

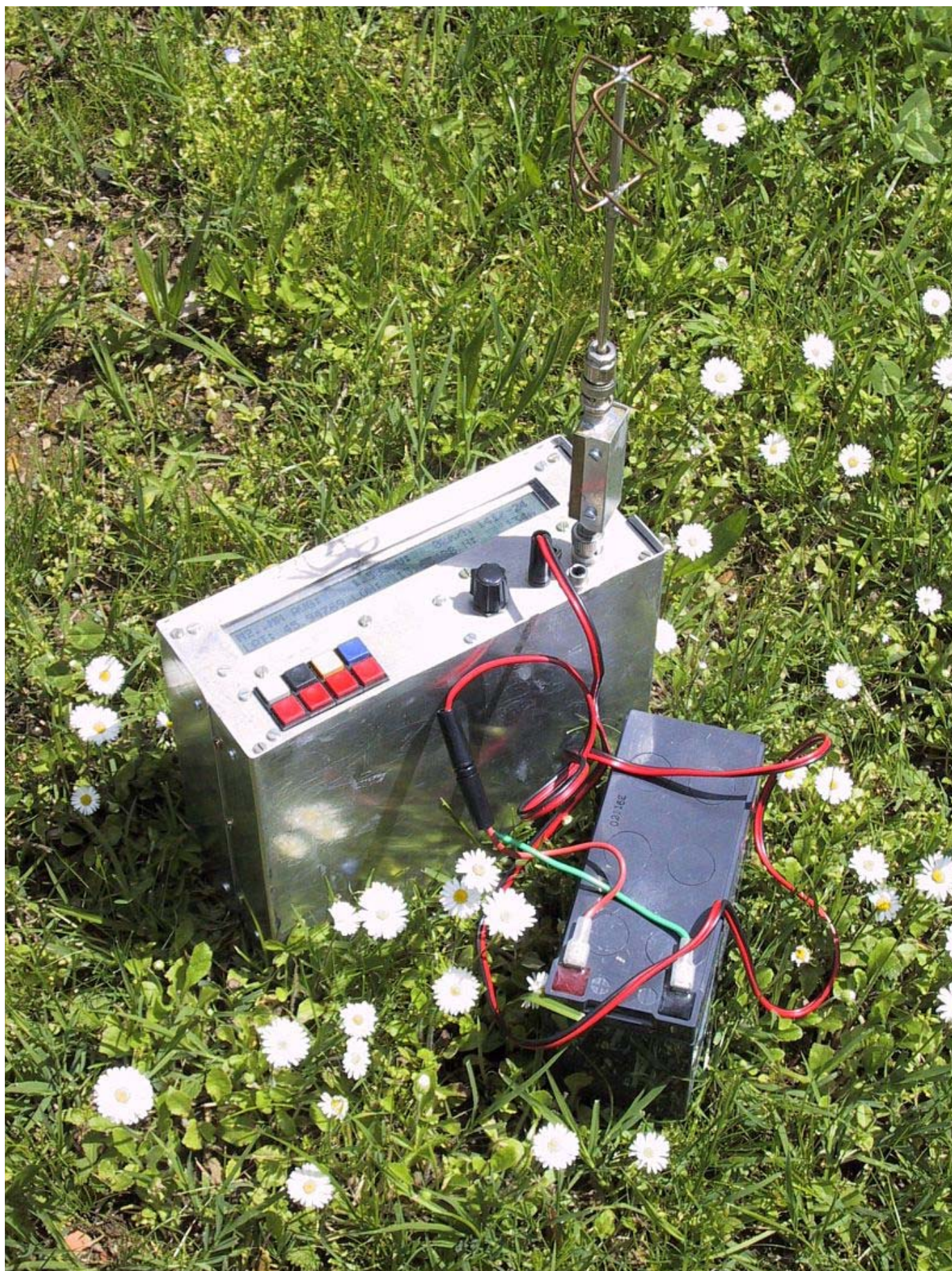
[\(THEORY\)](#) [\(ANALOG\)](#) [\(DIGITAL\)](#) (SOFTWARE) [\(HOME\)](#)

## A homemade receiver for GPS & GLONASS satellites

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### 5. GPS & GLONASS receiver software





### 5.1. GPS/GLONASS receiver software overview

Satellite navigation is one of the first applications that totally depends on the availability of suitable



computers and the corresponding software. Although initially the digital computer was only intended to solve the navigation equations, other tasks were being gradually added to simplify the hardware in front of and behind the computer itself. In the described GPS/GLONASS receiver even most of the signal processing is performed in software, just to keep the analog front-end and dedicated DSP hardware as simple as possible.

The software running in a GPS or GLONASS receiver is therefore very complex and includes a variety of very different functions. For example, digital signal processing requires quick but simple integer arithmetics while solving the navigation equations requires high-accuracy floating-point arithmetics. The latter does not need to be as quick as the former signal processing, but a considerable number of operations still need to be performed in a limited amount of time.

To make a fair comparison one should consider the development time for the hardware and for the software. In the case of the described navigation receiver, the development of the software required between two and three times the amount of time required to develop the hardware!

Unfortunately it is much more difficult to describe down to the smallest detail the software than the hardware. For the hardware one can draw the circuit diagrams and prepare detailed parts lists. On the other hand, detailed descriptions of the software tend to become boring and minor details tend to hide the real problem being solved.

Therefore only the major functions performed by the software will be described in this article. These include signal acquisition and processing, almanac and precision ephemeris data collection, time and frequency measurements, solving the navigation equations and data display in a suitable format for the user. At the end the user interface: display menus and user commands, will be described in detail.

