**NanoVFO synthesizer  
firmware version 3.4**

User guide

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**General principles of configuration**

The synthesizer is configured by editing the config.h, config\_hw.h and config\_sw.h modules.

**Board type selection**

The synthesizer firmware is universal and currently supports three types of boards

1. Version 3.0 boards. Does not include Port Expander 74HC595
2. Version 3.1 and higher boards with 74HC595 expander
3. SuperLED boards with additional frequency indication on ALS and support for two SI5351

The board type is specified using the following macros in the config\_hw.h file

#define HARDWARE\_3\_1  
#define HARDWARE\_SUPERLED

When you select a SuperLED board, the HARDWARE\_3\_1 macro is automatically enabled.

**Display**

The display type is specified using the following macros in the config\_hw.h file

#define DISPLAY\_OLED\_SH1106\_128x64 // 1.3”  
//#define DISPLAY\_OLED128x64 // 0.96”

Only one used needs to be uncommented

**Encoder**

The synthesizer is designed to work with a simple mechanical encoder that delivers 20 pulses per revolution or an encoder on an AS5600 magnetically sensitive microcircuit that produces 256 pulses per revolution.

For a mechanical encoder, intermediate states are taken into account, which allows you to get 2/4 times more pulses (quadruple mode may work unstably on some encoder instances).

The encoder parameters are configured in the config\_hw.h module  
The doubling/quadruple mode is given by constants

#define ENCODER\_MULT\_2  
//#define ENCODER\_MULT\_4

When using an encoder on the AS5600 chip, you must uncomment macro

#define ENCODER\_AS5600

The change in tuning frequency per revolution is given by the constant

#define ENCODER\_FREQ\_LO\_STEP 3000

In accelerated mode, tuning is 5 times higher - 15kHz per revolution (ENCODER\_FREQ\_HI\_STEP constant). Switching between the normal and accelerated tuning modes is carried out automatically depending on the speed of rotation of the encoder - if the frequency has changed by more than 1 kHz in a second, then the encoder switches to the accelerated mode. The switching threshold can be changed with the ENCODER\_FREQ\_HI\_LO\_TRASH constant

The synthesizer can generate a tuning frequency with a certain step (granularity). To do this, in the config\_hw.h file, you must set the constant

#define FREQ\_GRANULATION 50

By default, the tuning granularity is 50Hz, which is enough for comfortable work. If you need to disable granularity then comment out this definition

**Real time clock**

Real time clock DS3231 supported. The firmware automatically detects their presence - nothing needs to be configured

**Choice of synthesizer chips**

The program can work with SI570 and SI5351 synthesizers (up to 2x SI5351 in the SuperLED board version). They can be installed both at the same time, or either one separately. When installing two synthesizers, the signal of the first local oscillator is always formed using the SI570, because it has less phase noise, and the second and third (as needed) on the outputs of the SI5351. If only one SI570 is installed, then a single signal of the first local oscillator is formed. Specifying the synthesizers used is done using the following macros

#ifdef HARDWARE\_SUPERLED  
 #define VFO\_SI5351  
 #define VFO\_SI5351\_2  
#else  
 #define VFO\_SI5351  
#endif  
//#define VFO\_SI570

It is necessary to uncomment the ones that are used.

The SI570 does not have a place to mount on the board. It must be mounted on a separate board and connected via the I2C connector of the H4 I2C Ext bus. Power supply for SI570 must be done from a separate 3.3v stabilizer (for example AMS-1117-3.3)

The SuperLED version of the board can be used with either one SI5351 or two. If one SI5351 is used, it is necessary to comment out the VFO\_SI5351\_2 macro. The WC2 jumper is installed on the board and the I2C switch of the U14 bus is not installed. You can clock one SI5351 from an XTAL1 quartz resonator or from (TC)XO X1. Jumper WC1 is set depending on what potential the generator needs to operate at the enable input. Usually for TCXO it needs to be installed.

When using two SI5351s, they can only be clocked from (TC)XO X1. In this case, the WC2 jumper is not installed and the I2C bus switch U14 is installed.

**Frequency calibration**

Write the applied crystal/TCXO frequency for SI5351 in the SI5351\_CALIBRATION constant in config\_hw.h.

