2011

SEISMIC SIGNAL RECORDER
Baykal – 7 HR
Technical manual

EXPAS

Serial No.: _____

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1. INTRODUCTION

The technical manual contains information about the recorder, its structure, principle of operation, technical characteristics, and instructions on work with the device and software.

2. PURPOSE

Mobile high-resolution seismic signal recorder "Baykal-7HR" is an autonomous seismic station to record signals from external seismic or other sensors in a wide frequency range with a high accuracy and reference to absolute time scale.

The device can be used for short- and long-term seismic and geophysical measurements in real field conditions in a wide range of temperatures. Small consumed power from an external accumulator, large nonvolatile memory volume, a built-in high-stability generator and a GPS module with a high-quality analog-to-digital tract provide excellent working characteristics for solving a wide class of problems.

3.SPECIFICATIONS.

Parameter	**units**	**value**	**options**
Number of channels		3	6
Data width	bit	24	1
Input type		differential	
Input impedance		24Kohm || 4700pF	
Sampling frequency FD	sample/sec	50,100,200,500, 1000, 2000	
Bandwidth (-3 dB)*3	Hz	0 - 370	
Gain G		1,2,4,8,16,32,64	
Maximal input voltage (diff.) at G=1	V	± 12.3	
Conversion factor at G=1 at G=16	nV/count	1485.0 ± 2.0% 92.6 ± 2.5%	
Input referred noise (rms) G=1; FD=100 G=1; FD=1000 G=16; FD=100	uV	< 2.0 < 7.2 < 0.4	
Number of effective bits G=1; FD = 100 G=1; FD=1000 G=16; FD=100	bit	>21.5 >20.5 >20.0	
Storage type		SD miniSD (adapt.) microSD (adapt.)	
Capacity	Gb	**8**	up to 32
Inner generator stability (-20 - +60 °C)		$\pm 2*10^{-7}$	
Accuracy of time referencing to External GPS **Built-in GPS**	µs	± 2 **± 1**	
Voltage supply range	V	10 – 28 DC	

Power consumption *1, *2 «Wait» mode «Write» mode	W	 < 0.6 < 1.2	
Power supply for external active sensors		+5V(100 mA) -5V(100 mA)	
Interface with PC for control and data reading		USB 2.0 FULL SPEED	
Range of ambient temperatures	°C	-30 ÷ +60	
Recorder dimensions	mm^3	170 x 100 x 140	
Recorder weight	kg	2.5	

**1 –recorder switch on causes extra power consumption of 0.5 W by the internal temperature-stabilized generator at one-minute heating.*

**2 – GPS is switched off. It is switched on for a short time for generator tuning, consuming an additional power of 0.15 W.*

**3 – Characteristics of built-in digital filters for various sampling frequencies of signals are presented in Appendix 8.2*

Typical characteristics are listed in the table. Parameters shown by bold type are measured at calibration and testing of each recorder. These parameters are available in the individual technical passports of devices.

4. DELIVERY SET

№	Name	Q-ty	Comments
1	«Baykal-7HR»	1	Built-in GPS, 3 channels, 0.2 ppm
2	MicroSD card, 8 GB	1	With adapter (installed in recorder)
3	GPS antenna	1	Cable length: 5 m
4	Socket for power supply cable 2РМ18КПН7Г	1	
5	Socket for sensor connection cable 2РМ22КПН10Г	1	
6	Technical manual and program package	1	in Russian and English
7	Recorder technical passport	1	

5. STRUCTURE AND OPERATION.

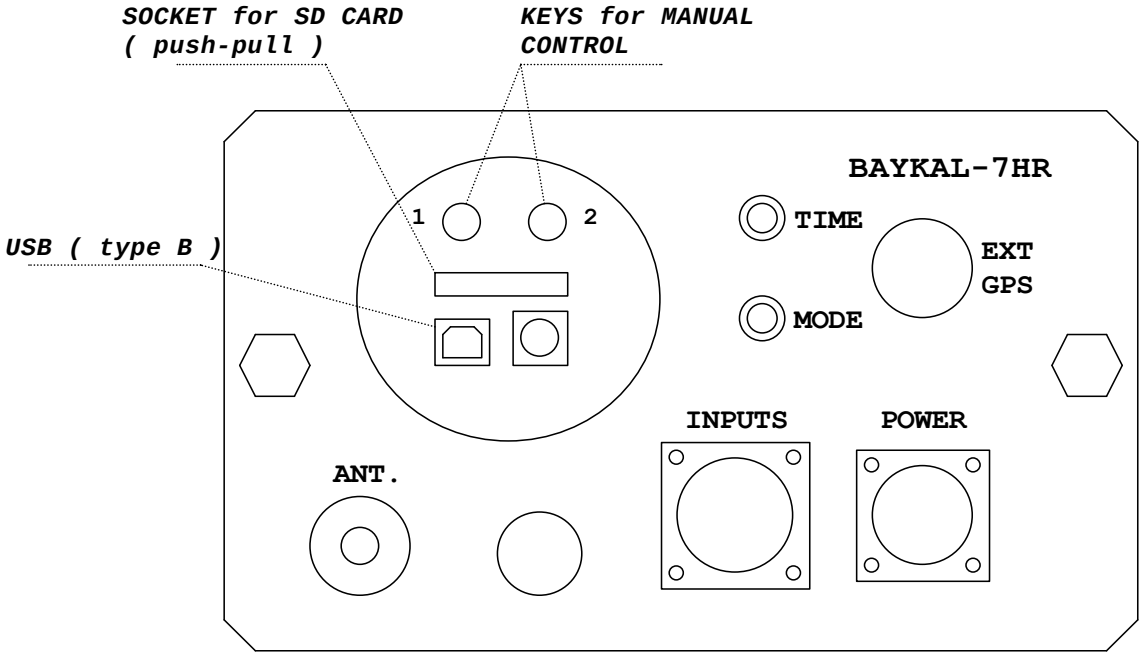
5.1. Structure of the recorder.

The recorder has a case and three electronic printed circuit boards.

The front panel has:

- Socket "POWER" to supply power to the recorder from an external power source or an accumulator. Standard accumulator voltage: 12 or 24 volt.
- Socket "INPUTS" to connect external sensors. Each of the three differential inputs has contacts +5V and -5V; there is a common contact to supply power to external active sensors.
- Socket "ANT." to connect the external active GPS-antenna. If a built-in GPS is not used, this socket is covered by a hermetic cap.
- Socket "EXT GPS" to connect the communication cable with an external GPS module
- LED indicators "TIME" and "MODE"
- Under the hermetic cap there are buttons 1 and 2, a slot to insert a SD-type memory card, socket USB-B to connect a PC, and a technological connector to upgrade the internal software.

Fig.1 Front panel.



The MCU board has

- master microcontroller
- FPGA chip
- GPS module
- precision clock generator (of the OCXO or TCXO type)
- USB driver of the FTDI type

The ADC board has

- galvanically isolated drivers of digital communication lines with an MCU board.

- delta-sigma A/D converters for each measurement channel

- input circuits with a low-pass filter and protection against static discharges

The SD_CARD board has a socket for a memory card.

