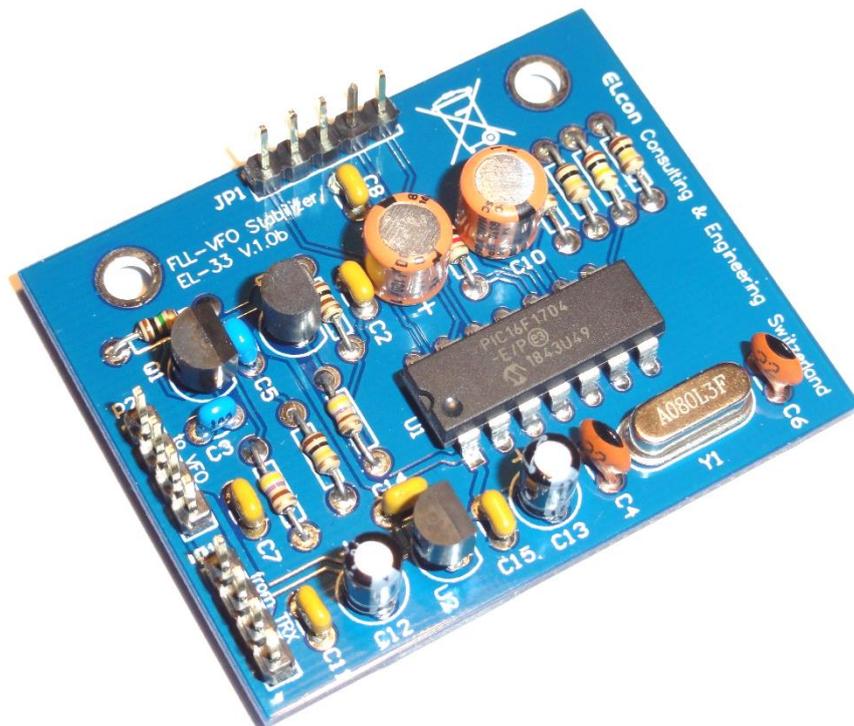


# EL-33

## FLL-VFO Stabilizer

for transceivers without PLL or DDS frequency conditioning  
e.g. Yaesu FT-301D etc.



## Building and functional description

Version 1.0c

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Important! Hints or tips for the correct function of the EL-33.



Watch it! Absolutely observe.

## 1 Introductory remarks

Many radio amateurs still use older radios which do not have a modern frequency synthesizer. Today's digital operating modes, however, require a frequency stability that only modern transceivers can provide.

Usually a free-oscillating oscillator (VFO, Variable Frequency Oscillator) is the reason for the large frequency drift. The reason can be the insufficient voltage stabilization for the VFO, but mostly the fluctuating temperature is the reason for the drift of several 100 Hz.

The EL-33 module has been developed for all radios with free-floating VFO, but is especially suitable for installation in the Yaesu FT-301D transceiver.

## 2 How it works

The slow running away of the frequency is called frequency drift. With the help of temperature-controlled crystal oscillators (TCXO) or by installing a crystal in thermostats (oven-controlled crystal oscillator, OCXO) it is possible to build extraordinarily long-term stable oscillators.

Unfortunately, the performance of the VFO in the FT-301D does not match that of modern DDS oscillators in today's commercial amateur radios. We cannot redevelop the entire transceiver, but want to make the frequency stability of the VFO crystal stable with a relatively simple additional circuit.

The development of a frequency-stable VFO is difficult, because even an output power of more than 1mW generates so much heat in the transistors that it supports the frequency drift in the long run.

The reasons for the frequency drift are different. The temperature has a particularly strong effect on the capacitance diode, which is used for the "Clarifier" function, and thus on the stability factor of the entire oscillator. A temperature change changes the diode capacitance as well as the bias voltage of these diodes. The junction temperature changes, resulting in drift.

As you will see, this capacitance diode is not only bad, but with our VFO stabilization it changes into a useful component.

### 2.1 *The Frequency Locked Loop (FLL)*

A Frequency Locked Loop (FLL) is an electronic control system that generates a signal set to the frequency of an input or reference signal. This circuit compares the frequency of a controlled oscillator with the reference and automatically increases or decreases the frequency of the oscillator until its frequency (but not necessarily its phase) matches that of the reference.

