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USING INFRARED TO REMOTE CONTROL THE INCANDESCENT BULBS LIGHT INTENSITY IN A RESIDENCE

BY

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Abstract. The work describes the hardware structure of an infrared remote controlled system for adjusting the incandescent bulbs light intensity in a residence using pulse width modulation. The command transmission and reception are based on frames using Sony-SIRC protocol. The program, written in machine language, insures the reception of the infrared frames encapsulating user-sent commands. Each bulb is controlled within a multi-process system, based on a certain numerical value of the fill factor.

Key words: Sony-SIRC protocol; infrared receiver; incandescent bulb; pulse width modulation.

1. Introduction

The remote control is a frequently used method for audio and video devices in a home, but also for specialized equipment. Nowadays, it is used mainly the communication between a remote control and a receiver. The most used communication protocols are: ITT, JVC, NEC, Nokia, NRC17, Philips, RCA, Sharp, Sony-SIRC, X-sat, but there are also others. No common standard has been reached so far.

The structure of an infrared remote controlled system for adjusting the

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incandescent bulbs light intensity in a residence is depicted in Fig. 1. The notes have the following meanings: IRTx – infrared transmitter; IRRx – infrared receiver; CCU – command and control unit, actually an application system based on a microcontroller (µC_AS); PWM – pulse width modulation light bulbs control; OD - output drivers used to control the incandescent bulbs L_7, L_6, …, L_1, L_0; SI-RS232 – serial interface RS232; PC – personal computer.

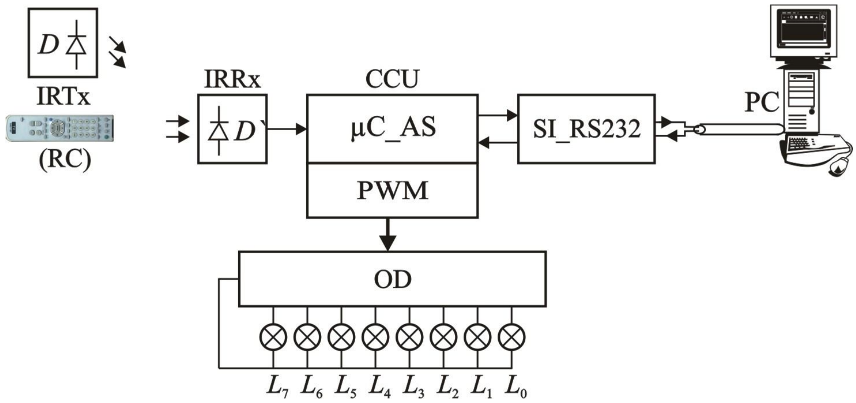

Fig. 1.

The incandescent bulbs are controlled by the microcontroller through software, using pulse width modulation. These are powered from a DC power source of 12/24/48 V and have the power of a few tens of watts (100 W at most).

The infrared transmitter is actually a remote control (RC) using Sony-SIRC protocol, coming from a TV set (address 01H). This obviously does not allow the use of a Sony TV set in the residence, because its operation would be interfered by the infrared commands meant for the light bulbs in the described application.

2. Sony-SIRC Protocol

The serial infrared control (SIRC) protocol from Sony has three versions that consist of the transmission of a START pulse followed by either 12, 15 or 20 data bits. The most common one used nowadays is the 12-bit version, being the simplest to implement.

The information sent by the Sony-SIRC protocol is an asynchronous serial multiplex that has the useful information bits organized in frames. A 12-bit Sony-SIRC protocol frame begins with a START pulse followed by a 7-bit command field and a 5-bit address field (Fig.2). The other two versions are similar to this one, but for the Sony-SIRC 15-bit version, the address field consists of 8 bits, while for the Sony-SIRC 20-bit version, the address field is followed by an 8-bit extension field. In each frame field, the bits are sent starting from the least significant bit (LSB) and finishing with the most significant bit (MSB).

The Sony-SIRC protocol modulates the infrared emitted radiation on a carrier frequency (f_p) of 40 kHz. The fill factor for the carrier signal is recommended to either 1/4 or 1/3. For the data bits the pulse width modulation is used, which means that for the logical “1” bit, carrier modulated infrared radiation is emitted with a longer duration (double) compared to logical “0” bit.