5.2. Recorder operations

First, with the user's application set the following parameters of recording:

- sampling frequency
- amplification for each channel
- at work in the "calendar" mode, set start time and record duration
- the user can also name the station and each channel and set the transformation coefficients for each channel.

Settings are stored in the recorder EEPROM.

After the device is placed at an observation point, external sensors, a GPS antenna or an external GPS module, an accumulator or another power source are connected to it. After the power is switched on, the recorder performs loading and self-testing, and the device goes to the "STOP" mode. Press control button 1 to switch the recorder to the "WAIT" mode. Now the recorder is ready for all further operations. If the operator made records to the calendar, the recorder waits for the start time of recording. In addition, recording can be switched on or off at any time by pressing button 2.

The recorded information can be read as follows:

- through USB of a PC (the main method)
- from a memory card in a typical card reader with the help of a special program.

5.3. Synchronization of the recorder

Once power is switched on, the internal program switches on the GPS and searches for visible satellites. After this, the inner generator is synchronized by UTS time from the GPS, and the GPS module is switched off. Then the GPS module is

periodically switched on, the internal generator drift is measured, and, when necessary, the frequency is tuned. The GPS module can be switched on and off at any time manually.

Owing to high precision of the inner reference generator, long-term measurements can be made without frequency tuning by the GPS module (in mines, basements, etc.). For this, synchronize the recorder before starting it.

A description of the operating modes and control buttons is given in Section 7.

6. GENERAL OPERATING INSTRUCTIONS

First of all, check

- completeness of the set according to Table 4
- the case for visible mechanical damages
- whether the indication and control units are available
- Before switching on the device, see Sections 5-7 of this manual.

Take into account the following:

- To connect a power source (accumulator) and seismic sensors, connection cables must be made via sockets supplied with the device. For description of sockets, see APPENDIX.

- Never use power supply voltage exceeding 30 V. Do not apply signal input voltage exceeding 13.0 V relative to the ground (zero) level of sensor power supply without external dividers.

- Replace the memory card only in switched-off device or in the "card change" mode. The card socket has a "push-pull" mechanism. To extract the card, push the card end up to a click and pull it out. To place the card, insert and press it up to a fixing click.

7.WORK WITH THE RECORDER.

7.1.Manual control.

The front panel has two control buttons (№1 and №2) and two indication LEDs: **"Time"** and **"Mode"**. The buttons allow switching on the recorder and writing a new file manually.

Pressing of any button is indicated by red light of the corresponding LED; long pressing (more than 2 seconds) is indicated by the LED turning off. Releasing of the button starts processing of the pressing. The response of the device depends on its current state.

The "Stop" mode is indicated by permanent yellow light of the **"Mode"** LED. Long pressing (more than 2 seconds) of button №1 starts the "Wait" mode, that is, the device starts the mode of processing of events according to the calendar. Similarly, long pressing of button №1 in the "Wait" mode switches the recorder to the "Stop" mode.

Press button №2 in the "Stop" mode to replace the card and/or initialize the current file allocation table and file counter.

The **"Card change"** mode is indicated by alternating red-green light of the **"Mode"** LED; it allows erasing the current SD-card or its replacement by a new one. Press button №2 to cancel the operation; press button №1 after replacing the card to initialize the SD-card; press buttons №1 and №2 simultaneously for a long time to start the erasing operation of the current card; in this case

All previous records will be lost!!!

The **"Wait"** mode is indicated by slow green flashing light (once per second). As stated above, long pressing of button №1 initiates the **"Stop"** mode. Short pressing of button №2 starts/stops the **"Write"** mode.

The **"Write"** mode is indicated by continuous green light. In this mode, press button №2 to complete the current record,

update the file allocation table in the card, and switch to the **"Wait"** mode of the next calendar event. If errors (card filling) occur during the recording, the device automatically switches to the **"Stop"** mode; this error state is indicated by flashing red light.

Long pressing of button №2 switches on/off the GPS module.

LED	Signal	Mode
Mode	Yellow flashing	"Internal testing"
Mode	Yellow	«Stop»
Mode	Green-red alternating	«Card change»
Mode	Green permanent	"Write or direct transmission"
Mode	Green flashing	"Wait for next calendar event"
Mode	Green-yellow alternating	"ADC heating"
Time	Yellow flashing	"No synchronization"
Time	Yellow permanent	"Synchronization"
Time	Yellow with green flashing	"Switched-on GPS module"
Mode	Red flashing	"Operation error"
	Red permanent	"Button pressed" or "start loading error"

7.2.Work with *baykal_7HR.exe* program.

The recorder memory card has two work areas: the FAT area (addresses from 4096 to 16383) and data area (addresses from 16384 to the maximal card address).

The FAT area is used by the UNIT controller to write tuning time and result, coordinates, recorder switch on/off for writing, etc. These data can be viewed.

The program baykal_7HR.exe is installed in the working directory. Before using the program, install drivers FTDI CDM2.04.16.exe or later version for work via USB ports.

Start the program after the device goes to a working state and the USB-connection is established.

At start the program checks the connected recorders and offers selection (if there is more than one recorder). At simultaneous operation with several devices, start the

corresponding number of program instances. In the working directory of the program, individual directories are created for each device; their names are formed on the basis of the selected recorder number, and file names are formed on the basis of the recording start dates.

The program can read previously recorded data, set new operation modes, make a work calendar, and calibrate displacements of working channels. Use an additional recording mode to write working channels into a file in a separate subdirectory and display them on the screen.