To accurately set the generation frequency, it is necessary to calibrate. Connect a frequency counter to any output of the SI5351. Select SI5351 XTAL from the FREQ menu. Use the encoder to set the lower 4 digits of the frequency. If the measured frequency is less than the one specified in the SI5351\_CALIBRATION constant, then set a negative value. For example, if SI5351\_CALIBRATION is set to 25000000 and the actual measured frequency is 25998700, then a negative calibration value should be set to -1300.

If the Si570 is installed, measure the frequency at its output. Change the SI570\_CALIBRATION constant in config\_hw.h to the measured frequency.

**Defining ranges**

In the config.h file, in the DEFINED\_BANDS macro, define the bands you need. Each range is on a separate line and ends with (except for the last range) a comma and a backslash (\).  
An example declaration for a single-band transceiver:

#define DEFINED\_BANDS \  
 {20, 14000000L, 14100000L, 14350000L, USB}

Example for multiple ranges:

#define DEFINED\_BANDS \  
 {80, 3500000L, 3600000L, 3800000L, LSB}, \  
 {40, 7000000L, 7045000L, 7200000L, LSB}, \  
 {20, 14000000L, 14100000L, 14350000L, USB}

Each band has start/end frequencies, SSB/CW boundaries, and a default sideband.

When changing the list of ranges, it is necessary to set their number in the BAND\_COUNT constant. For example

#define BAND\_COUNT 3

**Setting architecture and intermediate frequency**

Produced in the config\_sw.h file. First you need to uncomment the macro corresponding to the architecture of your receiver / transceiver.

1. **MODE\_DC** is a direct conversion. when receiving, the VFO frequency is formed on CLK0, when transmitting, the VFO frequency on CLK1 is shifted by the tone frequency cw
2. **MODE\_DC\_QUADRATURE** - direct conversion mode with quadrature formation. When receiving and transmitting SSB, the frequency is formed at the terminals CLK0, CLK1 with a phase shift of 90 degrees. The minimum tuning frequency is 2MHz (according to the SI5351 datasheet 4MHz) and may depend on the Si5351 instance
3. **MODE\_SUPER** – superheterodyne mode with one/two frequency conversions. The first local oscillator is always higher than the receive frequency by the IF frequency - this minimizes the number of affected points and other combinational interference to reception. Sideband selection is performed by changing the frequency of the second local oscillator (BFO) on the left / right filter slope.  
   For this mode, it is necessary to set the frequencies of the second local oscillator BFO\_LSB and BFO\_USB (in hertz). Usually they are set 300 Hz higher/lower than the beginning of the filter slope at the level of 3 dB. For example, if the filter has a 3 dB bandwidth from 9214250Hz to 9216650Hz, then the frequency setting will look like this:  
     
    #define BFO\_LSB 9216650L+300  
    #define BFO\_USB 9214250L-300  
     
   The letter L at the end of the number specifying the frequency is necessary to indicate to the compiler that large numbers are used (**L**ong).  
     
   If two frequency conversions are used, it is necessary to uncomment and set the frequency of the second IF using the following constant  
     
    #define BFO2 500000L  
     
   And also determine the type of filter for the second IF by uncommenting one of the following macros  
     
    #define BFO2\_LSB  
    #define BFO2\_USB  
     
   The choice of the required sideband in the case of double conversion is carried out by changing the frequency of the second local oscillator, which can be higher or lower than the frequency of the first IF.

**Determination of frequencies at the outputs of the synthesizer**

The config\_sw.h module defines macros that specify which frequencies and on which outputs of the synthesizer will be generated. The macros CLK(N)\_RX\_SSB/ CLK(N)\_RX\_CW and CLK(N)\_TX\_SSB/ CLK(N)\_TX\_CW are used for this (where N is the output number). The numbering of the outputs corresponds to the outputs on the board as follows:

1. If one SI5351 is used, then signals defined by macros CLK0, CLK1, CLK2 are generated on its outputs. In this case, the CLK3 macro is not used.
2. If two SI5351s are used on the SuperLED board, then the CLK0 signal is generated at the VFO1 output, and the CLK1, CLK2, CLK3 signals are generated at the VFO2 output.
3. If SI570 is used, it always generates CLK0. In this case, the remaining signals (CLK1, CLK2, CLK3) are generated either on one SI5351, or CLK1 and CLK2 on the output of VFO1, and CLK3 on VFO2.

