Monitoring and Control of Communication Equipment in Remote Locations

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Abstract - **Nowadays communication equipment is everywhere, not just in communication closets, where we have controlled environment. But still the equipment has strict operating requirements like temperature, constant power etc. This paper reviews a custom device to monitor and control environment parameters of the communication equipment. The prototype is constructed for use in remote places, where there are just few communication devices, but they have to be monitored. It enables monitoring the temperature, power, controls the cooling system and alerts for physical access to the equipment. In case of emergency, the devices can be stopped remotely. The device also implements a wireless connection for an automatic short-range identification of the supporting staff. It uses ZigBee stack from Microchip.**

Keywords – **Temperature control, Remote start/stop control**

I. Introduction

With the ever-expanding need of communication, more and more communication equipment is installed. Not always the equipment can be installed in optimal places and it can be difficult to provide the optimal operating conditions. Often communication equipment is installed on rooftops, underground or in remote locations.

If the case is to have a lot of equipment then there cannot be a compromise; main and backup cooling and power system have to be implemented; device that monitors the temperature, airflow, and humidity must be installed. Security system has to be installed. But in the case of a small rack or just a single device (e.g. repeater, or switch) the overall cost for the supporting equipment is just too high [3]. This is why we have created this prototype. The device monitors one of the most important parameter of the environment – temperature and has a built-in PID regulator to control a cooling system. Monitored as well is the power. If there are power issues, this can lead to malfunctioning of the devices that are very difficult to diagnose from a distance. The next aspect of the device is to monitor physical access to the equipment. This could prevent stealing equipment or compromising the integrity of the communication. In case of nature disaster, heat problems or unauthorized access, devices can be remotely turned on/off to avoid equipment damages and/or communication compromises. The device automatically reads the identification code of the support personal using short-range wireless radio connection. It uses the ISM band at 2,4GHz and free ZigBee (IEEE 802.15.4) stack protocol. The knowledge of ID code of the supporting staff is urgent due to security reason.

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II. Device Architecture

This project is built using Dallas's DS18B20, Microchip's 25LC1024, ENC28J60, PIC18F2620 and the newest BJ1305 chip. The block diagram is shown on Figure 2. The main microcontroller is PIC18F2620. It has build in four timers, 64kBytes of flash memory and 32kWords of program memory, 3986 bytes of RAM, three bidirectional ports and 10bit A/D converter.

The A/D converter is used to measure the power grid voltage. The input voltage for the A/D convertor must be between 0÷5V DC. To reduce the grid voltage to a value that can be measured by the PIC18F2620 an AC to DC convertor is used. In fact a power step-down transformer and a voltage rectifier do it. The nominal mains voltage of ~220V equals to +4.0V DC after the AC/DC conversion. Thus the maximum measured mains voltage value is ~275V. The pin RA0 from PORT A is used as analog input for the A/D module, which is set to 10bit accuracy.

The USART port is not used. Rather the TX pin is used as output to control the FAN (cooling system), and the RX pin is used as an input from the access control switch. To convert the levels from EIA232 to TTL, MAX232 is used. MAX232 is a dual driver/receiver with a built-in capacitive voltage generator that converts the TIA/EIA-232-F to 5V TTL/CMOS Levels. To be able to control a cooling fan or other cooling system, the current from the MAX232 needs to be amplified. The following schema is used:

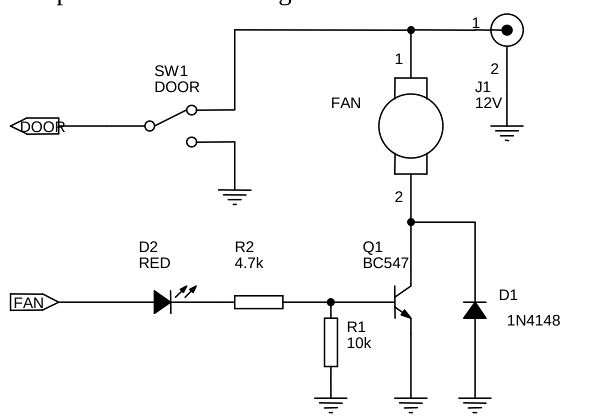

Figure 1 – FAN interface circuit

Three pins from PORT A (RA1, RA2 and RA4) of the main microcontroller are used to control the monitored devices. They can be set in ON or OFF state. This feature is very helpful to prevent damages of the equipment in case of overheating or power problems, or in case of compromising the physical security of the equipment and thus compromising the data security. The management is done via low current controlled optoisolated semiconductor relays. We used the MOC3043 for the optoisolator and the BTA16-600 triac for the AC semiconductor switch.