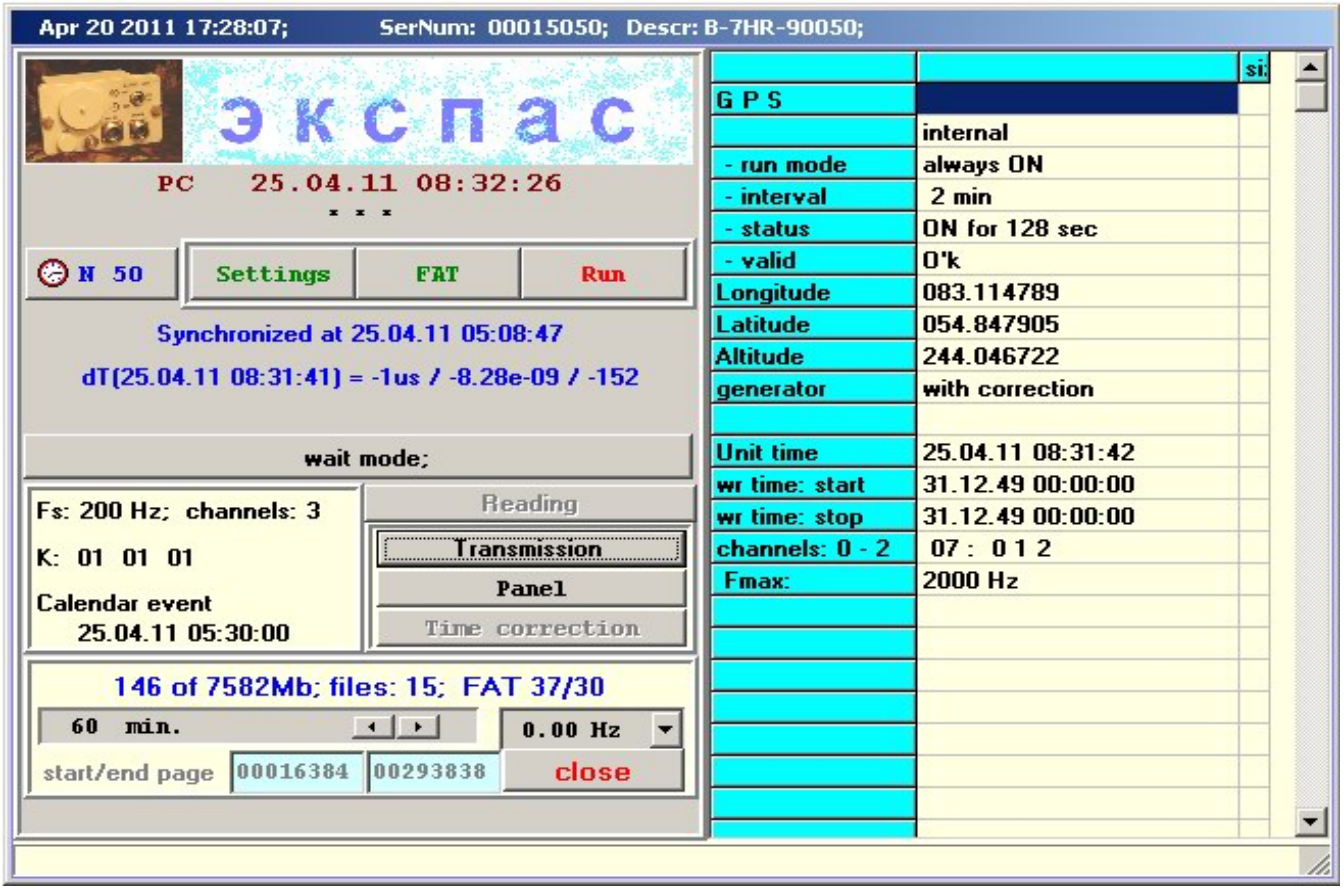


Fig.2. Main program window.

Top line: computer system time.

If the device is synchronized, synchronization time is displayed (***25.04.11 05:08:47***).

The time and result of the latest tuning: ***dT(25.04.11 08:31:41) = -1 μs / -8.28e-9 / -152***

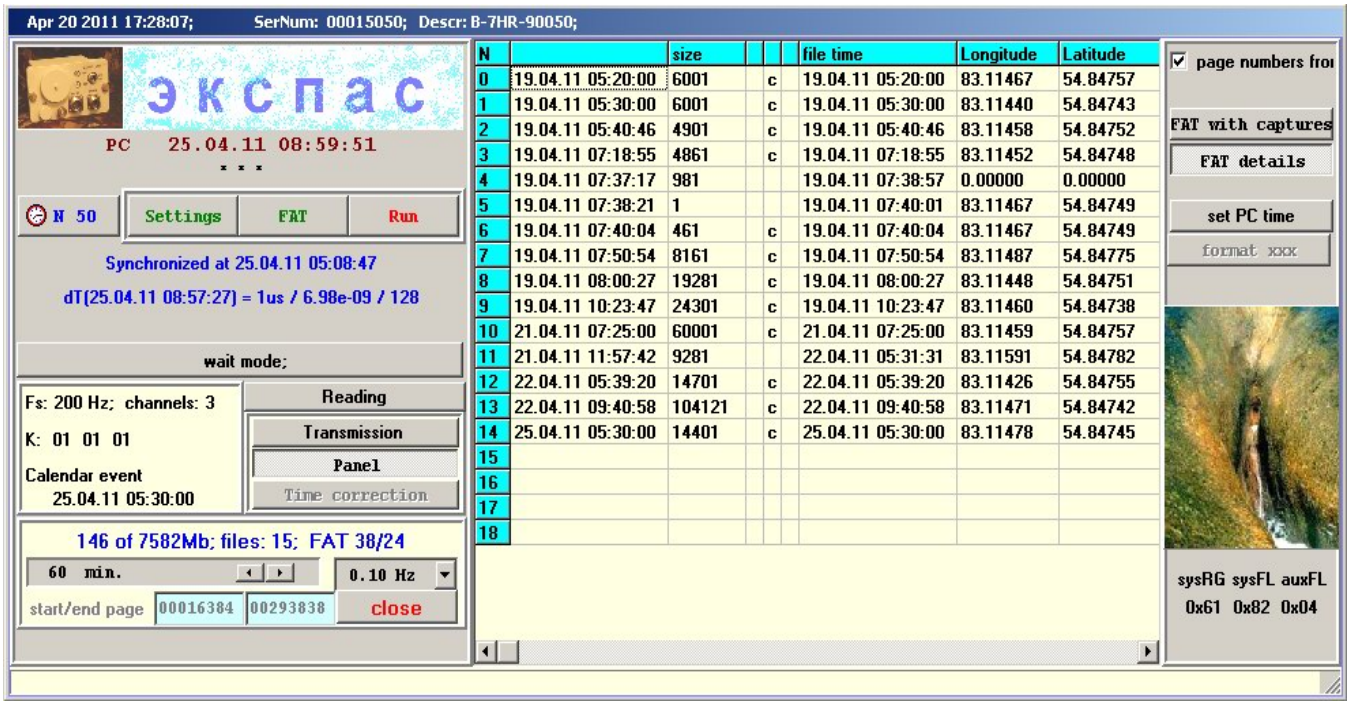
-152: absolute time drift is -152 /2000/ 65536; relative time drift is -8.28e-9.

The current state is the "Wait" mode. It is updated by clicking the panel. The clicking also updates some other windows. The clock button starts automatic status updating.

The data occupy 146 Mb from a total of 7582 Mb; the number of files: 15; the FAT size is 37 pages, and contains 30 records on the last page.

Fs: 200 Hz; the number of channels: 3 (the mode with a sampling frequency of 200 Hz and 3 channels is selected). Next line: gains from the first channel to the last channel. Switch-on time on calendar.

FAT records can be viewed by opening an additional panel and setting the "Correction" button in the active mode. This displays drifts if corrections are larger than 1 μs. All FAT records can be displayed if the "Details" button is activated.



N		size			file time	Longitude	Latitude
0	19.04.11 05:20:00	6001		c	19.04.11 05:20:00	83.11467	54.84757
1	19.04.11 05:30:00	6001		c	19.04.11 05:30:00	83.11440	54.84743
2	19.04.11 05:40:46	4901		c	19.04.11 05:40:46	83.11458	54.84752
3	19.04.11 07:18:55	4861		c	19.04.11 07:18:55	83.11452	54.84748
4	19.04.11 07:37:17	981			19.04.11 07:38:57	0.00000	0.00000
5	19.04.11 07:38:21	1			19.04.11 07:40:01	83.11467	54.84749
6	19.04.11 07:40:04	461		c	19.04.11 07:40:04	83.11467	54.84749
7	19.04.11 07:50:54	8161		c	19.04.11 07:50:54	83.11487	54.84775
8	19.04.11 08:00:27	19281		c	19.04.11 08:00:27	83.11448	54.84751
9	19.04.11 10:23:47	24301		c	19.04.11 10:23:47	83.11460	54.84738
10	21.04.11 07:25:00	60001		c	21.04.11 07:25:00	83.11459	54.84757
11	21.04.11 11:57:42	9281			22.04.11 05:31:31	83.11591	54.84782
12	22.04.11 05:39:20	14701		c	22.04.11 05:39:20	83.11426	54.84755
13	22.04.11 09:40:58	104121		c	22.04.11 09:40:58	83.11471	54.84742
14	25.04.11 05:30:00	14401		c	25.04.11 05:30:00	83.11478	54.84745
15							
16							
17							
18							

Fig.3. Additional panel.