Such circuits are used as frequency doublers, for FM demodulation and for stabilizing RC oscillators.

With this circuit technology we want to stabilize our strongly drifting VFO of the FT-301.

The block diagram of the FFL is shown in Figure 1.

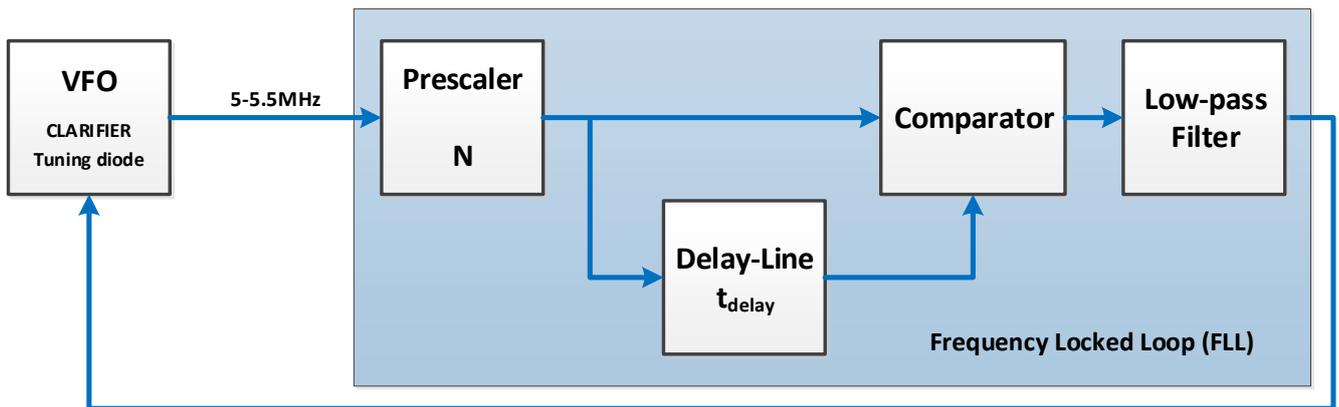


Figure 1

The circuit has a negative feedback loop that acts on the VFO. For frequency correction, the capacitance diode built into the VFO (primary for CLARIFIER) is also used.

The input signal of the FLL is the VFO frequency. The prescaler only serves to generate a symmetrical square wave signal that can be processed with a modern microcontroller. This frequency signal is compared with the identical but  $t_{delay}$  delayed signal. The comparator generates a correction signal which then controls the frequency of the VFO via a low-pass filter. Since the signals are averaged over complete cycles, the output of the FLL is phase-independent.

The FLL engages with every lockup point  $= f_{VFO} + n \cdot f_{step}$ . This has the advantage that the FLL immediately stabilizes the VFO after the VFO tuning knob is no longer turned.

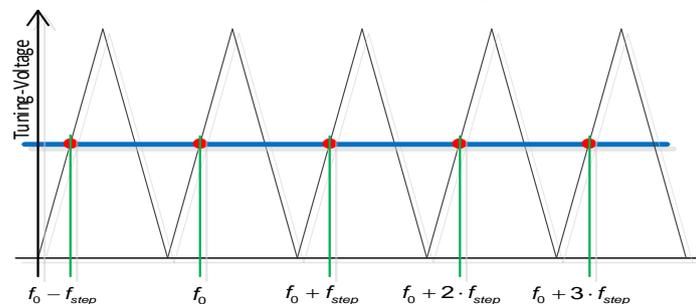


Figure 2

If e.g. and  $t_{delay} = 0.2s$  amount  $N = 2$ , then the FLL step size will  $f_{step} = 10Hz$  be. Mathematically derived, the lockup point can be calculated as follows:

$$f_{step} = \frac{N}{t_{delay}}$$

A derivation is left to the reader as an exercise.

The snap-in step frequency is independent of the FLL input frequency and therefore constant over the entire VFO range.