The communication between the main microcontroller, the Ethernet controller and the memory for the WEB interface is done through a shared hardware SPI bus.

25LC1024 is 1Mbit serial SPI memory. It can be used as a byte-level EEPROM memory or a Flash memory. This memory holds the user web interface content for the build-in WEB server.

For recognizing the nearby maintenance personal, a wireless identification is used. It is done with the implementation of the ZigBee protocol. The hardware transceiver that we used in the design is the MRF24J40 chip. It is interconnected to the main microcontroller by the serial SPI bus. Operating radio frequency is centered at 2.4GHz, which is license free ISM radio band.

The Ethernet controlled is based on ENC28J60. It has a built-in 8-Kbyte SRAM buffer, SPI interface and two programmable LED outputs. The maximum speed of the SPI is 10Mb/s. The main advantage of using the ENC28J60 is to reduce the communication signals for the inter-connection with the CPU. The SPI interface uses only four signals: clock; data in; data out; chip-select, while the common Ethernet controller uses more than 20 signal pins which complicate the hardware design.

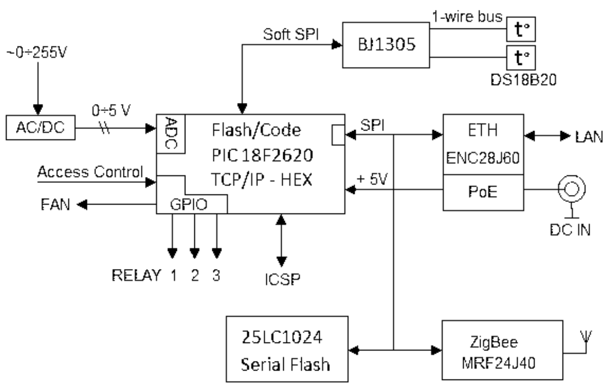

Figure 2 – Block diagram of the monitoring device

The prototype is powered via PoE. The PoE module converts the 48V DC to a +3.3V DC for the Ethernet controller and +5V DC for the main unit. The power module is based on a DC/DC convertor LM2575HVT for the +5V; also a linear low-drop stabilizer BA033T is used to further reduces the +5V to a +3.3V.

III. Goals in the Project

Main reason to design this device is to fulfill the need of inexpensive device that monitors equipment in remote areas. When it comes to monitoring server rooms there are plenty of products available. But for monitoring single devices the available products are not cost effective. Our main goals are:

- Monitoring the most important parameters of the environment – temperature and voltage. When equipment is installed in remote and tiny locations, there is no space for humidifiers, fire prevention devices, noise sensors etc. Thus there is no need to monitor things like: airflow, humidity, dust and noise levels etc.
- Maintain low cost – the microcontrollers used in the design are less than 20USD.
- Simple usable device – the web interface is straightforward with two access levels. The basic level is used just to monitor the environment and the password-protected level is used to set temperature and control equipment.
- Low power consumption – each used microcontroller has a consumption of 10-15mA on +5V and the Ethernet controller uses 350mA on the +3.3V power supply. This makes the device suitable for long lasting usage on UPS or battery power.
- Compact design – with its small design it's much smaller than other 1U rack mountable control devices.

IV. Software Stack

Microchip offers a free licensed TCP/IP stack optimized for the PIC18, PIC24, dsPIC and PIC32 microcontroller families[1]. The stack is modular in design and is written in the 'C' programming language. Effective implementations can be accomplished in roughly 28-34 KB of code, depending on modules used, leaving plenty of code space on Microchip's cost effective, high-density micro-controllers for the user application. We used the stack and add the top application layer to work together.

In the current application we used MPFS2 file system library to store the WEB content in external SPI eeprom thus we used the SPIEEPROM library. For the WEB server implementation we have used HTTP2. The other included modules are the Announce (provides device hostname and IP address discovery), DHCP (dynamically resolve IP address), SNTP (NTP client), DNS (resolve the IP address by hostname), NBNS (NetBIOS Name Service), ARP (Address Resolution Protocol) and the TCP library (Transmission Control Protocol).

The size of the current firmware, including the mentioned above modules is 28824 bytes (Program memory) and the application uses 2056 bytes of Data Memory (RAM).

The stack is divided into multiple layers, where each layer accesses services from one or more layers directly below it. Per specifications, many of the TCP/IP layers are "live", in the sense that they not only act when a service is requested, but also when events like time-out or new packet arrival occurs.