The overall software is written in different languages due to the differing functions to be performed: MC68010 assembly language, DSP computer high-level language and even directly in machine code.

The digital signal processing software is written in the MC68010 assembly language. The corresponding file has the extension .ASM. This file is first compiled into machine code and then into hexadecimal format, so that it can be easily inserted in the DSP computer high-level language.

The orbital mechanics and navigation equation part is written in the DSP computer high-level language. The latter supports a floating-point format with a 32-bit mantissa and a 16-bit exponent. A 32-bit mantissa is generally sufficient considering the accuracy of the data obtained from the GPS or GLONASS satellites. The corresponding file has an extension .SRC and can be compiled into an .EXE file and executed on a DSP computer equipped with the described dedicated DSP hardware board, but with an unmodified CPU board!

In a portable GPS/GLONASS receiver all of the software is stored in a 27C256 EPROM. The latter includes a starting program, the high-level language compiler and a version of the .SRC file with all of the comments and other unnecessary symbols removed. When the portable receiver is turned on, the program will be compiled in the RAM. This operation takes around 10 seconds and is necessary to save EPROM space, since the compiled program in the RAM takes around 100kbytes.

The present discussion applies to the current software versions V122 (GPS) or V39 (GLONASS). When running the software on a DSP computer, the type of display may be selected by the TOTAL/PARTIAL RESET switch while starting the program: switch open (TOTAL RESET) selects the LCD while switch closed (PARTIAL RESET) selects the CRT display. Of course the LCD can only be selected in a stand-alone, portable receiver and the corresponding input on the CPU board MUST BE LEFT OPEN!

## 5.2. Real-time tasks: signal acquisition & processing

The signal acquisition and processing tasks run under the 1kHz interrupts requested by the dedicated DSP hardware module. The tasks include the multiplexing of the single-channel hardware

among four different satellites, the C/A-code synchronization acquisition and tracking, the carrier lock acquisition and tracking, the 50bps navigation-data demodulation, bit synchronization and frame synchronization with parity check and finally the averaging of the measured code phase, code rate and carrier frequency.

After an interrupt request is received from the dedicated DSP hardware, the interrupt-servicing routine will first latch the content of all of the counters in the dedicated hardware. It will then read the latched content and reset and arm the interrupt request flip-flop. The hardware counters are never reset. The actually integrated value is computed from the difference between the actual counter content and the previous sample content. The four differences are further normalized using the result from the reference 1ms divider. Finally, the interrupt-servicing routine also increments a 32-bit millisecond counter, which is later used to relate the measurements to the 50bps navigation data.

The single-channel hardware is multiplexed among all of the satellites received. However, due to the limitations of the hardware, switching to another satellite will corrupt one millisecond of data. Therefore, the basic multiplexing period includes one millisecond to switch the hardware followed by 8 milliseconds to collect the data from a given satellite. After this 9-millisecond period the hardware is switched to another satellite. The multiplexing rate is therefore 111 hops per second.

The multiplexing rate and especially the multiplexing sequence have to be chosen carefully. The navigation data is transmitted at a speed of 50bps, so one bit is 20ms long and lasts exactly 20 interrupt periods. If the navigation data is to be collected from a given satellite, then this satellite should get at least a few 1ms samples of data from each 20ms bit period. Further, the multiplexing period should not be an integer submultiple of the bit period, so that the bit transitions can be detected.

Considering the limitations of the single-channel hardware, the multiplexing sequence can not allow collecting the navigation data from more than two satellites at a time. In practice, since four satellites need to be received for a navigation solution, the navigation data can only be collected from a single satellite at a time using half of the single-channel hardware time. The remaining hardware time is split among the remaining three satellites. The privileged satellite that gets more hardware time of course needs to be periodically exchanged to allow collecting the navigation data from all four satellites.

There is yet another constraint on the multiplexing sequence. If a certain satellite only gets a few sampling periods, then false locks of the carrier recovery loop become very likely. In order to avoid this, the following multiplexing sequence is used in the described GPS/GLONASS receivers (1 = privileged satellite, 2, 3 & 4 = others):

```
121213141412131314
121213141412131314
...
```

The complete multiplexing sequence therefore repeats after 18 multiplexing periods or 162 milliseconds.

The C/A-code synchronization is always obtained from the signal magnitude obtained from the dedicated hardware. The signal phase information is intentionally not used for this purpose since the carrier phase lock is a much more critical operation. Therefore, for the C/A-code synchronization, the early and late magnitudes are computed from the related I and Q sums for every 1ms accumulation period. These sums are then averaged over the 8 milliseconds containing valid data in a 9-millisecond multiplexing period.

The initial state of the receiver is unlocked and the C/A-code synchronization acquisition has to be obtained first. The hardware variable delay will therefore be scanned through all possible C/A-code phases (1023 for GPS and 511 for GLONASS) by incrementing the variable-delay counter in suitable steps (6 for GPS or 9 for GLONASS). When a signal magnitude above threshold is detected, the software switches to the synchronization maintaining routine. A suitable time constant is built-in to prevent the loss of lock on short signal interruptions. In the synchronization-tracking mode, the software performs as a second-order phase-locked loop, computing the C/A-code phase and rate from the measured early-minus-late difference.

The signal carrier still includes the 50bps 0/180 BPSK navigation data, so a Costas-loop demodulator is required to obtain both the regenerated carrier for doppler measurements and the 50bps navigation data. The Costas-loop demodulator operates on every 1ms signal sample I & Q components computed as an average of the early/late data. The loop feedback is a second-order network computing the carrier phase and frequency.