The FFL is very fast compared to a PLL circuit (Phase Locked Loop), because not the phase but the frequency is corrected.

### FT-301D (VFO Drift measurement)

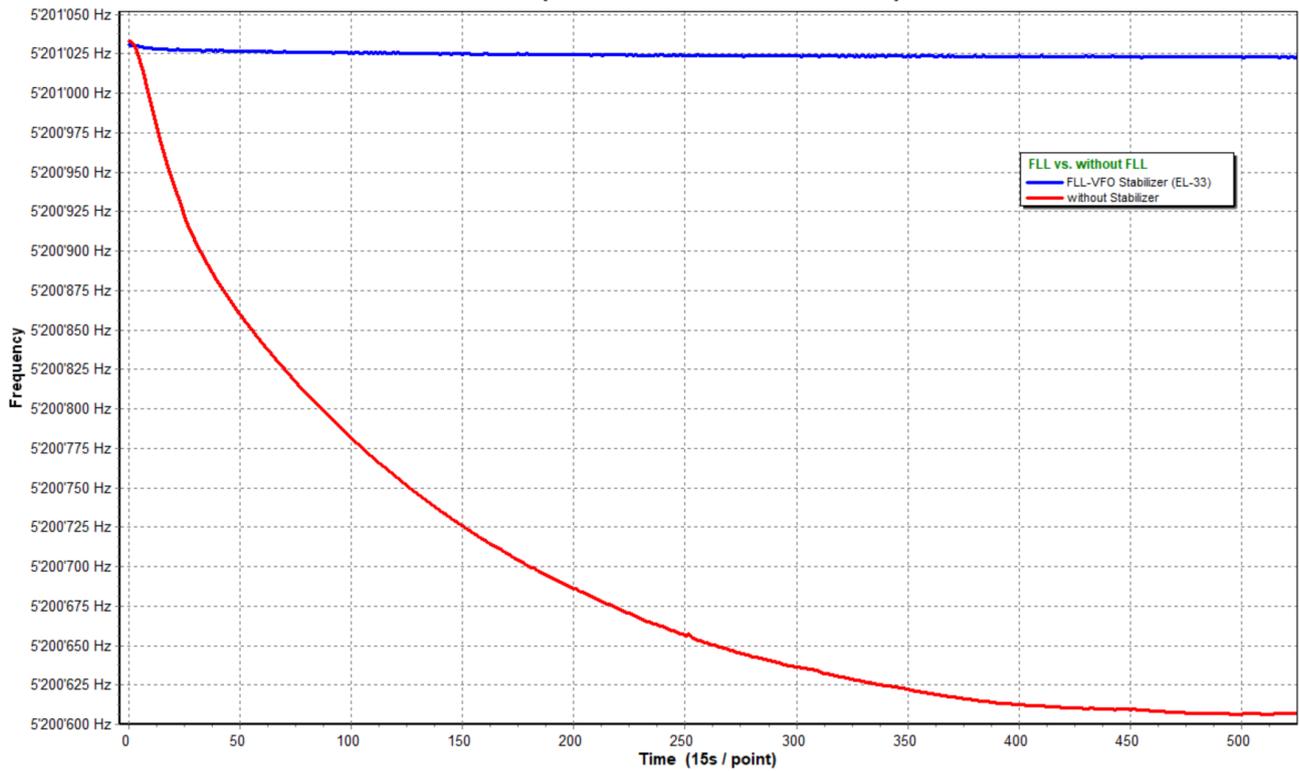


Figure 3

The effect of the FLL-VFO stabilizer can be seen in Figure 3. Measurements were taken over a period of approx. 2h (525 x 15s) after switching on the FT-301D. Without stabilization the VFO drifts about 425Hz. Such a strong drift is extreme annoying in CW or SSB mode, and digital modes are unthinkable.

### 3 Assembly of the module

For the assembly you need the following tools and additional material:

- ◆ Pin soldering iron 50 to 80W
- ◆ tin solder Ø 0.5mm with flux core
- ◆ small needle-nose pliers
- ◆ fine side cutter

It is advisable to study and print this documentation carefully because it is a safe reference when you assemble the module and allows you to control every step taken.

