# SUB-MASTER MICROCONTROLLER FOR "HOME CONTROL ON FINGERTIPS"

**Grisha Spasov[1], Nikola Hadzhinikolov[1], Galidia Petrova[2]**

[1]Department Computer Systems and Technologies, [2]Department of Electronics, Technical University of Sofia – branch Plovdiv, Tzanko Djustabanov N° 25, 4000 Plovdiv, Bulgaria, phone: +359 32 659 576, e-mail: gvs@tu-plovdiv.bg

*Increasing house equipment with different technical facilities like domestic appliances, TVs, Audio and Video systems, Air-conditioner, security home systems, etc. leads to the fast development of Networked Embedded Systems for 'home automation'. Usually they are distributed systems with hierarchical architecture including three layers: master, sub-masters, and end-devices. The availability of modern microcontrollers with embedded network hardware and software, based on TCP/IP protocol stack, facilitate the development of these systems and their fast integration in Internet environment.*

*The paper describes the realisation of a sub-master controller and its main interactions with master controller from one side and with end-devices from the other side. The communication with end-devices using the most typical interfaces is presented and the sub-master application software is commented in short.*

**Keywords:** sub-master microcontroller, home automation, embedded systems.

## 1. INTRODUCTION

Increasing house equipment with different technical facilities like domestic appliances, TVs, Audio and Video systems, Air-conditioner, security home systems, etc. leads to the fast development of Networked Embedded Systems for 'home automation'[1]. Usually these systems employ a centralized architecture, based on hierarchical three-layer model involving master, sub-masters and end-devices. Each of them has their features and suitable interfaces to communicate with each other. Master accepts the commands from the authorized user and transmits it to the definite sub-master and the sub-master manipulates the end-device.

We have developped such a system for home automation that we have called "Home Control on Fingertips" (HOCFIT). It is based on microcontrollers with embedded hardware and software means for integrating into computer networks, based on TCP/IP communication. In this paper we discuss the realization of a second layer sub-master controller, its main functions, interfacing to the end-devices and applied software.

## 2. SUB-MASTER SYSTEM OVERVIEW

The main functions of the sub-master controller could be specified as follows:

1. Interaction with the Master device:

- The communication with Master device is based on widespread HTTP1.1 protocol via TCP/IP. The channel layer typically uses fast Ethernet;

- Wireless Bluetooth back-up connection is needed when Ethernet is disconnected for any reason or for the lack of Ethernet cable infrastructure;
- The sub-master must support DHCP client and application protocol based on Web interface;

2. Interaction with the end-devices:

- Infrared remote control for end-devices – through IrDA;
- Relay output control for switched end-devices;
- Digital input/output monitoring and control of end-devices though GPIO;
- Temperature and humidity measurements in rooms;
- To support the universality and flexibility to interact with new appliances a USB interface in necessary to be implemented, too.

The functional diagram of sub-master controller is shown on figure 1.

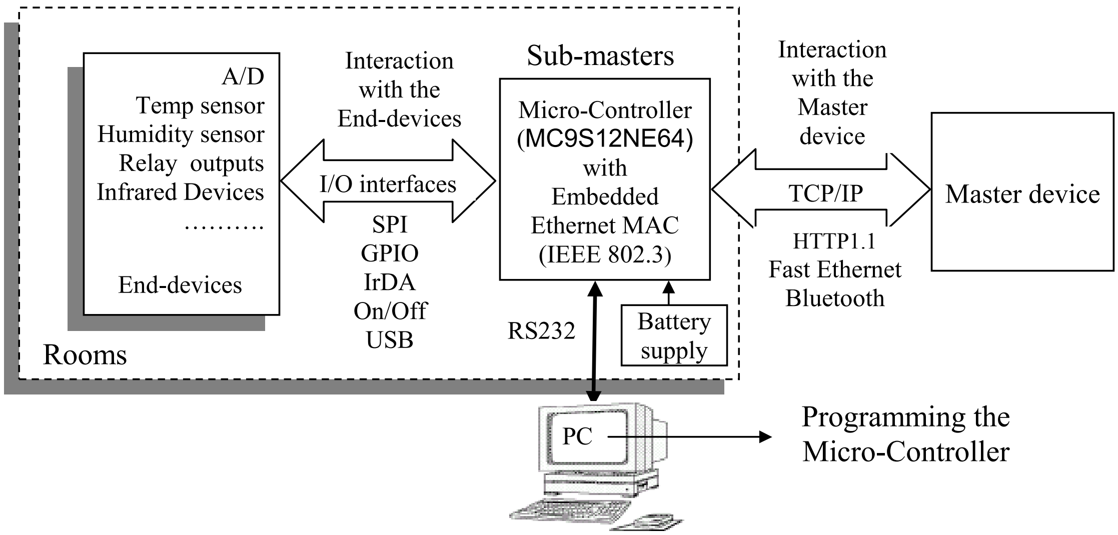


*Figure 1. Functional diagram of sub-master microcontroller.*

For realization of sub-master controller we have chosen the MC9S12NE64 microprocessor (Freescale) [3]. It supports many different interfaces: RS232, Ethernet – 10/100 Mbps, SPI, $I^2C$, GPIO. RS232 interface is used for connection to PC for programming the module, while the others support the interactions with the Master controller and the end-devices. The IrDA, USB and Bluetooth are implemented in addition to complete the functionality of the sub-master controller.