The carrier-lock operation is not simple. Initially, the whole frequency range from -500Hz to +500Hz is scanned. To prevent false locks, the scanning is stopped only when the residual loop error becomes small enough. Finally, the locking point needs to be checked for the +/-500Hz ambiguity caused by the 1kHz sampling rate. The latter ambiguity is resolved by counting the number of transitions in the demodulated data stream in every 8 milliseconds of valid data in a multiplexing period. Since valid GPS data only has transitions every 20ms (GLONASS every 10ms), there can be at most one transition in 8ms of data. If the frequency is wrong, there are at least 6 transitions and this can be detected easily.

Of course, the phases of both code and carrier PLLs need to be adjusted for the following multiplexing period, accounting for all of the time spent by the hardware processing the signals from other satellites.

In a navigation receiver the code phase and the carrier frequency are the main parameters to be measured and these are supplied by the corresponding phase-locked loops. In addition to this, the code rate is also used by the software to compute a rough approximation for the carrier frequency and eliminate the ambiguity caused by the 1kHz signal sampling rate. Before further processing, the code phase, code rate and carrier frequency are averaged over 16 multiplexing periods corresponding to a time span of 288ms (privileged satellite) or 864ms (other satellites). The averaged measurements are placed in a FIFO memory together with 1ms time tags, to be read by the main program.

The last task performed by the interrupt routine is navigation data processing. The latter includes yet another PLL for bit synchronization. This PLL locks on the transitions in the data stream. The demodulated 1ms samples containing the transitions are rejected while all of the other available samples for a given satellite are accumulated into bits (GPS) or half-bits (the GLONASS manchester phase is not known yet).

The following navigation data processing depends on the data format and this is slightly different between GPS and GLONASS. The GPS data is formatted into 30-bit words containing 24 true data bits and 6 parity-check bits. The word synchronization is obtained by checking the parity bits, including the last two bits of the previous word, for any possible word phase. The BPSK polarity ambiguity is also resolved by the parity bits. The synchronized and checked GPS data words are placed in another FIFO memory together with 1ms time tags, to be read by the main program.

The GLONASS data is formatted into lines with 85 data bits in manchester format and a non-manchester sync pattern, for a total duration corresponding to 100 bits. The sync pattern is not used in the described GLONASS receiver. The synchronization is obtained by checking the 8 parity bits for any possible half-bit phase (200 possible phases), to resolve the manchester phase ambiguity as well. Since the data bits are differentially encoded, there is no polarity ambiguity to be resolved. Like in the GPS receiver, the correctly received data lines are placed in another FIFO memory together with 1ms time tags, to be read by the main program.

### 5.3. Main program loop tasks

Since most of the functions performed by the main program loop require high-accuracy floating-point arithmetics, the main program is mainly written in the DSP computer high-level language. Of course all of the interfaces to the interrupt routine and to the various peripherals (initialization of the dedicated DSP hardware, LCD drive, real-time clock chip) are at least partially written directly in the MC68010 machine code and are inserted in hexadecimal format in the program source code.

The main program loop executes once for every new set of averaged measured data. The latter is available every 864 milliseconds for the three satellites that get less hardware time. The privileged channel supplies three separate sets of averaged data in the same time period, but the excess data is not used by the main program loop.

The main program loop also updates the LCD or writes a new line on a CRT display. The internal operation of the program is however independent of the selected menu on the display. The menu only affects the keyboard functions and some computations closely related to the format of the displayed data, like coordinate conversions.

The first task of the main program loop is to write the look-up tables in the dedicated DSP hardware memory. This operation is done at receiver power-up, when changing satellites, when adjusting the carrier frequency (in 1kHz steps) or when switching the privileged satellite. The satellites can be selected manually, but usually the software is set to automatically select visible satellites.

When a given satellite is selected, the receiver requires some time to lock on its signal. The software will first look for all possible C/A-code phases. If the lock is not achieved, the main program loop will change the hardware look-up table frequency in 1kHz steps in a given frequency range (20kHz in the GPS receiver or 25kHz in the GLONASS receiver). Of course the look-up table frequencies for all four satellites can also be preset manually.

The look-up tables are rewritten when switching the privileged satellite for several reasons. When all four satellites have been acquired, this happens every minute, synchronized to the major data frames transmitted every 30 seconds from both GPS and GLONASS satellites. Since switching the privileged satellite includes some loss of data, other operations that corrupt the data, like rewriting the look-up tables, may be performed at the same time without any additional losses. The look-up tables are rewritten to correct for large variations of the doppler shift or local reference oscillator drift. Further, the new look-up tables are rewritten with a randomly chosen phase relationship between the carrier phase and code phase, to avoid any possible interferences between the carrier and the code when averaging the measured data over a longer period of time.

The main loop will then process all of the navigation data accumulated in the corresponding FIFO memory. The software looks for the frame sync and formats the data into frames. Additional checks are made before the formatted data is used. Correctly received frames are used to collect the precision ephemeris orbital data for the given satellite, to update the almanac containing less accurate data about the whole satellite navigation system and to set the GPS/GLONASS receiver real-time clock chip.

The next task is to collect the code phase and carrier frequency measurement results from the corresponding FIFO memory. The most recent data is always used together with the previous sample to relate all of the data to a single time point using linear interpolation. This simplifies the following computations, since the positions and velocities of all four satellites need to be calculated for a single point in time.

The measured data and the satellite positions and velocities (computed from the precision ephemeris data) are then assembled into the navigation equations. A set of three time-difference navigation equations is obtained from code-phase differences and another set of three doppler-difference navigation equations is obtained from carrier-frequency differences.

