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MANAGEMENT OF THE RDA5807M DIGITAL TUNER WITH ATMEL MICROCONTROLLER

BY

PETRUȚ DUMA[1,*] and EUGEN PETAC[2]

[1]“Gheorghe Asachi” Technical University of Iași,
Faculty of Electronics, Telecommunications and Information Technology,
[2]“Ovidius” University of Constanta,
Faculty of Mathematics and Computer Science

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Abstract. The paper describes the hardware structure for the realization of a FM radio receiver, implemented with the specialized integrated circuit RDA5807M, being commanded and controlled by ATMEL microcontroller. The tuner used contains only a few blocks in the structure of a classic receiver and is based on an integrated digital audio signal processor, which implements the other blocks necessary for radio operation through the software. The written command program performs a series of development commands for the application, such as: power-on, initialization, channel selection, band, tuning, volume, oscillator frequency, channel search, programming of the various functional indicators in the FM tuner, displaying and replacing the data written or read from the radio receiver via the I^2C serial communication protocol so on.

Keywords: software defined radio, digital low IF tuner, FM tuner interface, digital signal processor, I^2C protocol.

1. Introduction

The radio receivers have the role of selecting a radio station from the multitude of signals received by the antenna, then demodulating, decoding,

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

filtering and amplifying the received signal, and finally to allow listening to the selected channel in a speaker. The superheterodyne receptor has superior selectivity, is currently the most widely used and is included in classic stationary or portable radios, in special or amateur radio communications.

The architecture of the current receivers has evolved a lot with the development of the broadcasting services, with the achievement of the high quality electronic components and their large-scale integration.

Currently used digital receivers, known as software defined radios (SDRs), are state-of-the-art and use digital signal processing (DSP); thus, many functions are performed by software, such as: FM demodulation, multiplex stereo signal decoding, filtering, amplification, channel selection and other processing. With this solution, many hardware blocks of the classic receiver are no longer needed, which reduces the size and cost of the specialized integrated circuit, allows the development of new functions through the software and achieving an efficient transmission in the band used.

In this paper we deal with the interface and management of the digital tuner RDA5807M, its command and control with a development system based on an ATMEL family microcontroller and the software implementation of development, testing and verification commands.

2. FM Radio Receiver from the RDA5807M Series

The frequency demodulation radio receiver RDA5807M is manufactured by the company RDA Microelectronics and ensures the reception of the channels in the FM band. The main features of this FM tuner are: fully integrated radio receiver with low energy consumption; receives FM signals in the frequency band from 50 MHz to 115 MHz; the selection of the radio channels is programmable by increasing or decreasing with a step of 100 KHz, 200 KHz, 50 KHz or 25 KHz between the channels; the digital tuner has a low intermediate frequency, with image rejection down-converter, with high-performance analog/digital converters; digital frequency synthesizer, fully integrated and controlled by software; automatic or manual tuning for channel search; internal clock oscillator that works with an external quartz crystal of 32.768 KHz or other values; automatic digital adjustment of the amplification; adaptive digital noise cancellation; detects and switches the stereo/ monophonic signal; performs the mute function by software; 50μs or 75 μs programmable de-emphasis; receive signal strength indicator (RSSI) and signal to noise ratio (SNR); low frequency accentuation; low-pass signal filtering; digital volume four-bit control for the output signal; standard level of the output signal; the received signal is listened to by directly connecting a pair of stereo headphones; I^2C serial communication interface on two wires; - has implemented radio data system (RDS) and radio broadcast data system (RBDS) etc.

The internal block diagram of the RDA5807M radio receiver is shown in Fig.1; the notations used have the following meaning: A – FM receiver antenna; LNA – low noise amplifier; Lim – FM signal limiter; M_1, M_2 – area of

differential mixers; DC – differential dephasing cells; PGA – programmable gain amplifiers; I, Q – signal component in phase, respectively in quadrature; ADC – analog-digital converters; aDSPc – audio digital signal processing core; DAC – digital-analog converters; L, R – left or right channel of stereo output signal; VCO – voltage controlled oscillator; Syn – frequency synthesizer; Osc – clock oscillator; RDS – radio data system; RBDS – radio broadcast data system; RSSI – received signal strength indicator; I^2C SBI – I^2C serial bus interface; LDOVR – low drop-out voltage regulator.