Pressing of the "**FAT**" button updates the table on the right of the program main window containing information about card records and file lengths on the card and the filter type (obtained from the device settings). The file length and filter type set by the operator can be copied onto the computer disc for storage and subsequent processing by pressing the button "**UNIT reading**".

The recorder switch-on start time: 1980. At synchronization, correct time is set, and the times of all previously written files are corrected. Mark **C** denotes that file recording started after synchronization. During work, time is periodically saved on the SD-card. At the next switch on, the last saved time is the start time.

After recording of file 4 (see Fig.3), the device power was turned off. File 5 was recorded immediately after, but the recorder was switched off without synchronization (mark **C** is absent and the device time coincides with the file time. This means that the record was made after the fixed time). File 11 was also recorded without synchronization, but since it took place, we know the real time of the record (the new file time, mark **C** is absent).

File names will correspond to the file start times (the right values). The file length in the table is given as the number of sectors (blocks of 512 bytes each) recorded onto the SD-card. The latitude and longitude are also displayed. The records contain an integer number of completely filled sectors. The first sector of every file has recording parameters. **Notice that the size of records in the timetable is given in minutes!**

When a file is selected, windows containing its "**start/end**" margins become active. When the flag "**FAT addresses**" is removed, these addresses can be changed by pressing the buttons "**+**", " **-** ", " **Ctrl +** " … on the main and additional PC keyboards (or by direct input). The lower (status) line displays information about the first and last

sectors of the file; it is clear from this information whether these are addresses of the same file or of different files.

Records not completed in the ordinary way (due to sudden switch off during recording, accumulator run-down, or for other reasons) have a special mark. They can be read in the same way as properly closed files, but with the loss of file end data since the last information was saved in the FAT area. To read such a file, open an additional panel and remove the flag «**FAT addresses**», which opens access to start/end windows of the file sectors. Setting of a finite file address that is longer than the record size starts the file read operation. The program will determine and write all sectors of this record into the file.

During reading the program uses the time recorded on each page. If there is an error in the FAT address mode, the program **closes**. In sector-by-sector reading the program closes the file if it finds an error, and opens a new file if it finds the next "good" sector. The reading is completed if the sector shown in the window is reached, or there is no record, or the time in the "good" sector corresponds to the previous switch-on.

Notice that if the first read page does not contain recording parameters, the device will use the current settings in the recorder memory (in principle, the recorder can be changed or reading can be made on another device).

In operation, the tuning interval given in the settings is used to compare the device time with the GPS time. The results are used to correct the generator frequency for the device time to be the same as the GPS time at the next comparison. If, for some reason, comparison is not made, the corrected frequency will be used.

The time drift typically does not exceed several microseconds. Hence, the read mode with "**correction**" makes sense only if the following was made: initial synchronization,

antenna disconnection, long recording, antenna connection, and tuning.

PC time setting: computer system time correction.

Set "Baikal-7HR" operation modes by pressing the button "**Settings**". This opens an additional dialogue window shown in Fig.4. The dialog window has 6 inlays and buttons to save programmed modes of recorder operation.

The inlay "**Main**" (see fig.4) is used to set common parameters for all channels and files. Pull-down lists allow the operator to select a recording frequency of the seismic signal from a series of integer values relative to a base frequency of 2000 Hz, an interval for the generator tuning, and an internal or external GPS receiver. Additional filters and splitting size of large files for file reading to the computer. Flag "**Alignment to hour**" specifies what type of alignment is used: to the beginning of a file or to UTC hour.

File names at card reading are written in the following format:

1) full names **MMDDHHmmu<idNUN>.ss** ,

where **MM** is the month; **DD** is the day; **HH** is the hour; **mm** are the minutes; **ss** are the seconds; **u** is the delimiter; ***id NUN*** is the UNIT identifier and number.

2) short names **DDHHmm.NUN**

In the «**Transmission**» mode, additional month-day directories are created. File names are always created in the form **DDHHmm.S** (**S** denotes tens of seconds).

Input settings of operation modes and calendar data can be saved not only in the recorder internal memory but also in a special file, pressing button "**-> file**", on the computer for their subsequent input to other recorders.

The button «**Calendar**» in the field "**Input from file**" inputs to the current recorder only data on switch-on times and operation duration, whereas the nearby button «**Settings**» takes from the file all parameters from all inlays.

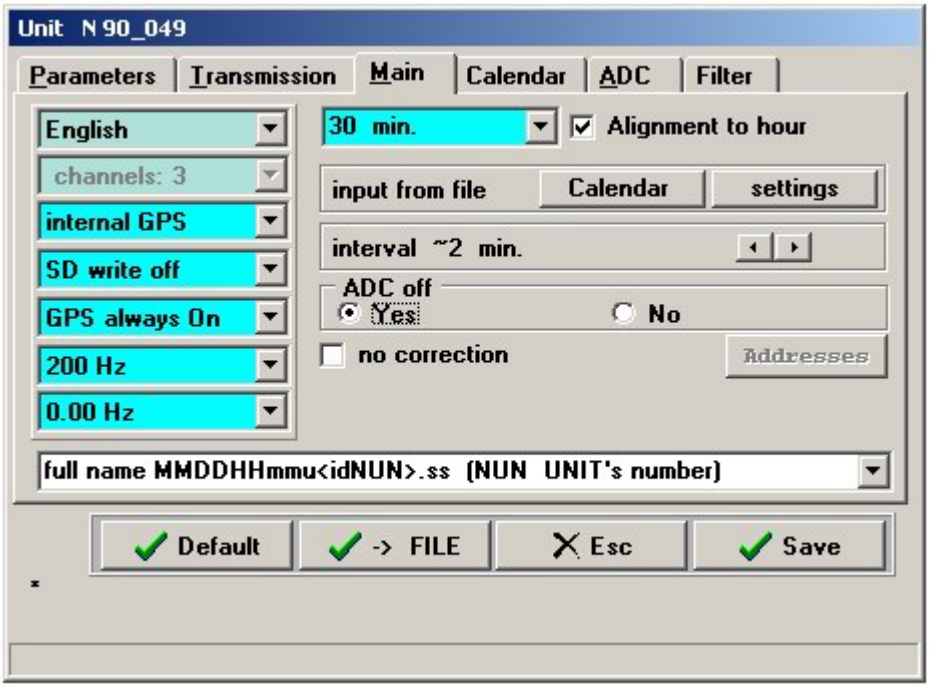


Fig. 4. Dialog window of Baykal-7HR settings.

No correction – Not tune generator (not recommended).

