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Automatic GPS-based Vehicle Tracking and Localization Information System

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Abstract: *The convergence of GPS technologies, wireless communications, and Internet is seen as the key to the GPS consumer market. The proposed vehicle tracking and localization system allows: remote and mobile control and vehicle monitoring (position and velocity) via SMS commands and answers; passenger voice notification when vehicle get near to next railway or bus station, actual arrival and scheduled time, vehicle velocity; remote software and databases upgrade. Combining single-chip GPS receiver and system-on-chip personal computer with embedded HTTP/FTP/Telnet Servers above mentioned information can be send as a SMS to any device that has access to wireless network or Internet.*

Key words: *Vehicle tracking and localization, GPS navigation, Mobile Internet.*

INTRODUCTION

Defining the accurate location of vehicles (trains, buses, river and sea transport vehicles) in real time, is very necessary in the practice because of two main reasons:

1. Possibility for remote tracking the location and obtaining information for keeping the schedules, for deviations from preliminary set cource or about problems, arising during travel. The centralized processing of this information enables the increase in the safety and the maximum quick reaction in emergency cases.
2. Possibility to inform the passengers about:
   - approaching a station or a bus stop, so that they can prepare to get off;
   - arrival time and the next stop in the route;
   - travel speed and eventual delays.

The system offered uses a single-chip GPS-receiver in order to localize the vehicle. In the near future, it is expected that GPS-technologies [3] will find more and more civil applications, mainly due to their combining with the Internet technologies and the achievements in the mobile communications. By means of the Beck's single-chip personal computer SC12 with built-in network possibilities, the information received for the vehicle travel speed can be sent as SMS or e-mail to any computer which is connected with Internet or GSM-terminal. The system requires coverage of the vehicle course by a GSM mobile operator aiming at exchange of commands and data through SMS. Due to the TCP/IP application program interface integrated in SC12 it is possible to automatically and distantly upgrade the software and the data (information about the course and the schedule, files with compressed speech) through FTP session.

The passengers are informed through voice synthesizer. This schematic solution enables:

- the usage of the existing Intercom systems in the vehicles (in this way is solved the problem with data transfer between the wagon composition for the trains);
- the reduction of the price of the system (the usage of expensive information panels with LEDs is not necessary);
- the reduction of the time for system installation.

DESCRIPTION OF HARDWARE

The hardware realization of the system for automatic tracking and notifying the location of the vehicle is based on three single-chip systems. The selected schematic solution, shown as a block diagram in Fig.1, allows for reduction of the sizes and the price of the printed circuit board and improves the reliability of the system.

