Wireless Transmission of Images from a charge-coupled device (CCD) Camera

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Abstract:
Aim of this article is to describe a development of a camera system which enables a wireless image transmission. We used a small CCD camera for taking images, that camera is connected to a special module developed during this work. The camera system is composed of three main parts – a service module with the camera (works as a transmitter), a coordinator (serves as a receiver) and a control program with a user interface (runs on a PC). The wireless communication (data transfer) between the service module and the coordinator is based on the IEEE 802.15.4 standard. The coordinator is common product of the company Freescale, but the service module is designed and developed specifically for the system. Software for all three parts is also developed for that purpose. The finished system can take an image from a remote location and wirelessly send it to the PC.

INTRODUCTION

The article describes a design of software and hardware for a wireless data transfer from the charge-coupled device (CCD) camera. The camera system consists of a transmitter, a receiver and PC with a control program and a user interface. As the receiver existing equipment is used, the transmitter is designed and manufactured during this work so as the software for all components. The created camera system is used for a remote acquisition of images. It can by used, for example, in these applications:

- **Security systems** – scanning when a door is opened, motion in the monitored area or periodical check of an area.
- **Monitoring** - checking the condition of a monitored area or object, for example control of fuel level.
- **Remote reading** - periodical readings of the inaccessible meters (water meters, gas or electricity).

In the firs section we describe the camera system, then we present hardware for the service module. After that we introduce the software for the whole system. In the final section we discuss the results.

THE CAMERA SYSTEM

As was mentioned above, the camera system consists of tree main parts: the transmitter (a service module for the camera, an end device), the receiver (a coordinator) and PC with necessary software. Control of the entire system, image storage and its display performs the control program running on PC. The service module provides control of the CCD camera, illumination of a scene, saving up to four images into a serial memory, repeated scanning and sending images on the basis of inputs from connected external sensors. It communicates with the coordinator via a wireless interface and the coordinator is connected to PC via a serial line (see block diagram on Figure 1). The network topology is a star. System can consists of one coordinator and one up to four end devices.

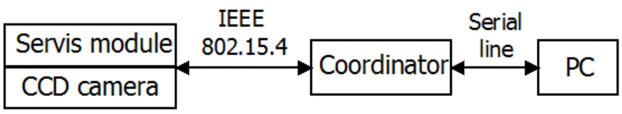

Fig. 1: The camera system [5]

Description of the camera

The camera uses a charge-coupled device technology. CCD uses a physical phenomenon known as the photoeffect. Impacting light releases electrons in a number corresponding to light intensity. The released electrons are stored in capacitive bins corresponding to each pixel. Image information is obtained by finding the size of charge for each pixel. The CCD camera was chosen for its small size, good resolution, a small operating current (60 mA) and because it is a color camera.
Used camera is a type C328R manufactured by COMedia company [1]. The camera module has small dimensions (20 mm x 28 mm), see Figure 2. The camera uses a color sensor which allows a resolution up to 640x480 pixels when using JPEG format. It is also possible to focus manually, which enable to scan object from short distance. DC voltage of 3.3 V is needed for powering the camera.

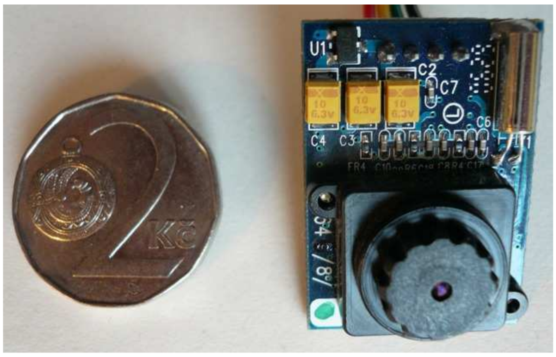

Fig. 2: The camera module [5]

Wireless interface - IEEE 802.15.4 standard

Wireless data transmission is realized using the radio interface according to IEEE 802.15.4 standard [2], [3]. Hardware implementation is based on Freescale radios [4]. IEEE 802.15.4 is a new international communication standard (November 2004) for small-scale network (PAN - Personal Area Networks) and for small distances, the range is usually called as 30 m indoors and 70-100 m in free space. It is designed for low power devices that do not have high demands on the transmission speed (at 2.4 GHz, the maximum speed is 250 kbps). The standard defines the physical and the access layer protocol (PHY and MAC), which uses the ZigBee protocol. It operates in unlicensed frequency bands.

