an infrared induced signal, where the coded address is only from 0 to 3 for simplifying the design of the RSU system in this paper.

(2) The infrared receiver module begins to wait for the infrared ID signal from the OBU device on the vehicle about 350 ms.

(3) The M502 will read the decoded data by the decoder when receiving a valid ID signal, otherwise switch to the next coded address and repeat the above operations.

(4) After checking the ID code, if this vehicle's ID code has already existed in the database of the parking system, and then the system will open the parking barrier gate, record the time to enter or exit, and take picture for this vehicle. Besides, the recorded information and picture related to this vehicle are also uploaded to the system host computer by network.

(5) Based on the consideration of safety, the parking barrier gate does not drop down until the vehicle has completely passed through the gate.

4 Experimental Results and Analysis

For implementing the proposed OBU device shown as Fig. 2, a 9V battery is provided as a main power source, two useful chips with ultralow standby current, HT12E and HT12D, are used as the encoder and decoder, respectively. The oscillator (NE555) is used to generate a carrier of 38 KHz and modulate the ID number from HT12E, and it does not work at standby state until the ID number words need to be transmitted. In addition, the infrared receiver and transmitter employ a standard IR receiver module and some IR LEDs including a driving NMOS, respectively. Fig. 15 shows the practical completed prototype of the infrared-based parking system including the related apparatuses of the RSU system, the simulated small car with an OBU device, and the remote monitoring host computer, where the monitoring GUI webpage is storied in the web sever that was built in the M502 embedded system module. The environment of experimental measurement is shown in Fig. 16.

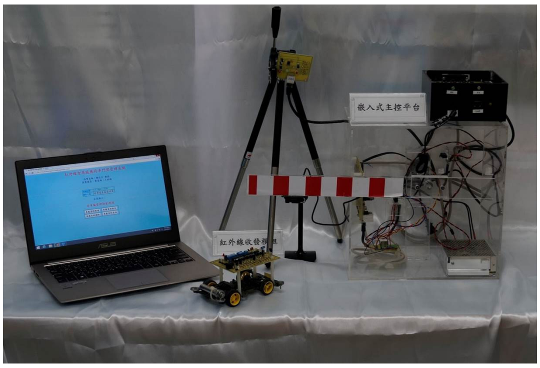

Fig. 15. Prototype of infrared-based parking system

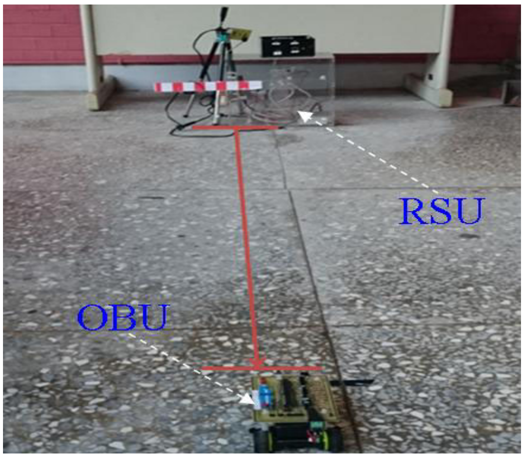

Fig. 16. Environment of experimental measurement

4.1 Effect of Delay Control for OBU device

To evaluate the effect of delay control on identifiable distance, we try to change different values for C_1 and C_2 existed in the delay control circuit of the OBU device, and we find that the RSU system cannot identify the ID signal from the OBU device due to data collision if no capacitors are added. Besides, if only C_1 or C_2 exists alone, the improvement on identification rate is not obvious. Therefore, by selecting $C_1 = 4.7$ uf and $C_2 = 10$ uf, the identifiable distance can achieve up to 10 meter shown in Table 1 [6], and it is an optimal choice for the design of the delay control circuit.

Table 1. Identifiable distance vs. C_1 and C_2

C2 \ Id. Distance \ C1	0	4.7 uf
0	0	3.7m
10 uf	4.5m	10m
22 uf	9.5m	10m
47 uf	10m	10m
R1=KΩ, R2=470KΩ		

4.2 Identification Rate

At RSU system end, the stability to identify the infrared ID signal from the OBU device is inversely proportional to the distance between RSU system and OBU device, which is because the received infrared intensity of the RSU system decreases down as the distance increases. Especially under sunlight interference, the identification rate will significantly reduce as the distance increases. Fig. 17 shows the variety of the identification rate under different conditions. Without any interference, as at indoor space, the identification rate can maintain 90% in a range less 5 m; it still has an identification rate of 53% even at a distance of 10 m. However, under sunlight interference, the identification rate dramatically decreases down from a distance larger than 1 m, and the RSU system almost cannot identify any infrared ID signal from the OBU device when the distance is over 5 m.

