BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LVIII (LXII), Fasc. 1, 2012
Secţia
ELECTROTEHNICĂ. ENERGETICĂ. ELECTRONICĂ

TRANSMITTING AND RECEIVING DIGITAL COMMANDS THROUGH TELEPHONE NETWORK USING DUAL TONE MULTI-FREQUENCY SIGNALS (I)

BY

PETRUŢ DUMA[*]

“Gheorghe Asachi” Technical University of Iaşi
Faculty of Electronics, Telecommunications and Information Technology

Received: December 19, 2011
Accepted for publication: March 3, 2012

Abstract. The paper describes the hardware structure of a telephone line interface that, used in conjunction with an application system equipped with an ATMEL family microcontroller and with the interface to the user process, performs the transmission/reception of digital commands between remote processes using Dual Tone Multi-Frequency (DTMF) signaling through telephone networks. The line interface performs various telephone line operations, *i.e.* monitoring the line and the telephone set status, sending outgoing calls to the exchange, receiving incoming call signals, separating the directions of the DTMF signaling exchanged through the line, receiving and sending DTMF signals, receiving tones and transmitting information voice messages.

Key words: telephone line interface; subscriber line monitoring; active differential system for DTMF signaling; application system with microcontroller.

1. Introduction

In order to use telephone networks to transmit and receive digital commands that require a small amount of binary data to be exchanged between

[*] *e-mail*: pduma@etti.tuiasi.ro

remote user processes, Dual Tone Multi-Frequency (DTMF) signaling can be used. This allows one to command processes using a simple telephone set, knowing the communications protocol and the system access key. The basic structure of a system for transmitting and receiving digital commands between user processes is shown in Fig. 1.

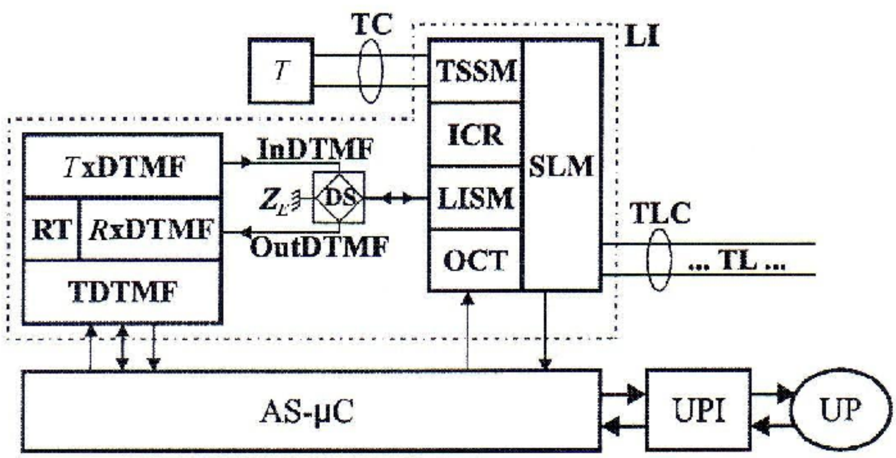

Fig. 1

The system consists of a line interface (LI) and a user process interface (UPI), both managed by an application system equipped with an ATMEL family microcontroller (AS-μC). The line interface performs the following tasks: subscriber line monitoring (SLM), direction separation for DTMF signaling using an active differential system (DS) and an impedance balancer (Z_E), DTMF signals transmission (*T*xDTMF) and reception (*R*xDTMF) through a DTMF transceiver (TDTMF).

The subscriber line monitoring includes: line interface status monitoring (LISM), telephone set status monitoring (TSSM), incoming call reception (ICR) and outgoing call transmission (OCT) from/to the exchange. The DTMF transceiver also performs the reception of the tones (RT) send by the telephone exchange to indicate the current stage of the process of setting a telephone connection (other acronyms are: TL – telephone line; TLC - telephone line connector; *T* – telephone; TC – telephone connector; UP – user process).