V. Temperature Measurement – BJ1305

The temperature measurement is based on custom developed chip with signature BJ1305 (U301 on figure 3). In fact this is an 8-bit microcontroller with special developed firmware for temperature measurement and display. The BJ1305 chip controls 2-row, 3-digit 7-segment LED display for real time temperature monitoring. The colors of LEDs are red for outside temperature (U304) and green (U305) for the inside temperature. The accuracy for displaying is one digit after the dot point when the temperature is in the range [10.0˚C ÷ 99.9˚C] or [-9.9˚C ÷ –0.1˚C]. The displaying accuracy is two digits after the dot point when the temperature is in the range [0.00˚C ÷

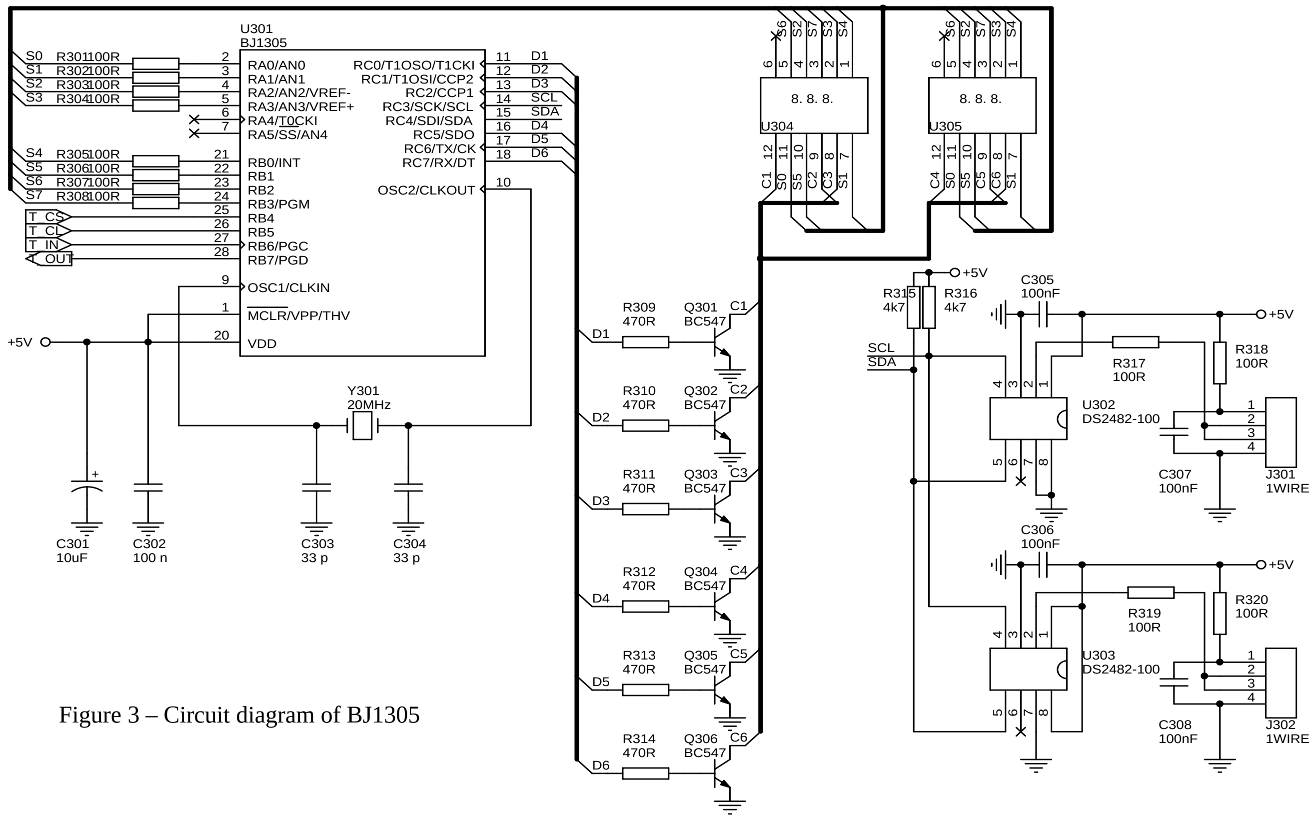

Figure 3 – Circuit diagram of BJ1305

9.99˚C]. The displaying accuracy is one degree (no dot point) when the temperature is under the 100˚C or it is down than –10˚C. The internal measurement accuracy depends on the physical thermometer. We used external 1-wire digital thermometers from Dallas (DS18B20) for the physical measurements.