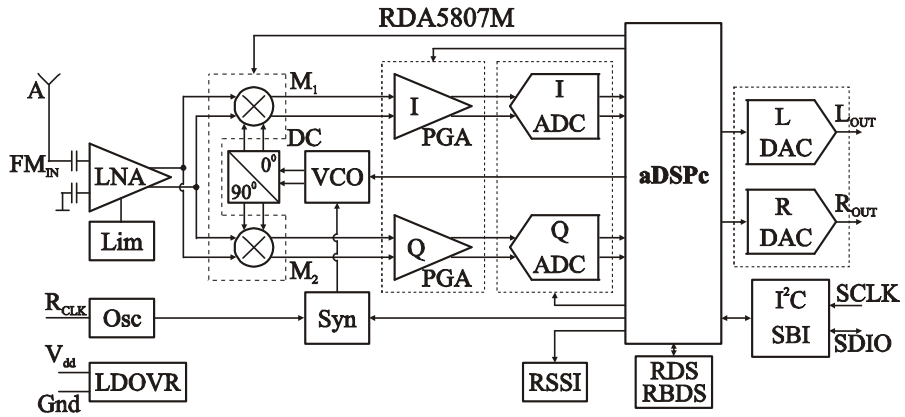

Fig. 1 – RDA5807M tuner block diagram.

For receiving broadcasting programs, the RDA5807M tuner uses a low-intermediate frequency digital architecture in order to avoid the problems of direct conversion, to reduce the complexity of further product development, but also to reduce manufacturing costs.

The receiver has a low noise amplifier at the input that works in the FM band; the input of the LNA also contains an adaptive circuit with FM antennas. There follows a range of multi-phase differential mixers that demodulate the received FM signal at a lower intermediate frequency and reject the image frequency. The mixers are connected to the differential output of the LNA on one side, respectively to the differential output of the VCO passed through the dephasing cells, on the other side. Mixer outputs provide I and Q components in quadrature.

The frequency synthesizer generates the signal for VCO through successive processing of the signal from the internal clock oscillator, driven by an external quartz crystal with the reference frequency of 32.768 KHz. Other quartz crystals with standardized frequency and selectable by software can be connected.

PGAs amplify the two components in intermediate frequency quadrature from the mixer outputs; these components are converted to digital by two high performance differential analog-digital converters. All other

processing required to receive a broadcasting station is done digitally by software.

The digital audio signal processor performs the channel selection, demodulates the FM signal, filters the received digital signals, decodes the received stereo multiplex signal, automatically switches the stereo mode to monophonic and vice versa, with the limitation of the output signal noise, amplifies the digital output signal, realizes low frequency accentuation, performs other necessary processing and transmits the stereo digital signal to the outputs.

The DACs convert the digital audio signal into the analog signal and ensure high fidelity for the stereo audio signal from the FM tuner outputs. These output signals are low-pass filtered and amplified before being supplied to L_{OUT} and R_{OUT}.

The I^2C serial bus interface provides communication with a microcontroller for programming, status reading, writing/reading data to/from the RDA5807M receiver and managing all functional blocks of the FM tuner for receiving a broadcasting station.

3. RDA5807M Tuner Interface

The command and control of the RDA5807M tuner is done with the development microsystem equipped with an ATMEL microcontroller. The receiver is fully integrated into a single chip, is produced in CMOS technology, has a small number of external connections and requires few external components. The interface made for the management of this FM radio receiver is shown in Fig. 2.

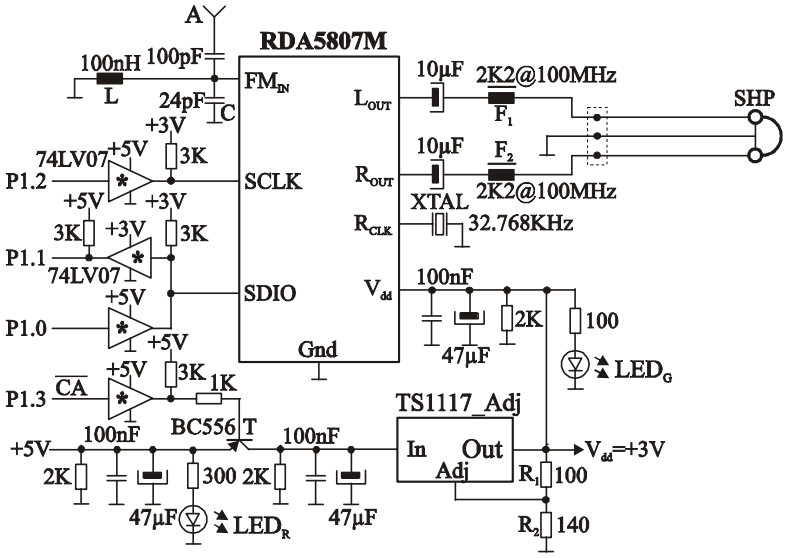

Fig. 2 – RDA5807M tuner interface.