The present paper covers the telephone line monitoring and the direction separation for DTMF signaling, further documentation being prepared to cover the other topics related to this application: controlling the DTMF transceiver, the microcontroller-based application system, the software generation of the DTMF transmission and reception processes, incoming call reception, telephone line monitoring, exchange-originated tones reception and finally the transmission and reception of the digital commands between remote user processes.

2. Monitoring the Subscriber Line and Separating the Directions

The hardware structure required for the subscriber line interface is shown in Fig. 2. The interface performs the following functions: sends outgoing calls to the exchange for setting telephone connections, monitors the line interface, receives calling signals from the exchange and monitors the telephone set.

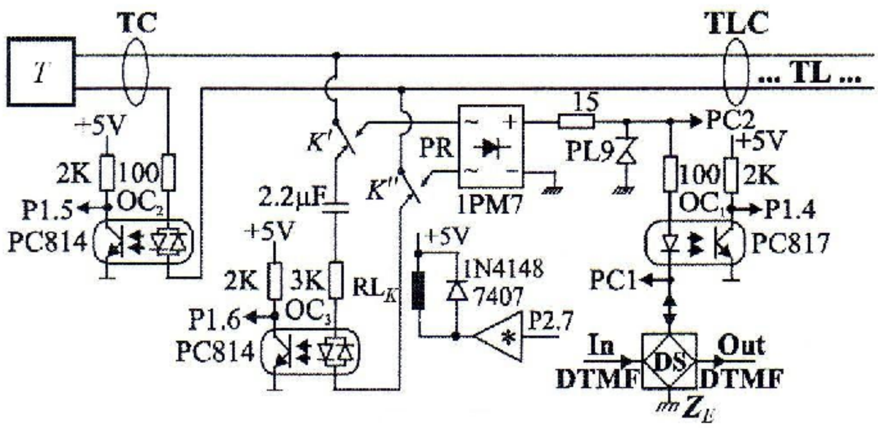

Fig. 2.

Contacts *K*' and *K*" of relay RL_K are set in position to receive a calling signal from the exchange. In order to send a call, relay RL_K must be engaged by sending a logical "0" from the microcontroller to the input of the open collector buffer 7407, which determines contacts *K*' and *K*" to switch position. The DC loop consisting of the exchange's DC power supply, the telephone line, the bridge (1PM7), the photocoupler OC_1 and the active differential system DS, is closed. The photo-transistor included in photocoupler OC_1 becomes saturated, and the logical "0" level from P1.4 indicates that the line has been occupied by the microcontroller in order to set a telephone link, to send the number of the called subscriber and to send/receive digital commands. Releasing the link consists of disengaging the relay RL_K, which resets the contacts *K*' and *K*" to the position shown in Fig. 2, the DC loop becomes open and P1.4 switches into logical "1" level.

When the exchange sends a call signal, the DC component does not pass through the 2.2 μF capacitor, while the AC component will open the corresponding LED. When the current passes through 0, the LEDs are not lit and the photo-transistor included in OC_3 is blocked, but during positive/negative alternations of the signal, the corresponding LED is lit and the photo-transistor becomes saturated. In this manner P1.5 will receive a rectangular waveform signal having a double frequency compared to the call signal. This signal will be received by the microcontroller for 20…30 s, then relay RL_K is engaged, the DC component of the call signal will close through the line interface, and the exchange will cut the transmission of the call signal. The occupied status of the telephone line is signaled with logical "0" applied at P1.4 in the manner described in the previous section, and the microcontroller starts to send/receive digital commands.

If the interface has also a telephone set connected to allow for conversations to take place, then, when the receiver is off-hook, the DC loop closes through the telephone line, one of the two LED's of the photocoupler OC_2 is lit, the photo-transistor is saturated and P1.5 gets a logical "0". During the conversation, microcontroller will test P1.5 status in an wait program loop. When the receiver is on-hook, the DC loop is open and P1.5 gets a logical "1".