The DS18B20 digital thermometer provides 12-bit Celsius temperature measurements. It communicates over a 1-Wire® bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C, over the range of -10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls [4], temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems [2].

The use of 1-Wire bus was directed due the following benefits:

- Single Contact Sufficient for Control and Operation
- Unique ID Factory-Lasered in Each Device
- Power Derived from Signal Bus ("Parasitically Powered")
- Multidrop Capable: Supports Multiple Devices on Single Line
- Exceptional ESD Performance

The design uses special drivers to convert the 1-Wire® to I^2C bus. This is done to simplify the software development by using a hardware bus converter. The design uses DS2482-100 chip, developed from Dallas. The BJ1305 read the temperature information from two external digital sensors (J301, J302) using I^2C commands to the U302 and U303.

The DS2482-100 is an I²C to 1-Wire® bridge device that interfaces directly to standard (100kHz max) or fast (400kHz max) I²C masters to perform bidirectional protocol conversion between the I²C master and any downstream 1-Wire slave devices. Relative to any attached 1-Wire slave device, the DS2482-100 is a 1-Wire master. Internal factory trimmed timers relieve the system host processor from generating time-critical 1-Wire waveforms, supporting both standard and Overdrive 1-Wire communication speeds.

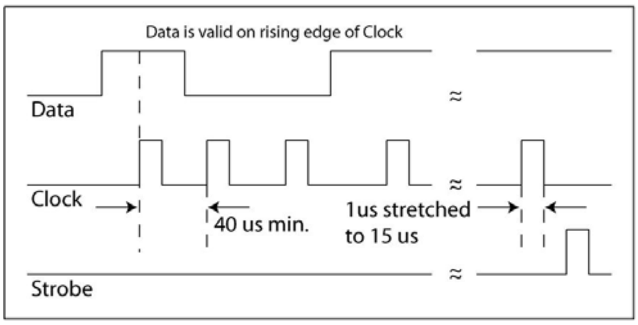

Figure 4 – Time diagram of the signals to BJ1305

To optimize 1-Wire waveform generation, the DS2482-100 performs slew rate control on rising and falling 1-Wire edges and provides additional programmable features to match drive characteristics to the 1-Wire slave environment. Programmable strong pull-up features support 1-Wire power delivery to 1-Wire devices such as EEPROMs and sensors. The DS2482-100 combines these features with an output to control an external MOSFET for enhanced strong pull-up application. The I²C slave address assignment is controlled by two binary address inputs, resolving potential conflicts with other I²C slave devices in the system.

Temperature information can be read from BJ1305 using a SPI bus (pins 25 to 28 of U301), like a 32bit value. The low significant 16 bits represents the internal temperature, while the most significant 16 bits represents the outside temperature. The format of the temperature coding is similar like the DS18B20 representation.

The communication is based on figure 4. The BJ1305 is always a slave device, so master does the start of the communication. Master notes for the reading process by pull down the T_CS signal (pin 25 of the U301). This signal is illustrated as a strobe signal on Fig .4 because when it is in high stage, the reset routine of the communication is started. This means that when the T_CS goes from high to low stage, then the bit counter will resets to zero.

Data can be read bit by bit on T_OUT (pin 28). It is fetched by the clock signal, generated from the master device. Data is valid on rising edge of the clock signal (Figure 4). The clock signal goes to the U301 on signal line T_CL (pin 26).

In other words, the BJ1305 is simple temperature reader and protocol converter from two 1-Wire DS18B20 to SPI bus. It also implements dynamic led indication of the temperatures using external transistors Q301-Q306 and LED modules U305 and U304 (3-digit common cathode led indicators) with signature names BC56-12GWA and BC56-12SRWA, manufactured by Kingbright LTD.

VI. Conclusion

After testing the prototype in laboratory and live network conditions, it has met the project goals. Under the laboratory conditions, were tested the temperature sensors. The difference between the measured temperature with the prototype and precise laboratory thermometer was not more than 0.5˚C. The prototype successfully operated the external cooling system. For the live test the device worked for a month without crashing.

Our future goals are to expand the capabilities of the device with:

- SNMP support – in order to integrate the device with database server and/or other monitoring software. This will enable the creation of baselines for predictions of possible future problems.
- E-mail notification – email will be sending in case of emergency situation. That will enable the user to automatically notify the proper technician, for faster troubleshooting. It will also enable the implementation of SMS notification, with the use of MAIL to SMS platform.
- Built-in battery – to make the device self-sustainable in case of power outage or UPS failure.
- Additional access level in the web interface – to be able to delegate just the required permission to the different groups of support staff/technicians.

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