The time-difference navigation equations are solved first, using the Newton's method. The starting point is taken in the Earth's center ( $x=y=z=0$ ). From this starting point the Newton's method requires between three and four iterations to converge to the final result for a user located on the Earth's surface. The result in Cartesian coordinates  $x,y,z$  is then converted to longitude, latitude and height.

The position obtained may now be corrected for the propagation anomalies in the ionosphere and troposphere. The present software does not apply any correction for the ionosphere. The navigation equations are only corrected for the troposphere at the calculated height and the Newton's method is iterated once again to obtain the final result.

Since the position is already available from the time-difference navigation equations, the doppler-

difference navigation equations are solved to obtain the velocity of the user. Solving the doppler-difference equations for the velocity does not require a numerical iterative method, since the equations result linear for this unknown. The computed velocity vector is converted into magnitude, azimuth and elevation on the display.

The accuracy of the navigation solution depends on the geometry of the satellites. In place of the GDOP the software only computes the determinant of the linearized system of equations at the calculated position. This determinant is a dimensionless quantity. The higher the determinant, the more accurate the solution. If the determinant is too low, an error condition is signalled. The doppler-difference equations have the same determinant if solved for velocity.

The main program loop also performs data averaging. Both position and velocity are averaged. Only good data with no error signalled is added to the average. The determinant of the system of equations is used as a weight for each new data set added to the average. Of course the averaging buffer may be manually reset if desired.

The display includes several different menus and two of them are devoted to the immediate and averaged data. The position may be displayed in different formats: degrees only, degrees, minutes and seconds or Gauss-Krueger rectangular grid. Other menus are used to show the receiver status and the almanac data.

Finally, the main program loop usually also performs an automatic satellite selection. This function is triggered if an error condition is signalled continuously for a certain period of time (100 main loops). The software then uses the almanac data and the real-time clock to find the visible satellites at the averaged user location. The receiver is then programmed for the four visible satellites with the highest elevations on the sky. Although this procedure does not yield the best GDOP, its operation is foolproof.

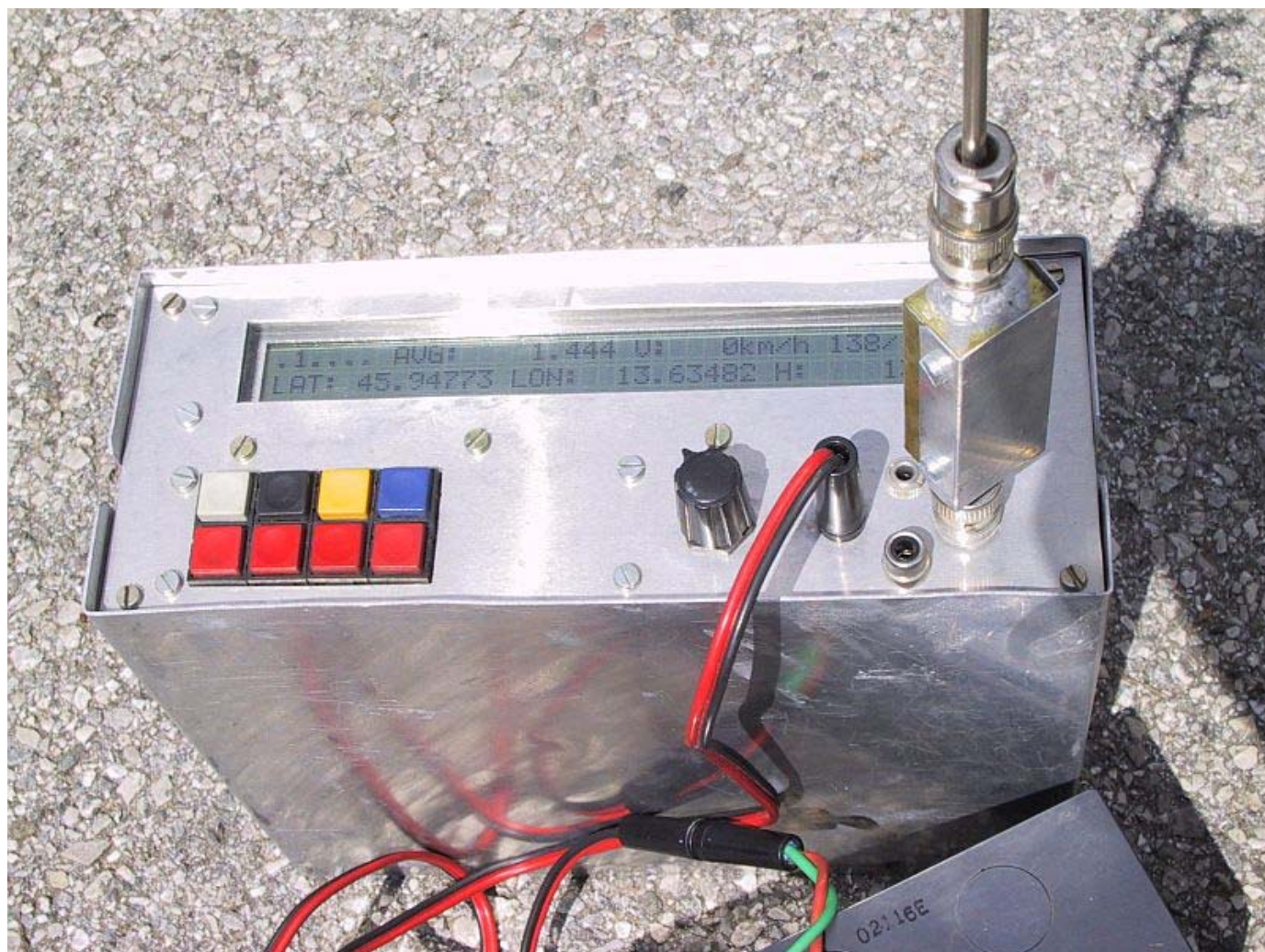
#### 5.4. Software menus and commands

Since a portable GPS/GLONASS receiver only has a small keyboard with a few keys and a small alphanumeric display, the various user commands need to be arranged into several different menus. The organization of the commands in the different menus is shown on Fig. 62.