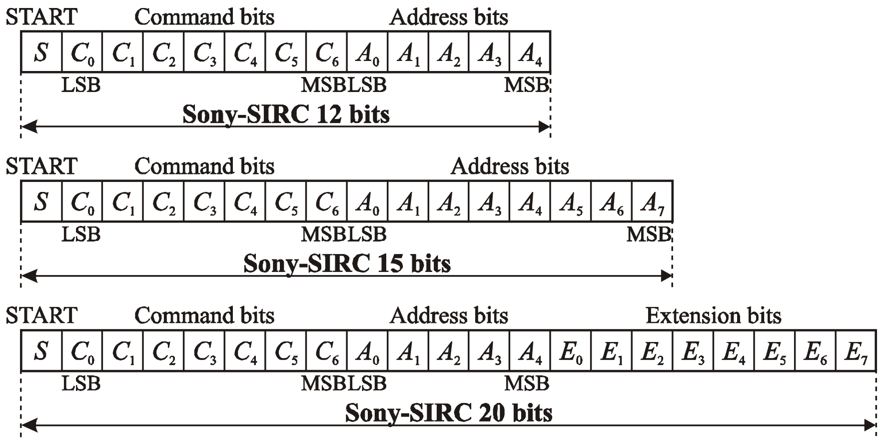

Fig. 2.

The START pulse sends carrier modulated infrared radiation for 2.4 ms (Fig. 3) in order to allow the time required for the infrared receiver to prepare for the reception of the data bits (performs gain adjustment for the input amplifier). This START pulse consists of the transmission of 96 carrier signal periods (T_P).

The address bits field (A_4, A_3, …, A_0) is used to address the device for which the command is meant. In this manner, it is avoided the situation where a command destined to one device to influence other devices found in the coverage area of the remote control. The addresses of the main audio/video devices are: 01 – TV set; 02 (03) – video cassette recorder; 06 – laser disc unit; 12 – surround sound; 15 – cassette player; 16 – tuner; 17 – compact disc player; 18 – equalizer; 7/19 – experimental equipment and so forth.

The command bits field (C_6, C_5, …, C_0) serves for the transmission of the relevant information for the addressed device. The main command codes for a TV set are: 00…09 – digital keys 1, 2, … 9, 0; 16 – channel +; 17 – channel –; 18 – volume +; 19 – volume –; 20 – mute; 21 – power; 22 – reset; 23 – audio mode; 24 – contrast +; 25 – contrast –; 26 – colour +; 27 – colour –; 30 – brightness +; 31 – brightness –; 38 – balance left; 39 – balance right; 47 – stand-by; etc.

The logical “0” data bit is 1.2 ms long and consists of a pause lasting for 0.6 ms followed by the carrier modulated infrared radiation emission for another 0.6 ms (Fig. 3). The infrared radiation pulse for this bit spans for 24 periods of the carrier signal (T_P).

The logical "1" data bit is 1.8 ms long and consists of a pause lasting also for 0.6 ms followed by the carrier modulated infrared radiation emission for 1.200 ms (Fig.3). In this situation, the infrared radiation pulse spans for 48 periods of the carrier signal (T_P).

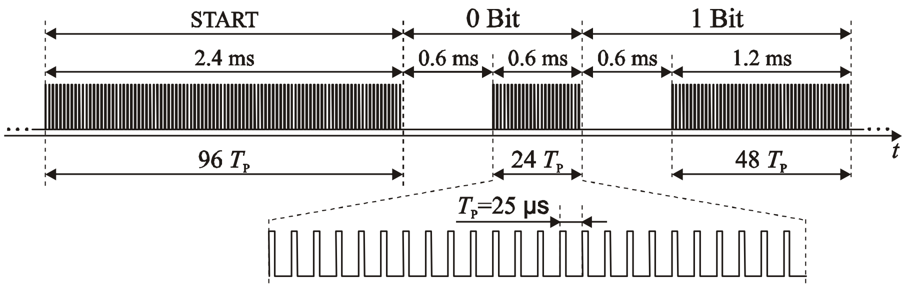

Fig. 3.

In Fig. 4 is represented the waveform for a Sony-SIRC frame transmission that includes the START pulse, followed by a command corresponding to numerical value 07 (digital key 8) and the address of the selected device 01 (TV-set). The pulses in the figure represent radiation emission, while during logical "0"-pause, no radiation is emitted.