Make sure that the workstation is free of static charges so that the microcontroller already soldered in and programmed is not damaged. It is helpful to wear an antistatic bracelet. The illustrations of the individual components on page 8 should help you to identify the various elements by shape and color.



Soldering is one of the most important tasks when setting up this device. Even with a carefully assembled kit, a bad solder joint can make it impossible for the device to function and spoil all the fun.

It is easy to create a good solder joint if the following rules are followed:

1. Use a temperature-controlled pin soldering iron with approx. 50 to 80 Watt. A 1 to 2mm wide chisel or pyramid point is best.
2. Set the temperature to a maximum of 320°C for lead-free tin and 360°C for leaded tin. Too high temperatures damage the circuit board.
3. The soldering tip must always be clean and well tinned. Wipe the tip often on stainless steel wool (you can buy it in every supermarket in the cleaning department), never on a wet sponge, because then the soldering iron tip cools down unnecessarily and the heat is missing afterwards on the soldering point.
4. Do not use aggressive solder pastes, but high-quality solder wire with a flux core.
5. Hold the tip of the soldering iron only once, but long enough (approx. 2 to 5s) at the place to be soldered so that the solder can flow well. During this time, apply very little solder between the solder joint and the solder tip.
6. Never touch the circuit boards with your fingers on the solder surfaces, otherwise a good solder joint is no longer possible. Should this happen anyway, clean the circuit board with a lint-free cloth moistened with household petrol.



When soldering, always make sure that you do not inadvertently touch already assembled elements with the soldering iron and melt them.

The resistors in the component list also include the respective color coding (see also Table 1). If you are not sure how to handle color coding, it is better to measure the resistance value with an ohmmeter before soldering.

Color coding of resistors with 4 rings				
Color	Resistance value in $\Omega$			tolerance
	1st ring (1st digit)	2nd ring (2nd digit)	3rd ring (multiplier)	4th ring
none	-	-	-	$\pm 20\%$
silver	-	-	$10^{-2} = 0.01$	$\pm 10\%$
gold	-	-	$10^{-1} = 0.1$	$\pm 5\%$
black	-	0	$10^0 = 1$	-
brown	1	1	$10^1 = 10$	$\pm 1\%$
red	2	2	$10^2 = 100$	$\pm 2\%$
orange	3	3	$10^3 = 1'000$	-
yellow	4	4	$10^4 = 10'000$	-
green	5	5	$10^5 = 100'000$	$\pm 0.5\%$
blue	6	6	$10^6 = 1'000'000$	$\pm 0.25\%$
violet	7	7	$10^7 = 10'000'000$	$\pm 0.1\%$
grey	8	8	$10^8 = 100'000'000$	-
white	9	9	$10^9 = 1'000'000'000$	-

Table 1



Observe the mounting direction for all polarized components (diodes, electrolytic capacitors, etc.).

### 3.1 Parts list

#### EL-33 Board

Number	Component No.	Description of the
1	R1	100 $\Omega$ 1/8 W (brown-black-black) [Component 1]
2	R2, 5	470 $\Omega$ 1/8 W (yellow-violet-brown) [Component 1]
1	R6	1k $\Omega$ 1/8 W (red-black-red) [Component 1]
1	R11	10k $\Omega$ 1/8 W (brown-black-orange) [Component 1]
4	R3, 7, 9, 10	100k $\Omega$ 1/8 W (brown-black-yellow) [Component 1]
2	R4, 8	1M $\Omega$ 1/8 W (brown-black-green) [Component 1]
2	C4, 6	15pF Ceramic marked with 150 [Component 2]
2	C3, 5	1nF Ceramic marked with 102 [Component 2]
6	C2, 7, 8, 11, 14, 15	0.1 $\mu$ F Ceramic marked with 104 [Component 2].
2	C12, 13	10 $\mu$ F/16V electrolytic capacitor [Component 4], observe polarity 100 $\mu$ F/10V electrolytic capacitor [Component 6], observe polarity.
2	C9, 10	<u>Attention:</u> Do not touch the terminals with your fingers as these are special "low leakage" capacitors.
2	P1, 2	1x4 Male connector [Component 11]
1	JP1	1x5 Male connector [Component 11]
1	Q1	JFET BF256B [Component 10]
1	Q2	NPN Transistor BC548C [Component 10]
1	U1	Microcontroller PIC16F1704 I/P [Component 8] programmed
1	U2	5V LDO Voltage Regulator MCP1702-5002E/TO-ND [Component 9]
1	Y1	8MHz Crystal HC-49U [Component 7]
1		Board EL-33 [Component 21]
8		Dupont / Pololu connector (female) [Component 12]