"**SD write on/off**": switch on/off of simultaneous background recording onto the card in the transmission mode.

"**ADC off**": No – ADC is permanently switched on (high power consumption).

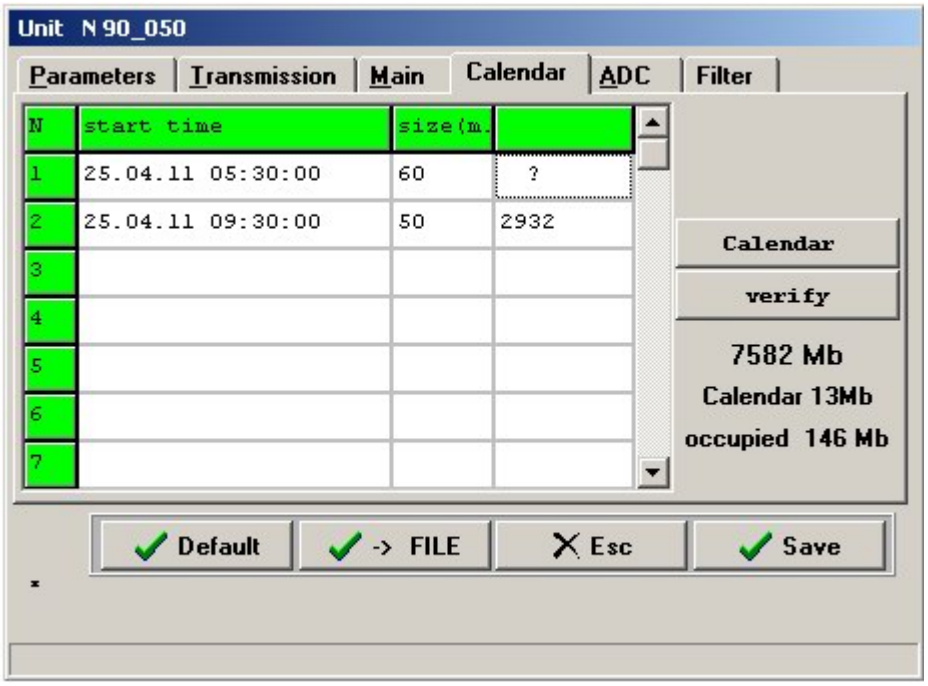
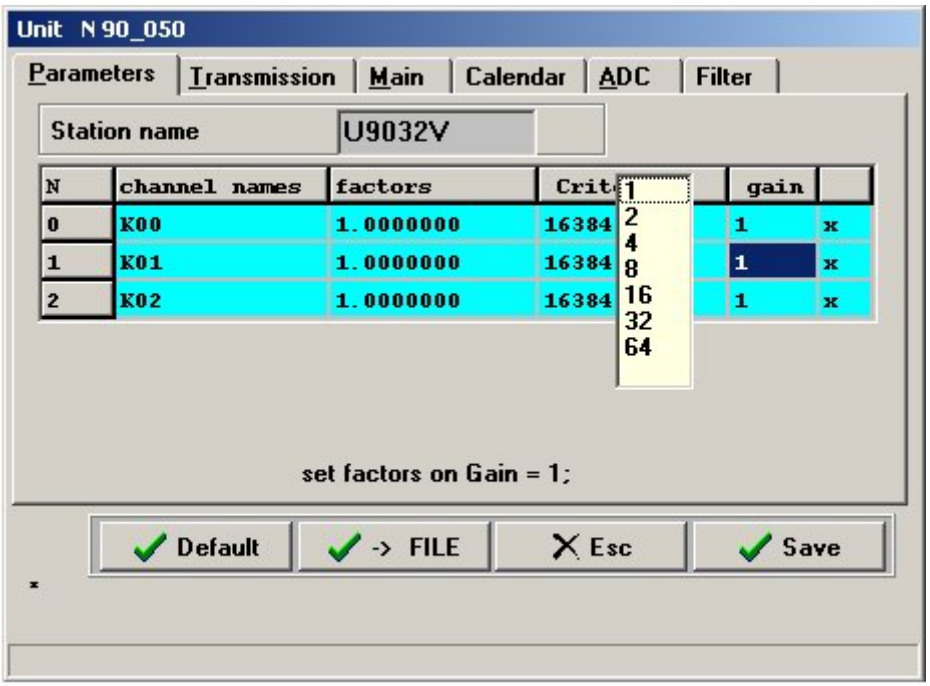


Fig.5. Inlay «Calendar»

The inlay "**Calendar**" is used to set start times and lengths of the records at autonomous operation. In this implementation, the max number of calendar records is 255, but there are no limitations on the recorded file size, which is limited only by the card size. The record length is specified in minutes!

Additional buttons allow the operator to avoid errors at calendar data input. Double click on the time field in the table displays the calendar. Text strings (in the right bottom corner) show how much card space is used, and the calendar shows how much additional space will be occupied by the calendar.

The last column shows the time left before the start of recording in seconds, and the sign "?" means that the time in the calendar string is expired.



?

Fig. 6. Inlay «Parameters»

The inlay "**Parameters**" allows the operator to input mnemonic symbols of channels, transformation coefficients of seismic sensors (… / volt), the analog tract gain (the right button displays the pull-down panel with coefficients that can be used), and specify criteria (in ADC units) to identify "strong" events (the inlay "**Transmission**").

"**X**" in the last column means that the channel is present in the record. Selection: right button.

The button "**Save**" becomes **GREEN** when changes in the SETUP (except for the "**Calendar**") were made.

The inlay "**ADC**" allows the operator to measure the constant offsets in all recorded channels, save these data in the device, and then subtract them in the recoding of seismic signals. Notice that the input offsets will be used only after their saving. Device inputs must be shorted.

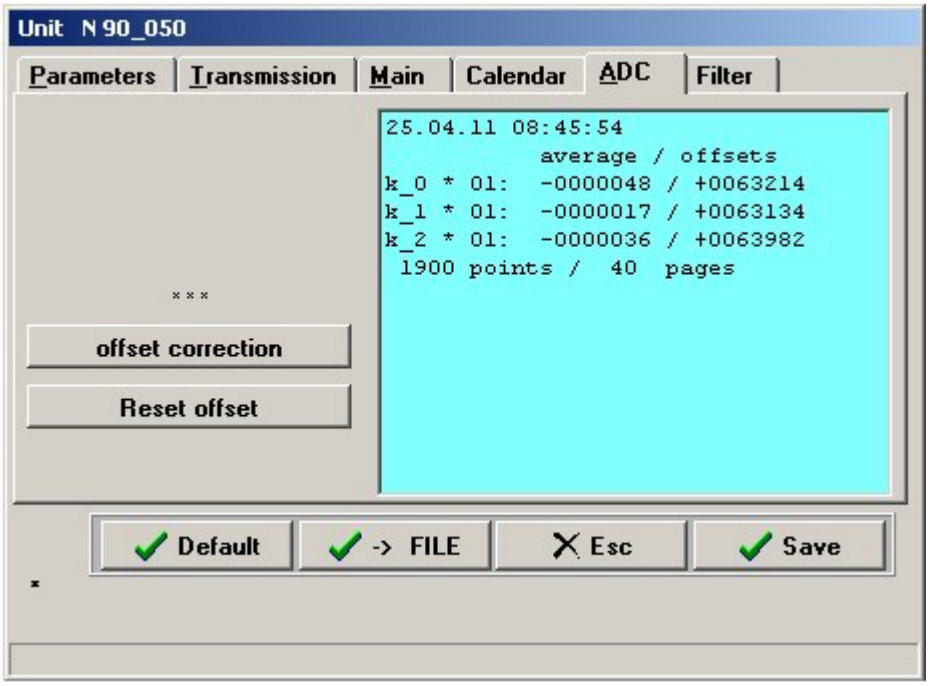


Fig. 7. Inlay «ADC»

The button «**Transmission**» in the main window of the program starts the recorder in the direct signal transmission mode with the current settings. The program displays an additional signal indication window.