Frequency macros can use numbers, predefined macros, arithmetic operators, and parentheses. When using numbers, you must add a letter at the end **L**. For example **500000L**.

A value of zero indicates that the output will be disabled.

The following macros are predefined:

**VFO**, **BFO**, **BFO2** are the frequencies of the first, second and third local oscillators

**CWTX** – frequency of the CW signal at the transmit frequency

**QWIF** – frequency of the CW signal in the passband of the first IF filter (corresponds to the frequency of the received CW tone)

**BFO2CW** - third local oscillator frequency for CW mode when using a CW filter with a BFO2 center frequency

**CAT management**

The synthesizer can emulate the FT-817 or TS-480 CAT protocol. The desired protocol is selected using macros CAT\_PROTOCOL\_KENWOOD\_TS480 and CAT\_PROTOCOL\_YAESU\_FT817 in config\_hw.h. The FT-817 protocol is more compact compared to Kenwood and allows you to free up 0.5kb of code. The CAT\_BAUND\_RATE constant sets the speed of the com port.

// select type of CAT protocol (only one!)  
//#define CAT\_PROTOCOL\_KENWOOD\_TS480  
#define CAT\_PROTOCOL\_YAESU\_FT817

// com-port speed  
#define CAT\_BAUND\_RATE 9600

The synthesizer can be put into transmit mode by issuing a command via the CAT protocol. In this case, the PTT input of the synthesizer has priority. If a command came over CAT to switch to TX transmission mode, then by pressing and releasing PTT we can cancel it and return to RX receive mode. The logic corresponds to that used in the FT-817 transceiver.

**CW support**

The synthesizer contains built-in electronic keyer that can operate in normal or iambic mode. The synthesizer has three message banks, each 84 characters long. Messages are recorded using a CW key. When transmitting, the characters are decoded and displayed on the display for self-control purposes.

All synthesizer functionality related to CW support can be disabled using the ENABLE\_INTERNAL\_CWKEY macro in the config.h module (enabled by default). This may be relevant for transceivers without telegraph support or in order to save memory, since it takes about 3kb of code.

**Assignment of the pins of the synthesizer**

**PTT** - input. enable TX mode. The active level is low. The input is pulled up to + 5V (PullUp). The input is protected from bounce of button contacts. In transmission mode, any actions with the keyboard and encoder are blocked, and an active control signal is generated at the TX output.

**TX** – output. signal to switch the transceiver to TX mode. The active level is set to OUT\_TX\_ACTIVE\_LEVEL (high by default)

**ATT, PRE** – attenuator and LNA on/off outputs. Active levels are set by the constants OUT\_ATT\_ACTIVE\_LEVEL and OUT\_PRE\_ACTIVE\_LEVEL (high by default). When transmitting, the outputs are at an inactive level (attenuator and LNA are disabled)

**CW** - output. The active level is set to OUT\_CW\_ACTIVE\_LEVEL (high by default). Indicates that the synthesizer is in CW mode. The DISABLE\_CW\_ON\_CWTX macro can control the behavior of this output in transmit mode.

**Key** - output. The active level is set to OUT\_KEY\_ACTIVE\_LEVEL (high by default). CW switch signal for envelope shaper.

**Tone** – CW tone output. In tuning mode controlled by ENABLE\_TONE\_ON\_TUNE macro (off by default)

**S-Meter** - S-meter signal input. The input impedance is high, allowing the input to be connected directly to the AGC detector capacitor. Calibration of the S-meter is performed in the corresponding menu item. Depending on the calibration, the direct or inverse scale mode is automatically selected.

**Temp** (**CWDec**) – input of the LM35 temperature sensor located on the power amplifier cooling radiator.

**SWR\_F, SWR\_R** – input signals from the forward and backward wave detector of the SWR sensor. If they are not connected, then you need to comment out the ENABLE\_SWR\_SENSOR macro in config\_hw.h - this will prevent the firmware from displaying the SWR value on the display

**DIT, DAH** – CW manipulator inputs. The active level is low. The inputs are pulled up (PullUp) to +5V by internal resistors. In the case of using an external key (configurable in the menu), its output is connected to any of these inputs.

**Band1…Band 5** – (for all boards except the SuperLED version) output. BPF control signals. By default, the active level is high. It can be changed to low with the BAND\_ACTIVE\_LEVEL\_LOW macro. If the number of bands (set in DEFINED\_BANDS in config.h) is greater than 5, then the binary code of the selected band is generated at the outputs.