MENU KEYS - DISPLAY FUNCTION				
	KEY #4 (CODE \$34)	KEY #5 (CODE \$35)	KEY #6 (CODE \$36)	KEY #7 (CODE \$37)
MENU	SHOW RX CHANNEL DATA	SHOW IMMEDIATE NAV DATA	SHOW AVERAGED NAV DATA	SHOW STATUS/ALMANAC
ACTION AFTER FIRST PRESSING	SHOW RX CHANNEL DATA	SHOW IMMEDIATE NAV DATA	SHOW AVERAGED NAV DATA	SHOW GENERAL STATUS
ACTION AFTER REPEATED PRESSING	INCREMENT RX CHANNEL NUMBER (2,3,4,1,2....)	NO ACTION	NO ACTION	SHOW VISIBLE SATELLITES (ALMANAC)
PARAMETER KEYS	KEY #0 (CODE \$30)	DECREMENT CHANNEL PRN#/CHN#	NO ACTION	CLEAR AVERAGED DATA
	KEY #1 (CODE \$31)	INCREMENT CHANNEL PRN#/CHN#	SET LON/LAT DEGREES/MINUTES/SECONDS DISPLAY FORMAT	
	KEY #2 (CODE \$32)	DECREMENT CHANNEL IF (1kHz STEPS)	SET LON/LAT DEGREES/DECIMAL FRACTION DISPLAY FORMAT	
	KEY #3 (CODE \$33)	INCREMENT CHANNEL IF (1kHz STEPS)	SET X/Y GAUSS-KRÜGER DISPLAY FORMAT	
				SET ALL RX CHANNELS (PRN#/CHN# AND IF) FROM ALMANAC
				TOTAL RESET (CLEAR ALL CMOS RAM DATA) PRESS 9 TIMES!
				SET MAN SATELLITE SELECT MODE
				SET AUTO SATELLITE SELECT MODE

Fig. 62 - GPS/GLONASS receiver software commands.





The keyboard has 8 different keys. Four of them (corresponding to ASCII characters "4", "5", "6" and "7") are used to select the four main menus. Depressing these keys only changes the content of the display and the functions of the other keys, but does not affect the internal operation of the GPS/GLONASS receiver. Some of these keys have additional functions if depressed more than once. Depressing key "4" cyclically shows all four virtual receiver channels (satellites) on the display. Depressing key "7" cyclically shows the general receiver status and the almanac data for all currently visible satellites.

The remaining keys (ASCII "0", "1", "2" and "3") are called parameter keys. Depressing these keys affects the internal operation of the GPS/GLONASS receiver as a function of the current menu. The mode of operation of these keys is also dependent on the actual menu. Some functions allow a repeated action of these keys during just one main program loop (864ms), like setting the channel IF. Other functions are intentionally slowed down, like the total reset of the receiver. The latter requires depressing the corresponding key for at least 9 times and just one entry is allowed for each main program loop, to avoid unintentional loss of data.

In order to understand the commands of a GPS/GLONASS receiver it is necessary to understand the internal operation of the latter. A GPS/GLONASS receiver includes a nonvolatile RAM to store the almanac data and a real-time clock that are always powered by a small internal NiCd battery. The nonvolatile RAM is used to store the almanac data and the approximate user position as a result of previous receiver operation. At power-up this data is used together with the real-time clock data to find all visible satellites and speed-up the acquisition of four usable satellite signals.

When a GPS or GLONASS receiver is first powered up, all of the nonvolatile RAM contains random data and a total reset is required. The total reset erases all almanac data and puts the receiver in the manual satellite select mode. All receiver virtual channels are set to a central carrier frequency and GPS PRN#16 or GLONASS CHN#13. The menu "4" is selected to show the virtual channel #1

data.

The initial satellite signal acquisition without any almanac data may take a large amount of time, especially in a single-channel receiver. The receiver does not know which satellite to look for nor its frequency offset caused by the doppler shift and by the unknown frequency drift of the receiver itself. The current software for the described GPS/GLONASS receiver is not able to select different satellites automatically without any almanac data, so this has to be done manually.

After manually selecting the satellite(s), the software is going to try to achieve C/A-code lock. If the latter does not occur on the given IF frequency, the receiver is going to scan the expected IF frequency range in 1kHz steps by writing the corresponding look-up table. Only the privileged satellite IF is scanned in the range from 2310kHz to 2330kHz (GPS) or from 1675kHz to 1700kHz (GLONASS).

While searching for the initial signal acquisition there is a small difference between the GPS and GLONASS receivers. The GPS constellation is now complete and more than four visible satellites can be found at any time, so the GPS receiver is only going to switch the privileged channel after a satellite signal is acquired. On the other hand, the GLONASS constellation is not complete and sometimes there is just one visible satellite, so the GLONASS receiver is going to try a different virtual channel with a different satellite if the current privileged satellite was not acquired.

