

Technical Description of the Autotuner board

ATU-100 Extended board

by N7DDC.

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Attention! The information published in this document is true only when using a device with firmware version **3.0**. If you are unable to find out which software version is being used, update to firmware version 3.0 using the programmer to ensure that the information from the description matches the device properties.

You can download the latest version of firmware, PCB sources, schematic and documentation here:

https://github.com/Dfinitski/N7DDC-ATU-100-mini-and-extended-boards/tree/master/ATU_100_EXT_board

The schematic in editor:

<https://easyeda.com/rolin791/atu-100-7x7>

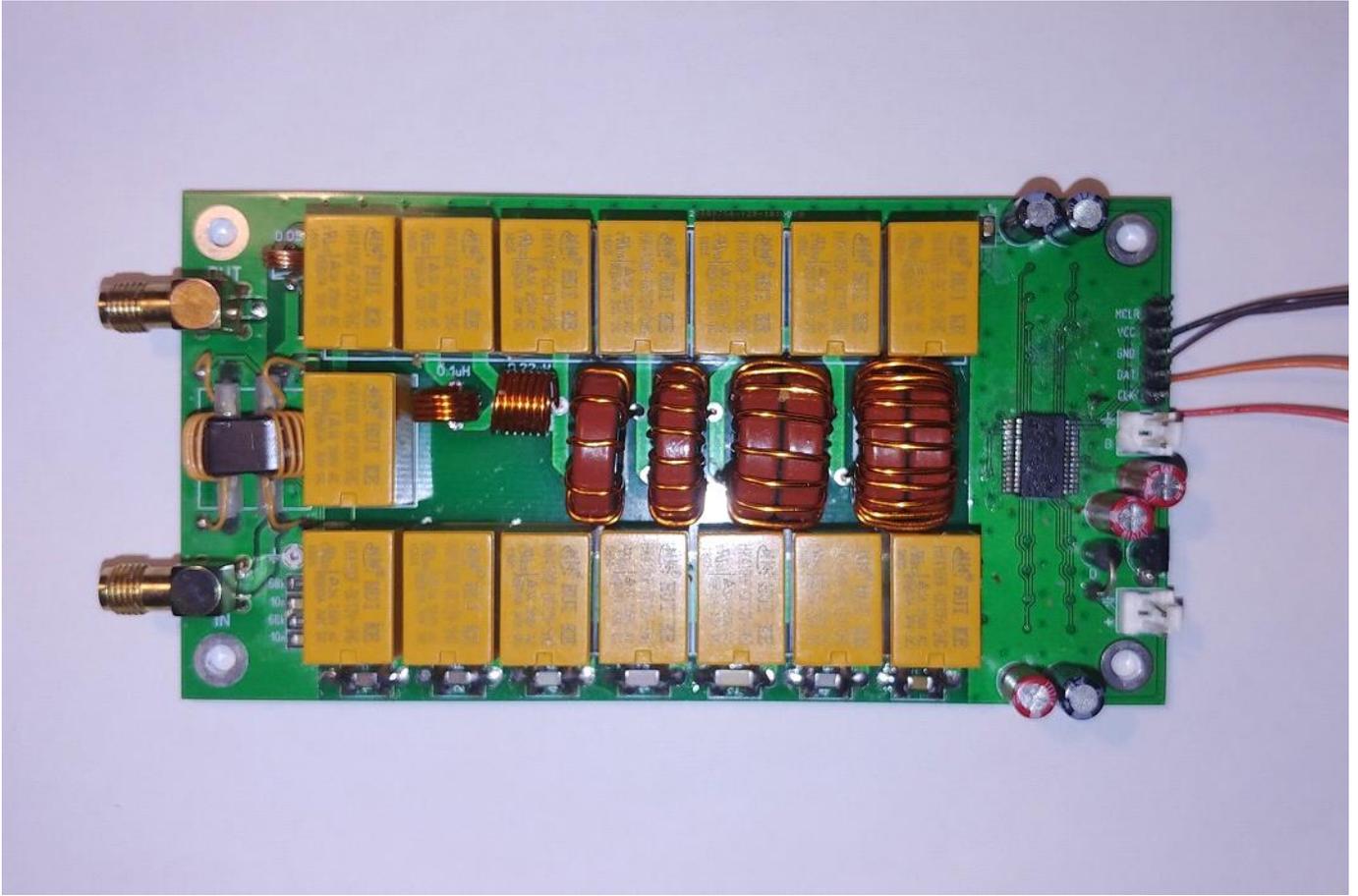
Purpose

The device is intended for use as an element of amateur radio equipment, as part of amplifiers or transceivers, or as a separate device that performs the function of matching the output impedance of power amplifiers (PA) with antenna feeders.