Usage is primarily aimed for industrial applications, building automation and consumer electronics. The main advantages are reliability, easy implementation, very low power consumption and low cost of these devices. IEEE 802.15.4 divides the devices according to level of provided services to devices which implement the complete protocol framework (FFD - Full Function Device) and a devices that implement only necessary functions (RFD - Reduced Functionality Device).

HARDWARE FOR THE SERVICE MODULE

The hardware design is based on requirements for the service module. It is mainly operating the camera, maintaining the radio communication and storing images [5] a [6].

When the module receive control message (see below) for scanning it must turn on the camera and establish a communication with it. Then the camera can take an image and send it to the module. After obtaining an image from the camera, it is split into packets (number depends on the size of the image, see below), which can by send via the wireless interface.

The radio communication arranges a modem PAN 4551, with according software, see below.

The service module must also save images into the serial memory for possible re-sending to the coordinator.

As other functions, it must provide an adequate illumination of a scanned scene. The module also allows a connection of external sensors via optocouplers to expand possible uses or other devices via the serial line (at 3.3 V level). The module is powered by DC voltage and can operate on batteries. Overall design is shown on Figure 3.

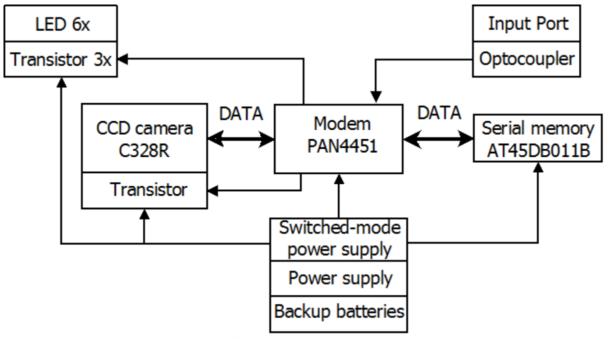

Fig. 3: Overall structure of the service module [5]

Main parts

Wiring and a printed circuit board have been designed in Eagle 4.16r2 Light. The main hardware parts of the service module are:

- Modem PAN 4551 (Panasonic)
- Serial memory AT45DB011B
- Switched-mode power supply
- LED, transistors, optocouplers etc.

The camera is connected to the service module and is powered by it. The serial memory is also powered from service module.

Switched-mode power supply

The power supply design is based on a monolithic control circuit MC34063A, see Figure 4. Required output voltage of the power supply is 3.3V (memory and wireless module may have a lower power, but the camera module requires optimal supply as 3.3V). The values of some passive components (resistors, capacitors) can be read from the datasheet, the rest (value of the induction of a coil and a voltage divider) were calculated.

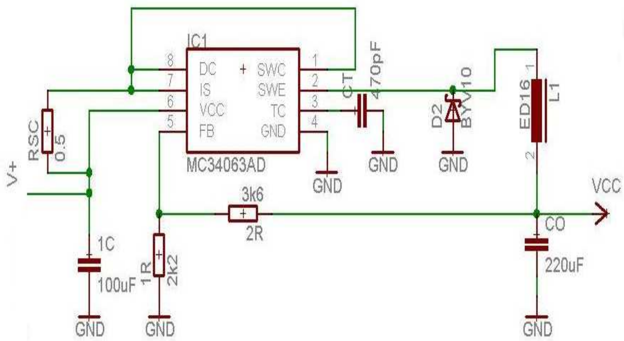

Fig. 4: Design of the switched-mode power supply [5]

Serial memory

The serial memory keeps the image in need of re-transmission and preserves the image in case of interruption in communication with the coordinator.
The memory is divided into two units, a data stack and a main memory. The stack is used to speed up the work with data. It is only possible to write a whole page (264 B) into the memory. Data are firstly written to the stack (the stack size is one page) and consequently its content is written in one page of the main memory. Modifying the content of one page of the main memory directly is not possible, it must by done externally. Reading is possible directly from the main memory or via the stack. Writing and reading are internally controlled and only need the starting address (of the stack or page of main memory).