2	Dupont / Pololu Housing 4-pole [Component 13]
1	Soldering eye angled [Component 14]
2	Heat shrinkable tubing transparent 3.2mm [Component 15]
2	Heat shrink tubing black 1.2mm [Component 16]
2	Wire strand yellow 15cm [Component 17]
2	Wire strand red 15cm [Component 17]
2	Wire strand violet 15cm [Component 17]
1	Wire strand blue 6cm [Component 17]
2	Screw M3 / 10mm [Component 18]
2	Spacer sleeve 5mm [Component 19]
2	Screw 3mm [Component 20]

Table 2

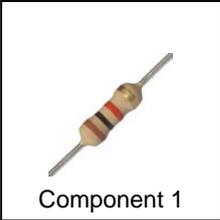
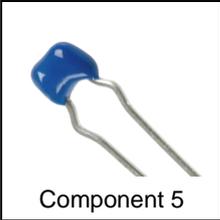
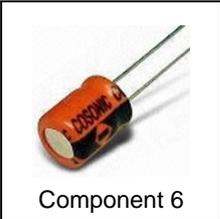
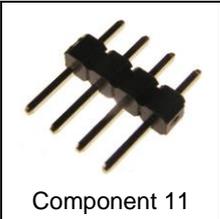
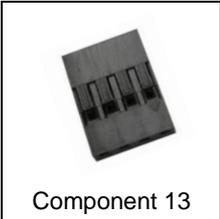
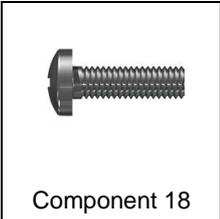
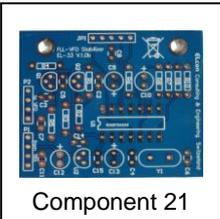
				
				
				
				
				

Table 3

### 3.2 Mounting the circuit board

The assembly diagrams of the small circuit board can be found in chapter 6.6 (see Figure 18).

Assemble the following components using the parts list (Table 2):

- R1 to R10, resistors
- Y1, Crystal 8MHz →The crystal is soldered in with a small distance to the board.  
 Cut a paper or plastic strip 4mm x 30mm (thickness approx. 0.2mm) and place it on the component side between the two crystal connectors. After soldering, remove the strip again.
- Q1, BF245 JFET →Observe installation direction!
- Q2, BC548 NPN Transistor →Observe installation direction!
- U2, IC MCP1702 LDO Voltage regulator → Observe installation direction!
- C2 to C8 and C11, C14, C15 Capacitors
- C9, C10, C12, C13 Electrolytic capacitors → pay attention to the polarity! (white line = minus, see chapter 6.6, Figure 18)
- P1, P2 male connector 1x4 and JP1 male connector 1x5  
 The pin strips must lie flat on the PCB and be vertical.
- Check all solder joints very carefully!  
Use a magnifying glass if necessary, because even the smallest, unwanted solder bridges can have fatal effects.  
 Especially with the transistors Q1 and Q2 and the voltage regulator U2 the greatest attention is given.

## 4 Conversion of the FT-301D

### 4.1 Preparation of the FT-301D



Mechanical assembly must be carried out strictly in the following order, otherwise problems may occur.

- Remove the cover of the device, which is secured by four plastic rivets.
- Unplug the speaker terminal cable.
- Turn the unit upside down and remove the 12 screws and the bottom cover.
- Turn the unit over again so that the top is facing upwards.
- Loosen the two screws on the AM UNIT (PB1556) and pull the unit out of the socket to get more space to work on the VFO.