For development of communication software between sub-master and Master controller open-source 'Open TCP/IP' is used. Platform employed for development of the application software for communication of MC9SNE64 with end-devices is CodeWarrior 4.1.

The battery supply is envisaged to be in use when the power supply of the electrical network breaks down. It is important to save the tuned parameters and temporary data stored in the sub-master. Every time when the supply voltage falls under the predefined threshold the battery supply is switched on. The next step is to send data stored in sub-master controller to Master device. Each situation that defines abnormal work of the system generates Exceptions. These Exceptions are written to Log file, so documentation of the system is present and everyone, who has the necessary rights, is able to see the work of the system.

### 2.1 Infrared remote control

We intent to control devices through infrared interface employing IrDA in TV mode. The realisation of the channel is based on CS8130 [4]. The CS8130 is an infrared transceiver integrated circuit. The receiver channel includes on-chip high gain PIN diode amplifier, IrDA, TV remote compatible decoder and data pulse stretcher. The transmitter path includes TV remote compatible and operates from 1200 to 115000 baud as SIR IrDA1.1. According to our purpose we use only transmitter function of the CS8130, but receiver one is scalable. We use only mode 3 of infrared data format, which is TV remote control mode. The modulation frequency is ~ 38 kHz. The IR bit rate is 2400 bps. Both modulation frequency and bit rate vary significantly for different manufacturer and remote control models, that is being defined in the customer Web interface. Hence, the user must define all needed information and Master controller notifies sub-master for changes to be done.

The connection of CS8130 to microcontroller MC9S12NE64 and the format of data sent are shown on the figure 2.