SOFTWARE FOR THE CAMERA SYSTEM

All tree main components of the system (the service module for the camera, the coordinator and PC) require software for their proper function. Applications for the coordinator and the service module are developed in CodeWarrior, the control application is developed in MS Visual C++ 2008 Express Edition.

Software for the service module

Application is responsible for operating the service module. In the wireless network the service module operates as the end device (RFD). Provides turning on and off the camera module, establishing communication, arranges the camera setup, performs images storage, illuminations a scene and sends images to the coordinator.
The service module is primarily controlled through messages sent by the coordinator. These messages are data packets with size of two bytes where the first one determines the type of a command and the other is additional information (if needed). It is also possible to start scanning from input of external sensors which can be attached to the service module through optocouplers. The service module is also responsible for sending error messages and other information to the coordinator.
An important part of the module is the serial memory. The memory is used to store up to four images for their possible reuse. For each image a fixed data space is reserved based on average size of images (see Results). Images are stored such way, that four recent photos are stored (always the oldest image is overwritten). Images from the memory can by load and sent on a demand. It is also possible to delete any image. For work with the memory is necessary to firstly upload control data in it. Then is possible to either read or write data into it. For easy work with the serial memory a library is developed. Functions in the library are divided into three groups (for read, for write and auxiliary).

Software for the coordinator

The coordinator provides communication between PC and the service module. To PC is connected via a serial interface, with the service module communicates using the wireless protocol IEEE 802.15.4. The coordinator receives commands from the control program via serial line, determines what type of a command it is and then sends the appropriate message to the service module. The coordinator also has to control the radio communication, receive data packets from the service module (error, info or data messages), request for resending of any lost or corrupted packets and so on.

Control program

Program is developed in language C++ and run under OS Windows XP. It is a user interface and provides control of the whole camera system, see Figure 5.

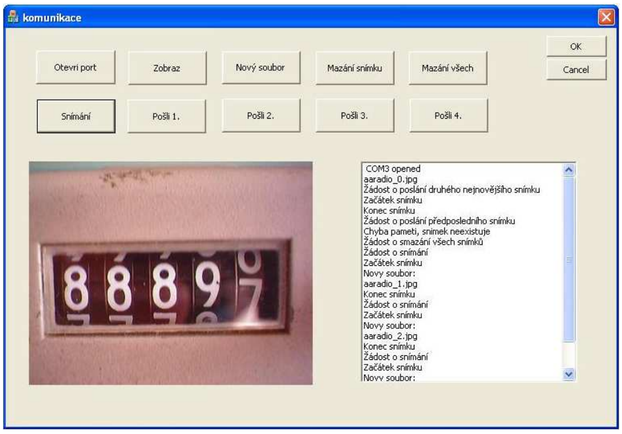

Fig. 5: The Control program window [5]

In the upper part of the window are control buttons, right part is an event log area and on the left a preview of an image is shown. The control buttons are used for sending messages to the camera (via coordinator). In the log area the history of messages (for example request for scanning), error events and other information (for example end of receiving of an image) are shown and stored for better readability of past events. The preview shows last received image to the user.
The control program is also responsible for receiving of data packets and their joining into one file – the image. The control program distinguishes three types of data packets: error messages, info messages and data packets. Each type has to be handled in a different way. How data packets are handled is shown on Figure 6.
The program spends most of the time waiting for an event on the serial line. After receiving any data (an event on the serial line), it has to distinguish what type of event it is (error, info or data packet). When the decision is made, the event is handled accordingly to the type of the event.