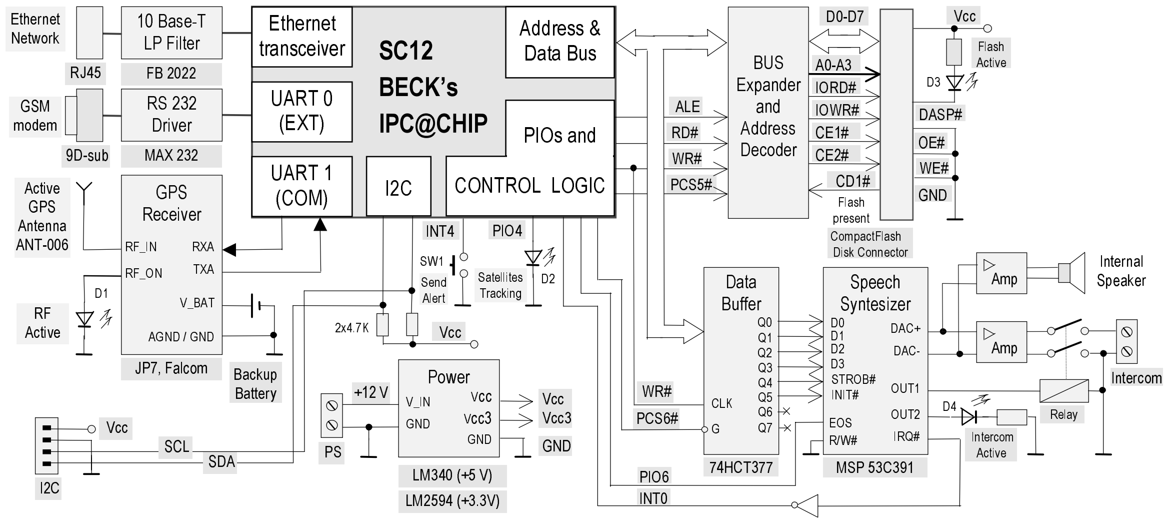

Fig.1. Block-diagram of hardware

Functional description of important modules follows:

1. Control module

Hardware control is realized by means of a single-chip system SC12 [1] of the company BECK GmbH. SC12 is a single-chip personal computer with a built-in microcontroller AMD186ED (16-bit CPU@20MHz) and hardware-software possibilities for operation in network environment. For the particular solution the following modules of SC12 are used:

- Ethernet transceiver (only 10Base-T filters FB2022 are needed for connection with local network);
- IDE interface (access to external Compact Flash Disk);
- Serial Asynchronous Interface UART0 (connection with personal computer or GSM modem/terminal - only RS232C drivers and receivers MAX232 are needed);
- Serial Asynchronous Interface UART1 (connection with GPS receiver JP 7);
- I2C interface (connection with keyboard and LCD);
- Interrupt Controller (interrupt requests from speech synthesizer detection);
- Programmable Input and Outputs (PIOx) and Chip Select signals (PCSx);
- Internal Flash Disk (512 KB);
- Internal DRAM (512 KB);
- Watchdog timer (part of security system).

2. GPS receiver

The single-chip GPS receiver JP7 [5] of the company FALCOM GmbH is used. JP7 is 12-channel receiver (25.4mmx25.4mmx3mm), based on the chipset SiRFstarIIe. The receiver is programmed to measure for 300ms through intervals of 10 s. In this mode, the average consumption is approximately 5mA for power supply voltage +3.3V.

JP7 requires following external components:

- active 3V GPS antenna (ANT-006 from FALCOM) - the antenna voltage is provided by the internal power management;
- backup battery (1.8V - 3.6V) - it is used to enable the warm and hot start features of the GPS receiver and to supply internal Real Time Clock (RTC).

3. Voice synthesizer

System-on-chip voise synthesizer MSP53C391 [4] from Texas Instruments, Inc. is used. The algorithms for voice decompression, supported by the synthesizer, are described in Table 1.

Table 1. Supported speech decompression algorithms

Algorithm	Data transfer rate, kbps	Sampling Frequency, KHz
LPC	from 1.5 to 3	8, 10
MELP, v.4.1	from 2 to 3.5	8, 10
CELP, v.3.4	4.2, 4.8, 5.8, 6.2, 8.6, 10.7	8, 10
PCM	64	8, 10

In the particular solution the algorithm CELP (Code Excited Linear Prediction) is used, aiming at compression of words and expressions, necessary for the system in mode "information of passengers". The selected sampling frequency is 8KHz and data transfer rate is 6kbps. This mode is a compromise between the quality of the synthesized speech and the coefficient of compression (approximately 1KB for 1 second of speech).

The Frequency Modulation (FM II) music synthesizer, which is built in the chip, is used to generate musical identifiers for beginning and end of each message. In this case the frequency of discretezation is 10KHz.

The synchronization of the exchange with the control module is realized through interruption request, which is generated upon readiness for receiving of new data (method 3, interrupt 2). In this mode, except the four data lines, only two control lines are necessary: INIT# for the hardware initialization of the synthesizer and a strobe signal for write operation - STROB#. Upon end of synthesized speech, the signal EOS is generated.

The output OUT1 controls a relay, which switches on and off the external Intercom system. By means of the LED D4, controlled through output OUT2, the presence of connection with the Intercom is visualized. These outputs are controlled in two modes: automatic mode – upon activation of the mode "Voice navigation in menu", or upon voice message received, and manual mode – through the system menu.