If filtered signals (the current filter is in the lower line) simultaneously (in the example: within the **20**-point window) exceed the set criteria (from the window "**parameters**"), the file being recorded in the transmission mode will have an exclamation mark "!" in the file extension field (i.e., an event took place).

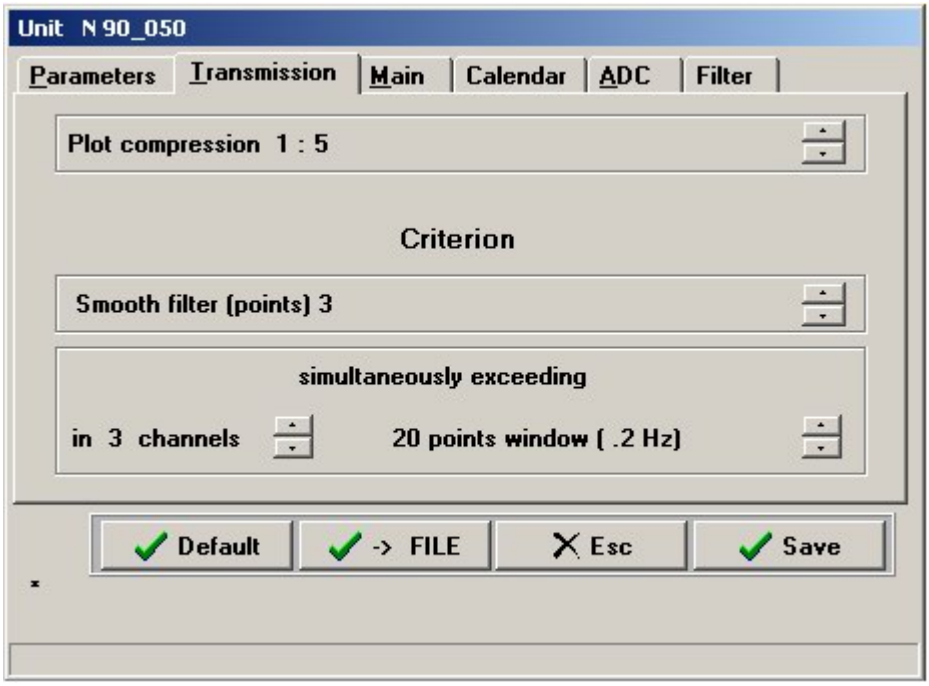


Fig. 8. Inlay "Transmission"

One can draw not only the signal itself but the filtered signal (used for the criterion) changing the filter "on the run" to select the event identification mode (Fig. 8).

This mode can be used to test whether the seismic sensors are in order and correctly connected or to test the analog tract by the known signal; the received data are recorded into a file on the computer. The buttons  on the right are used to change the display scale of the corresponding channel. Left click (LMC) in the figure field activates the corresponding channel (the number and current min/max of this channel are in the lower line: **K00(0) -46 / -41**). Right click (RMC) shows, at the top, the value corresponding to this field coordinate.

The button "**Y**" denotes self-scaling, change of scales of all channels in such a way that the signal amplitude corresponds to the display band.

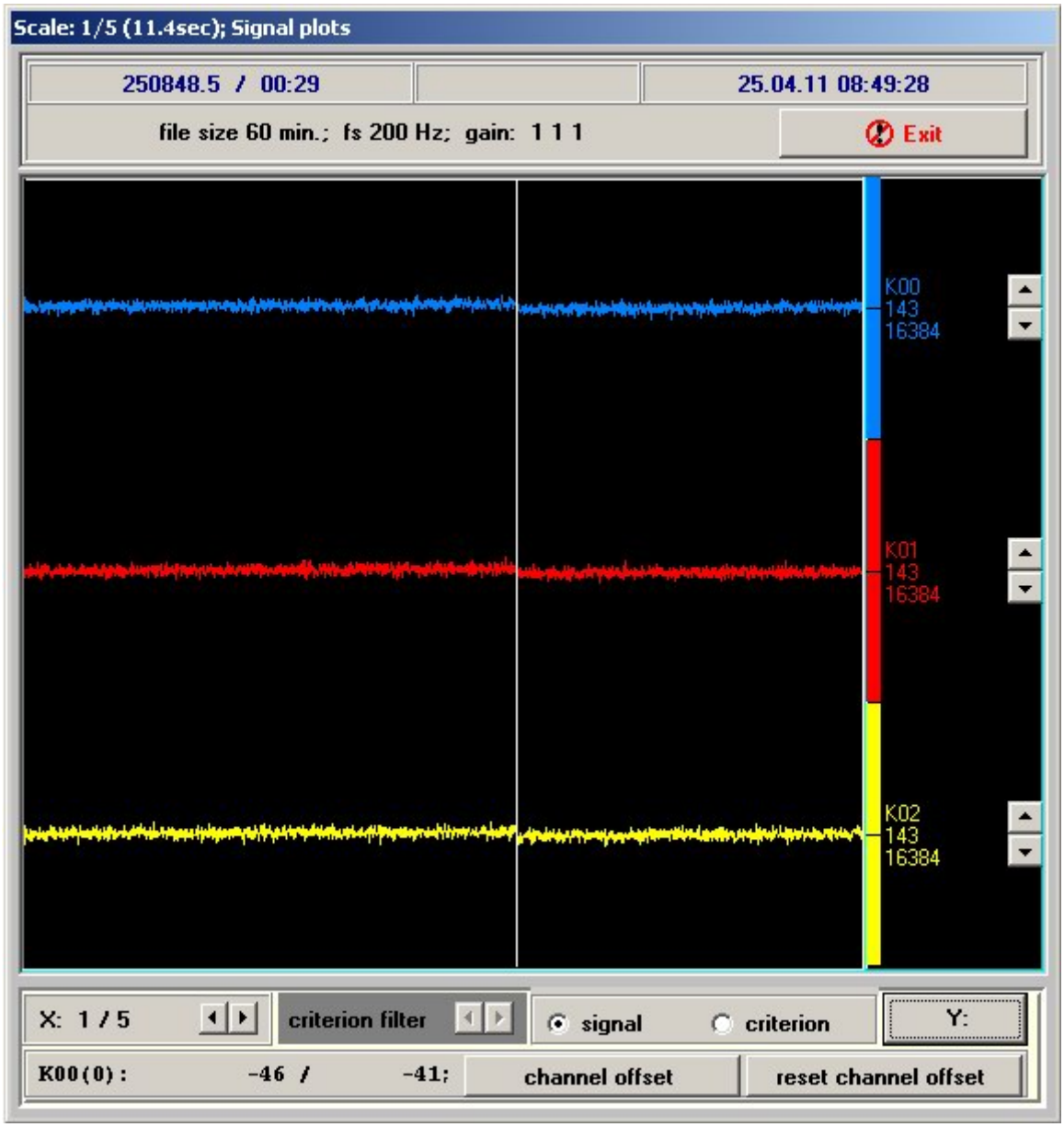


Fig. 8. Transmission mode.