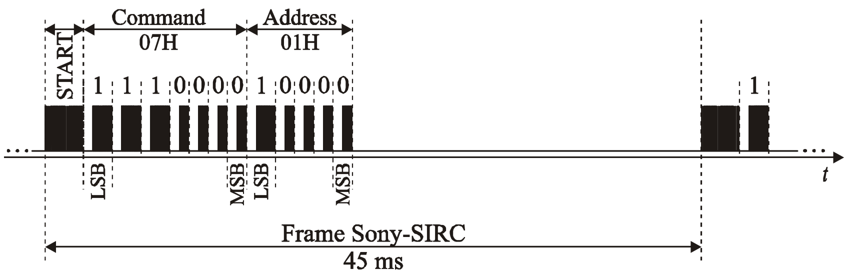

Fig. 4.

A Sony-SIRC frame takes from 16.8 ms (only logical "0" bits are sent) up to 24 ms (only logical "1" bits are sent). When a recurring command is sent, Sony-SIRC frames are repeated every 45 ms, measured from the beginning of first START pulse until the beginning of the next one.

3. Infrared Control of Incandescent Bulbs

The infrared receiver detects and decodes the signal and provides the relevant information for the command of the selected device. This must include an infrared photo-diode, followed by an amplifier with a gain control circuit and a demodulation block. The infrared receiver functions are commonly integrated nowadays in a single integrated circuit and do not require any external components.

The application uses a TSOP57240 miniature infrared receiver that fulfill all the previous described requirements and its epoxy lens cap is designed as an infrared filter. The basic features of the infrared receiver are: half angle sensitivity φ = ±75°; photo detector and preamplifier is on package; interval filter for PCM frequency; improved immunity against ambient light; insensitive to supply voltage ripple and noise; wavelength λ_P = 950 nm for maximal relative spectral sensitivity ($S(\lambda)_{rel}$ = 1); requires a minimum irradiance of 0.2 mW/m^2; carrier frequency of 40 kHz; etc.

The internal structure of the infrared receiver is shown in Fig. 5 and includes: photodiode PIN along with the polarization circuit (D'), the preamplifier for the received signal (PA), the automatic gain control circuit (AGC), the band-pass filter (BPF) centered on the carrier frequency, demodulator (DM), the receiver control circuit (CC) and the output driver (OD).

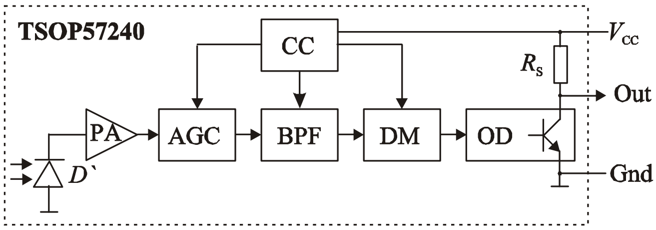

Fig. 5.

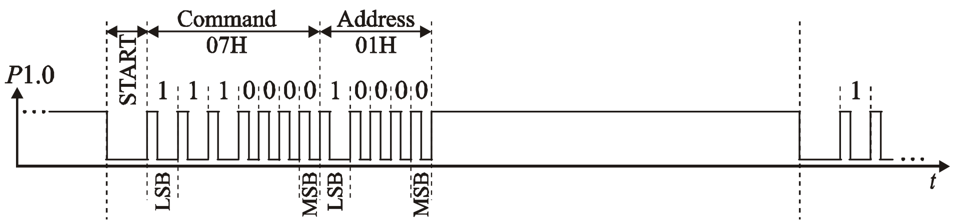

Fig. 6.

An infrared radiation pulse with a certain duration provides at output OUT of the receiver a logical “0” level with the same duration. When no radiation is received, output OUT provides logical “1” level. For the Sony-SIRC frame presented in Fig. 4, output OUT of the receiver will produce the waveform shown in Fig. 6.

In order to decode Sony-SIRC frames, it is required a hardware structure consisting of a command and control unit equipped with microcontroller AT89S8253 (Fig. 7). This requires besides the microcontroller a 24 MHz quartz crystal for the clock oscillator, an *RC* group and an initialization switch, *K*, decoupling capacitors and a MAX233 circuit for performing serial asynchronous communications with a serial console (PC).

Output OUT of the infrared receiver is connected to input *P*1.0 of the microcontroller in order to allow for the reception and analysis of the Sony-SIRC frames.