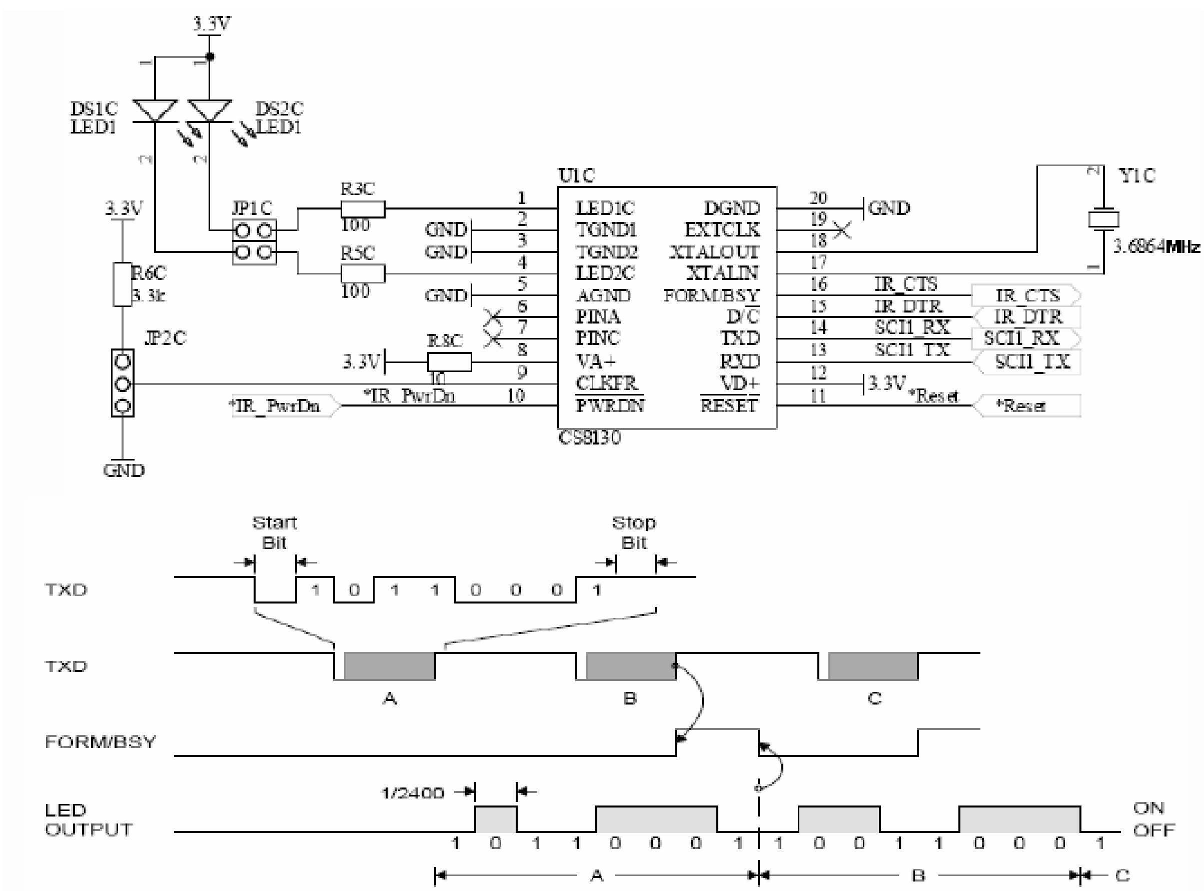


*Figure 2. Connection of CS8130 to MC9S12NE64 and data format.*

During transmission of IrDA, the start and stop bits presented in the incoming data from the microcontroller are stripped off. The remaining data bits are sent out at 2400 bps. Since there should be no gaps in the transmitted data, the input data is buffered in a 22-chracter location FIFO. The characters are received on the TxD pin while the previous characters are being transmitted. To prevent overflow hardware handshake mechanism is supported. If the FIFO is one character away from being full, the FORM/BSY pin is brought high, indicating that MC9S12NE64 must stop transmitting. And if one another character has been transmitted, FORM/BSY pin is brought low, indicating that sending of data could be initiated again. The modulation frequency is determined by the modulator divider registers. The transmitted bit rate is determined by the TV Remote transmit bit rate divider.

The applied software is designed for minimum consumption, so the CS8130 is turned off when is not in use. That is possible by controlling PWRDN pin – when it is brought low all internal logic stops including the crystal oscillator. When the PWRDN pin goes high the crystal oscillator will start again.

**2.2 Digital input and relay output control**

Some devices could be controlled by IrDA, Bluetooth or interfaces as Ethernet, but others only through a switch. Relay is alternative decision and allows easy control to such end-devices. The interface is standard - the relay is driven by a transistor connected directly to the GPIO of the microcontroller.

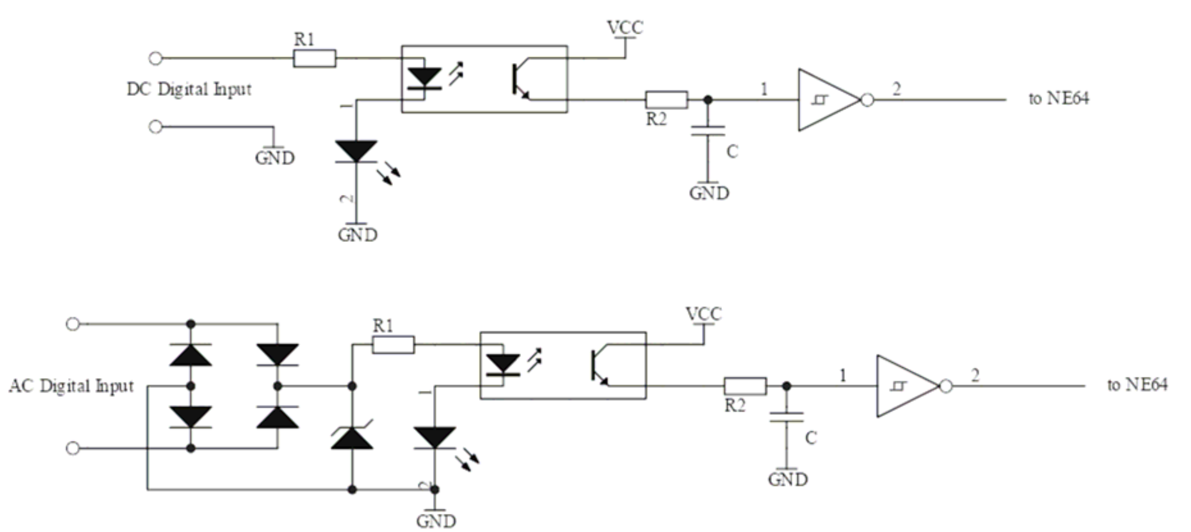


*Figure 3. Connection of DC and AC signals to digital input pins.*

Figure 3 illustrates the circuits used for connection of digital (DC or AC) signals to digital input pins of MC9S12NE64 [5]. The opto-couplers ensure electrical isolation of input signals. The digital inputs and outputs of sub-master microcontrollers are configured individually for each room. That means we are able to connect different type of end-devices to the system and could control and monitor each one of them. In that way the changes have happened in the house configuration will take effect in the web interface. Sub-master evaluates the changes and notifies master controller. Respectively the Master updates the status of web interface for changes that had happened, so customer is keeping in touch what is the current configuration status of the house.