DTMF signals generated/received by the DTMF transceiver are unidirectional, while the telephone line carries bi-directional signals. In order to separate the directions of the analog signals from the telephone line, an active differential system is used. This is implemented with integrated circuit TEA1062, also used in telephone sets for similar reasons, but with the required adjustments. The TEA1062 used for line interfacing has the following features: operates at low line voltage; has an internal voltage regulator with adjustable static resistor and is powered from the telephone line; includes a high-impedance microphone amplifier and a receiver amplifier, that allow the connection of various types of capsules; has a wide adjustment range for the microphone and the receiver amplifiers' gains; compensates the losses on the telephone line using either of the two amplifiers; presents a gain curve adaptable to the power supply from the exchange; generates a supply voltage for other external circuits.

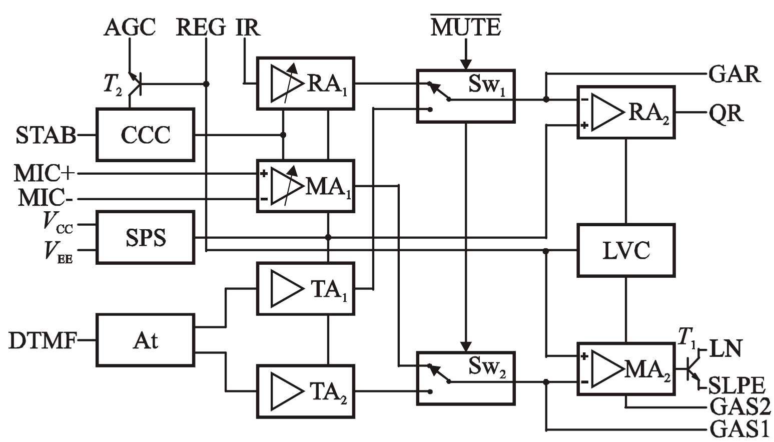

Fig. 3.

The basic internal structure of this circuit is presented in Fig. 3, the notations having the following meanings: RA_1, RA_2 – receiver amplifiers; MA_1, MA_2 – microphone amplifiers; TA_1, TA_2 – tones amplifiers; At – attenuator;

Sw_1, Sw_2 – switches; SPS – stabilized power supply; CCC – current control circuit; LVC – low voltage circuit.

Line interfacing is made by a hardware structure as presented in Fig. 4, while powering the circuit is made from the telephone line. The power supply voltage, V_{CC} , may be used for powering external peripheral circuits, but only with a maximal current of 1.2 mA. The internal regulator is uncoupled with capacitor C_3.

The intensity of the DC current that runs through the TEA1062 is determined by the exchange supplied voltage, the internal resistance of the exchange's power supply block and the DC resistance of the telephone line.

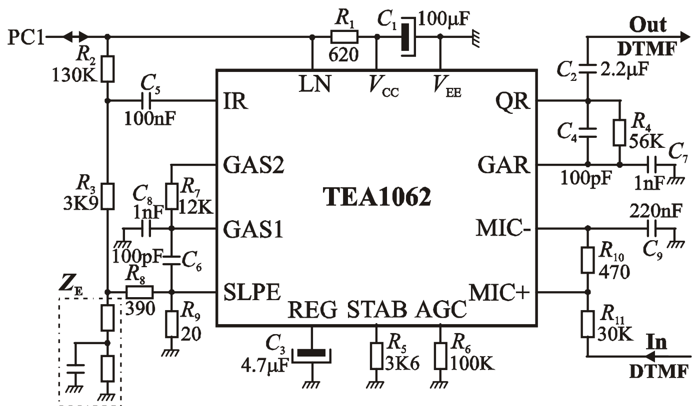

Fig. 4.