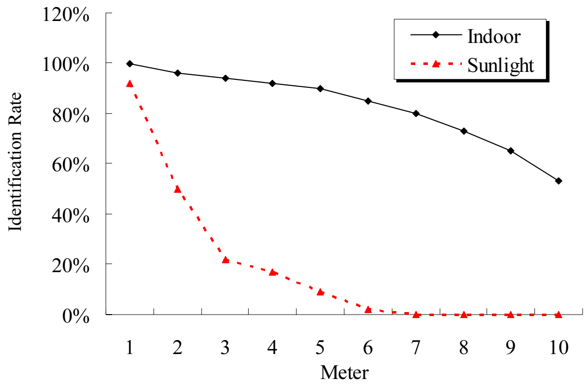

Fig. 17. The identification rate under different conditions

4.3 Standby Power Comparison

Similar to OBU architecture shown in Fig. 5, the conventional OBU devices use an MCU as their main controller to replace the delay control circuit, even the encoder and decoder, but they need an extra wake-up circuit to awake their MCU [2] from an idle or power down mode. The wake-up circuit usually uses a comparator [15] to detect the voltage size of infrared signal, and then the comparator’s output will awake the MCU to work. Besides, for supplying a lower operating voltage to MCU, it is necessary for the conventional OBU devices to require a voltage regulator, however, a minimum load current is required to maintain regulation even the MCU remains in a standby state [16]. In Table 2, three frequently used MCUs: 89S51, MSP430, and PIC16F153 [17-19] are respectively used to implement three processor-based OBU devices, in order to make a comparison with the proposed non-processor OBU device on their standby power consumption. Both MSP430 and PIC16F153 are RISC-type MCUs, and they offer a feature of extreme low power to suit for wearable devices. Herein, the supply battery voltages of these OBU devices are all 9V to obtain a longer transmission distance, and the required components in Table 2 mean the elements that dissipate current when staying in a standby state. We find that the OBU devices using RISC-type MCUs almost have no power consumption at a power-down mode, but the required voltage regulators still dissipate current even in a standby state. Relatively, the proposed non-processor OBU device only dissipates an ultralow current caused by decoder, and the main dissipated current is from the infrared receiver module. Therefore, the proposed non-processor OBU device has less standby power consumption than that of the processor-based OBU devices.

Table 2. Standby Power Consumption for different OBU Devices

OBU Types / Required Components	Proposed OBU	89S51 OBU	MSP430 OBU	PIC16F153 OBU
Decoder (HT12D)	0.2 μA	NA	NA	NA
Comparator (MAX971)	NA	4 μA	4 μA	4 μA
MCU (Power Down)	NA	50 μA@5V	0.1 μA@3V	0.05 μA@3V
IR Receiver (IRM0208_A538)	1 mA	1 mA	1 mA	1 mA
Voltage Regulator (LM317)	NA	3.5 mA	3.5 mA	3.5 mA
Standby Power Consumption	9.018 mW	40.786 mW	40.5363 mW	40.5361 mW

5 Conclusions

For building a low-cost and safe parking system with automatic identification and control, the design of an infrared-based parking system is exposed in this paper. In addition to practically implementing the RSU system controlled by an embedded system module, a non-processor OBU device is especially proposed to reduce its power consumption. From our experimental results, the RSU system can successfully recognize the OBU ID code by infrared communication, and the proposed OBU device, by the design of the delay control circuit, can avoid the data collision and send more ID words to enhance the identification stability of the RSU system due to increasing the identifiable distance. Moreover, the standby current of the proposed OBU device is nearly only dissipated in the receiver module, which is not large than 1 mA. Based on the consideration of high identification rate under no interference, a sensing distance of 5 m is an optimal choice, and thus it can suit for applying to indoor or basement parking lots. In the future, how to reduce sunlight interference will be a next design issue for an infrared-based parking system.

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