The RDA5807M circuit is integrated into a 10-pin MSOP capsule; the brief meaning of the external connections is: FM_{IN} – FM input in the low noise amplifier; R_{CLK} – reference clock input into the internal oscillator; L_{OUT}, R_{OUT} – analog audio outputs of the stereo signal; SCLK – serial clock input of the I^2C interface (maximum operating frequency is 400KHz); SDIO – serial data input/ output of the I^2C interface; V_{dd}, Gnd – DC power supply terminals.

At the FM input, a LC shock (100 nH & 24 pF) and the radio receiver antenna are connected via a 100pF capacitor. The application uses as antenna the ground wire from the pair of stereo headphones that allow listening to the received signal.

At the R_{CLK} input, a quartz crystal (XTAL) with the reference frequency of 32.768 KHz is connected for the internal clock oscillator that controls the frequency synthesizer. Other quartz crystals can be used, with the frequency selected by the software and which can have only one of the values: 12 MHz, 13 MHz, 19.2 MHz, 24 MHz, 26 MHz or 38.4 MHz. An external clock oscillator can also be connected to this input (unused solution).

At each of the analog audio outputs streaming the received stereo signal (L_{OUT} & R_{OUT}), are serial connected a 10µF signal coupling capacitor, a 2.2KΩ@100MHz FM band ferrite (F_1, F_2) and a socket for connecting the stereo headphones (SHP) with the impedance of 2 × 32 Ω, needed for listening to the received signal.

The FM tuner has an I^2C serial interface for communication with the ATMEL microcontroller. The SDIO (bidirectional) serial data line and the SCLK clock line (input) are connected via open drain buffers (74LV07) to the P1 port lines of the microcontroller (Fig. 2). The buffers perform the logical levels transfer between the microcontroller of the development system that is used, powered at +5 V, and the tuner, that is powered at +3 V. The final application is intended to be managed by a microcontroller powered at +3 V, in which case the empty drain buffers are no longer necessary.

The RDA5807M integrated circuit is supplied with DC voltage from 2.7 V to 3.3 V. It is recommended a continuous supply voltage that has a typical value of 3 V, in which case it consumes a maximum current of 20mA. In the powerdown mode selected by the software, a current of less than 15µA is consumed.

In the interface shown in Fig. 2, the FM tuner is powered at + 3 V from a three-points adjustable voltage integrated stabilizer (TS1117_Adj). This stabilizer requires external resistors (R_1, R_2), filter capacitors (100nF, 47µF) and two LEDs to indicate the presence of +5V (LED_R) and +3 V (LED_G) respectively. The output voltage V_{dd} of the stabilizer is set by the internal reference voltage (V_{REF} = 1.25 V) and the resistive divider R_1 & R_2.

The power is commanded by an open drain buffer (74LV07) and a BC556 transistor (T). The signal $\overline{CA}$ that controls the FM tuner supply is active on logical level 0 and is supplied by the software on line P1.3 of the microcontroller. After supplying the radio receiver, a time of several tens/

hundreds of ms is needed for the initialization of the internal circuits, after which the I^2C interface becomes operational.

4. Management of the RDA5807M Tuner

The RDA5807M tuner has an I^2C (Inter-Integrated Circuit) serial interface for data communication. The microcontroller that manages the application and communication is the master and provides the clock signal, while the FM tuner is the slave. The I^2C bus is available if the data line (SDIO) and the clock line (SCLK) are inactive (1 logic). The microcontroller is used to perform data transmission/reception in/from the FM tuner. It generates a command consisting of transmitting the START condition and the control byte, then, it transmits the data that is written to the tuner or receives the data that is read from the tuner, and finally transmits the STOP condition.

The START (S) condition consists of a falling edge transmitted on the data line, while the clock line is stable on logical level 1. The STOP condition (P) consists of an ascending edge transmitted on the data line, while the clock line is stable and has the logical level 1 (Fig. 3).