**2.3 Temperature and humidity measurements**

For temperature and humidity measurements we use SHT11/71 intelligent sensor from Sensirion [6]. The main characteristics of the sensor include high signal quality, a fast response time and insensitivity to external disturbances. Performing analog-to-digital conversion "in place" makes the signal practically insensitive to noise. Each SHT11/71 is individually calibrated and calibration coefficients are programmed into the memory. The 2-wire serial interface and internal voltage regulation allow easy and fast system integration.

The connection of SHT11/71 directly to the sub-master by means of the digital 2-wire interface is illustrated on figure 4. This interface is optimized for sensor readout and power consumption and it is not compatible with $I^2C$ interfaces.

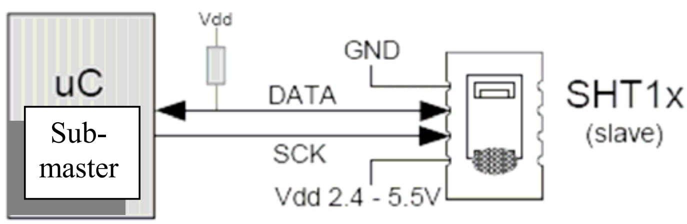


*Figure 4. Connection of temperature/humidity sensor to sub-master microcontroller.*

A measurement using SHT11/71 is a two-step procedure. First, it is necessary to send command for measurement to the sensor and get the data through the digital interface. Second, it is necessary to convert data from sensor to real physical values and to calculate the temperature compensation of the humidity data.

3. SUB-MASTER APPLICATION SOFTWARE

**3.1 Sub-master to master connection**

The software for the connection of Sub-Masters to Master is based on the open source liciense OpenTCP [7] released by Viola Systems Ltd.

When the sub-master connects to the network it starts *Init* phase - running the DHCP client to get an IP address and then sends to the master data for the end-devices that could be controlled [2]. After that it enters the second phase – *Configure* and *Monitor*. In this phase the sub-master is sending periodically the status of the end-devices and waiting messages for configuration (or reconfiguration) from the Master. If there is an emergency situation the sub-master enters the *Exceptions* phase where it informs the master for the emergency and then returns again to second phase.

### 3.2 Control of the end-devices

The communication is fully based on interrupts (software and hardware). For most of the end-devices there is a timer which generates an event when to check their status. Then sub-master sends data to the Master and performs a corresponding task depending on the results of the status checking. The USB, the security system, the Real-time clock and the status of the power supply (wherever it is AC supply or Battery) use hardware interrupt to inform the sub-master for their status.

## 4. CONCLUSIONS

We have designed a system, which will help people to be in touch with their home any time and anywhere. It will be helpful for people with physical disabilities and to their relatives. The system is capable to control several sub-master controllers and a large number of end-devices. In this paper we presented the realization of a Sub-master controller and its main functions to communicate with Master device and to control different types end-devices typical for home environment.

The future work will be oriented to extending the Sub-master functions for be-directional communication with some end-devices using IrDA or other wireless interfaces. In that way some tests and diagnostics of the status of these devices could be integrated in the system functions.

The perspectives for interaction of sub-master to master device will be oriented to implementation of Web-services for embedded applications.

The research and experiments in this paper are part of National Science Fund of Bulgaria project – "**ВУ-966**", 2005, entitled "Web Services and Data Integration in Distributed Automation and Information Systems in Internet Environment".

## 5. REFERENCES

[1] Estrin, D., G. Borriello, R. Colwell, J. Fiddler, M. Horowitz, W. Kaiser, N. Leveson, B. Liskov, P. Lucas, D. Maher, P. Mankiewich, R. Taylor, J. Waldo, *Embedded Everywhere. A Research Agenda for Networked Systems of Embedded Computers*, NAP Washinton, D.C. 2001, ISBN 0-309-07568-8.

[2] Jan Axelson, *Embedded Ethernet and Internet Complete*, Lakeview Research LLC, 2003, ISBN 1-931448-00-0.

[3] *Freescale MC9S12NE64 data sheets & Codewarrior* – http://www.freescale.com/ne64

[4] *Cirrus Logic CS8130 data sheet*, http://www.cirrus.com/en/products/pro/detail/P61.html

[5] Zdravko Karakehayov, *Applied microcomputer systems*, Technika, 1995.

[6] www.sensirion.com/sensors/humidity/ – *SHT71 datasheets and info*.

[7] *OpenTCP*, www.opentcp.org