Unlike the **mini board**, this device can contain a set of from 5 to 7 inductances and from 5 to 7 capacitors, which allows it (in the maximum configuration) to work effectively in a wide frequency band, overlapping radio amateur HF ranges from 1.8 MHz to 50 MHz.

The numerous settings of the algorithms available to the user allow the use of a microprocessor and a control circuit in other auto-tuner projects in various variations. Nevertheless, there is the concept of a basic scheme, which the author follows.

The basic model, according to the author, contains a set of 7 switched inductances with an uneven pitch, from 0.05 μH to 4.5 μH , a set of 7 capacitors with uneven pitch, from 10 pF to 1 nF. The parameters used by default guarantee reliable operation of the device in the basic version and are the main parameters for testing during software development by the author. Many parameters can be changed by the user on their own, which can change the behavior of the device and even make it unusable. Please read the description carefully before making any changes.



Using the «base model»

The author assumes that the device can be used in two scenarios: as an additional module as part of a transceiver or amplifier, or as a standalone device in a separate case, with or without indication. There is no need to redo something. Both the button for manual start of tuning and the output of the control signal from the control processor of the transceiver or amplifier can be connected to the control connector.

A short impact on the control line of less than **250 ms**, whether with a button or a control signal, will cause the tuner elements to reset to their original state, when all inductances and capacitances are turned off. A longer hold on the control signal will trigger the start of the setup process. The result of each configuration process is stored in the non-volatile memory of the device and is restored after turning off and on the power.

Additional signals for better integration with existing equipment can be taken from the RA7 and RA6 microprocessor connectors. This is the Tx_request signal (carrier request for tuning) in direct and inverse form. This signal is issued by the device's processor for the time necessary for tuning, during which the transmitter must provide a continuous carrier of suitable power. This can be used to automate

the configuration process when the user does not need to perform additional actions, except for how to press the TUNE button. This is not necessary, since the device allows tuning with any input signal of sufficient power, be it speech, modulated with an RF signal by any type of modulation, telegraphic packets, and even a noise-like signal. Tuning will stop when the input signal is low and resume when it appears. That is, the tuning can occur directly in the normal operation of the equipment.

However, for reliable operation of the device, it is advisable to use this signal to reduce the signal power of the transmitter to safe for the device values during tuning, for example by acting on the ALC loop.

The **Tx_request** signal can also be used to connect a LED that will indicate the activity of the adjustment process in the case when using the LCD indicator is undesirable or impossible.

Indication

In general, the device can be used without display elements, while for monitoring the operation of the device you can use, for example, the scale of the SWR meter built into the transceiver or a separate external SWR meter. Of course, when using an autotuner as a separate device in your own case, it would be very convenient to have your own display for monitoring the operation and this device allows you to implement it in different ways.