The data bits are changed only during the logical level 0 of the clock signal; data bits are not modified during the logic level 1 of the clock signal because it would be equivalent to generating the control signals of the I^2C protocol.

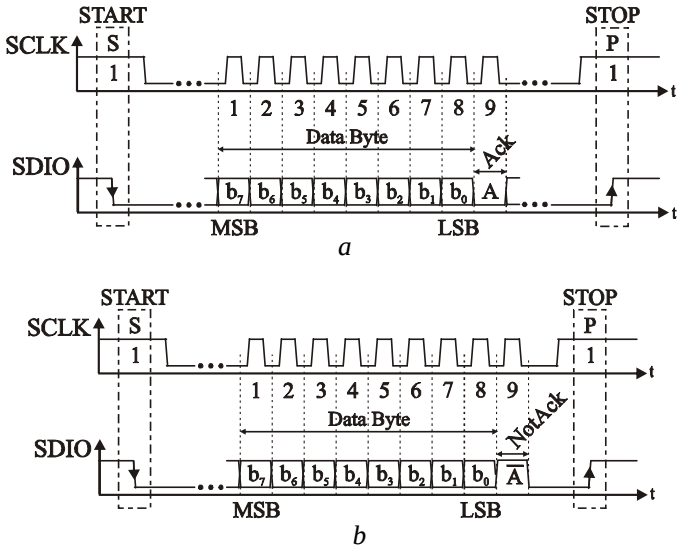

Fig. 3 – I^2C serial communication.

Bits of one byte are transmitted on the data line starting with the most significant bit (b_7) and ending with the least significant bit (b_0). After transmitting the data bits from a byte, the receiving circuit confirms the received

byte with an acknowledgment bit (A), defined as logical 0 during the ninth period of clock transmitted by the master (Fig. 3*a*).

Moreover, the master microcontroller also confirms with an acknowledgment bit every byte received from the slave tuner; this operation mode also determines the reception of the next data byte. When the master no longer wishes to receive the next data byte, it closes the data receive command with a not acknowledge bit ($\overline{A}$), defined as logical 1 (Fig. 3*b*).

The control byte (CB) consists of the specific seven-bit address for identifying the FM tuner on the I^2C bus and a bit for the read/write indicator ($I= R/\overline{W}$). The RDA5807M tuner has the address 001 0000.

The read/write indicator sets the working mode for a command transmitted by the master microcontroller to the slave tuner, as follows: $R/\overline{W}=0$ when the microcontroller transmits (writes) data to the FM tuner or $R/\overline{W}=1$ when the microcontroller receives (reads) data from the FM tuner (Table 1).

Table 1

Control Byte Structure

Tuner ID address							I	Control byte								CB
a_6	a_5	a_4	a_3	a_2	a_1	a_0	$R/\overline{W}$	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0	Hexa
0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	20H
0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1	21H

The internal registers of the RDA5807M tuner are 16-bit registers and are intended for circuit programming or for various condition and state indicators. These registers, denoted by R0, R1, R2, R3, R4, …., RA, RB, RC, RD, …., are organized as a 16-bit memory that, at the addresses 00H, 01H, 02H, 03H, 04H, …., 0AH, 0BH, 0CH, 0DH, …., contain these registers.

The FM tuner registers can be written or read by the microcontroller. However, the address where these registers can be accessed is not visible and cannot be specified by software. For register selection, the FM tuner has a seven-bit internal address counter.

The internal address counter is loaded with address 02H by the START condition of the I^2C protocol and by the $R/\overline{W}$ indicator reset, in order to perform a write operation in the tuner and, respectively, it is loaded with the address 0AH by the START condition and by the $R/\overline{W}$ indicator set, for performing a read operation from tuner. This counter is incremented by one unit after writing/reading any 16 bit register; after the counter address reaches the maximum value and the registers access command is continued, then the counter is reset. Then, the register R0 is addressed and so on.

A command transmitted by the microcontroller for programming the registers (writing) in the tuner consists of: transmission of the START condition; transmitting the control byte with the $R/\overline{W}$ indicator reset, selected

for a write operation (20H); the data is transmitted by the microcontroller to the tuner starting with the transmission of the high byte of the R2 register, then the low byte of the R2 register, after which the high byte of the R3 register is transmitted, then the low byte of the R3 register and so on (until writing the last byte); the tuner sends the acknowledgment bit (A) after each received byte; finally, the STOP condition is transmitted (Fig. 4).