After a satellite signal has been acquired, the key "4" menu shows the most important receiver parameters:

```
RX:    virtual channel number
SV:    GPS satellite PRN code number
CH#    GLONASS satellite RF channel number
CF:    look-up table preset central IF frequency (kHz)
R:     measured IF frequency (kHz, from code rate)
S:     signal level (S-meter)
SVH:   satellite health flag (0=OK)
URA:  GPS user range accuracy (m)
ASF:   GPS anti-spoofing flag (0=OFF)
En:    GLONASS ephemeris upload age (days)
AOE:   GLONASS ephemeris age (s)
```

If the receiver has been turned on for the first time or has not been used for a considerable period of time (more than one week), the best thing to do is to collect the complete almanac data first. To speed-up the almanac data collection it is recommended that the remaining three receiver virtual channels are set to the same satellite and to the same IF frequency as the channel that already acquired a satellite. After all four virtual channels achieved signal lock, the almanac data collection takes 12.5 minutes for GPS or 5 minutes for GLONASS, since the GLONASS receiver does not make use of half of the almanac frames.

The accumulated almanac data can be checked by repeatedly pressing key "7". The almanac data includes the satellite name/number plus the following information:

```
CH#    GLONASS RF channel number
EL:    elevation (degrees)
AZ:    azimuth (degrees)
DF:    doppler frequency shift (Hz, polarity as in the IF)
A/E    GPS almanac/precision ephemeris data
SVH:   satellite almanac health flag (GPS 0=OK, GLONASS 1=OK)
ASF:   GPS anti-spoofing & configuration flag
UTC:   UTC date and time
```

The elevation, azimuth and doppler shift are computed for the reference user position as obtained from the averaged data. After a total reset this reference position is set in central Europe. Checking the almanac it is possible to find out when the receiver can be switched to automatic satellite selection. In the automatic satellite selection mode, the program selects the four satellites with the highest elevations and sets the corresponding central IF values in the hardware look-up tables. This selection can be done immediately by pressing key "0" in menu "7" or by switching the program to do this automatically after a period of bad data (key "3" in menu "7").

After four satellites have been acquired, the display may be switched to menu "5" or "6", to show respectively the immediate or averaged data. These menus show the following:

DET: determinant of the system of equations (menu "5" only)  
 AVG: averaging weight (menu "6" only)  
 V: velocity vector magnitude (km/h), azimuth & elevation  
 LAT: latitude (degrees or m, north)  
 LON: longitude (degrees or m, east)  
 H: height above ellipsoid (m)

At the beginning of all menus (except the almanac) the receiver status error codes appear, as shown on Fig. 63. These codes show the general receiver status, the current privileged virtual channel and the status of the single virtual channels. Most of the codes used are obvious, but three of them require further explanation. In the general receiver status, code "P" means that the computed position deviates too much from the previous main program loop. On the other hand, code "E" is only activated after the averaging weight gets larger than 5 and means that the equations themselves deviate too much from the already computed average position. Finally, code "T" in the virtual channel status appears quite frequently since the current software does not handle the overflow of the C/A-code variable-delay counter correctly.

**Status indicator format: <GS> <DC> <C1> <C2> <C3> <C4>**

**<GS> = general receiver status**

. = general receiver operation ok  
 G = poor satellite geometry  
 P = position deviation error  
 E = navigation equation error  
 1 = channel 1 bad  
 2 = channel 2 bad  
 3 = channel 3 bad  
 4 = channel 4 bad  
 M = more channels bad

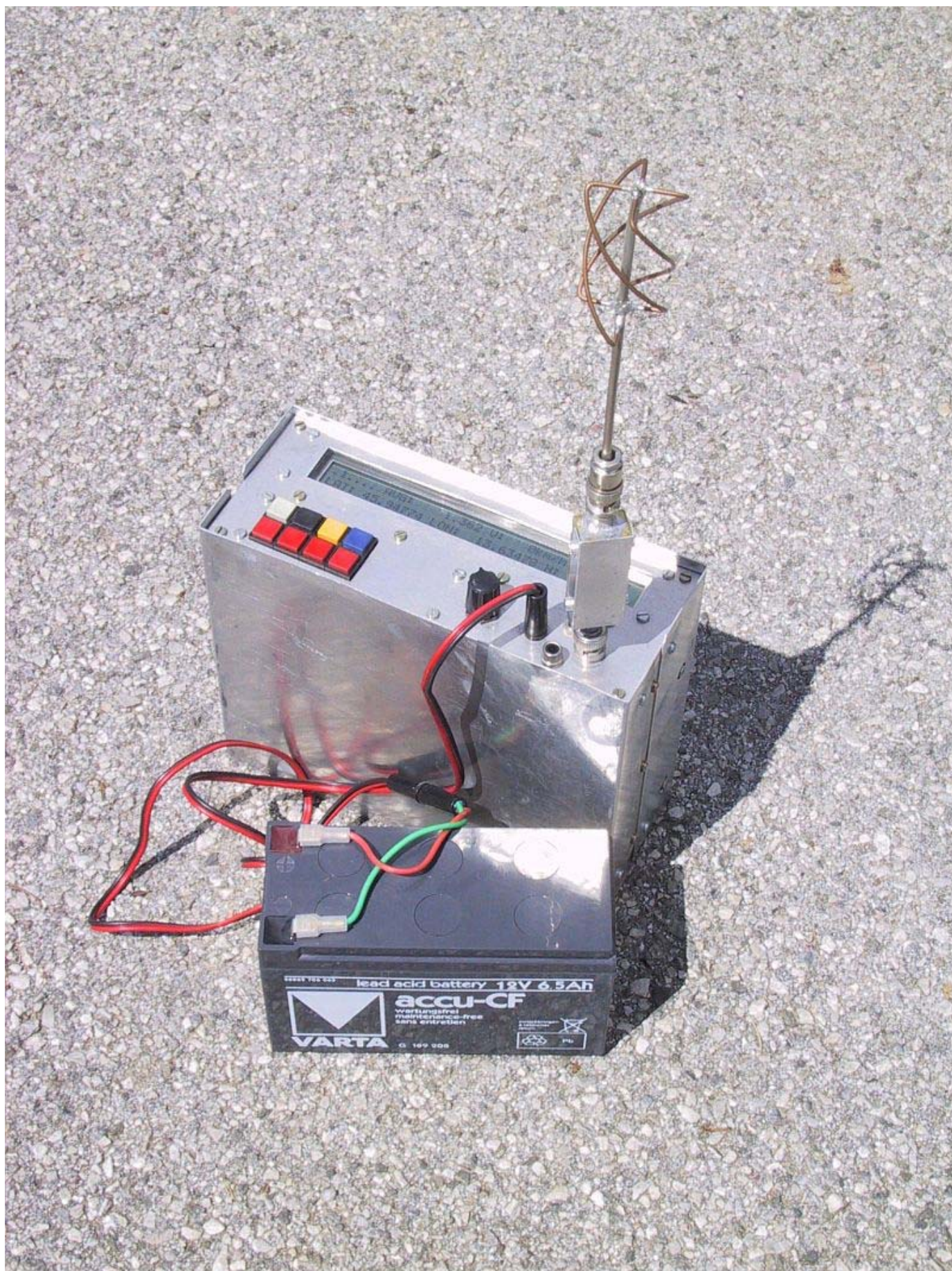
**<DC> = current (privileged) data channel: 1, 2, 3 or 4**