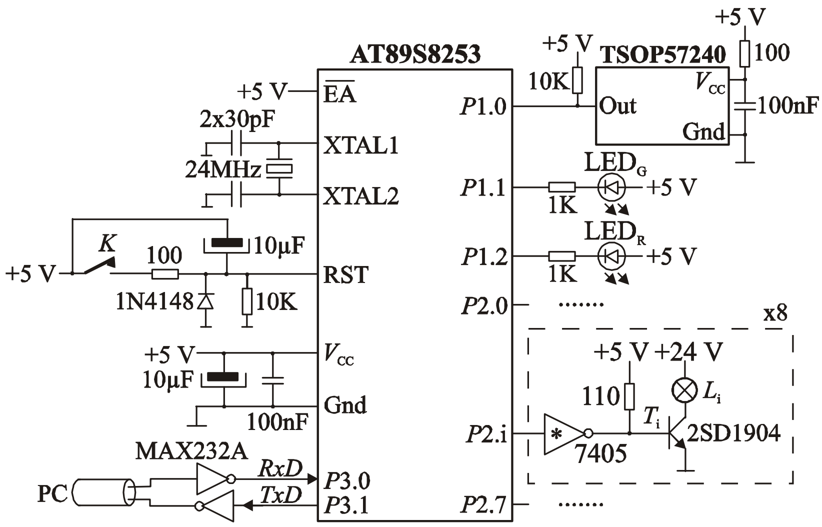

Fig. 7.

During frame reception, the microcontroller provides a low level at output *P*1.1 in order to light up the green signalization LED (LED_G) and a logical high in order to turn it off when frames are not received. When an erroneous frame is received, the microcontroller turns off LED_G and turns on the error red LED (LED_R) by setting output *P*1.2 in logical low during the corresponding frame reception and during the pause between frames, but no longer than 250 ms.

In order to control the eight incandescent light bulbs, L_i , (i = 0.7), using the port output lines *P*2.i, adequate driver circuits are used, consisting each of an open-collector inverter buffer (7405) and a switching transistor T_i. The bulbs used have a nominal voltage of 24 V and take a 2 A current. The switching transistors are type 2SD1904 (V_{CE} = 50 V, I_C = 5 A, β = 70). A logical low level at any output of port *P*2 saturates the transistor and lights the corresponding bulb, while a high level blocks the transistor and turns off the corresponding bulb.

All bulbs are controlled using pulse width modulation (PWM) with a 20 ms period and a 10% step for in order to grow or diminish the fill factor.

In Table 1 are given a few examples of numerical values that determine to turn off a bulb (L_7), to turn another on (L_3), to light up a bulb with fill factor of 50% (L_5) or another value (20% for L_6, 80% for L_4 , etc.); this data structure is updated in the software image of the process by the commands sent through infrared by the user. The command program extracts the current numerical value from the software image of the process and sends it to port *P*2 every 2 ms. The software image is stored in the internal data memory of the microcontroller starting from address 20H.

Table 1

	Software image										**Bulb status**
Bit 7	1	1	1	1	1	1	1	1	1	1	L_7 (from *P*2.7) off
Bit 6	0	0	1	1	1	1	1	1	1	1	L_6 (from *P*2.6) on 20%
Bit 5	0	0	0	0	0	1	1	1	1	1	L_5 (from *P*2.5) on 50%
Bit 4	0	0	0	0	0	0	0	0	1	1	L_4 (from *P*2.4) on 80%
Bit 3	0	0	0	0	0	0	0	0	0	0	L_3 (from *P*2.3) on (100%)
Bit 2	0	0	0	1	1	1	1	1	1	1	L_2 (from *P*2.2) on 30%
Bit 1	0	0	0	0	0	0	1	1	1	1	L_1 (from *P*2.1) on 60%
Bit 0	0	0	0	0	0	0	0	0	0	1	L_0 (from *P*2.0) on 90%
Data	**80H**	**80H**	**C0H**	**C4H**	**C4H**	**E4H**	**E6H**	**E6H**	**F6H**	**F7H**	
Address	**20H**	**21H**	**22H**	**23H**	**24H**	**25H**	**26H**	**27H**	**28H**	**29H**	

The program consists of an initialization sequence, a main program and the software sequence for serving interrupt requests. Following the system's power on and the microcontroller's initialization, the application initialization program section is executed. This consists of initializing the stack point indicator, the system variables, the output ports in order to turn off the light bulbs and the signalization LEDs, the *T*2 counter for setting a serial communication rate of 9,600 bit/s, the microcontroller's serial asynchronous interface used to communicate with the serial console, counter *T*0 for generating periodic interrupts every 50 µs, etc.