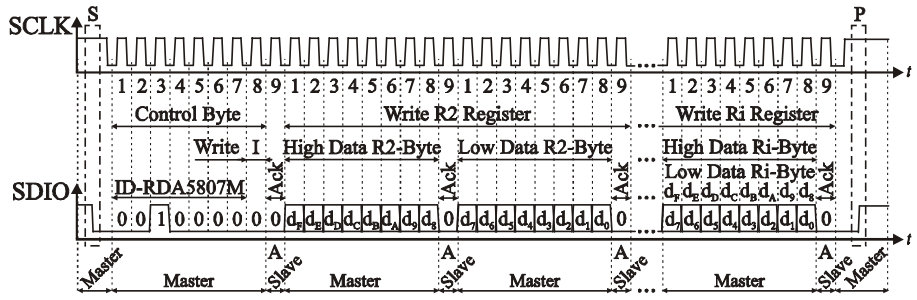

Fig. 4 – Command for writing data into the tuner.

A command sent by the microcontroller to read tuner registers (status) consists of: transmission of the START condition; transmitting the control byte with the R/$\overline{W}$ indicator set, selected for a read operation (21H); then follows the reception of the data in the microcontroller from the tuner, which starts with the reception of the high byte of the RA register, then the low byte of the RA register, after which the high byte of the RB register is received, then the low byte of the RB register and so on (until reading the last byte); the microcontroller sends the acknowledgment bit (A) after each received byte, except for the last byte of data when the microcontroller transmits a not acknowledge bit ($\overline{A}$); finally, the STOP condition is transmitted (Fig. 5).

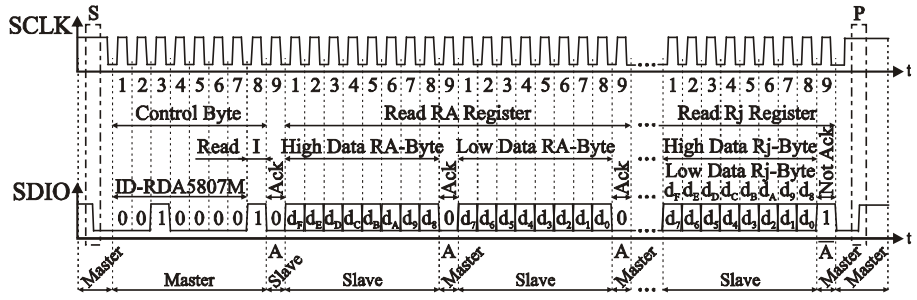

Fig. 5 – Tuner read data command.

The command program for managing this FM tuner is based on a series of program segments that perform the following basic functions: TS – transmits the START condition; TP – transmits the STOP condition; TIDW – transmits the control byte for a tuner data write operation; TIDR – transmits the control

byte for a tuner data read operation; RA – receives the acknowledge bit from the tuner; TA – transmits the acknowledge bit to the tuner; TNA – transmits the not acknowledge bit to the tuner; TB – transmits one byte of data to be written in the high/low part of a tuner register; RB – receives a data byte read from the high/ low part of a tuner register; TW – transmits a data word (two bytes) for writing a register in the tuner (first the high byte, then the low byte); RW – receives a data word (two bytes) read from a tuner register (first high byte, then the low byte).

These program segments are used in the implementation of two basic subroutines for transmitting and receiving data blocks, as follows: WRBD - the microcontroller transmits (writes) a data block in the tuner for programming the registers; RDBD - the microcontroller receives (reads) a data block from the tuner with the status of the registers.

The development system equipped with an ATMEL microcontroller is connected to a personal computer (used as a hyper terminal) via the universal asynchronous serial interface. This allows the development of user commands for more facilities, for the control and functional testing of the FM tuner. The commands implemented by the RDA5807M tuner management software are summarized below; the commands end with the ENTER (.) terminator, while the BLANK separator (_) must be typed between the parameters.