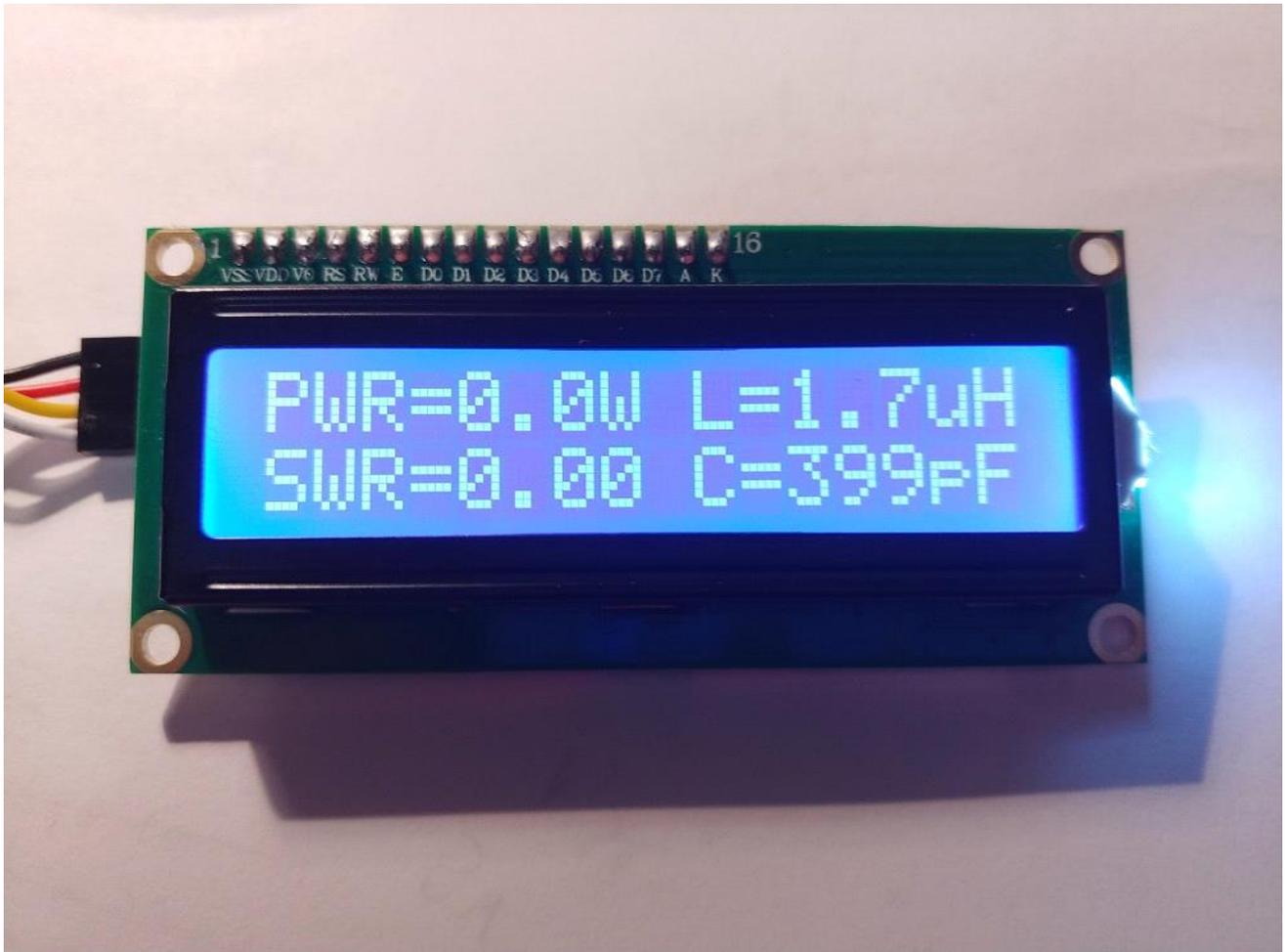
The easiest way is to connect a two-color red-green LED with a common anode to the pins of the connector for programming the processor. In order for this method of display to work, you need to change some of the default values, which will be discussed below. The common anodes must be connected to the VCC pin of the connector (+5 V power), the cathode of the green LED through the current limiting resistor to the pin CLK of the connector, the cathode of the red LED through the current limiting resistor to the DAT connector. Thus, the LED will be able to generate three colors of light, green, orange and red, depending on the SWR in the line with which the matching process was completed.

Green color of a luminescence will speak about SWR in a line less than 1.5, orange - less than 2.5 and red at SWR more than 2.5. The LED will go out at the moment of the start of the adjustment and will glow immediately after its completion.

Much more information about the operation of the device can be provided by connecting to the connector for programming a standard two-line 1602 LCD display. You will also need a small I2C port expander card to convert the parallel LCD control code to an I2C serial bus. These are widely used boards using the PCF8574T chip and having an access address on the 4E bus. This is the indication that the author uses by default, and the default firmware is already configured to work with such an

indicator. Some port extension cards use PCF8574 chips with an “AT” index and they have a different bus access address. They can also be used by specifying the desired address (which will be described below).

The pins of the programming connector when the LCD is connected are used for their intended purpose, VCC is 5 Volt power supply, GND is ground, DAT and CLK are data and clocking lines respectively.



The left side of the indicator displays the power throughput and SWR. The peak detector mode is used, which allows to accurately measure the signal power of the transmitter when using various types of modulation.