TEA1062 includes an internal current regulator operating at the level set by R_5. When the current from the telephone line (I_{LT}) is greater than the sum of the integrated circuit supply current (I_{CC}) and the current required by the peripheral circuits connected to V_{CC} (I_P) with more than 0.5 mA, then the excess current (I_{SLPE}) from terminal LN is shunted by $T1$ to ground. The stabilized voltage on terminal LN is

$$V_{LN} = V_{ref} + I_{SLPE}R_9 = V_{ref} + (I_{LT} - I_{CC} - I_P - 0.5\text{ mA})R_9. \quad (1)$$

V_{REF} is the 3.7 V temperature compensated internal voltage reference and R_9 is a 20 Ω connected to SLPE and to the ground (V_{EE}).

In normal operating conditions, when $I_{SLPE} >> I_{CC} + I_P + 0.5$ mA, the static behavior of the circuit is similar to a 3.7 V stabilizing diode with an internal resistance equal to R_9.

If the current from the telephone line is below 8…9 mA, then the internal reference voltage automatically adjusts to a lower value that allows the connection of multiple terminals that may operate limited features.

The automatic compensation for telephone line loss is made using R_6.

The automatic gain control adjusts the microphone amplifier gain depending on the line DC current. The control range is 5.8 dB, which corresponds to a 5 km line of 0.5 mm diameter twisted copper cable, having a 176 Ω/km resistance and an average attenuation of 1.2 dB/km. When dimensioning resistor R_6, one must take into account the power supply voltage and the internal resistance of the exchange's power supply block.

The DTMF input used for sending over the telephone line tones that indicate key pressing or DTMF signals is not used. In this case, input MUTE of circuit TEA1062 is left unconnected, and switches Sw_1 and Sw_2 keep permanently connected the microphone and the receiver amplifiers.

The microphone amplifier with symmetrical inputs (MIC+, MIC–) has the input impedance of 64 kΩ and the voltage gain is typically 52 dB and proportional to R_7 (68 kΩ). The stability of this amplifier is accomplished using C_6 and C_8 capacitors. The inputs of the microphone amplifier are connected through a resistive divisor that attenuates a few tens of times (64) the output from the DTMF generator. Resistor R_7 has a low value (12 kΩ) imposed by the 800 mV line signal.

The receiver amplifier with input, IR, and non-inverting output, QR, provides a typical voltage gain of 31 dB, also proportional with R_4 (100 kΩ). The stability of this amplifier is accomplished using C_4 and C_7 capacitors. The output of the receiver amplifier is connected through a capacitor to the input of the DTMF receiver. The reaction resistor, R_4, must be smaller (56 kΩ) for a signal of several hundreds of mV.

The local effect rejection network consists of $R_1 \parallel Z_{line}$, R_2, R_3, R_8, R_9 and Z_E (Fig. 5). It has the role to prevent (ideally completely) the signal coming from the output of the microphone amplifier to flow into the input of the receiver amplifier.

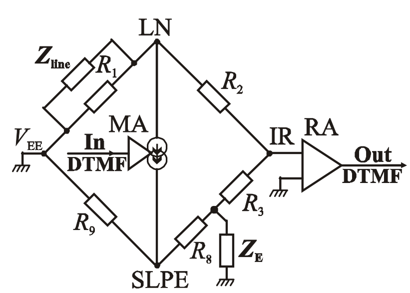

Fig. 5

The maximal compensation is obtained when balanced bridge conditions are realized

$$\frac{R_1}{R_9} = \frac{R_2}{R_3 + R_8 \parallel Z_E}, \tag{2}$$

$$\frac{Z_E}{Z_E + R_8} = \frac{Z_{\text{line}}}{Z_{\text{line}} + R_1}. \tag{3}$$

For fixed values of resistors R_1, R_2, R_8 and R_9, condition (2) will be realized, in order to make sure of the proper operation of the local effect rejection network, if

$$|R_8 \,||\, Z_E| << R_3. \tag{4}$$

For an optimal local effect rejection, the condition (3) must be fulfilled, so that

$$Z_E = \frac{R_8}{R_1} Z_{\text{line}} = k Z_{\text{line}}. \tag{5}$$

In order to avoid altering the transmission gain, it is required that

$$|R_8 + Z_E| >> R_9. \tag{6}$$

The line impedance depends notably on the line type and length. The balance circuit impedance must be set in order to compensate a medium length line, making sure all the same that acceptable results are obtained also for short lines (tens…hundreds meters) and long ones (a few kilometers).