8. Appendix.

8.1. Recorder connectors.

Connector «INPUTS»

Type: 2РМГ22Б10Ш.

Contact No.	Signal name	Relative channel No.	comments
1	Inverting input (-)	Channel 0	Differential analog input signal
2	Direct input (+)		
3	Inverting input (-)	Channel 1	Differential analog input signal
4	Direct input (+)		
5	Inverting input (-)	Channel 2	Differential analog input signal
6	Direct input (+)		
7	Shield		Protective grounding
8	0 V	Ground	Connected with ground of secondary power supply
9	+ 5 V		Positive power bus of active sensors
10	- 5 V		Negative power bus of active sensors

Socket «POWER»

Type: 2РМГ18Б7Ш

Contact No.	Signal name	Comments
1		
2		
3		
4		
5		
6	Power supply (+)	+ 10 ÷ +28 V
7	Power supply (-)	0 V (isolated from case)

8.2. Characteristics of digital filters.

Sampling rate Sample/sec.	cutoff frequency at level 0.7 (-3 dB) Hz	cutoff frequency at level 0.9 Hz
2000	800	760
1000	400	380
500	200	190
200	75	70
100	37	35
50	18	17

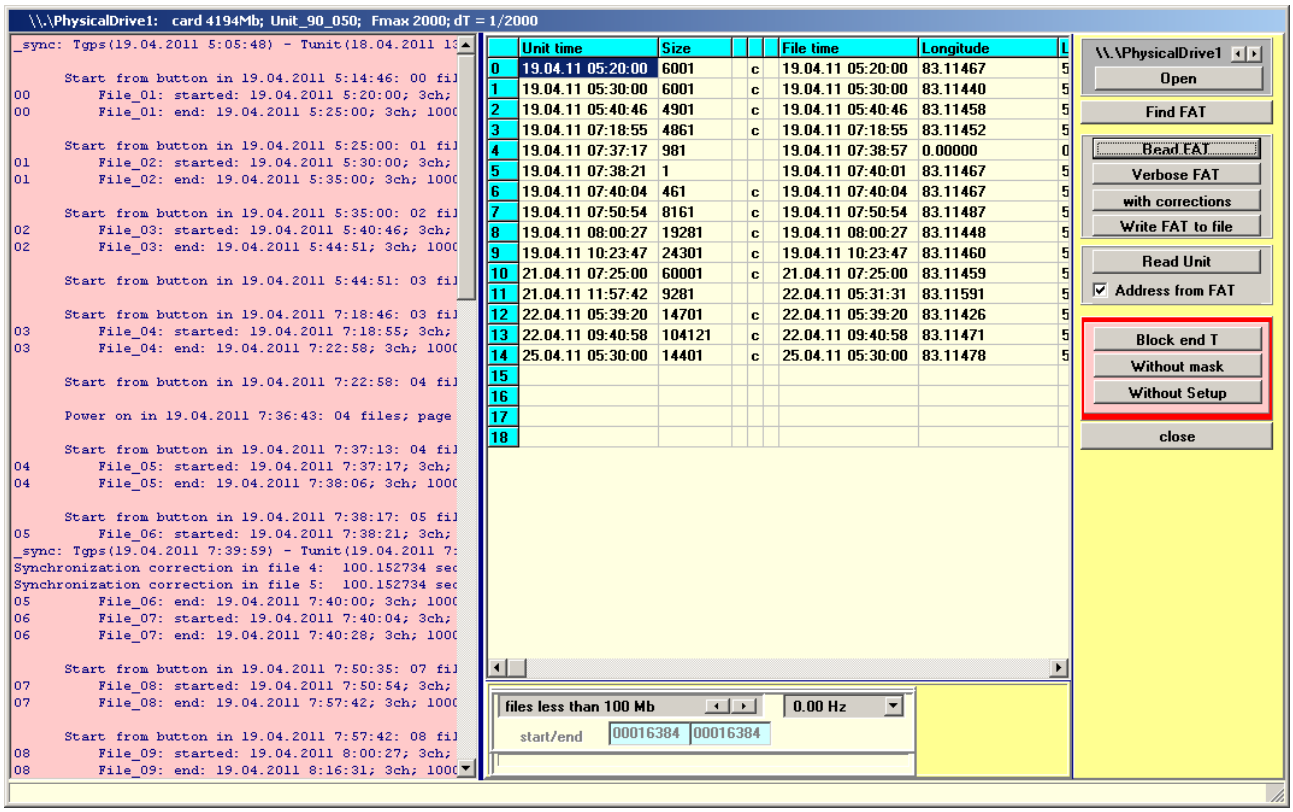
8.3. Card reader program

The program "Read_Baykal_Fl.exe" is used for SD-card reading written by "Baykal-7HR" recorder. To read files insert card into standard USB card reader and start the program.

The main program window will appear as shown at the picture below. Area on the left is used for test output of the reading results. Central area is for file list written on SD card. Control panel with buttons and checkboxes is on the right part of window.

For automatic device determination press the button "Find FAT". Operator can also specify device manually. For this, operator has to choose device in the top right corner and press the button "Open". After device will be open it is necessary to press "Read FAT" button for file list reading. The file list will be displayed in the central area and list of events will be displayed in the left at the same time. For more detailed output you need activate «Verbose FAT» and «with corrections» buttons and re-read the file list. If «Write FAT to File» button was activated before reading, binary FAT file will be created on the computer too.

To choose files from the list use right mouse click (RMC) and special mark "x" appears in the string of chosen file. Then press "Read Unit" to start process of reading. In this case reading occurs within card area specified in the FAT, but you can also specify any start and end sectors in the fields "start/end" after deactivating "Address from FAT" checkbox on the control panel.