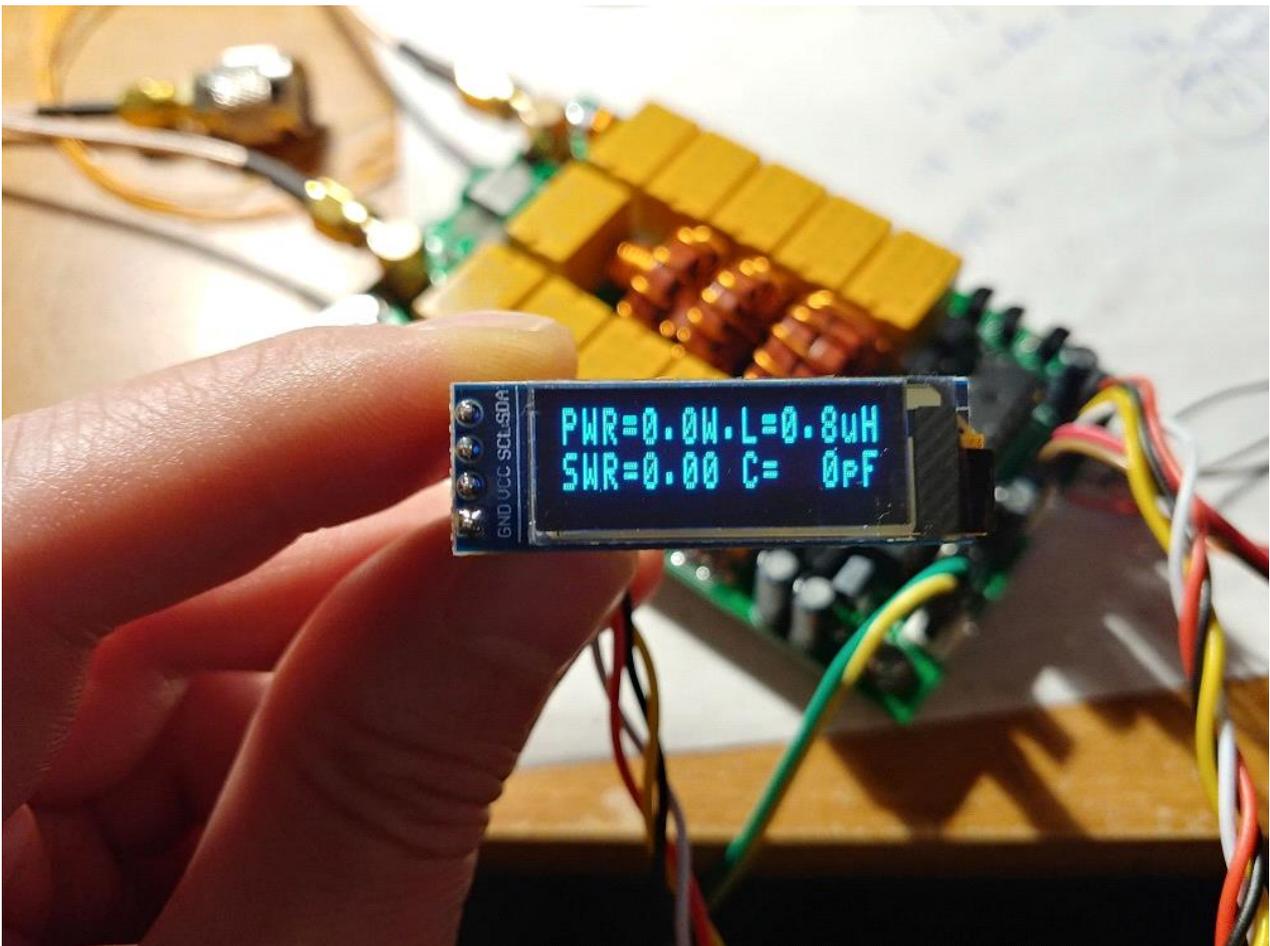
The right side shows the inductance and capacitance values set by the device as a result of the last tuning process. Indication is carried out in the first and second lines, and indications L and C can be interchanged. This is used to display the connection point of capacitors according to the classical L-shape scheme. So, if the inductance is on the top line, it is assumed that the capacitor of the tuner is connected after it, that is, to the output. If the inductance value is displayed on the bottom line below the capacitance value, then the capacitance is connected before inductance, that is, to the input.

The display may also briefly show some inscriptions explaining the current modes

of operation of the device. These are TUNE, RESET, OVERLOAD (when a signal with a power of more than 150 watts is applied to the device).