P_ – turn on/off the radio receiver's +3V power supply;

R_ – FM tuner on/off;

O_ – turn on/off the internal clock oscillator;

A_ – enable/disable tuning execution mode (automatic/manual);

Z_ – enable/disable the high impedance state at the audio outputs;

M_ – turn on/off the signal received at the audio outputs (mute);

C_p1. – received radio channel selection;

B_p1. – tuner frequency band selection; p1 = 0 for the 87,…,108 MHz band used in Europe and the US; p1 = 1 for the 76,…,91 MHz band used in Japan; p1 = 2 for the 76,…,108 MHz band used internationally; p1 = 3 for the 65,…,76 MHz band used in Eastern Europe or for the 50,…,65 MHz band;

E_p1. – radio channel spacing selection; parameter p1 is 0, 1, 2 or 3 for channel spacing with a deviation of 100 KHz, 200 KHz, 50 KHz and 25 KHz respectively;

X_ – external quartz crystal frequency selection for internal clock oscillator;

S_ – stereophonic or monophonic hearing selection;

T_ – tuner activation for automatic channel search;

SU. / SD. – search for radio channels up or down the selected frequency band;

V_p1. – setting the volume for the audio output signal;

I. - RDA5807M soft tuner initialization;

FW. / FR. – programmed channel frequency display, respectively received channel frequency display;

IR_p1_p2. / IW_p1_p2. – initialization of starting address table data (p1)

and number of registers (p2) read from the tuner, respectively written in the tuner;

RD. – reads the tuner registers and uploads them to the read data table;

WR. – write the tuner registers with the numeric values in the write data table;

DIR. / DIW. – displays the indicators in the registers read from the tuner, respectively written in the tuner; the command displays the name of the indicators and the corresponding numerical value in the data table for reading and writing for all accessed indicators;

SIW_ / SIR_ – displays and/or substitutes the indicators in the registers written in the tuner, respectively, read from the tuner; the command displays the names of the indicators and the corresponding numerical value in the data table for writing, respectively, reading, followed by the possibility of replacing this numeric user value, with another numeric value, for all the accessed indicators.

Other registers read/write commands are implemented, that is display and/or substitute written/read data at bit, byte or word level; these commands are simpler, but the management of the indicators in the registers is made with greater difficulty.

5. Conclusions

The structure of the described radio receiver is built in practice. It is simple and occupies a minimal hardware volume. The application contains the RDA5807M digital tuner which requires few passive components around it, the open drain buffers, the DC power supply source. The command and control of the FM receiver is performed at this stage with a development system equipped with the AT89S8253 microcontroller.

The RDA5807M integrated circuit contains only a few blocks from the structure of a classic analogue radio receiver and is based on a powerful digital audio signal processor core that implements through software, the functions required for receiving a channel, which gives optimum signal quality provided at audio outputs for most diverse reception conditions.

The command software is based on a series of program segments that perform the basic functions of the I^2C communication protocol and with which two essential subroutines have been implemented, one for programming the FM tuner control registers, and the other for reading the state and the registers from FM tuner.

The realized program implements a series of general commands that activate/deactivate: the power supply, the FM tuner, the internal clock oscillator, the high impedance state from the audio outputs, while other commands select the radio channel, the frequency band, the spacing of the channels, the quartz crystal frequency from the internal oscillator, stereo or monophonic hearing, automatic channel search, volume, circuit initialization, display of programmed or received channel frequency etc. At the base of the

application are the commands that display and substitute the data to be written in the radio receiver in different formats, respectively the commands that display the data read from the radio receiver in different formats.

The development program is written in machine language, offers many facilities and occupies an 8.5 KB program memory area, due to the numerous development commands implemented.

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GESTIONAREA TUNERULUI DIGITAL RDA5807M CU MICROCONTROLER ATMEL

(Rezumat)

Lucrarea descrie structura hard pentru realizarea unui radioreceptor FM, implementat cu circuitul integrat specializat RDA5807M, comandat şi controlat de un microcontroler ATMEL. Tunerul utilizat conține doar câteva blocuri din structura unui receptor clasic şi se bazează pe un procesor digital de semnal audio integrat care implementează celelalte blocuri necesare funcționării radioreceptorului prin soft. Programul de comandă scris realizează o serie de comenzi de dezvoltare pentru aplicație, cum ar fi: alimentare, inițializare, selecție canal, bandă, acord, volum, frecvență oscilator, căutare canal, programare a diferiților indicatori funcționali din tunerul FM, afişare şi substituire a datelor scrise sau citite din radioreceptor prin intermediul protocolului de comunicație serială I^2C etc.