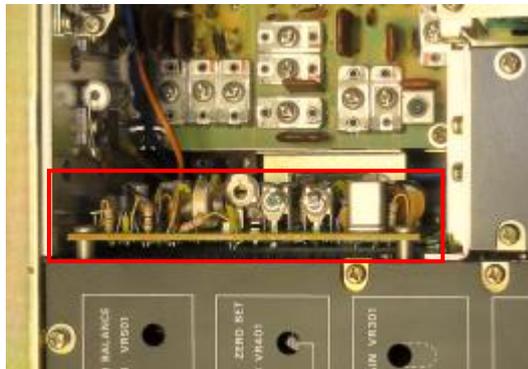


Figure 4

- Remove the adhesive tape that mechanically secures the 3-pin plug on the back of the VFO from falling out (see Figure 5).

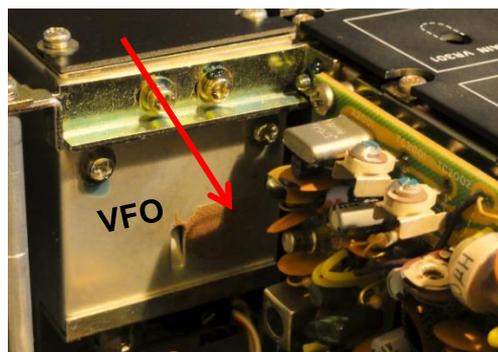


Figure 5

- Pull the black, 3-pin plug on the VFO and push the plug downwards so that you can hold it on the underside.
- Turn the unit over again so that the underside faces upwards.
- Open the plug and desolder all 3 wires.  
(CLAR = blue-white, =  $+6V_{REF}$  orange-white, RF-VFO = white)
- Desolder the white wire on the COUNTER MIXER UNIT PB-1541 (connection in the middle).

- Prepare a 4-pin "Dupont / Pololu" female connector with 15cm wires (see Figure 6). [Component 12, Component 13, Component 17].  
Pin1 = CLAR (yellow), Pin2 = +6V<sub>REF</sub> (red), Pin3 = RF (violet), Pin4 = GND (blue)

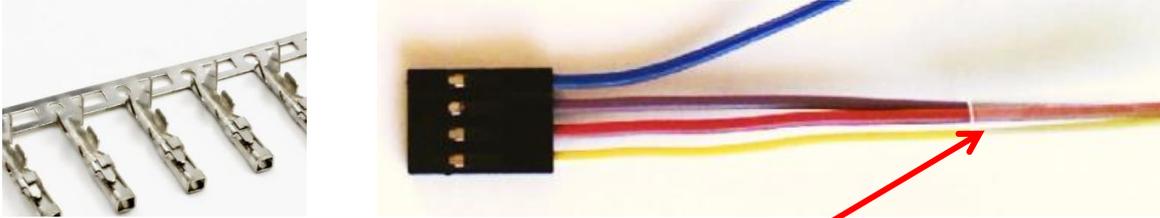


Figure 6

- Push a piece of heat shrink tubing (L=1cm, Ø=3mm) [Component 15] over the wires yellow, red and violet.
- Solder the wires to the 3-pin connector as shown in Figure 7 close the connector with the small cap. If you do not use the same wire colors, make sure that the wires are soldered in the same order.

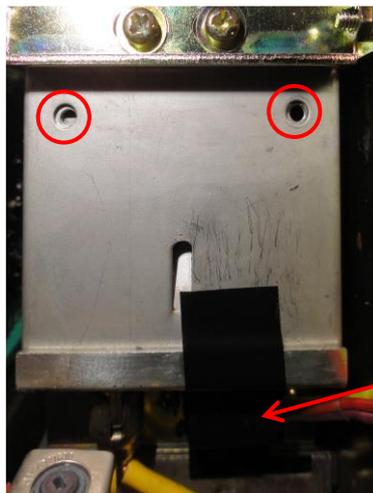


Attention: The screw must not be tightened too much, otherwise the plastic cover may break.