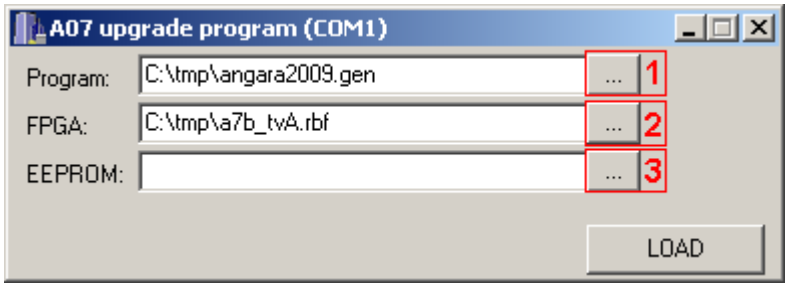

\\.\PhysicalDrive1: card 4194Mb; Unit_90_050; Fmax 2000; dT = 1/2000
Unit time
Size
File time
Longitude
\\.\PhysicalDrive1
Open
Find FAT
Read FAT
Verbose FAT
with corrections
Write FAT to file
Read Unit
Address from FAT
Block end T
Without mask
Without Setup
close
files less than 100 Mb
0.00 Hz
start/end
00016384
00016384

8.4. Software upgrade procedure.

The device has the software upgrade function. This is done with the help of one or several files that can be loaded by using the program a07_upgrade.exe

To update software, do the following:

1. Switch off the recorder if it is switched on.
2. Insert the special cable in socket RS-232. The other end of the cable must be connected to the computer COM-port (if the computer does not have a COM-port, use a usb-com adapter not included in the delivery set).
3. Start the program a07_upgrade.exe. The program window is shown in the figure below.
4. Select files to be loaded. For this, use the buttons located near the fields of the corresponding file name type (shown by figures in the Figure).
5. Press the button «LOAD».
6. Wait until the renovation process ends.
7. Close the program.
8. Switch off the CB.
9. Remove the cable from socket RS-232



Interconnections of programming cable:

DB-9F	Mini-DIN-6
1	-
2	6
3	4
4	-
5	1, 2, 3, 5
6	-
7	-
8	-
9	-

DB-9F socket pins 7 and 8 must be shortened. Pins 1, 4, and 6 must also be shortened.

8.5. Data file format.

All data are saved in the little-endian format (i.e. the lower byte goes first). The file has the following format:

```
struct xx_file
{
    struct main_header_xx60  main;
    struct channel_header    channel[channel_number];
    struct data_point        data[points_number];
};
```

A file starts with the main header. The main header has the following format:

```
struct main_header_xx60
{
    uint16_t channel_number;      // number of channels
    uint16_t reserved1;
    uint16_t version;             // Current version – 60 (0x3C)
    uint16_t reserved2[6];
    uint16_t digits;              // ADC width – 24 (0x18)
    uint16_t reserved3;
    uint16_t frequency;           // sampling frequency
    uint16_t reserved4[4];
    char station_name[16];        // Recorder name
    double reserved5[3];
    double latitude;              // Latitude
    double longitude;             // Longitude
    uint64_t reserved6[2];
    uint64_t time_begin;          // File start time
    uint16_t reserved7[4];
};
```

Comments:

10. The field time_begin shows time in 1/256000000 fractions of a second relative to 00:00:00 of January 1, 1980.
11. The latitude and longitude are given in degrees. A positive value corresponds to the Northern and Eastern Hemispheres, respectively.

The main header is followed by channel headers whose number is given in the field «channel_number» of the main header. The channel headers have the following format:

```
struct channel_header
{
    short phys_num;              // Physical number of channel
    short reserved[3];
    char channel_name[24];       // Channel name
    char sensor_type[24];        // Sensor type
    double channel_k;            // Channel coefficient
    double reserved;
};
```

Comments:

1. Channel headers can be located in arbitrary order, but the channel data must be recorded in the same order.
2. Physical numbers must be unique for all channels in a file.

The headers are followed by data in the form of an array of structures data_point. The array is continued to the file end; its length is not given directly anywhere. Each point

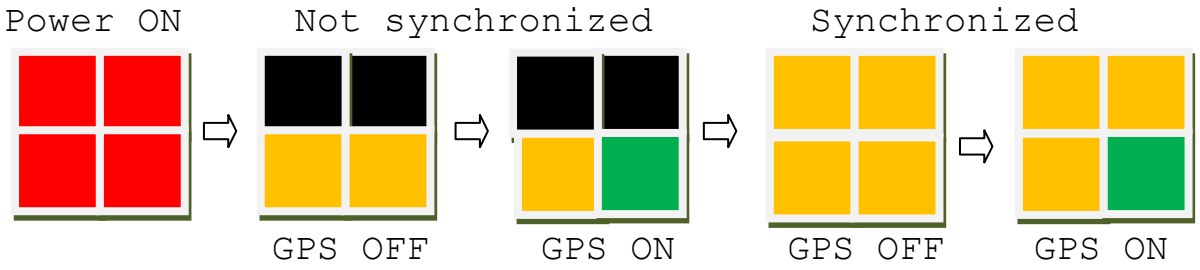
describes the channel value at the time separated from the previous one by the sampling period. The time of the first point is shown in the field "time_begin" of the header main_header_xx60.

```
struct data_point
{
     int32_t value[N];
}
```

Here value[i] denotes the data of the i-th channel ("i" is the channel header index in the array of structures "channel_headers".

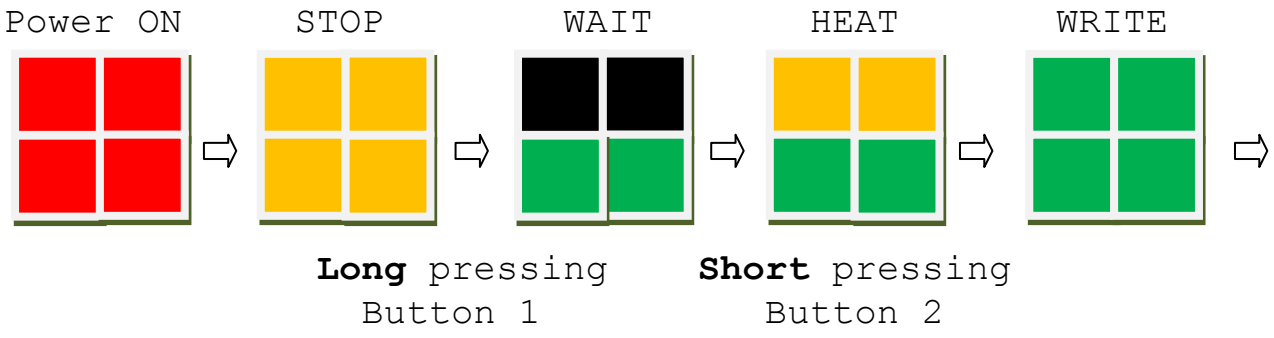
8.6. Working states and LED indications

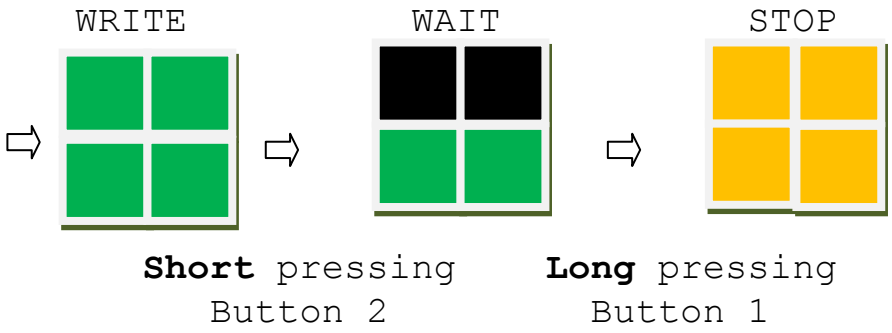
LED "TIME"



GPS module is switched ON and OFF periodically or by **Long** pressing Button 2

LED "MODE"





LED "MODE"