**<Cn> = channel n status**

. = channel operation ok  
 A = almanac only, precision ephemeris bad (GLONASS only)  
 B = 50bps nav-data bit synchronization missing  
 C = C/A-code synchronization missing  
 D = RF carrier doppler measurement deviation too high  
 E = precision ephemeris not updated (GPS only)  
 F = carrier lock missing  
 L = RF signal level too low  
 N = no orbital data available (GLONASS only)  
 R = satellite atomic clock parameters not updated (GPS only)  
 S = different precision ephemeris subframes (GPS only)  
 T = C/A-code timing measurement deviation too high  
 U = nav-data to C/A-code synchronization not updated  
 M = multiple errors

**Fig. 63 - GPS/GLONASS receiver status error codes.**





Finally, the general status menu (key "7") shows some interesting data about the receiver: the satellites currently selected, AUTOMATIC or MANUAL satellite selection, the measured nominal IF frequency of the receiver (without the doppler shift), the measured receiver master oscillator



frequency and the UTC date and time.

## 6. Conclusion

The GPS and GLONASS systems are mainly intended for navigation, but there are many other less advertised but not less important nor less interesting applications of these systems. Since these systems are known and the technology to use them is available to anyone, we radio-amateurs should consider our own applications of these systems [13].

Although the navigation itself is not of much interest to radio-amateurs, it would probably make much more sense to transmit GPS or GLONASS coordinates of a contest location rather than the inaccurate EU or WW locator, which is already not accurate enough for serious microwave or laser communications. By the way, GPS and GLONASS use almost the same coordinate system and a long time average shows differences in the order of only 10m between the two systems.

A side product of both GPS and GLONASS is accurate time and frequency broadcast. In order to achieve the specified navigation accuracy, the timing measurements have to be performed to an accuracy of about 10ns. The same requirement applies to the on-board satellite atomic clocks. The final user time transfer accuracy ranges between 30ns and 100ns, depending also on the knowledge of the exact user location. Thus the user should also compute his position even if he only needs accurate time.

Radio-amateurs could use this time transfer capability of both GPS or GLONASS every time when accurate synchronization is required. Coherent communications are just an example, the accuracy of GPS or GLONASS offers more than this: for example, the actual propagation path of the radio signal and the propagation mechanism could be investigated in this way.

The frequency broadcast accuracy of both GPS and GLONASS is in the range of  $10^{-12}$ , far better than can be achieved with HF or LF standard frequency transmitters. The accuracy of the latter is limited to around  $10^{-7}$  by the propagation effects alone, and this is not enough for serious microwave work. GPS and GLONASS are also available globally 24 hours per day and are not limited by the transmitter range, propagation effects or low-frequency electronic pollution.

Finally, GPS and GLONASS represent a step away from being just an operator of black-box amateur-radio equipment. Although there are several ready-made GPS receivers on the market, we will probably have to develop our own receivers for our experiments, both the hardware and the software. Building such a receiver may be an interesting challenge as well. The receiver shown in this article is perhaps just the first step, other related projects or better receivers will hopefully follow soon.

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## GPS/GLONASS RECEIVER HARDWARE & SOFTWARE UPDATE #1

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Since the publication of the series of articles about the GPS/GLONASS receiver in UKW-Berichte/VHF-Communications there have been a few modifications of the hardware and software of these receivers. The original articles describe the operation of the GPS software V122 and GLONASS software V39. The current update describes the new GPS software V125 and GLONASS software V42. The new GPS V125 and GLONASS V42 include the following modifications:

- (1) Improved internal operation of the software. The new software is able to handle the overflows of the hardware counters correctly thus almost eliminating the occurrence of the "T" error.
- (2) Additions to the command set:
  - (2.1) In menu #5, key #0 will shift the privileged RX channel.
  - (2.2) In menu #7, key #0 has a new function: in AUT mode it operates as before while in MAN mode this command sets the carrier frequencies of the currently selected satellites.
  - (2.3) In menu #7, key #1 has an additional function: the receiver will display the Keplerian elements of the GPS/GLONASS satellites as decoded from the almanac data before entering the total RESET sequence.
- (3) A simple bidirectional RS-232 interface is included,

requiring only a few additional hardware components to be installed in the receiver.