Figure 7

- Shrink the heat shrink tubing close to the 3-pin connector (see Figure 7).
- Plug the 3-pin connector back into the VFO and secure it with insulating tape to prevent it from falling out (see Figure 8).



3-pin plug secured

Figure 8

- Remove the two screws and washers from the VFO. (see Figure 8).

- Make a second 15cm long 3-pin Dupont / Pololu cable as shown in Figure 6, but leave pin 4 empty.  
 Pin1 = CLAR (yellow)  
 Pin2 = (+6V<sub>REF</sub> red)  
 Pin3 = RF (violet)  
 Pin4 = empty



Figure 9



The cable is used when installing the FFL VFO stabilizer module.

## 4.2 Installation of the module

- For the installation of the FLL-VFO Stabilizer Module EL-33 only the screws enclosed with the kit may be used, because longer screws can damage the capacitor inside the VFO.

- Screw the assembled and optically inspected circuit board according to Figure 11 onto the spacer sleeves [Component 19]. Use the two spring washers [Component 20] directly under the screw head.

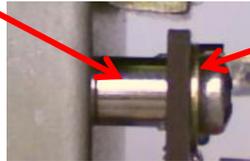


Figure 10

- The solder lug [Component 14] for the ground connection (GND) is mounted on the left fastening screw.

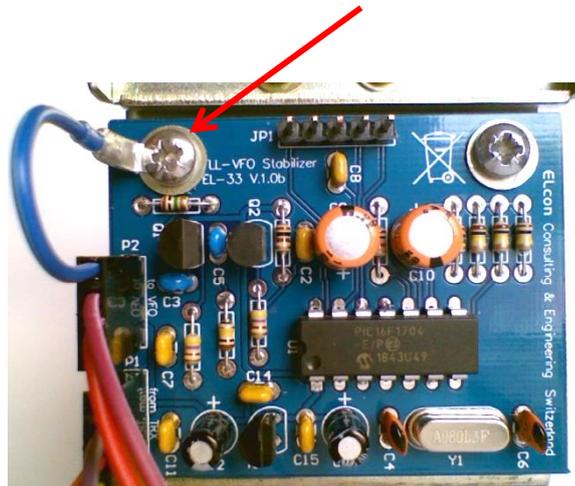


Figure 11

- Plug the 4-pin Dupont / Pololu connector into the P2 pin header with pin1 at the bottom (designation: "to VFO").
- Slide the shrink tubing (L=2cm, Ø=3mm) [Component 15] over the blue wire and solder the wire to the solder eye.

- Slide the heat shrink tubing over the solder lug and shrink with hot air.

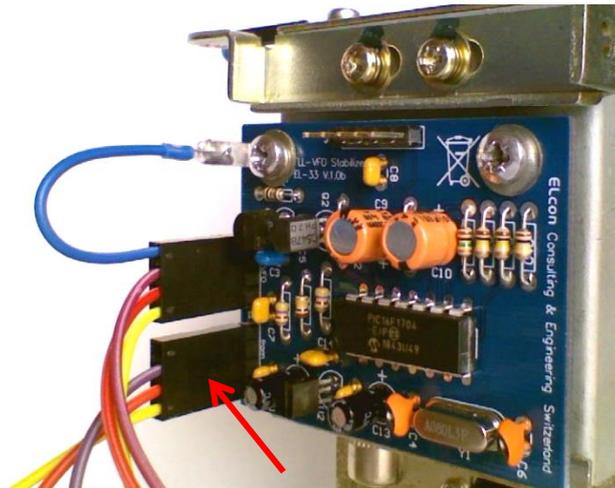


Figure 12

- Connect the prepared 3-pole cable with Dupont / Pololu plug to the pin header P1 with pin1 at the bottom (designation: "from TRX").
- Push the three wires down so that you can grip them on the bottom of the unit.
-  For the following steps, shorten the stranded wires to the appropriate lengths.
- Solder the violet wire to the pin "RF-Input" of the COUNTER MIXER UNIT PB-1541 (connection in the middle, see Figure 13).