**BPF0…BPF3**– (only for boards of the SuperLED version) output. binary code for selecting the BPF range. By default, the active level is high. It can be changed to low with the BAND\_ACTIVE\_LEVEL\_LOW macro.

**LPF0…LPF4**– (only for boards of the SuperLED version) output. low-pass filter control in the power amplifier. Corresponds to cutoff frequencies 2.5/4/8/16/32MHz. By default, the active level is high. It can be changed to low with the LPF\_ACTIVE\_LEVEL\_LOW macro.

**TUNE** – (only for boards of SuperLED version) output. the active level is set to OUT\_TUNE\_ACTIVE\_LEVEL (high by default). Indicates that the transceiver is in antenna tuning and SWR measurement mode.

**QRP** – (only for boards of SuperLED version) output. the active level is set to OUT\_QRP\_ACTIVE\_LEVEL (high by default). Indicates that low power mode is enabled.

**Keyboard and synthesizer controls**

All buttons on the keyboard have two functions. The main one (the first line in the figure) is called simply by pressing a button. Secondary (second line) - called with a long press. The duration of pressing a button, which is perceived as a long one, is set by the LONG\_PRESS\_DELAY constant in milliseconds (default is 1 second).

The top left button performs different functions depending on whether the ENABLE\_INTERNAL\_CWKEY macro is defined in the config.h module or not. If the macro is not defined, then the electronic key is disabled and a short press on this button calls up the menu, and a long press -sets the frequency to zero. Otherwise, a short press causes the transmission of a previously recorded CW message, and a long press causes the synthesizer menu.

In the "square" version of the synthesizer circuit board, the buttons are located under the display in one row. The button sequence is as follows



**BAND** - range switching. If there are 3 or more ranges, a list of ranges will be displayed. Navigation in it is carried out by the encoder, and the range selection is by pressing the BAND button again, or the button on the encoder

**ATT/PRE** - Turns on the attenuator, LNA, or turns off both in a circle

**MODE** – the synthesizer itself selects the mode depending on the tuning range and frequency. With this command, you can force the mode to be changed to the desired

**VFO A/B, STORE** - two VFO with independent tuning frequency are available on each band. The button allows you to switch between them. With a long press, it sets the frequency of the second VFO equal to the frequency of the current one (remembers the current frequency in the second cell).

**LOCK** - blocking the encoder and keyboard commands, which can lead to a change in the tuning frequency. At the same time, auxiliary functions remain available (for example, turning on the attenuator). Press again to unlock.

**MENU** – call the synthesizer menu

**ZERO** - sets the frequency "by zero". The frequency is rounded up to the nearest multiple of 500Hz.

**CW MEMO** - transmission by telegraph of previously recorded messages. The synthesizer has three message memory banks (**A**, **B**, **C**), each 84 characters long. The memory bank is selected by pressing a button on the keyboard. Pressing the EXIT button exits the mode.

**BANK A**

**BANK B**

**BANK C**

**EXIT**

**ENCODER  
EXIT**

**Synthesizer Menu**

The synthesizer menu has a multi-level structure. Use the encoder to navigate through the menu items. Press the button **MENU** to select the current item. Pressing any other button exits the menu one level up.

Editing of parameters is done with the help of the encoder. Memorization of edited values ​​- by pressing the button **MENU**. Cancel editing - by pressing any other button of the synthesizer.

If the parameter defines the on/off state, then it is necessary to use the numerical values ​​0 - off, 1 - on.

**TUNE** – switch to the antenna tuning mode. The synthesizer enters tone transmission mode. For boards of the SuperLED version, active levels are formed at the outputs **TUNE** and **QRP**. The display shows the SWR value and output power.

**QRP** (only for the SuperLED board version) – enables/disables the low power operation mode. In this case, the QRP output will have an active level.

**SPLIT** - turns on/off the SPLIT mode. First you need to tune in to the frequency that we will use for transmission and press the button **STORE** (long press). Next, tune in to the receive frequency and activate the SPLIT mode. When switching to transmission, the frequency will be changed to the previously memorized frequency.  
When you turn on the SPLIT mode, the corresponding inscription will appear on the display.  
SPLIT mode will not turn on if the frequency to transmit is not stored or if it is on a different band. To enable operation in SPLIT mode on different bands, uncomment the ENABLE\_SPLIT\_MULTIBAND macro in the config.h module.