Then, the program initializes the variables used for: the Sony-SIRC frames infrared reception process, for the PWM command process for light intensity adjustment of the 8 bulbs connected to port *P*2 and for the process in charge of analysing the user commands received and software image updating. Afterwards, the program tests whether the serial console can communicate with the microcontroller and the interrupt system is validated.

If the microcontroller is able to communicate with the serial console, then the main program variables are initialized, the console screen is cleared and a launch message is displayed. The main program has the lowest priority and continues by displaying on one row the commands received in infrared and the eventual errors and on the next row the fill factor for each bulb.

If the serial console does not communicate with the microcontroller, the main program is not executed and the system enters a stand-by loop, waiting for interrupts.

Every 50 µs an interrupt is issued by counter *T*0, in order to sample the signal from the infrared receiver and to analyse this signal during several consecutive samples to establish whether a START pulse was issued, or a data bit of 0 or 1 was received. Using the numerical values of the received data bits, the command and the address are determined from the currently received frame. Then the programs checks if the address from the received frame concerns a PWM command for the bulbs light intensity adjustment, the received command is verified and, subsequently, the analysis and the corresponding update of the software image are performed.

The implemented infrared commands allow to increase or to decrease by 10% the fill factor for each bulb independently or for all bulbs. A five-command group allows either to turn off all bulbs, or to light them up with a fill factor of 30%, 50%, 70% and 100%. Another four-command group performs the transfer of a user pre-defined sequence from the non-volatile memory of the microcontroller into the software image of the PWM processes enabling to turn off or on the bulbs with different numerical values for the fill factor.

The program section serving interrupt requests also counts interrupts. In this manner, at every 40 interrupts (2 ms), the PWM process that commands the bulbs connected in port *P*2 is updated with the corresponding data from the software image of the process.

4. Conclusions

The described hardware structure was built in practice; it is simple and consists of the infrared receiver, an application system equipped with microcontroller AT89S8253 and the output drivers used to command the incandescent bulbs using pulse width modulation for adjusting light intensity. In this manner the lightning provided is comfortable, agreeable, easy to adapt to various necessities but also economical, and can be used in homes, office spaces, shops, museums or other environments.

The number of the light bulbs included in the application can be expanded up to several tens, only by adding output drivers to the microcontroller's ports. The structure of these drivers can be easily replaced by optotriacs that allows the use of incandescent light bulbs powered from the AC mains.

The command program is a multi-process system designed to receive Sony-SIRC frames, to update the software image corresponding to the pressed key and to control through PWM the light bulbs. Commands were implemented for increasing or decreasing by 10% the fill factor, for turning off the light bulbs or turning them on with a certain fill factor, but also with various numerical values pre-set by the user in sequences stored in the non-volatile memory.

The command program was written in machine language and takes a memory area of 3.7 Kbytes. The user can store in the non-volatile memory of the microcontroller other sequences that include numerical values for the fill factor for adjusting the bulbs light intensity according to his own needs.

The software structure allows alter the step for increasing or decreasing the fill factor in a range from 1% to 25%, with the possibility to implement a command that accomplishes this function. The macro-state used for receiving the Sony-IRC frames can be easily redesigned in order to implement any other infrared protocol.

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TELECOMANDA ÎN INFRAROŞU A INTENSITĂȚII LUMINOASE PENTRU BECURILE CU INCANDESCENȚĂ DINTR-O LOCUINȚĂ

(Rezumat)

Se descrie structura „hard” a unui sistem cu telecomandă în infraroşu pentru comanda intensității luminoase a becurilor dintr-o locuință utilizând modulația impulsurilor în durată. Transmiterea comenzilor şi recepționarea acestora în infraroşu se face pe baza de cadre care folosesc protocolul Sony-SIRC. Programul realizat în limbaj maşină asigură recepționarea cadrelor în infraroşu cu comenzile transmise de utilizator, iar fiecare bec este comandat în cadrul unui sistem multiproces cu o anumită valoare numerică a factorului de umplere.