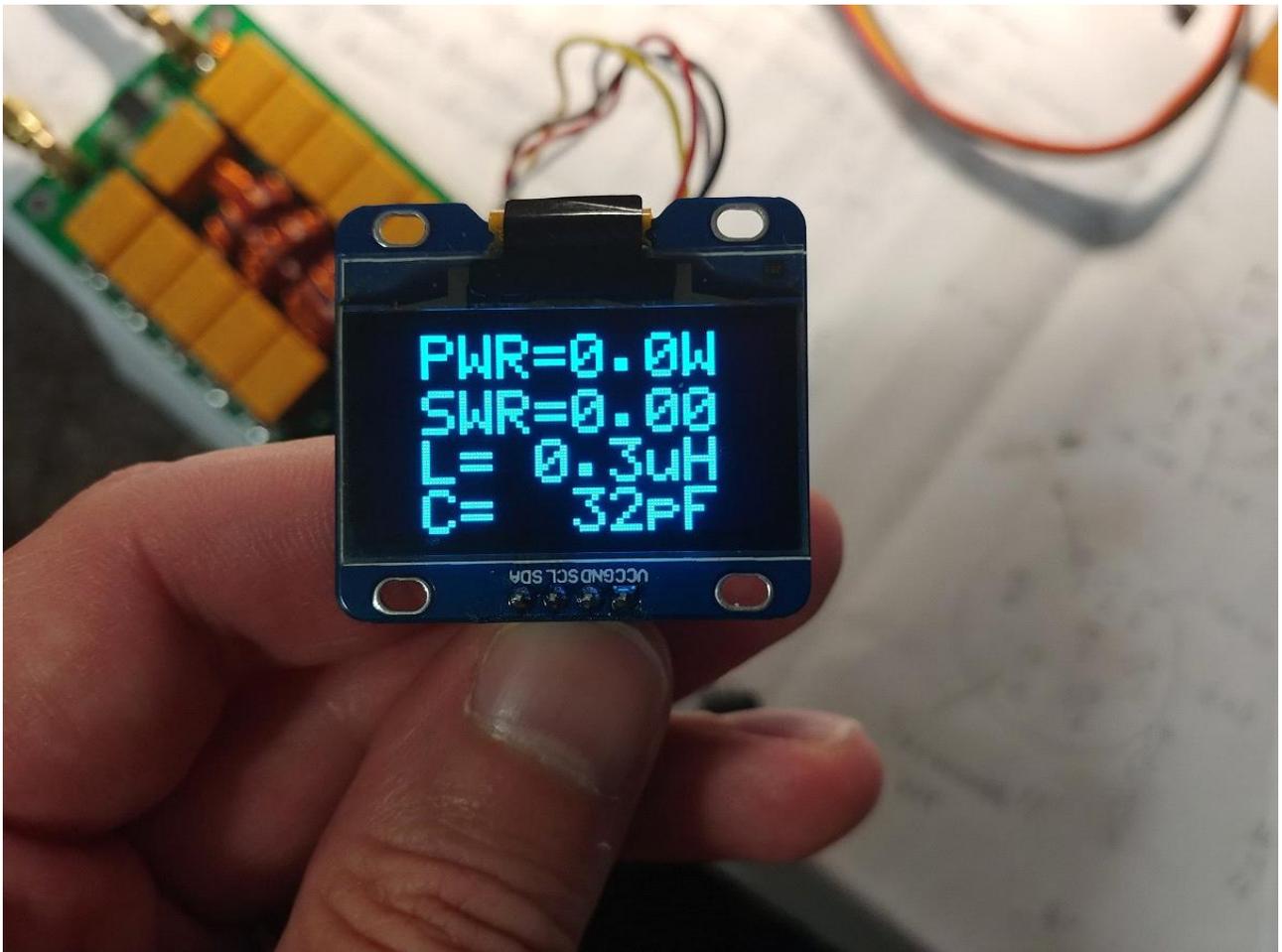
To reduce the size of the device, it is possible to connect small-sized OLED displays that use the same I2C bus to control.

These are monochrome OLED displays with a SSD1306 controller and with a resolution of 128x32 pixels with a diagonal of 0.91 inches, with a resolution of 128x64 pixels with diagonals of 0.96 and 1.3 inches. These displays are connecting in the same way, but in order for them to work correctly, the firmware parameters should be changed (to be described below).



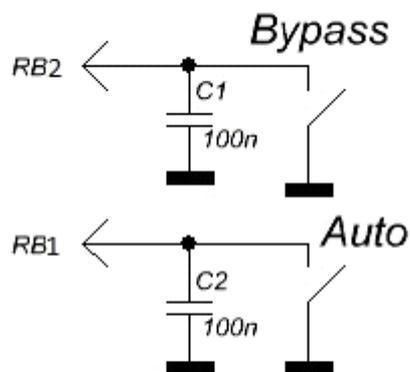
The indication on the 0.91 128x32 display looks like on a regular 1602 display, while having tiny dimensions.

The indication on 128 * 64 displays looks a little different, in four rows and with larger characters.



Additional buttons

The device also allows you to connect two additional buttons that extend the basic functionality. These are the Bypass and Auto buttons. The buttons are connected respectively to the ports of the RB1 and RB2 processor. It is recommended to use ports blocked by capacitors to avoid interferences, which may hinder the processor operation.



Pressing the Bypass button causes a temporary shutdown of all capacitances and inductances on the path signal from the input to the output. This mode has the corresponding indication on the LCD display in the form of an underscore. If Auto mode has been activated, its operation will be temporarily stopped while the Bypass mode is in effect. Pressing the button again turns off Bypass mode and the device reconnects the capacitances and inductances that were installed at the end of the last tuning process. Auto mode will also resume if it has been activated previously.