**CW KEY** – settings of the built-in CW key

1. **ENABLE** - Enables built-in key. If 0 then the external key connected to the DIT or DAH input is used with an active low level.
2. **SPEED** - key speed in WPM
3. **TONE** - frequency self-monitoring and frequency shift for CW signal shaping
4. **SEND DECODER** - allows decoding CW during transmission
5. **BREAK IN DELAY** – the duration of the delay in msec, during which the synthesizer switches to the receive mode if the key is not pressed
6. **IAMBIC** – setting the parameter to 1 enables the iambic mode of the manipulator
7. **DASH-DOT RATIO** – duration of a dash in tenths of the duration of a dot. The default is 30, which gives the dash three times the length of the dot
8. **LETTER SPACE** – the duration of the pause between letters in tenths of the duration of the dot. Default 30 (three times the duration of a point)
9. **WORD SPACE** – duration of a pause between words when transmitting MEMO messages. Specified in tenths of a point. Default 70 (seven times the duration of a dot)

**CW** **MEMO** – work with memory banks of CW messages. The synthesizer has three message memory banks (**A**, **B**, **C**), each 84 characters long. After selecting the required bank from the list, the following options are available:

1. **PLAY** – displays and plays the message without switching to transmission mode. You can interrupt playback by pressing any button on the keyboard.
2. **RECORD** – turns on the message recording mode using the CW key. The message text is displayed on the screen. Recording ends automatically after a pause longer than twice the length **BREAK IN DELAY**
3. **CLEAR** - clears the message
4. **SAVE** - saves changes to the memory bank

**DISPLAY** – display and power management

1. **ANALOG GAUGE** – (SuperLED version only) sets whether the OLED display will show the S-meter or the standard status screen.
2. **LED HIGH**, **LED LOW** – (only for the SuperLED version) sets the brightness of the LED indicators in the operating mode (**HIGH**) and energy conservation (**LOW**). Three levels are available: 0 - off, 1 - medium brightness, 2 - maximum brightness
3. **PWR DWN DELAY** – how many seconds after the last operator activity to switch to the energy saving mode. 0 - disables power saving mode
4. **BRIGHT HIGH** – brightness in active mode. 15 is the maximum.
5. **BRIGHT LOW** – brightness in power saving mode. 0 - redeemed

**SENSOR** – setting up voltage and temperature sensors

1. **VCC SETUP** – allows you to calibrate the measurement of the supply voltage
2. **TEMP** – enables/disables reading data from the temperature sensor. If reading is enabled, it displays the current temperature on the right
3. **TEMP WARN** – sets the temperature threshold, above which the temperature value on the display starts flashing, attracting the operator’s attention
4. **TEMP STOP** - sets the temperature threshold after which the transmission is blocked

**FREQ** – frequency calibration

1. **LSB SHIFT** - additional frequency shift of the second local oscillator relative to the BFO\_LSB constants
2. **USB SHIFT** - additional frequency shift of the second local oscillator relative to the BFO\_USB constants
3. **SI5351 XTAL** – SI5351 calibration. Detailed description of the procedure in the section "Frequency Calibration"

**CLOCK** - setting the current time

**S-METER** – S-meter calibration

The procedure for calibrating the S-meter consists in applying signals with known levels to the input of the receiver and storing them. Requires external oscillator with calibrated output and attenuator.

**SWR** – SWR meter calibration. Attention! All calibration steps must be carried out with the load connected!

1. **SWR 1.5/2.0/3.0** – allows you to correct the non-linearity of the SWR detector. To do this, it is necessary to connect exemplary loads in series and select the appropriate menu item. The transceiver will be put into low power transmission mode **TUNE**. The display will show the value from the forward/reverse wave inputs (SWR\_F, SWR\_R). To save the data, press the button **MENU**. Pressing any other button will exit the setting mode and return to the top level menu.
2. **POWER** – calibration of the output power meter. The transceiver will enter continuous signal transmission mode **TUNE**. Measure the power on the connected load dummy and use the rotary encoder to change the power displayed on the display to the measured one. Click the button **MENU** to remember changes or any other to undo.
3. **TX MAX POWER** - sets the maximum power output by the amplifier

**FULL RESET** - complete reset of all settings to default values