Figure 13

-  In the following steps, connect the two wires (orange-white and blue-white), which you soldered out of the 3-pin VFO connector, to the FLL-VFO stabilizer module.
- Solder the two stranded wires (red and orange-white) together. Use a black shrink tubing (L=2cm, Ø=1.6mm) [Component 16] for insulation.
- Solder the two stranded wires (yellow and blue-white) together. Use a black shrink tubing (L=2cm, Ø=1.6mm) [Component 16] for insulation.



Figure 14

- Reconnect the AM UNIT (PB-1556) and tighten the two screws.

#### 4.3 CLAR Potentiometer Reverse direction of rotation

The VFO stabilization superimposes its control voltage on the "CLARIFIER" voltage to correct the VFO frequency. However, the voltages are thereby negated, which results in a reversal of the direction of rotation of the "CLAR" potentiometer. This shortcoming is corrected relatively easily with the following modification:

- Turn the unit so that the top is facing upwards.



Figure 15

- Carefully desolder the blue wire and the 3.9kΩ resistor on the "CLAR" potentiometer (see Figure 16, ① to ③) and solder them again in reverse.



Figure 16

## 5 Operation

For the operation of the FLL-VFO Stabilizer Module EL-33 no special settings are required. You can use the transceiver as usual, but the big advantage is that the VFO is crystal stable and the drift is compensated.

## 6 Appendix

### 6.1 Specifications

Frequency:	2 - 20MHz
Input level:	> 100mV
Power supply:	6 to 13V / 30mA
Dimensions:	50(L) × 40(W) × 15(H) mm

All specifications are subject to change without notice or obligation.

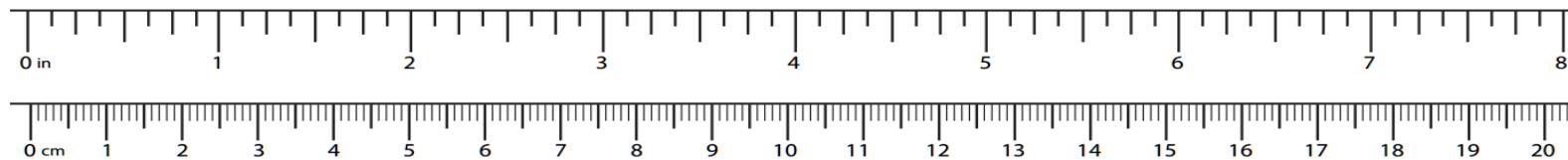


Translated into English by Dave Bohlen, N0EDS, Roland Elmiger, HB9GAA, and Katharina Sanz Elmiger.

The reference for the content of this document is in German.

There is no guarantee for the accuracy of the translation.

### 6.2 Ruler



### **6.3 Repair / Warranty**

We have no influence on the correct and proper assembly and can only guarantee the completeness and flawless condition of the components. We guarantee that the components will function in accordance with their characteristic values when not installed and that the technical data of the module will be adhered to when professionally processed in accordance with the installation instructions and commissioned or connected and operated as prescribed. We do not warrant or assume any liability for damages or consequential damages in connection with this product. We reserve the right to repair, rectify, deliver spare parts or refund the purchase price. Further claims are excluded.

The following criteria will not be repaired or are not covered by warranty:

- if acidic solder, solder grease or acidic flux etc. was used for soldering.
- if the kit has been improperly soldered, glued and assembled.
- during modifications and repair attempts on the module.
- in case of unauthorized modification of the module or the circuit.
- in case of improper removal of components not provided for in the design, improper free wiring, etc.
- Use of other components not originally part of the kit.
- in the event of incorrect assembly and wiring, as well as the resulting consequential damage.
- damage caused by non-observance of the operating instructions or the schematic and assembly diagram.
- if the module is connected to an incorrect voltage or type of current or if the polarity is incorrect.
- in the event of faulty operation or damage due to negligent handling or misuse.
- defects caused by bridged fuses or the use of incorrect fuses.

In all cases the transport costs of the kit shall be borne by you.

### **6.4 Disclaimer of liability**

Any actions based on the information contained in this document are taken at the user's own responsibility. Any liability is excluded, both for direct and indirect damages and consequential damages that may arise in connection with the use of the information contained in this document.