- (3.1) The RS-232 interface output circuit is shown on Fig.1. Because of hardware limitations, the bit rate can only be set to 1000bps. The output data format is a serial asynchronous transmission including a start bit, 8 data bits, no parity and one stop bit. The output signal level ranges from 0V to +5V only, although these levels are usually accepted by most RS-232 receivers. The signal polarity is inverted as usual in RS-232: 0V represents a logical "1" while +5V represents a logical "0". The data output matches the LCD display content, the display clear command being replaced by a CR/LF combination.

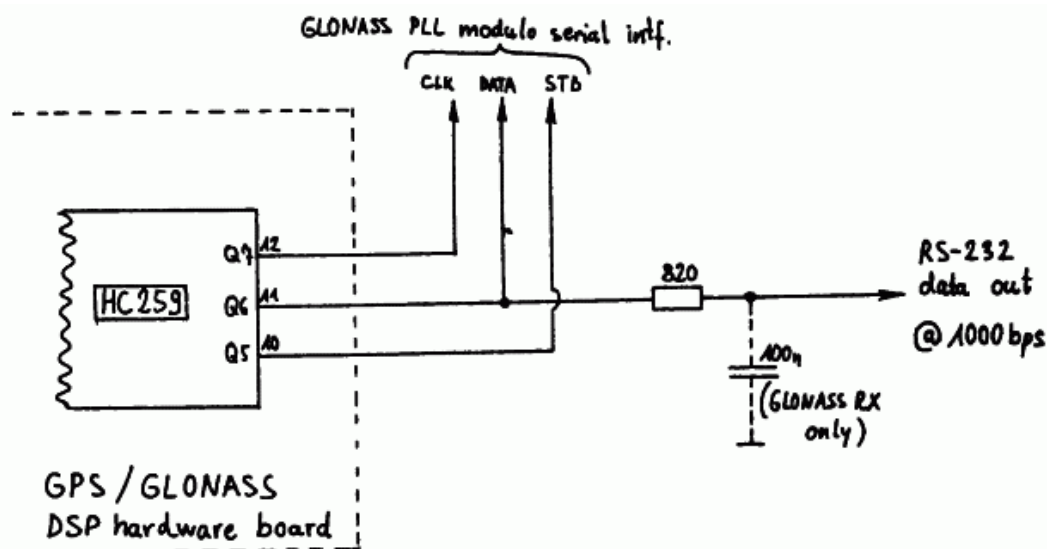


Fig. 1 - RS-232 interface output circuit.

- (3.2) The RS-232 interface input circuit is shown on Fig.2. Because of hardware limitations, the bit rate can only be set to 100bps or 10 times slower than the output rate. The RS-232 input can be used to issue commands identical to those coming from the 8-key keyboard. Only ASCII characters "0", "1", "2", "3", "4", "5", "6" and "7" are therefore accepted as valid commands. All other codes are simply ignored. The data format is 8 bits, no parity, one or more stop bits. The signal polarity is inverted as usual in RS-232.

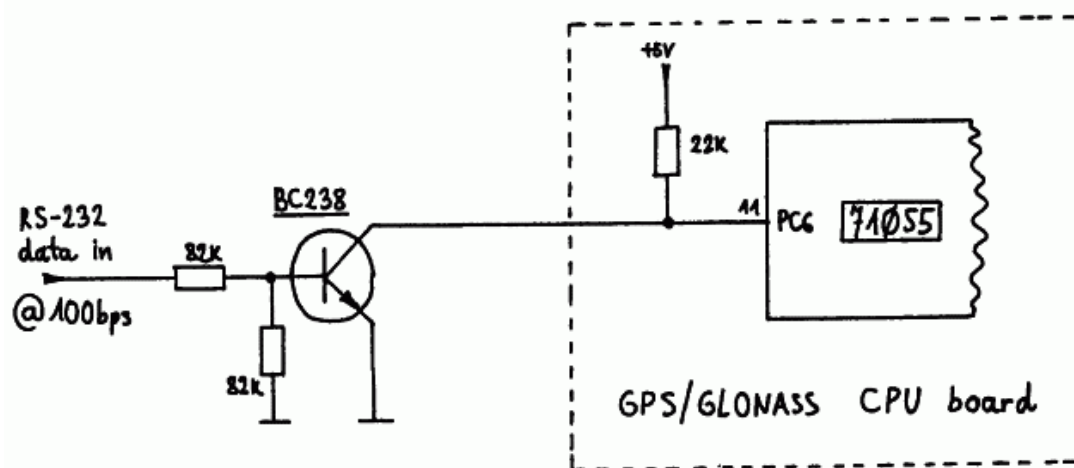


Fig. 2 - RS-232 interface input circuit.

Since the PC6 input is now used for the RS-232 interface input, it can no longer be used to select the display type, CRT or LCD. The latter selection is thus preset in the software. The new receiver software is supplied in three files. The .SRC file is intended to be compiled and executed on a DSP computer, equipped with a GPS/GLONASS hardware board. The .BIN file is a compressed version of the program to be burned in a 27C256 EPROM for a stand-alone GPS/GLONASS receiver. Finally, the .ASM file is only supplied as an information about the internal operation of the main interrupt routine that includes all of the digital signal processing. GTERM is a 1000bps RX, 100bps TX RS-232 terminal program for the DSP computer.

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