Pressing the Auto button activates the automatic mode of the device, which is displayed on the display as a dot sign. The device will remember to turn on the automatic mode, and will remain with it even after turning off the power, until it is turned off again by pressing it again. Automatic mode can also be activated by changing the parameters during the firmware installation (will be described below).

Automatic mode

The automatic mode of operation provides a unique opportunity for the user to use the device without the need to press buttons and connect any external control.

The device can be designed without buttons, without indication and at the same time will perform its function of matching the resistance of the antenna power supply line.

The algorithm uses the following: if the current SWR exceeds 1.3 and it has changed to $(1.3 - 1)$ relative to the value recorded after the previous tuning process, the tuning mode is activating. Usually, this condition is easily met when the bands are changing, which causes an immediate triggering of the new tuning process.

If necessary, the trigger threshold of the tuning can be changed by changing the parameters during the firmware installation (described below).

Special modes of operation

The device has several special modes of operation, designed to facilitate the process of assembling, debugging or troubleshooting.

When power is applied to the device with all three pressed buttons Tune, Bypass

and Auto, the Fast Test mode is activated. In this mode, the device provides power to all relays, which allows you to quickly identify faults associated with transistor switches or soldering faults.

When power is applied to the device with the Bypass and Auto buttons pressed, the device enters the simple Test Mode. In this mode, you can manually, step by step, use the Bypass and Auto buttons to change the value of capacitance or inductance. A long press on the Tune button allows you to select which elements will be moved at the moment, and a short press changes the point of connection of the capacitor. In this mode, it is possible to measure input power and SWR in line. The whole process is accompanied by a clear indication.

Possible device modifications

The microprocessor and its software allow you to control a series from 5 to 7 inductances and from 5 to 7 capacitance, with a linearly increasing step, or nonlinearly. Component ratings can be arbitrary, their values can be specified in the firmware parameters during processor programming to correctly display the values on the display.

When choosing the number of elements less than the maximum (7), the lower bits of the control bus work.

Incorrect configuration of the firmware or errors in the sequence of control elements may lead to failures during setup or to the complete inability to configure. At the same time, an exact indication of the values may affect only the accuracy of their display on the display, but not the operation of the tuning algorithm.

Technical Characteristics, «Base model»