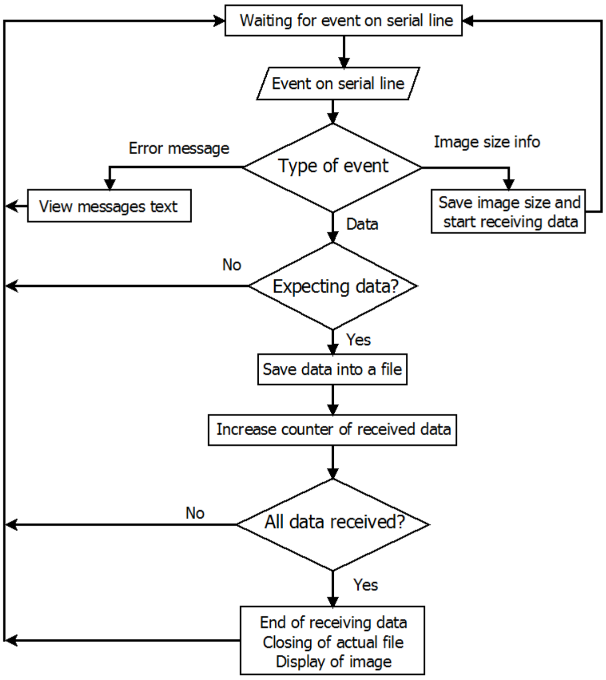

Fig. 6: Data packets handling diagram [5]

RESULTS

In first part, wireless data transmission is evaluated, in particular the dependence between packages sizes and transmission speed. In the second part, the camera and images are evaluated.

Wireless data transmission

A dependency of transmission speed on the size of a data packet is measured. A fixed amount of data (3 000000 B) is being sent from the service module (end device) to the coordinator. From these data a bit rate is calculated for each packet size. For measurements are used Freescale radios [4]. The measurement is performed in a brick family house and the end device and the coordinator are located in adjacent floors. When the end device is placed out of the house (the coordinator remains inside) a significant deterioration of the signal occurs and transmission is possible only in some places.
The coordinator was connected to PC via a serial line. For the measurement a specific application is created. For every size of data packets is the measurement performed five times and then a mean value of a bit rate is calculated. The measurements suggest that the larger data packet is used, the higher is the bit rate, see Table 1.

Table.1: Mean values (success of about 98%)

Package size[B]	Time [s]	Bit rate [kb/s]
20	871	27,5
40	480	50,1
60	358	67,3
80	286	83,9
100	247	97,1

The Camera

Image is obtained 3 seconds after the request for scanning (one second it takes to establish communication and initialization, two seconds takes the camera to adjust to light conditions). Follow data transmission depends on the size of the image, such as total time to scan and transfer an image size of 15 kB is about 15 s.
The size of the scanned images depends on what is on the image. Whole black or white image has size about 7 kb, multicolored and structured image size is about 31 kB. Size of an image capturing an object on the background is around 15 kB.
Testing show that the illumination is effective only for nearby objects (up to 1.5 meters), see Figure 7. For illuminating of distant objects or scenes, such as cars on a street, an external light is needed. Also when installing the camera for the first time it is necessary to focus it manually.

Fig. 7: An illuminated image, size about 14 kB [5]

CONCLUSION

During the work the camera system for wireless transmission of images is designed and implemented. Based on testing work and communication with the CCD camera, hardware and software for the service module for the camera is designed and implemented. Also software for the whole system (the service module, PC and the coordinator) is developed.
As part of the solution the test program is create to evaluate the transmission properties of the chosen radio communication protocol (IEEE 802.15.4). The dependency of the bit rate of the radio interface on the size of data packets is discussed. The testing shown that a bit rate increases with increasing of data packets size. After testing the camera the evaluation of its characteristics is presented, as well as evaluation of images sizes in dependency on the character of the scanned scene.
The system can be further improved by modification for possible operation on batteries (for example use of sleep and power saving modes for modem in service module), outdoor use or implementing more powerful

external lights for suitable illumination of distant objects.
The result of this work is the complete system that realizes wireless transfer of images from the CCD camera to PC.

ACKNOWLEDGEMENT

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