4. I2C interface

The I2C interface is used to connect the control module with a keyboard (4x4) and display (LCD 2x20, DEM 20231 SYH from Display Elektronik GmbH). Their connection with the I2C interface is realized by means of 8-bit I2C I/O extenders and PCF8574 from Philps. The system is capable of functioning without the availability of keyboard and display, however, in this case the adjustment of the system can be realized through a personal computer or SMS commands. If the display is not switched on (being recognized by software), the "voice navigation in menu" mode is activated.

5. Interface for connection with an external FLASH disk

The external disk is Compact FLASH module SDCFB-32-768 (32MB) from SanDisk GmbH [7]. It is used in order to make records of:

- the compressed words and phrases in Bulgarian, English and French (which languages are to be active is set in the file CHIP.INI or through the menu of the system);
- the information about the stations of the selected route (name and coordinates of the stations, time of arrival and departure time);
- travel history of the vehicle for a period of up to 1 month.

6. Power supply

The system is powered with +12V DC. The necessary power supply voltages and the schemes of their realization are:

- +5V/600mA, LM 340T-5.0;
- +3.3V/100mA, LM 2594N-3.3.

DESCRIPTION OF SOFTWARE

One of the advantages of SC12 is the great number of application program interfaces [2] and the possibility to use any of the development program environment. SC12 is with integrated real-time operation system (RTOS). The tasks (max. 20 for user needs) switch time is 1ms. The software is realized on the base of the modular principle. All modules are compiled (Borland C++, v.5.2) into a single EXE file, which is started after switching the system power supply on. The description of the more important program modules is as follows:

1. **POST**. The module contains procedures for initialization of the operation mode and testing the program-accessible integrated circuits. The initialization is realized depending on the values of the variables from the INIT section of the system configuration file CHIP.INI. The module is activated after RESET of SC12. The testing sequence is as follows:

- Checking the version of BIOS. It should be at least 1.04.
- Activating the security system. It is used to restore system operation after a fatal error: enables the Watchdog-timer (restarts SC12 in case of incorrect sequence of instructions) and installs a user error handler (invalid operation code, stack overflow, error from the core). Upon activation of the error handler function, SC12 is restarted by the software. The system restore its working status after 5 s.
- Intitialization of the external FLASH disk. It is performed in the following sequence:
  - set mode (Logical Block Addressing, 8-bit transfer);
  - receive external Flash Disk parameters (number of cylinders, heads, total number of sectors and sectors per cylinder) - IDE command Identify Drive is used.;
  - read content of Master Boot Record to check partition type - SC12 works only with DOS 12-bit or 16-bit FAT and 16 or 32 bit sectors.);
  - install user functions for sector read write operations;
  - logical installation of external disk.

After the initialization, the external disk becomes accessible as drive B: and it's operated with as the internal FLASH disk (drive A:).

- Initialization of the GPS receiver. The receiver supports two transfer protocols: SiRF binary and NMEA (National Marine Electronics Association) ver. 2.20. After RESET the SiRF-protocol is active. After the initialization of the receiver with SiRF commands the NMEA-protocol is selected. JP7 is programmed to operate in the Trickle Power mode – to measure within 300ms (on time) through intervals of 10 s. The following UART protocol is set: 19200bps, 8bit data, No parity, 1 stop bit.
- Initialization of the GSM-modem. It is realized through the system of AT-commands [6], which the GSM-modem (the GSM-terminal) recognizes. With the command AT+CMGF=0 the Protocol Description Unit (PDU) data format is set.
- Check for the presence of a keyboard and display.
- Initialization of Speech synthesizer:
  - hardware initialization (set pin INIT# low for 1 ms);
  - program initialization (send following command sequence F, F, F, F, 0, A, 1, 0, 0, F, F, F, F, F, F);

- turn the intercom off (set pins OUT1 and OUT2 low, command 0x20);
- set default volume to value of variable VOLUME from CHIP.INI configuration file, command 0x2F);
- check synthesizer's functionality (signal EOS must be received after sending voice message "The system is active").