The range of permissible supply voltages: 10 - 15 V DC

Maximum current consumption: 400 mA*

Maximum working throughput: 100 watts

Maximum possible measured power: 150 watts

Minimum power required to start tuning: 5 watts **

The minimum possible measured power: 0.1 watts

Measurement step at power up to 10 Watts: 0.1 Watt

Measurement step with power above 10 watts: 1 watt

Accuracy of power measurement: 10%

Maximum installed inductance: 8.53 μ H

The minimum installation step of inductance: 0.05 μ H

Maximum installed capacity: 1869 pF

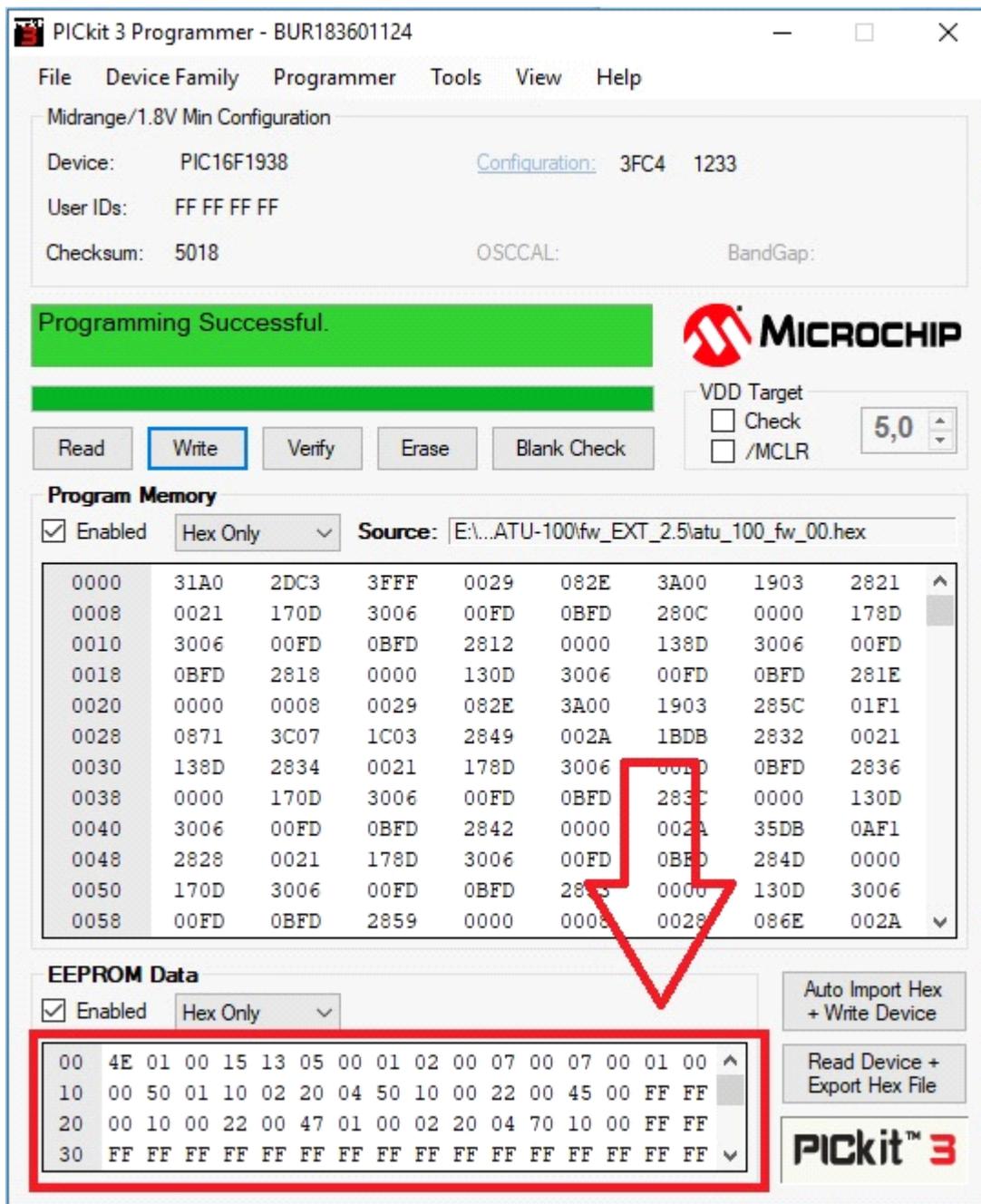
Minimum capacitance installation step: 10 pF

* Typical consumption 150-200 mA

** Some parameters may be changed if necessary.

Change of default settings

During programming of the microprocessor, in addition to writing directly to the control code (program), it is also proposed to record a small number of cells of the rewritable memory EEPROM. The information in these cells can be changed by the user before programming. During each start of the processor, its program first reads data from the cells of long-term memory in order to further use this information for work. Thus, the user can easily change many parameters of the device without understanding the much more complex software development processes.



Below will be described in detail all the significant cells used in this version of the firmware.

Please note that the numbering of the cells starts from zero, and the numbering is given in hexadecimal code. Numbering with such rules is called "addressing," and the cell number in this format is called the „cell`s address". For example, the cell with the address 10 is not the tenth cell in the account. This will be the 16th cell. Below will be given only the addresses of the cells, since the addressing is used in the program for programming the processor.

The data in the cells themselves also represent values in hexadecimal code, however, this is done for the convenience of users that there will be no need to

convert our usual values into hexadecimal format. So, for example, to record power values of 15 watts, it is enough to write the number 15 in the cell, and to set the SWR 1.7, just write the number 17. Carefully read the description and focus on the default values.

For convenience, the firmware can be read from the microprocessor, change memory cells and write back. To return all values to the default values it is enough to re-flash the original author's firmware.

00 — I2C address setting cell of the connected display.

The port extension board for display 1602 made on the PCF8574AT chip has the address 7E, on the chip with the "T" index - 4E. OLED displays usually have an address of 78 or 7A. It is allowed to record any address in the cell for normal operation with the connected I2C device. The default value is 4E, which corresponds to the LCD display 1602 with an extension board with the PCF8574T chip.

01 — cell to indicate the type of display connected.

A value of 00 corresponds to a connected two-color LED.

Value 01 - 1602 LCD with port extension card.

Value 02 - OLED display 128 * 32, 03 - OLED display 128 * 32, an inverted image.

Value 04 - OLED display 128 * 64, 05 - OLED display 128 * 64, an inverted image.

Attention! Work with displays other than those described above is not provided by the device.

02 — automatic activation cell. If you plan to use the device without additional buttons, you can enable the automatic mode by setting the value to 01. The default value is 00. When you activate the mode from the button, the processor will write the value 01 to this cell, thus remembering the user's choice.