3. Conclusions

The hardware structure of the line interface described was built in practice, and along with the application system equipped with microcontroller AT89S8253 and the interface of the user process, it performs the transmission/ reception of digital commands using DTMF signaling through the telephone network between remote processes. This structure is usable in applications that require low amount of command data to be transferred, when command delays are not an issue and only non-frequent maintenance is required.

The telephone line monitoring is performed by a minimal hardware structure that performs: outgoing call transmission to the exchange, telephone line monitoring, incoming call reception and telephone set status monitoring in order to allow telephone conversations. The direction separation of the DTMF signals from the subscriber line is performed by an active differential system that controls the amplitude of the signals, compensates line losses, adjusts the gain control to the exchange's power supply and is powered by low voltage from the telephone line.

The line interface is galvanically separated using photocouplers and relays for various digital signals, and, respectively, with linear isolation amplifier for the DTMF signals.

REFERENCES

Borcoci E., *Sisteme de comutație digitale*. Ed. Vega, Bucureşti, 1994.
Căpățînă O., *Proiectarea cu microcalculatoare integrate*. Ed. Dacia, Cluj-Napoca, 1992.
Ciurea D., *Transmisiuni telefonice*. Ed. MatrixRom, Bucureşti, 2004.
Duma P., *Microcontrolerul INTEL 8051. Aplicații*. Ed. TEHNOPRESS, Iaşi, 2004.
Hintz J.K., Tabak D., *Microcontrollers. Architecture, Implementation and Programming*. McGraw Hill, New York, 1993.
Peatmann B.J., *Design with Microcontrollers.* McGraw Hill, New York, 1998.
Rădulescu T., *Telecomunicații*. Media Publishing, Bucureşti, 1994.
Somnea D., Vlăduț T., *Programarea în Assembler.* Ed. Tehnică, Bucureşti, 1992.
*** ATMEL, Family Microcontroller, Data Book, 1998.
*** California Micro Devices, M8880, Teltone Component Data Book, 1990.
*** Matsushita Electric Works, TQ-Relays, Data Sheet, 2000.
*** MAXIM, RS232 Drivers/Receivers, Data Sheet, 2001.
*** Philips Semiconductors, TEA1062, Data Sheet, 1997.
*** Sharp Electronic Components, Photocoupler, Data Sheet, 1998.
*** Texas Instruments, Data Book, 1992.
*** Texas Instruments, Isolation Amplifier, Data Sheet, 2011.

TRANSMITEREA ŞI RECEPȚIONAREA COMENZILOR NUMERICE PRIN REȚEAUA TELEFONICĂ UTILIZÂND SEMNALE DTMF (I)

(Rezumat)

Se descrie structura hard a unei interfețe de linie telefonică care împreună cu un sistem de aplicație echipat cu un microcontroler din familia ATMEL şi interfața procesului utilizator realizează transmiterea/recepționarea de comenzi numerice cu semnale DTMF prin rețeaua telefonică, între procese aflate la distanță. Interfața de linie monitorizează linia telefonică care constă din supravegherea liniei, transmiterea unui apel la centrală, recepționarea semnalului de apel şi supravegherea terminalului telefonic, separarea sensurilor semnalelor DTMF vehiculate prin linie, recepționarea şi transmiterea semnalelor DTMF şi transmiterea unor mesaje vocale de informare.