If all tests are successful, the next voice message is generated - ″and full functional″, in the other case - ″but not functional″. If the synthesizer is not functional, an information for the problem, detected during initialization, is visualized on the display. If a display has not been recognized, the LCD D2 starts blinking with frequency 0.5Hz.

2. **GPS receiver**. When information from the GPS receiver is needed, the relevant NMEA incoming message is sent to it in following format:

$PSRF<mid>,<data>,<cksum>,<eom>, where:

mid is a message identifier consisting of three numeric characters (100 to 105);
data are message specific data;
cksum is a two-hex character checksum as defined in the NMEA specification;
eom is an identifier for end of message (CR, LF).

The information, obtained from the receiver upon a valid measurement is:

- latitude and longitude;
- course and speed;
- number of GPS satellites in view;
- current time.

In case the calculation of the necessary parameters is impossible (the number of the visible satellites is smaller than 4), the current coordinates of the object are calculated basing on the course and the previous values of the location and speed. In this case the LED D2 does not light.

3. **SPEECH synthesizer**. The algorithm for sending a voice message is the following:

- save in internal DRAM all required speech files;
- wake up speech synthesizer (pulse the INIT# pin low for 6 ms);
- send compressed speech data in following format:
  - command header (F, F, F, F, F, 0, A);
  - synthesis algorithm code (08 = CELP 8.6kbps, Fs=8KHz);
  - speech data.

After recording the first four bits of data, a generation of interrupt request is waited for. The procedure, servicing this request, reads the next data from DRAM and sends the data to the synthesizer. It reads the data until signal STROB# is activated. Data is transmitted until activating an End Of Speech (EOS) signal.

4. **GSM modem**. The GSM modem is used for communications with the control station via SMS commands.

To send a SMS, the CMGS command is used, as its format is:

AT+CMGS=<length><CR><PDUdata><ctrl+z>, where:

length is a number of octets in data block;
ctrl+z is an identifier for end of command (ASCII code 26).

The message itself is encoded in the data block in PDU format.

To receive a SMS, the AT+CMGL=0 command is sent, through which a check for the availability of a new message is performed. In this case, the GSM modem/terminal sends back a reply in the following format:

+CMGL:<index>,<stat>,[<alpha>],<length>,<CR><LF><PDUdata>, where:

index is a message position in read/delete memory;
stat is a message status (received read);

alpha should be an empty string but not omitted;
length is the length of the actual TP data unit in octets;
PDUdata is a message in PDU format.

5. **UPGRADE**. The module is used to automatically update the software or the data files. For that purpose, by means of preliminary set time period a check for the availability of connection with a local network is performed. Upon detection of such event, an authorized GET request is sent to the central HTTP server for new information available. In case of a positive answer, the exchange is realized via a FTP session, at the end of which SC12 is restarted by the software.

6. **REPORT**. The module generates a report in HTML format for the movement of the vehicle for the requested by user day (identifier of the vehicle, name of station, arrival time, departure time). The system makes archive of this information for a period of 1 month. The report can be obtained and through a personal computer, connected to UART0 or through a HTML browser after authorization with user name and password.

ANALYSIS AND CONCLUSIONS

A system for remote tracking of vehicles and voice messaging of the passengers has been developed. The main functional possibilities and advantages of the system are:

- Remote (mobile) control of the system via SMS commands;
- Transmission of information for the location and speed of the vehicle upon receiving the relevant SMS command in preliminary set time intervals or upon reaching a station;
- Voice messaging of the passengers about: approaching a stop and arrival time; travel speed, stay and probable delay;
- Automatic updating of the software and data files;
- Connection with a personal computer;
- Voice navigation in the menu of the system;
- Generation of HTML report for the movement of the vehicle;
- High reliability due to the single-chip systems used;
- The security module ensures blocking of the system in case of an invalid operation code, fatal errors and incorrect sequence of the instructions;
- Possibility for sending alarm messages by pressing a button (SW1).

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