03 — timeout cell after giving a signal to activate or release a relay. This time also includes the time required to establish the voltage at the output of the RF detector after the relays have been established at the specified positions. Specified in milliseconds, the default value is 15. Too short amount of time can cause malfunctions during tuning process.

04 — cell to set the threshold settings in automatic mode.

It is recorded in the format: the first number is the SWR integer part, the second number is the tenths. The default value is 13. That is, when the automatic mode is activated, the tuning process will be triggered when the SWR is above 1.3 and when it changes to (1.3 — 1).

05 — minimum power cell required to start the setup.

Recorded in the format: the first number - tens of watts, the second number is watts. The default value is 05, that is, the tuning will only work at an input power is

at least 5 watts or above. Too low value may result in insufficiently fine tuning.

In the high power measurement mode (cell 30 is activated), the cell value sets tens of watts. That is, the installed 05 corresponds to 50 watts, 12 - 120 watts.

06 — **cell for maximum power** for safe tuning. If the input power is above this value, the tuning will not be performed and the device will wait the power level to be set by the user. Recorded in the same format. If the value is 00, the maximum power check is not performed. The default value is 00.

In the high power measurement mode (cell 30 is activated), the cell value sets tens of watts. That is, the installed 10 corresponds to 100 watts, 25 to 250 watts.

07 — **cell to set the rows offset down** (vertically move) for OLED displays. May be necessary for some displays. The default value is 01.

08 — **cell to set the offset rows to the left** (horizontally move) for OLED displays. May be necessary for some displays. The default value is 02.

09 — **cell to set the maximum initial SWR value**, when tuning occurs. Values are specified in the format: the first number is the SWR integer part, the second number is the tenths. If the value is 0, the check is not performing and the tuning always works. The default is 0.

0A – **cell to set the number of installed inductances**, can be 05, 06 or 07. The default value is 07.

0B – **if the inductance line has a linear pitch** 01 should be entered in the cell. The default value is 00.

0C – **cell to set the number of installed capacitances**, can be 05, 06 or 07. The default value is 07.

0D – **if the capacitances line has a linear pitch** 01 should be entered in the cell. The default value is 00.

0E – **enable software correction of nonlinearity of diode`s RF detector**. It should be disabled if the circuit has a hardware correction. The default value is 01 (enabled).

0F – **inverse inductance control**. It is necessary to turn on when using a relay with normally open contacts for switching inductances. The default value is 00 (disabled).

Starting from address 10, the values of the installed inductances. Two cells per value are used, starting with the smallest inductance. Inductances are written in nanohenry. For example, 4 μH is 4,000 nanohenry. We write in cells 40 00. 110 nanohenry - write 01 10. A total of 14 cells are used, two for each installed inductance.

Starting from address 20, the values of the installed capacitors. All values in picofarad. For example, 82 picofarads are written as 00 82. 1.2 nanofarads are written as 12 00. 14 cells are used, two for each capacitor .

30 — cell installation power measurement capabilities up to 9999 watts. For proper operation, you should use a tandem-match with a suitable ratio of turns. Activation at value 01. By default it is disabled, value 00.

31 - cell for setting a ratio of turns of the tandem match on which depends the upper limit of the measured power. The default value is 10, which corresponds to a maximum measured power of about 150 watts.

To be able to measure power up to 1500 watts, you should use the high power indication mode and a tandem match with a ratio of 1 to 32.

If the power does not exceed 40 watts, it makes sense to use a tandem-match with a ratio of 1: 5 turns, which will allow to work better with a minimum power of 1-5 watts.

For other power values, the ratio of turns should be calculated so that the voltage at the measuring inputs of the microprocessor at maximum power does not exceed 4.096 Volts for the PIC16F1938 processor and 5.0 Volts for the PIC18F2520 processor.

32 – cell for setting the time of glow display or his backlite, in seconds . The backlite is glowing whilw press any buttons and if RF power comes to input. Π By default it is disabled, value 00.

33 — cell for setting of an additional indication mode,
value 00 — for indicating L and C only.
value 01 — for indicating the power delivered to the antenna and efficiency of fider and transmitter nwhen input power is enough for correct SWR meassuring.
By default is enable, value 01.

Warning!!! The device does not take into account its own efficiency.

34 — cell for setting a feeder power loss ratio, the first number — integer part of decibell, second number — ten's parts of decibell. Velue by default — 1.2 (12 written in the cell). this value uses for counting the power delivered to antenna. The loss value can be found in the reference data for the used cable or you can measure the

exact value yourself.

If it is not necessary to take into account feeder losses, the value 00 should be written into the cell, then the calculations will correspond only to the mismatch losses.

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